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Solar Thermal Repowering Systems Integration

Final Report

Prepared By
Stearns-Roger Services, Incorporated
Denver, Colorado

SERI

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SOLAR THERMAL REPOWERING SYSTEMS INTEGRATION

FINAL REPORT

AUGUST 1979

MASTER

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STEARNS-ROGER SERVICES, INCORPORATED
DENVER, COLORADO

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FOREWORD

This final report was prepared under subcontract AH-9-8037-1 as a part of SERI task 5121.11, the Supply Task of the Repowering Strategy Analysis. The objective of the Repowering Strategy Analysis is to define a government role in repowering that constitutes an efficient investment in pursuit of viable private markets for heliostat-based energy systems. The purpose of the Supply Task is to determine the installed cost of solar systems and components in a repowering program, and to outline the manufacturing investment required to achieve those costs.

The primary goal of this study is to identify the cost of integrating a solar thermal system into an existing power plant. In the early considerations of repowering, it was commonly assumed that the electrical generating plant was virtually free, an assumption which produced a large benefit for repowered plants. This study is intended to test that hypothesis by outlining the sources of repowering integration cost and scoping the magnitude and variability of those costs.

This project shows that the integration cost can be quite low if the plant is in good condition and the major plant systems do not require extensive modification. However, if the turbine, generator, or major auxiliary systems are in need of significant repair, the integration cost increases substantially. The overriding conclusion is that it is not possible to generalize in advance what the integration cost will be for a particular plant. Each unit which is considered to be a repowering candidate must be carefully evaluated to determine if its age and condition are consistent with its cost-effective use as as repowered plant.

Dennis N Horgan Jr

Dennis N. Horgan, Jr.
Policy Analysis Branch

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SUMMARY

The purpose of this study was to identify the effect of solar thermal repowering on balance-of-plant costs for several candidate gas/oil fired electric power generating units. The study was prepared in conjunction with the SERI Repowering Strategy Analysis currently in progress.

The scope of the study included the following tasks:

Task 1 Southwest Repowering Candidate Plant Classification.

The purpose of this task was to classify the plants which have been identified as repowering candidates into generic categories for use in Tasks 3 and 4. The candidates have been identified in two market surveys. One by Public Service Company of New Mexico (PNM) in their solar hybrid repowering study and one by MITRE in their Solar Thermal Repowering Market Survey.

Task 2 Solar Repowering Technology Assessment

The purpose of this task was to look at solar central receiver technologies which are under development (e.g., once-through steam receiver, drum type receiver, molten salt and liquid metal-cooled receivers) in light of the concept of solar repowering. Interface requirements by receiver type for use in the Systems Integration task were identified.

Task 3 Systems Integration

This task identified the "most promising" repowering combinations used in the development of an interface catalog of the balance-of-plant modifications necessary to attach the solar system.

Task 4 Cost Estimates

Cost estimates were prepared under Task 4 for each of the combinations identified in Task 3, including turbine inspection and overhaul requirements necessary to extend turbine life.

This study has identified four generic plant classes (25-50 MWe non-reheat units, 75-200 MWe non-reheat units, 75-200 MWe reheat units, and 225-600 MWe reheat units) as being representative of all of the repowerable steam Rankine units identified by the PNM and MITRE studies. Also, the various central receiver types that have been studied under DOE sponsorship have been classified in two categories, water/steam receivers and molten salt/liquid metal receivers. There are therefore eight combinations of generic plant type and receiver type.

Of these eight combinations six were selected for detailed cost evaluations.

These are:

1. 50 MWe non-reheat, 50% repowering, water/steam receiver
2. 100 MWe non-reheat, 50% repowering, water/steam receiver
3. 100 MWe reheat, 50% repowering, salt or sodium-cooled receiver
4. 100 MWe reheat, 100% repowering, salt or sodium-cooled receiver
5. 350 MWe reheat, 50% repowering, salt or sodium-cooled receiver
6. 350 MWe reheat, 100% repowering, salt or sodium-cooled receiver

Cost estimates were prepared for the balance-of-plant modifications identified in Section 4.0 for each of the six generic combinations listed above. The cost estimates were prepared by Stearns-Roger's cost estimating department and were based on previous power plant cost experience for similar size units using labor rates representative of the southwestern United States.

The estimated cost range of plant modification, reflecting unit size, receiver type and percent solar repowering, is shown in Table S-1.

As indicated in Table S-1, a wide cost range exists for balance-of-plant modifications to facilitate solar repowering. The principal cost factors are turbine-generator and control system modification requirements which depend on the age and condition of the unit. The balance-of-plant repowering cost is higher on water/steam receiver sytems owing to boiler feed pumps and feedwater system modifications, which are not required for salt/sodium-cooled receivers using intermediate heat exchangers. As expected, the percent solar repowering (e.g., 50% vs. 100%) does not have a significant cost impact on balance-of-plant costs.

TABLE S-1 BOP COST SUMMARY
SOLAR REPOWERING INTEGRATION STUDY
(1979 DOLLARS IN THOUSANDS)

UNIT RATING-% REPOWER, RECEIVER TYPE	50 MWe-50% WATER/STEAM		100 MWe-50% WATER/STEAM		100 MWe-50% SODIUM OR SALT		100 MWe-100% SODIUM OR SALT		350 MWe-50% SODIUM OR SALT		350 MWe-100% SODIUM OR SALT	
EXPECTED COST RANGE	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
4100 Site, Struct, Misc.	18	270	20	337	17	300	17	300	23	378	23	378
4200 Turbine Plant Equip.	848	2530	1040	3393	579	2662	694	3120	1235	5290	1312	5595
4300 Electric Plant Equip. (Including Controls)	159	788	178	864	186	944	190	964	238	1156	336	1547
4800 Distrib. & Indirect	277	971	348	1293	240	1199	270	1369	461	2104	505	2271
TOTAL COST	1302	4559	1586	5887	1022	5105	1171	5753	1957	8928	2176	9791
UNIT COST												
$/kWt Repower	20	71	13	48	9	43	5	24	5	22	3	12
$/kWe Repower	52	182	32	118	20	102	12	58	11	51	6	28

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SECTION 1.0

INTRODUCTION

This study is an analysis of the technical requirements and cost of integrating a solar thermal steam supply system into an existing power plant. It was performed as a part of the Repowering Strategy Analysis. The first section of this introduction is an overview of the repowering strategy analysis and its objectives. The second part is a discussion of the scope and limitations of this study and the final section is an outline of this report.

1.1 PERSPECTIVE ON THE REPOWERING STRATEGY ANALYSIS

The retrofit of solar central receiver heat supply systems to existing steam-electric generating stations, an application known as "repowering," is being considered as a major programmatic effort by the Department of Energy's Large Solar Central Power Systems Program. Several promising features of repowering lead to this interest:

Technical: Repowering offers a relatively low-risk technical path to large scale test and demonstration of central receiver technology. Partical reliance on existing hardware places both cost and technical emphasis on the heat supply system, where the major uncertainties lie. However, the hybrid nature of repowered plants permits them to operate even if the solar heat supply system is not completely successful.

Demand: The confinement of risk to the solar portion of the plant makes utility involvement more attractive, and facilitates cost-sharing arrangements between the public and private sectors. Early involvement of the eventual user group promises to increase the market development value of the test and demonstration program in several important areas: relevance, credibility, dissemination, response.

Supply: The requirements for cost effectiveness of the solar heat supply system are possibly less stringent in repowering than in new capacity applications. If this is so, then the opportunity for early hardware sales for repowering may be an important advantage for the development of the supply industry. (This question is addressed in the report of the Repowering Supply Task.)

Energy Displacement: While the likely population of repowerable plants in the Southwest is not large (roughly 4-6 GWe), it is heavily reliant on oil and gas. Thus the direct effects of repowering on energy displacement are in the desired categories.

The determination of an appropriate government response to the opportunities of repowering is an important policy question, and is the major reason for the Repowering Strategy Analysis. The study objective is:

> To define a government role in repowering that constitutes an efficient program investment in pursuit of viable private markets for heliostat-based energy systems.

In support of that objective, the study is designed to identify the scope and nature of the repowering opportunity within the larger context of its contributions to central receiver technology development and commercialization.

1.2 SCOPE AND LIMITATIONS OF THIS STUDY

This study is an effort to generalize the detailed repowering analysis of Reeves Station which was done by Stearns-Roger and Westinghouse for Public Service Company of New Nexico (1). In that study the cost of adapting Reeves 2 for repowering was significant although PNM had already performed many of the needed modifications. The objective of this study is to try to expand the Reeves experience to make some general statements about the total population of repowerable units in the Southwest.

It was impossible for this study to perform the type of exhaustive plant specific analysis of the PNM study for all of the 99 plants identified in the PNM study. As a result, the methodology of this study was to select a set of four prototypical generic plants which are representative of the types of repowerable plants in the Southwest. For these generic plants a set of six likely repowering combinations was identified from among the solar technology options. An integration requirements catalog for each of the combinations was developed and that catalog was then costed for each combination.

Although this approach gives a general profile of the cost of repowering it has several limitations. The first limitation is that while the costs may be representative, the plants are prototypical with the result that the cost of any specific plant may vary greatly from the values given here. A second limitation is that the six combinations of plant and receiver which we recosted were chosen on the basis of existing conceptual studies and professional judgement. The developemnt of detailed system designs which would have been necessary to select the optimal repowering combinations was outside the scope of this study. Similarly, this study only examined the repowering of existing gas or oil-fired steam Rankine plants. Brayton cycles and combined cycles were not a part of this study, and the use of solar feedwater heating was not considered.

1.3 ORGANIZATION OF THE REPORT

This study was divided into four tasks and the report organization follows the task structure. The first task was to outline the criteria of repowerability and classify the candidate plants into general categories. The results of this task are given in Section 2. Section 3 documents Task 2 which is a survey of receiver systems under development viewed for their suitability for repowering. Section 4 identifies six promising repowering combinations and develops a catalog of interface requirements for each. The last section contains the cost estimates for each of the items in the Interface Catalog. The detailed cost sheets are included in the Appendix.

SECTION 2.0

REPOWERABILITY CRITERIA AND PLANT CLASSIFICATION

2.1 EXISTING MARKET SURVEYS

This study is based on two studies that attempted to identify candidate plants for solar hybrid repowering within the Southwest United States. The first was the study performed by Public Service Company of New Mexico (PNM) (1) and entitled "Technical and Economic Assessment of Solar Hybrid Repowering"; the second was the MITRE study "Solar Thermal Repowering: Utility Industry Market Potential in the Southwest" (2). No additional field surveys nor communications were made with utilities in preparation for this project.

Both the MITRE study and the PNM study attempted to ascertain the utility repowering potential in the southwestern U.S.* The two studies resulted in widely disparate estimates for the potential size of the solar repowering market (10,917 MWe from the PNM study, 18,067 MWe from the MITRE study). The difference in the estimates is due partly to differences in survey procedures, but mainly it is due to differing definitions of what a repowerable plant consists of.

2.1.1 The PNM Study

PNM made a literature survey based on FPC Form 12 data and identified 755 gas and oil-fired units in the southwest with ratings less than 200 MWe. The aggregate generating capacity was 40,954 MW. A questionnaire was then distributed to 78 selected utilities representing "most" of the electric generating capacity in the southwestern United States. The percentage of the 40,954 MW of generating capacity represented by the 78 utilities was unstated. Of the 78 utilities sent the survey, 61 responded, and of those approximately 50 utilities with 272 units and a total rated capacity of 19,700 MWe indicated interest in solar repowering. The 272 units represented a solar repowering potential of about 11,200 MWe. Of those 272 units, 206 had land available within 2500 feet, representing a repowering potential of about 7200 MWe. This group of units was further restricted to those units with a repowering potential (based on available land for collector fields at 6 acres/MWe) of more than 50%; 82 units representing 5198 MWe of effective repowering potential were remaining as the potential market for solar repowering. Of these 82 units, 47 were non-reheat steam Rankine units with 1983 MWe of rated capacity, 29 were reheat steam Rankine units with 3066 MWe of rated capacity and 6 were combustion turbines with a rated capacity of 156 MWe.

*Arizona, California, Colorado, Louisiana, Nevada, New Mexico, Oklahoma, Texas, Utah and in MITRE study Kansas and Wyoming.

Using a similar procedure and with the same restrictions (land available within 2500 feet, repowering potential greater than 50%), PNM then performed a utility telephone survey of units with ratings above 200 MWe and identified 17 units with a solar repowering potential of 5728 MWe; the total repowering market potential was determined as 5189 MWe, plus 5728 MWe or 10,917 MWe.

2.1.2 The MITRE Study

The MITRE study used records of the Federal Energy Regulatory Commission to identify 197 sites within the Southwest that utilize oil or gas-fired steam turbines (combustion turbines were not considered for repowering). Only plants with ratings greater than 25 MWe were considered. A random sample of 33 sites was generated and representatives of the selected utilities were interviewed to determine the following:

(1) The utility's attitudes regarding solar repowering.

(2) If there was sufficient land (enough for at least 25 MWe of repowering) close enough to the site (within 15,000 feet) to repower a substantial portion of the existing site capacity, based on one square mile of field area being necessary to repower 150 MWe (about 4.3 acres/MWe).

(3) The local environmental and political circumstances that might affect repowering potential.

The estimated potential for repowering at each site sample was then extrapolated to arrive at a statewide total including sites not in the sample; the state totals were then summed to arrive at an estimate for the Southwest. MITRE thereby estimated the potential market for solar repowering at 18,067 MWe.

Table 2-1 shows the major differences in assumptions between the PNM and MITRE studies.

Table 2-1

PNM and MITRE Study Differences

	PNM	MITRE
Sampling Technique	100% sample	Random (33 sites)
Distance to Available Land for Collector Field	2500 ft	15,000 ft
Minimum Repowering Requirement	50%	25 MWe
Collector Field Land Req.	6 acres/MWe	4.3 acres/MWe
Combustion Turbines Scheduled?	Yes	No
Total Repowering Market Potential	10,917 MWe	18,067 MWe

2.2 CRITERIA FOR REPOWERABILITY

The following list of criteria, while not all inclusive, identifies the major factors which affect the solar repowerability of a given plant.

- Geographic location of plant
- Land availability, characteristics, and location
- Plant fuel type
- Type of cycle
- Steam conditions
- Size of unit
- Load factor - peaking, intermediate, base load
- Heat rate
- Utility generation mix
- Time of day and season of power demand peak for utility
- Transient performance of turbine/generator and boiler
- Control system
- Age and condition of plant
- Favorable attitude of utility, favorable institutional environment

These factors are discussed in more detail in the following sections.

2.2.1 Geographic Location of Plant

The amount of electrical energy that can be derived from a heliostat array of a given size is closely related to the annual average direct normal solar insolation. Therefore, the geographic location of the plant is a strong determinant of the economics of repowering. Both studies were limited to states in the Southwest - a region characterized by high direct normal solar insolation. The MITRE study stated a requirement of a minimum of 2000 kWh per square meter per year of direct normal solar insolation for a plant site to be considered a candidate for repowering. Figure 2-1 shows the Average Annual Direct Normal Insolation across the United States in thousands of Btus per square foot. The 2000 kWh per square meter per year criteria encompasses the area of greatest interest and is indicated by the heavy line.

2.2.2 Land Availability, Location, and Characteristics

Since solar repowering requires a relatively large amount of undeveloped land for the collector field, the availability and cost of vacant land located near the plant site are important criteria in determining the feasibility of repowering a given unit. Ideally, the available land should be rectangular in shape and located to the north of the existing plant site to minimize piping runs. The land should be flat or of a uniform, gentle grade (surround collector field) or a uniform grade sloping to the south (for a northside collector field). This will minimize the earth moving costs for the development of an efficient collector field. Drainage of the site should be such that no large, expensive diversion structures would be required. Soils at the site should be of such a character that simple heliostat foundations will be adequate.

In general, neither the PNM nor the MITRE survey addressed any of the characteristics of the available land other than size related to the possible percentage of repowering and the parcel's distance from the plant. PNM used a criterion that the land be within 2500 feet of the plant; MITRE used 15,000 feet. The PNM criterion seems overly restrictive, especially so since location of the collector field relative to the plant is not taken into account. For the concept design for the solar repowering of PNM's Reeves Unit No. 2, the receiver was located about 2500 feet from the unit, even though the collector field was contiguous with the plant area; the collector field was located south of the plant area and the receiver tower was located considerably off center on the north-south axis toward the south boundary of the collector field. If land had been available to the north of the plant for a collector field, the steam and feedwater piping lengths could have been reduced considerably. Conversely, the 15,000 foot distance that was allowed by MITRE seems excessive. The poor transient response of long feedwater lines is likely to cause temperature control problems during insolation transients. Thus, it is likely that the maximum feasible distance from the plant to collector field will be between 2,500 and 15,000 feet.

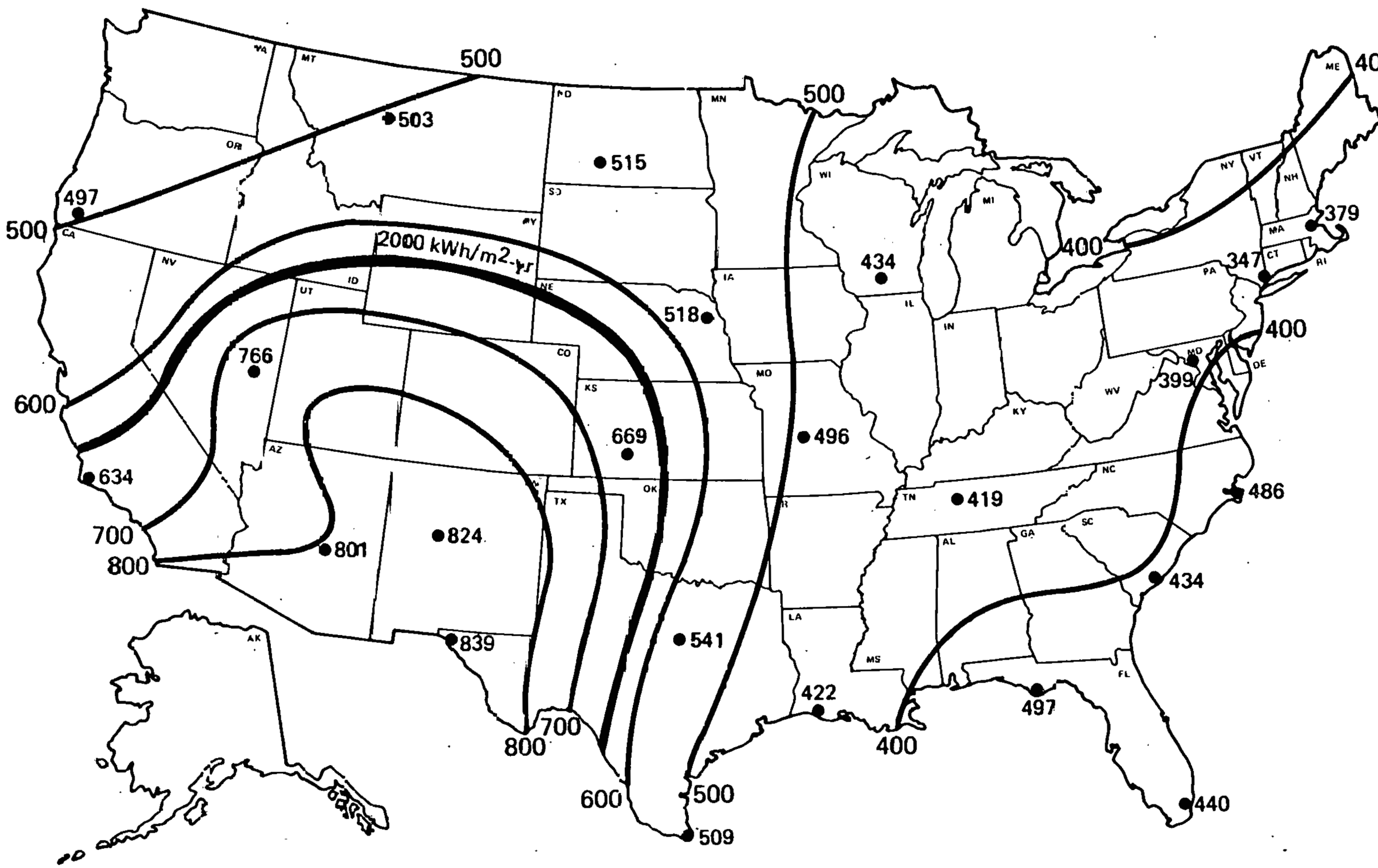

Figure 2—1 AVERAGE ANNUAL DIRECT NORMAL INSOLATION (1000 BTU/FT2)

It is also difficult to specify one constant for the number of acres of land required for one MWe of repowering (PNM used 6, MITRE used 4.3). A number of factors, including design insolation, collector field and receiver type, size of field, and plant heat rate influence the number of acres required to repower one MWe. In areas of high land costs, it might be economic to pack heliostats more densely and accept higher blocking and shadowing losses to trade off increased heliostat cost for savings in land cost.

2.2.3 Plant Fuel Type

In the MITRE and PNM studies, only oil or natural gas fired units were considered as candidates for solar repowering. Since the cost of the solar repowering are weighed against the benefits of fuel cost savings, units which are currently burning high cost fuel (natural gas or fuel oil) are more practical to repower than units burning relatively low cost fuel (coal). The repowering of coal fired plants would also present additional technical problems such as slow boiler response, poorer land availability near the plant because of the extensive coal and ash handling facilities that are generally present, and possibly degraded solar insolation due to stack emissions. For the purposes of this study only oil and gas-fired units are considered.

2.2.4 Type of Cycle

The type of steam cycle employed, reheat or non-reheat, is important in assessing the repowerability of a unit. Turbine cycle efficiencies are generally higher for reheat units, which improves the plant economics. However, the solar repowering of reheat cycle units using water/steam receiver technology will require more complex receiver design than the Rocketdyne designed once-through external receiver to be used at the Barstow pilot plant. There are two approaches to solar reheating using water/steam receiver technology. The first is the use of receiver steam in a steam to steam heat exchanger. This approach has the disadvantages of low heat transfer coefficients which implies a large heat exchanger, and the possible need for higher receiver temperatures to achieve acceptable reheat performance. A second approach to water/steam reheating is to use a reheat steam line in conjunction with the superheat section of the receiver, or the addition of an auxiliary reheat receiver located below the main receiver. Both of these approaches are currently being studied by Babcock and Wilcox and Combustion Engineering under Contract to Sandia Laboratories as a part of the advanced water/steam receiver program.

Steam reheating using advanced technology receivers (molten salt or liquid metal) is more feasible. The steam would be reheated in an intermediate molten salt or liquid metal to steam heat exchanger similar to another heat exchanger used to generate the main steam. Heat exchanger costs would be lower because the molten salt or liquid metal would not have to be at a high pressure and the heat transfer rate would be more favorable. Since the heat exchangers could be located in or adjacent to the repowered unit, the economic penalty of long hot and cold reheat steam piping could be avoided.

2.2.5 Steam Conditions

Steam conditions, temperature and pressure, also help to determine the turbine cycle efficiency and therefore the heliostat field size and cost required to repower a unit. Generally, the higher temperature and pressure units will have higher turbine cycle efficiencies. The main steam temperature and pressure also have a bearing on steam and feedwater piping cost and may influence the optimal receiver design. Table 2-2 adapted from the PNM report shows the relationship between unit size, number of units, and operating conditions for steam Rankine units. The table includes some units which are not repowerable due to lack of available land within 2500 feet and other units which could be repowered only to small percentages.

2.2.6 Size of Unit

The size of the unit under consideration, both in absolute terms and relative to the installed capacity of the owner utility, is important in assessing the solar repowerability. The size of the unit is important in that solar repowering a significant percentage of a large unit requires relatively large parcels of undeveloped land nearby for the heliostat field. The turbine for a large unit is less tolerant of rapid load changes due to non-uniform steam output from the solar receiver. Since large turbines, generally have thicker shells and more massive rotors, the metal sections require more time to reestablish thermal equilibrium after internal steam temperature changes that necessarily occur when throttle flows vary significantly. The mechanical stresses that result are more severe and occur for longer periods with large turbines. In areas where solar insolation can be expected to show rapid short term variation, solar repowering of large units may not be practical unless some form of thermal (buffering) storage is employed.

Table 2-3 adapted from the PNM report shows the relationship between size and possible repowering percentage based on a collector field land requirement of 6 acres per MWe. The table includes all units which were identified as repowering candidates by the utilities. Some of the candidate units included in the table do not have land for collector fields available at distances closer than 2500 feet.

Table 2-2

Steam Turbine Units

Operating Conditions (Pressure/Temperature)

	NON-REHEAT UNITS					REHEAT UNITS			UNIT TOTALS	SUBTOTAL UNIT RATINGS, MWe
PRESSURE: (psig)	350	600	850	1250	1450	1450	1800	2000 & UP		
TEMPERATURE: (°F)	625	825	900	950	950	1000 1000	1000 1000	1000 1000		
PLANT RATING (MWe)										
0 to 10	12	12	1						25	186
11 to 25	3	10	13	1		1			28	557
26 to 50	4	1	23	9		3			40	1590
51 to 75			14	15		5	5		39	2713
76 to 100			3	5	2	15	3		28	2504
101 to 125				11	13	11	10		45	4919
126 to 150						1	8	3	12	1610
151 to 200							25	2	27	4562
Over 200*								61	61	25,594
UNIT SUBTOTALS	19	23	54	41	15	36	51	66		
UNIT TOTALS					152			153	305	
TOTAL UNIT RATINGS										44,235

*The PNM survey did not ascertain operating characteristics of units rated greater than 200 MWe It is assumed that most of these units are rated at 2400 psi or higher.

Table 2-3

Percentage of Repowerability By Size of Unit

RATED SIZE (MWe)	REPOWERING PERCENTS				
	1 to 25	26 to 50	51 to 75	76 to 100	TOTAL
0 to 10	12	7	C	6	25
11 to 30	30	2	C	27	59
31 to 50	15	0	1	14	30
51 to 70	13	4	1	9	27
71 to 100	8	6	1	28	43
101 to 150	32	10	4	15	61
151 to 200	15	0	2	10	27
Over 200*					61
TOTAL NUMBER OF UNITS	125	29	9	109	333**

*Data for percentage of repowerability not presented in PNM study.
**Includes 21 combustion turbines in the size range 11 to 50 MWe, 3 in the size range 51 to 100 and 4 in the size range 101 to 150 MWe.

2.2.7 Load Factor

The range of unit sizes identified as candidates for solar repowering includes peaking (generally smaller units), intermediate, and base loaded units. Solar repowered units are usually conceived to be operated with capacity factors associated with intermediate units (about 40%), but unless the fossil boiler is fired at night to provide steam to the turbine (which may be mandatory in the case of the larger turbines) the service will be cycling as it is with peaking units. The water treatment equipment, boiler design, and other auxiliary equipment on peaking units may be more compatible with solar repowering and require less modification.

2.2.8 Heat Rate

The cost of a solar thermal steam supply system is proportional to the turbine cycle heat rate. As a result, it is desirable to repower the most efficient units possible. However, these units are likely to be high pressure reheat units which will require more advanced (and more expensive) steam generation equipment.

2.2.9 Utility Generation Mix

The solar repowered plant is most economically operated at maximum solar output whenever possible. This means that during reduced load periods the solar repowered unit may displace energy normally provided by a base load unit. If the base-loaded units of the utility in question are low cost coal or nuclear fired units, the economics of solar repowering will not be as favorable as they would be if the base-loaded units were oil- or gas-fired boilers.

2.2.10 Time of Day and Season of Power Demand Peak for Utility

Unless large thermal storage systems are employed, the energy output from the solar portion of a solar repowered plant is closely related to the daily and seasonal variation in the direct normal solar insolation at the plant site. The economics of solar repowering will be more favorable for those utilities whose chronological load shapes closely match the natural variation in direct normal solar insolation. Generally higher cost energy from peaking units will be displaced in those cases. Solar repowering will be less economic for utilities with winter or evening load peaks.

2.2.11 Transient Performance of Turbine-Generator and Boiler

An important consideration affecting the solar repowerability of a given unit is the capability of the existing boiler and turbine-generator to operate under transient conditions imposed by the solar plant. Such factors as boiler turndown (the ratios of maximum to minimum steady state steam flow), allowable ramp rates (percentage per minute rates of increase or decrease in steam flow) for boiler and turbine and unit age and history pertaining to transient or cyclic operation must be considered. These considerations are similar to those which must be made on older conventional units following their transfer from base-load to peaking or cyclic operation.

Neither the PNM nor MITRE repowering surveys included sufficient data on specific units to judge their suitability for extended thermal cycling or transient operation. Turbine load ramp rates will depend on the allowable turbine temperature ramp rates which in turn depend on the temperature change in the turbine parts (steam chest, casing, rotor, etc.) and the number of thermal cycles to which the turbine will be subjected and must be determined by the turbine manufacturer. Typical turbine temperature ramp rates range from 300 degrees F to 400 degrees F per hour for a turbine metal temperature change of about 200 degrees F. Provisions for increasing the cyclic life of existing turbines are discussed under Task 3, Systems Integration Analysis.

According to the Westinghouse Large Turbine Division Power Plant Design Manual For Large Turbines (3), on a nuclear turbine a load change of 100% to 50% (corresponding to a turbine first stage temperature change of about 80 degrees F) can be made instantaneously without exceeding the stress corresponding to a 10,000 cycle fatigue capability. Restoration of load can then be made as rapidly as possible to 100%. Thus, if the percentage of repowering is limited to 50% and no more than 10,000 insolation transients are expected during the life of the repowered unit, the fatigue life of the turbine may not present any operational limitations even if thermal (buffering) storage is not employed.

2.2.12 Control System

Repowering of an existing fossil-fired generating unit involves the integration of new sophisticated control technology (solar plant) with the existing unit control system. The solar hybrid control system must provide safe and reliable control under all plant operating modes including fossil boiler only, solar only, or combined solar and fossil operation, and under all conditions of startup, shutdown, transient, steady state and emergency operation.

In general any unit suitable for repowering utilizing current proven power plant control technology, either pneumatic or electronic, can be modified to interface with the new solar plant control systems without significant changes to the existing control system. It is necessary, however, to provide both solar and fossil plant operation by a single operator from a central control room. For most solar hybrid repowering applications this may require the addition of a new control room plus additional room for the computer systems and computer electronic hardware and logic equipment associated with the solar plant control system.

2.2.13 Age and Condition of Plant

The age of the unit under consideration for repowering and its general condition determine the costs that would be incurred for necessary overhauls of existing non-solar equipment. Replacement or overhauls will, in general, be required for existing non-solar equipment so that plant availability can be assured during the design life of the solar equipment, perhaps 30 years.

