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SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN

Final Report

MASTER

August 1, 1980

Work Performed Under Contract No. FC03-79CS30311

Hilo Coast Processing Company
Pepeekeo, Hawaii

U.S. Department of Energy

Solar Energy

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Final Report

SOLAR PRODUCTION
of
INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN

Prepared by

TEAM, INC.

With Assistance From

Hilo Coast Processing Company - Pepeekeo, Hawaii
C. Brewer Company - Honolulu, Hawaii
University of Hawaii - Honolulu, Hawaii

Prepared for

The U.S. Department of Energy
San Francisco Operations Office

August 1, 1980

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I. EXECUTIVE SUMMARY

This report is the final effort in the Phase I design of a solar industrial process heat system for the Hilo Coast Processing Company (HCPC) in Pepeekeo, Hawaii. The project was cost shared by HCPC, the U.S. Department of Energy, C. Brewer and Company and the University of Hawaii. TEAM Inc. was responsible for the system design, and was greatly assisted in this task by the above organizations.

The Hilo Coast Processing Company is owned and operated by a cooperative of sugarcane growers. The facility is used to wash, grind and extract sugar from the locally grown sugarcane and it operates 24 hours a day, 305 days per year.

The major steam requirements in the industrial process are for the prime movers (mill turbines) in the milling process and heat for evaporating water from the extracted juices. Bagasse (the fibrous residue of milled sugarcane) supplied 84% of the fuel requirement for steam generation in 1979, while 65,000 barrels of #6 industrial fuel oil made up the remaining 16%.

These fuels are burned in the power plant complex which produces 825^{O}F, 1,250 psi superheated steam to power a turbo-generator set which, in addition to serving the factory, generates from 7-16 megawatts of electricity that is exported to the local utility company. Extracted steam from the turbo-generator set supplies the plant's process steam needs. During normal cane crushing operation, enough bagasse is produced to satisfy the plant's total energy needs. However, fuel oil must be burned when either (1) the bagasse has a high moisture content, (2) the cane crushing operation is shut down for maintenance or (3) during peak electrical demand.

By supplementing the industrial process's steam supply with solar generated steam, bagasse will be "freed-up" and can be stored for use when fuel oil would otherwise be burned.

The system consists of 42,420 $ft.^2$ of parabolic trough, single axis tracking, concentrating solar collectors. The collectors will be oriented in a North-South configuration and will track East-West. A heat transfer fluid (Gulf Synfluid 4cs) will be circulated in a closed loop fashion through the solar collectors and a series of heat exchangers. The inlet and outlet fluid temperatures for the collectors are 370°F and 450°F respectively. These temperatures will be constantly maintained via a variable flow rate through the collectors (the flow rate will vary in direct proportion to the level of insolation).

Superheated steam will be the final product of the solar energy system. The plants' return condensate at 206°F will be preheated to saturated liquid conditions in the first heat exchanger. It will then enter an unfired boiler where it will undergo a phase change to a saturated vapor. A third heat exchanger tube bundle located in the vapor region of the boiler will superheat the steam. Final steam quality at the steam generator will be 420°F and 165 Psia.

The system's operation will be completely automatic with manual override capabilities for all critical operations. The data acquisition system meets the requirements of the publication "Data Acquisition and Analysis Guidelines for IPH Demonstration Projects" and provides for on-site data acquisition and reduction.

On-site insolation values were recorded throughout Phase I and were used to estimate the available resource. Based on this analysis it is estimated that the net useable energy delivered to the industrial process will be 7.2×10^9 Btu's per year. With an HCPC boiler efficiency of 78% and 6.2×10^6 Btu's per barrel of oil, the solar energy system will displace 1489 barrels of oil per year.

II. DESCRIPTION OF INDUSTRIAL PROCESS

A. General Information

The Pepeekeo Sugar Factory is the largest mill on the island of Hawaii and is run by Hilo Coast Processing Company (HCPC), a sugar cooperative jointly owned by Mauna Kea Sugar Company and nearly 400 independent cane growers located on the Hilo Coast.

The primary product of the factory, of course, is sugar and about 113,000 tons were produced in 1979. Sugar cane is a two year crop in Hawaii and about 12,500 acres are harvested in rotation annually at HCPC. One acre yields about 100 tons of net cane from which 10 tons of sugar can be processed. Molasses is also produced as a by-product and sold as a livestock food supplement.

Bagasse, which is the fibrous waste remaining after the sugar juice has been extracted from the cane, is burned to produce steam and is the base fuel for the plant. Steam is used in-house for sugar processing and to generate electricity both for in-house use and for export to the local utility company under a firm power contract.

The raw sugar is shipped to the mainland where it is refined. All Hawaiian sugar and molasses are marketed through C & H Sugar Refining Company, a cooperative jointly owned by all of the sugar companies in Hawaii.

B. Use of Bagasse and Oil as Fuel

The boiler at HCPC can burn fuel oil, bagasse or woodchips. In 1979, bagasse and woodchips accounted for 84% of the heat produced at the power plant, compared to 77% in 1978. the above percentage (84%) represents about 370,000 tons of bagasse and 640 tons of woodchips. the remaining 16% of heat was supplied by 65,000 barrels of #6 industrial fuel oil.

Sugar cane is processes 24 hours per day, 6 2/3 days per week, and 45 weeks per year. Eight (8) hours each week the processing plant shuts down for routine maintenance in addition to a 4 week annual plant shutdown for general maintenance and equipment refurbishing.

During normal cane processing, the bagasse that is produced supplies 100% of the fuel needs for the plant. However, the power plant must either supplement the bagasse with oil or switch over to oil entirely under any one of three conditions; (1) periods of peak electrical demand (HCPC has a firm contract to furnish the local utility, HELCO 100,000 MWH per year, at levels of 7 MW minimum and 16 MW maximum on demand) or (2) when the bagasse has a high moisture content or (3) during the weekly maintenance period when no bagasse is produced.

By supplying part of the steam for the cane processing, the solar system will reduce the demand for bagasse and allow it to be stored and then used when oil would otherwise be required.

HCPC projects that 1.09 million tons of net cane (excludes cane trash and debris) was harvested in 1979 and about 1/3 of the weight of this net cane was bagasse or some 380,000 tons. The bagasse is normally 50% moisture by weight and has a heating value of approximately 3,500 Btu per pound. In general, one ton of bagasse is an equivalent fuel to a barrel of fuel oil.

As a co-generation plant, process heat is generated at HCPC at about 60% efficiency when firing bagasse in the furnace because of the moisture content and combustion characteristics of the bagasse. Electric energy is usually generated at only 25% efficiency when the power plant is operated as a straight condensing unit. However, with steam extraction for cane processing, the power plant operates at an overall cycle efficiency of between 25% to 60% depending on the steam heat to electric power ratio. If oil were the fuel, process steam is generated at 78% efficiency and electric power is generated at 30% efficiency with no steam extraction (i.e., full condensing).

The 100,000 MW furnished to HELCO is about 23% of the annual electrical power requirements of the entire island of Hawaii. Power from other sugar mills on the island brings this figure up to 40%.

C. Steam and Condensate Flow Loop

The HCPC boiler steam at 1200 psig (825°F) flows to the 28 MVA turbo-generator at an average 24 hour flow rate of 300,000 lbs/hr. Process steam at 160 psig is extracted at an average rate of 132,000 lbs/hr after passing through the high pressure section of the turbine. The remaining steam goes through the low pressure end of the turbine and is condensed in a water cooled condenser. This condensate flows to the deaerator for reuse as boiler feedwater.

The 160 psig extracted steam is desuperheated and sent to 3 large sugar mill noncondensing turbines which shred and crush the cane. If insufficient 160 psig steam is extracted through the turbo-generator, the 1200/160 psig make-up valve will be automatically activated to supply additional steam to the system directly from the 1200 psig steam line. Note: Current use limited to boiler startup only.

The 12 psig saturated steam which exits the mill turbines is utilized to boil sugar juices in the first cell evaporator and in turn create enough vapors to provide steam for the evaporators, pans, and juice heaters. Additionally, 12 psig steam is provided by the exhaust steam from the power plant boiler feed pump steam turbine (when used). A 160/12 psig makeup valve is also provided to assure adequate 12 psig process steam supply to satisfy all requirements of the boiling house.

The condensate from the 1st evaporator effect is pumped back to the power plant condensate storage tank for reuse as boiler feedwater. Since only about 87% of the steam, as condensate, is returned to the power plant from sugar processing, raw water is used as boiler makeup after demineralization.

All boiler feedwater passes through the deaerator for heating and removal of dissolved oxygen. It then is pumped to the boiler through a high pressure heater and economizer.

The corresponding flows of steam and condensate are shown in Figure II-1. The pressure and temperature measuring points are indicated in Table II-1 with values given for average operating conditions.

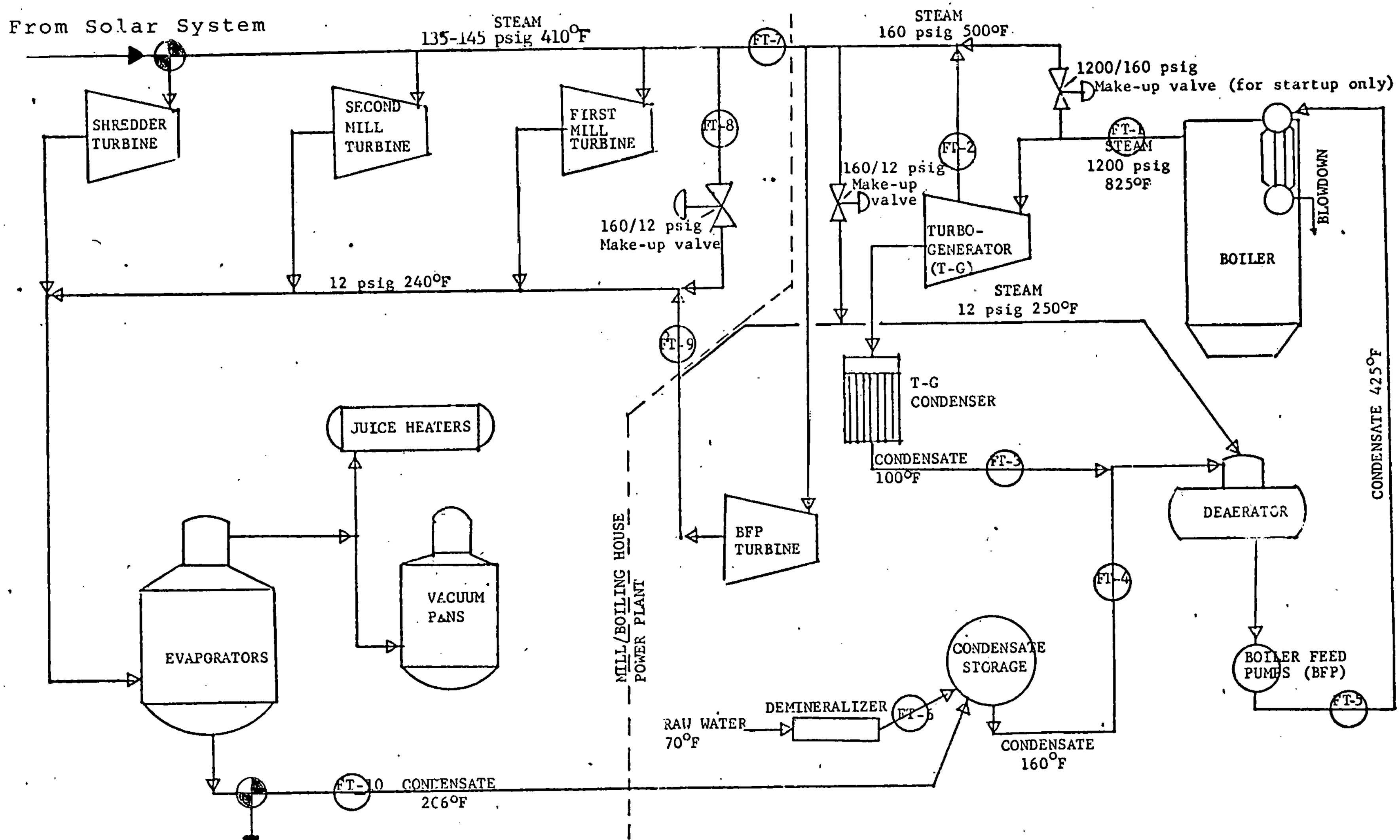


FIGURE II-1. HCPC FACTORY/POWER PLANT STEAM/CONDENSATE FLOW LOOP

Table II-1

Average Flow, Temperature and Pressure Readings

FT-1	MAIN STEAM FLOW Ave. 300,000 lbs/hr, 1200 psig, 810^{o}F (Flow Pressure & Temperature)
FT-2	TURBO-GENERATOR EXTRACTION STEAM FLOW 202,000 lbs/hr. 425^{o}F, 160 psig (Flow and Pressure only)
FT-3	T-G HOTWELL CONDENSATE Average 108,000 lbs/hr. 100^{o}F (Flow and Temperature only)
FT-4	CONDENSATE TRANSFER TO DEAERATOR Ave. 201,000 lbs/hr. 160^{o}F, 60 psig (Flow and Pressure only)
FT-5	BOILER FEEDWATER Ave. 209,000 lbs/hr, 425^{o}F, 1400 psig (Flow only)
FT-6	DEMINERALIZER BOILER MAKE-UP WATER Ave. 21,000 lbs/hr. 70^{o}F (Flow only)
FT-7	HIGH PRESSURE PROCESS STEAM TO FACTORY Ave. 132,000 lbs/hr. 135-145 psig, 410^{o}F (Flow, Pressure, Temperature)
FT-8	160 psig/12 psig STEAM MAKE-UP STATION 40,000 lbs/hr average, 135 psig, 400^{o}F (Flow, Pressure, Temperature)
FT-9	STEAM SUPPLY FROM POWER PLANT 30,000 lbs/hr, 12 psig, 250^{o}F (Flow and Pressure only)
FT-10	FIRST EFFECT EVAPORATOR CONDENSATE RETURN TO POWER PLANT 142,000 lbs/hr, 206^{o}F (Flow and Temperature only)

III. PRELIMINARY DESIGN

A. DESCRIPTION OF PLANT/SOLAR SYSTEM INTERFACE

1. Preliminary Design

The two "points of contact" with the existing plant where the solar system will interface are (1) the condensate return line inside the boiling house and (2) the supply steam header just after it enters the mill building. Figure III-1 is a plant plan view and details the feedwater and steam interface locations. The distance from the existing boiling house to the solar system pump house is approximately 625 feet. A 1½" diameter pipe will be used for the feedwater and it will be secured to an existing overhead pipe rack. The steam line is approximately 365 feet long and runs from the pump house to the steam header inside the mill building. The pipe will be 4" in diameter and will also be secured to existing overhead pipe racks that parrellel the cane cleaner.

Figure III-2 is a simplified flow schematic of the proposed system which details the steady state design temperatures and pressures at key points.

The condensate at the feedwater connection is at 206^{O}F and 27 Psia. A turbine pump will be used to increase the pressure to approximately 200 Psia which will be sufficient back pressure to allow water to flow into the unfired boiler. The operation of the turbine pump will be controlled by the water level sensor in the unfired boiler. A low water level will turn the pump on and a high water level will turn if off.

The pressurized feedwater will first flow through the preheater where it will increase in temperature approximately 130^{O}F and exit close to a saturated liquid at 165 Psia.

FIGURE III-1

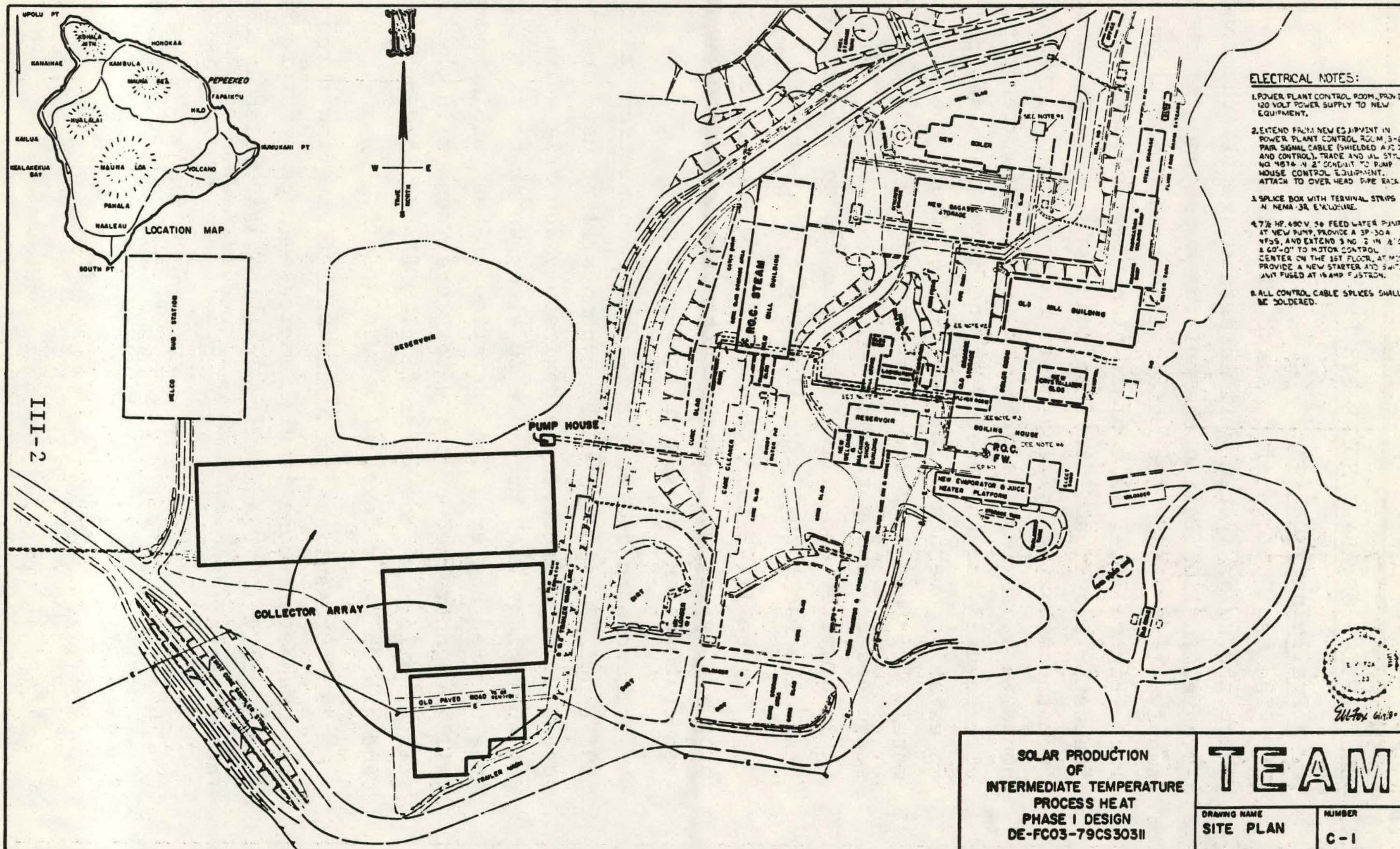
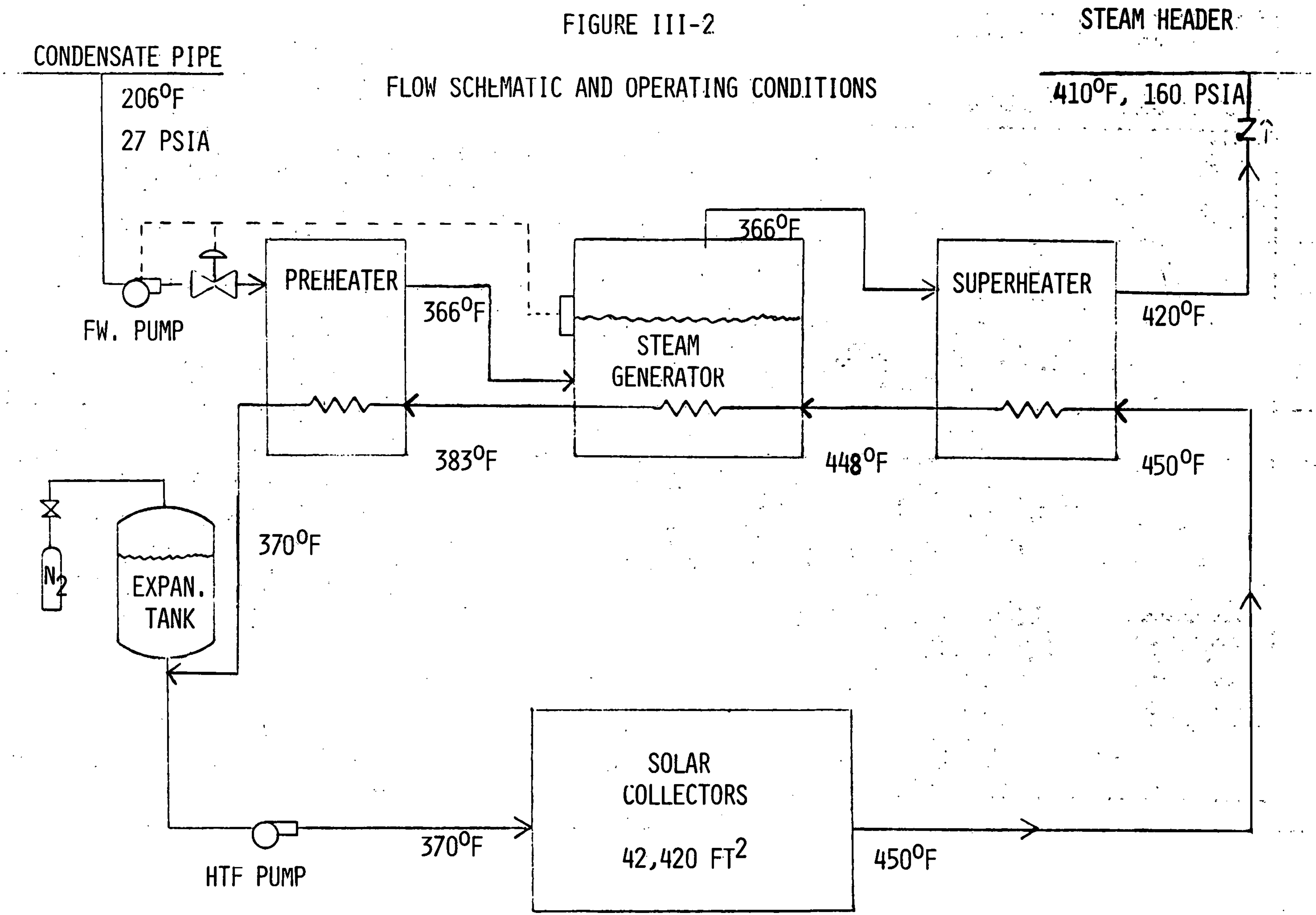

LOCATION MAP
UPOLU PT
HONOKAA
KAWAIHAE
KAMUELA
PEPEEKEO
MAUNA KEA
PAPAIKOU
HILO
HUALALAI
KAILUA
KUMUKAHI PT
KEALAKEKUA BAY
MAUNA LOA
VOLCANO
PAHALA
NAALEHU
SOUTH PT
W
E
TRUE NORTH
HELCO SUB - STATION
RESERVOIR
PUMP HOUSE
COLLECTOR ARRAY
OLD PAVED ROAD
TRAILER WASH
P.O.C. STEAM
MILL BUILDING
NEW BOILER
NEW BAGASSE STORAGE
OLD MILL BUILDING
RESERVOIR
BOILING HOUSE
P.O.C. F.W.
NEW EVAPORATOR & JUICE HEATER PLATFORM
ELECTRICAL NOTES:
1. POWER PLANT CONTROL ROOM, PROVIDE 120 VOLT POWER SUPPLY TO NEW EQUIPMENT.
2. EXTEND FROM NEW EQUIPMENT IN POWER PLANT CONTROL ROOM, 3-6 PAIR SIGNAL CABLE (SHIELDED AND CONTROL). ATTACH TO OVER HEAD PIPE RACK.
3. SPLICE BOX WITH TERMINAL STRIPS IN NEMA-3R ENCLOSURE.
4. 7½ HP. 480 V. 3φ FEED WATER PUMP.
5. ALL CONTROL CABLE SPLICES SHALL BE SOLDERED.
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311
TEAM
DRAWING NAME
SITE PLAN
NUMBER
C-1

FIGURE III-2

FLOW SCHEMATIC AND OPERATING CONDITIONS



The unfired boiler will further heat the saturated liquid producing saturated vapor at 165 Psia. A superheater tube bundle located in the vapor region of the boiler will provide the 54° F superheat required in the steam header.