Table 2-4 adapted from the PNM report classifies the repowerable Rankine units rated at 200 MWe or less by age and type, and also gives estimated retirement dates and the operating utilities' assessments of general unit condition. Although the units must be examined individually using the procedures outlined in Section 4, it is unlikely that all of the older units would pass such a screening. As a result, the number of candidate repowerable units is likely to be smaller than that shown in Table 2-4.

2.2.14 Favorable Attitude of Utility

It can be assumed that utility companies evidenced favorable attitudes towards repowering by responding to either survey. If the technical and economical feasibility of solar repowering can be demonstrated, it is quite likely that utilities which are not currently interested in repowering might change their positions and identify additional repowerable units.

2.3 PLANT CLASSIFICATION

Using the above information, the plants were classified into four general categories as shown in Table 2-5. This classification covers the range of repowerable plants and is the basis for the generic plants used in the System Integration Analysis described in Section 4.

Table 2-4

Unit Age, Condition, and Estimated Date of Retirement

CATEGORY	STEAM TURBINE-NON-REHEAT	STEAM TURBINE-REHEAT
Year Built		
Before 1941	7	0
1941-1950	37	0
1951-1960	81	51
1961-1970	17	26
1971 +	10	15
	152	92
General Unit Condition		
New	9	12
Good	110	77
Fair	26	3
Poor	7	0
	152	92
Estimated Retirement		
1978-1980	3	0
1981-1990	64	5
1991-2000	44	34
2001 +	25	45
	136	83

Table 2-5

Plant Classification/Typical Characteristics

TYPE OF UNIT	NON-REHEAT		REHEAT	
UNIT RATING, MW	25 - 50	75 - 125	75 - 200	225 - 600
INITIAL PRESS, PSIG	850 - 1250	1450 - 1800	1450 - 1800	1800 - 2400
INITIAL TEMP. °F	900 - 950	950 - 1000	950 - 1000	1000
FUEL TYPE	Gas/Oil	Gas/Oil	Gas/Oil	Gas/Oil
TYPICAL GROSS TURBINE CYCLE EFF.	34-35%	39-40%	42-43%	42-44%
YEAR BUILT	71% after 1950		100% after 1950	
CONDITION OF UNIT	Good		Good	
CURRENT USE	INTER./PEAK		BASE/INTERMEDIATE	
CURRENT ESTIMATED RETIREMENT DATE	80% by 2000		47% by 2000	

SECTION 3.0

SOLAR REPOWERING TECHNOLOGY ASSESSMENT

In order to assess the problems of solar repowering existing plants, it is necessary to review the primary solar central receiver technologies which are under development in light of the concept of repowering and identify the interface requirements by receiver type.

3.1 LITERATURE REVIEW

A review of the DOE sponsored Large Solar Central Power System program reports was made which identified two categories of solar central receiver concepts applicable to this study, namely, the Central Receiver Solar Thermal Power System which utilizes water/steam receivers and the Advanced Central Receiver Power Systems which utilize molten salt or liquid metal receivers with intermediate heat exchangers.

3.2 SOLAR CENTRAL RECEIVER SYSTEM DESCRIPTIONS

For the purpose of this study, four candidate solar central receiver systems have been selected for the Systems Integration Analysis; a brief description of the various receiver concepts is given below.

3.2.1 Water/Steam Once-Through Receiver

For the external, once-through water/steam receiver concept the McDonnell Douglas Astronautics Company (MDAC) 100 MWe Commercial Plant Concept (4) was chosen. This concept is shown in Figure 3-1. Receiver steam conditions are 11.1 MPa (1600 psig) and 516 degrees C (960 degrees F).

In the MDAC once-through receiver concept, feedwater enters the receiver preheat panels where the water is heated before entering the boiler panels where evaporation and superheat take place. Feedwater flow is controlled by temperature control valves preceding each boiler panel, thus maintaining the steam outlet temperature at the set point. Receiver steam pressure is controlled by the turbine control valves. No steam reheat is provided for in the MDAC design.

3.2.2 Water/Steam Drum Type Cavity Receiver

The Martin Marietta central receiver concept (5) was selected as an example of a cavity type receiver employing a natural circulation (drum type) boiler concept. Figure 3-2 shows the Martin Marietta 160 MWe Commercial Plant schematic using an admission-type, non-reheat turbine. Receiver outlet steam conditions are 10.78 MPa (1550 psig) and 515 degrees C (960 degrees F).

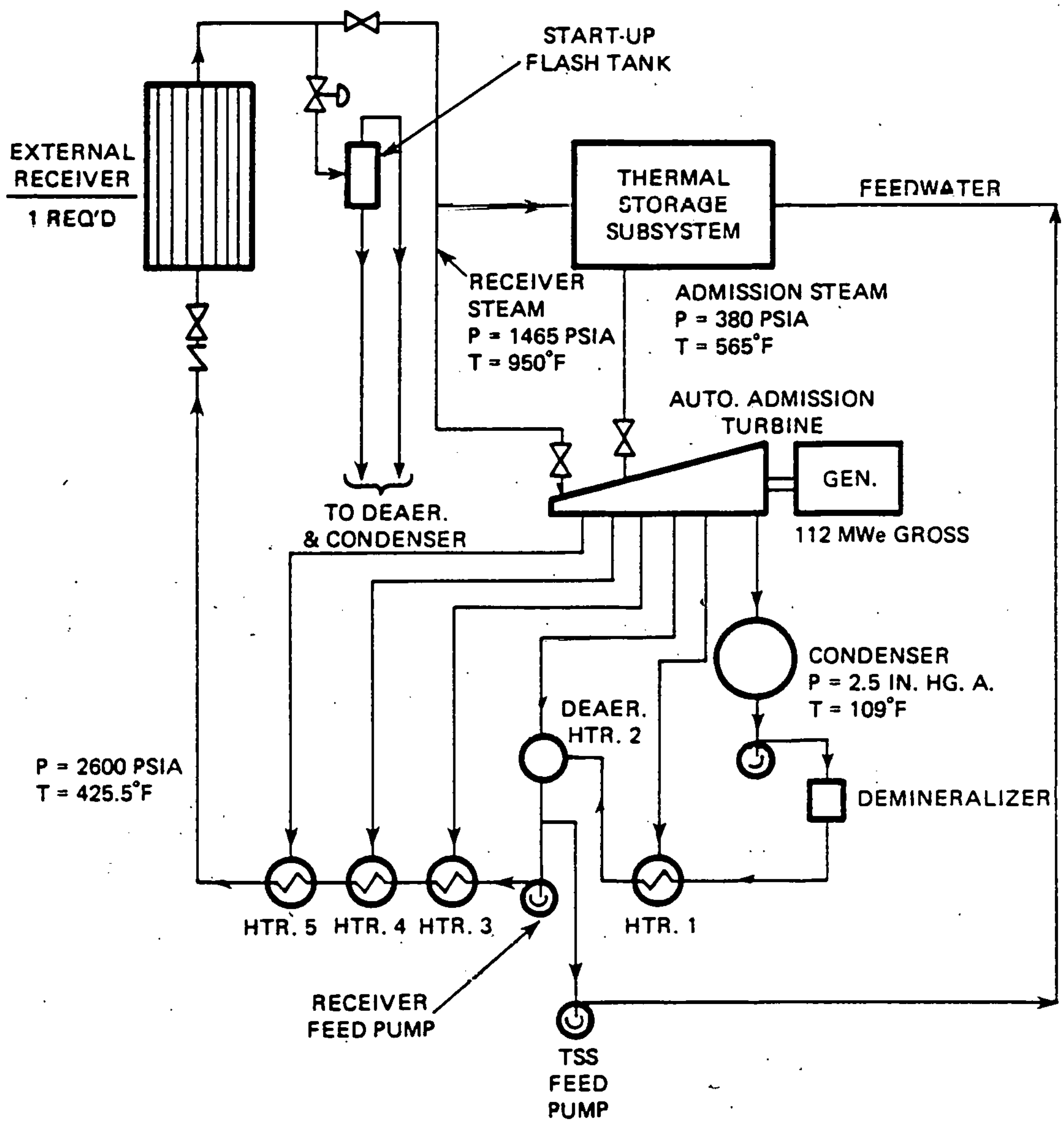

Figure 3—1. SIMPLIFIED WATER/STEAM CENTRAL RECEIVER COMMERCIAL SYSTEM SCHEMATIC McDONNELL DOUGLAS

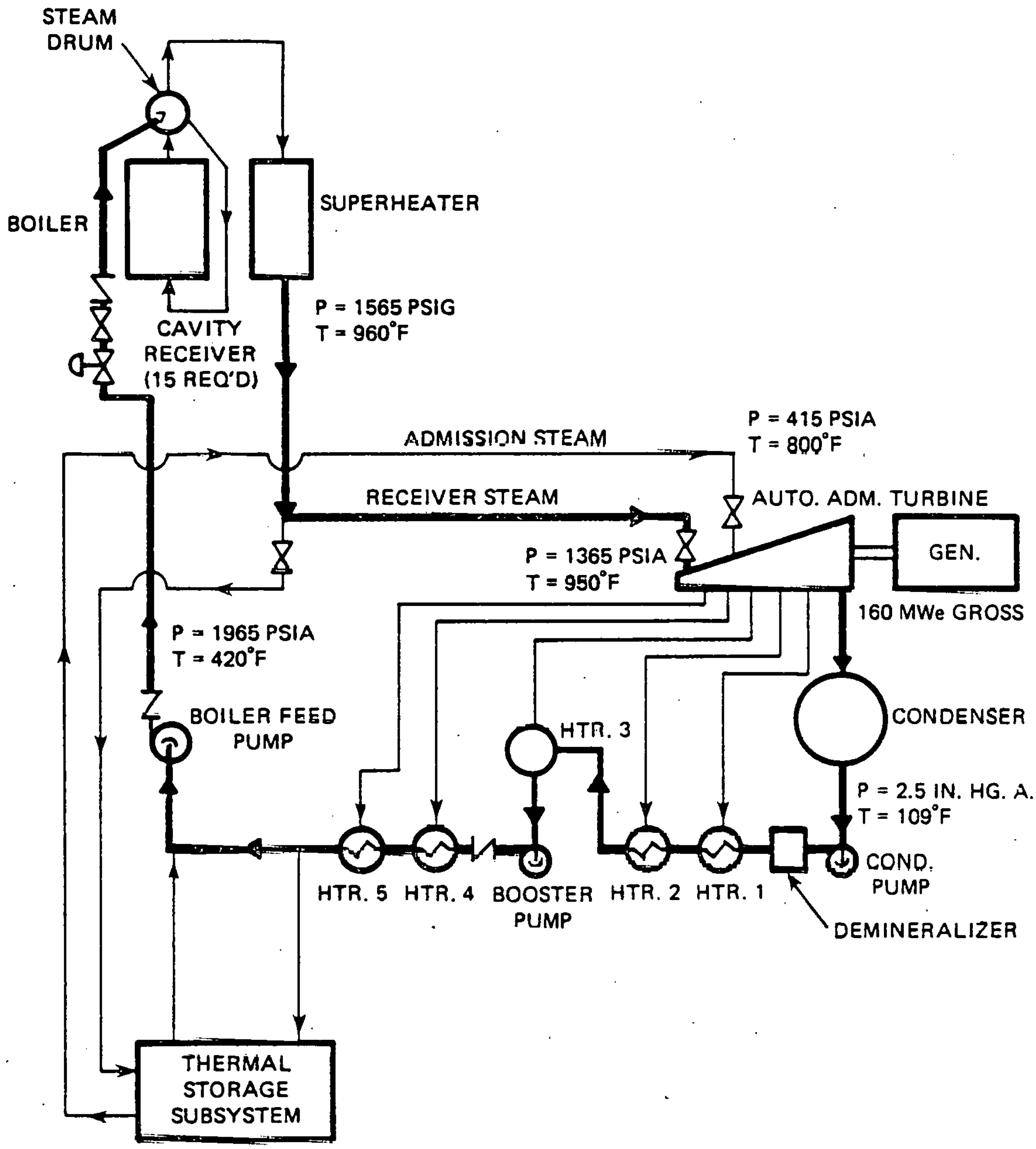

Figure 3—2. SIMPLIFIED WATER/STEAM CENTRAL RECEIVER COMMERCIAL SYSTEM SCHEMATIC MARTIN MARIETTA

In the Martin receiver concept, feedwater enters a steam drum before passing into the boiler tubes which generate saturated steam from feedwater. The steam/water mixture from the boiler tubes enters the steam drum where a steam/water separation occurs. Saturated steam leaving the steam drum enters the superheater which raises the temperature of the steam to the required superheater outlet temperature. Feedwater flow to the receiver is controlled by a three-element feedwater regulator. Superheated steam temperature is controlled by spray water attemperation.

3.2.3 Molten Salt Receiver

A conceptual receiver power system utilizing molten salt was developed by Martin Marietta (6) under the Advanced Central Receiver Power System program. This system is schematically shown in Figure 3-3. The proposed plant size was 300 MWe (net) with turbine inlet steam conditions of 16.5 MPa (2400 psig) and 510 degrees C (950 degrees F) with a single reheat to 510 degrees C (950 degrees F).

3.2.4 Liquid Metal Receiver

A conceptual design of an advanced central receiver power system utilizing a sodium-cooled receiver concept was developed by Rockwell International (7). The basic system configuration is depicted in Figure 3-4 for a 100 MWe Commercial Plant. The sodium heat transport loop operates in the temperature range of 288 degrees C (550 degrees F) to 593 degrees C (1100 degrees F). A conventional reheat steam turbine is used with initial steam conditions of 12.4 MPa (1800 psig) and 538 degrees C (1000 degrees F) with reheat to 538 degrees C (1000 degrees F).

3.3 INTERFACE REQUIREMENTS BY RECEIVER TYPE

For the purpose of defining the interface requirements used in the Systems Integration two solar central receiver types were considered, namely the water/steam receiver (once-through or drum type) and the molten salt or sodium-cooled receiver.

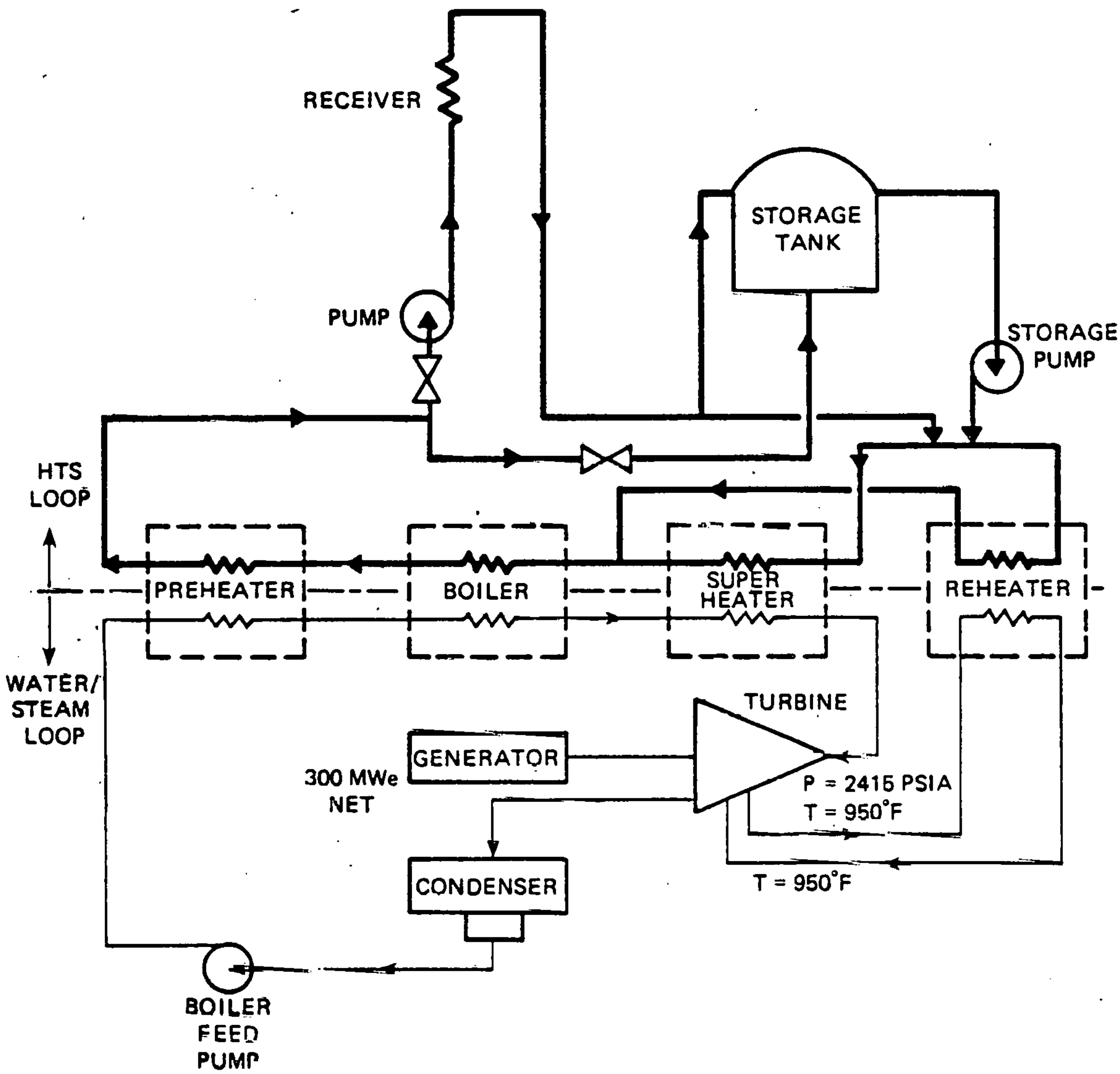

Figure 3—3. SIMPLIFIED MOLTEN SALT WATER-STEAM SYSTEM SCHEMATIC
MARTIN MARIETTA

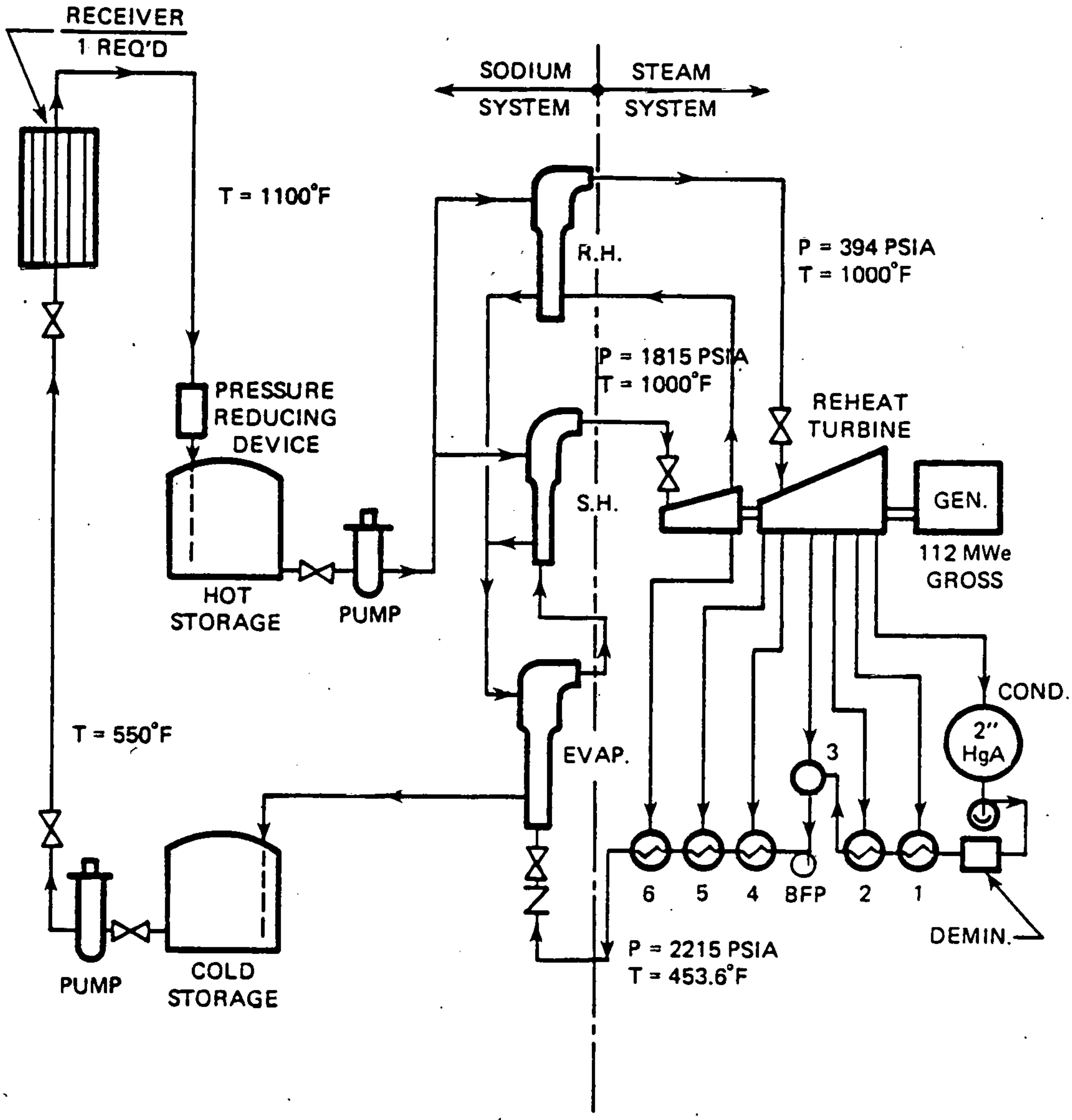

Figure 3–4. SIMPLIFIED SODIUM-COOLED CENTRAL RECEIVER COMMERCIAL SYSTEM SCHEMATIC ROCKWELL INTERNATIONAL

3.3.1 Water/Steam Receiver

From the standpoint of solar repowering, the two water/steam receiver concepts (external, once-through and cavity, drum type) have very similar interfaces with an existing plant. The primary differences are the methods of feedwater flow and steam temperature control and the receiver start up procedures. For the purpose of this study, then, it was assumed that a single interface schematic could represent both water/steam receiver concepts, as shown in Figure 3-5, without significant error.

As shown in Figure 3-5, the principal interfaces between the solar plant and existing plant for the water/steam receiver concept are:

1. Receiver steam supply to the existing main steam line to turbine.

2. Feedwater return to receiver.

3. Power and emergency power supply from the existing EPG (Electrical Power Generating) system to the collector, receiver and master control subsystems in the solar plant.

4. Control system interfaces between the existing EPG control room and master control.

3.3.2 Salt or Sodium-Cooled Receiver

The functional interfaces between the solar plant and existing plant for the salt or sodium-cooled receiver systems are shown in Figures 3-6 and 3-7 for the non-reheat and reheat cases, respectively. From a systems integration standpoint the sodium or salt-cooled receivers can be treated alike. The sodium or salt-cooled receiver systems with buffer storage and intermediate sodium/salt-to-steam heat exchangers provide a practical means of steam reheating, thus offer an advantage over the water/steam receiver concepts currently being developed.

As shown in Figure 3-6, the interface requirements for the sodium/salt-cooled receiver are the same as those for the water/steam receiver since the buffer storage and intermediate heat exchangers are considered part of the solar plant. Reheating adds two additional interface points, i.e., hot and cold reheat steam connections to the existing reheat lines, as shown in Figure 3-7.

A summary of the major interface points by receiver type is shown in Table 3-1.

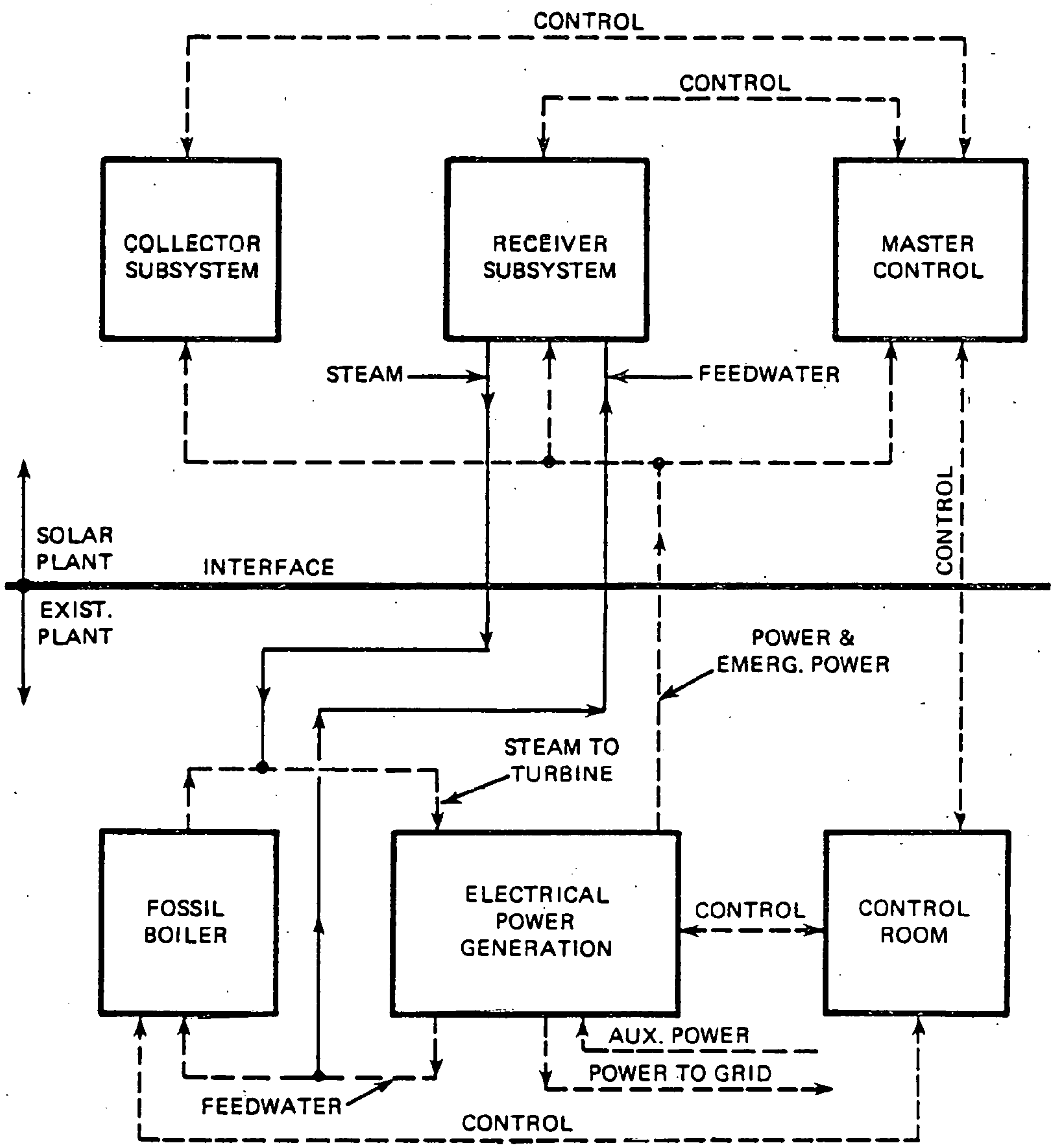

Figure 3–5. FUNCTIONAL INTERFACE DIAGRAM - WATER/STEAM RECEIVER (NON-REHEAT) SOLAR HYBRID REPOWERING

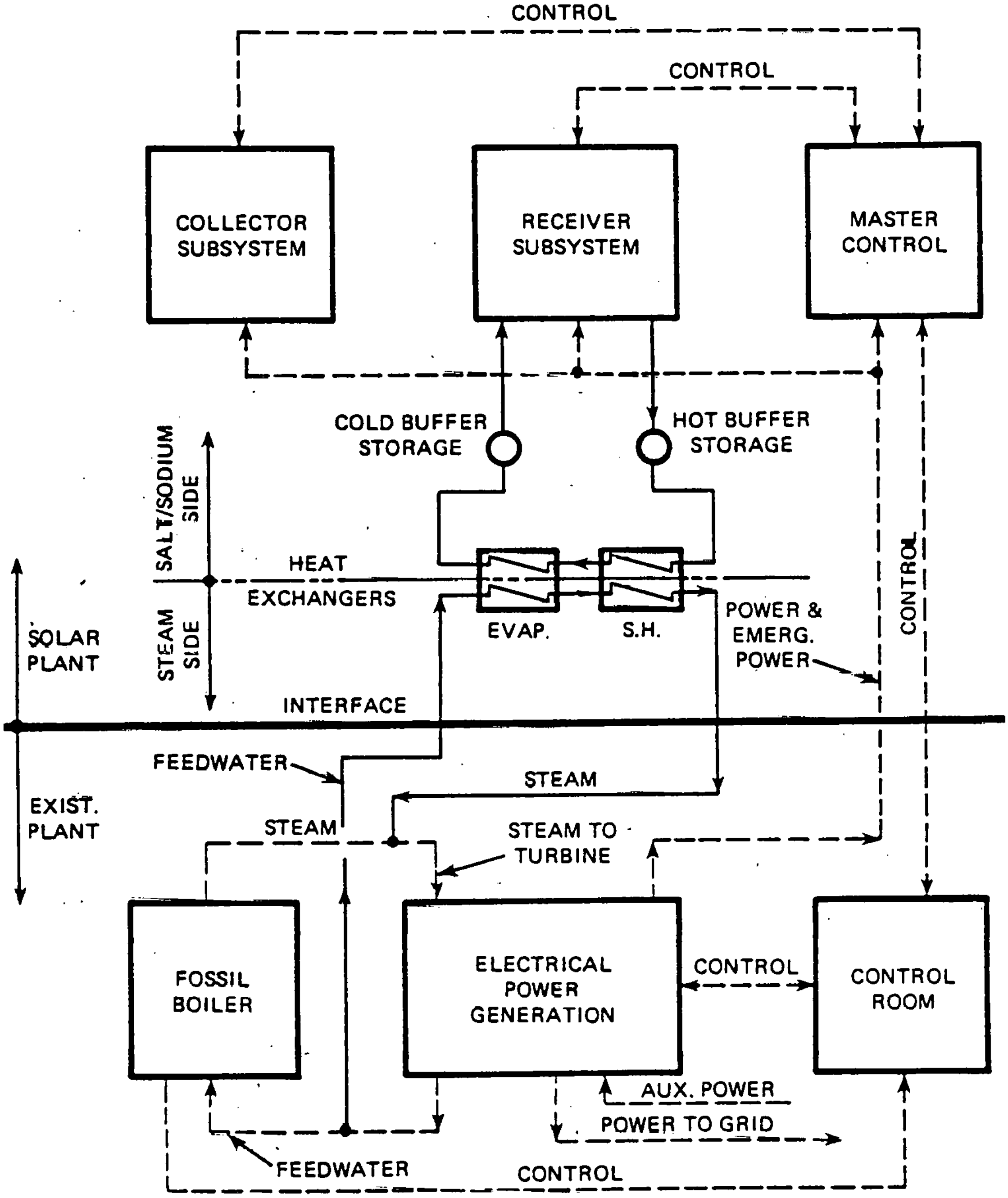

Figure 3–6. FUNCTIONAL INTERFACE DIAGRAM - MOLTEN SALT OR LIQUID METAL (SODIUM) COOLED RECEIVER (NON-REHEAT) SOLAR HYBRID REPOWERING