A spring loaded check valve in the superheated steam line will regulate the flow of the solar generated steam. The pressure on the solar side of the valve will gradually increase, once circulation through the solar field begins. The pressure will eventually exceed that in the plant's steam header (pressure at the point of contact varies from 150-160 Psia during normal operation) and the valve will open enough to allow steam flow into the plant. The valves operation will be completely automatic requiring no sensors or control electronics. It is a simple and reliable method of insuring that all available solar generated steam is utilized in the plant.

2. <u>Tradeoff Analysis</u>

A major tradeoff analysis was performed during the preliminary design to identify the most appropriate location for the two points of contact.

Possible locations for the feedwater interface included the deaerated feedwater tank inside the power plant and the condensate return line in the boiling house. The advantage of the deaerated feedwater interface was the water quality at that point. The deaerated feedwater normally flows directly into the existing high pressure boiler and has been demineralized and deaerated to prevent corrosion and scale build-up in the boiler. These same benefits would accrue to the steam generator and pipes for the water/steam side of the solar system without additional expenditures if the interface was located at the deaerated tank.

The primary drawback to that location however is the additional 300 feet of piping required. The boiling house is 300 feet closer to the solar array and water quality of the condensate at this point is relatively good with only 10 ppm dissolved solids. Although a chemical feed system will be needed to scavenge any dissolved oxygen in the freedwater, the cost of this system is still much less than 300 feet of insulated pipe.

An additional advantage that is accrued by interfacing at the boiling house is the lower temperature water available there (206^{o}F vs 240^{o}F at the power plant). The cooler feedwater allows a 10^{o}F lower collector inlet temperature which results in a slightly higher collector operating efficiency.

The point of connection for the solar generated steam was dictated primarily by the proximity of the existing steam header to the solar field. That is, the shortest distance between the two was chosen in order to minimize thermal losses from the steam line. The point of contact, conveniently enough, is just inside the mill building, right before the steam header divides for the individual turbines. This location insures the immediate use of the solar generated steam by the mill turbines and still allows for steam utilization during mill shut-down since it can also flow back to the pressure and temperature reducing station and be used in the boiling house.

B. SOLAR COLLECTORS

1. Collector Selection

The three most prominent solar collector types both field tested and readily available on the market today are flat-plate, evacuated tube and concentrator. Neither flat-plate or evacuated tube collectors are capable of producing the 450^{o}F fluid temperature required to produce steam at the HCPC sugar processing plant. Of the several concentrating collector designs available the parabolic trough concentrator has emerged as the most effective and competitive solar collector for applications in this temperature range.

TEAM, Inc. has been in continuous contact with the three leading parabolic trough collector manufacturers, Acurex, Suntec and Solar Kinetics, Inc. to determine which system is most cost effective for this application. The results of instantaneous efficiency measurements made at Sandia Laboratories on many concentrating collectors are shown in Figure III-3. Of the three considered here, the Hexcel collector (now produced by Suntec) is only slightly (approx 2%) more efficient than the Solar Kinetics T-700 while both are greater than 10 percentage points more efficient than the Acurex model at the higher temperatures. However, while instantaneous efficiency measurements at normal incidence are reasonable standardized tests, additional information is required in order to estimate actual year long collector performance. For single axis tracking parabolic troughs the direct insolation incidence angle varies throughout the course of a day or a year and one must consider what effect this variation has on collector efficiency in order to correctly assess the collector's long term energy delivery. The incident angle modifier $K(\Theta) = N(\Theta)/N(\Theta = O)$, where Θ is the direct radiation incidence angle onto the collector, and N is the collector optical efficiency, has been determined for the three parabolic troughs considered here. Figure III-4 compares all day averages of K for the three collectors (N-S axis orientated) at three times during the year. The optical efficiency of the SKI T-700 is shown to be least affected by solar incidence angle and therefore its year long thermal output is highest.

Of course, cost is the other important consideration in determining the most cost effective collection system. It has been found that the Solar Kinetics T-700 is the least expensive of the three. It's uninstalled cost is $20 per square foot of aperture area compared to approximately $22 and $27 for the Suntec and Acurex collectors. Therefore, the most cost effective solar collector for this application was determined to be the SKI T-700.

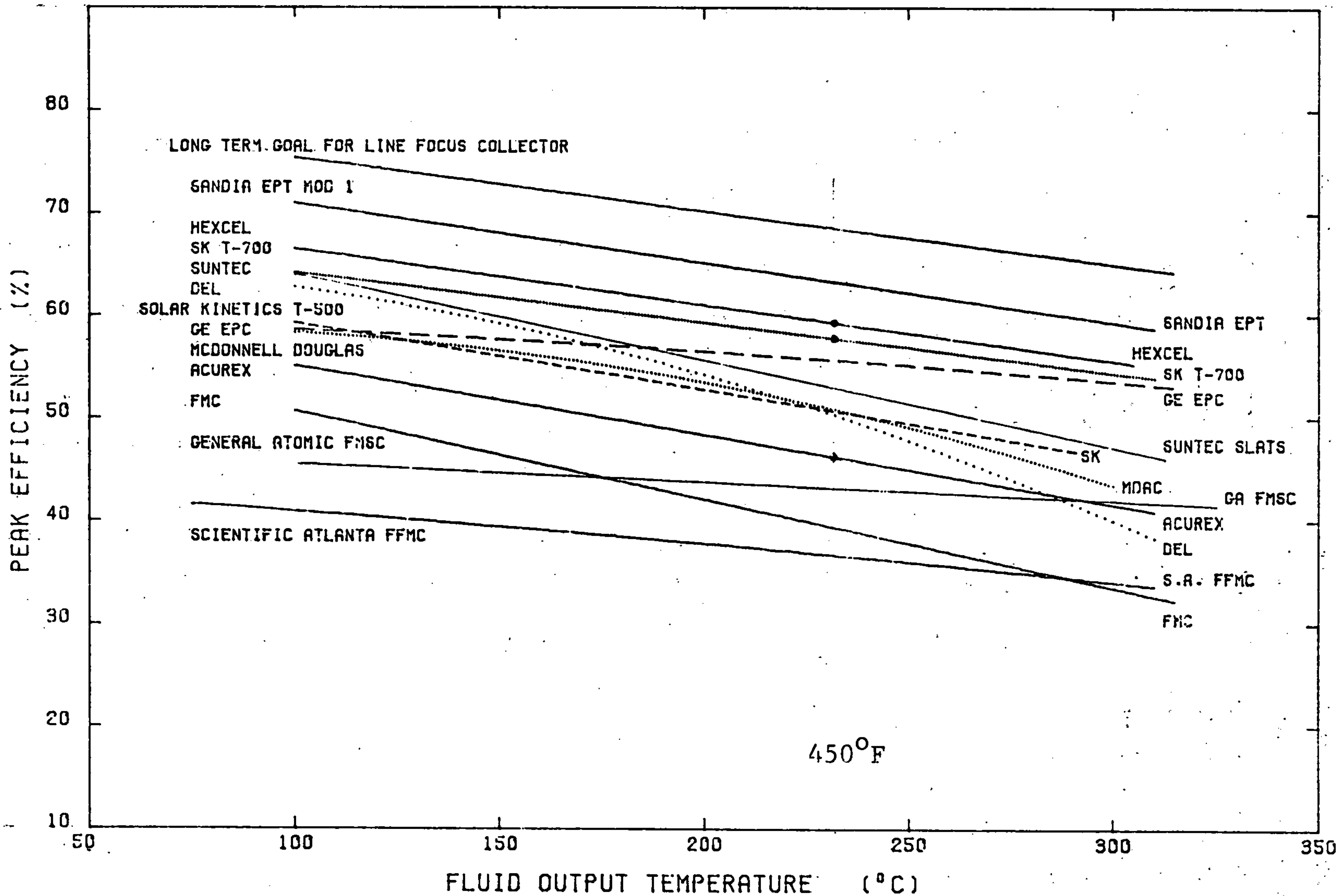


Figure III-3 COMPARISON OF COLLECTOR EFFICIENCY VS OUTPUT TEMPERATURE

9 17 79

Figure III-4

All-Day Average of Incidence
Angle Modifier K for Three
Collectors with North-South Axis*

Collector Type	Summer	Equinox	Winter
Solar Kinetics (T-700)	1.000	0.997	0.891
	1.000	0.996	0.866
Suntec (Hexcel)	0.995	0.970	0.868
	0.997	0.965	0.847
Acurex	1.000	0.971	0.683
	1.000	0.963	0.627

Top number represents collection cutoff time one hour before sunset. Bottom number represents cutoff time two hours before sunset.

*From H. Gaul and A. Rabl, "Incidence Angle Modifier and Average Optical Efficiency of Parabolic Trough Collectors," SERI/TP-34-246R

2. Collector Performance

The performance of the SKI T-700 parabolic trough collector has been thoroughly evaluated at the Sandia Laboratories test facility. It is a 90° rim angle trough with an aperture of 140 ft^2. It's instantaneous peak noon efficiency was shown in figure III-3. The efficiency equation can be written as

$$N = 0.675 - 0.0688 \frac{\Delta T}{I}$$

where ΔT is the temperature difference between the average receiver temperature and ambient temperature and I is the direct radiation incident upon the collector. As mentioned previously, the incidence angle modifier, K, must be applied to the first term in the above equation to account for reduced optical efficiency at other than normal incidence. Figure III-5 shows K as a function of incidence angle. End losses, cosine losses, and collector-on-collector shading losses must also be taken into account when calculating all day collector array efficiency. TEAM, Inc. has developed a computer model, PARABL, which calculates hourly performance of a parabolic trough at a given site, with East-West or North-South axis orientation, under given insolation conditions. Figure III-6 shows the total HCPC collector array gross output on the day of the year of highest thermal output (April clear day) as simulated by PARABL. The average array efficiency on that day is 45% while the peak efficiency is about 59%.

3. Materials of Construction

The T-700 linear parabolic trough collector has demonstrated reliability of design and construction through high performance in several applied solar energy projects, including the DOE funded solar irrigation project at Willard, N.M. Figure III-7 describes its mechanical features. The collector sturcture is extremely resistant to deflection because of its monocoque design. The mirror surface is precisely shaped by 0.040 in. thick, aircraft grade, T-6 aluminum skin stretched over numerically-

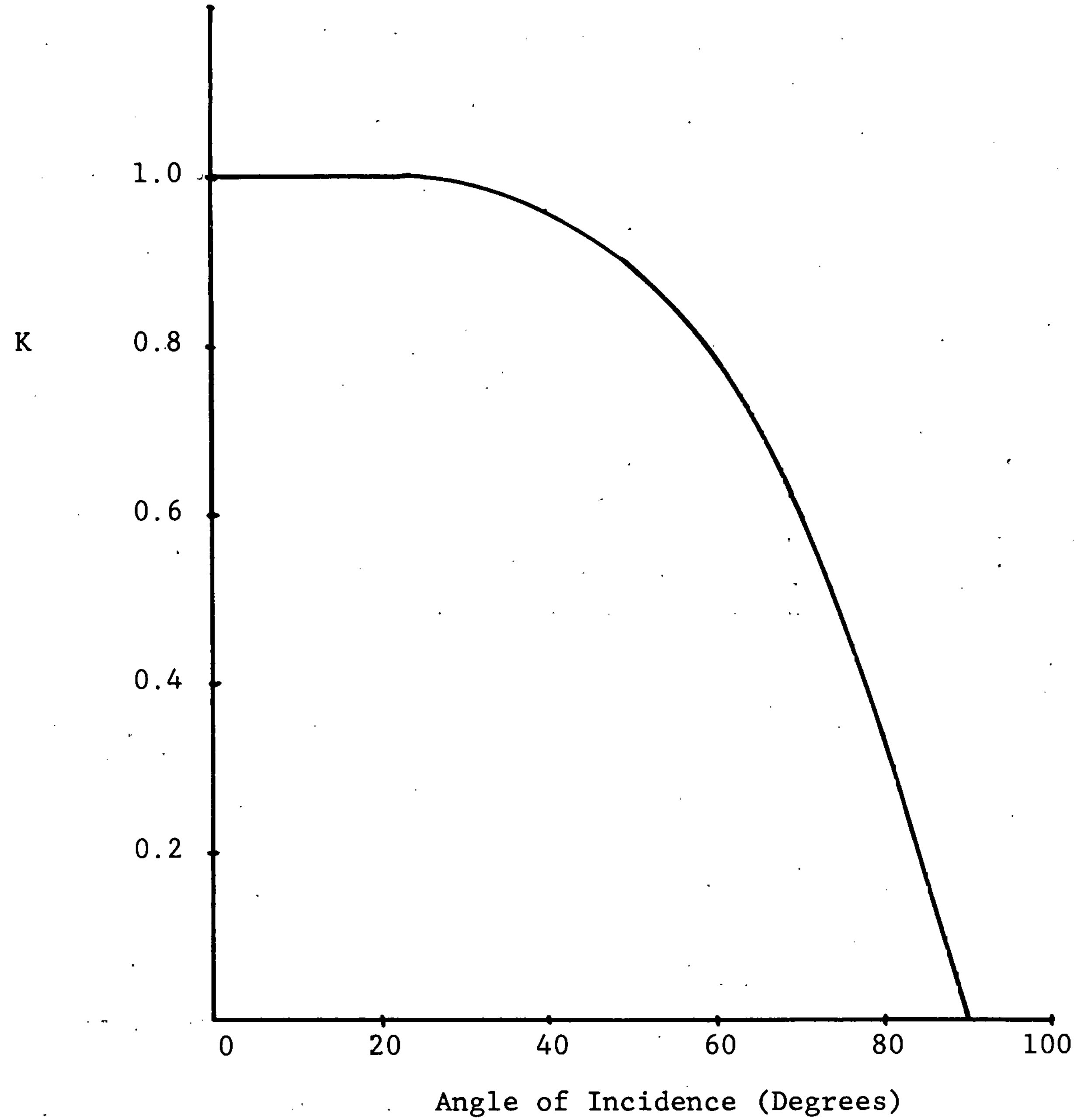
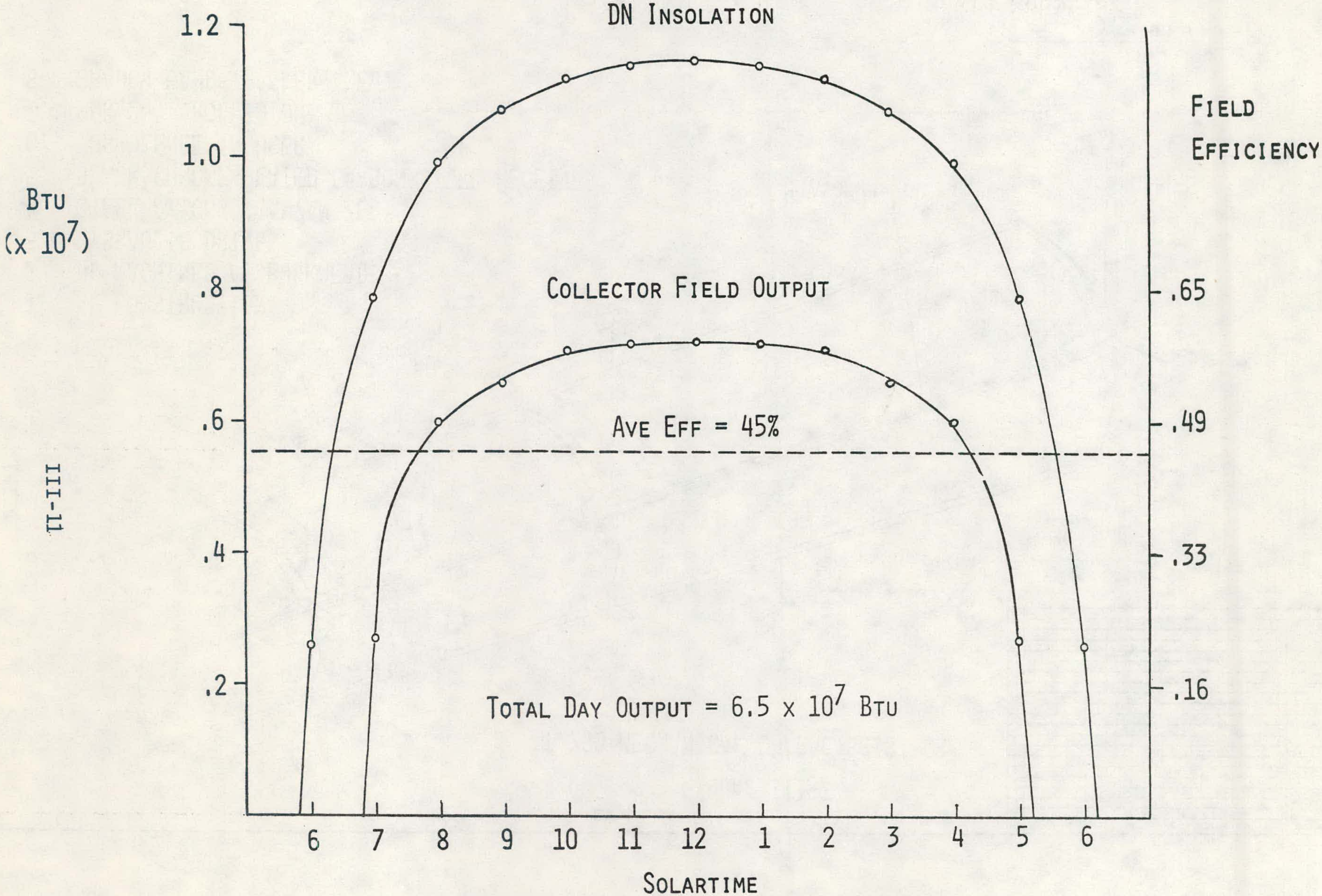


Figure III-5 Solar Kinetics T-700 Incidence Angle Modifier

FIGURE III-6



BEST DAY COLLECTOR FIELD OUTPUT

FIGURE III-7

T-700 MECHANICAL CHARACTERISTICS

NO.	STOCK NO.	QTY.	ITEM NAME — DESCRIPTION	DWG NO
1			[illegible] MODULE [illegible]	
2			[illegible]	[illegible]
3			[illegible]	
4			RECEIVER [illegible]	
5			[illegible] END [illegible]	[illegible]
6			[illegible]	
7			SHADOW [illegible]	
8				
9				
10				
11				
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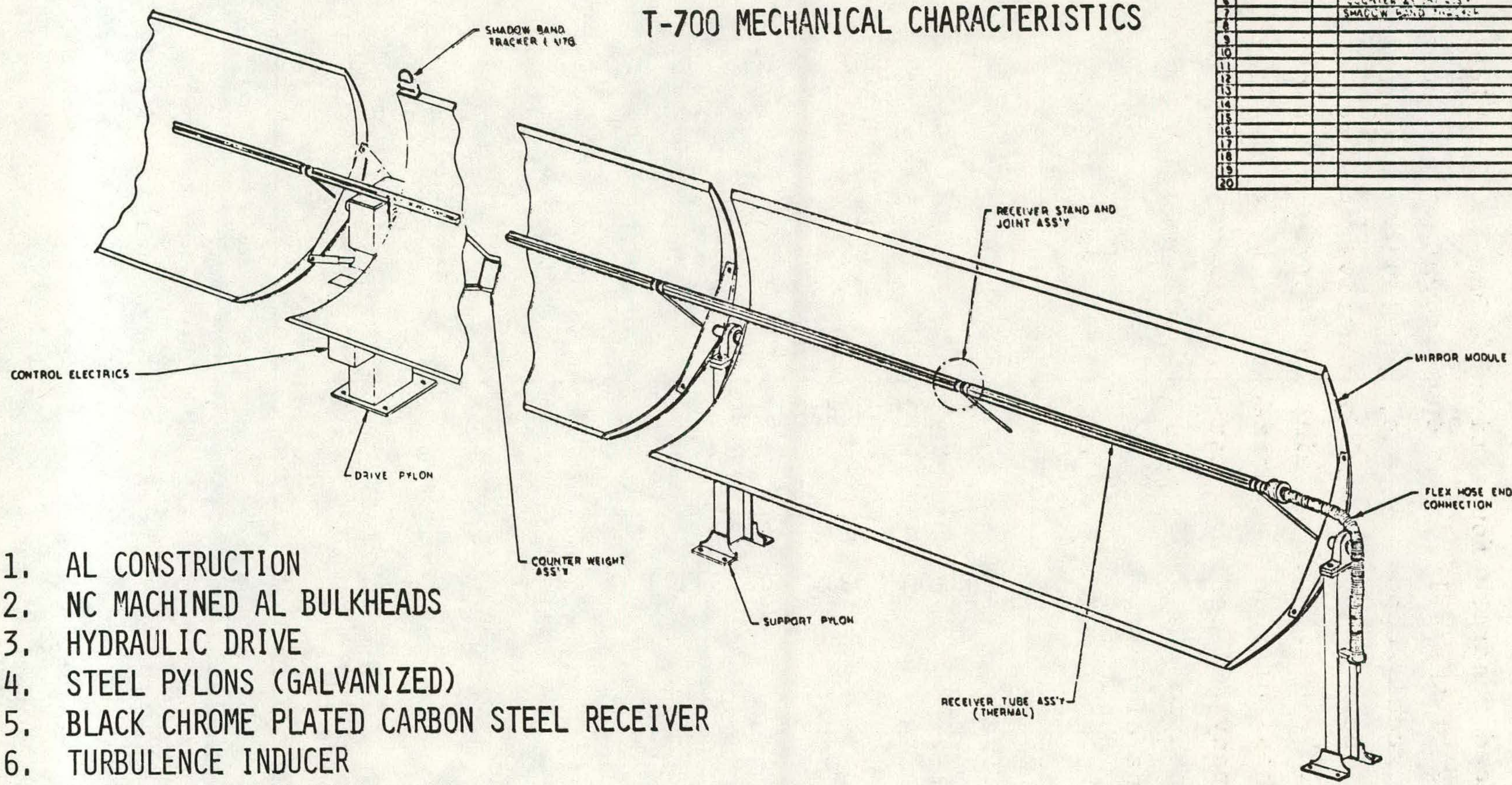


1. AL CONSTRUCTION
2. NC MACHINED AL BULKHEADS
3. HYDRAULIC DRIVE
4. STEEL PYLONS (GALVANIZED)
5. BLACK CHROME PLATED CARBON STEEL RECEIVER
6. TURBULENCE INDUCER
7. FEK-244 (ROLLED ON)
8. SHADOW BAND TRACKER (NEW)

SKC-A 00-084 D

SOLAR KINETICS INC.

DATE 9-5-79

T-700 A BASIC ROW [illegible]

(THERMAL)

controlled machine cast aluminum bulkheads for proven strength and true surface optical quality. Each trough section is supported by steel pylons which bolt to reinforced concrete foundations. Due to the high corrosiveness of the salt water environment at the oceanside site the steel support pylons, usually hot-dipped galvanized, will have an additional protective coating applied. This will be a zinc rich paint (Devcon-Z) which has been used successfully on galvanized steel by a Hawaii Electric Company substation located next to the HCPC plant (the substation is nine years old and shows no significant signs of oxidation or deterioration). The support pylons will be inspected and touched-up as necessary every five years.

The receiver consists of a 1.5 in. I.D., 0.065 in. wall, black chrome plated steel tube enclosed by a 1.75 in. I.D. pyrex tube which insulates the receiver tube from the environment. The steel tube absorptivity and emissivity at 500^{o}F are 0.94 and 0.18 respectively. A 0.016 in. thick ribbon with three twists per foot creates heat transfer fluid flow turbulence through the receiver tube which enhances heat transfer at low flow rates.