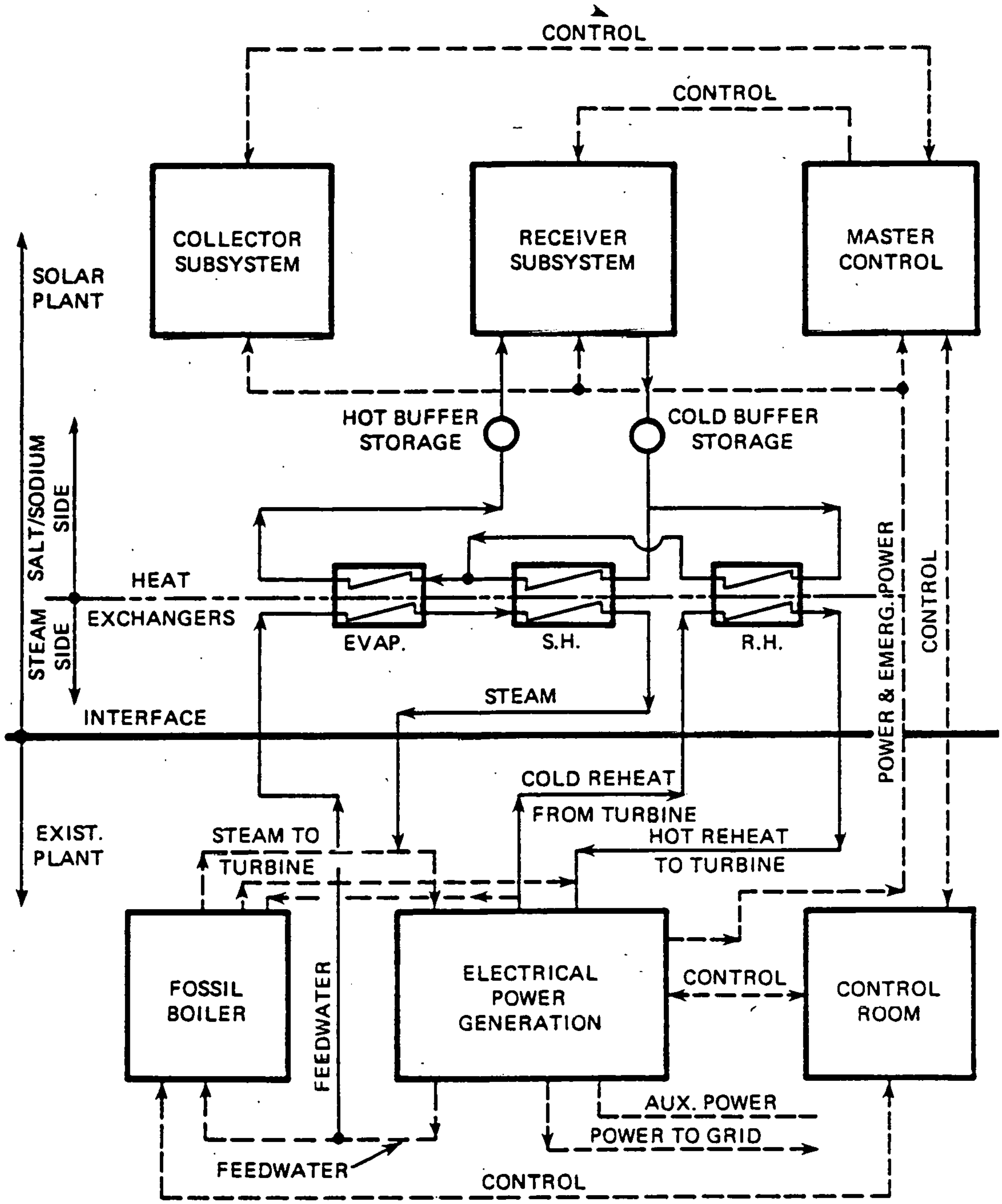

Figure 3–7. FUNCTIONAL INTERFACE DIAGRAM · MOLTEN SALT OR LIQUID METAL (SODIUM) COOLED RECEIVER (REHEAT) SOLAR HYBRID REPOWERING

Table 3-1

Major Interface Points By Receiver Type

Interface With Existing Plant	Receiver Type	
	Water/Steam	Salt/Sodium
1. Receiver Steam	X	X
2. Hot Reheat Steam	Not Applicable	X (If Required)
3. Cold Reheat Steam	Not Applicable	X (If Required)
4. Feedwater	X	X
5. Power Supply	X	X
6. Master Control	X	X

X Denotes interface requirement

3.4 EXISTING PLANT MODIFICATIONS

In addition to the major interface requirements previously identified by receiver type, several other balance of plant modifications will be required to facilitate solar repowering which are essentially independent of receiver type. These modifications include turbine-generator and boiler modifications for extended life, control systems modifications, condensate treatment, equipment cooling water additions, control room modifications, piping modifications required by ASME and ANSI codes, and modifications or additions to existing electrical equipment including emergency and uninterruptible power supplies. These items are discussed in Section 4.

SECTION 4.0

SYSTEMS INTEGRATION

4.1 PROMISING COMBINATIONS

This study has identified four generic plant classes (25-50 MW non-reheat units, 75-125 MW non-reheat units, 75-200 MW reheat units, and 225-600 MW reheat units) as being representative of all of the repowerable steam Rankine units identified by the PNM and MITRE studies. Similarly, the various central receiver types that have been studied under DOE sponsorship have been classified in two categories, namely water/steam receivers and molten salt/liquid metal receivers. There are therefore eight combinations of generic plant type and receiver type.

Of these eight combinations, six were selected for detailed cost evaluations. These are a 50% repower of 50 MW and 100 MW non-reheat units using a water/steam receiver, and a 50% and 100% repower of 100 MW and 350 MW reheat units using a salt or sodium cooled receiver. These combinations were selected to give a reasonable mix of both plant types and receiver technologies. Water/steam technology was not used for the reheat units and the absence of inexpensive buffer storage for water/steam receivers limited the repowering fraction to 50%. Both 50% and 100% repowering fractions were selected for the reheat units to examine the economies of scale in integration cost. The technical details of these combinations are discussed in the next section.

4.2 INTERFACE REQUIREMENTS CATALOG

4.2.1 Representative Unit Descriptions

Table 4-1 shows the unit descriptions which have been selected as representative of each of the four classes of units shown in Section 2.

Table 4-1. Representative Unit Descriptions

	Unit 1	Unit 2	Unit 3	Unit 4
Type of Unit	Non-reheat	Non-reheat	Reheat	Reheat
Unit Rating, MWe gross	50	100	100	350
Throttle Pressure, psig	1250	1450	1800	2400
Throttle Temp., oF	950	1000	1000	1000
Hot Reheat Temp., oF	NA	NA	1000	1000
Fuel Type	Oil	Oil	Oil	Oil
Boiler Type	Natural Recirculation Drum	Natural Recirculation Drum	Natural Recirculation Drum	Natural Recirculation Drum
Gross Turbine Cycle Efficiency, %	38.8	40.4	42.0	43.5
Year On Line	1959	1959	1959	1965
Condition of Unit	Good	Good	Good	Good
Current Use	Intermediate or Peaking	Intermediate	Intermediate	Intermediate Or Base Load
Existing Feedwater	Makeup	Makeup	Makeup	Makeup
Treatment System	Demineralizer	Demineralizer	Demineralizer	Demineralizer
Condensate Pump Flow (lb/hr)	293,000	551,000	475,420	1,595,000
Boiler Feed Pump Flow (lb/hr)	408,000	777,000	653,900	2,364,500
% Repowering (Maximum)	50	50	50, 100	50, 100

Gross Turbine Cycle Efficiency. The gross turbine cycle efficiencies shown in Table 4-1 are based on the AIEE-ASME preferred standards or GE performance specifications for turbine-generators.

Year On Line. As was shown in Table 2-4, 98 of the 152 (64%) non-reheat units of 200 MWe rating or less identified as repowering candidates by PNM were constructed between the years 1951 and 1970. Of the 92 reheat units rated 200 MWe or less, 77 (84%) were constructed between the years 1951 and 1970. (Age data on units rated at over 200 MWe were not presented). With the exception of the 350 MWe unit, the generic units are assumed to have gone on line in 1959, which is about midway in the span of years in which the bulk of the units were built. The 350 MWe unit is assumed to have gone on line in 1965, reflecting the fact that the larger reheat units tend to be the more recently constructed.

Condition of Units. As was shown in Table 2-4, 119 (78%) of the 152 non-reheat repowering candidate units were identified by the utilities as being in "new" or "good" condition. Only 33 (22%) of the non-reheat units were characterized as being in "fair" or "poor" condition. Most of these units are among the 44 units which were constructed prior to 1951. Among the reheat units 200 MWe or less which were identified as repowering candidate units, only 3 (3%) of the 92 units were classified as being in "fair" condition and none were classified as being in "poor" condition. The remaining 89 units (97%) were classified as being in "new" or "good" condition. Accordingly, the hypothetical units were described as being in "good" condition.

Current Use. 73 (48%) of the 152 non-reheat repowering candidate units were identified as being in base or intermediate (non-cycling) service by the utilities. 31 (20%) were identified as being in standby service (most of these are the older units that are in "fair" or "poor" condition) and 46 (30%) are in peaking (cycling) service. Among the reheat units 88 of 92 (96%) are in base or intermediate use and only 4 (4%) are in peaking service. Accordingly, the small 50 MWe unit is assumed to have been operated as an intermediate or peaking unit, the two 100 MWe units as intermediates, and the 350 MWe unit as an intermediate or base unit. Among the 30% of the small, non-reheat units that are operating as peaking units, some may already have been retrofitted with condensate polishing systems and water treatment equipment that are recommended for solar repowered units. The costs of required plant modifications will, of course, be lower in those cases.

Existing Feedwater Treatment System. The existing feedwater treatment system is assumed to consist of two bed (cation and anion) feedwater makeup demineralizers for the three smaller units and a 3 bed (cation, anion, and mixed bed) feedwater makeup demineralizer for the 350 MWe unit. Chemical feed equipment adequate to feed 3 feedwater chemicals is assumed to be in use at all four units.

Condensate and Boiler Feed Pump Flows. The design flows shown were obtained from the AIEE-ASME preferred standards or GE performance specifications for turbine-generator units.

Percentage of Repowering. For the two nonreheat units, the maximum percentage of repowering is assumed to be 50%. This means that, under conditions of maximum solar insolation, the steam flow from the solar receiver (water/steam system) or main steam generator (molten salt/liquid metal system) is 50% of the rated throttle steam flow for the turbine. Steam flow from the reheat heat exchanger will also be approximately 50% of rated reheat steam flow. In the cases of the two non-reheat units to be repowered with water/steam receivers, 50% repowering appears to be the maximum that is technically feasible, as was discussed previously. For the two reheat units employing molten salt or liquid metal receivers the inclusion of a one-half hour buffer storage system is assumed, and both 50% and 100% repowering are studied.

4.2.2 P & I Diagrams

Piping and instrument diagrams have been prepared for each of the four hypothetical units for the purpose of defining solar plant-balance of plant piping and control interface requirements. Six P & I diagrams are included as follows:

- Figure 4-1 50 MW Nonreheat, Water/Steam Receiver, 50% Solar Repowering
- Figure 4-2 100 MW Nonreheat, Water/Steam Receiver, 50% Solar Repowering
- Figure 4-3 100 MW Reheat, Salt or Sodium-Cooled Receiver, 50% Solar Repowering
- Figure 4-4 100 MW Reheat, Salt or Sodium-Cooled Receiver, 100% Solar Repowering
- Figure 4-5 350 MW Reheat, Salt or Sodium-Cooled Receiver, 50% Solar Repowering
- Figure 4-6 350 MW Reheat, Salt or Sodium-Cooled Receiver, 100% Solar Repowering

4.2.3 Description of Balance of Plant Modifications

The following is a description and selection rationale for system/equipment modifications necessary to facilitate solar repowering of an existing gas/oil-fired steam electric unit. The systems or equipment modifications are described in the following order:

- Turbine-Generator
- Boiler

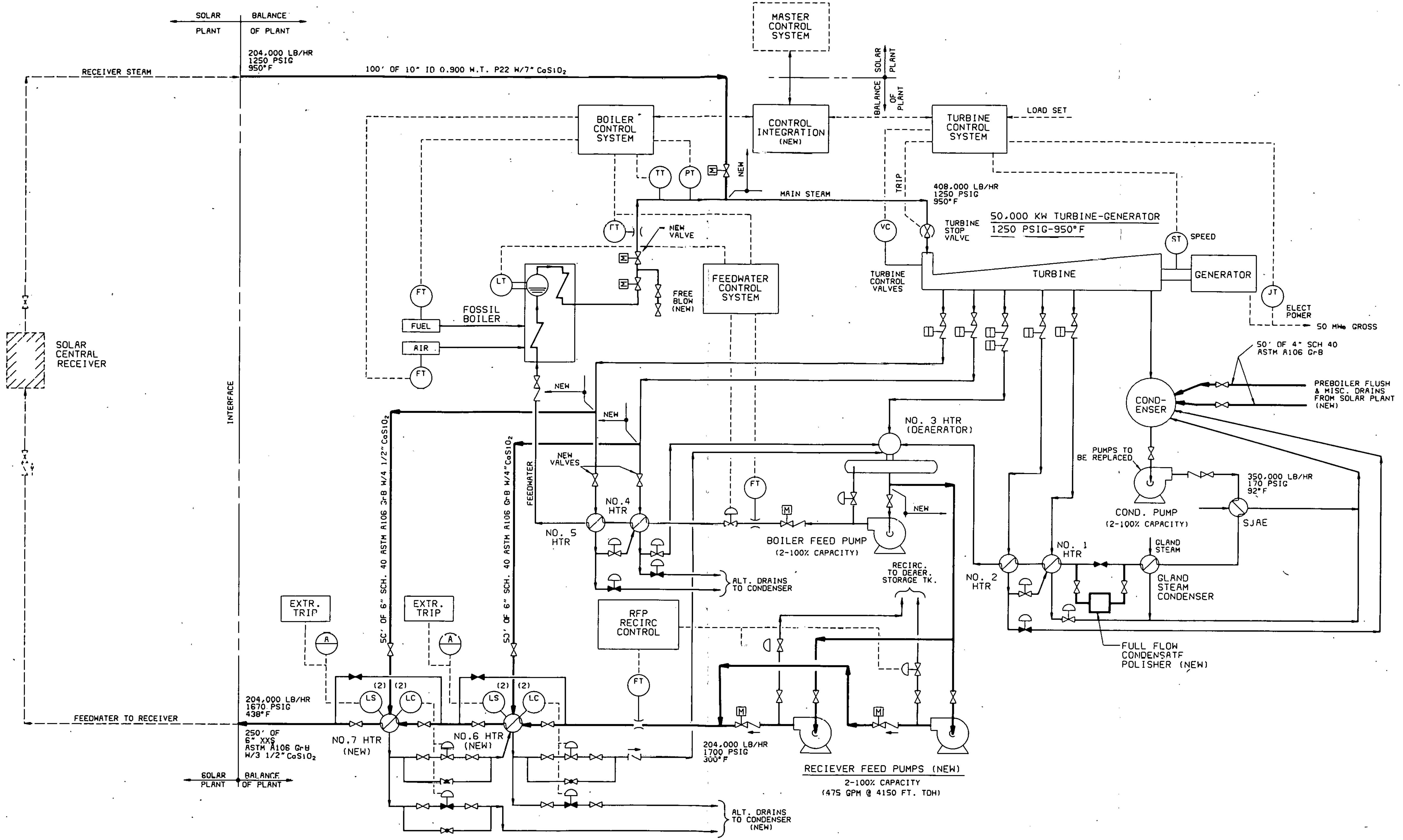

Figure 4–1. **P&I DIAGRAM**
50 MWe NON-REHEAT TURBINE
50% SOLAR REPOWERING WATER/STEAM RECEIVER

IGS NO. 8F9418
6/12/79

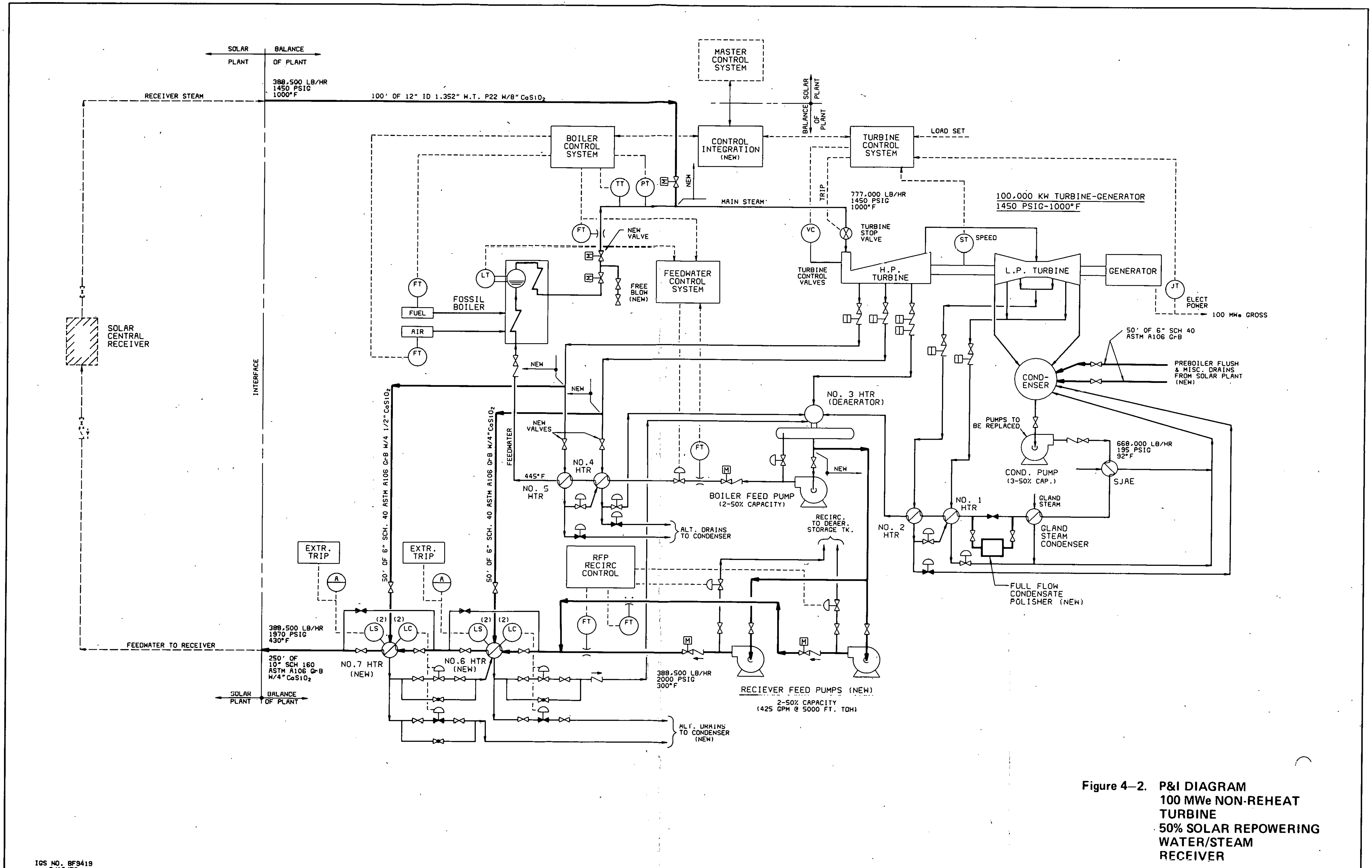

**Figure 4—2. P&I DIAGRAM
100 MWe NON-REHEAT
TURBINE
50% SOLAR REPOWERING
WATER/STEAM
RECEIVER**

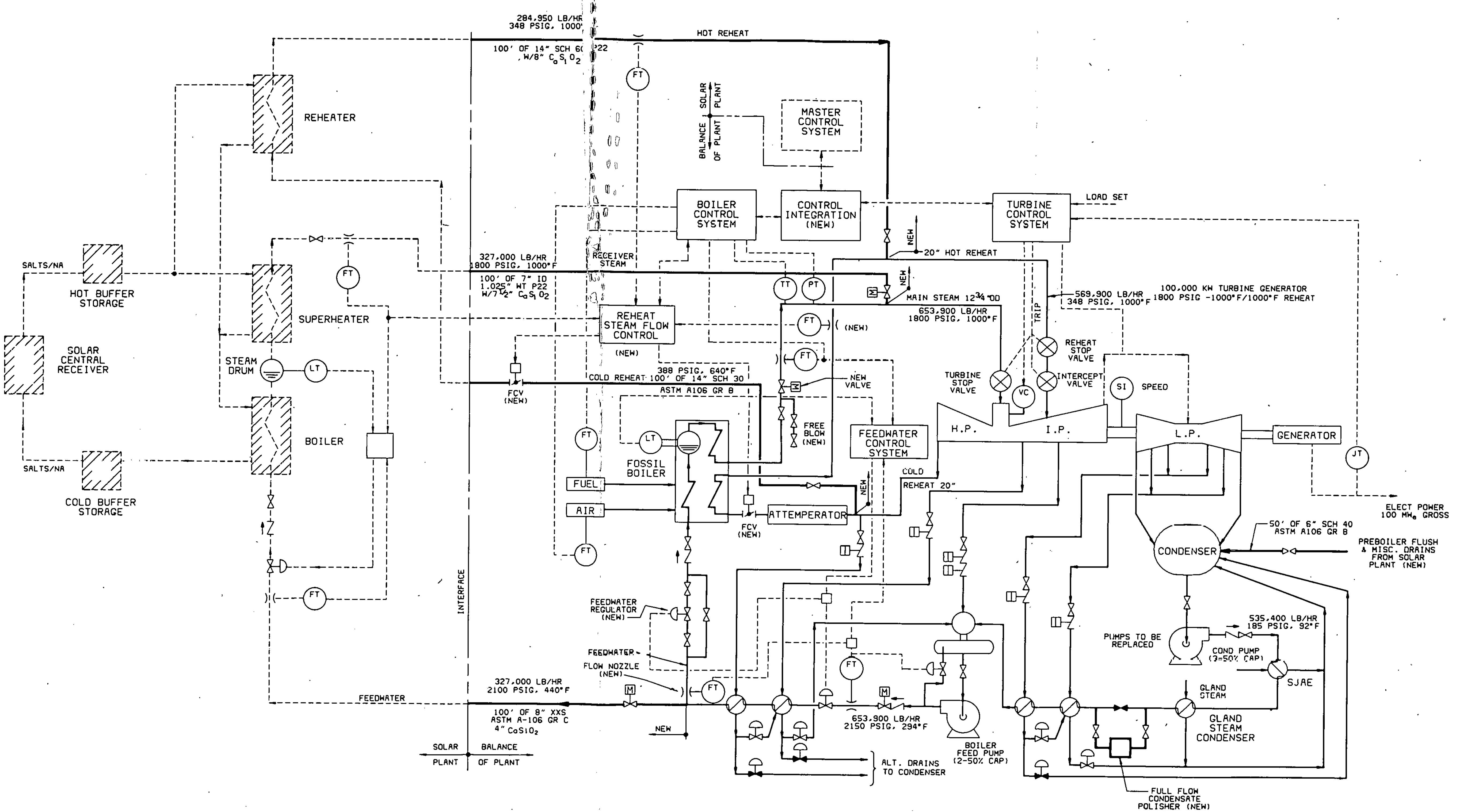

**Figure 4–3. P&I DIAGRAM
100 MWe REHEAT TURBINE
50% SOLAR REPOWERING
MOLTEN SALT OR
LIQUID METAL COOLED
RECEIVER**

IGS NO. BF9420
6/12/79

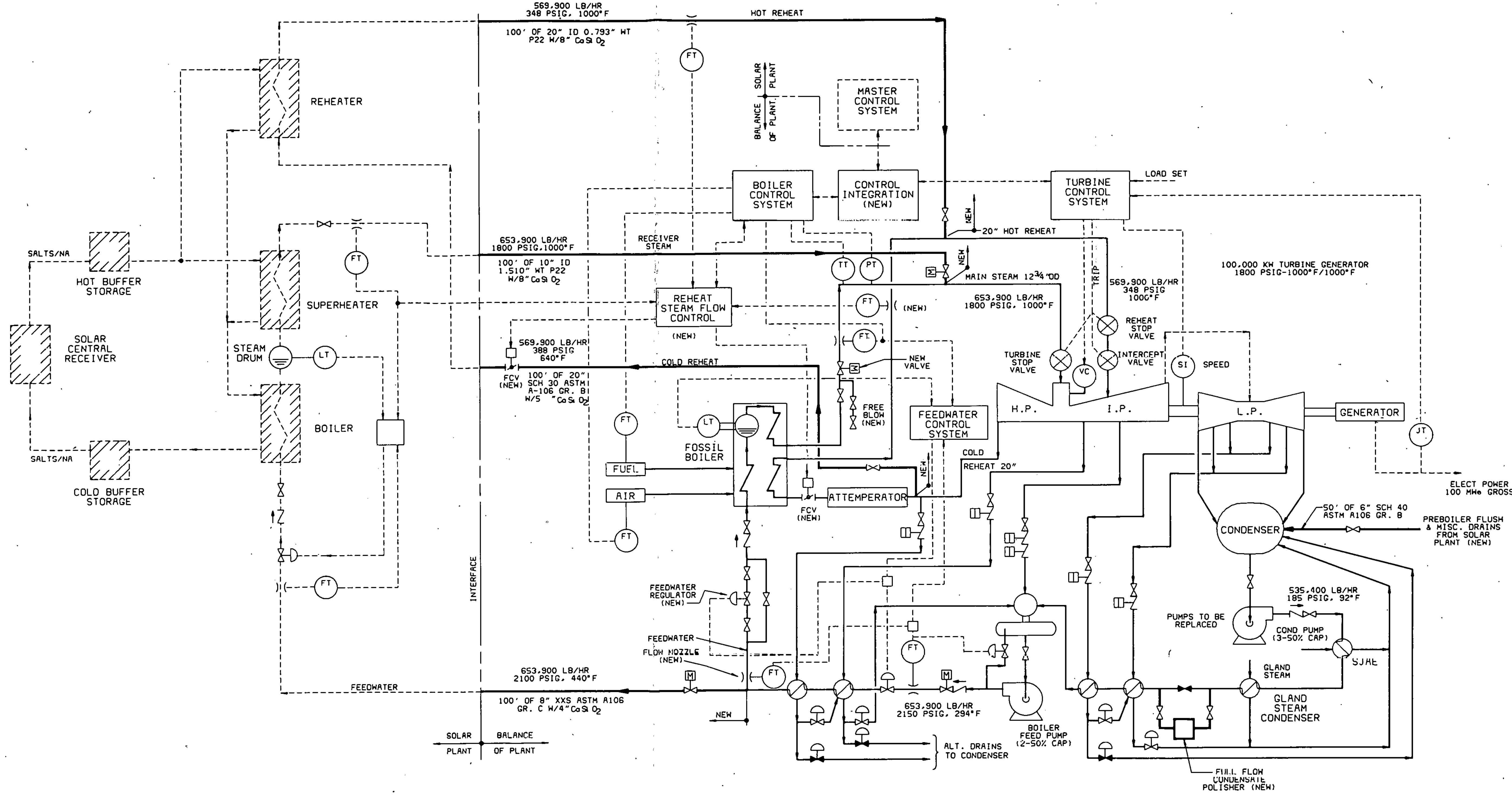

Figure 4—4. **P&I DIAGRAM**
100 MWe REHEAT TURBINE
100% SOLAR REPOWERING
MOLTEN SALT OR
LIQUID METAL COOLED
RECEIVER

IGS NO. BF9421
6/12/79

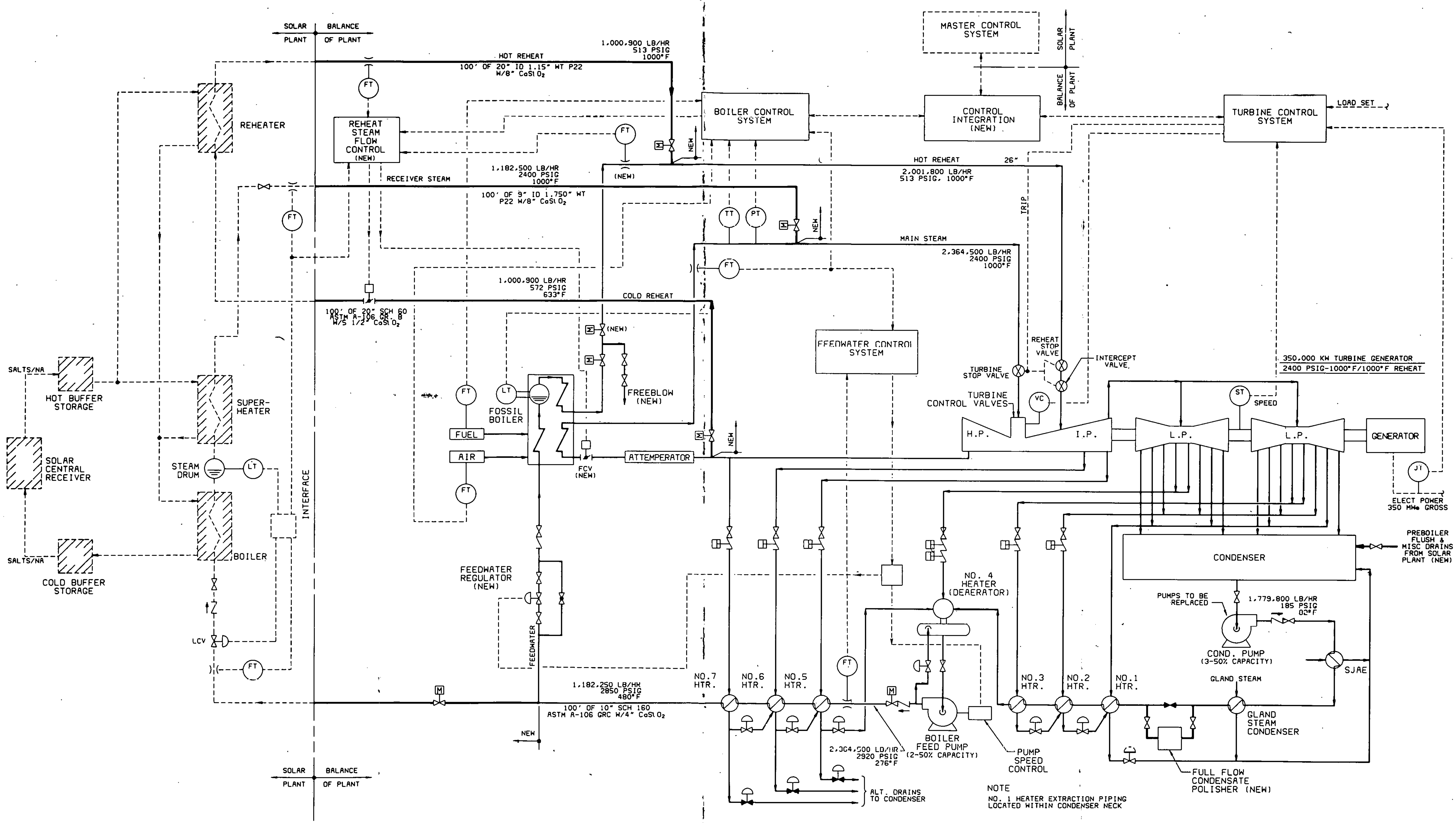

Figure 4–5. **P&I DIAGRAM 350 MWe REHEAT TURBINE 50% SOLAR REPOWERING MOLTEN SALT OR LIQUID METAL COOLED RECEIVER**

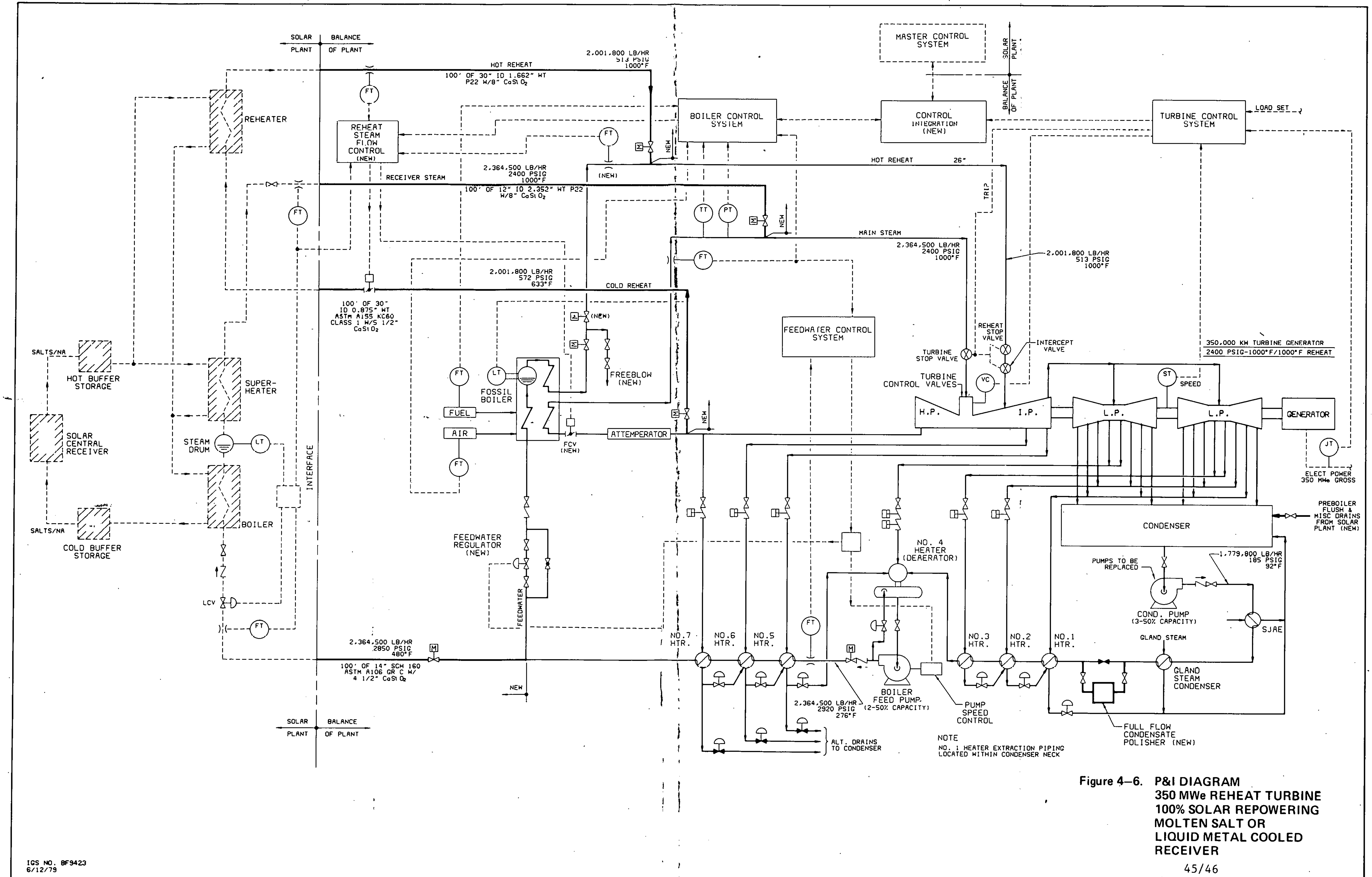

Figure 4–6. P&I DIAGRAM 350 MWe REHEAT TURBINE 100% SOLAR REPOWERING MOLTEN SALT OR LIQUID METAL COOLED RECEIVER

- Control System
- Pumps
- Piping
- Feedwater Heaters
- Electrical System
- Water Treating System
- Miscellaneous Systems

4.2.3.1 Turbine-Generator Modifications. Since the existing steam turbine-generator unit in a solar repowered plant will be required to operate reliably for 30 years after the solar plant addition, and in some cases under rather adverse cycling duty, the turbine condition and provisions for extending turbine life are important considerations. The typical repowering candidate units identified in the PNM study were reported to be in good condition and are being used for either intermediate or peaking load service. The scheduled retirement date for these units is generally before the year 2000.

Historically, older steam turbines are shifted to cycling duty after newer, more efficient units are put on line. Units which have been converted to cycling duty have been observed to be more subject to cyclic stress fatigue failure than base loaded units. Since many, if not most, solar hybrid power plants are expected to be operated as cycling or peaking units, the operating techniques and physical modifications implemented to minimize fatigue cracking and maximize operational life in units converted to cycling duty should apply. The principal aim of the operating techniques is to reduce the degree and frequency of temperature transients during startup, load changes, solar transients and shutdown.

The extent of turbine-generator modifications required to extend turbine-generator life will depend on the maintenance and operating history and condition of the specific unit to be repowered. There are, however, three types of procedures and modifications that should be considered when extended cycling turbine-generator operation is planned. They are:

- Inspection:
    - Complete turbine-generator dismantling and visual inspection.
    - Nondestructive testing of turbine components, such as radiographic or magnetic particle examination of critical points of castings, bore-scope of the turbine rotor, etc., to detect stress cracking.

- Repair/Overhaul:
  - Repair or renew parts in accordance with the manufacturer's recommendation (based on their experience with similar turbines converted to cycling service) or parts which are damaged.
- Turbine Upgrading:
  - Install thermocouples to check turbine metal temperatures in critical areas to facilitate startup and monitoring during turbine operation.
  - Modify turbine control system to provide valve management required for throttle pressure control. An electro-hydraulic control system is recommended because of its greater capability for handling load cycling, faster response, and compatibility with the solar plant control system (master control).
  - Consider variable pressure control to minimize turbine first stage metal temperature changes during load reduction prior to shutdown.

G.E. states that the required modifications to set a unit up for cyclic duty for 30 years would have to be determined on a specific unit basis. Some of the older units could require such things as: new high pressure shells, new 1st stage nozzle configurations, new valve arrangements, new rotors, generator rewinding, new control systems, and supervisory instrument systems. Units with water seals might need to be converted to steam seals.

General Electric's assessment is that it is almost impossible to provide realistic estimates of required modifications without assessing specific units. General Electric recommends their cyclic study approach which is an in-depth review of the specific turbine-generator set requiring extensive engineering on both the turbine and generator.

An outline of General Electric's study is as follows:

1. Review of unit history to:

   a. Document alteration to the unit.

   b. Outline major casualties.

   c. Determine material used in original construction.

2. Review of instruments.

   a. General upgrading recommendation.

b. Determine adequacy of thermocouples to:

(1) Detect water induction.

(2) Monitor first stage temperature.

(3) Monitor valve chest temperature.

(4) Monitor stop valve.

(5) Monitor packing steam temperature.

(6) Monitor seal steam temperature.

(7) Monitor temperatures at additional locations as necessary.

c. Resistance temperature device applications. Review for:

(1) Monitoring thrust bearing temperatures.

(2) Monitoring journal bearing temperatures.

d. Printer recorder; recommendations.

e. Start-up speed control recommendation.

(1) Long-range speed control.

(2) Acceleration meter.

(3) Load limit pilot valve application.

3. Vibration monitoring.

4. Review of controls:

a. Minimum load requirement.

b. Heat rate effect.

c. Boiler effect.

5. Turbine mechanical construction review:

a. Internal turbine inspection recommendations.

(1) Periphery magnetic particle inspection.

(2) Periphery sonic inspection.

(3) Bore magnetic particle inspection.

(4) Bore sonic inspection.

(5) Wheel sonic inspection.

6. Mechanical history review.

a. Shell construction.

b. Rotor potential crack study.

(1) Caused by misalignment.

(2) Rotor machining.

(3) Rotor improvement.

(a) Front end machining.

(b) Material.

c. Nozzle construction.

(1) Design.

(2) Material.

d. Intermediate construction.

(1) Bolting.

e. Clearances.

(1) Axial.

(2) Radial.

(3) Back thrust bearing.

(4) Detrimental effect on heat rate loss.

f. Thrust bearing construction.

(1) Loading.

(a) Copper back.

(b) Thermocouples.

g. Stop valve casing construction review.

(1) Low cycle fatigue analysis.

(a) Past thermal ramp history.

(b) Inspection recommendation.

(c) Replacement.

h. Control valve chest.

(1) Low cycle fatigue analysis.

(a) Past thermal ramp history.

i. Main steam lead review.

(1) Identification.

(2) Application.

j. Bucket review.

(1) Application history.

(2) Vibration history.

(3) Replacement recommendation.

k. Conversion of packing.

(1) Steam seal #1 packing.

(2) Material application.

(3) Back clearance review.

l. Water removal review.

m. Borescope opening.

(1) Location.

7. Engineering recommendation.

a. Rotor life expenditure curve.

b. Shell ramp curves.

c. Comparison

d. Starting and loading charts.

(1) Control life expenditure.

(2) Pre-warming recommendation.

8. Recommendation of frequency of inspection.

9. Maximum turbine capability.

a. Without material changes.

b. With material changes.

10. Maximum generator capability.

a. Without material changes.

b. With material changes.

Figure 4-7 is a decision tree for the inspection of steam turbine rotors; it was adapted from a Westinghouse publication (8) and so is specifically applicable only to Westinghouse turbines. However, other turbine manufacturers recommend similar inspection programs for their units. The four inspections that Westinghouse recommends for their units are rotor exterior inspections, rotor interior inspections, High Pressure blade groove inspections, and Intermediate Pressure blade groove inspections.

The rotor exterior inspection, which Westinghouse recommends to be done during every major turbine inspection, includes the following:

- Truth and diameter (to detect high temperature creep) checks.
- Nondestructive tests including magnetic particle and dye penetrant tests to detect surface and near surface flaws.
- Miscellaneous checks including coupling inspection, autostop inspection, and overspeed trip setting, and inspection for hard particle or moisture erosion of blading.

The rotor interior inspection is recommended for certain units as shown on the decision tree and includes the following:

- Bore diameter measurements to determine rate of high temperature creep.
- Bore honing and polishing followed by a visual inspection and a magnetic particle inspection.

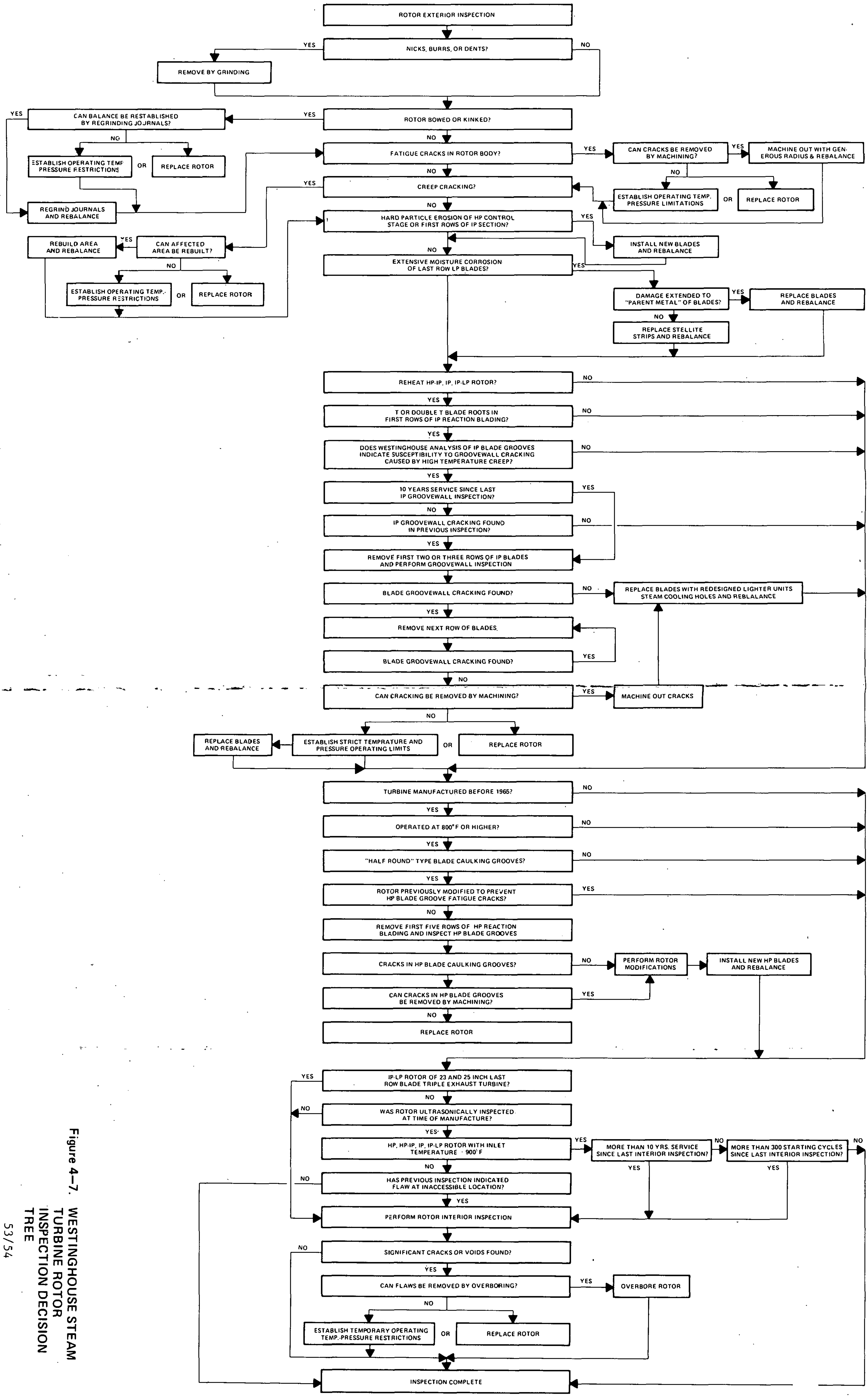

Figure 4—7. WESTINGHOUSE STEAM TURBINE ROTOR INSPECTION DECISION TREE

- Ultrasonic inspection with three different transducers at 2.25 and 5 MHz to detect interior flaws and cracks.

- On 1000 degrees F units which have not been cored previously, a core sample is laboratory tested for notch sensitivity and fracture ductility.

The high pressure blade groove inspection is recommended for High Pressure or High Pressure - Intermediate Pressure rotors operated at 800 degrees F and higher and utilizing "half-round" type HP blade caulking grooves. (This typically applies to the first five rows of reaction blades of most turbines manufactured before 1965). It is recommended that this inspection be done during the next major inspection outage on every rotor that has not previously been modified to prevent HP blade groove fatigue cracking. Since the blade tenons must be machined off to remove the blades, the original blades cannot be reinstalled; a set of replacement blades (6-12 months lead time for manufacture) is required. The blade grooves are inspected using techniques similar to the exterior surface inspection, i.e., magnetic particle and dye penetrant inspection. About 55% of the units inspected have already demonstrated cracks in the rotor, and the other 45% are expected to crack, given a few more years of cyclic duty.

Westinghouse recommends that the following rotor geometry modifications be performed during the inspection. These modifications will extend the thermal cyclic fatigue capacity of the modified areas by a factor of 7 or 8, according to Westinghouse.

- Enlarging the expansion grooves ahead of the first row of reaction blading.

- Eliminating the semicircular caulking piece groove and increasing the size of the fillets in the first five reaction blade grooves.

- Increasing the radii of the expansion grooves on both sides of the High Pressure dummy.

- Increasing the radii of the labyrinth seal expansion grooves in the number 1 and number 2 inner gland areas.

- Other surface machining where necessary to eliminate stress rise and cracks.

Westinghouse recommends that the Intermediate Pressure reaction blade groove walls be inspected on certain reheat units. The inspection consists of the removal of two or three rows of blades followed by nondestructive testing of the blade grooves. Any cracks found are removed by machining, if possible, and the blades are replaced with new units, often of an improved design (lighter and with steam cooling holes to the groovewall area).

4.2.3.2 Boiler Modifications. For most solar hybrid repowering applications the existing gas/oil-fired boiler will require few, if any, modifications. Some important operational considerations include turn-down ratio (the ratio of maximum to minimum steam flow), steam temperature control and allowable ramp rates, particularly if thermal (buffering) storage is not employed. For most gas/oil-fired boilers a turn-down ratio of 5-to-1 with all burners in service and in automatic control is generally achievable without burner or fuel and air supply system modifications.

All boilers have the general characteristic that superheat and reheat steam temperatures begin to drop as steam flow is reduced to below approximately half-load. For example, at 25 percent load the superheater outlet temperature and reheater outlet temperature may be 100-150 degrees F below rated steam temperatures. Therefore, when the fossil boiler is operating below half-load the receiver (or steam generator) steam temperature will have to be higher than rated to achieve rated steam temperature at the turbine throttle.

Boiler ramp rate (the rate of boiler load increase or decrease) is an important consideration when operating in parallel with the solar receiver because of solar insolation transients which directly affect solar steam output if thermal storage is not employed. The maximum allowable ramp rate for the Reeves unit as reported in the PNM report was 30 percent per minute. It is believed that most gas/oil-fired boilers can accommodate ramp rates of 30 percent per minute, or higher, when increasing load from approximately 20 percent to full load on drum type boilers. The usual limiting factors on ramp rate are drum swell and priming. Drum swell is the rapid rise in the boiler drum water level caused by the rapidly increasing volume of steam bubbles in the boiler tubes, which displaces water. Drum level control instability or critical high drum level unit trips can result. Priming is caused by high drum levels and is the carryover of liquid droplets through the steam separators into the superheater; in extreme cases water carryover into the turbine can result.

4.2.3.3 Control System Modifications. It is assumed that the steam plant controls utilize the "boiler following" control concept and are either pneumatic or electronic control systems. In the "boiler following" control concept the boiler control system operates to control turbine throttle pressure by varying the firing rate while the turbine control system varies turbine control valve position to throttle main steam flow in response to speed and load settings. With the addition of the solar plant it will be necessary to modify the control systems to permit integration of the existing plant control systems with the master control system and to enable the plant to operate either in a "boiler following" or "turbine following" mode of operation. In the "turbine following" mode, used during solar-only plant operation, the turbine control system operates to maintain turbine throttle pressure by varying turbine control valve position as the solar plant steam flow varies. This modified or coordinated control system will then enable the solar hybrid plant to operate in the fossil-only mode, solar-only mode or combination solar/fossil mode as required.

A general description of the anticipated plant control system modifications follow:

- Control Integration. The present turbine/boiler control systems will be coordinated through a new distributed analog control (DAC) system. The DAC will provide an interface between the existing plant control systems, i.e., combustion control and turbine control systems, new control loops (such as throttle pressure control, throttle temperature control, receiver feed pump control and reheat steam flow control), and the new solar subsystem controls with the master control computer.

- Control Room Modifications. For solar hybrid repowered units, it is considered a requirement that both solar and fossil plant operation be accomplished by a single operator from a central control room. For most solar hybrid repowering applications this would require the addition of a new control room; the existing unit control panels would have to be relocated to the new control room or as an alternative new control panels could be installed. However, some plants, such as PNM's Reeves Station, have control panel space provided for a future unit which can be utilized by the solar control panels; therefore a new control room would not be required. For the purpose of this report control room modifications will range from minimal modifications to a completely new environmentally controlled control building which houses the unit solar/fossil control panels and consoles, computers, and logic equipment.

- Computer and Logic Room Additions. Computer systems and electronic hardware associated with solar plants require an environmentally controlled space for optimum performance. The computer room would typically house the Master Control System (MCS) computer and the collector computer, in addition to digital conversion units, multiplexing equipment and magnetic tape units. The computer room would also contain programmer's consoles and printers for the two computers as well as the plant computer engineer's console, printer and recorders and work space.

  The logic equipment room would house the MCS and collector computer terminal cabinets, analog control system and terminal cabinets, interface logic systems, etc., and would be environmentally controlled.

  It is unlikely that adequate space for computer and logic equipment would be available in most existing plants to be repowered, therefore, new rooms must be provided for this equipment along with the associated HVAC equipment.

4.2.3.4 Pumps. As discussed in the section on water treatment, full flow mixed bed condensate polishers will be required for repowering each of the generic plants. In addition, it is recommended that the low pressure heater drains be cascaded to the condenser, rather than being pumped into the condensate stream, so that corrosion products present in the shell side of the low pressure heaters can be removed by the condensate polisher. Since there is a substantial pressure drop through a mixed bed demineralizer, the condensate pump duty will be increased significantly, both flow and required total developed head. For this reason, it is assumed that new, larger capacity condensate pumps will be required to repower each of the four units. A requirement for two 100% capacity pumps has been assumed for the 50 MW unit; three 50% capacity pumps are to be provided for each of the larger units.

Required condensate pump flow capacity was obtained from the AIEE-ASME preferred standards for the two non-reheat units, and heat balances for representative 100 MW and 350 MW units in the case of the two reheat units. A pressure drop allowance of 70 psi for the mixed bed condensate polisher and 15 psi per feedwater heater was used in all cases. A deaerator water level height of 60 feet and pressure of 60 psia was assumed for each of the non-reheat units; a deaerator water level of 60 feet and a pressure of 56 psia was used for the 100 MW reheat unit. For the 350 MW unit the assumed height of the deaerator water level was 100 feet and the pressure 42 psia. In all cases the required pump driver power was calculated using an assumed efficiency of 70%. It should be noted that the pumps were sized with sufficient capacity for the nominal ratings of the units but would not necessarily have enough capacity for operation at maximum turbine-generator capability, particularly in the cases of the units built to the AIEE-ASME preferred standards for turbine-generators. These units are capable of generating considerably more power at valves wide open, 5% overpressure than their nominal rating.

In repowering the two non-reheat units new receiver feedwater pumps will be required. Since repowering with water/steam central receivers will require pumping feedwater lengthy distances to elevated receivers, and additional frictional losses will be incurred in the steam piping back to the turbine building, existing boiler feed pumps in units to be repowered will in general not have sufficient head capability to service the solar receiver. Accordingly, new receiver feed pumps were sized for the 50 and 100 MW nonreheat units. For the 50 MW unit, steam and feedwater line lengths of 7000 feet were assumed, corresponding to a receiver located about 5000 feet from the turbine. (The extra pipe length is required for expansion loops and for the vertical risers in the receiver tower.) The pipe sizes chosen resulted in a total frictional loss of about 250 psi in the feedwater and steam piping. Frictional losses of 25 psi for the receiver temperature control valves and 15 psi per feedwater heater were allowed, and the water level in the receiver tower was assumed to be 400 feet above the pump.

For the 100 MW unit, the steam and feedwater line lengths were assumed to be 10,000 feet, corresponding to a receiver tower located about 7000 feet from the turbine. Total piping frictional loss was about 300 psi and the water level in the receiver was assumed to be 575 feet above the pump. As with the 50 MW unit, frictional losses of 25 psi for the receiver temperature control valves and 15 psi for each feedwater heater were assumed.

For both the 50 and 100 MW units, the receiver feed pumps were assumed to have an efficiency of 75% including the variable speed coupling.

It is not envisioned that the repowering of the reheat units using salt or sodium receivers and intermediate heat exchangers will require new feed pumps. The fossil boiler feed pumps should have sufficient head capability to serve the water side of the heat exchangers used to generate steam.

4.2.3.5 Piping. Piping materials and sizes are as shown on the process and instrumentation diagrams, Figures 4-2 through 4-7. In general, conventional ASTM A106 carbon steel piping of the appropriate schedule and class is proposed for low temperature applications and seamless chrome molybdenum steel piping (ASTM A335 Grade P22) of the required wall thickness is proposed for high temperature applications. All piping is in accordance with ANSI B31.1 Code for Pressure Piping or ASME Boiler and Pressure Vessel Code, Section I Power Boilers, as applicable.

4.2.3.6 Feedwater Heaters. Since the required feedwater pressure in the water/steam receiver loop is considerably higher than the boiler feedwater pressure, separate high pressure heaters in the solar receiver feedwater stream are required. The feedwater heaters were specified using representative heat balances. The tubing material specified is carbon steel to eliminate the possibility of deposition of copper in the receiver tubes or turbine. It is not envisioned that repowering units using salt or sodium receivers and intermediate heat exchangers will require new high pressure feedwater heaters.

4.2.3.7 Electrical System Modifications. Figures 4-8 thru 4-13 depict the anticipated electrical system additions required for solar repowering, and the interfaces with the existing plant system. These diagrams are based on typical fossil fuel steam power plants with unit connected generator-transformers.

Solar auxiliary power during normal operation will be supplied by the "Solar Auxiliary Transformer." During start up, or when the "Solar Auxiliary Transformer" is not available, auxiliary power will be supplied by the existing plant "Start Up Transformer."

An emergency generator(s), diesel engine driven, will automatically start if auxiliary power fails. The main purpose of the emergency generator is to slew the heliostats to prevent overheating of the receiver when heat transfer medium flow stops on loss of auxiliary power. The generator is sized to supply the reactive power required by the heliostats at 40% power factor. To reduce the size of the emergency generator, heliostats are slewed in four (3) (for 50 and 100 megawatt units) or eight (for 350 megawatt units) successive steps. One-fourth of the heliostats (one-eighth for the 350 MW unit) are slewed just off the receiver, then another fourth (or eighth) are slewed, etc., until the entire field is slewed just off the receiver. Then portions of the field are slewed to the stowed position in successive steps until all heliostats are stowed.

Existing plant generator, transmission, and auxiliary system voltages shown on the diagrams are typical. The "Solar Auxiliary Power" systems will utilize the same voltage as the plant auxiliary system, if feasible. This may not be the same as the voltage shown.