The reflector surface is FEK-244, an acrylic film made by Minnesota Mining and Manufacturing with an average specular reflectivity of 0.84. This surface is bonded to the smooth substrate provided by the collector skin. Weather testing on 3M reflective films by Solar Kinetics has shown less than 5 percent specular loss over 11 years and no other unsatisfactory degradation. Samples of the FEK-244 have been in place at the collector site since November 20, 1979 and are exhibiting no permanent degradation or particle deposition.

4. Modes of Operation

The standard Solar Kinetics solar trackable unit configuration consists of a row of individual collectors placed end-to-end with a maximum of six collectors (120 ft) per unit. Solar tracking is actuated by a hydraulic drive mechanism located at the center of the collector row. The hydraulic drive effectively eliminates backlash experienced by other drive mechanisms due to continous wind buffeting, and provides a cushioning effect to sudden loads. A differential light-sensitive shadow bar device provides the analog tracking signal to the hydraulic drive for solar acquisition and continuous solar lock-on. An electrical adjustment of the shadow bar is provided to change the sensitivity of the tracker. An adjustment providing accurate tracking during clear days but preventing searching during cloudy days can be accommodated by the SKI system. A time delay adjustment can also be made. Proper adjustment of these two will provide accurate tracking and keep the system locked on during cloudy days.

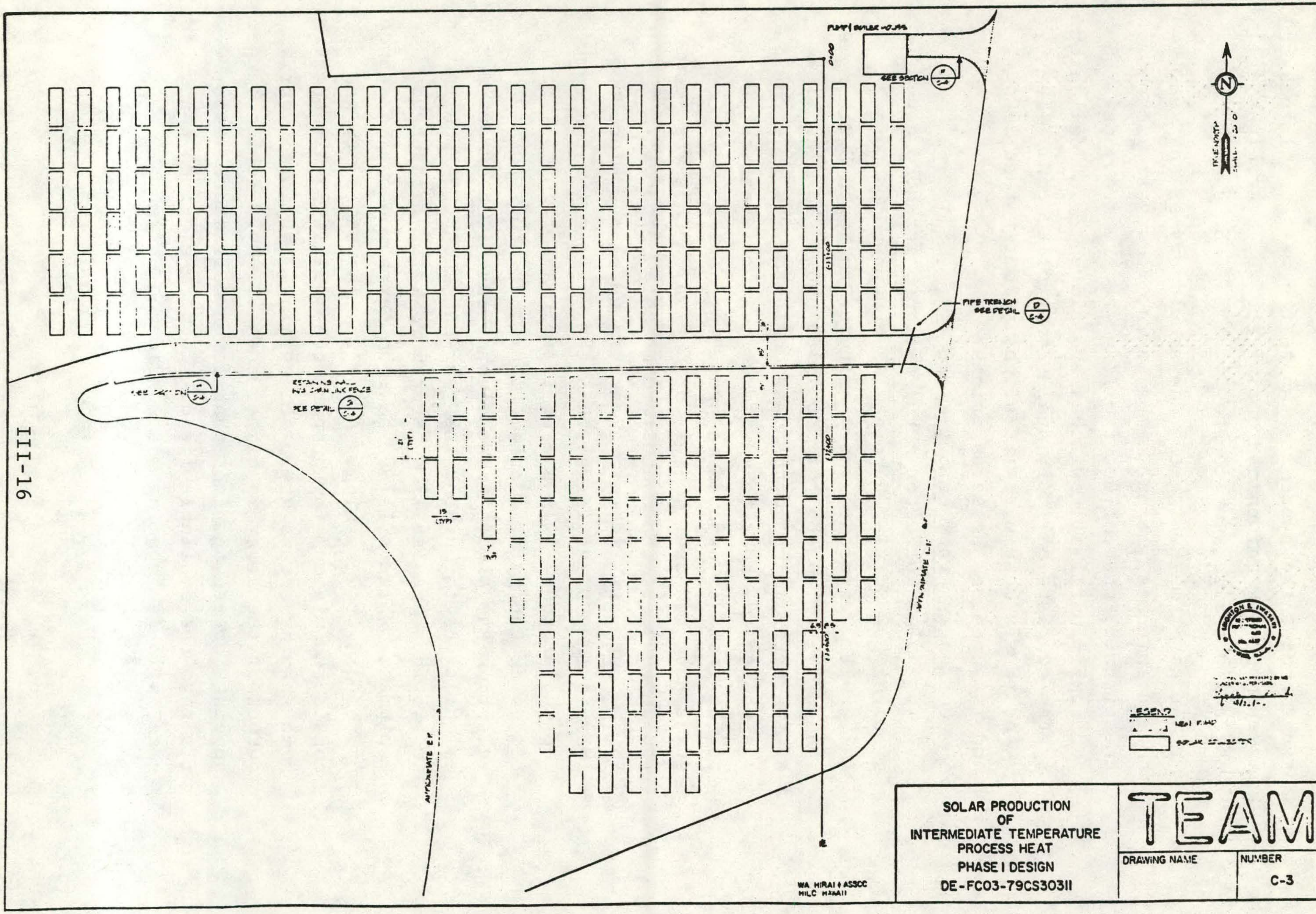
There are several conditions under which the collector will be sent to the stow position. They are high temperature, rain, night fall, high winds and loss of flow. A field contact closure device will be used to open the circuit to the stow relay. When this occurs the automatic tracker is deenergized and a signal is directed to the stow position. The stow slave relay is energized when the stow relay loses its signal (open circuit) and a stow bypass valve is activated. This allows the hydraulic fluid to circumvent the adjustable flow control valve and the collector is driven to the stow position at a rapid rate. Upon reaching stow the stow limit switch opens the circuit to the stow slave relay coil and the entire system is at rest. This method of stowing the collector is used as the automatic night stow through the use of a light switch. At dawn the light switch closes the stow relay coil circuit and the automatic tracker is again energized. When the sunlight causes sufficient shadow differential on the light sensitive transistors, the system tracks to the west until lock-on is reached and maintained during the day. At night fall the collector is sent to stow by the light switch.

At any time during the day should any of the stow hazard switches (light, temp., rain, flow, etc.) open the circuit, the collector will go to the stow position and remain until all switches are closed. The collector system consists of individually controlled rows. The standard six module row is slightly longer than 120' and is supported by seven pylons.

5. Collector Array Layout

The solar collector array designed for HCPC consists of 303 SKI T-700 parabolic trough collectors (42,420 ft.^{2} aperture area) oriented in North-South rows spaced 15 ft. apart. Figure III-8 shows the plan view of the array. The North-South collector row orientation was chosen in order to maximize the total year output of the field as opposed to providing a relatively constant, and reduced, monthly output which East-West rows would produce. The nonuniform monthly output of a North-South axis is unimportant in this case since the load is many times larger than the maximum field output, and the process will have no trouble absorbing all of the solar energy available. The 15-ft. row spacing selection was based upon collector-on-collector shading calculations throughout the year and upon the requirement to provide accessibility between rows for maintenance equipment. Figure III-9 shows how array output is reduced by reducing row spacing. A row spacing of 15 ft. was considered minimum for proper accessibility. Although some shading occurs at 15-ft. spacing, the total yearly output of the array is higher than it would be for larger spacings due to the fact that fewer collectors would fit into the available field. Therefore, given the field size, a 15-ft. spacing was considered optimum.

FIGURE III-8



PIPE TRENCH
SEE DETAIL
SEE SECTION
LEGEND
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
TEAM
DRAWING NAME
NUMBER
C-3
WA HIRAI & ASSOC
HILO HAWAII

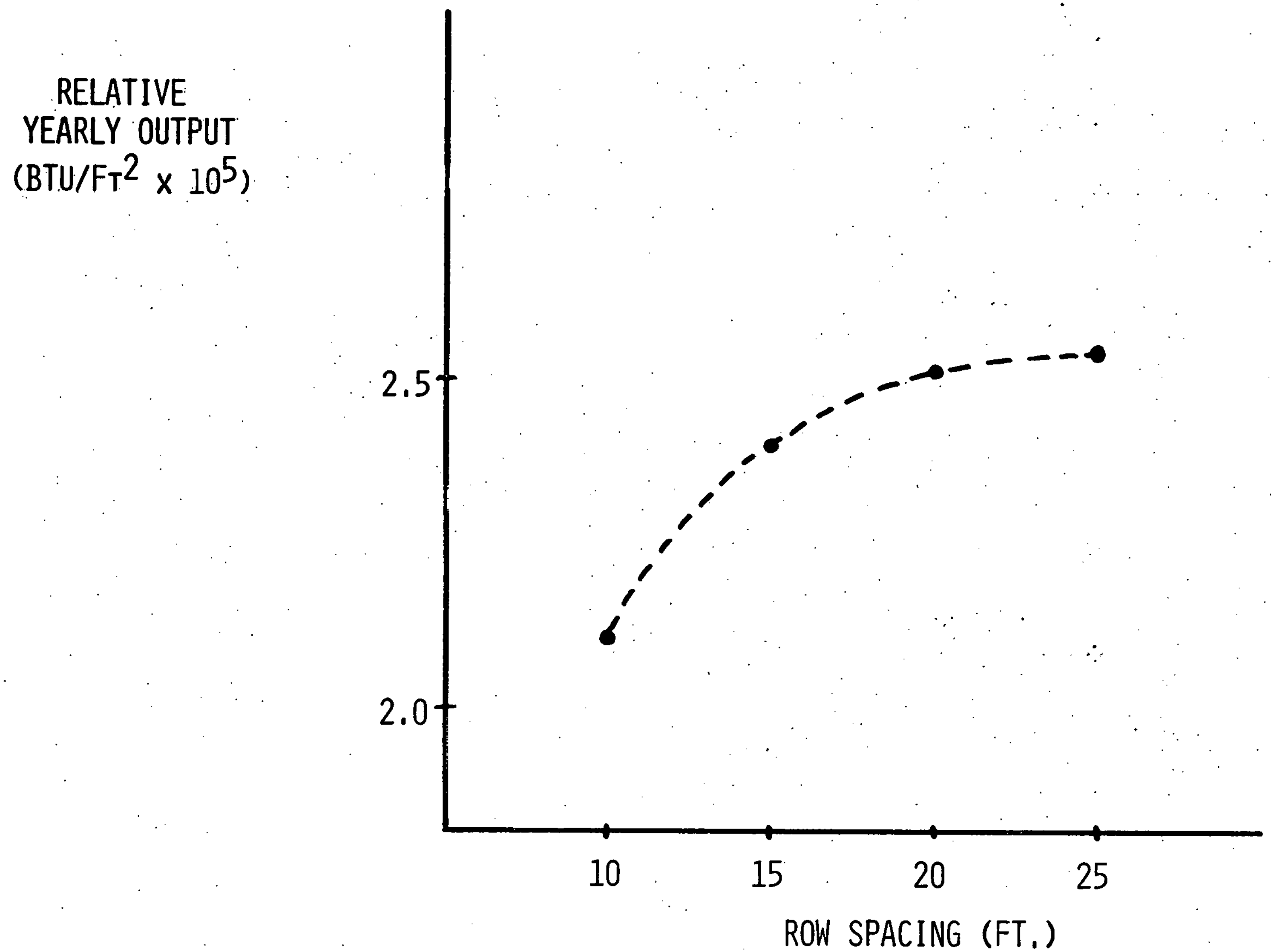


FIGURE III-9 SHADING EFFECT FOR NORTH-SOUTH ROWS @ HILO

6. Collector Foundations

The normal pylon foundation for the Solar Kinetics T-700 collector is a concrete pier 24 in. in diameter and buried approximately 5 ft. deep. The soil at HCPC (reference following section - Site Conditions) is quite soft in spots, and the cohesion value is low. Consequently, the soil will not support a point force such as a concrete pier, and shallow spread footings have been designed for the collector foundations. Figure III-10 is a plan view of the foundations' arrangement and details a typical foundation.

Collectors are cantilevered from pylons which are anchored to individual footings. Loads consist of the gravity weights of the collectors and the forces resulting from wind pressures on the collectors.

The wind loads have been obtained by wind tunnel tests. These data, which are contained in "Summary of Wind Load Data for Parabolic Trough Solar Collector Configurations" by Duane E. Randall of Sandia Laboratories, cover individual collectors and multiple collectors in multiple rows.

All pylons support vertical and lateral loadings. The center pylon in each row (a "D" foundation), which supports the drive mechanism for all collectors in the row, must also resist the wind-induced torque for the entire row. Due to a shielding effect demonstrated by the test data, loads at interior rows will be less than those at exterior rows. The differences in the supported loads accounts for the different sizes of the foundations. As expected, the exterior drive foundations are the largest since they must support their vertical weight and the wind-induced torque for the entire row.

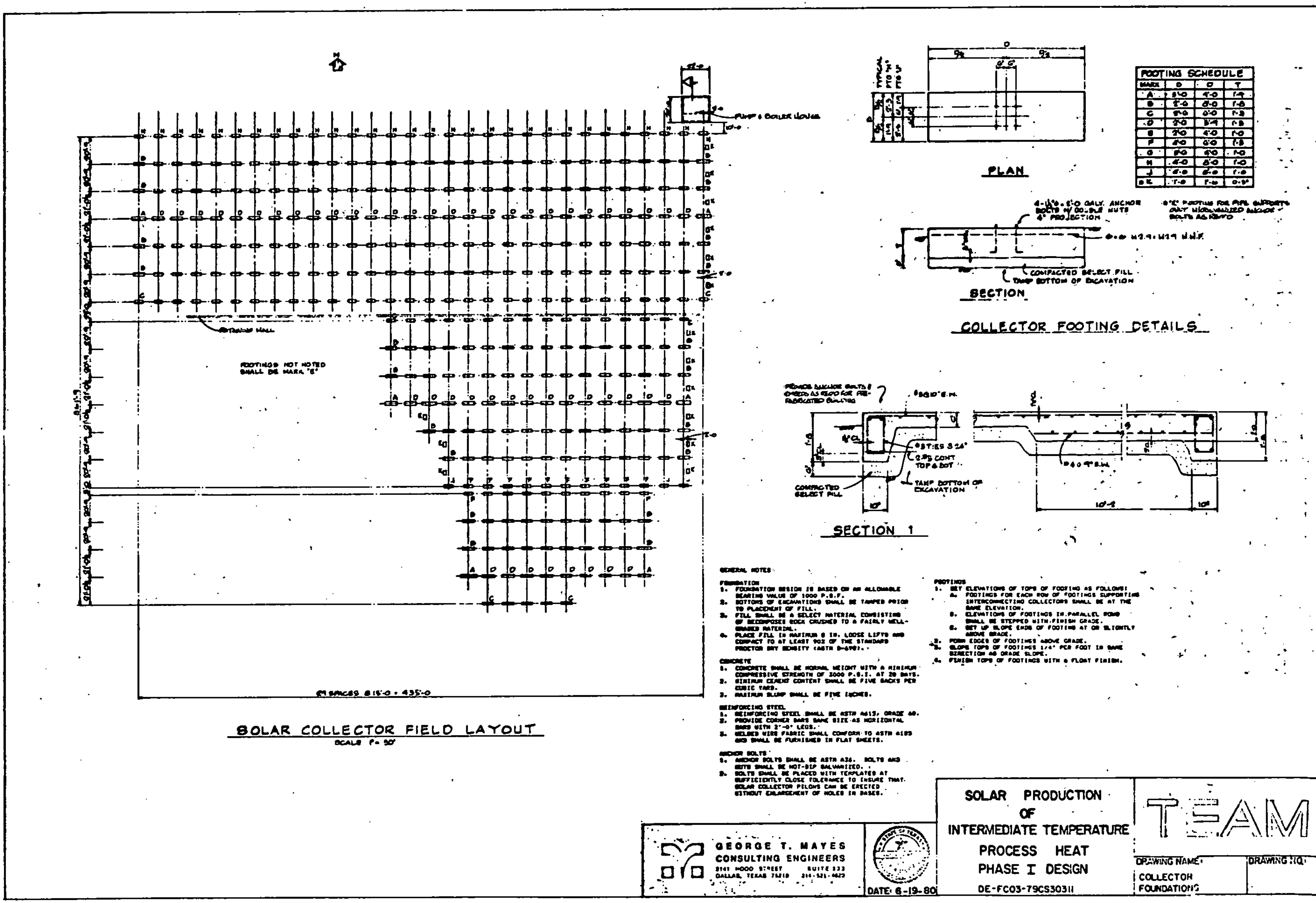


FIGURE III-10

Due to the substantial rainfall at the site (150-160 in. per year) soil erosion around collector foundations is a potential problem. Existing vegetation consists primarily of tall grasses (4 ft. and over) which form a thick matting of vegetation at the soil surface. These grasses are very effective in preventing soil erosion, however their quick growth and height make them unsuitable as ground cover for the solar field.

Fortunately, a local variety of grass called "Hilo grass" has been developed that grows to a maximum height of 2 ft. It develops the same ground level matting as the indigenous grass so soil erosion is eliminated, yet at 2 ft. tall it will not interfere with normal collector operations. This grass is used by the local macademia nut industry as the undergrowth for their orchards. Maintenance consists of annual fertilizing for weed control and cutting on a semi-annual basis or as desired for aesthetic purposes.

The thick matting at the surface will allow light vehicular access to the collector rows without major rutting, thus prepared roadways are not necessary.

C. SITE CONDITIONS

The plant is located on the northeast coast of the island of Hawaii approximately 100 ft. above the ocean on a bluff. It is surrounded on three sides by sugar cane fields and is in a predominately agricultural area on the windward side of the island. The city of Hilo is approximately 10 miles south of the plant and the closest public highway is ¼ of a mile away with limited and restricted access to the plant.

The site chosen for the location of the solar field is approximately 300 ft. from the point of contact with the plants steam header. An additional site is available to the west for future expansion of the solar field, however, it is approximately 600 ft. from the steam header and was ruled out as the primary location for the solar array. The field has a clear and unobstructed view to the south, east and west, and is bordered on the north by a small 2 acre reservoir and a few large trees.

1. Soil Conditions

Test borings were made in an area adjoining the collector field in the period 1971-1972 and reported by Walter Lum Associates, Inc. The borings closest to the site (approximately 50 feet away) have been taken as representative of the geological formations to be encountered.

The soils may be generalized as follows:

(1) A surface layer of soft, saturated, brown clayey silt formed from volcanic ash to a depth of 10 to 15 feet.

(2) Medium to stiff clayey silt containing decomposed lava rock to a depth of about 40 feet.

(3) Lava rock to the end of the borings.

The water table was measured at a depth of 17 feet and moisture content of the surficial material ranged as high as 261 percent with average values of about 180 percent at a depth of 5 feet.

Standard penetration tests indicated average blow values in the range of 2 to 4 blows per foot and unconfined compression tests showed values of about 2100 p.s.f. Some very soft spots may be encountered, however, as indicated by one instance in which the sampler was pushed into the soil by the weight of the hammer.

2. Meteorological Conditions

Summaries of the existing meteorological and physical conditions at the site are as follows:

insolation - See Section IV-A

precipitation - Rainfall at the site is 150"-160"/year with 60% of it occurring between the months of November and April.

cloudiness - The dominant cloud pattern is a tradewind pattern, with a slight increase in

	cloudiness in the late afternoon. A few miles inland an afternoon cloudiness and rainfall pattern is produced by upslope movement and a thermal coupling with the on-shore tradewinds.
winds -	The pattern is a daily land and sea breeze cycle, with average wind velocities of 0-15 mph.
salt -	Mild because sea-breeze forces are low.
temperatures -	Average annual temperature of 73°F with the lowest temperature recorded of 55°F (91 year history), and the highest on record of 93°F.
seismological stability -	Seismic Zone 3.

E. <u>DISTRIBUTION NETWORK</u>

1. <u>System Configuration and Operating Temperatures</u>

The preliminary design of the distribution system consists of two circulation loops (one for the heat transfer fluid and one for the water), a series of heat exchangers and the solar collector array.

A closed loop/heat transfer fluid configuration was selected, as opposed to a system employing pressurized water and flashing it to steam, primarily because of the low working pressures and subsequent low pumping cost that a closed loop system experiences. Pumping costs are directly proportional to the head or pressure that must be developed, and a closed loop configuration only requires a head large enough to overcome piping friction. A flash steam system, however, requires a head to overcome the piping friction plus the head loss experienced in the flash tank. Over the lifetime of the system, the parasitic pumping costs outweigh any difference in initial equipment cost. This is especially true for large systems where pumping requirements will also be large.

The heat transfer fluid will exit the collector field at 450°F and first flow into a superheater tube bundle, located in the vapor region of the steam generator. Next it flows into a tube bundle located in the liquid region of the steam generator and finally into a separate feedwater preheater. The fluid's exit temperature from the heat exchangers will be 370°F and its peak flow rate will be 340 gpm. A variable flow rate through the collector field (based on insolation conditions) will maintain a constant fluid outlet temperature.

Feedwater, from the plant's condensate return line, will exit the boiling house at 27 Psia and 206°F. The feedwater pump will raise the pressure to 200 Psia and will maintain the proper water level in the unfired boiler.

The feedwater will flow through the heat exchangers in a counter flow pattern to the heat transfer fluid, first entering the preheater where its temperature will be raised to saturated liquid conditions at 170 Psia and 366°F. After passing through the unfired boiler and the superheater, the feedwater will exit as a superheated vapor at 165 Psia and 420°] It will then blend with the steam in the plant's steam header. The peak flow rate for the feedwater will be 16 gpm.

The major design decision associated with the distribution system was to select the operating temperatures of the heat transfer fluid. It was obvious from the outset that the operating temperatures of the fluid affect selection of the flow rate, pump size, pipe size, insulation thickness, collector efficiency and the number and size of heat exchangers.

Temperatures and pressures at the points of contract between the plant and solar system dictated the minimum possible temperature of the heat transfer fluid. The pressure of the solar generated steam (165 Psia) must be slightly higher than the pressure in the plant's steam header (160 Psia) to insure that flow into the header occurs. Since saturation conditions will exist in the steam generator, the temperature there will be the saturated water temperature at 165 Psia (366°F).

Once the conditions within the steam generator were established, numerous thermodynamic iterations were performed to determine relationships between the transfer fluid's flow rates and operating temperatures.

The minimum fluid temperature that is attainable is 370°F and this is attainable only with the use of a feedwater preheater. Without the feedwater preheater, the minimum fluid temperature is 400°F.

After establishing thermodynamic relationships between temperatures and flow rates, three temperature regimes were chosen for in-depth analysis: 370-450°F (selected because 80°F delta T is the minimum recommended by the manufacturer), 370-550°F (selected because 550°F approaches the operating limits for the solar collectors and many heat transfer fluids) and 400-500°F (selected to determine the effects of eliminating the feedwater preheater). All three systems are shown schematically in Figures III-11 through III-13.

Table III-1 presents the installed costs of equipment that varies from system to system. It also lists the parasitic pumping costs for each option over a 20 year lifetime.

The major differences between the systems are flow rates (340, 138 and 254 gpm peak respectively),heat exchanger configurations (the 400-500°F system does not have a feedwater preheater) and amounts of solar energy collected (i.e., collector operating efficiencies).

Table III-2 summarizes the results of the tradeoff analysis and indicates that the 370-450°F temperature range is the most cost effective.