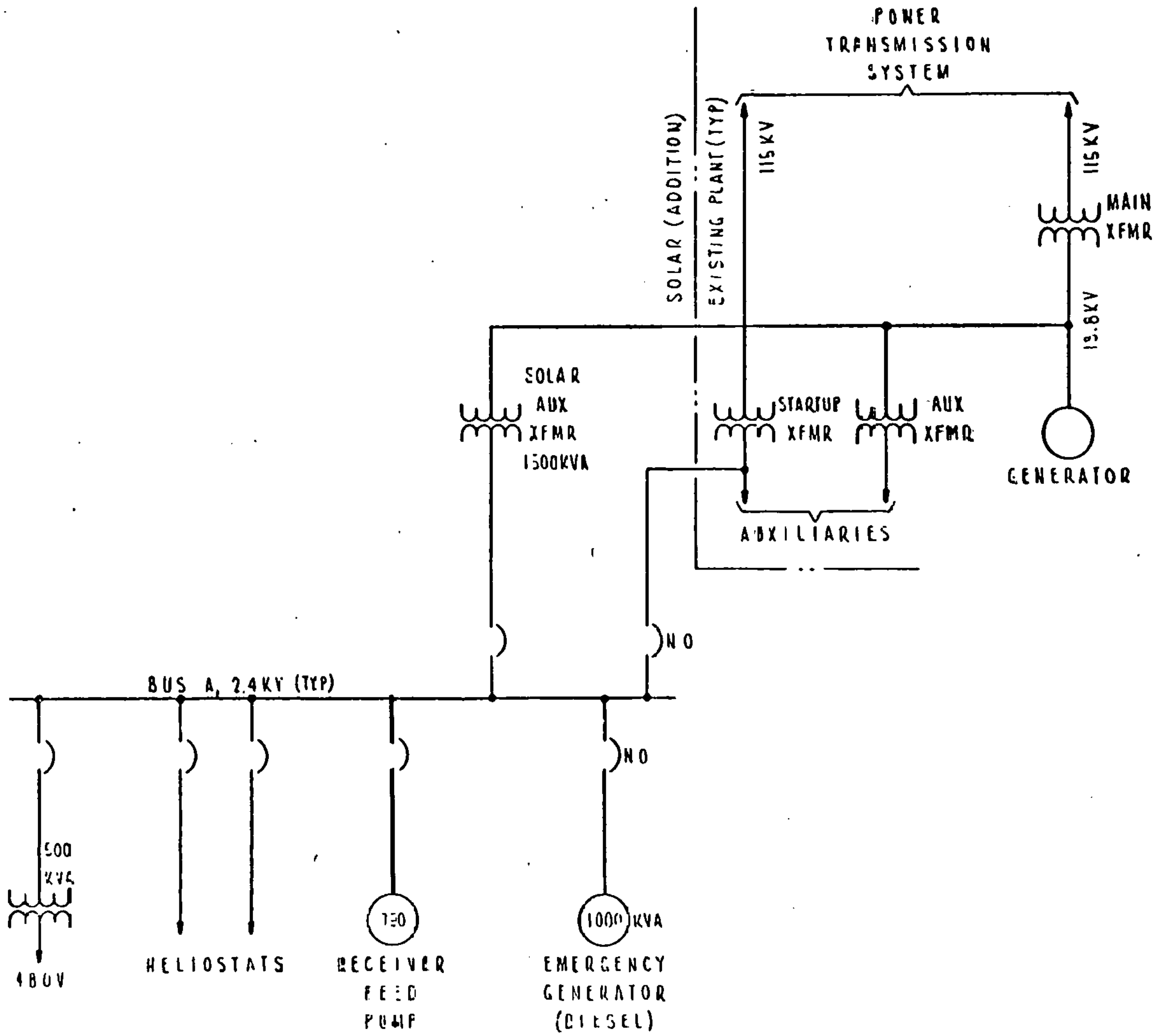

**Figure 4-8. ONE LINE DIAGRAM - 50MW PLANT
50% SOLAR REPOWERING
WATER/STEAM RECEIVER**

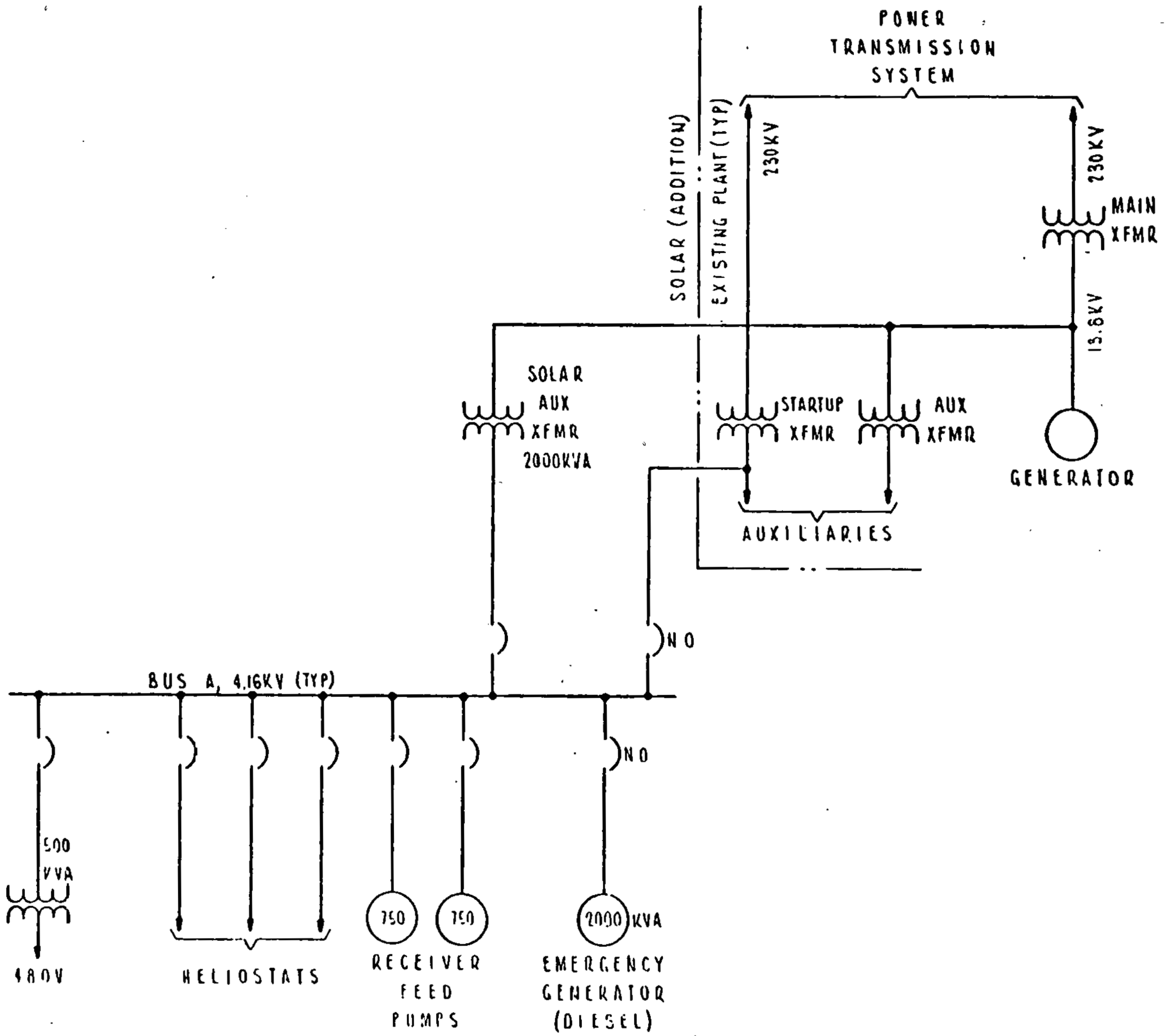

Figure 4-9. ONE LINE DIAGRAM - 100MW PLANT
50% SOLAR REPOWERING
WATER/STEAM RECEIVER

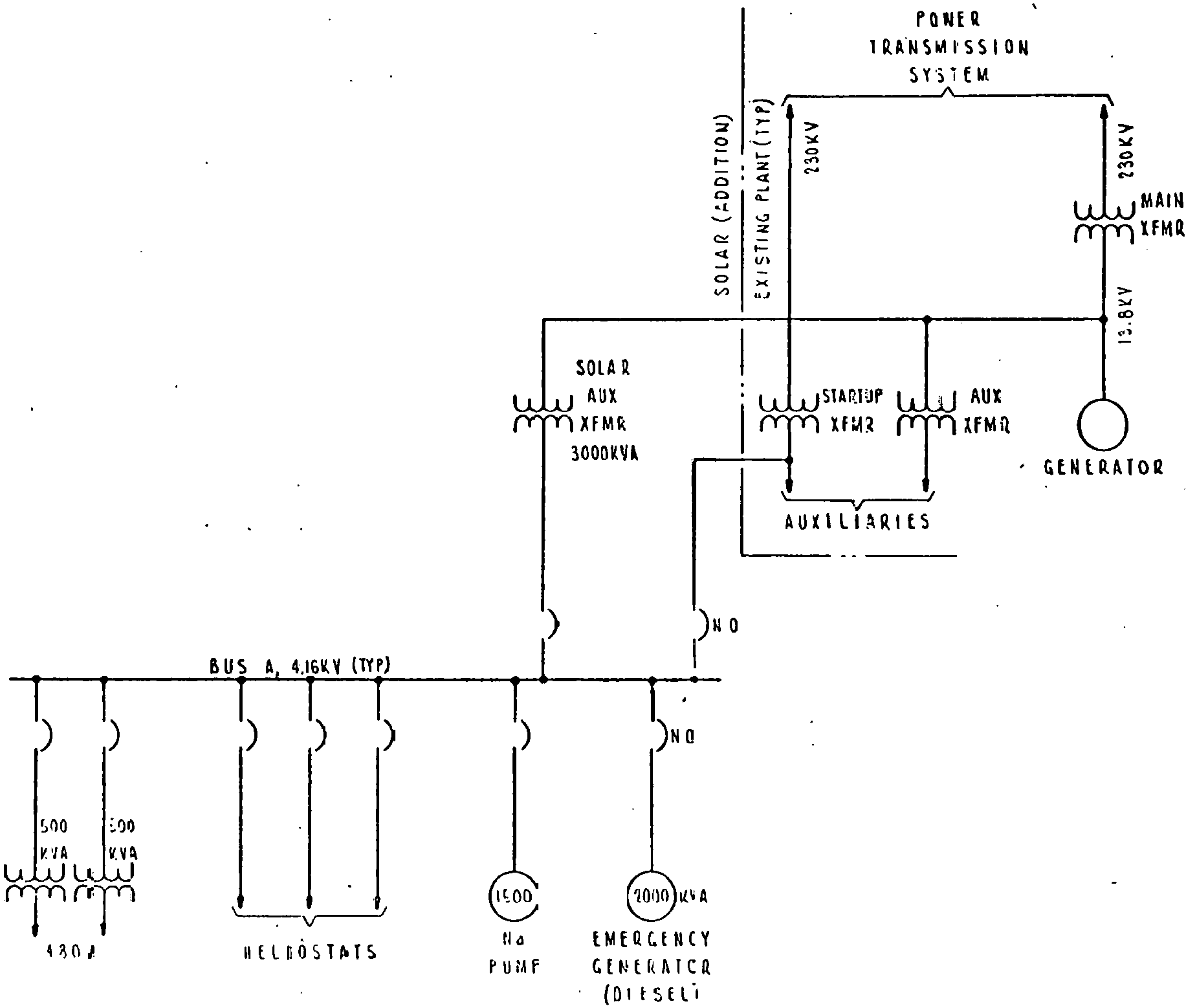

Figure 4-10. ONE LINE DIAGRAM - 100MW PLANT
50% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

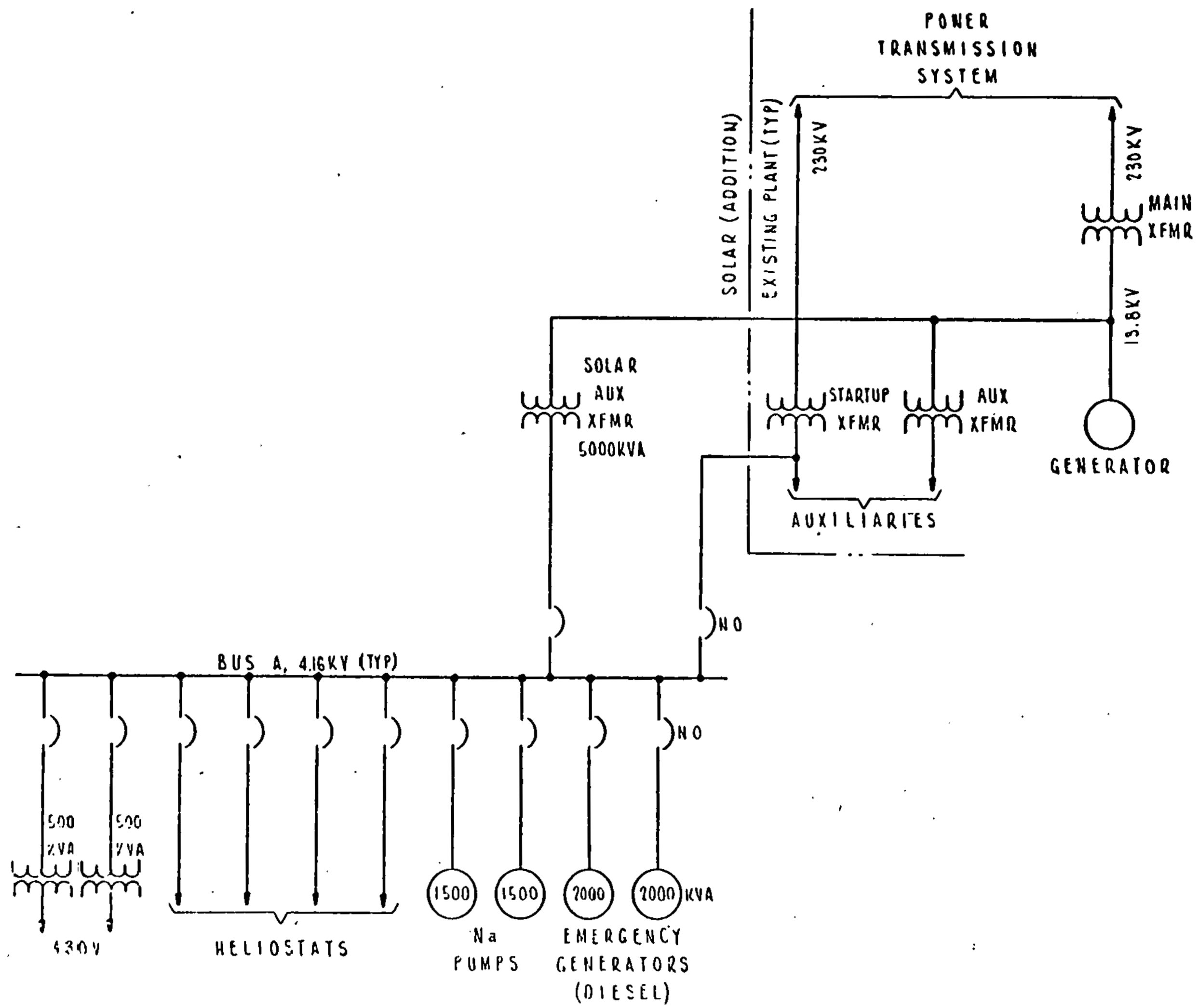

Figure 4-11. ONE LINE DIAGRAM - 100MW PLANT
100% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

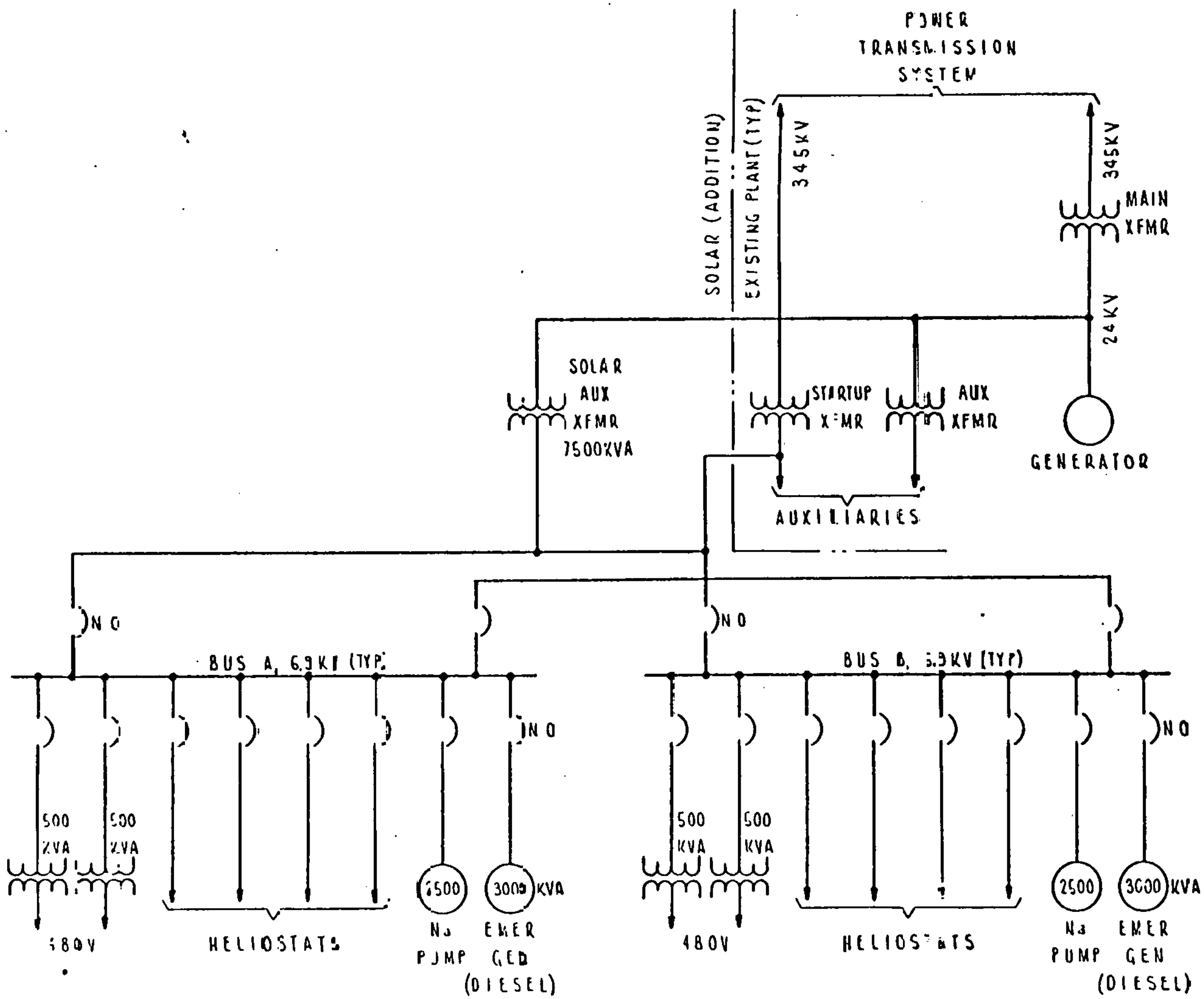

Figure 4-12. ONE LINE DIAGRAM - 350MW PLANT
50% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

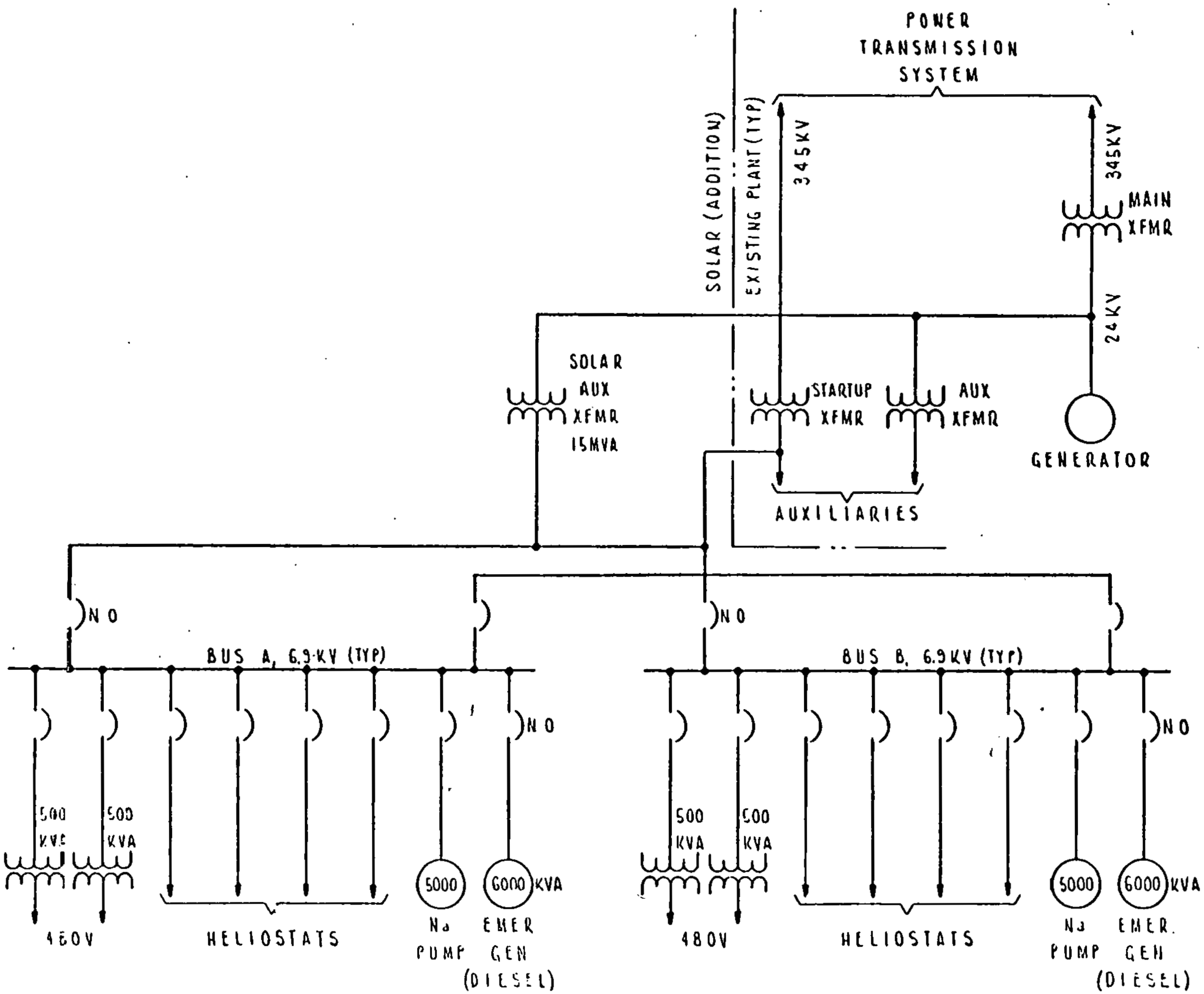

Figure 4-13. ONE LINE DIAGRAM - 350MW PLANT
100% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

The Solar Auxiliary Transformer sizes indicated are tentative. The tranformer must be about twice the capacity required by the largest motor to obtain satisfactory voltage during motor starting. In some cases this factor determine the transformer size. In other cases transformer size was determined based on anticipated load.

An uninterruptible power system (UPS), shown in Figure 4-14, has been included to cover the solar control system requirements, i.e., plant computer, analog system, collector computer, receiver controls, annunciator and interface logic system.

Water Treatment System Modifications. Feedwater treatment and water sampling system additions have been assumed for each of the four hypothetical units utilizing once-through and drum type water/steam receivers or heat exchangers. Items considered are: Condensate Polishing, Condensate/Feedwater System Corrosion, Make-up Demineralizer, Chemical Feed Systems and Sampling Systems.

- Condensate Polishing. It is recommended that condensate polishers be installed in each of the four units because of the cyclic operation associated with solar units. Such cyclic operation inevitably results in the entry of sufficient dissolved oxygen into the cycle to generate large quantities of corrosion product, principally oxides of iron and copper. The concentration of these constituents in the condensate/feedwater system must be maintained at quite low levels to ensure system integrity and efficiency. In addition, the changes in velocity of the condensate and feedwater associated with cyclic operation result in a deposition and resuspension of silica-bearing silt. Condensate polishing is quite successful in reducing the concentrations of both corrosion products and silt.

  Since ion exchange resin temperature limitations dictate the installation of the polisher immediately downstream of the condensate pumps, provisions must be made for recycle of feedwater heater drains to the condenser for clean-up each time the unit is started up. If the system is shut down for a significant period of time, recycle provisions must be included for the entire feedwater system.

  Should McDonnell-Douglas type once-through receivers be used (as opposed to "drum type" receivers), provisions for recycling must be more elaborate, including a recycle loop from downstream of the receiver back to the condenser hotwell.

  Once-through boilers require extremely high quality water, necessitating the use of condensate polishers regardless of whether the unit is base loaded or cyclic.

- Condensate/Feedwater System Corrosion. In addition to utilization of condensate polishing and recycling, other aspects of corrosion in the system must be addressed. To assure rapid system clean-up, every effort

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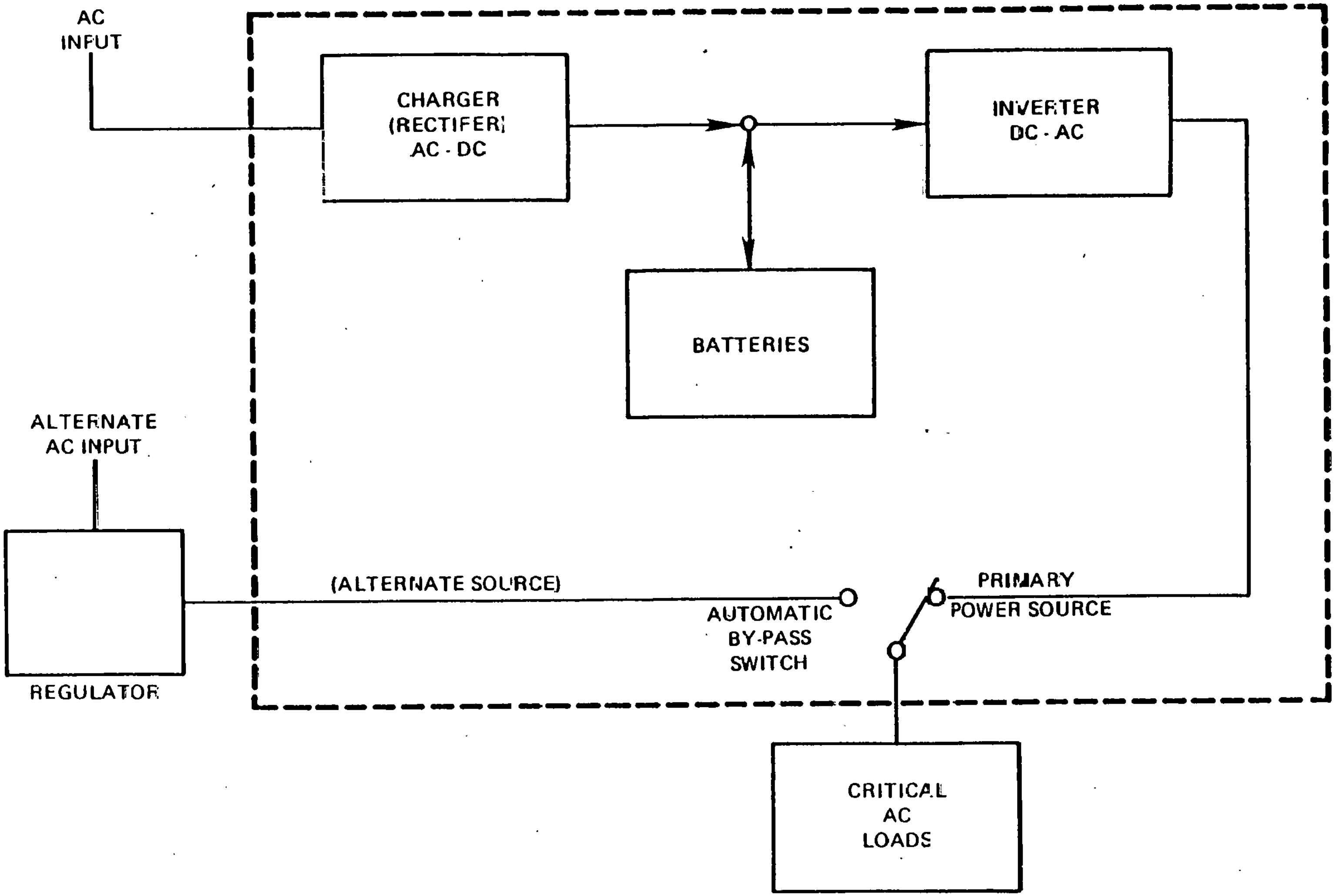

Figure 4-14. UNINTERRUPTABLE POWER SYSTEM

should be made to obtain maximum deaeration in the condenser. Also, ammonia will probably be used for pH control in the system. Since copper and admiralty tubing are particularly susceptible to ammonia attack, and since ammonia concentrations can be high in the air removal section of the condenser, it is advisable to retube that section with another material such as 90-10 copper-nickel or 70-30 copper-nickel, if it is currently tubed with the more susceptible alloys. If the condenser is currently tubed with 304 stainless steel, this material would also be satisfactory in the air removal section.

Utilization of copper-bearing alloys in feedwater heaters in once-through steam generator systems has led to occasional difficulties with passage of the copper through the steam generator and subsequent deposition in the turbine. Because of the increased corrosion associated with cyclic operation, such a problem would be expected to be more severe in such a case. Accordingly, if a once-through receiver or intermediate heat exchanger is considered, consideration should be given to retubing the feedwater heaters with noncopper-bearing materials. Austenitic stainless steel is frequently used in low pressure heaters, with carbon steel used in the high pressure heaters. Such retubing need not be considered with drum-type boilers.

- Make-Up Demineralizer. The 50 MW and 100 MW units are assumed to have two-bed make-up demineralizers, i.e., a strongly acidic cation exchanger followed by a strongly basic anion exchanger. The 350 MW unit is assumed to have a three-bed make-up demineralizer, i.e., a strongly acidic cation exchanger followed by a strongly basic anion exchanger followed by a mixed bed polisher. In order to avoid imposing an additional ionic load on the condensate polisher, and to provide more operating flexibility, it is recommended that the 50 MW and 100 MW make-up demineralizers be equipped with mixed bed polishers.

- Chemical Feed Systems. It is assumed that each unit currently is equipped with three chemical feed systems, one for feeding ammonia or a neutralizing amine, one for feeding an oxygen scavenger such as hydrazine, and one for feeding phosphates to the boiler. Granting this assumption, no additional chemical feed systems (aside from those which will be furnished as an integral part of the additional ion exchange systems) will be required.

- Sampling Systems. If the units are equipped with drum-type receivers, some additional sampling and monitoring facilities will be required to check condensate polisher performance and monitor for corrosion products.

  If the units are equipped with once-through receivers of the McDonnell-Douglas type, or once-through intermediate heat exchangers, a much more elaborate sampling facility of the type used with higher pressure units is needed. It is assumed that these units are not presently equipped with such elaborate sampling facilities.

4.2.3.9 Miscellaneous Systems Modifications. In addition to the major systems or equipment modifications required to accommodate solar repowering, several minor systems are also affected. Chief among these are Bearing Cooling Water System, Instrument Air System, Fire Protection System and Heating, Ventilating and Air Conditioning System.

- Bearing Cooling Water System. Bearing cooling water requirements will increase due to the addition of new receiver feedwater pumps (for the water/steam receiver systems) and sample coolers for receiver feedwater and steam samples. For receiver feedwater pumps utilizing hydraulic variable speed drives, the cooling water requirements could range approximately 100 gpm to 300 gpm per pump, depending on the pump size and power requirements. Sample cooling water requirements would be relatively small, say 5 gpm per cooler. For the purpose of this study, it is assumed that the existing plant bearing cooling water pumps and heat exchangers are adequate to handle the increased cooling water flow and heat rejection and that an allowance need be made only for additional cooling water piping and controls.

- Instrument Air System. Along with control system modifications for the repowered plant will come an increase in instrument air demand. Most of the new control system additions will be electronic; however, instrument air is required for new control valves, new heater level controllers, new condensate polishers, etc. It is assumed that only extensions of existing instrument air piping are required and that the existing plant instrument air compressors and dryers are adequate.

- Fire Protection System. Excluding receiver and thermal storage, fire protection would only be required for the new computer and logic rooms and outdoor solar auxiliary transformer. For the computer and logic rooms, a Halon 1301 total flooding system is recommended. The outdoor solar auxiliary transformer would be protected with an automatic water deluge system.

- Heating, Ventilating and Air Conditioning. Heating, ventilating and air conditioning will be required in the new computer and logic rooms. Rooftop air conditioning units and rooftop heating and ventilating units will be assumed for these rooms. Steam or hot water for the heating coils is assumed to be supplied from an existing plant heating source.