This system has the highest installed and operating cost, due to its higher flow rates, larger piping and lifetime

FIGURE III-11

FLOW SCHEMATIC AND OPERATING CONDITIONS

370-450°F

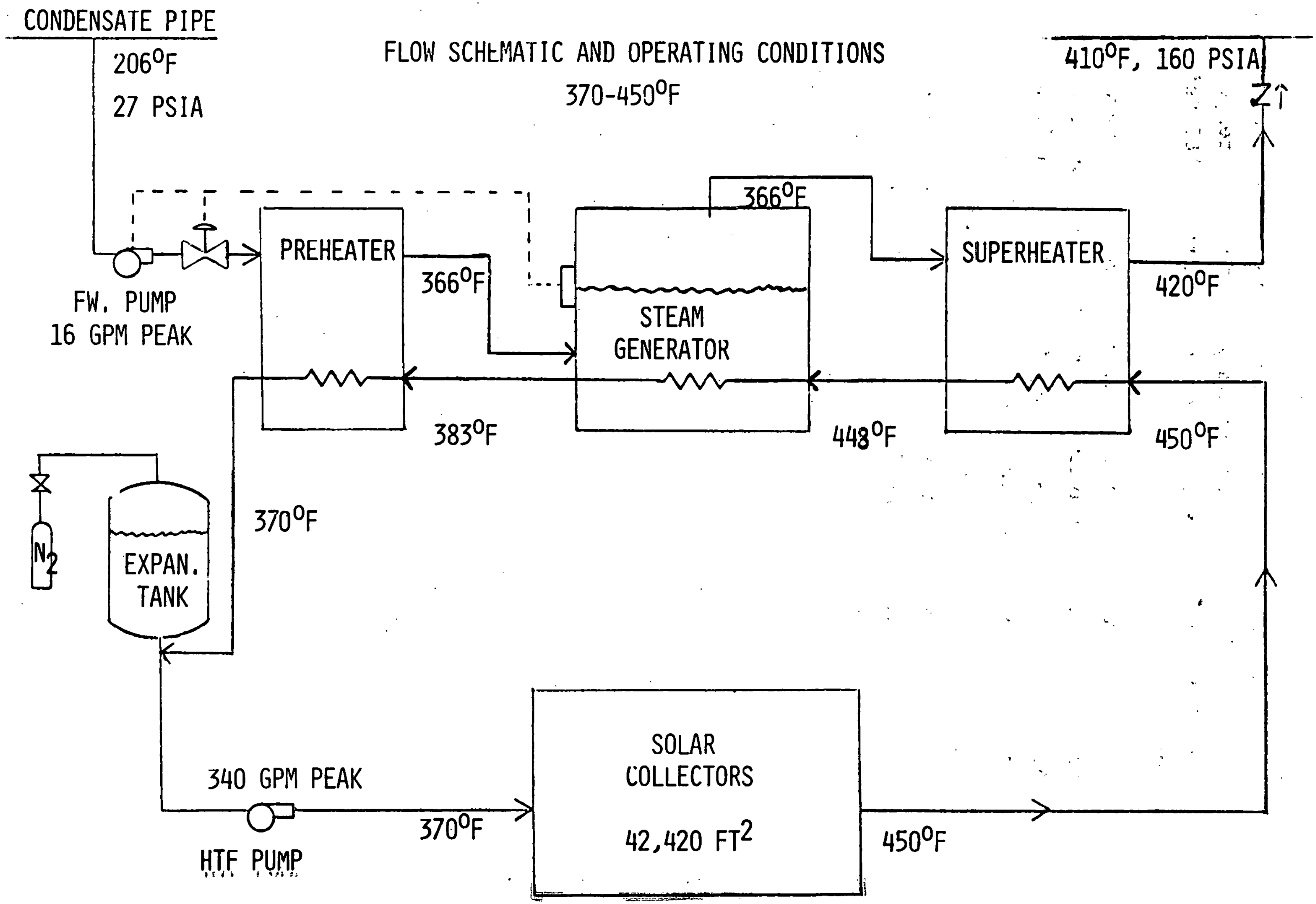


FIGURE III-12

FLOW SCHEMATIC AND OPERATING CONDITIONS

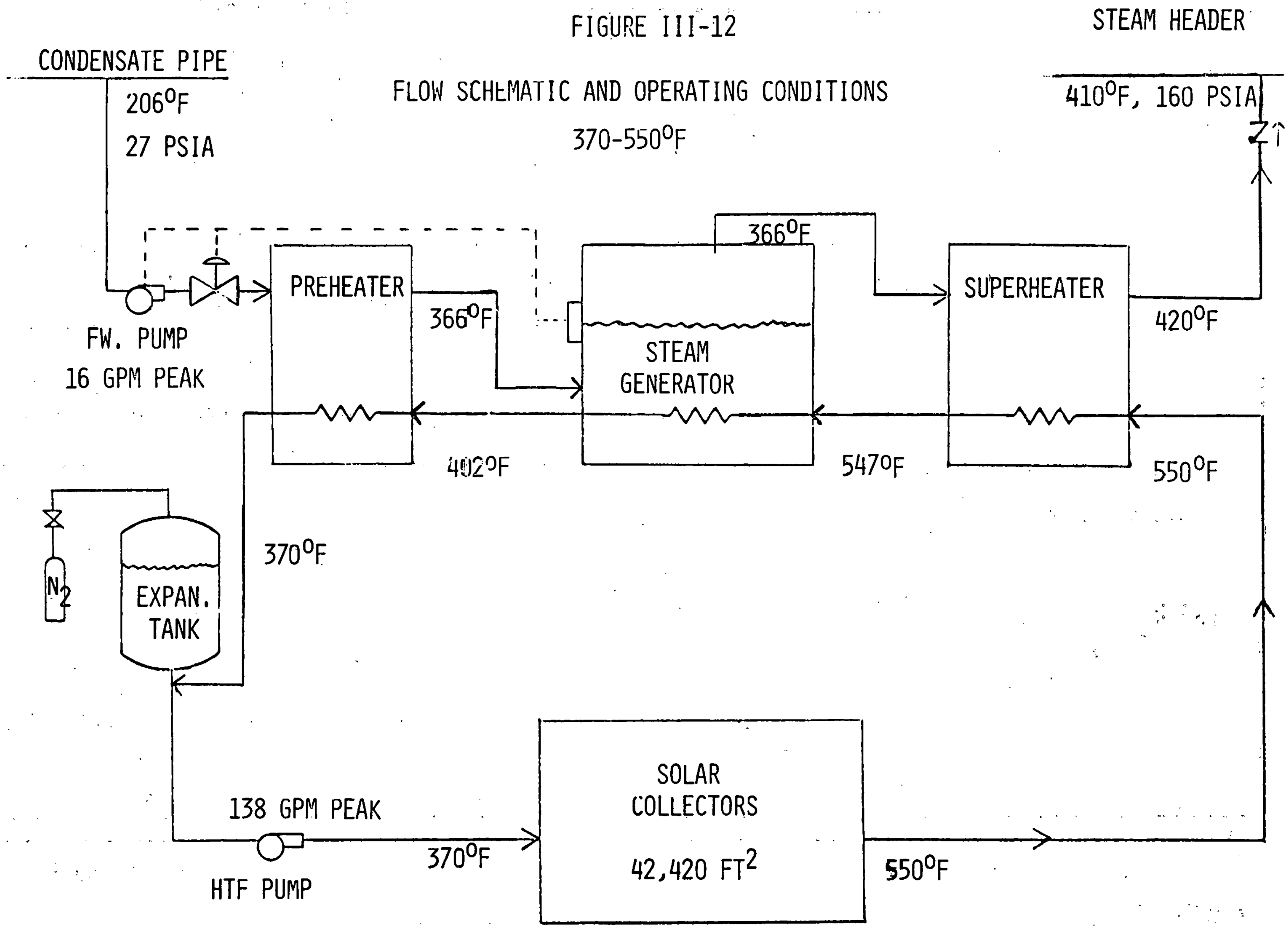


FIGURE III-13

FLOW SCHEMATIC AND OPERATING CONDITIONS
400-500°F

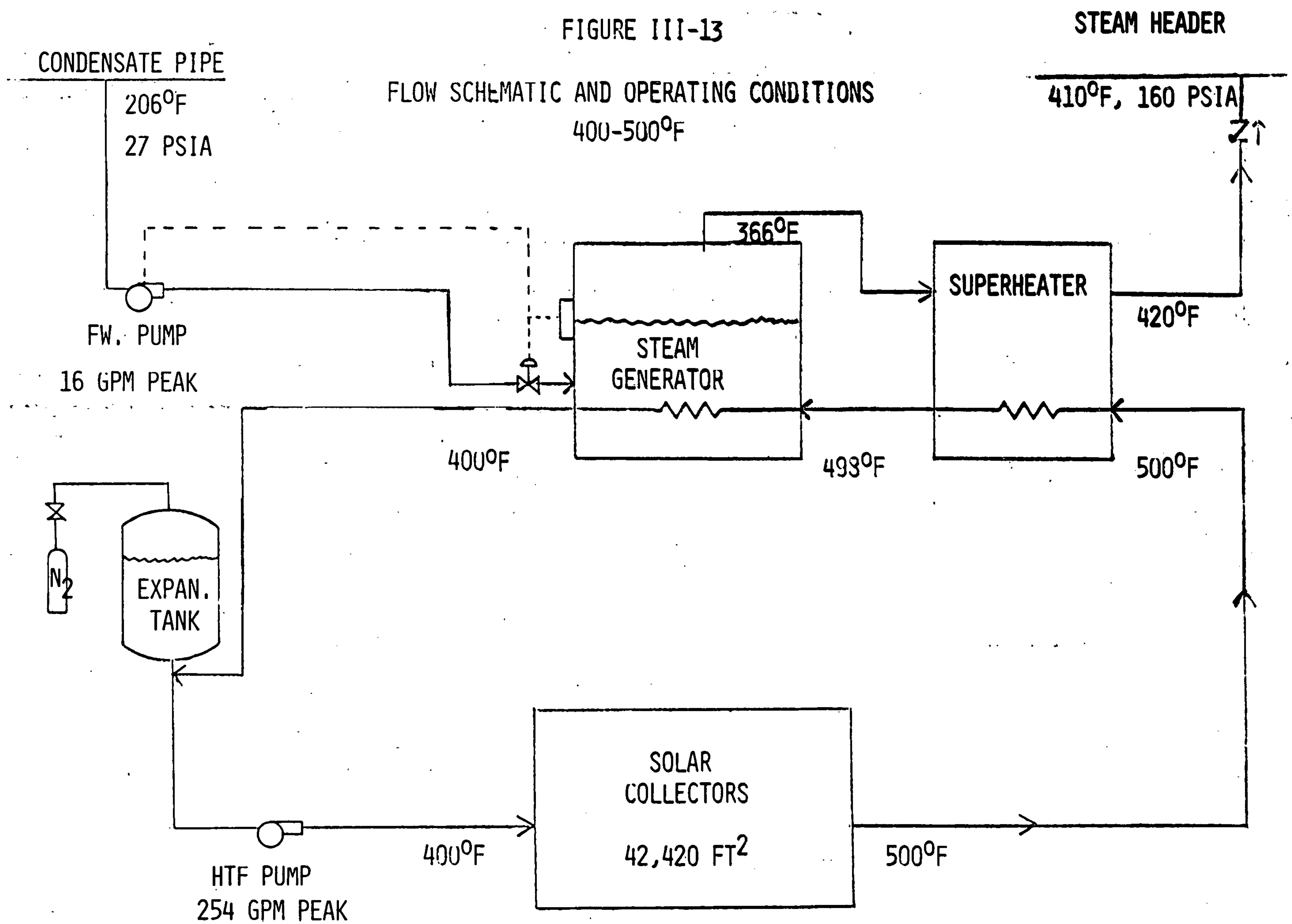


TABLE III-1

INSTALLED SYSTEM CONFIGURATION COSTS*

$(T_i - T_o)$	370-450°F	370-550°F	400-500°F
Piping, Fittings and Valves	76,050	73,150	74,150
Insulation	36,750	36,550	36,650
Unfired Boiler	33,500	31,800	32,800
Feedwater Preheater	4,000	4,000	0
Superheater	2,000	1,700	1,800
Collector Field Circulation Pump	8,750	7,600	8,400
Feedwater Pump	400	400	400
Expansion Tank	1,700	1,700	1,500
Present Value Pumping Costs*	34,400	11,300	22,600
TOTAL COST	197,600	168,200	178,300

*Costs were estimated from construction handbooks and equipment suppliers for preliminary design analysis.

*Assumes: (1) 20 year life, (2) $.09/kWH, (3) 6 Hrs/day, 305 days/yr pump operation, (4) fuel escalation of 13%/yr and 10%/yr inflation.

TABLE III-2

SYSTEM CONFIGURATION OPTIONS

$(T_i - T_o)$	370-450^oF	370-550^oF	400-500^oF
Configuration Variable Costs	197,600	168,200	178,300
Solar Energy Collected	$8.52x10^9$ Btu/yr	$8.24x10^4$ Btu/yr	$8.34X10^9$ Btu/yr
Difference in Solar Energy Collected	$2.8x10^8$ Btu/yr	0	$1.0x10^8$ Btu/yr
Present Value Difference in Solar Energy Collected*	33,600	0	11,900
Equalized System Costs	164,000	168,200	166,400

*Assumes: (1) $25.21/barrel oil, (2) 78% combustion efficiency, (3) 13% fuel escalation and 10% inflation, (4) 20 year lifetime, and (5) $6.2x10^6$ Btu/barrel.

pumping cost; however, it also collects and utilizes more solar energy because of its lower temperatures and resulting increases in collector operating efficiencies. The increase in the amount of energy collected more than compensates for the higher installation and operating costs.

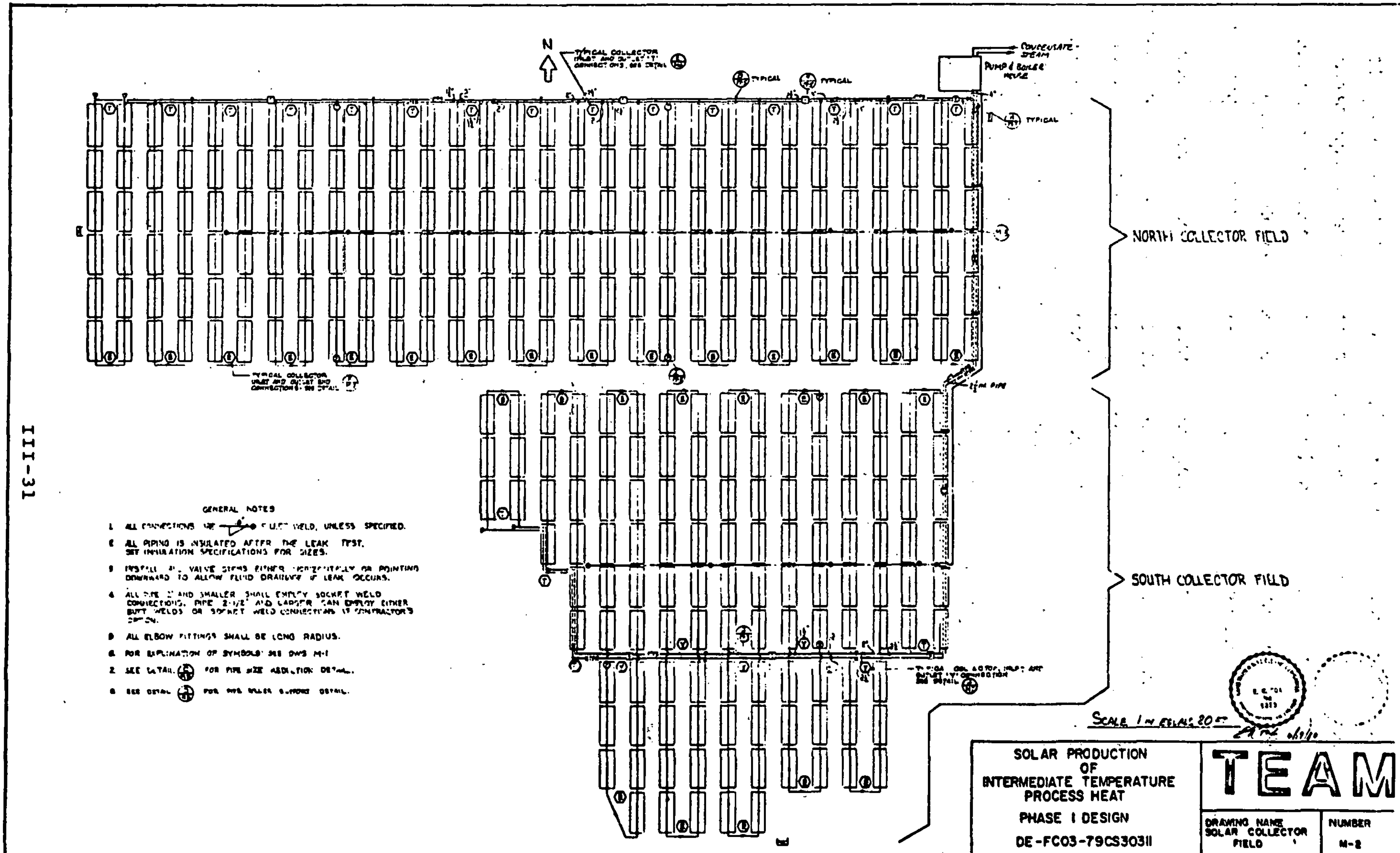
It is interesting to note, however, that when all three systems were adjusted for differences in solar energy collected, the costs of the systems varied by less than $5,000. This indicates that the tradeoffs between collector operating temperatures almost equal out in the final analysis and that parameters other than system efficiency or costs could determine the optimum or most desirable system. In particular, it is felt that material limitations and system safety present the most pressing arguments for operating at the lowest temperature possible. Most heat transfer oils have flash and fire points well below 500°F and by operating at temperatures closer to or below these critical points system safety is enhanced proportionately.

2. <u>Piping Layout</u>

The preliminary design of the collector field piping network is diagrammed in Figure III-14. It consists of a central pump house located in the northeast corner of the field and two parallel distribution loops supplying the solar collectors.

Many of the design decisions related to the piping layout were predetermined due to existing conditions at the site. The pump house, for instance, which contains the heat transfer fluid (HTF) pump, expansion tank and steam generator, was located in the northeast corner because this is the closest point in the field to the interface connection with the plant's steam header. Alternate locations that are closer to the plant were investigated. however, they were eliminated since thermal losses are minimized if the heat transfer occurs at the collector field.

FIGURE III-14



The use of two parallel circulating loops was the obvious arrangement once the configuration of the solar collectors was established. Any other configuration requires additional piping and results in higher pumping cost and thermal losses.

Schedule 40 steel pipe will be used throughout the system, with welded or flanged connections. Raised face, 300 lb. flanges are required due to the low viscosity and tendency of heat transfer fluids to leak at high temperatures.

The three temperature regimes that were analyzed during the preliminary design resulted in different flow rates and sizes of pipe in the solar field. As would be expected, the system with the lowest flow rate had the lowest installed cost since it could use a smaller diameter pipe. However, installed costs did not differ by more than 6% for all three networks, yet the flow rates more than doubled.

Design parameters on which pipe selection was based for the preliminary design were: (1) minimum fluid velocity of 4 feet per second (fps), maximum velocity 10 fps and (2) minimum pressure drop 0.8 PSI/100 feet, maximum pressure drop 4 PSI/100 feet. A more in-depth analysis was performed for optimizing pipe sizes during the detailed design which accounted for pumping costs and heat loss (see section IV-C for details).

A direct return piping pattern is employed in the preliminary design because of the savings in piping, insulation and pumping cost. The obvious disadvantage of this system is the possibility and likelihood of a flow imbalance occurring at flow rates other than the original set rate. Collector operating efficiencies will vary with flow, however, due to the relatively constant slope of the SKI collector efficiency curve between the temperatures of 400-600°F, a mild flow imbalance is not a detrimental characteristic.

The collector group farthest from the pump will receive a reduced flow and thus operate at a higher average temperature and lower efficiency, yet the collector group closest to the pump will operate at a lower temperature and higher efficiency. On the average, the field will perform as if each row had equal flows and were operating at the temperatures of the total field. The important parameters regarding efficiencies are total flow and field inlet and outlet temperatures.

The main problem with flow imbalances in the collector field is the possibility of flow starvation to one or more collector rows, resulting in an overtemperature situation and subsequent collector stowing. The collectors must then be manually restarted, thus incurring a maintenance cost along with the lost energy that would not be collected.

To avoid overtemperature situations, the system will be manually balanced during system checkout, at a flow rate corresponding to average insolation conditions (approx. 260 Btu/ft.^{2}/hr.). At insolation levels other than average, a mild blow imbalance will be acceptable since the variances in outlet temperatures will not produce an overtemperature condition.

Three configurations of flow through collector rows were examined during the preliminary design: (1) each collector row in parallel, (2) two collector rows in series and (3) three collector rows in series.

The choice of piping two collector rows in series was based on the reduced plumbing, insulation and pumping costs incurred with this configuration. The other two choices would necessitate piping headers at both ends of collector rows and would require additional piping and insulation along with increased pumping costs.

As shown below in Table III-3, the operating parameters that change are pressure drop and flow rate through the receiver. The amount of heat transferred and the overall collection efficiency are essentially flow rate independent once turbulent flow conditions exist in the receiver. (Solar Kinetics has a twisted metal ribbon in the receiver that induces turbulence at low flow conditions). Average collector efficiency is the same for all three cases and thus the simplest piping network became the governing parameter.

Table III-3

Flow Through Collector Rows

	1 Row in Series	2 Rows in Series	3 Rows in Series
$T_{in} = 370^{o}F$	m = 7 gpm	m = 13 gpm	m = 20 gpm
$T_{out} = 450^{o}F$	Δp = 4 psi	Δp = 13 psi	Δp = 27 psi

3. Pump Selection

One of the first design decisions that was made regarding overall system philosophy and operation was the decision to have a variable flow rate through the collector field. The flow rate will increase or decrease depending on the level of insolation, and the result will be relatively constant temperatures throughout the system.

The primary advantage of this operational philosophy, as opposed to a system with a constant flow, is the decrease in lifetime pumping costs which far outweigh the higher initial costs of the variable flow equipment. In addition, collector operating efficiencies will be somewhat higher with the variable flow system since collector temperatures will be constant regardless of insolation conditions. The constant flow system, however, will have higher outlet temperatures during peak conditions and thus the collectors would operate at a lower efficiency.

The preliminary design consists of a variable speed motor controller and a 45 horsepower motor coupled with a 3500 RPM centrifugal pump. The operating temperature of the pump will be 370^{o}F, and the pump will be actively cooled via a small volume of water (< 2 gpm) circulating around the pump seals.

Once the decision to use a variable flow rate was established, the next decision centered on the means to vary the flow. The two ways of varying the flow that were investigated were (1) mechanical throttling and (2) electronic throttling (i.e.: Controlling the motor's speed).

Mechanical throttling employs a flow control valve that opens or closes incrementally depending on the flow rate desired. As the valve opens or closes, it in effect changes the system head that the pump sees and the operating point on the pump curve changes.

Electronic throttling varies the input signal to the motor which changes the speed of the motor's output shaft, thus changing the output of the pump.

The results of the tradeoff analysis that was performed for the throttling options are presented in Table III-4. The obvious choice for every temperature regime analyzed, was the electronic throttling. This was due to the overwhelming difference in lifetime pumping costs. Mechanical throttling decreases flow rates by increasing head loss and moving along a fixed speed pump curve. Electronic throttling, however, decreases flow rates and head loss simultaneously, actually moving from one pump curve to another as the rpm's change.

As shown in Table III-4, the difference in power consumption between the two means of throttling is 13 Hp

TABLE III-4

PUMPING OPTIONS

	370-450°F		370-550°F		400-500°F	
	Mech Throt	Elec Throt	Mech Throt	Elec Throt	Mech Throt	Elec Throt
Peak Operating Conditions	340 gpm 288 ft.hd. 33 Hp	340 gpm 288 ft.hd. 33 Hp	138 gpm 210 ft.hd. 10 Hp	138 gpm 210 ft.hd 10 Hp	254 gpm 250 ft.hd. 21 Hp	254 gpm 250 ft.hd. 21 Hp
Average Operating Conditions	237 gpm 332 ft.hd. 26 Hp	237 gpm 147 ft.hd. 13 Hp	91 gpm 255 ft.hd. 8 Hp	91 gpm 120 ft.hd. 4 Hp	168 gpm 303 ft.hd. 17 Hp	168 gpm 132 ft.hd. 8 Hp
Present Value* Pumping Cost	$74,900	$34,400	$22,600	$11,300	$48,100	$22,600
Installed Cost	$ 5,950	$ 8,750	$ 4,800	$ 7,600	$ 5,500	$ 8,400
Total Life-Cycle Costs*	$80,850	$43,150	$27,400	$18,900	$53,600	$31,000

*Assumes: (1) $.09/kWH, (2) 6 Hrs/day, 305 days/year operation, (3) fuel escalation of 13%/yr, (4) Inflation of 10%/yr, and (5) 20 year lifetime.

(26-13 Hp) or 50% for the 370-450^{o}F system and 9 Hp (17-8 HP) or 53% for the 400-500^{o}F system. The clear choice for all three options was electronic throttling.

Table III-4 also highlights the pumping tradeoffs between the different collector operating temperatures that were investigated. It is important to note that the initial equipment cost for each option did not change drastically, even though flow rates more than doubled from the high to low case. As expected, lifetime pumping costs were usually 3 to 4 times larger than initial installed costs.

4. Heat Exchanger Configuration

The preliminary design of the heat exchanger configuration consists of three heat exchangers in series; a superheater, unfired boiler and a feedwater preheater.

The feedwater preheater raises the temperature of the feedwater to the saturation temperature at 170 Psia (366^{o}F). In addition it further cools the heat transfer fluid and thus increases the collector's operating efficiency.

The unfired boiler consumes 85% of the collected solar energy in the process of changing the saturated liquid to a saturated vapor. Close to 6.7 x 10^6 Btu's/hour will be transferred during peak operation and the heat transfer fluid will exit the boiler at 383^{o}F.

The superheater will add 54^{o}F superheat to the saturated vapor and its exit conditions will be 420^{o}F and 165 Psia. Instead of being a separate heat exchanger from the steam generator, the superheater will simply be a tube bundle located in the vapor region of the unfired boiler. This not only reduces the cost of the equipment but also reduces the thermal mass and thermal losses of the system by incorporating both items in one insulated "shell".

The major tradeoff analysis that were performed to determine the cost-effectiveness of heat exchanger configurations is outlined in Table III-5.

TABLE III-5

HEAT EXCHANGER OPTIONS

$(T_i - T_o)$	370-450°F	370-550°F	400-500°F
Heat Exchanger Configuration	Superheater Unfired Boiler Feed-water Pre-heater	Superheater Unfired Boiler Feed-water Pre-heater	Superheater Unfired Boiler
Equipment Cost	\$39,500	\$37,500	\$34,600
Solar Energy Collected	8.52×10^9 Btu/yr	8.24×10^9 Btu/yr	8.34×10^9 Btu/yr
Difference in Solar Energy Collected	2.8×10^8 Btu/yr	0	1×10^8 Btu/yr
Present Value of Difference in Solar Energy Collected	\$33,600	0	\$11,900

A heat exchanger configuration was matched to each temperature regime in question, and the cost and amount of solar energy collected for each was compared.

The difference in installed cost between the heat exchanger configurations is due to the number and size of heat exchangers. The 370-450^{o}F system employs three heat exchangers, and with only a 450^{o}F maximum temperature, larger surface areas are required than with a 550^{o}F or 500^{o}F temperature. The 400-500^{o}F system employs only two heat exchangers and eliminates the feedwater preheater.

The value of operating at as low a temperature as possible is illustrated by the amounts of solar energy collected for the different temperatures. The 370-450^{o}F system operates at an average temperature of 410^{o}F and collects approximately 2.8 x 10^{8} Btu/yr. more than the 370-550^{o}F system which operates at an average temperature of 460^{o}F. The dollar value of this energy over the 20 year system lifetime is $33,600.

5. Pipe Insulation

Fiberglass pipe insulation will be used throughout the system on all straight lengths of pipe and at all welded connections. Cellular glass insulation will be used at all flanged and threaded connections because of the potential fire hazard incurred with fiberglass should it become saturated with the heat transfer fluid at temperatures above 500^{o}F. The cellular glass is a closed cell insulation and does not have a large surface area that could become saturated with the fluid.

The system will be pressure tested during checkout to ensure the integrity of all connections. During the life of the system, the most likely place for a leak to occur will be at the flanged and/or threaded connections, therefore, the cellular glass will be used at these locations.

All insulation will be weather proofed and protected by a .016" aluminum jacket.

The most economic thickness of insulation has been selected for each pipe size as listed below and the criteria used for the selection are described in the next section.

1.5" pipe - 2.0" insulation
2.0" pipe - 2.0 insulation
2.5" pipe - 2.5" insulation
3.0" pipe - 2.5" insulation
4.0" pipe - 2.5" insulation

Fiberglass, calcium silicate, urethane foam and cellular glass were initially considered as insulating materials. The important insulating properties of these materials are listed in table III-6. Urethane foam was rejected because of its low operating temperature (less than $250^{o}F$).

Calcium silicate and cellular glass were rejected because of their lack of availability, higher cost and poorer thermal performance. Their main advantages are their ability to withstand high temperatures ($1200^{o}F$) and applied pressure without deforming.

Fiberglass was chosen in preference to other insulation possibilities for a number of reasons:

- o Least costly
- o Best insulating properties for the temperature range
- o Readily available, and
- o Ease of installation (high degree of experience of contractors with the material)

To determine the most economic thickness of insulation, the total life-cycle value of the lost heat for various thicknesses were projected for a 20 year lifetime. Installed costs were obtained from equipment suppliers and contractors and were plotted in dollars as a function of insulation thickness per linear foot of pipe.

TABLE III-6

INSULATION PROPERTIES

INSULATION	MAX OPERATING TEMP (^{o}F)	CONDUCTIVITY @400^{o}F (BTU-IN/HR-FT^{2}-^{o}F)	HEAT CAPACITY BTU/FT^{3}-^{o}F	COMMENTS
FIBERGLASS	650	.44	1.33	LOW COST READILY AVAILABLE EXTENSIVE CONTRACTOR EXPERIENCE
URETHANE	250	---	.76	LOW COST MODERATE AVAIL-ABILITY LITTLE CON-TRACTOR EXPERIENCE
CELLULAR GLASS	800	.59	2.16	HIGH COST POOR AVAILABILITY LITTLE CONTRACTOR EXPERIENCE
CALCIUM SILICATE	1200	.48	3.36	MODERATE COST MODERATE AVAIL-ABILITY MODERATE CONTRACTOR EXPERIENCE

Heat loss was calculated on the basis of Btu's lost per year per linear foot of pipe, as a function of insulation thickness. To assign a dollar value in present dollars to the energy lost, the following assumptions were made:

- $T_{fluid} = 410^{o}F$, $T_a = 80^{o}F$
- $25.21 per barrel of oil (Hilo Coast's most recent figure)
- 6.2×10^6 Btu per barrel
- 78% boiler efficiency to replace the lost solar energy
- 13% fuel cost escalation per year
- 10% annual inflation
- 20 year life cycle

By summing the dollar value of the heat lost and the installation costs for each thickness, the most economic insulation thickness for each pipe diameter was determined. It is the point of minimum total cost. Table III-7 summarizes the results of the analysis.

It is interesting to note that when overnight thermal losses were taken into account, the optimum insulation thickness decreased in some cases by ½ inch. This was due to the heat capacity of the insulation which represented 33% of the thermal mass for a 1½ inch pipe and 14% for a 4 inch pipe. All field piping reaches ambient temperature within a twelve hour period, and since overnight losses represent 70% of the total heat loss, more Btu's were saved by decreasing the pipe's thermal mass (i.e.: reducing insulation thickness) than were saved during system operation with increased insulation thicknesses.

6. Heat Transfer Fluid Selection

Therminol 55 was originally proposed as the working fluid in the solar loop. However, in light of the high operating temperatures (370-450^{o}F) of the HCPC system and the low flash point of T-55 (350^{o}F), it was decided to further examine other available fluids for use in the system.

TABLE III-7

OPTIMUM INSULATION THICKNESS

PIPE DIA.	INSUL. THICK(IN)	ANNUAL HT. LOSS(Btu/L.F)	ENERGY VALUE($)	PRESENT WORTH VALUE	INSTALLED COST($/L.F)	TOTALS($/L.F
1½"	1	$136.1x10^3$	.71	15.98	7.54	23.52
	1.5	113.7	.59	13.28	8.39	21.67
	2	95.9	.50	11.25	10.21	21.46*
	2.5	100.8	.53	11.93	11.02	22.95
2"	1.5	133.5	.70	15.75	9.27	25.02
	2	111.6	.58	13.05	10.87	23.92*
	2.5	108.1	.56	12.60	11.74	24.34
	3	106.0	.55	12.38	13.38	25.76
2½"	1.5	154.5	.81	18.23	9.88	28.11
	2	131.6	.69	15.53	11.65	27.18
	2.5	122.4	.64	14.40	12.58	26.98*
	3	116.2	.61	13.73	14.27	28.00
3"	1.5	176.1	.92	20.70	10.49	31.19
	2	144.9	.76	17.10	12.48	29.58
	2.5	138.8	.72	16.20	13.68	29.88*
	3	130.9	.68	15.30	15.29	30.59
4"	1.5	211.7	1.10	24.75	11.34	36.09
	2	173.8	.91	20.48	13.68	34.16
	2.5	162.8	.85	19.13	15.34	34.47*
	3	152.6	.80	18.00	17.21	35.21

Since the fluid will cool relatively rapidly when a system leak occurs, a flash point near the system's peak operating temperature will provide a safety margin so as to minimize the fire hazard.

Table III-8 lists the important properties of numerous heat transfer fluids, and it shows that there are several fluids that meet the flash point requirement. Namely . . .

Fluid	Flash Point	Manufacturer
Synfluid 4cs	445°F	Gulf
Synfluid 6cs	465	Gulf
888-HF	450	Bray Oil
Syltherm 444	450	Dow Corning
Syltherm 510	527	Dow Corning

Additional considerations for fluid selection are specific heat, viscosity (or pumping costs), fluid lifetime materials compatability, cost and toxicity.

Gulf synfluid 4cs has the best combination of properties for the HCPC application and will be the fluid used in the collector loop. It has the highest specific heat of all the fluids considered and the second lowest viscosity at 100°F so the cold start-up and overall pumping costs will be minimized.

The synfluid meets the white mineral oil specifications for the Food and Drug Administration and may be used as a component on equipment intended for use in contact with food. It also is approved by the U.S. Department of Agriculture for incidental food contact in meat and poultry establishments so toxicity is not a problem.

The Dow Corning fluids are slightly more stable, but with an inert nitrogen blanket on the expansion tank the 4cs should have a 20+ years service life.

Fluid	Manufacturer	Remarks	Freeze/ Pour Pt. (F)	Viscosity (cs.) at 100 F	Specific Heat (BTU/lb F)	Thermal Conductivity (BTU/HrFt F)	Flash Pt. (F)	Fire Pt. (F)	Cost $/Gal
SYNFLUID 2CS 4CS 6CS	Gulf		-100 -100 - 90	5.4 18.3 33.3	0.62 (300 F) 0.62 (300 F) 0.57 (300 F)	0.082 (200 F) 0.073 (300 F) 0.074 (300 F)	320 445 465	360 495 520	6.00 (bulk
THERMINOL 60	Monsanto	High cost	- 90	4.9	0.445(200 F)	0.0731(200 F)	310	320	10.27
DOWTHERM LF	Dow	High pour point	- 25	2.75	0.44 (212 F)	0.076 (212 F)	260	280	10.88
TRIBUTYL PHOSPHATE	IMC Chemical Group, Inc.	Not applicable Above 200 F	<-112	3.8 (85F)	0.41		295		8.27
COOLANOL 35	Monsanto	High cost and viscosity	<-120	6.5	0.45 (77 F)	0.077 (77 F)	350	400	52.82
BUTYL CARBITOL	Union Carbide	Low flash point	- 90	6.8			240		4.91
THERMINOL 44	Monsanto	High viscosity	- 80	8.8	0.508(200 F)	0.076 (200 F)	405	438	
COOLANOL 45	Monsanto	High cost and viscosity	<- 85	12.2	0.45 (77 F)	0.078 (77 F)	370	430	49.25
SYLTHERM 444	Dow Corning	High cost Low c_p High K	-121	17	0.39 (212 F)	0.080 (200 F)	450	500	18.40
510				38	0.436 (200 F)		527		18.40
888-HF	Bray Oil Co.	High viscosity	<- 85	4.51 (210 F)			440		6.80
THERMINOL 55	Monsanto	High viscosity	- 40	23	0.521(200 F)	0.0701(200 F)	350	410	2.52 (bul:
HEXYL CELLOSOLVE	Union Carbide	Low flash point	- 58	5.85 (68 F)			195		6.62

Table III-8, Heat Transfer Fluid Properties

Finally, of the fluids considered, 4cs is the least expensive. These reasons make it an excellent choice for this application, and even though it will cost more than twice the T-55, the additional fire and toxicity protection is well worth the expense.

E. CONTROL SYSTEM

The control subsystem will contain the control and display equipment for all subsystems which comprise the IPH demonstration project. All control functions will be performed by closed loop sensor/control actuator combinations at selected points throughout the solar energy system. Provisions have been made for manual intervention and control as considered appropriate. The control subsystem will be designed to have the following characteristics:

- o it will provide all necessary system control to allow continuous unmanned system operation;
- o it will be responsive to system fault conditions and shall perform automatic protection actions, including system turn-off, to prevent damage to the system or components;
- o it will have a display panel depicting the system status for rapid visual monitoring of general system condition;
- o controls will be designed so that a loss of control power results in an orderly system shut-down using a back-up power system.

The controls subsystem will include two main sections; the solar thermal array and fluid distribution network. Each of these will be discussed in detail below.

Solar Thermal Array

The basic unit for the collector array will be the set of six concentrating collectors installed in series and controlled as a single unit. The unit controller will be set between the third and fourth collector and will control all six collectors from the same drive mechanism. The control sequences to be implemented include:

(a) Morning wake-up

(b) Normal track

(c) Pause and

(d) Unit Stow

The following is a brief explanation of the control sequences.

Morning Wake-Up

Upon receipt of a suitable actuating signal from the control room, sufficient insolation and the absence of high winds, rain, etc., the system will provide a signal to start the fluid pump. After fluid flow is established, the collectors will unstow and begin rotating westward to obtain the sun. Westward rotation will continue until the tracker acquires the sun.

Normal Track

The acquisition angle for the tracking unit is about 20 degrees. Once the sun comes within the tracker acquisition angle the rotation caused by the morning wake-up sequence is disabled and acquisition/tracking sequence begins. This mode remains in operation until interrupted by insolation, meteorological, or manual signals.

Pause

The pause operational mode deactiviates the solar tracking mode. This mode is used to halt the rotation of the collectors when the sun becomes obscured by clouds. The pause mode remains in effect as long as the sun is obscured. Once the cloud cover has passed, the tracker will reacquire the sun and commence normal tracking. If the sun has moved outside the acquisition angle of the tracker, the collectors will automatically stow.

Unit Stow

This operational mode causes the unit to cease its present operation and stow the collectors. The stow mode is activated when the insolation falls below a preset level, rain, high winds, loss of primary power, loss of fluid flow, excessive temperature in the thermal receivers or when the steam loop conditions are outside of specific pressure tolerences.

The solar field has been divided into five subfields for control purposes. This is to prevent excessive utility surge loads which would result if every drive pylon were activated simultaneously. The five separate subfields will recieve control signals from the central field controller. In addition, each subfield will have a manual controller located in the HCPC power plant master control room, where field status may be monitored visually via closed circuit TV. The manual control panel will provide the same control functions as discussed above. Each collector unit will also be individually controllable in the field. A master field ON/OFF switch will be provided on the master control panel and in the pump house ODAS room. Both switches must be "ON" before the system will operate.

Fluid Distribution Network

Outlet temperature from the field will be controlled by varying the flow rate of the fluid through the collectors. Flow rates through the solar system will be controlable from about 50% to 100% of full fluid flow. Computer simulations indicate that this is sufficient to control the field outlet temperature without significant thermal instabilities in the system.

A thermally actuated bypass valve will be employed in the heat transfer fluid loop. The valve will allow the fluid to by pass the steam generator during morning start-up or when the fluid is not at a useable temperature. This will prevent thermally shocking the steam generator tube bundles with ambient temperature fluid at morning start-up, as well as preventing thermal draining of the steam generator during marginally sunny periods.

The boiler/superheater will have a water level control built into the unit. The unit will sense the water level in the boiler and, if it is below a preset level, a signal will be sent to the water pump turning it on. When the water level rises above a fixed level, the pump will be turned off. A control valve at the entrance of the feedwater preheater will maintain pressure in the line and prevent fluid backflow.

A spring loaded check valve at the steam interface with the plant, will allow steam to enter the main line only when the solar side pressure exceeds the pressure in the main line. Since the temperature of the steam will control the pressue, only steam of a predetermined quality will be allowed to enter the main steam line. A pressure actuated valve will be located at the outlet of the steam generator on the superheated steam line. The valve will prevent thermal draining of the generator overnight, which would occur due to the cooling steam pipe. As the pipe cooled, the internal pressure would decrease and tend to rob the generator of its pressure, temperature and energy. The valve will be set to close at a pressure below approximately 135 Psia and will open at a pressure above 145 Psia.

Emergency controls for the fluid distribution loop will sense the steam outlet pressure and cause the solar system to shut down if they are outside predetermined limits. This will consist of stowing the collectors, turning off the water pump, and turning off the heat transfer fluid pump.

An additional emergency control consists of a collector fluid overpressure sensor near the boiler/superheater. Its purpose is to detect a leak in the heat exchanger bundles and prevent mixing of the transfer fluid with the plant's treated water. Overpressurization in the transfer fluid piping will result in system shut down. A level switch, located in the oil expansion tank, will also shut down the solar energy system if the level is too low. All sensors will prevent the system from starting up if preset conditions are exceeded. Visual displays indicating the out of bounds condition are provided on the master control panel.

The steam overpressure indicator is a blinking display, and the level and oil pressure switches are connected to status lights on the display panel.

The master control panel will contain five displays. These displays will show the field oil outlet temperature, steam termperature, steam pressure, oil flow rate and steam flow rate. Each display will provide over-range alarm in the form of a blinking display.

F. DATA ACQUISITION

The on-line data acquisition system (ODAS) is completely independent of the process control function. It's sole purpose is to collect and store sufficient operating data to evaluate the performance of the solar energy system. The basic philosophy is to make absolute measurements of the quantities of interest, transfer these data through a signal conditioner, if required, and into the memory of a computer. The necessary calibration factors would be applied to each piece of data to convert it to the appropriate engineering units, and the results used to compute various system performance parameters. All pertinent data thus obtained will be stored on magnetic tape or hard disc for further system evaluation and analysis.

The data acquisition system will be designed to incorporate the following features:

(a) Capable of scanning and processing data from at least 20 channels with modular expansion to 120 or more channels.

(b) Input DC voltage from a few milliwatts to 20 VDC. Unit will be capable of withstanding accidental connection to 120V AC to inputs without damage.

(c) The A/D converter will have a minimum of 12 bits resolution.

(d) A standard line printer for output of hourly and daily reduced data.

(e) Nine-track 1600 BPI magnetic tape or sealed, hard disc capable of storing at least one week of operational information.

(f) A minimum of two RS232C ports for connection to additional peripherals and for possible telecommunications use.

(g) Battery powered real-time clock to provide timing information to the system.

(h) Selectable single channel digital readout in engineering units.

(i) Capability to provide output with on-line printer or digital readout without disturbing data acquisition or data output to storage.

(j) The operating programs and stored data shall be unaffected by power outages, and power failures shall not disturb data filed on tape or disc.

(k) The system will be immune to line and environmental electrical interference. Analog inputs shall be capable of rejecting 120 db of common mode noise at 60 Hz.

(l) Programmable in a high level language to perform time summation, averages, manipulation of input data, and polynomial calibration factors for direct sensor data. The system will provide diagnostic plain text messages to flag subsystem operating problems.

(m) The computer system will be operational in the temperature and relative humidity range of $5^{\circ}C$ to $40^{\circ}C$ and 5% to 90% respectively. The system shall be kept in a sheltered environment during operations.

(n) System operation shall have a software protected operating mode. Only by input of a user supplied password will the operator be allowed to modify or halt the operation of the ODAS function.

(o) System shall include a high/low printed and displayed alarm flag.

(p) Sensor sampling and summing rate shall be variable from channel to channel and operator selectable. Time periods will be from 10 seconds to 10 minutes.

(q) System shall provide diagnostic plain text messages to flag operating problems in the solar energy system, data acquisition system, or the sensors.

Conceptually, the system will consist of a computer controller, a data storage medium, a scanner/data collection interface, signal conditioner and the sensors. Control of the scanner/data collection interface is to be performed by the computer controller via the IEEE-488 General Purpose Interface BUS.

IV. DETAILED DESIGN

A. Collector Array Performance

Estimate of Available Insolation

Ideally, in order to accurately simulate yearly sola collector field performance, long term insolation data must be available at the site. However, at HCPC no such long term dire normal insolation data exists. Therefore, one can only estimat average insolation values from values available from nearby sites, or derive values from clear day insolation calculations adjusted by meteorological conditions at the site or at nearby weather stations. On the island of Hawaii, several stations (including one in Hilo) have gathered global insolation data over many years, but have not measured either diffuse or direct normal insolation. The Cloud Physics Observatory at Hilo (HCPC has measured direct normal, diffuse and global radiation since September of 1978. However, this HCPO data is not directly useful in estimating HCPC insolation because:

(1) is it only short term data and therefore cannot be considered representative of the long term average insolation conditions, and

(2) the average insolation conditions at HCPO are significantly different from those at HCPC due to the meteorological (i.e., cloud cover) differences between the two sites.

Table IV-1 shows measured differences in insolation between the two. HCPC not only experiences higher global radiation, but also has a lower percentage of diffuse radiation than HCPO. Therefore, average direct normal insolation estimates for simulation purposes have been based upon ASHRAE clear day direct normal insolation values for 20^{O}N latitude reduced by monthly average percent possible sunshine at the HCPC site.

Monthly percent possible sunshine numbers for the HCPC site have been derived from long term percent possible sunshine numbers for Hilo which are published in the NOAA climatic atlas. These values were adjusted for use at the HCPC site by multiplying by the ratio of the average direct radiation on a

TABLE IV-1 COMPARISON OF SITE & HCPO INSOLATION CHARACTERISTICS

	$\frac{DIFF}{GLBL_{SITE}}$	$\frac{DIFF}{GLBL_{HCPO}}$	$\frac{(GLBL)_{SITE}}{(GLBL)_{HCPO}}$	$\frac{(BEAM\ ON\ HORIZ)_{SITE}}{(BEAM\ ON\ HORIZ)_{HCPO}}$
NOV	0.48	0.57	1.12	1.33
DEC	0.41	0.45	1.04	1.13
JAN	0.34	0.40	1.13	1.23
FEB	0.41	0.51	1.12	1.33
AVE	0.41	0.48	1.10	1.26

horizontal surface (global minus diffuse) measured at HCPC from November 1979 to February 1980, to the average direct radiation on a horizontal surface at HCPO during the same months: 1.26, as shown in Table IV-1.

Though this technique is not completely accurate, it is considered reasonable in this case in which very little data is available. In fact, Table IV-2 compares the adjusted ASHRAE direct normal insolation values used, for the months in which data was taken at HCPC, and the actual insolation data On the average, our estimates are shown to be slightly less than the measured insolation at HCPC. Therefore, our predicted yearly solar system output is expected to be reasonably representative of actual average year output, or at least may be slightly conservative. (Additional insolation data, only made available at the writing of this report, for the months of March and April 1980, show even greater variance between direct insolation at the site and the Cloud Physics Observatory. The ratios of beam radiation on a horizontal surface at HCPC to that at HCPO have been found to be 1.9 and 2.7 for the months of March and April, 1980, respectively, highly demonstrative of the different insolation levels at locations separated by only about 10 miles.)