4.3 LIST OF INTERFACE REQUIREMENTS

This section describes the interface requirements for the various repowering combinations.

4.3.1 <u>50 MWe Non-Reheat, Water/Steam Receiver, 50% Solar Repowering</u>

<u>Turbine-Generator Modification Options</u>. (50 MW, non-reheat, 1250 psig - 950 degrees F)

- Complete turbine-generator inspection and overhaul.

- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electro-hydraulic control system
- Variable pressure control
- Generator modifications

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based).
- Control panel and control console modifications.
- Boiler combustion control system modifications.
- Turbine control system (Included in Turbine-Generator Modification Options).
- Annunciator, 30 windows.
- Miscellaneous instrumentation.
- Control room modifications/additions.
- Computer and logic room additions (building 38' x 38' x 21' high).

Pumps.

- Two 100% Condensate Pumps - 700 gpm @ 450 feet TDH, canned vertical turbine pumps with 125 hp, 1760 rpm, 480V, 3 phase odp motor drivers.

- Two 100% Receiver Feed Pumps - Barrel type multistage 475 gpm @ 4150 feet TDH, 293 degrees F feedwater, s.g. 0.922, hydraulic variable speed coupling with 750 hp, 3600 rpm, 2400V, 3 phase odp motor drivers.

Piping.

- Receiver Feed Pipe - 6 inch XXS ASTM A106 Gr. B, 250 feet long to interface. Insulation 3-1/2 inches $CaSiO_2$ with aluminum lagging.

- Receiver Steam Pipe - 10 inch ID 0.900 inch wall thickness seamless 2-1/4% chrome - 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 117 lb/ft. Insulation 7 inches $CaSiO_2$ with aluminum lagging.

Feedwater Heaters.

- High Pressure Heaters No. 6 and No. 7 - New horizontal closed feedwater heaters with internal desuperheating, condensing, and subcooling zones are required to heat the receiver feedwater. The tube material is ASTM A79 carbon steel.

- The feedwater heater design and operating conditions are as shown on Table 4-2.

Table 4-2. Feedwater Heater Design and Operating Conditions (50 MWe Non-Reheat, 50% Repowering)

Tubeside	Heater No. 6	Heater No. 7
Feedwater Flow (lb/hr)	204,000	204,000
Feedwater Inlet Temperature (°F)	300	371
Feedwater Outlet Temperature (°F)	371	438
Tube Design Temperature (°F)	375	442
Operating/Design/Test Pressure (psig)	1700/2040/3060	1700/2040/3060
Terminal Temperature difference (°F)	0	0
Shellside		
Steam Flow (lb/hr)	13,867	14,723
Steam Inlet Temperature (°F)	517	670
Operating/Design/Test Pressure (psia)	176/185/278	372/391/587
Shell Saturation/Design/Skirt Design Temp. (°F)	371/375/530	438/442/690
Drain Inlet Flow (lb/hr)	14,723	---
Drain Inlet Temperature (°F)	381	---
Drain Outlet Flow (lb/hr)	28,590	14,723
Drain Outlet Temp (°F)	310	381
Drains-Cooler Approach (°F)	10	10
Total Heat Exchanged (10^6 Btu/hr)	14.972	14.620

Electrical Modifications/Additions

1 Transformer, Auxiliary Power 1500 KVA, 13.8-2.4 KV
7 Metalclad Switchgear Units 2.4 KV, 1200 Ampere
Lot Load Centers, Incl.
1 Transformer, Power, 300 KVA, 2.4 KV - 480 Volts
  Lot Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot Motor Control Center, Incl.
    Starters and Circuit Breakers as Required
1 Battery, Lead Acid, 125V DC
1 Battery Charger, 480V AC - 125V DC
1 Uninterruptible Power System, Incl.
    Inverter 125V DC to 120/208V AC, 3 phase
    Transformer-Rectifier 460V AC, 3 phase - 125V DC
    Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
1 Diesel-Generator Unit, 240 KW, 1000 KVA at 0.80 PF, 2400V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 700 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 25 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

4.3.2 100 MWe Non-Reheat, Water/Steam Receiver, 50% Solar Repowering

Turbine-Generator Modification Options. (100 MW, non-reheat, 1450 psig - 950 degrees F)

- Complete turbine-generator inspection and overhaul.
- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electrohydraulic control system
- Variable pressure control
- Generator rewinding

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based)
- Control panel and control console modifications
- Boiler combustion control system modifications
- Turbine control system (Included in Turbine-Generator Modification Options)
- Annunciator, 30 windows
- Miscellaneous instrumentation
- Control room modifications/additions
- Computer and logic room additions (building 42.4' x 42.4' x 21' high)

Pumps.

- Three 50% Condensate Pumps - 675 gpm ea. @ 450 feet TDH with 2 pumps operating, canned vertical turbine type with 125 hp, 1760 rpm, 480V, 3 phase odp motor drivers.

- Two 50% Receiver Feed Pumps - Barrel type multistage 425 gpm ea. 5000 feet TDH with both pumps operating, 293 degrees F feedwater, s.g. 0.922, hydraulic variable speed coupling with 750 hp, 3600 rpm, 4160V, 3 phase odp motor drivers.

Piping.

- Receiver Feed Pipe - 10 inch Sch. 160 ASTM A106 Gr. C. 250 feet long to interface. Insulation 4 inches $CaSiO_2$ with aluminum lagging.

- Receiver Steam Pipe - 12 inch ID 1.852 inch wall thickness seamless 2-1/4% chrome - 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 299 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

- HP Heaters Extraction Piping - 6 inch Sch. 40 ASTM A106 Gr. B. Each 50 feet long.

Feedwater Heaters.

- High Pressure Heaters No. 6 and No. 7 - New horizontal closed feedwater heaters with internal desuperheating, condensing, and subcooling zones are required to heat the receiver feedwater. The tube material is ASTM A79 carbon steel.

- The feedwater heater design and operating conditions are as shown in Table 4-3.

Table 4-3

Feedwater Heater Design and Operating Conditions
(100 MWe Non-Reheat, 50% Repowering)

Tubeside	Heater No. 6	Heater No. 7
Feedwater Flow (lb/hr)	388,500	388,500
Feedwater Inlet Temperature (°F)	300	375
Feedwater Outlet Temperature (°F)	375	430
Tube Design Temperature (°F)	380	435
Operating/Design/Test Pressure (psig)	2000/2400/3600	2000/2400/3600
Terminal Temperature difference (°F)	0	0
Shellside		
Steam Flow (lb/hr)	27,664	22,480
Steam Inlet Temperature (°F)	562	710
Operating/Design/Test Pressure (psia)	184/193/290	344/361/540
Shell Saturation/Design/Skirt Design Temp. (°F)	375/380/580	430/435/730
Drain Inlet Flow (lb/hr)	22,480	---
Drain Inlet Temperature (°F)	385	---
Drain Outlet Flow (lb/hr)	50,144	22,480
Drain Outlet Temp (°F)	310	385
Drains-Cooler Approach (°F)	10	10
Total Heat Exchanged (10^6 Btu/hr)	30.099	22.756

Electrical Modifications/Additions.

1 Transformer, Auxiliary Power 2000 KVA, 13.8-4.16 KV
9 Metalclad Switchgear Units 4.16 KV, 1200 Ampere
Lot Load Centers, Incl.
    1 Transformer, Power, 500 KVA, 4.16 KV - 480 Volts
    Lot Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot Motor Control Center, Incl.
    Starters and Circuit Breakers as Required
1 Battery, Lead Acid, 125V DC
1 Battery Charger, 480V AC - 125V DC
1 Uninterruptible Power System, Incl.
    Inverter 125V DC to 120/208V AC, 3 phase
    Transformer-Rectifier 460V AC, 3 phase - 125V DC
    Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
1 Diesel-Generator Unit, 480 KW, 2000 KVA at 0.80 PF, 4160V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 1350 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 50 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

4.3.3 100 MWe Reheat, Salt or Sodium-Cooled Receiver, 50% Solar Repowering

Turbine-Generator Modification Options. (100 MW, reheat, 1800 psig - 1000 degrees F/1000 degrees F)

- Complete turbine-generator inspection and overhaul.
- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electrohydraulic control system
- Variable pressure control
- Generator rewinding

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based)
- Control panel and control console modifications

- Boiler combustion control system modifications
- Turbine control system (Included in Turbine-Generator Modification Options)
- Annunciator, 30 windows
- Miscellaneous instrumentation
- Control room modifications/additions
- Computer and logic room additions (building 42.4' x 42.4' x 21' high)

Pumps.

- Three 50% Condensate Pumps - 550 gpm ea. at 425 feet TDH with 2 pumps operating, canned vertical turbine type with 100 hp, 1760 rpm, 480V, 3 phase odp motor drivers.

Piping.

- Steam Generator Feed Pipe - 8 inch XXS ASTM A106 Gr. C. 100 feet long to interface. Insulation 4 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Main Steam Pipe - 7 inch ID 1.025 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 96 lb/ft. Insulation 7-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Cold Reheat Pipe - 14 inch Schedule 30 ASTM A106 Gr. B. 100 feet long to interface. Insulation 5-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Hot Reheat Pipe - 14 inch Schedule 60, seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

Electrical Modifications/Additions.

1 Transformer, Auxiliary Power 3000 KVA, 13.8-4.16 KV
9 Metalclad Switchgear Units 4.16 KV, 1200 Ampere
Lot Load Centers, Incl.
 2 Transformers, Power, 500 KVA, 4.16 KV - 480 Volts
 Lot Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot Motor Control Center, Incl.
 Starters and Circuit Breakers as Required
1 Battery, Lead Acid, 125V DC
1 Battery Charger, 480V AC - 125V DC
1 Uninterruptible Power System, Incl.
 Inverter 125V DC to 120/208V AC, 3 phase
 Transformer-Rectifier 460V AC, 3 phase - 125V DC
 Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
1 Diesel-Generator Unit, 480 KW, 2000 KVA at 0.80 PF, 4160V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 1100 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 40 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

4.3.4 100 MWe Reheat, Salt or Sodium-Cooled Receiver, 100% Solar Repowering

Turbine-Generator Modification Options. (100 MW, reheat, 1800 psig - 1000 degrees F/1000 degrees F)

- Complete turbine-generator inspection and overhaul.
- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electrohydraulic control system
- Variable pressure control
- Generator rewinding

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based)
- Control panel and control console modifications
- Boiler combustion control system modifications
- Turbine control system (Included in Turbine-Generator Modification Options)
- Annunciator, 30 windows
- Miscellaneous instrumentation
- Control room modifications/additions
- Computer and logic room additions (building 42.4' x 42.4' x 21' high)

Pumps.

- Three 50% Condensate Pumps - 550 gpm ea. at 425 feet TDH with 2 pumps operating, canned vertical turbine type with 100 hp, 1760 rpm, 480V, 3 phase odp motor drivers.

Piping.

- Steam Generator Feed Pipe - 8 inch XXS ASTM A106 Gr. C. 100 feet long to interface. Insulation 4 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Main Steam Pipe - 10 inch ID 1.510 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 220 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Cold Reheat Pipe - 20 inch Schedule 30 ASTM A106 Gr. B. 100 feet long to interface. Insulation 5-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Hot Reheat Pipe - 20 inch ID 0.793 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 195 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

Electrical Modifications/Additions.

1 Transformer, Auxiliary Power 5000 KVA, 13.8-4.16 KV
11 Metalclad Switchgear Units 4.16 KV, 1200 Ampere
Lot Load Centers, Incl.
  2 Transformers, Power, 750 KVA, 4.16 KV - 480 Volts
  Lot Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot Motor Control Center, Incl.
  Starters and Circuit Breakers as Required
1 Battery, Lead Acid, 125V DC
1 Battery Charger, 480V AC - 125V DC
1 Uninterruptible Power System, Incl.
  Inverter 125V DC to 120/208V AC, 3 phase
  Transformer-Rectifier 460V AC, 3 phase - 125V DC
  Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
2 Diesel-Generator Units, 480 KW, 2000 KVA at 0.80 PF, 4160V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 1100 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 140 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

4.3.5 350 MWe Reheat, Salt or Sodium-Cooled Receiver, 50% Solar Repowering

Turbine-Generator Modification Options. (350 MW, reheat, 2400 psig - 1000 degrees F/1000 degrees F)

- Complete turbine-generator inspection and overhaul.
- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electrohydraulic control system
- Variable pressure control
- Generator rewinding

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based)
- Control panel and control console modifications
- Boiler combustion control system modifications
- Turbine control system (Included in Turbine-Generator Modification Options)
- Annunciator, 30 windows
- Miscellaneous instrumentation
- Control room modifications/additions
- Computer and logic room additions (building 44.7' x 44.7' x 21' high)

Pumps.

- Three 50% Condensate Pumps - 1800 gpm ea. at 475 feet TDH with 2 pumps operating, canned vertical turbine pumps with 300 hp, 4160V, 3 phase odp motor drivers.

Piping.

- Steam Generator Feed Pipe - 10 inch Schedule 160 ASTM A106 Gr. C. 100 feet long to interface. Insulation 4 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Main Steam Pipe - 9 inch ID 1.750 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 220 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Cold Reheat Pipe - 20 inch Schedule 60 ASTM A106 Gr. B. 100 feet long to interface. Insulation 5-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Hot Reheat Pipe - 20 inch ID 1.15 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 281 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

Electrical Modifications/Additions.

1 Transformer, Auxiliary Power 7500 KVA, 24-13.8 KV
20 Metalclad Switchgear Units 6.9 KV, 1200 Ampere
Lot Load Centers, Incl.
    4 Transformers, Power, 500 KVA, 6.9 KV - 480 Volts
    Lot Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot Motor Control Center, Incl.
    Starters and Circuit Breakers as Required
1 Battery, Lead Acid, 125V DC
1 Battery Charger, 480V AC - 125V DC
1 Uninterruptible Power System, Incl.
    Inverter 125V DC to 120/208V AC, 3 phase
    Transformer-Rectifier 460V AC, 3 phase - 125V DC
    Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
2 Diesel-Generator Unit, 720 KW, 3000 KVA at 0.80 PF, 6900V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 3600 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 140 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

4.3.6 350 MWe Reheat, Salt or Sodium-Cooled Receiver, 100% Solar Repowering

Turbine-Generator Modification Options. (350 MW, reheat, 2400 psig - 1000 degrees F/1000 degrees F)

- Complete turbine-generator inspection and overhaul.
- Nondestructive tests
  - Radiographic or magnetic particle examination of critical castings
  - Borescope of turbine rotor
- Turbine metal temperature thermocouples and recorder
- Electrohydraulic control system
- Variable pressure control
- Generator rewinding

Boiler Modifications. None required.

Control System Modifications/Additions.

- Distributed Analog Control System (microprocessor based)
- Control panel and control console modifications
- Boiler combustion control system modifications
- Turbine control system (Included in Turbine-Generator Modification Options)
- Annunciator, 30 windows
- Miscellaneous instrumentation
- Control room modifications/additions
- Computer and logic room additions (building 44.7' x 44.7' x 21' high)

Pumps.

- Three 50% Condensate Pumps - 1800 gpm ea. at 475 feet TDH with 2 pumps operating, canned vertical turbine pumps with 300 hp, 4160V, 3 phase odp motor drivers.

Piping

- Steam Generator Feed Pipe - 14 inch Schedule 160 ASTM A106 Gr. C. 100 feet long to interface. Insulation 4-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Main Steam Pipe - 12 inch ID 2.352 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 389 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Cold Reheat Pipe - 30 inch ID 0.875 inch nominal wall thickness ASTM A155 KC60 Class 1 pipe. 100 feet long to interface. Insulation 5-1/2 inches $CaSiO_2$ with aluminum lagging.

- Steam Generator Hot Reheat Pipe - 30 inch ID 1.662 inch wall thickness seamless 2-1/4% chrome 1% moly steel ASTM A335 Grade P22. 100 feet long to interface. Weight 643 lb/ft. Insulation 8 inches $CaSiO_2$ with aluminum lagging.

Electrical Modifications/Additions.

1	Transformer, Auxiliary Power 15 MVA, 24-6.9 KV	
20	Metalclad Switchgear Units 6.9 KV, 1200 Ampere	
Lot	Load Centers, Incl.	
	4	Transformers, Power, 750 KVA, 6.9 KV - 480 Volts
	Lot	Circuit Breakers, Low Voltage Power, 600 Volt, 800 Ampere
Lot	Motor Control Center, Incl.	
		Starters and Circuit Breakers as Required
1	Battery, Lead Acid, 125V DC	
1	Battery Charger, 480V AC - 125V DC	

1 Uninterruptible Power System, Incl.
Inverter 125V DC to 120/208V AC, 3 phase
Transformer-Rectifier 460V AC, 3 phase - 125V DC
Solid State Transformer Switch 120/208V AC, 3 phase, 4 Wire
2 Diesel-Generator Unit, 1440 KW, 6000 KVA at 0.80 PF, 6900V AC

Water Treating System Modifications/Additions.

- Condensate Polisher, two full capacity, 3600 gpm
- Mixed Bed Polisher for Make-up Demineralizer, 140 gpm
- Water Sampling and Monitoring System

Miscellaneous System Modifications.

- Bearing Cooling Water System
- Instrument Air System
- Fire Protection System
- HVAC System

SECTION 5.0

COST ESTIMATES

5.1 COSTING INTRODUCTION

Cost estimates were prepared for the balance-of-plant modifications identified in Section 4. The cost estimates were prepared by Stearns-Roger's cost estimating department and were based on previous power plant cost experience for similar size units using labor rates representative of southwestern United States. The estimated cost of a complete turbine-generator inspection for the unit sizes considered was supplied by General Electric Company and confirmed by actual field experience.

It is realized that all the balance-of-plant modifications identified will not be required on every unit since the equipment existing in and condition of individual units will vary considerably in actual practice. For this reason, a cost range for the balance-of-plant modifications has been assumed for each of the six generic combinations identified in Section 4. The balance of plant cost range was developed based on the following breakdown.

5.2 COSTING BREAKDOWN

<u>Turbine-Generator Unit</u>

Minimum Cost complete turbine-generator inspection only. The cost includes disassembly, inspection, and reassembly and does not cover any repairs or renewable parts.

Maximum Cost complete turbine-generator inspection, nondestructive tests, turbine metal temperature thermocouples and recorder, electro-hydraulic control system with valve management for turbine inlet pressure control, and an allowance for generator rewinding or turbine modifications.

<u>Control System</u>

Minimum Cost control panel modifications, boiler combustion control modifications, and 10 percent of the maximum miscellaneous instrument cost.

Maximum Cost distributed analog control system, control panel modifications, annunciator, miscellaneous instruments, control room modifications and a new building for new computer and logic equipment.

Pumps

Minimum Cost receiver feed pumps or feedwater booster pumps only (applicable to water/steam receiver only). No new pumps are required for sodium or salt receiver systems.

Maximum Cost receiver feed pumps (water/steam only) and condensate hotwell pumps.

Piping

Minimum Cost assume 25 percent of total piping cost estimate.

Maximum Cost 100 percent of total piping cost estimate. The total piping cost estimate includes all new pipe, valves, fittings and thermal insulation specified for critical piping systems (main steam, boiler feed, hot and cold reheat piping) in addition to the miscellaneous piping modifications shown on the P & I diagram for each unit.

Feedwater Heaters

Minimum Cost no new feedwater heaters required.

Maximum Cost two high pressure feedwater heaters (applicable to water/steam receivers only).

Water Treating

Minimum Cost assume no new condensate polisher or mixed bed makeup demineralizer required. Includes water sampling and monitoring equipment only.

Maximum Cost new full flow condensate polishers, new mixed bed makeup demineralizer and new water sampling and monitoring equipment.

Electrical

Minimum Cost assume 25 percent of total electrical system modification cost estimate.

Maximum Cost 100 percent of total electrical system modification cost estimate.

Miscellaneous Systems

Minimum Cost assumed 50 percent of total miscellaneous systems costs.

Maximum Cost use 100 percent of miscellaneous systems costs which include additions to the bearing cooling water system, instrument air system and fire protection system.

In general, the cost estimates presented here represent one-time capital expenditure to facilitate systems integration and plant updating due to solar repowering. The repowered plant's general condition is assumed to be good and no major existing equipment modifications or repairs are required for solar hybrid commercial operation. Since the plant life is to be extended beyond the plant's normal requirement date due to the solar plant addition it is reasonable to assume that major equipment overhauls and repairs will be required throughout the life of the repowered plant thus increasing O&M cost. This study has not attempted to identify increased O&M costs resulting from extending plant life.

5.3 COST ESTIMATES

The estimated total field cost range of plant modifications for the four unit sizes or types considered is shown in Table 5-1. Indirect costs shown are based on 76 percent of the estimated direct field labor cost and engineering is assumed to be 10 percent of the total field cost.

Figure 5-1 indicates the expected BOP repowering cost range in \$/kWth vs. unit rating for the water/steam and sodium or salt receivers. Figure 5-2 shows the BOP repowering cost range expressed in \$/kWe. Table 5-2 shows the balance-of-plant cost summary in accordance with the Cost Breakdown Structure format. The detailed cost estimates prepared for this study can be found in the Appendix.

Table 5-1. ESTIMATED COST RANGE OF PLANT MODIFICATIONS FOR SOLAR REPOWERING (1979 DOLLARS IN THOUSANDS)

UNIT RATING RECEIVER TYPE % SOLAR REPOWERED	50 MWe NONRHT. WATER/STEAM 50% REPOWERED		100 MWe NON RHT. WATER/STEAM 50% REPOWERED		100 MWe RHEAT NA OR SALT 50% REPOWERED		100 MWe REHEAT NA OR SALT 100% REPOWERED		350 MWe REHEAT NA OR SALT 50% REPOWERED		350 MWe REHEAT NA OR SALT 100% REPOWERED	
ITEM	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX	MIN.	MAX.	MIN.	MAX.
– TURBINE GEN.	100	725	220	915	250	945	250	945	500	1300	500	1300
– CONTROL SYSTEM	102	560	102	560	102	610	102	610	102	610	102	610
– CONT. BLDG (NEW)	0	104	0	130	0	130	0	130	0	144	0	144
– CONT. ROOM MOD.	0	52	0	65	0	65	0	65	0	72	0	72
– PUMPS	491	508	469	495	0	22	0	22	0	22	0	22
– PIPING	120	481	211	843	190	761	296	1185	572	2290	645	2580
– INSULATION	7	28	10	42	9	37	18	71	33	133	37	148
– HEATERS	0	126	0	142	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
– WATER TREAT.	130	660	130	954	130	895	130	895	130	1542	130	1542
– ELECTRICAL	57	228	76	304	84	334	88	354	136	546	234	937
– MISC. SYSTEM	8	17	8	17	8	17	8	17	8	17	8	17
– PAINTING	0	2	0	2	0	2	0	2	0	3	0	3
– EARTHWK, FNDN'S	10	97	12	125	9	88	9	88	15	145	15	145
– DIRECT COST	1025	3558	1238	4594	782	3906	901	4384	1496	6824	1671	7520
– INDIRECT COST	277	971	348	1293	240	1199	270	1369	461	2104	505	2271
– TOTAL COST	1302	4559	1586	5887	1022	5105	1171	5753	1957	8928	2176	9791

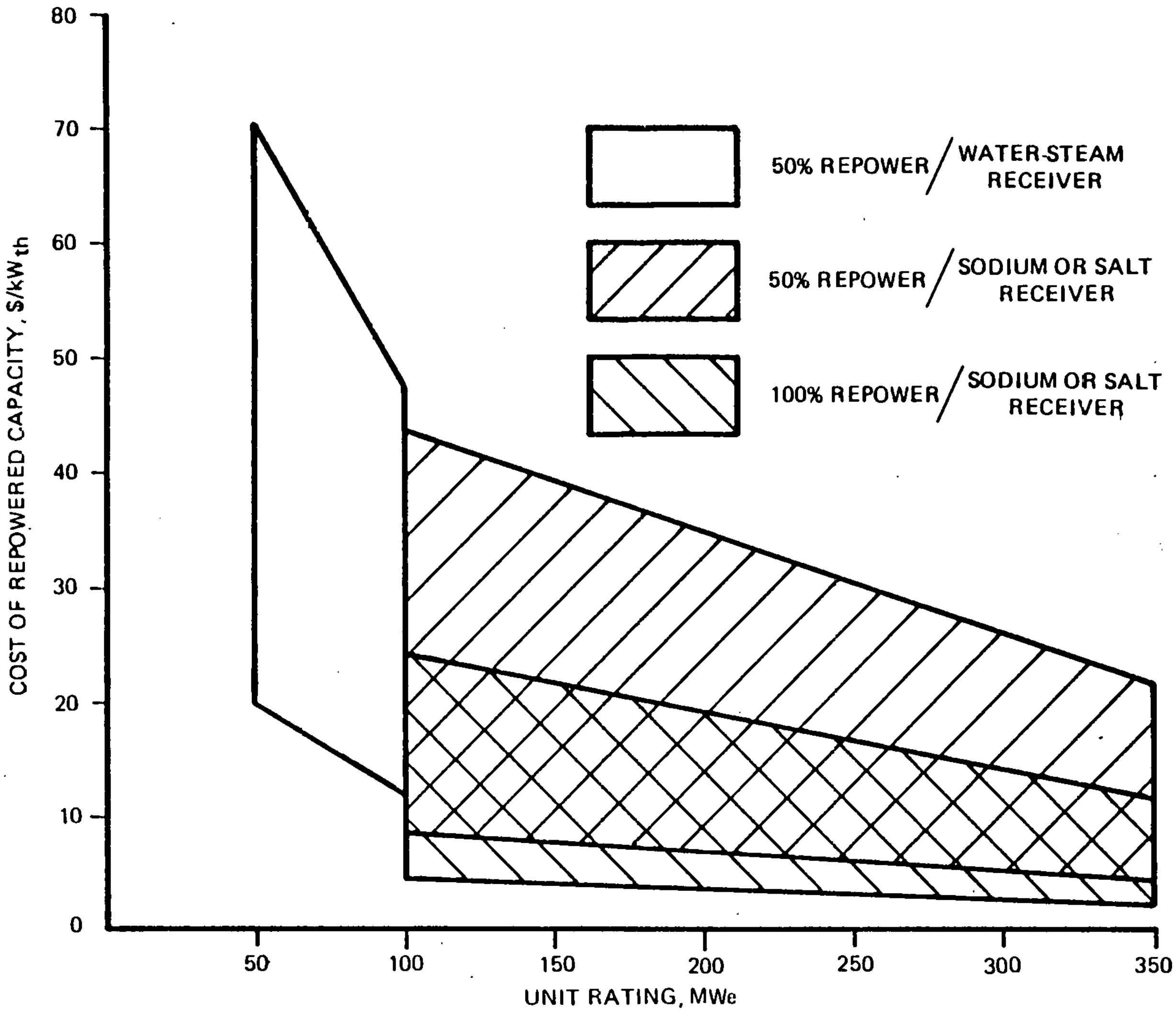

Figure 5–1. BOP COST OF REPOWERED CAPACITY PER kW_{th}

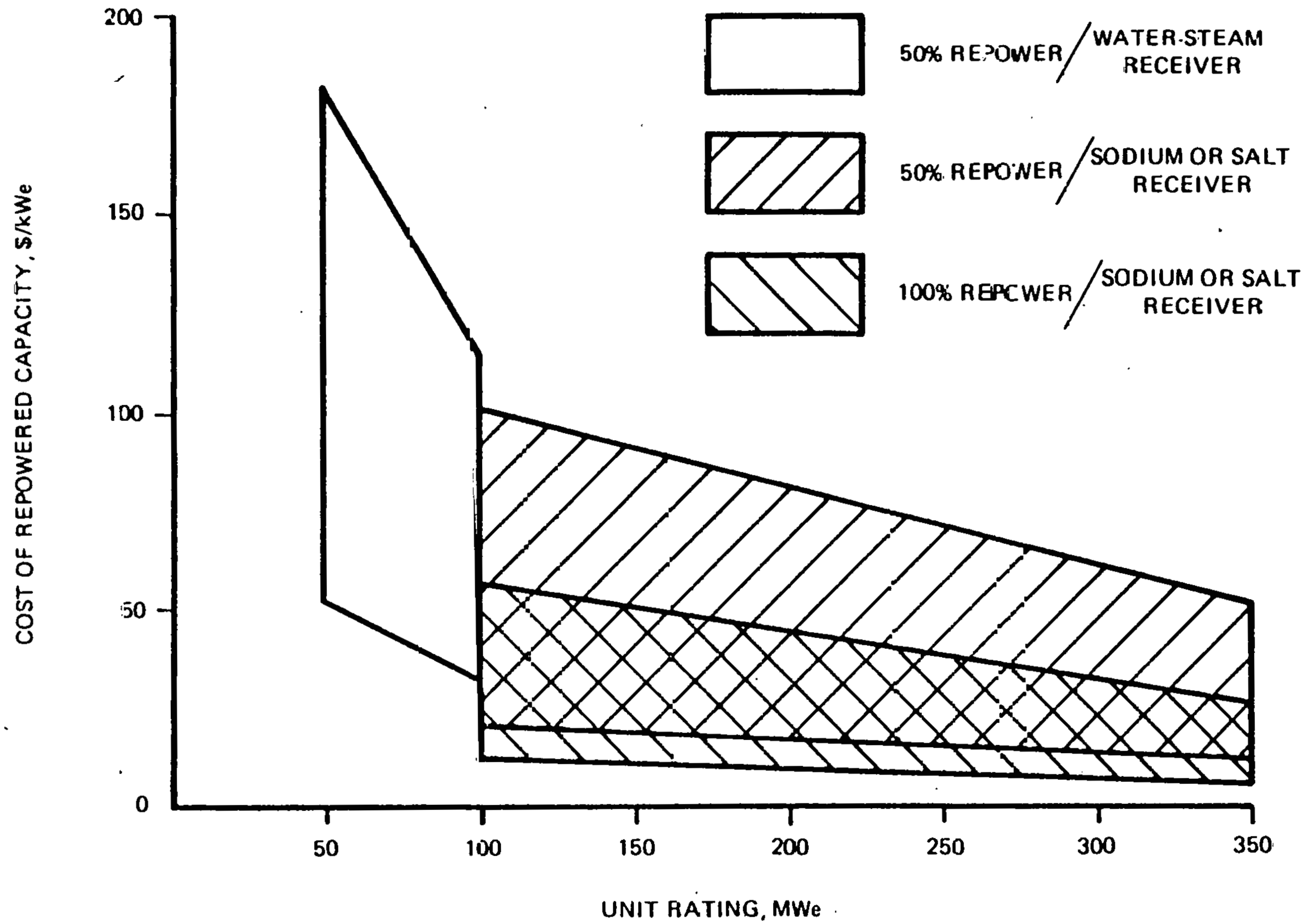

Figure 5–2. BOP COST OF REPOWERED CAPACITY PER kWe

Table 5-2. BOP COST SUMMARY
SOLAR REPOWERING INTEGRATION STUDY
(1979 DOLLARS IN THOUSANDS)

UNIT RATING - % REPOWER	50 MWe - 50%		100 MWe - 50%		100 MWe - 50%		100 MWe - 100%		350 MWe - 50%		350 MWe - 100%	
RECEIVER TYPE	WATER/STEAM		WATER/STEAM		SODIUM OR SALT		SODIUM OR SALT		SODIUM OR SALT		SODIUM OR SALT	
EXPECTED COST RANGE	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
4100 Site, Struct, Misc.	**18**	**270**	**20**	**337**	**17**	**300**	**17**	**300**	**23**	**378**	**23**	**378**
4110 Site												
4112 Yardwork	10	97	12	125	9	88	9	88	15	145	15	145
4120 Buildings												
4124 Control	0	156	0	195	0	195	0	195	0	216	0	216
4130 Misc. Equip.	8	17	8	17	8	17	8	17	8	17	8	17
4200 Turbine Plant Equip.	**848**	**2530**	**1040**	**3393**	**579**	**2662**	**694**	**3120**	**1235**	**5290**	**1312**	**5595**
4210 TG & Accessories	100	725	220	915	250	945	250	945	500	1300	500	1300
4220 Heat Rejection System	0	0	0	0	0	0	0	0	0	0	0	0
4230 Condensing	0	0	0	0	0	0	0	0	0	0	0	0
4240 Feed Heating	618	1145	690	1524	199	822	314	1280	605	2448	682	2753
4250 Working Fluid & Acc.	130	660	130	954	130	895	130	895	130	1542	130	1542
4300 Electric Plant Equip.	**159**	**788**	**178**	**864**	**186**	**944**	**190**	**964**	**238**	**1156**	**336**	**1547**
4310 Switchgear	0	0	0	0	0	0	0	0	0	0	0	0
4320 Station Svc. Equip.	46	182	61	243	67	267	70	283	109	437	187	750
4330 Protective Equip.	0	0	0	0	0	0	0	0	0	0	0	0
4340 Power Wiring & Acc.	11	46	15	61	17	67	18	71	27	109	47	187
4350 Master Control (EPGS)	102	560	102	560	102	610	102	610	102	610	102	610
4800 Distrib. & Indirect	**277**	**971**	**348**	**1293**	**240**	**1199**	**270**	**1369**	**461**	**2104**	**505**	**2271**
4810 Temp. Facilities & Equip.	69	242	89	329	64	319	72	347	123	561	133	600
4820 Spare Parts	0	0	0	0	0	0	0	0	0	0	0	0
4830 A&E Services	118	414	144	535	93	464	106	570	178	812	198	890
4840 Construction Mgmt.	86	300	110	409	79	397	88	431	153	697	166	745
4850 Startup & Checkout	4	15	5	20	4	19	4	21	7	34	8	36
4860 Contingency	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL COST	**1302**	**4559**	**1586**	**5887**	**1022**	**5105**	**1171**	**5753**	**1957**	**8928**	**2176**	**9791**

SECTION 6.0

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APPENDIX A

COST ESTIMATE WORK SHEETS

Stearns-Roger INCORPORATED

CLIENT: SERI

ORDER NO. C-22138 LOCATION: SOLAR REPOWERING PLANT MODIFICATION SYSTEMS INTEGRATION ANALYSIS

50 MW NON-REHEAT 50% SOLAR REP. WATER/STEAM RECEIVER

SHEET NO. 1 OF 10

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
4210	TG INSPECTION							100,000			100,000
4210	TG NON DESTRUCTIVE TESTS							20,000	5,000		25,000
4210	THERMOCOUPLES & RECORDERS							20,000	30,000		50,000
4210	TG ELECTROHYDRAULIC CONTROL SYS							105,000	245,000		350,000
4210	TG VARIABLE PRESSURE CONTROL										-
4210	GENERATOR MODIFICATIONS (REWIND)									200,000	200,000
	CONTROL SYSTEM MODIF/ADD										
4350	ANALOG CONTROL SYSTEM							75,000	175,000		250,000
4350	CONTROL PANEL & CONSOLE MODIF.							9,600	22,400		32,000
4350	BOILER COMB CONTROL SYS MODIF							15,000	35,000		50,000
4350	ANNUNCIATOR							7,500	17,500		25,000
4350	MISC. INSTRUMENTATION							81,200	121,800		203,000
	PUMPS										
4240	700 GPM @ 450' TDH, VERT.	2		7,000		220		3,300	14,000		17,300
	TURBINE, 125HP MOTOR, 1760 RPM										
	480V CONDENSATE										
	475 GPM @ 4150' TDH, BARREL	2		240,980		600		9,000	481,950		490,950
	TYPE MULTI STAGE, 750 HP, 3600										
	RPM 2400V FEED WATER										

Stearns-Roger INCORPORATED

CLIENT SERI SOLAR REPOWERING PLANT MODIFICATION

ORDER NO. C-22138 LOCATION SYSTEMS INTEGRATION ANALYSIS

WATER/STEAM RECEIVER

50 MW NON REHEAT 50% SOLAR REPOWERING

SHEET NO. 2 OF 10

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	PIPING										
	6" XXH A106	250	LF								
	3½" $CASIO_2$ INSUL W/AL LAGGING										
	BOILER FEED										
	10" 1.0 X .9" WALL, 2¼% CR	100	LF								
	1% M. A335 GR P22										
	7" $CASIO_2$ INSUL W/AL LAGGING										
	MAIN STEAM										
4240	TOTAL PIPING (SEE PAGES 4, 5)					5,805		89,280	392,020		481,300
4240	PIPE INSULATION (SEE PAGE 6)							11,240	16,865		28,105
	FEEDWATER HEATERS										
4240	#6 13867 #/HR 1300 SF			59,000		40		600	59,000		59,600
4240	#7 14723 #/HR 1500 SF			66,000		40		600	66,000		66,600
4300	ELECTRICAL (SEE PAGES 7 THRU 10)					2,140		34,300	193,400		227,700
	WATER TREATMENT										
4250	CONDENSATE POLISHER							64,000	360,000		424,000
4250	MIXED BED POLISHER							16,000	90,000		106,000
4250	WATER SAMPLING & MONITOR							19,500	110,000		129,500

Stearns-Roger
INCORPORATED

CLIENT: SERI SOLAR REPOWERING MODIFICATION
ORDER NO.: C-22138 LOCATION: SYSTEMS INTEGRATION ANALYSIS
50 MW NON REHEAT
WATER/STEAM RECEIVER
50% SOLAR REPOWERING

SHEET NO. 3 OF 10
BY: RHF
DATE: 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
4130	BEARING COOLING WATER SYSTEM							1,800	2,700		4,500
4130	INSTRUMENT AIR SYSTEM							3,000	4,500		7,500
4130	FIRE PROTECTION SYSTEM									5,000	5,000
	COMPUTER & LOGIC EQUIP ROOM										
4124	EXCAVATION	80	CY							400	400
	CONCRETE	54	CY	75.00	S/M	270	15.00	4,050	4,050		8,100
	BUILDING 38 x 38 x 21 HIGH	30324	CF	3.00/CF ERECTED						90,970	90,970
	HVAC	18772	CF	.26/CF INSTALLED						4,900	4,900
						TOTAL ROOM		4,050	4,050	96,270	104,370
4124	CONTROL ROOM MODIFICATION	(ASSUME ½ OF COMPUTER & LOGIC ROOM)						2,025	2,025	48,135	52,185

50 MW NON-REHEAT, WATER/STEAM RECEIVER-
50% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

SHEET NO. 4 OF 10

BY RJW

DATE 4/26/79

CLIENT

ORDER NO. C-22138 LOCATION

PIPING - CASE 3-1

50 MW NON-REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	SHOP & FIELD MATERIAL										
PIPE:	10" I.D. X 1" W.T. A335-P22 PIPE	100	LF	129.23					12,923		
	6" C.S. SCH.XXS. A106-GR.C. PIPE	250	LF	23.39					5,848		
	6" C.S. SCH. 40 A106-GR.B. PIPE	100	LF	7.21					721		
	4" A106-GR. B. PIPE	110	LF	4.25					467		
	2" C.S. SCH. 80 A106-GR.B. PIPE	50	LF	2.17					109		
	3/4" C.S. A106-GR.B. PIPE	100	LF	1.60					160		
VALVES&FTGS:	10" I.D. M.O. GATE VALVE (PRES.SEAL)	2	EA	27,800.00					55,600		
	10" A335-F22-90°ELL BENDS	6	EA	5,600.00					33,600		
	10" A335-F22-STRAIGHT TEES	1	EA	8,400.00					8,400		
	6"-1500# GATE VALVES-BW	8	EA	10,900.00					87,200		
	6"-1500# CHK. VALVES-BW	2	EA	9,300.00					18,600		
	6" SCH XXS.-TEES - BW	3	EA	263.75					792		
	6" SCH XXS.-90°ELLS-BW	20	EA	186.50					3,730		
	6"-WN-2500# FLG.	4	EA	550.00					2,200		
	6"-GATE VALVES-300# BW	4	EA	1,600.00					6,400		
	6"-SCH 40-90°ELLS-BW	10	EA	23.10					231		
	6" - WELDOLETS	2	EA	72.00					144		
	4"-GATE VALVES-300# BW	4	EA	940.00					3,760		
	4"-SCH 40-90°ELLS	12	EA	8.20					98		
	4" - WELDOLETS	4	EA	29.09					116		
	2" - 300 & GATE VALVES-S.W.	4	EA	160.00					640		
	2" - CONTROL VALVES - S.W.	2	EA	320.00					640		
	2" - SOCKOLETS	6	EA	8.20					49		

FORM 22-288 REV 1/79

50 MW NON-REHEAT, WATER/STEAM RECEIVER-
50% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

CLIENT

ORDER NO. C-22138 LOCATION

SHEET NO. 5 OF 10

BY RJW

DATE 4/26/79

PIPING - CASE 3-1

50 MW NON-REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
MAT'L CONT'D	2"-90°SCH 80 ELLS - S.W.	8	EA	11.45					92		
	3/4"-300# GATE VALVES - S.W.	8	EA	120.00					960		
	3/4"-GLOBE VALVES - S.W.	3	EA	120.00					360		
	3/4" CHECK VALVES - S.W.	1	EA	120.00					120		
	3/4"-CONTROL VALVES - S.W.	4	EA	240.00					960		
	3/4" SW - TEES	8	EA	3.86					31		
	3/4"-SW-90°ELLS	20	EA	3.07					61		
	HANGERS @ X.28 OF ABOVE MAT'L	LS	--	-----	--				68,603		
	TOTAL-SHOP & FIELD MATERIAL								313,615		
	SHOP FABRICATION @ X.25 OF MAT'L & HGRS.								78,404		
	TOTAL-MATERIAL & SHOP FAB. COST								392,019		
	FIELD LABOR COST										
	FACTOR @ .06 MH/LB (120 MH/TON)	75,000	LBS.	---	.06	4,500			--		
	SUBTOTAL - FIELD LABOR					4,500					
	PRORATABLE ALLOW: UNLOAD/STORE	5%				225					
	HYDROTESTING	7%				315					
	SCAFFOLDING	7%				315					
	HANGERS	10%				450					
	TOTAL-DIRECT LABOR & MATERIAL	710	LF			5,805	15.38	89,281	392,019		
	CASE 3-1										

A-6

PIPING INSULATION -
50% SOLAR REPOWERING SYSTEMS PLANT MODIFICATION

Stearns-Roger

SHEET NO. 6 OF 10

CLIENT ______

BY RJW

ORDER NO. C-22138 LOCATION ______

DATE 4/27/79

INSULATION SUBCONTRACT 50 MW NON-REHEAT
CAL-SIL INSUL W/ALUM. JACKET

PIPE O.D.	INSUL. THK.	DESCRIPTION	PIPING LF.	FTG. QTY.	XF	EQUIV. QTY.	LF.	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPING INSULATION - CASE 3-1															
12" O.D	7"	A335-P22	100'	9 ea.	X3	127	LF	68.70						8,725	
6" O.D.	3-1/2"	C.S. A106 PIPE	350'	53 ea.	X3	509	LF	27.50						13,998	
4" O.D.	3-1/2"	C.S. A106 PIPE	10'	20 ea.	X2	150	LF	20.55						3,083	
2" O.D.	2-1/2"	C.S. A106 PIPE	50'	20 ea.	X2	90	LF	9.26						833	
3/4" O.D.	2"	C.S. A106 PIPE	100'	44 ea.	X2	188	LF	7.80						1,466	
INSUL	TOTAL - 50 MW NON-REHEAT											11240	16865	28,105	
PIPE INSULATION - CASE 3-2															
16" O.D.	8"	A335-P22	100'	9 ea.	X4	136	LF	81.20						11,043	
6" O.D.	3-1/2"	C.S. A106	460'	36 ea.	X3	568	LF	27.50						15,620	
10" O.D.	4"	C.S. A106	250'	37 ea.	X3	361	LF	39.00						14,079	
2"-3/4"	AS ABOVE		---	---	--	---	--	-----						1,299	
INSUL	TOTAL - 100 MW NON-REHEAT											16815	25225	42,040	
PIPE INSULATION - CASE 3-3															
14" O.D.	8"	A335-P22	---	---	--	150	LF	75.00						11,250	
14" O.D.	5-1/2"	A106 PIPE	---	---	--	150	LF	45.00						6,750	
9" O.D.	7-1/2"	A335-P22	---	---	--	150	LF	68.70						10,305	
8" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	31.00						4,650	
6" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	27.50						4,125	
TOTAL	100 MW REHEAT											14830	22250	37,080	

FORM 22-288 REV 1/79

Stearns-Roger

SHEET NO. 7 OF 10

CLIENT SERI

BY JRO

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING WATER/STEAM REC.

DATE 4/25/79

CASE I

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	50 MWe NON REHEAT						16.00				
	WATER/STEAM RECEIVER										
	50% SOLAR REPOWERING										
	EQUIPMENT:										
	TRANSFORMER, AUXILIARY POWER,	1	EA			125		2000	11200	400	13600
	1500 KVA, 13.8-2.4 KV										
	METALCLAD SWITCHGEAR										
	2.4 KV - 1200 AMP.										
	SET, CONNECT, ANCHOR	7	SEC		20	140		2240	---	450	2690
	1200 A CB	1	EA			28		450	9765	INC	10215
	500 KVA TRANSF. 480 V.	1	EA			60		960	4500	INC	5460
	800 A CB	1	EA			20		320	3600	INC	3920
	200 A CB	2	EA		8	16		255	730	INC	985
	100 A CB	3	EA		7	21		335	870	INC	1205
	MOTOR CONTROL CENTER	1	LOT			110		1760	20000	90	21850
	UPS SYSTEM - 45 KVA	1	EA			---		---	75000	---	75000
	DIESEL - GEN. 240 KW	1	EA			156		2500	28500	250	31250
	1000 KVA 80% PF 2400 V AC										
						676		10820	154165	1190	66175

FORM [illegible] REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

50 MW NON REHEAT WATER STEAM REC.

SHEET NO. 8 OF 10

BY JRO

DATE 4/25/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE I CONT'D.						16				
	BUSWAYS:										
	1200 A ISC PHASE BUS	30	LF	30	2.0	60		960	990	200	2150
	FTGS.	3	EA	50	4.0	12		190	150	150	490
	BUS DUCT - 600 A	50	LF	50	.7	35		560	2500	30	3090
	CABLE - 250 MCM 5KV	200	LF	13.50	.09	18		290	2700	30	3020
	FROM SU XFF TO BUS A										
	5 KV TERMINATIONS	6	EA	10.50	4.0	24		385	65	40	490
	CIRCUITRY:										
	750 HP PUMP	150	LF			118		1895	3850	65	5810
	1000 KVA DEISEL GEN.	150	LF			158		2525	5125	90	7740
	TERM'S.	12	EA		.359	4		65	40		105
	CONTROL CKTS	2	EA			60		960	1200	35	2195
	TESTING, CHECK-OUT,					50		800	100	---	900
	TAG & IDENTIFY										
						539		8630	16720	640	25990

FORM 22-288 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

50 MW NON REHEAT WATER STEAM REC.

SHEET NO. 9 OF 10

BY JRO

DATE 4/25/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	LIGHTING										
	CONDUIT	650	LF		.146	95		1520	270	150	1940
	WIPE & TERMS	3665	LF		.015	55		880	220	INC	1100
	FIXTURES	16	EA		7.5	120		1920	2000	INC	3920
	ILLUMINATION TEST	16	EA		.25	4		65	---	---	65
	BREAKAGE ALLOWANCE	ALL	--		---	---		---	250	---	250
	COMMUNICATIONS										
	CONDUIT	585	LF		.147	86		1375	345	---	1720
	WIRE & TERMS	1025	LF		.039	40		640	425	---	1065
	EQUIPMENT	2	EA		15	30		480	1120	---	1600
	GROUNDING	900	LF		.12	108		1730	1150	---	1880
						533		8610	5780	150	14460

FORM : I REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATIONS

50 MW NON REHEAT WATER STEAM REC.

SHEET NO. 10 OF 10

BY JRO

DATE 4/25/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	DC EQUIPMENT										
	BATTERIES	1	SET	9000		30		480	9000		9480
	BATTERY RACK - 2 STEP	1	SET	450		10		160	450		610
	BATTERY CHARGER	1	EA	3400		16		255	3400		3655
						56		895	12850		13745
	SUMMARY					2140		34300	193400		227700

FORM 22-288 REV 1/79

PAGES A-12 to A-14

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100 MW, NON-REHEAT, WATER/STEAM RECEIVER-
50% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

SHEET NO. 4 OF 9

CLIENT ______

BY RJW

ORDER NO. C-22138 LOCATION ______

DATE 4/26/79

PIPING-CASE 3-2

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPE:	12"I.D.x1-7/8"W.T. A335-P22 PIPE	100	LF	328.90					32,890		
	(299 LB./FT.)										
	10" SCH. 160 C.S. A106 GR. C PIPE	250	LF	61.32					15,330		
	6" C.S. SCH 40 A106 GR. B	210	LF	7.21					1,514		
	2" C.S. SCH 80 A106-GR. B	50	LF	2.17					109		
	3/4" C.S. SCH 80 A106-GR. B	100	LF	1.60					160		
VALVES/FTGS.	12" IPM OPER GATE VALVE (PRES.SEAL)	2	EA	38,000.00					76,000		
	12"-5 DIA. F22 90° ELLS-BW-	6	EA	13,900.00					83,400		
	12" STRAIGHT TEE - F22	1	EA	17,375.00					17,375		
	10" MO GATE VALVES-BW	2	EA	22,000.00					44,000		
	10" GATE VALVES-BW	6	EA	16,800.00					100,800		
	10" CHECK VALVES-BW	2	EA	14,280.00					28,560		
	10" SCH 160 TEES-BW	3	EA	657.36					1,972		
	10" SCH 160-90° ELLS	20	EA	480.55					9,611		
	10" WN-600# FLG.	4	EA	272.25					1,091		
	6"-GATE VALVES-300#	8	EA	1,600.00					12,800		
	6"-90° ELLS-BW	22	EA	23.10					508		
	6" WELDOLETS	6	EA	72.00					432		
	2" GATE VALVES-S.W.	4	EA	160.00					640		
	2" CONTROL VALVES S.W.	2	EA	320.00					640		
	2" SOL	6	EA	8.20					49		
	2" 90° ELLS-SW	8	EA	11.45					92		
	3/4" GATE-GLOBE OR CHK VALVES-SW	12	EA	120.00					1,400		
	3/4" CONTROL VALVES-SW	4	EA	240.00					960		

UNITED STATES GC NMENT

2-Way Memo

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3/25/80

After checking with the author re: the missing pages, he indicated the information on pages A12-14 was removed because it was not pertinent but he overlooked renumbering the pages. Therefore, the referenced publication is ok as is.

[signature: R J Radhoff]

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2. TO BE RETURNED TO ORIGINATOR *(Receiver)*

OPTIONAL FORM 27 (Rev. 7-77)
GSA FPMR (41 CFR) 101-11.6

100 MW NON-REHEAT, WATER/STEAM RECEIVER-
50% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

SHEET NO. 5 OF 9

CLIENT

BY RJW

ORDER NO. C-22138 LOCATION

DATE 4/26/79

PIPING - CASE 3-2

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
MAT'L CONTD.											
	3/4" SW TEES	8	EA	3.86					31		
	3/4" SW-90° ELLS	20	EA	3.07					61		
	HANGERS @ X.28 OF MAT'L								120,519		
	TOTAL - MATERIAL								550,944		
	SHOP FABRICATION @ X.25 MAT'L &								137,736		
	HANGERS										
	TOTAL - MAT'L & FABRICATION COST								688,680		
	FIELD LABOR										
	FACTOR @ .06/LB (120 MN/TON)	130,000	LBS	----	.06	7,800					
	SUBTOTAL-FIELD LABOR					7,800					
	PRORATABLE ALLOW: UNLOAD/STORG.5%					390					
	HYDROTESTING 7%					546					
	SCAFFOLDING 7%					546					
	HANGERS 10%					780					
	TOTAL-DIRECT LABOR & MATERIAL	710	LF			10,062	15.38	154,754	688,680		
	CASE 3-2										

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FORM 22-288 REV 1/79

PIPING INSULATION-
50% SOLAR REPOWERING SYSTEMS

Stearns-Roger

CLIENT 100 MW NON REHEAT - WATER STEAM RECEIVER

BY RJW

ORDER NO. C-22138 LOCATION

DATE 4/27/79

INSULATION SUBCONTRACT
CAL-SIL INSUL W/ALUM. JACKET

PIPE O.D.	INSUL. THK.	DESCRIPTION	PIPING LF	FTG QTY	XF	EQUIV. QTY.	LF	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPING INSULATION-CASE 3-1															
12" O.D.	7"	A335-P22	100'	9 ea	X3	127	LF	68.70						8,725	
6" O.D.	3-1/2"	C.S.A106 PIPE	350'	53 ea	X3	509	LF	27.50						13,998	
4" O.D.	3-1/2"	C.S.A106 PIPE	110'	20 ea	X2	150	LF	20.55						3,083	
2" O.D.	2-1/2"	C.S.A106 PIPE	50'	20 ea	X2	90	LF	9.26						833	
3/4" O.D.	2"	C.S.A106 PIPE	100'	44 ea	X2	188	LF	7.80						1,466	
INSUL	TOTAL - 50 MW NON-REHEAT											11240	16865	28,105	
PIPE INSULATION - CASE 3-2															
16" O.D.	8"	A335-P22	100'	9 ea	X4	136	LF	81.20						11,043	
6" O.D.	3-1/2"	C.S.A106	460'	36 ea	X3	568	LF	27.50						15,620	
10" O.D.	4"	C.S.A106	250'	37 ea	X3	361	LF	39.00						14,079	
2"-3/4"	AS ABOVE	"	---	---	--	---	--	---						1,299	
INSUL	TOTAL - 100 MW NON-REHEAT											16815	25225	42,040	
PIPE INSULATION - CASE 3-3															
14" O.D.	8"	A335-P22	---	---	--	150	LF	75.00						11,250	
14" O.D.	5-1/2"	A106 PIPE	---	---	--	150	LF	45.00						6,750	
9" O.D.	7-1/2"	A335-P22	---	---	--	150	LF	68.70						10,305	
8" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	31.00						4,650	
6" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	27.50						4,125	
TOTAL		100 MW REHEAT										14830	22250	37,080	

FORM 2[illegible] REV 1/79

Stearns-Roger

CLIENT: SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

WATER STEAM REC.

100 MW NON REHEAT

SHEET NO. 7 OF 9

BY JRO

DATE 4/26/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE II SUMMARY ELECTRICAL										
4320	EQUIPT					945		15125	199105	1600	215830
4340	CIRCUITRY					1068		17095	31495	910	49500
4320	LIGHTING					274		4385	2740	150	
4320	COMMUNICATIONS					156		2495	1890	---	
4320	GROUNDING					108		1730	1150	---	
4320	DC SYSTEM					56		895	12850	---	
4320	MISC.					78		1250	2500	---	
	SUBTOTAL					2685		42975	251730	2660	297365
	LABOR EFFICIENCY	.15				400		6400	---	---	6400
	TOTAL					3085		49375	251730	2660	303765
	USE							49400	254400		303800

FORM 22-288 REV 1/79

Stearns-Roger

SHEET NO. 8 OF 9

CLIENT SERI

BY JRO

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION WATER STEAM REC.

DATE 4/26/79

CASE II 100 MW NON REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	100 MWe NON REHEAT						16.00				
	WATER/STEAM RECEIVER										
	50% SOLAR REPOWERING										
	EQUIPMENT										
	XRF, AUX POWER, 2000	1	EA			135		2160	13500	430	
	KVA 13.8 KV - 4.16 KV										
	METALCLAD SWITCHGEAR										
	4.16 KV - 1200 AMP										
	SET, CONNECT, ANCHOR	9	SEL		20	180		2880	---	550	
	500 KVA XRF 480 V.	1	EA			60		960	4500	INC	
	1200 A CB	1	EA			28		450	9765	INC	
	800 A CB	1	EA			20		320	3600	INC	
	400 A CB	1	EA			11		175	625	INC	
	300 A CB	5	EA		8	40		640	1825	INC	
	100 A CB	1	EA		7	7		115	290	INC	
	MOTOR CONTROL CENTERS	1	LOT			154		2,465	28000	125	
	UPS SYSTEM	1	EA			---		---	75000	---	75000
	DIESEL GEN, 2000 KVA	1	EA			310		4960	62000	495	
						945		15125	199105		

FORM 22-200 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION SOLAR REPOWERING PLANT MODIFICATION

100 MW NON-REHEAT WATER STEAM REC.

SHEET NO. 9 OF 9

BY JRO

DATE 4/26/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE II CONT'D.										
	BUSWAYS:										
	ISO PHASE BUS	30	LF			60		960	990	200	2150
	FTGS.	3	EA			12		190	150	150	490
	BUS DUCT	50	LF			35		560	2500	30	3090
	CABLE FROM SU XCF.	200	LF			18		290	2700	30	3020
	TO BUS A										
	5 KV TERMINATICNS	6	EA			24		385	65	40	490
	CIRCUITRY:										
	750 HP PUMPS	300	LF			236		3780	7700	130	11610
	2000 KVA DEISEL GEN	150	LF			300		4800	10250	170	15220
	LC XRF. TO MCC	100	LF			100		1600	5135	60	6795
	TERMINATIONS	18	EA		.359	6		100	50	---	150
	CONTROL CKTS	3	EA			180		2880	1800	100	4780
	TESTING, CHECK-OUT,	1	LOT			97		1550	155	---	1705
	TAG & IDENTIFY										
						1068		17095	31495	910	49500

FORM 22-288 REV 1/79

Stearns-Roger

SHEET NO. 1 OF 9

CLIENT SERI

BY RHF

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

DATE 4-27-79

100 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	TURBINE-GENERATOR MODIF.										
4210	INSPECTION							25,000	-		250,000
4210	NON DESTRUCTIVE TESTS							20,000	5,000		25,000
4210	THERMOCOUPLES & RECORDER							20,000	30,000		50,000
4210	ELECTROHYDRAULIC CONTROL SYS							105,000	245,000		350,000
4210	VARIABLE PRESSURE CONTROL										-
4210	GENERATOR REWINDING									270,000	270,000
	CONTROL SYSTEM MODIF/ADD.										
4350	ANALOG CONTROL SYSTEM							90,000	210,000		300,000
4350	CONTROL PANEL & CONSOLE MODIF.							9,600	22,400		32,000
4350	BOILER COMBUSTION CONTROL SYSTEM							15,000	35,000		50,000
4350	MODIFICATIONS										-
4350	ANNUNCIATORS, 30 WINDOWS							7,500	17,500		25,000
4350	MISC. INSTRUMENTATION							81,200	121,800		203,000
	PUMPS										
4240	550 GPM @ 425 FT IDH VERTICAL	3		6,000		300		4,500	18,000		22,500
	TURBINE, 100 HP, 1760 RPM										
	CONDENSATE										

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FORM 22-288 REV 1/79

Stearns-Roger

CLIENT: SERI
ORDER NO.: C-22138
LOCATION: 50% SOLAR REPOWERING PLAND MODIFICATION
SODIUM OR SALT RECEIVER
100 MW REHEAT

SHEET NO.: 2 OF 9
BY: RHF
DATE: 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	PUMPS (CONT'D)										
4240	480 V, ODP MOTOR										
	PIPING										
	8" XXS ASTM A106,	100 FT									
	GR. C. INSULATION - 4" $CASIO_2$										
	W/ALUMINUM LAGGING										
	BOILER FEED										
	7" I.D., 1.025" WALL THICKNESS,	100 FT									
	2¼% CHROME, 1% MOLY STEEL										
	ASTM A335 GR. P22, 96 LBS/FT										
	INSULATION - 7½" $CASIO_2$ WITH										
	ALUMINUM LAGGING										
	MAIN STEAM										
	14" SCH. 30 ASTM A106	100 FT									
	GR. A. INSULATION - 5½"										
	$CASIO_2$ W/ALUMINUM LAGGING										
	COLD REHEAT										

FORM 22-288 REV 1/79

Stearns-Roger
INCORPORATED

SHEET NO. 3 OF 9
BY RHF
DATE 4-27-79

CLIENT SERI
ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER
100 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	PIPING (CONT'D)										
	14" SCH. 60, 2¼% CHROME,	100 FT.									
	1% MOLY STEEL ASTM										
	A335 GR. P22 HOT REHEAT										
	INSULATION - 8" $CASIO_2$										
	W/ALUMINUM LAGGING										
4240	TOTAL PIPING (SEE PAGES 5 & 6					7,238		111,320	649,640		760,960
	WATER TREATING SYS. MODIF/ADD										
4250	CONDENSATE POLISHER							97,000	550,000		647,000
4250	MIXER BED POLISHER							18,000	100,000		118,000
4250	WATER SAMPLING & MONITORING SYSTEM							19,500	110,000		129,500
	MISC. SYSTEM MODIFICATIONS										
4130	BRG. COOLING WATER SYSTEM							1,800	2,700		4,500
4130	INSTR. AIR SYSTEM							3,000	4,500		7,500
4130	FIRE PROTECTION SYSTEM									5,000	5,000
4124	COMPUTER & LOGIC ROOM							5,025	5,025	119,820	129,870
4124	CONTROL ROOM MODIFICATIONS							2,513	2,512	59,910	64,935
	[illegible]TRICAL (SEE PAGES 7 THRU 9)					3,466		55,500	278,655		4,155