<u>Collector Array Performance Simulation</u>

As stated previously, TEAM, Inc., has developed a parabolic trough performance simulation code, PARABL, which was used to model the average year thermal output of the collector array designed for HCPC. All of the pertinent SKI T-700 parameters, e.g. peak noon efficiency curve, physical dimension incidence angle modifier, etc., were input along with monthly average ambient temperatures at Hilo, and hourly gross thermal output was computed for clear days of each month. As described in the last section, clear day insolation data input to the code was ASHRAE direct normal data for 20°N latitude reduced by a 0.95 clearness factor. Average monthly output was then calculated by reducing the clear month output by the long term

TABLE IV-2 COMPARISON OF MEASURED SITE INSOLATION vs ESTIMATED INSOLATION

	A(Btu/Hr-Ft^2)	B(Btu/Hr-Ft^2)	A/B
NOV 79	580.7	585	0.99
DEC 79	705.7	564	1.25
JAN 80	927.8	845	1.10
FEB 80	849.1	922	0.92
			1.07 AVE

A = Ave beam insolation on horizontal surface, measured at HCPC

B = ASHRAE clear day beam insolation on horizontal surface at 20^{0}N lat, times Hilo % possible sunshine, times 1.26 (adjustment from HCPO to HCPC) average monthly percent possible sunshine numbers for Hilo, adjusted by the factor of 1.26 (average measured ratio of beam radiation on a horizontal surface at HCPC to that of HCPO during the four-month period for which that data was available). Figure IV-1 shows how those average monthly outputs vary throughout a year. The gross thermal output from the array at HCPC during an average year then was computed to be 1.02×10^{10} Btu's. A computer study was performed to determine the effect of the slope variations in the collector field at HCPC and it was determined that the yearly gross collector output was only reduced by about 1% compared to a flat field. Therefore, a factor of 0.99 was used to reduce the expected field outpot.

PARABL Computer Printout of HCPC SIPH System

The following printout shows the hourly computed solar array output for a clear day of each month. The total monthly outputs shown are the total clear monthly outputs reduced by the percent possible sunshine numbers for Hilo, Hawaii. The other parameters shown are the fractions of the array aperture area which is not shaded at a given hour, the clear day direct normal insolation values input, the solar altitude above the horizon at a given hour, and the collector array overall efficiency for each hour.

B. Site Preparation and Grading Requirements

Existing and Proposed Topography

The existing topography of the proposed site is detailed in Figure IV-2. The field has a natural grade of 10% sloping down toward the northeast. The solar collectors will be oriented in the north/south direction and must be relatively level along this axis. Figure IV-3 outlines the topography that is required for the collector array.

To accommodate the collector configuration, the field will be graded to form two tiers. Both tiers will have a gradual upward slope from east to west averaging 4% with a maximum grade of 14% for the most northwesterly group of

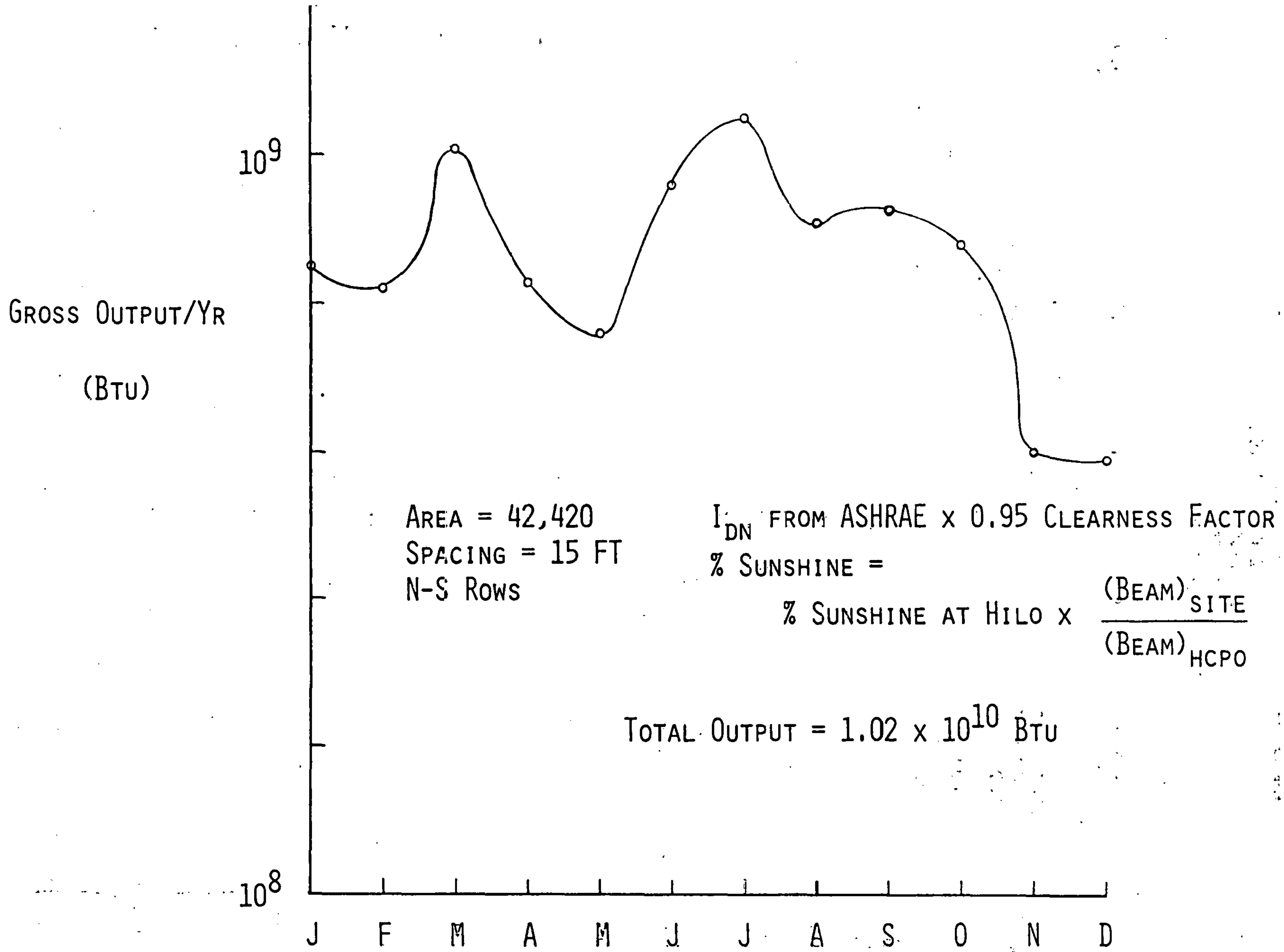


FIGURE IV-1 COLLECTOR FIELD GROSS OUTPUT THROUGH AVE YEAR

HCPC SIPH PERFORMANCE
NORTH-SOUTH

42,420 Ft^2

JAN 17 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
6 :AM	0	1	0	-9.21674	0
7 :AM	0	.2362	100.7	3.90437	0
8 :AM	.328086E 7	.720881	238	16.4628	.324968
9 :AM	.555891E 7	1	279.3	28.1032	.469189
10 :AM	.556984E 7	1	296.9	38.1932	.442244
11 :AM	.543774E 7	1	305	45.6534	.420289
12:NOON	.534732E 7	1	307.3	49.0167	.410207
1 :PM	.536989E 7	1	305	47.3019	.415045
2 :PM	.545417E 7	1	296.9	41.0405	.43306
3 :PM	.542756E 7	1	279.3	31.6815	.458103
4 :PM	.411455E 7	.87847	238	20.4688	.407544
5 :PM	54194.1	.398803	100.7	8.16654	.126868E-1
6 :PM	0	1	0	-4.79529	0

AVERAGE EFFICIENCY OF CLEAR DAY .344849

TOTAL CLEAR DAY OUTPUT .45615E 8
TOTAL MONTH OUTPUT .678752E 9

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FEB 16 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
6 :AM	0	1	0	-7.60918	0
7 :AM	298422	.291565	159.1	6.08773	.442171E-1
8 :AM	.429647E 7	.778022	254.1	19.3939	.398599
9 :AM	.63706E 7	1	286	32.0198	.525102
10 :AM	.645386E 7	1	300.7	43.3935	.505959
11 :AM	.638134E 7	1	307.3	52.3506	.48953
12:NOON	.631411E 7	1	309.2	56.862	.481396
1 :PM	.631096E 7	1	307.3	55.1538	.48413
2 :PM	.633445E 7	1	300.7	47.9783	.496598
3 :PM	.623626E 7	1	286	37.5356	.514029
4 :PM	.56536E 7	.994949	254.1	25.3962	.524506
5 :PM	.127341E 7	.521184	159.1	12.3593	.188681
6 :PM	0	1	0	-1.1808	0

AVERAGE EFFICIENCY OF CLEAR DAY .422977

TOTAL CLEAR DAY OUTPUT .559235E 8
TOTAL MONTH OUTPUT .65766E 9

R 16 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	=============	= ======	== ===	===== ===	==========
:AM	0	1	0	-2.93305	0
:AM	.139375E 7	.444938	187.6	11.1214	.175138
:AM	.565894E 7	.924128	256	25.0119	.521104
:AM	.679689E 7	1	282.2	38.5297	.567783
) :AM	.69923E 7	1	295	51.2234	.558763
1 :AM	.701887E 7	1	300.7	61.9037	.550254
2:NOON	.7012E 7	1	302.6	67.4637	.546264
:PM	.699305E 7	1	300.7	64.3196	.54823
:PM	.69495E 7	1	295	54.7299	.555343
:PM	.675092E 7	1	282.2	42.4568	.563943
:PM	.616788E 7	1	256	29.1199	.56797
:PM	.217042E 7	.592498	187.6	15.3129	.272734
:PM	0	.922804E-1	0	1.29212	0

AVERAGE EFFICIENCY OF CLEAR DAY .493411

TAL CLEAR DAY OUTPUT .639045E 8
TAL MONTH OUTPUT .812227E 9

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R 15 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	=============	= ======	== ===	===== ===	==========
:AM	0	.172134	25.7	3.21331	0
:AM	.254702E 7	.649373	190	17.2177	.316015
:AM	.598513E 7	1	243.2	31.3042	.580149
:AM	.660831E 7	1	266	45.3614	.58565
) :AM	.690095E 7	1	277.9	59.1861	.585396
1 :AM	.702095E 7	1	283.6	72.0631	.583605
2:NOON	.704396E 7	1	285	79.4047	.582641
:PM	.702095E 7	1	283.6	72.0631	.583605
:PM	.690095E 7	1	277.9	59.1861	.585396
:PM	.660831E 7	1	266	45.3614	.58565
:PM	.598513E 7	1	243.2	31.3042	.580149
:PM	.254702E 7	.649373	190	17.2177	.316015
:PM	0	.172134	25.7	3.21331	0

AVERAGE EFFICIENCY OF CLEAR DAY .452636

TAL CLEAR DAY OUTPUT .651687E 8
TAL MONTH OUTPUT .66472E 9

#################################

MAY 15 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============ =	======	== ===	===== ===	==========
6 :AM	0	.327733	61.8	7.00515	0
7 :AM	.314182E 7	.782205	188.1	20.5982	.393752
8 :AM	.565295E 7	1	233.7	34.4155	.570225
9 :AM	.630897E 7	1	255.1	48.3785	.583012
10 :AM	.663972E 7	1	266	62.432	.588434
11 :AM	.680464E 7	1	271.7	76.5229	.590398
12:NOON	.685686E 7	1	273.6	88.6005	.590798
1 :PM	.680504E 7	1	271.7	75.1146	.590433
2 :PM	.663868E 7	1	266	61.0239	.588342
3 :PM	.630572E 7	1	255.1	46.9773	.582711
4 :PM	.564626E 7	1	233.7	33.0261	.569549
5 :PM	.290134E 7	.737858	188.1	19.2273	.363613
6 :PM	0	.281353	61.8	5.66235	0

AVERAGE EFFICIENCY OF CLEAR DAY .462405

TOTAL CLEAR DAY OUTPUT .63702E 8
TOTAL MONTH OUTPUT .612176E 9

###################################

JUN 11 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============ =	======	== ===	===== ===	==========
6 :AM	0	.367207	71.3	7.71873	0
7 :AM	.314205E 7	.811019	184.8	20.9808	.400812
8 :AM	.541276E 7	1	228	34.5089	.559646
9 :AM	.607944E 7	1	248.9	48.2054	.575795
10 :AM	.643182E 7	1	259.8	61.9905	.583612
11 :AM	.660196E 7	1	265.1	75.736	.587074
12:NOON	.666132E 7	1	267	86.9371	.588137
1 :PM	.660196E 7	1	265.1	75.736	.587074
2 :PM	.643182E 7	1	259.8	61.9905	.583612
3 :PM	.607944E 7	1	248.9	48.2054	.575795
4 :PM	.541276E 7	1	228	34.5089	.559646
5 :PM	.314205E 7	.811019	184.8	20.9808	.400812
6 :PM	0	.367207	71.3	7.71873	0

AVERAGE EFFICIENCY OF CLEAR DAY .461694

TOTAL CLEAR DAY OUTPUT .619974E 8
TOTAL MONTH OUTPUT .762568E 9

###################################

JUL 17 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============	= ======	== ===	===== ===	==========
6 :AM	0	.293738	58	5.79578	0
7 :AM	.273476E 7	.744947	180	19.1742	.358159
8 :AM	.537706E 7	1	225.6	32.816	.561869
9 :AM	.605046E 7	1	247	46.6302	.577459
10 :AM	.641033E 7	1	258.4	60.5538	.584813
11 :AM	.65873E 7	1	264.1	74.5321	.587988
12:NOON	.663097E 7	1	265.5	88.1704	.588765
1 :PM	.658861E 7	1	264.1	77.327	.588105
2 :PM	.641442E 7	1	258.4	63.347	.585186
3 :PM	.605975E 7	1	247	49.4079	.578345
4 :PM	.539364E 7	1	225.6	35.5673	.563602
5 :PM	.318664E 7	.832145	180	21.8849	.41734
6 :PM	0	.385429	58	8.44457	0

AVERAGE EFFICIENCY OF CLEAR DAY .460895

TOTAL CLEAR DAY OUTPUT .614339E 8
TOTAL MONTH OUTPUT .837959E 9

####################################

AUG 14 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============	= ======	== ===	===== ===	==========
6 :AM	0	.199292	21.9	3.66506	0
7 :AM	.231966E 7	.667377	173.9	17.4809	.314452
8 :AM	.55586E 7	1	228.5	31.4713	.573467
9 :AM	.625679E 7	1	252.2	45.5506	.584838
10 :AM	.659699E 7	1	264.6	59.6222	.58774
11 :AM	.674024E 7	1	270.3	73.4261	.58784
12:NOON	.678477E 7	1	272.2	84.0356	.587593
1 :PM	.673765E 7	1	270.3	75.6342	.587613
2 :PM	.659365E 7	1	264.6	61.955	.587442
3 :PM	.625541E 7	1	252.2	47.8998	.584709
4 :PM	.556402E 7	1	228.5	33.8138	.574026
5 :PM	.270162E 7	.743526	173.9	19.803	.366229
6 :PM	0	.278092	21.9	5.95122	0

AVERAGE EFFICIENCY OF CLEAR DAY .456612

TOTAL CLEAR DAY OUTPUT .621094E 8
TOTAL MONTH OUTPUT .731649E 9

####################################

SEPT 15 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============	= ======	== ===	===== ===	=========
6 :AM	0	.113296	0	1.9619	0
7 :AM	514639	.609129	85	16.0511	.142729
8 :AM	.578039E 7	1	238	30.0551	.572545
9 :AM	.646856E 7	1	265.5	43.7852	.574345
10 :AM	.673902E 7	1	278.8	56.8089	.569814
11 :AM	.684586E 7	1	285.5	67.7652	.565264
12:NOON	.687187E 7	1	287.4	72.233	.56366
1 :PM	.685581E 7	1	285.5	66.2122	.566085
2 :PM	.675508E 7	1	278.8	54.7235	.571172
3 :PM	.648495E 7	1	265.5	41.5288	.575799
4 :PM	.578864E 7	.999529	238	27.7334	.573362
5 :PM	317424	.527491	85	13.7052	.880338E-1
6 :PM	0	1	0	-.385768	0

AVERAGE EFFICIENCY OF CLEAR DAY .487528

TOTAL CLEAR DAY OUTPUT .594222E 8
TOTAL MONTH OUTPUT .74872E 9

####################################

OCT 15 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
====	============	= ======	== ===	===== ===	=========
6 :AM	0	.700181E-1	0	.234381	0
7 :AM	.129194E 7	.566227	144.4	13.9656	.210914
8 :AM	.549254E 7	1	240.4	27.2757	.538602
9 :AM	.615441E 7	1	273.6	39.8001	.530274
10 :AM	.632885E 7	1	288.8	50.7567	.516603
11 :AM	.635853E 7	1	295.9	58.4509	.506572
12:NOON	.637313E 7	1	297.8	60.2277	.504495
1 :PM	.642064E 7	1	295.9	55.1684	.51152
2 :PM	.643329E 7	1	288.8	45.5515	.525128
3 :PM	.627002E 7	1	273.6	33.6708	.540234
4 :PM	.431668E 7	.806099	240.4	20.6902	.423297
5 :PM	323863	.319922	144.4	7.13823	.528718E-1
6 :PM	0	1	0	-6.72612	0

AVERAGE EFFICIENCY OF CLEAR DAY .441865

TOTAL CLEAR DAY OUTPUT .557639E 8
TOTAL MONTH OUTPUT .708759E 9

####################################

NOV 14 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
6 :AM	0	1	0	-2.99593	0
7 :AM	178623	.463125	95.5	10.1006	.440922E-1
8 :AM	.442143E 7	.940208	231.3	22.5525	.450626
9 :AM	.546695E 7	1	274.1	33.9183	.470181
10 :AM	.555247E 7	1	292.1	43.3877	.44811
11 :AM	.550833E 7	1	300.2	49.5982	.432552
12:NOON	.551161E 7	1	302.6	50.9587	.429377
1 :PM	.560144E 7	1	300.2	47.0061	.439864
2 :PM	.571081E 7	1	292.1	38.9613	.460888
3 :PM	.564554E 7	1	274.1	28.4106	.485541
4 :PM	.317476E 7	.704759	231.3	16.4286	.323568
5 :PM	0	.218515	95.5	3.61445	0
6 :PM	0	1	0	-9.70476	0

AVERAGE EFFICIENCY OF CLEAR DAY .362254

TOTAL CLEAR DAY OUTPUT .467719E 8
TOTAL MONTH OUTPUT .477074E 9

###################################

DEC 10 OUTPUT

HOUR	BTU/HR(FIELD)	% UNSHAD	DN INS	SOLAR ALT	EFFICIENCY
6 :AM	0	1	0	-6.15242	0
7 :AM	0	.349468	70.3	6.64017	0
8 :AM	.353062E 7	.83022	228	18.7503	.365044
9 :AM	.513913E 7	1	274.6	29.7512	.441182
10 :AM	.516512E 7	1	294	38.91	.414155
11 :AM	.505964E 7	1	302.6	45.0771	.394166
12:NOON	.502149E 7	1	305	46.9424	.388116
1 :PM	.511018E 7	1	302.6	43.9787	.398104
2 :PM	.52513E 7	1	294	36.9916	.421065
3 :PM	.523666E 7	1	274.6	27.3158	.449556
4 :PM	.298785E 7	.719543	228	16.0042	.308925
5 :PM	0	.236087	70.3	3.70496	0
6 :PM	0	1	0	-9.20642	0

AVERAGE EFFICIENCY OF CLEAR DAY .325483

TOTAL CLEAR DAY OUTPUT .42502E 8
TOTAL MONTH OUTPUT .474322E 9

###################################

TOTAL AVERAGE YEAR OUTPUT = .816659E 10 $X .99^{(1)} X\ 1.26^{(2)} = 1.02 \times 10^{10}$ Btu[3]
AVERAGE YEAR THERMAL EFFICIENCY = .524298
(1) Field Slope Adjustment
(2) HCPC Beam vs HCPO Beam Adjustment
(3) Adjust by 305/365 for gross useable output

Figure IV-2

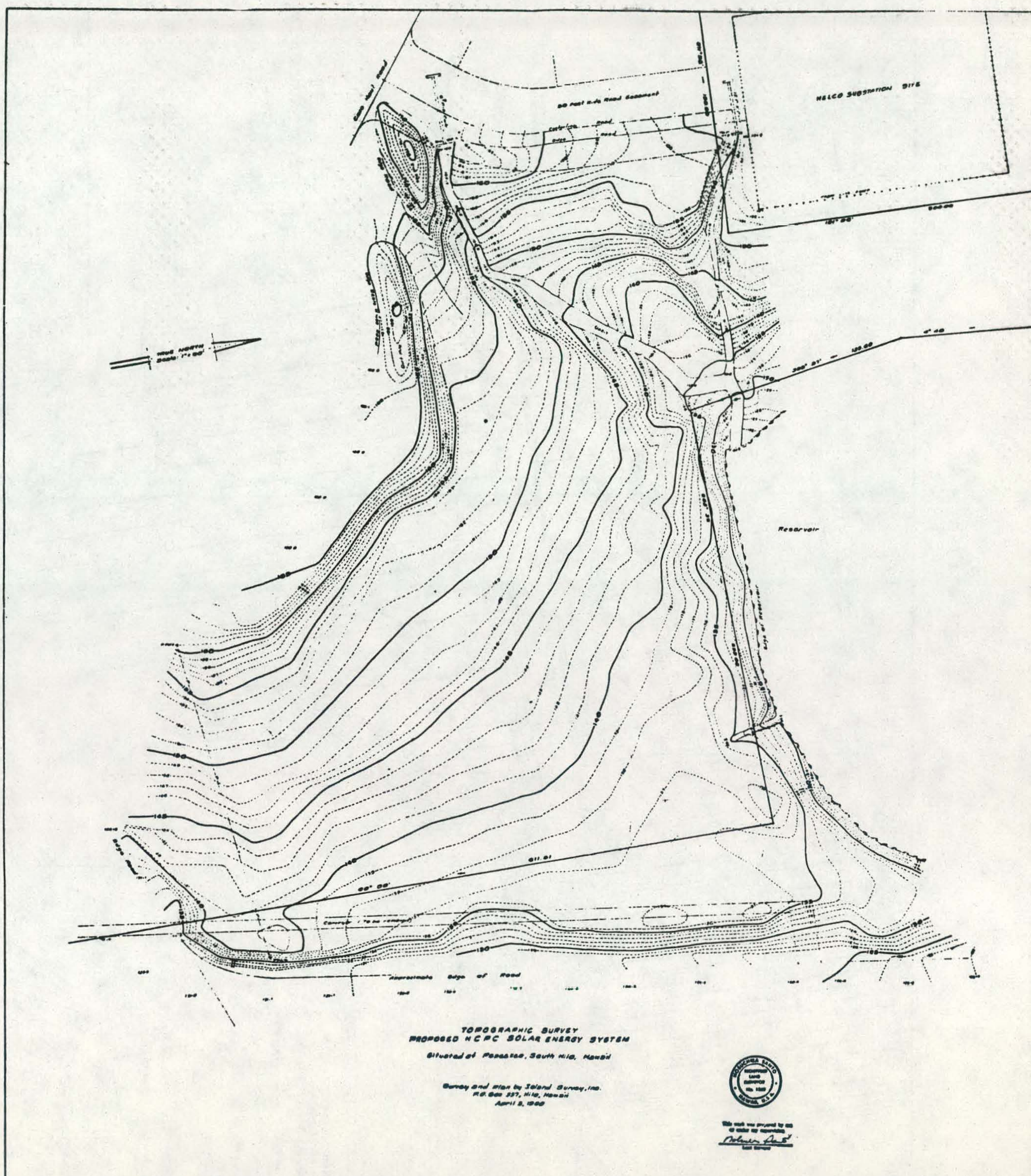
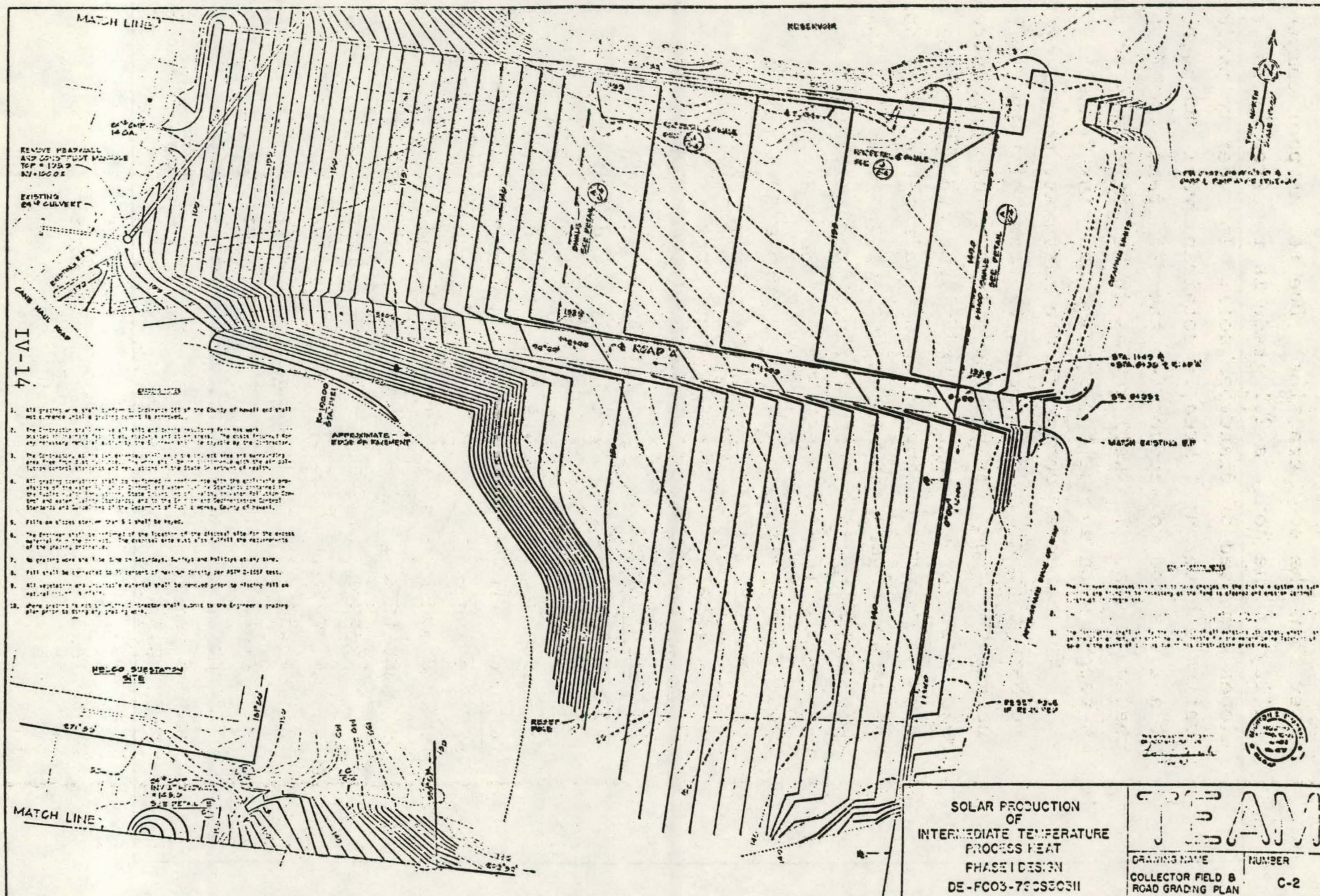

HELCO SUBSTATION SITE
Reservoir
Approximate Edge of Road
TOPOGRAPHIC SURVEY
PROPOSED HCPC SOLAR ENERGY SYSTEM
Survey and plan by Island Survey, Inc.