100 MW RH MOLTEN SALT-
50% SOLAR REPOWERED

Stearns-Roger

SHEET NO. 4 OF 9

CLIENT

BY RJW

ORDER NO. C-22138 LOCATION

DATE 4/27/79

PIPING-CASE 3-3

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPE:	14" A335-P22 SCH. 60 PIPE	100	LF	93.56					9,356		
	14" C.S. A106-GR. A-SCH. 30 PIPE	100	LF	38.50					3,850		
	8" C.S. A106-GR. C. SCH. XXS	100	LF	29.20					2,920		
	7" I.D. x 1" W.T.-A335-P22 PIPE	100	LF	105.60					10,560		
	6" C.S. A106-GR. B. W/VALVES-FTGS.	70	LF	75.00					5,250		
VALVES/FTGS:	20" FLOW CONTROL MOV VALVE-BW	1	EA	33,000.00					33,000		
	20" X 14" RED. TEE-BW	4	EA	4,600.00					18,400		
	12-3/4" x 7" ID TEE-F22-BW	1	EA	3,960.00					3,960		
	7" I.D. MO. GATE VALVE	1	EA	22,000.00					22,000		
	12" I.D. MO GATE VALVE	1	EA	43.000.00					43,000		
	7"-F22-90° ELLS-BW	6	EA	4,000.00					24,000		
	14" PRESS. SEAL GATE VALVES	3	EA	29,000.00					87,000		
	14"-A335-F22 90° ELLS	6	EA	19,350.00					116,100		
	14"-CS-SCH. 30 90° ELLS	6	EA	170.00					1,020		
	8" XXS-90° ELLS	6	EA	268.00					1,608		
	8" MOTOR OPER VALVES	2	EA	6,000.00					12,000		
	8" GATE & GLOBE VALVES	3	EA	4,000.00					12,000		
	HANGERS @ X.28 OF MAT'L										
	TOTAL-MATERIAL								519,711		
	SHOP FABRICATION-X.25 of MAT'L & HGRS.								129,928		
	TOTAL-MAT'L & FAB. COST								649,639		

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FORM 22-288 REV 1/79

Stearns-Roger

CLIENT SERI

BY RJW

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING

DATE 4/27/79

PIPE-CASE - 3-3

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	FIELD LABOR										
	FACTOR @ .06 MH/LB.	93,500	LBS	--	.06	5,610					
	SUBTOTAL - FIELD					5,610					
	PRORAT. ALLOW: UNLOAD/STORE 5%					281					
	HYDRO 7%					393					
	SCAFFOLD 7%					393					
	HANGERS 10%					561					
	TOTAL DIRECT LBR & MATL	470	LF			7,238	15.38	111,320	649,639		

FORM 22 REV 1/79

PIPING INSULATION-
50% SOLAR REPOWERING SYSTEMS

Stearns-Roger

SHEET NO. 6 OF 9

CLIENT

BY RJW

ORDER NO. C-22138 LOCATION

DATE 4/27/79

INSULATION SUBCONTRACT
CAL-SIL INSUL W/ALUM. JACKET

PIPE O.D.	INSUL THK.	DESCRIPTION	PIPING LF.	FTG. QTY.	XF	EQUIV QTY.	LF.	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPING INSULATION - CASE 3-1															
12" O.D.	7"	A335-P22	100'	9 ea	X3	127	LF	68.70						8,725	
6" O.D.	3-1/2"	C.S.A106 PIPE	350'	53 ea	X3	509	LF	27.50						13,998	
4" O.D.	3-1/2"	C.S.A106 PIPE	110'	20 ea	X2	150	LF	20.55						3,083	
2" O.D.	2-1/2"	C.S.A106 PIPE	50'	20 ea	X2	90	LF	9.26						833	
3/4" O.D.	2"	C.S.A106 PIPE	100'	44 ea	X2	188	LF	7.80						1,466	
INSUL	TOTAL - 50 MW NON-REHEAT											11240	16865	28,105	
PIPE INSULATION - CASE 3-2															
16" O.D.	8"	A335-P22	100'	9 ea	X4	136	LF	81.20						11,043	
6" O.D.	3-1/2"	C.S.A106	460'	36 ea	X3	568	LF	27.50						15,620	
10" O.D.	4"	C.S.A106	250'	37 ea	X3	361	LF	39.00						14,079	
2"-3/4"	AS ABOVE		---	---	--	---	--	---						1,299	
INSUL	TOTAL - 100 MW NON-REHEAT											16815	25225	42,040	
PIPE INSULATION - CASE 3-3															
14" O.D.	8"	A335-P22	---	---	--	150	LF	75.00						11,250	
14" O.D.	5-1/2"	A106 PIPE	---	---	--	150	LF	45.00						6,750	
9" O.D.	7-1/2"	A335-P22	---	---	--	150	LF	68.70						10,305	
8" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	31.00						4,650	
6" O.D.	3-1/2"	A106 PIPE	---	---	--	150	LF	27.50						4,125	
TOTAL	100 MW REHEAT											14830	22250	37,080	

FORM 22-288 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT REC.

100 MW REHEAT

BY JRO

DATE 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/M.H	LABOR	MATERIAL	OTHER	TOTAL
	CASE III SUMMARY										
4320	EQUIPT					1054		16865	214905	1860	233630
4340	CIRCUITRY					1288		20615	39180	1430	61225
4320	LIGHTING					274		4385	2740	150	
4320	COMMUNICATIONS					156		2495	1890	---	
4320	GROUNDING					108		1730	1150	---	
4320	DC SYSTEM					56		895	12850	---	
4320	MISC.					78		1250	2500	---	
	SUB TOTAL					3014		48235	275215	3440	326890
	LABOR EFFICIENCY					452		7235	---	---	7235
	TOTAL					3465		55470	275215	3440	334125

Stearns-Roger

CLIENT: SERI

ORDER NO.: C-22138 LOCATION:

CASE III

SHEET NO.: 8 OF 9

BY: JRO

DATE: 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	100 MW PLANT REHEAT										
	SALT OR SODIUM-COOLED										
	RECEIVER, 50% SOLAR										
	REPOWERING:										
	3000 KVA XRF.	1	EA			180		2880	20300	575	
	SWITCHGEAR	1	LOT			290		4640	20605	465	
	500 KVA XRF.	2	EA			120		1920	9000	200	
	MCC'S	1	LOT			154		2465	28000	125	
	UPS SYS.	1	LOT			---		---	75000	---	75000
	DEISEL GEN.					310		4960	62000	495	
						1054		16865	214905	1860	233630

FORM 22-288 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22133 LOCATION

SHEET NO. 9 OF 9

BY JRO

DATE 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE III CONT'D.										
	BUSWAYS. INCREASE	30	LF			33		1320	1650	330	3300
	25% OVER CASE II										
	BUS DUCT - 25% OVER	50	LF			43		695	3125	40	3860
	CASE II										
	CABLE: SUXRF. TO MCC	200	LF			23		375	3360	40	3775
	CIRCUITRY										
	PULLS					788		12600	28560	840	42000
	TERM'S					8		135	55	---	190
	CONTROL CKTS.					225		3600	2220	180	6000
	TESTING					118		1890	210		2100
						1283		20615	39180	1430	61225

Stearns-Roger
INCORPORATED

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER
100 MW REHEAT

SHEET NO. 1 OF 8
BY RHF
DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	TURBINE-GENERATOR MODIF										
4210	INSPECTION							250,000			250,000
4210	NON DESTRUCTIVE TESTS							20,000	5,000		25,000
4210	THERMOCOUPLES & RECORDER							20,000	30,000		50,000
4210	ELECTROHYDRAULIC CONTROL SYS							105,000	245,000		350,000
4210	VARIABLE PRESSURE CONTROL										-
4210	GENERATOR REWINDING									270,000	270,000
	CONTROL SYSTEM MODIF/ADDITIONS										
4350	ANALOG CONTROL SYSTEM							90,000	210,000		300,000
4350	CONTROL PANEL & CONSOLE MODIF							9,600	22,400		32,000
4350	BOILER COMBUSTION CONTROL SYSTEM							15,000	35,000		50,000
4350	MODIFICATIONS										-
4350	ANNUNCIATORS, 30 WINDOWS							7,500	17,500		25,000
4350	MISC. INSTRUMENTATION							81,200	121,800		203,000
	PUMPS										
4240	550 GPM @ 425 FT TDH VERTICAL	3		6,000		300		4,500	18,000		22,500
	TURBINE, 100 HP, 1760 RPM										

Stearns-Roger
INCORPORATED

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

100 MW REHEAT

SHEET NO. 2 OF 8

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	PUMPS (CONT'D)										
- 4240	480V, ODP MOTOR										
	PIPING										
	8" XXS, ASTM A106,	100 FT.									
	GR. C. INSULATION - 4" $CASIO_2$										
	W/ALUMINUM LAGGING BOILER FEED										
	10" I.D., 1.510" WALL THICKNESS,	100 FT.									
	2¼% CHROME, 1% MOLY STEEL										
	ASTM A335 GR. P22, 220 LBS/FT										
	INSULATION - 8" $CASIO_2$										
	W/ALUMINUM LAGGING MAIN STEAM										
	20" SCH. 30 ASTM A106	100 FT.									
	GR. A. INSULATION - 5½"										
	$CASIO_2$ W/ALUMINUM										
	LAGGING COLD REHEAT										

Stearns-Roger
INCORPORATED

SHEET NO. 3 OF 8
BY RHF
DATE 4-27-79

CLIENT SERI
ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER
100 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	PIPING (CONT'D)										
	20" I.D., 0.793" WALL	100 FT									
	THICKNESS, 2¼% CHROME, 1% MOLY										
	STEEL ASTM A335 GR. P22, 195										
	LBS/FT HOT REHEAT										
	INSULATION - 8" $CASIO_2$										
	W/ALUMINUM LAGGING										
4240	TOTAL PIPING (SEE PAGES 5 & 6)							174,625	1,010,965		1,185,590
	WATER TREATING SYSTEM MODIF/ADD										
4250	CONDENSATE POLISHER							97,000	550,000		647,000
4250	MIXER BED POLISHER							18,000	100,000		118,000
4250	WATER SAMPLING & MONITORING SYSTEM							19,500	110,000		129,500
	MISC. SYSTEM MODIFICATIONS										
4130	BRG. COOLING WATER SYS.							1,800	2,700		4,500
4130	INSTR. AIR SYSTEM							3,000	4,500		7,500
4130	FIRE PROTECTION SYSTEM									5,000	5,000
4124	COMPUTER & LOGIC ROOM							5,025	5,025	119,820	129,870
4124	CONTROL ROOM MODIF. (ASSUME 1/2 COMP. & LOGIC ROOM)							2,513	2,512	59,910	64,935
	ELECTRICAL (SEE PAGES 7 THRU 9)					3,701		61,800	292,500		354,300

100 MW R.H. MOLTEN SALT -
- 100% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

SHEET NO. 4 OF 8

CLIENT SERI

BY RJW

ORDER NO. C-22138 LOCATION

DATE 4/27/79

PIPING CASE 3-4

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	20" I.D. x 3/4" W.T. A335-P22 PIPE	100	LF	214.50					21,450		
	20" C.S. A106 GR.A SCH 30 PIPE	100	LF	70.00					7,000		
	10" I.D. x 1-1/2" WT A335-P22 PIPE	100	LF	242.00					24,200		
	8" C.S. A106 GR.C-SCH. XXS W/FTGS/	110	LF	285.00					31,350		
	VALVES										
	6" C.S. A106 GR.B-SCH 40 W/FTGS/	70	LF	75.00					5,250		
	VALVES										
	20" GATE VALVE-ALLOY (PRESS SEAL)	2	LF	82,000.00					164,000		
	20" GATE-600# BW-	1	LF	71,400.00					71,400		
	20" GATE-600# MOTOR OPER.-BW	2	LF	77,000.00					154,000		
	20" ALLOY 90^{O} ELLS-BW	6	LF	10,900.00					65,400		
	20" ALLOY-TEES-BW	2	LF	17,000.00					34,000		
	20" C.S. SCH 30-90^{O} ELL-BW-	6	LF	775.00					4,644		
	20" C.S. SCH. 30-TEE-BW-	1	LF	1,160.00					1,160		
	10" ALLOY-90^{O} ELLS-BW-	6	LF	6,500.00					39,000		
	10" ALLOY TEE-BW-	1	LF	9,000.00					9,000		
	HANGERS @ X.28 MATL.								176,919		
	TOTAL-MATERIAL								808,773		
	SHOP FAB. @ X.25-MAT'L & HGRS.								202,193		
	TOTAL - MAT'L & FAB. COST								1,010,966		

FORM 22-... REV 1/79

100 MW R.H. MOLTEN SALT -
-100% SOLAR REPOWERING PLANT MODIFICATION

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION

PIPING - CASE 3-4

SHEET NO. 5 OF 8

BY RJW

DATE 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	FIELD LABOR										
	FACTOR @ .06 MH/LB	146,700	LBS	-	.06	8,802					
	SUBTOTAL - FIELD LABOR					8,802			-		
	PRORATABLE ALLOW: UNLOAD/STORE 5%					440					
	HYDRO 7%					616					
	SCAFFOLD 7%					616					
	HANGERS 10%					880					
PIPING -	TOTAL - DIRECT LABOR & MATERIAL	480	LF			11,354	15.38	174,625	1,010,966		
INSULATION @ .07 OF DIRECT MAT'L										70,768	
INSUL - SUBCONTRACT										70,768	

FORM 22-288 REV 1/79

Stearns-Roger

CLIENT SERI
ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER
100 MW REHEAT

SHEET NO. 6 OF 8
BY
DATE

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE IV SUMMARY										
4320	EQUIPT.					977		18,245	222,035	1,985	242,265
4340	CIRCUITRY					1553		24,850	45,440	1,400	71,690
4320	LIGHTING					274		4,385	2,740	150	
4320	COMMUNICATIONS					156		2,495	1,890	-	
4320	GROUNDING					108		1,730	1,150	-	
4320	DC SYSTEM					56		895	12,850	-	
	MISC					94		1,505	2,860	-	
	SUB TOTAL					3218		54,105	288,965	3,535	346,605
	LABOR EFFICIENCY					483		7,730	-	-	7,730
	TOTAL					3701		61,835	288,965	3,535	354,335

FORM: 3 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER

CASE IV 100 MW REHEAT

SHEET NO. 7 OF 8

BY

DATE

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	100 MWe REHEAT										
	SALT OR SODIUM-COOLED										
	RECEIVER, 100% SOLAR										
	REPOWERING										
	EQUIPT										
	XRF 5000 KVA	1	EA			195		3120	28,650	600	
	SWITCHGEAR -	11	SEC		20	220		3520	-	760	
	500 KVA XRF	2	EA		60	120		1920	9,000	INC	
	1200 A CB	1				28		450	9,765	INC	
	800 A CB	1				20		320	3,600	INC	
	400 A CB	2		625	11	22		350	1,250	INC	
	200 A CB	6		365	8	48		770	2,190	INC	
	100 A CB	2		290	7	14		225	580	INC	
	MOTOR CONTROL CENTERS	1	LOT					2610	30,000	130	
	UPS SYSTEM	1	LOT	-	-	-	-	-	75,000	-	75,000
	DEISEL GEN	1	EA			310		4960	62,000	495	
						977		18,245	222,035	1,985	242,265

FORM 22-288 REV 1/79

Stearns-Roger

SHEET NO. 8 OF 8

BY

DATE

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION
SODIUM OR SALT RECEIVER

100 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	CIRCUITRY					1553		24,850	45,440	1,400	71,690
	LIGHTING										
	COMMUNICATIONS			SEE SUMMARY							
	GROUNDING										
	DC SYSTEM										
	MISC.										

FORM 22 REV 1/79

Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

350 MW REHEAT

SHEET NO. 1 OF 6

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	TURBINE-GENERATOR MODIF.										
4210	INSPECTION							500,000			500,000
4210	NON DESTRUCTIVE TESTS							20,000	5,000		25,000
4210	THERMOCOUPLES & RECORDER							20,000	30,000		50,000
4210	ELECTROHYDRAULIC CONTROL SYS.							105,000	245,000		350,000
4210	VARIABLE PRESSURE CONTROL										-
4210	GENERATOR REWINDING									375,000	375,000
	CONTROL SYSTEM MODIF/ADDITIONS										
4350	ANALOG CONTROL SYSTEM							90,000	210,000		300,000
4350	CONTROL PANEL & CONSOLE MODIF.							9,600	22,400		32,000
4350	BOILER COMBUSTION CONTROL SYSTEM							15,000	35,000		50,000
4350	MODIFICATIONS										-
4350	ANNUNCIATORS, 30 WINDOWS							7,500	17,500		25,000
4350	MISC. INSTRUMENTATION							81,200	121,800		203,000
	PUMPS										
4240	1800 GPM @ 475 FT IDH VERTICAL	3		9,000		300		4,500	18,000		22,500
	TURBINE, 300 HP, 1760 RPM										

FORM 22-288 REV 1/79

Stearns-Roger

SHEET NO. 2 OF 6

CLIENT SERI

BY RHF

ORDER NO. C-22138 LOCATION 50% SOLAR REPOWERING PLANT MODIFICATION SODIUM OR SALT RECEIVER

DATE 4-27-79

350 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	PUMPS (CONT'D)										
4240	4160 V, ODP MOTOR										
	PIPING										
	10" SCH-160 ASTM A106,	100 FT.									
	GR. C. INSULATION - 4" $CASIO_2$										
	W/ALUMINUM LAGGING										
	BOILER FEED										
	9" I.D., 1.75" WALL THICKNESS,	100 FT									
	2¼% CHROME, 1% MOLY STEEL										
	ASTM A335 GR. P22, 220 LBS/FT										
	INSULATION - 8" $CASIO_2$ WITH										
	ALUMINUM LAGGING										
	MAIN STEAM										
	20" SCH. 60 ASTM A106	100 FT									
	GR. A. INSULATION - 5½"										
	$CASIO_2$ W/ALUMINUM LAGGING.										
	COLD REHEAT										

FORM 22-288 REV 1/79

Stearns-Roger

CLIENT: SERI

ORDER NO. C-22138 LOCATION: 50% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

350 MW REHEAT

BY: RHF

DATE: 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	PIPING (CONT'D)										
	20" I.D. 1.15" WALL THICKNESS	100 FT									
	2¼% CHROME, 1% MOLY STEEL										
	ASTM A335 GR. P22, 281 LB/FT.										
	INSULATION - 8" $CaSiO_2$ WITH										
	ALUMINUM LAGGING HOT REHEAT										
4240	TOTAL PIPING (SEE PAGE 5)							394,345	1,895,625		2,289,970
	WATER TREATING SYSTEM MODIF/ADD.										
4250	CONDENSATE POLISHER							212,000	1,200,000		1,412,900
4250	MIXER BED POLISHER								-		-
4250	WATER SAMPLING & MONITORING SYS.							19,500	110,000		129,500
	MISC. SYSTEM MODIFICATIONS										
4130	BRG. COOLING WATER SYSTEM							1,800	2,700		4,500
4130	INSTR. AIR SYSTEM							3,000	4,500		7,500
4130	FIRE PROTECTION SYSTEM									5,000	5,000
4124	COMPUTER & LOGIC ROOM							5,550	5,550	133,240	144,340
4124	CONTROL ROOM MODIFICATION							2,775	2,775	66,620	72,170
	ELECTRICAL (SEE PAGE 6 & 7					5,960		95,400	450,400		545,800

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350 MW R.H. - 50% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

Stearns-Roger

SHEET NO. 4 OF 6

CLIENT SERI

BY KJW

ORDER NO. C-22138 LOCATION

DATE 4/27/79

PIPING - CASE 3-5

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
PIPING	6" CS A106-GR B SCH40 W/FTGS/VALVES	70	LF	75.00					5,250		
	10" CS A106-C SCH 160 W/FTGS/VALVES	120	LF	805.46					96,655		
	9" ID x 1 3/4" WT CHROME-MOLY PIPE	120	LF	242.00					29,040		
	20" ID x 1 1/4" WT CHROME-MOLY PIPE	200	LF	309.10					61,820		
VALVES/FTGS	9" ID - 90° ELL BENDS	8	EA	11,000.00					88,000		
	20" ID - 90° ELL BENDS	12	EA	19,000.00					228,000		
	20" ID MO VALVE GATE (PS)	5	EA	88,000.00					440,000		
	20" ID TEES (X 24)	4	EA	23,750.00					95,000		
	9" ID - TEES	3	EA	9,000.00					27,000		
	9" ID MO VALVE GATE (PS)	3	EA	38,000.00					114,000		
	HANGERS - X.28 MAT'L								331,734		
	SUBTOTAL								1,516,499		
	SHOP FAB @ X.25								379,125		
	TOTAL - MAT'L & FAB COST								1,895,624		
	FIELD LABOR	323,740	LBS	-	.06	19,424					
	PRORATABLES X.32					6,216					
	PIPING - DIRECT LBR & MAT'L	510	LF			25,640	15.38	394,343	1,895,624		
INSULATION	SUBCONTRACT @ 7% DIRECT MAT'L.									132,694	

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Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION

SHEET NO. 5 OF 6

BY JRO

DATE 4-27-79

CASE V

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	350 MWe REHEAT										
	SALT OR SODIUM-COOLED										
	RECEIVER, 50% SOLAR										
	REPOWERING										
	EQUIPT										
	7500 KVA 24-13.8 KV	1	EA			410		6,560	43,000	1,300	
	XRF										
	METAL CLAD SWITCHGEAR										
	6.9 KV, 1200 AMP										
	SET, CONNECT, ANCHOR	20	SEC		20	400		6,400	-	1,665	
	1200 A CB	2	EA	9765	28	56		895	19,530	1,665	
	800 A CB	4	EA	3600	20	80		1,280	14,400	1,665	
	400 A CB	2	EA	625	11	22		350	1,250	1,665	
	200 A CB	8	EA	365	8	64		1,025	2,920	1,665	
	100 A CB	4	EA	290	7	28		450	1,160	1,665	
	500 KVA XRF	4	EA		60	240		3,840	18,000	1,665	
	MOTOR CONTROL CENTER	1	LOT			440		7,040	80,000	350	
	UPS	1	LOT	-	-	-	-	-	75,000	-	75,000
	720 KW GEN 6.9 KV					235		3,760	95,000	375	

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Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION

SHEET NO. 6 OF 6

BY JRD

DATE 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	CASE V CONT'D										
	PG 1					1,975		31,600	350,260	3,690	385,550
4320	CIRCUITRY					2,464		39,425	70,965	2,250	112,640
4340	LIGHTING					274		4,385	2,740	150	
4320	COMMUNICATIONS					156		2,495	1,890	-	
4320	GROUNDING					108		1,730	1,150	-	
4320	DC SYSTEM					56		895	12,850	-	
4320	MISC.					150		2,400	4,400	-	
	SUB TOTAL					5,183		82,930	444,255	6,090	533,275
	LABOR EFF.	.15				777		12,430	-	-	12,430
	TOTAL					5,960		95,360	444,255	6,090	545,705

Stearns-Roger INCORPORATED

SHEET NO. 1 OF 5

CLIENT SERI

BY RHF

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION

DATE 4-27-79

SODIUM OR SALT RECEIVER

350 MW REHEAT

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	TURBINE-GENERATOR MODIF.										
4210	INSPECTION							500,000			500,000
4210	NON DESTRUCTIVE TESTS							20,000	5,000		25,000
4210	THERMOCOUPLES & RECORDER							20,000	30,000		50,000
4210	ELECTROHYDRAULIC CONTROL SYSTEM							105,000	245,000		350,000
4210	VARIABLE PRESSURE CONTROL										-
4210	GENERATOR REWINDING									375,000	375,000
	CONTROL SYSTEM MODIF/ADDITIONS										
4350	ANALOG CONTROL SYSTEM							90,000	210,000		300,000
4350	CONTROL PANEL & CONSOLE MODIF.							9,600	22,400		32,000
4350	BOILER COMBUSTION CONTROL SYSTEM							15,000	35,000		50,000
4350	MODIFICATIONS										-
4350	ANNUNCIATORS, 30 WINDOWS							7,500	17,500		25,000
4350	MISC. INSTRUMENTATION							81,200	121,800		203,000
	PUMPS										
4240	1800 GPM @ 475 FT. TDH VERTICAL	3		9,000		300		4,500	18,000		22,500
	TURBINE, 300 HP, 1760 RPM										

Stearns-Roger INCORPORATED

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

350 MW REHEAT

SHEET NO. 2 OF 5

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	PUMPS (CONT'D)										
4240	4160 V, ODP MOTOR										
	PIPING										
	14" SCH. 160 ASTM A106, GR. C.	100 FT.									
	INSULATION - 4½" $CASIO_2$										
	W/ALUMINUM LAGGING BOILER FEED										
	12" I.D., 2.352" WALL THICKNESS,	100 FT									
	2¼% CHROME, 1% MOLY STEEL										
	ASTM A335 GR. P22, 389 LBS/FT										
	INSULATION - 8" $CASIO_2$ WITH										
	ALUMINUM LAGGING MAIN STEAM										
	30" I.D., 0.875" WALL THICKNESS,	100 FT.									
	ASTM A155 KC60 CLASS 1										
	PIPE INSULATION - 5½" $CASIO_2$										
	WITH ALUMINUM LAGGING										
	COLD REHEAT										

Stearns-Roger INCORPORATED

CLIENT SERI

ORDER NO. C-22138 LOCATION 100% SOLAR REPOWERING PLANT MODIFICATION

SODIUM OR SALT RECEIVER

350 MW REHEAT

SHEET NO. 3 OF 5

BY RHF

DATE 4-27-79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	$/MH	LABOR	MATERIAL	OTHER	TOTAL
	PIPING(CONT'D)										
	30" I.D., 1.662" WALL THICKNESS,	100 FT.									
	2¼% CHROME, 1% MOLY STEEL,										
	ASTM A335 GR. P22, 643										
	LB/FT INSULATION 8" CASIO$_2$										
	W/ALUMINUM LAGGING, HOT REHEAT										
4240	TOTAL PIPING (SEE PAGE 5)							460,200	2,119,625		2,579,825
	WATER TREATING SYSTEM MODIF/ADD										
4250	CONDENSATE POLISHER							212,000	1,200,000		1,412,000
4250	MIXER BED POLISHER										-
4250	WATER SAMPLING & MONITORING SYSTEM							19,500	110,000		129,500
	MISC. SYSTEM MODIFICATIONS										
4130	BRG. COOLING WATER SYS.							1,800	2,700		4,500
4130	INSTR. AIR SYSTEM							3,000	4,500		7,500
4130	FIRE PROTECTION SYSTEM									5,000	5,000
4124	COMPUTER & LOGIC ROOM							5,550	5,550	133,240	144,340
4124	CONTROL ROOM MODIF.							2,775	2,775	66,620	72,170
	ELECTRICAL (SEE PAGE 6)					8,754		140,000	797,000		937,000

350 MW - 100% SOLAR REPOWERING
SODIUM OR SALT RECEIVER

Stearns-Roger

CLIENT

ORDER NO. C-22138 LOCATION

PIPING - CASE 3-6

SHEET NO. 4 OF 5

BY RJW

DATE 4/27/79

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MAN HOURS UNIT	MAN HOURS TOTAL	MAN HOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	30" ID X 1 3/4" WT CHROME ALLOY PIPE	200	LF	-					945,140		
	& 30" CS A155 KC-60 PIPE -										
	(100 LF EA) W/VALVES & FTGS										
	12" ID X 2-1/2" WT CHROME MOLY PIPE	100	LF	-					209,665		
	W/VALVES & FITTINGS										
	14" CS A106-SCH160 W/FTGS & VALVES	100	LF	-					164,710		
	6" CS A106-SCH 40 W/FTGS. & VALVES	70	LF	75.00					5,250		
	HANGERS @ X.28										
	SUBTOTAL								1,695,699		
	SHOP FAB @ X.25								423,925		
	TOTAL - MATL & FAB COST								2,119,624		
	FIELD LABOR	377,800	LBS	-	.06	22,668					
	PRORATABLES @ .32					7,254					
	PIPING - DIRECT LBR & MTL					29,922	15.38	460,200	2,119,624		
INSULATION	SUBCONTRACT @ 7% DIR MTL									148,374	

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Stearns-Roger

CLIENT SERI

ORDER NO. C-22138 LOCATION

SHEET NO. 5 OF 5

BY JRO

DATE 4-27-79

CASE VI

ACCOUNT	ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L UNIT COST	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	LABOR	MATERIAL	OTHER	TOTAL
	350 MWe REHEAT										
	SALT OR SODIUM-COOLED										
	RECEIVER 100% SOLAR										
	REPOWERING										
4320	EQUIPT					3,470		55,520	631,530	6,940	693,990
4340	CIRCUITRY					4,435		70,965	127,730	4,055	202,750
4320	LIGHTING					274		4,385	2,740	150	7,275
4320	COMMUNICATIONS					156		2,495	1,890	-	4,385
4320	GROUNDING					108		1,730	1,150	-	2,880
4320	DC SYSTEM					56		895	12,850	-	13,745
	MISC					255		4,080	7,780	-	11,860
	SUB TOTAL					8,754		140,070	785,670	11,145	936,885
	LABOR EFF.	.15									

FORM 22-288 REV 1/79

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15. Supplementary Notes

Project Managers: Horgan, Dennis; Taylor, Roger

16. Abstract (Limit: 200 words)

This report is a solar repowering integration analysis which defines the balance-of-plant characteristics and costs associated with the solar thermal repowering of existing gas/oil-fired electric generating plants. Solar repowering interface requirements for water/steam and salt or sodium-cooled central receivers are defined for unit sizes ranging from 50 MWe non-reheat to 350 MWe reheat. Finally balance-of-plant cost estimates are presented for each of six combinations of plant type, receiver type and percent solar repowering.

17. Document Analysis

a. Descriptors Solar Thermal Power Plants; Repowering; Fossil Fuel Power Plants; Power Plants; Retrofitting; Cost; Cost Benefit Analysis; Reheat Cycle; Ranking Cycle; Components; Site Selection; Size; Load Management; Marketing

b. Identifiers/Open-Ended Terms Research; Power Range 10-100 MW; Power Range 100-1000 MW

c. UC Categories

62-C

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