Figure IV-3


MATCH LINE
RESERVOIR
APPROXIMATE EDGE OF EASEMENT
MATCH EXISTING E.P.
HELCO SUBSTATION SITE
MATCH LINE
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DRAWING NAME
COLLECTOR FIELD 8
ROAD GRADING PLAN
NUMBER
C-2

collectors. The northern tier will be an average of seven feet lower than the southern tier. Due to the poor compacting ability of the soil, a 2:1 grade is required by the state for slopes composed of disturbed soil. In order to maximize the available horizontal area, a retaining wall has been used inste of a 2:1 slope to account for the difference in height between the two tiers. The wall varies in height from 4 to 10½ feet ar is topped with a four foot tall chain link fence.

The notched section in the northwest corner of the southern tier will accommodate two rows of three collectors and has been included because only cutting is required. The major cost for grading is for filling and compacting new soil. A cut is relatively inexpensive requiring only bulldozer work. The unique expense for these collectors is the additional 140 feet of 1½ inch diameter pipe required to reach them. On a cost per million Btu's delivered, the energy from these collectors is approximately $15/MMBtu more expensive than the energy from the rest of the field or approximately 9% more. Since these collectors will yield the energy equivalent of 30 barrels of oil per year, it is felt the small premium is justified.

Collector Accessibility

A 15 foot wide gravel road divides the two tiers and provides access to the northern section of collectors. Cleanin or maintenance equipment can be rolled down every other collect row and a large enough turning radius is available for small service vehicles. Access to the southern collector array is limited by the above ground supply and return headers which run east to west through the middle of the section. To access the collectors bordered by the retaining wall and the main headers, moveable ramps will be fabricated which can span the headers and support the weight of a light vehicle.

Field access will be required primarily only for periodic collector cleaning. This will probably entail a small, wagon mounted compressor and about 150 feet of hose that can be pulled through the rows and possibly lifted over the headers. Vehicular access should only be required for major maintenance operations such as complete collector replacement.

Additional Site Preparation Requirements

Two swales will traverse the field in the north-south direction to assist in water runoff. Along the north edge of the collector field, filling the swales, bordering the reservoir and enclosing the pump house, will be 9 inch tall crushed rock berm. The purpose of the berm is for fluid containment in case of a major pipe rupture. It will consist of crushed rock ½ to 3 inches in diameter and coarse sand. The berm will be porous enough to allow rainwater to filter through yet will act as a dam for the viscous heat transfer fluid at ambient temperatures.

Another site preparation feature is the installation of approximately 150 feet of 24 inch storm drain in the northwest corner of the field. The proposed grading plan calls for filling the existing ravine which now serves as an open channel for runoff from the surrounding fields. The storm drain is needed to replace the open channel and provide for runoff.

C. Piping Design

1. Sizing Criteria

The philosophy that was followed throughout the preliminary and detailed design was to make the system as energy efficient as possible. In keeping with this design philosophy, a major analysis was performed to optimize pipe sizes throughout the system.

The two primary impacts that pipe size has on energy efficiency are in pumping costs and heat losses. Large diameter pipes, for example, experience a low friction loss and consequently minimize pumping costs; however, the large diameter pipes also have a large heat transfer surface area so heat losses are large. In addition, the large diameter pipes will have a large thermal capacity so overnight thermal losses are increased. These two factors, heat loss and pumping costs, were traded off during the analysis to determine the optimum diameter for various flow rates.

The analysis consisted of the following steps:

o determine relationship between diameter and pumping power.

- determine relationship between diameter and 24 hour heat loss.
- total the pumping power and heat loss for specific flow rates, and
- identify optimum flow range for each diameter.

The relationship between diameter and pumping power is expressed in the equation below;

$$H_L = F \frac{L}{D} \frac{V^2}{2g}$$

where

H_L = head loss or energy loss
F = friction factor
L = length of pipe
D = diameter
V = fluid velocity
g = gravitational constant

For the analysis, flow rates were fixed and the head loss associated with different diameter pipes was calculated. Pumping efficiencies were estimated and a gross power requirement assigned to each flow rate/diameter pair on a linear foot of pipe basis.

Operational and overnight heat losses were also calculated on a linear foot basis for the various pipe diameters. These values were adjusted for boiler efficiency to arrive at a gross power requirement.

The two power requirements, pumping and heat losses, were totaled to determine the gross power requirement for the fixed flow rates using different diameter pipe. Table IV-3 details the results of the analysis and Figure IV-4 depicts the results in a graphical form.

As expected, for a range of flow rates, there is one pipe diameter that will minimize power consumption or conversly maximize energy efficiency. For the HCPC system, the diameter versus flow rate combination that minimize energy consumption are:

TABLE IV-3

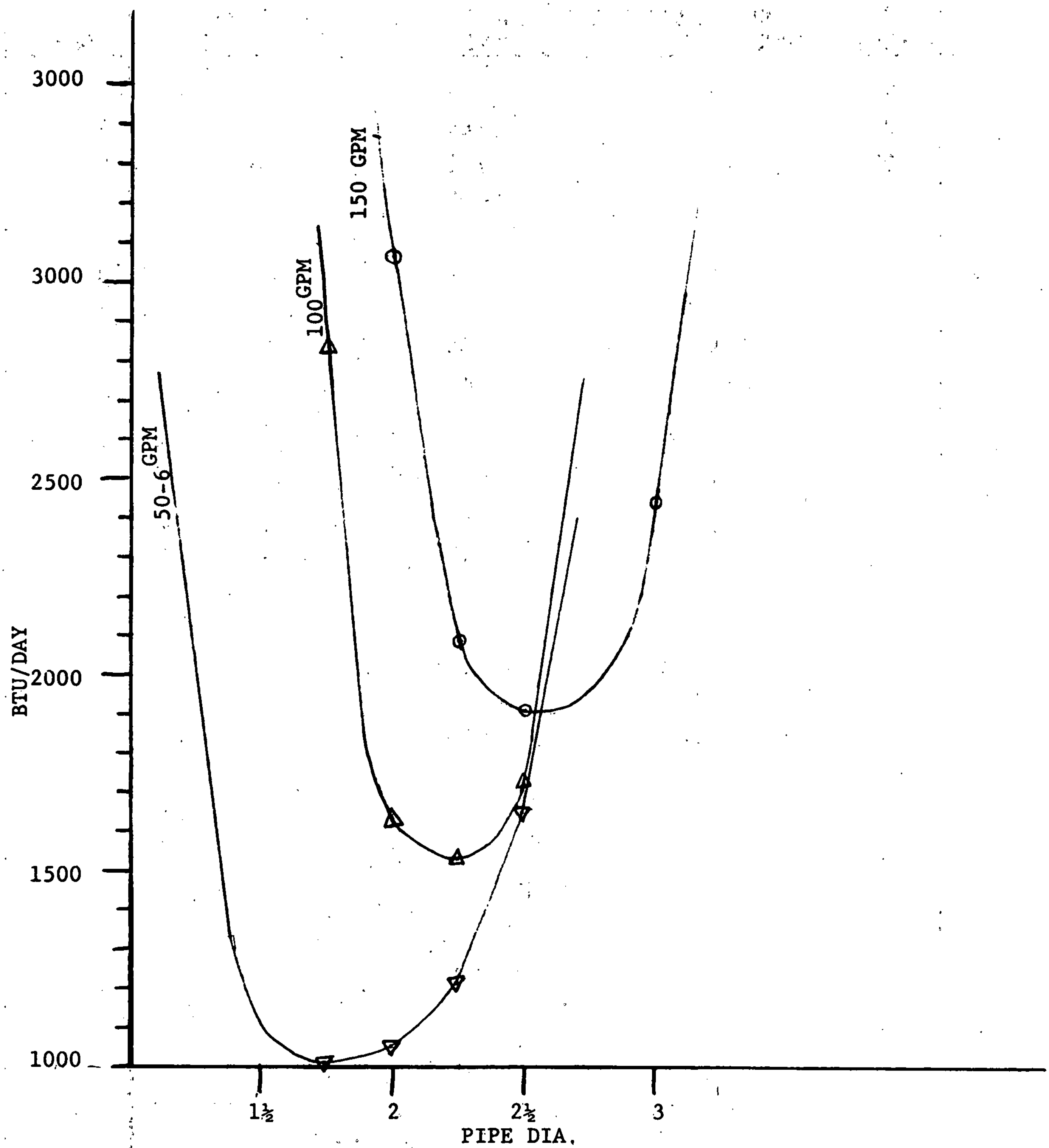
PIPE SIZING ANALYSIS - TABULATED RESULTS

FLOW (GPM)	DIA. (IN)	PUMP ENERGY (BTU/DAY)	ADJ PUMP ENERGY* (BTU/DAY)	HT. LOSS (BTU/DAY)	TOTAL (BTU/DAY)
150	4	10	64	2378	2442
	3	41	265	1642	1907
	2½	124	798	1290	2088
	2	326	2099	973	3072
100	3	13	84	1642	1726
	2½	38	245	1290	1535
	2	101	650	973	1623
	1½	324	2086	745	2831
50	3	2	13	1642	1655
	2½	5	32	1290	1322
	2	13	84	973	1057
	1½	42	270	745	1015

*Adjusted by ratio of electricity costs to oil costs.
Electricity costs: $0.09/KWH = $26.40 X 10^{-16}/Btu
Oil costs: $25.22/Barrel = $4.1 X 10^{-6}/Btu
Cost ratio: 6.4:1

FIGURE IV-4

PIPE SIZING ANALYSIS - GRAPHICAL RESULTS



Flow	Diameter
120-220 GPM	3"
80-120	2½"
60-80	2"
0-60	1½"

The flow rates used to layout the piping network correspond to average insolation conditions. A pumping penalty will be incurred during peak insolation periods due to the undersized pipe, however, this is acceptable since peak conditions occur relatively few times during the year.

2. Flow and Pressure Drops

The flow rates corresponding to peak, average and minimum insolation conditions are 340, 237, and 188 gallons per minute respectfully. This translates into a flow rate of 1.1, 0.8 and 0.6 gpm per collector for the three flow conditions. Most collector series consist of 12 collectors, however, a few consist of only 6, 7, 8 or 10 collectors in series. The solar kinetics' receiver tube has been designed to include a removeable twisted steel ribbon that induces turbulent flow at low flow rates through the receiver.

The HCPC system was analyzed to determine if the turbulators were needed or if even at the lowest flow rate turbulent flow would occur. The highest flow rate of 13.5 gpm will occur in the 12 collector series under peak insolation. The lowest flow rate of 3.7 gpm will occur in the 6 collector series under minimum insolation. The analysis indicated that the turbulators are required for all of the collectors to insure turbulent flow conditions. Even at the highest flow rates (13.5 gpm), the Reynolds number is approximately 24,000 which means the flow is not fully turbulent. The turbulators will provide the additional "roughness" to insure that receiver flow conditions match the conditions during efficiency testing and that the collectors will perform as predicted.

Table IV-4 lists the flow rates, head loss and pump RPM's corresponding to peak, average and minimum insolation levels for both the heat transfer fluid pump and the feedwater pump.

Flow through the collector field will vary directly with the level of insolation as measured by the field outlet temperature. The flow rate will be controlled by a motor controller which varies the motor's RPM's. The HTF pump has a rated speed of 3500 RPM's, however, a 9% slip will occur between the motor controller and the motor so that peak RPM's will be 3185 and average will be 2208. The feedwater pump, however, will be a constant speed pump and will account for variations in insolation by operating for different lengths of time.

Pressure drops through the system have been calculated for maximum, average and minimum flows and are listed in Table IV-4. It is interesting to note that with a 44% increase in flow rate (average to maximum) the head loss increases by almost 100%. As a percentage of total pressure drops, individual components can be represented as follows:

Component	% of Total Head
Collector series	10%
Field piping	60%
Steam Generator	30%

3. Flow Balancing

Balancing Requirements

As indicated in Table IV-4, there is a substantial difference in pressure drop from minimum to maximum flow rates (76-288 feet of head). In addition, with 60% of the pressure drop occurring in the supply and return headers, there is a substantial difference in collector inlet pressures. The collector series closest to the pump house will have an inlet pressure close to 88 feet during average flow while the series farthest from the pump house will have an inlet pressure close to 47 feet.

TABLE IV-4

PUMPING CONDITIONS

H T F PUMP	MAXIMUM	AVERAGE	MINIMUM
Flow (gpm)	340	237	187
Head (Ft H_2O)	288	147	76
Speed (RPM)	3185	2208	1750
F.W. PUMP			
Flow (gpm)	16	11	8
Head (Ft H_2O)	420	420	420
Speed (RPM)	1750	1750	1750

This pressure differential will result in flow imbalances throughout the field with the collectors closest to the pump house receiving most of the flow since the fluid will travel the path of least resistance. The potential problem with a flow imbalance is that the flow to the collectors at the end of the header could be so slow that the fluid would reach the maximum allowable temperature ($600^{O}F$ for the T-700) and the collector would stow. Once the collector is stowed due to fluid overtemperature, it no longer collects available energy and it must be manually reactivated.

To avoid this condition, adjustable balancing valves will be placed at the inlet to each collector series. The valves will artificially create a pressure drop at the collector inlet which will counterbalance the variation in pressure due to the collector's position along the manifold. In this way, each collector series flow loop (pump to collector and back) will have the same pressure drop and the fluid will flow equally through all collectors.

To minimize the complexity of the piping network, a passive balancing system has been incorporated. That is, the balancing valves will be adjusted and set at system start-up, so that flow through all collector series is completely balanced. The valves will then be "locked" in place (i.e.; adjusting handles removed) and will become a passive element in the network from then forward. Temperature control valves, which automatically control the flow through a collector series by opening or closing based on fluid temperature, were considered as a means of balancing the system, however, because of temperature limitations, increased complexity, added failure potential and the additional costs associated with the valves, this option was eliminated.

The system will be completely balanced for average flow conditions (total field flow of 237 gpm) during system start-up and the valves locked in place at this setting. This will yield equal outlet temperatures from all collector rows regardless of their position in the field or the number of collectors in series. At flow rates other than average, a flow imbalance may occur. However, this will not be detrimental to system performance because the variation in outlet temperatures will not be so large as to cause fluid overtemperature and collector stowing. All outlet temperatures during average flow will be at a relatively constant 450°F. This provides a 150°F "cushion" before collectors begin to stow. If, however, during system operation, collectors did continuously reach the overtemperature condition, adjustments could be made to the field flow pattern via the balancing valves and acceptable set points could be experimentally determined.

Partial Field Shading

An attempt was made during the detailed design to anticipate and analyze the systems reaction to cloud cover over part of the field.

Two scenarios were analyzed:

1) 50% of the field receives 25% of normal insolation while 50% receives 100% of normal insolation.

2) 75% of the field receives 25% of normal insolation while 25% receives 100% of normal insolation

The first scenario resulted in a maximum outlet temperature of 498°F from the collectors that received 100% of normal insolation while the shaded array outlet temperature was 402°F.

The second scenario resulted in a maximum outlet temperature of 553°F from the unshaded array and 347°F from the shaded array.

Indications from the analysis are that for steady state flow conditions, 80% partial field shading would result in overtemperature and stowing conditions for the unshaded collectors. It is realized, however, that steady state flow conditions will not exist with the variable flow design and that the flow rate will decrease as shading occurs. As the flow rate decreases, the fluid outlet temperature in the unshaded collectors will increase and approach the stow temperature.

Collector stowing due to partial field shading is not considered a major potential problem because of the transient nature of clouds and the thermal capacity of the system. It is highly unlikely that a specific portion of the collector fluid will be shaded for continuous period while the rest of the field receives full sun. In addition, the system will contain approximately 1100 gallons of fluid and at the average pumping rate of 237 gpm it will take close to three minutes before the shading effects would be felt.

4. Expansion Bellows

In keeping with the energy efficient design philosophy, expansion bellows instead of "U" expansion loops have been used to allow for pipe expansion and contraction as it is thermally cycled during the operational day. The disadvantages of the expansion loops are the increased heat transfer area and thermal mass of the additional piping. The expansion bellows are placed directly in line with the manifold pipes and welded in place eliminating up to 15 feet of additional pipe per bellows. With a total of 20 bellows deployed in the field, this is a savings of 300 feet of pipe and the associated thermal losses.

The bellows are stainless steel and will be welded in place for a lead tight seal. Under design conditions, the bellows will have a life of greater than 10,000 cycles which with one cycle per day will be 27+ years.

For additional safety and protection, three guides, spaced at 120^{o} around the pipe, have been provided to minimize torsional and squirm pressures on the bellows. Weep holes at the bottom of the aluminum jacket around the bellows will also be provided for early leak and failure identication.

Table IV-5 summarizes the expansion bellows sizing calculations. The required expansion is 3.6 inches and they have been specified for 4 inches of expansion capability.

5. Pipe Supports

Collector field piping will be ground mounted on either roller or fixed supports as detailed in the system plans. Collector footings adjacent to the supply and return manifolds have been enlarged to accommodate the pipe supports. This will reduce the labor requirement since three foundations, two pipe supports and one collector, will be included in one, while the material requirement will be slightly increased. The longest unsupported span is 10 feet with most supports being placed on 8 feet centers.

Roller supports will include a "C" shaped steel bracket that will be welded to the bottom side of the pipe. The bracket will sit on the support roller and prevent the pipe from sagging into and crushing the fiberglass insulation.

To allow free movement in the pump house, all pipes will be placed overhead and supported via ring or clevis type hangers.

Feedwater and steam pipes will be secured to existing overhead pipe racks throughout the plant.

TABLE IV-5

EXPANSION JOINT CALCULATIONS

Assumptions: Coefficient of Thermal Expansion (steel pipe)
6.8×10^{-6} in/in °F
Ambient Temperature - 60°F
Maximum Temperature - 550°F
Maximum distance between bellows - 90 ft.

Required Expansion:

$$(6.8 \times 10^{-6} \text{ in/in } ^\circ\text{F})\ (550-60^\circ\text{F})\ (90 \text{ ft})\ (12 \text{ in/ft})$$

$$= 3.6 \text{ inches}$$

Deflection capabilities specified = 4.0 inches.

D. Insulation and System Heat Losses

1. Insulation

The detailed design of the insulation subsystem remains unchanged from that proposed in the preliminary design. Major features include:

- the use of fiberglas insulation on all straight pipe runs and around welded connections;
- the use of cellular glass insulation around fiberglass and threaded connections with an impermeable barrier at the interface between the cellular glass and fiberglas insulations;
- the use of a .016 inch aluminum protective jacket on all outside piping;
- an insulation thickness schedule of 2 inches thick on pipe 2 inches in diameter and smaller, 2½ inches thick on pipe 2½ inches in diameter and larger and 2 inches thick on all equipment;
- providing weep holes in the underside of the aluminum jacket at expansion bellows, valves, control connections and other areas where a leak is likely to occur.

2. System Heat Losses

System heat losses can be categorized into 3 headings; pipe losses during system operation, pipe losses during system shut-down (herein called overnight losses) and equipment losses.

Operating pipe losses for a typical hour are tabulated in Table IV-6. For a six-hour operating day these losses total 1.03×10^6 Btu's.

Similarly overnight pipe losses for a typical day are tabulated in Table IV-7 and total 2.98×10^6 Btus. Overnight losses are almost 3 times higher than operational losses and are a major drawback to intermediate temperature SIPH systems. The problem arises because the fluid piping and insulation are at an average temperature of 410^oF when the system shuts down at night and by morning everything has cooled to ambient temperature.

The simplest solution is to find a secondary process that requires a lower grade heat and continue circulating the heat transfer fluid until the new minimum useable temperature is reached. At HCPC this is not possible since exhaust steam from the mill turbines is usually more than enough to satisfy the

TABLE IV-6

OPERATING PIPE HEAT LOSS SUMMARY

Pipe Dia.	Op. Temp.	Ht. Loss	Lin. Ft.	TOTAL
HTF Loop				
1½"	450°F	55 Btu/Hr-Ft.	350	19,250 Btu/Hr
	410	46	620	28,520
	370	39	350	13,650
2"	450	66	90	5,940
	370	45	90	4,050
2½"	450	71	440	31,240
	370	47	440	20,680
3"	450	76	70	5,320
	370	53	70	3,710
4"	450	90	20	1,800
	370	63	20	1,260
			SUBTOTAL	135,420
F W LOOP				
4"	415	77	360	27,720
1½"	204°F	13	630	8,190
			SUBTOTAL	35,910
			TOTAL	171,330/Btu/Hr

TABLE IV-7

OVERNIGHT PIPE HEAT LOSS SUMMARY

Pipe Dia.	Mat'l	Ht. Loss/Ft	Lin. Ft.	TOTAL
1½"	Pipe	107 Btu/Day-Ft	7,620	814,700 Btu/Day
	HTF	111	7,620	845,800
	Insul	97	1,320	128,050
2"	Pipe	143	180	25,750
	HTF	204	180	36,700
	Insul	92	180	16,550
2½"	Pipe	230	880	202,400
	HTF	315	880	277,200
	Insul	119	880	104,700
3"	Pipe	301	140	42,150
	HTF	454	140	63,550
	Insul	154	140	21,550
4"	Pipe	428	40	17,100
	HTF	805	40	32,200
	Insul	180	40	7,200
			SUBTOTAL	2.64×10^6 Btu/Day

F W LOOP

Pipe Dia.	Mat'l	Ht. Loss/Ft	Lin. Ft.	TOTAL
1½'	Pipe	40	630	25,300
	H_2O	93	630	58,600
	Insul	36	630	22,850
4"	Pipe	428	360	154,100
	H_2O	34	360	12,250
	Insul	180	360	64,800
			SUBTOTAL	337,900
			TOTAL	2.98×10^6 Btu/Day

low grade heat requirement of the evaporation process.

Another solution would be to drain the hot fluid from the collector field and store it overnight, losing only 20 or 30^{o}F's worth of energy. This solution was investigated for HCPC, however, it was not implemented because of the marginal savings and increased complexities that were incurred.

The overnight losses can be broken down into piping (42%), heat transfer fluid (47%) and insulation (11%) components. Thus, even by draining the fluid, less than 50% of the energy is recoverable. On an annual basis the dollar savings at HCPC would total approximately $1500 and with the added complexity, (the system would need to allow daily filling and draining) the cost-effectiveness was marginal.

Total system heat losses are detailed in Table IV-8 for a typical year at HCPC. Annual thermal losses will be 1,302 $X\ 10^{6}$ Btus and with a gross useable collector output of $8.5\ X\ 10^{9}$ Btus, thermal losses represent 15% of the collected energy.

E. Mechanical Components

1. Steam Generator

Besides the solar collectors, the steam generator is the most important piece of equipment in the mechanical system. It provides the interface between the heat transfer fluid and the feedwater/steam for the plant.

The generator will be a standard Patterson-Kelley Series 380 model that will be modified with a tube and shell preheater and a superheat tube bundle.

Major components of the steam generator are described below:

- feedwater preheater - this is a small tube and shell heat exchanger that will be firmly attached to the support skids of the steam generator. Feedwater will be heated close to saturation in the preheater while the heat transfer fluid (HTF) will be further cooled.

TABLE IV-8

TOTAL SYSTEM HEAT LOSS SUMMARY

	RATE	ANNUAL*
HTF LOOP PIPE		
Operational	135,420 Btu/Hr	247.8×10^6 Btu
Overnight	2.64×10^6 Btu/Day	805.2
FW/STEAM LOOP		
Operational	35,910 Btu/Hr	65.7
Overnight	337,900 Btu/Day	103.1
STEAM GENERATOR	207,900 Btu/Day	63.4
EXPANSION TANK	26,400 Btu/Day	8.1
BLOWDOWN	4,760 Btu/Hr	8.7
	TOTAL	$1,302 \times 10^6$ Btu/Yr

* 6 Hrs/Day, 305 Days/Yr Operation

The feedwater preheater increases overall system efficiency by reducing the HTF temperature to its lowest possible value and insuring that all available solar energy has been transferred to the industrial process.

- saturated steam tube bundle - this tube bundle will be located in the liquid region of the steam generator shell and will provide the energy to change the phase of the feedwater from a saturated liquid to a saturated vapor. This phase change process will consume 85% of the useable solar energy. The tube bundle will be supported on heavy steel tracks and will be completely removeable for periodic maintenance.

- superheated steam tube bundle - this tube bundle will be located in the vapor region of the generator shell and will provide the energy to superheat the saturated vapor by 54°F. It also will be supported on steel tracks and is removeable for maintenance.

- water level controller - this assembly senses the water level inside the generator and controls the feedwater pump and generator inlet solenoid valve. A low water condition activates the pump and opens the normally closed solenoid valve. Once the high water level is reached the controller turns off the pump and de-energizes the solenoid.

- inlet solenoid valve - this valve will be placed in the feedwater line upstream from the preheater. Its purpose is to provide a barrier between the pressure in the steam generator and that in the feedwater line (the feedwater line will have to be at a higher pressure to flow into the generator). It has been placed upstream of the preheater because of the lower temperature there and because the preheater will now be tied into the pressure relief system of the steam generator.

- automatic blowdown assembly - this assembly provides for automatic periodic sampling of the boiler water to determine if the solids concentration exceeds acceptable limits. When the concentration exceeds the acceptable limits, the controller will open the blowdown valve for a preset time period to "blow down" a quantity of the concentrated water. Feedwater hardness is approximately 10ppm and blowdown is estimated at 9 gallons per hour.

Figure IV-5 shows the dimensions and details of the steam generator. The generator shell will be fully x-rayed and stress-relieved according to ASME codes and will have a design pressure of 200 psig. The tube joints will be seal-welded and pressure-tested to 500 psig. The tubes have a design pressure of 500 psig; however, the actual working HTF pressure will not exceed 30 psig under normal operation. The generator will be factory-insulated with 2" of high density fiberglass.

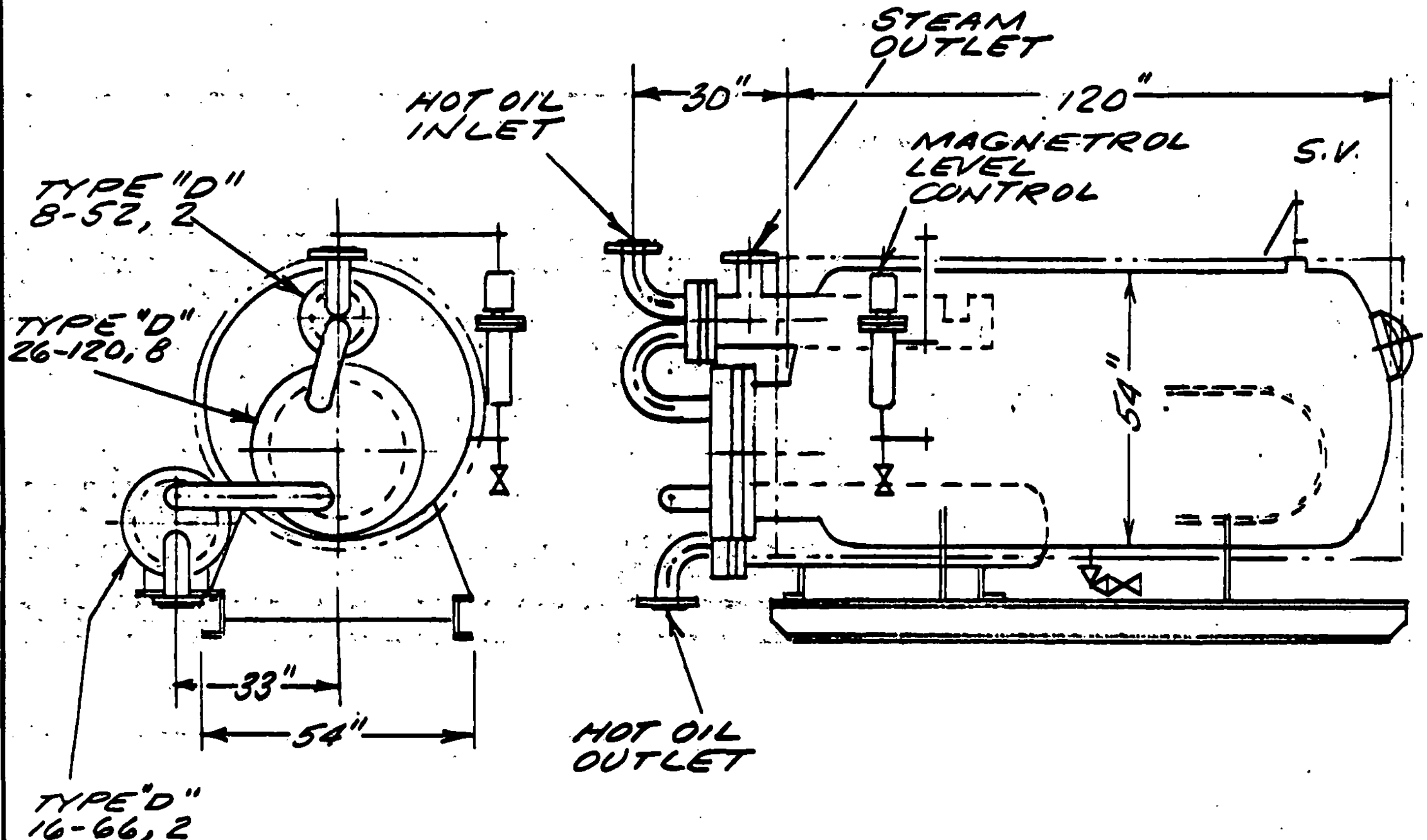
Design conditions for the generator correspond to peak insolation conditions in the solar field and are listed below:

	Flow (lb/hr)	T_{in} (°F)	T_{out} (°F)
HTF	129,000	450	370
Water	7,900	202	420

To avoid the possibility of the HTF contaminating the plant's condensate/steam (the HTF could foul the plant's high pressure boiler if a large enough volume was mixed with the boiler feedwater) in the event of a tube bundle leak or rupture, a pressure actuated valve will be installed in the steam line just downstream from the steam generator.

The purpose of the valve is to insure that the steam generator pressure is always higher than the HTF pressure and, therefore, if a leak or rupture occurred, flow would go toward the HTF and not into the steam.

The valve will close when the pressure in the steam line falls below 135 psia and will open at a pressure above 145 psia. By closing at 135 psia, the valve will thermally isolate the steam generator from the steam line which will continue to cool and lose pressure overnight. At 135 psia, the steam generator temperature will still be 347°F and calculations indicate that the generator only loses 30°F in an 18-hour idle period. Thus, it will take over 81 hours for the generator pressure to reach that in the HTF line (the HTF line pressure falls to 17 psia when circulation stops--2 psia from nitrogen pressure in expansion tank plus 15 psia atmospheric).



PATTERSON-KELLEY COMPANY
Div. of Taylor Wharton Co.-HARSCO Corporation
EAST STROUDSBURG, PA. 18301

REFERENCE NO.	DRAWN BY-
	CHECKED-
FILE -A-	DATE-
REVISED-	

Figure IV-5. Steam Generator Dimensions and Details.

At the end of 81 hours, the generator will be at atmospheric pressure and 212°F. From there on a vacuum will develop in the generator and the potential for water contamination exists. However, it is unlikely that the system will be shut down very often for 81 hours. At least 98% of the time the generator will have a higher pressure than the HTF and flow would be into the HTF line if a pinhole leak existed. The leak would be detected either by visually observing venting steam from the expansion tank pressure relief valve or by tapping the system drain valve periodically to check for water accumulation.

2. Heat Transfer Fluid Pump

The heat transfer fluid pump conforms to ANSI specifications for high temperature and pressure industrial applications. Its rated speed is 3500 RPM; however, with 9% slippage between the motor and motor controller, the peak RPM's will be 3185. The pump has mechanical seals and a closed impeller which yields higher efficiencies.

The HTF temperature at the pump is 370°F and a jacketed stuffing box cover has been provided for pump cooling. Tap water must be circulated through the jacket at a 1-2 gpm flow rate to maintain acceptable seal temperatures. A thermally actuated valve will be placed in the tap water line upstream of the pump and the temperature probe will be placed as close as possible to the jacket outlet. As the pump begins to operate, the water in the jacket will heat up and the valve will gradually open, allowing water to circulate and cool the jacket. The open and close set temperatures will have to be determined experimentally, based on the proximity of the temperature probe to the jacket outlet. This will be done during system check-out.

3. Feedwater Pump

The feedwater pump will be remotely located from the solar energy system in the plant's boiling house. It will obtain feedwater by tapping into a condensate holding tank in the boiling house basement. The distance from the tank to the solar system pump house is approximately 700 feet and a pressure drop of 62 feet is incurred in the pipe (12 feet friction plus 50 feet elevation). In addition, the pump must supply 330 feet of pressure head to account for the difference in inlet and outlet pressures (27 psia at the condensate tank and 170 psia at the steam generator). The total pressure head that must be supplied by the pump, therefore, is approximately 392 feet at a flow rate of only 16 gpm.

A turbine pump was selected for this application because of its high head, low flow pumping characteristics. Turbine pumps are designed for these unusual conditions and will therefore be reliable in operation.

4. <u>Expansion Tank</u>

A 500-gallon expansion tank will be required to absorb the changes in fluid volume as it is thermally cycled over the course of an operating day. Table IV-9 details the expansion tank sizing calculations. The tank will be pressure rated for 50 psig and will be insulated with 2" of fiberglass.

The fluid level in the tank will vary from approximately 3/4 (hot) to 1/4 (cold) full as the fluid is thermally cycled. An emergency low-level switch will be installed to alert operating personnel and shut the system down when the tank is only 1/5 full. This precaution will guard against a major fluid spill. In the event of a pipe rupture, operating personnel will be immediately notified and can react to stop and contain the HTF before it contaminates the local environment.

Associated with the expansion tank is a nitrogen gas bottle and pressure regulator that will enable the expansion tank to be "blanketed" with inert nitrogen gas. Synfluid 4cs will oxidize slightly when exposed to air. The nitrogen blanket will replace any air in the expansion tank and thus enhance the fluid's stability and service life. To prevent nitrogen gas venting the pressure regulator will be set at 2 psig while the expansion tank pressure relief valve will

TABLE IV-9

Expansion Tank Sizing Calculations

Assumptions: T_{low} = $50^{o}F$

T_H = $450^{o}F$

Piping Volume @ $50^{o}F$ = 1160 gallons

Coef. of Thermal Expansion = $0.00045/^{o}F$

1160 gallons x $0.00045/^{o}F$ X $(450-50)^{o}F$

Expansion Volume = 209 gallons

209 gallons = 50% of Tank Volume

Required Tank Volume = 418 gallons

∴ USE 500-GALLON TANK

be set at 50 psig. Thus, a 48 psig range is allowable in the tank as the gas is compressed and expanded during the day.

F. Pump House

1. Structure

The pump house will be a standard, rigid frame steel building with dimensions of 22 feet long and 20 feet wide, 10 feet eave height and 1:12 roof pitch. It will contain the majority of the mechanical, electrical, control and data acquisition equipment for the system. It will be located at the northeast corner of the solar field at the closest point in the field to the steam interface with the mill building.

The pump house will have an eight feet wide by 9 feet high rollup garage door for major equipment accessibility and two exterior doors. A gravity forced ventilator on the roof plus two fixed louvers in the east and west walls will provide substantial natural ventilation. During equipment maintenance periods, the garage and exterior doors can be opened if necessary for additional ventilation.

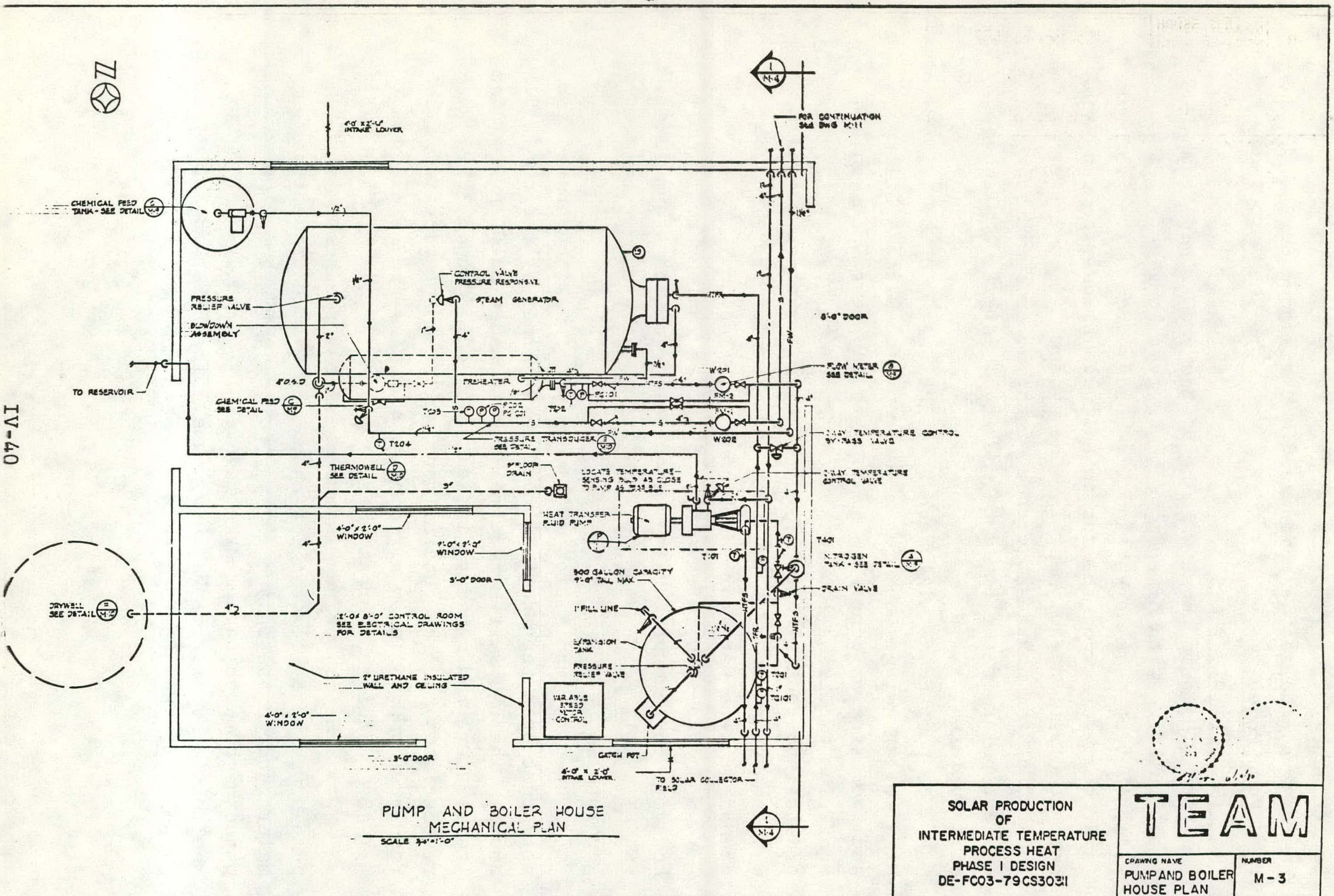
Standard slab thickness is 6 inches for the building; however, to account for the added weight of the steam generator, the slab will be "beefed up" to 12 inches thick under the generator.

The data acquisition (DAQ) equipment will be housed in a 12 feet by 8 feet control room in a corner of the pump house. The DAQ system requires a semiconditioned environment (temperature and humidity limits of 41-104°F and 5-90% respectively) so the control room walls and ceilings will be insulated and a window air conditioner will be installed.

2. Equipment Arrangement

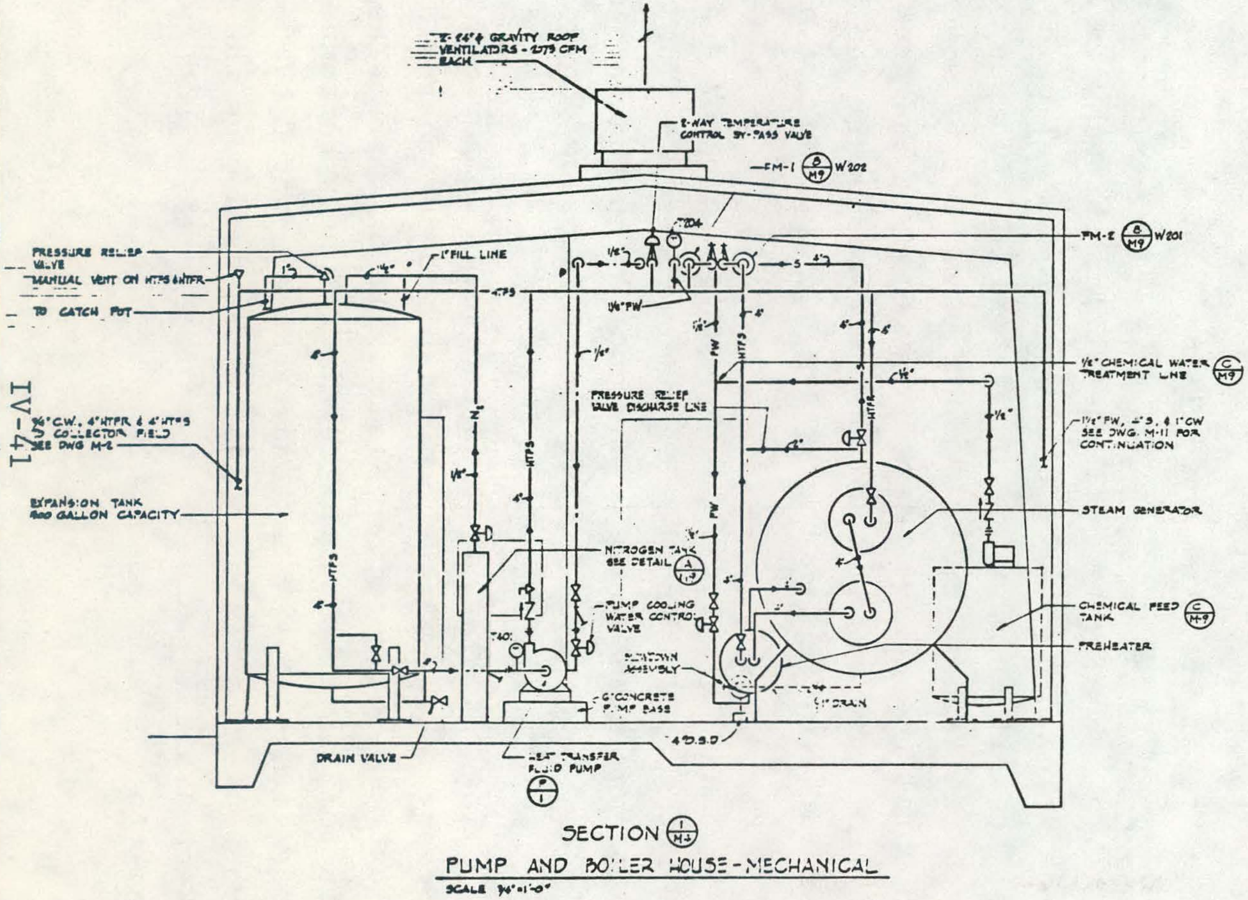
The objectives in arranging the equipment in the pump house were (1) to allow easy access to equipment for maintenance purposes and (2) to provide efficient flow patterns between equipment. Figures IV-6 and IV-7 are plan and section views of the pump house. The first objective was accomplished by placing equipment with moving parts and/or

Figure IV-6



CHEMICAL FEED TANK - SEE DETAIL
FOR CONTINUATION SEE DWG M-11
INTAKE LOUVER
PRESSURE RELIEF VALVE
BLOWDOWN ASSEMBLY
CONTROL VALVE PRESSURE RESPONSIVE
STEAM GENERATOR
PREHEATER
TO RESERVOIR
CHEMICAL FEED SEE DETAIL
FLOW METER SEE DETAIL
W201
W202
T104
PRESSURE TRANSDUCER SEE DETAIL
THERMOWELL SEE DETAIL
FLOOR DRAIN
3-WAY TEMPERATURE CONTROL BYPASS VALVE
3-WAY TEMPERATURE CONTROL VALVE
HEAT TRANSFER FLUID PUMP
4'-0" x 2'-0" WINDOW
3'-0" DOOR
T401
NITROGEN TANK - SEE DETAIL
DRAIN VALVE
500 GALLON CAPACITY
1" FILL LINE
EXPANSION TANK
PRESSURE RELIEF VALVE
DRYWELL SEE DETAIL
2" URETHANE INSULATED WALL AND CEILING
4'-0" x 2'-0" WINDOW
3'-0" DOOR
CATCH POT
4'-0" x 2'-0" INTAKE LOUVER
TO SOLAR COLLECTOR FIELD
PUMP AND BOILER HOUSE MECHANICAL PLAN
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311
TEAM
DRAWING NAME
PUMP AND BOILER HOUSE PLAN
NUMBER
M-3

Figure IV-7



SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
PUMP & BOILER HOUSE SECTION	M-4

requiring periodic maintenance in an open unencumbered space. The HTF pump, for example, is in the middle of the floor with an open area completely surrounding it. It can be worked on from all angles with minimum encumberments. The steam generator has been placed in front of the garage door so that the tube bundles which vary in length from 4 to 10 feet can be slid out for cleaning. In addition, all piping in the pump house will be hung overhead to facilitate equipment and personnel movement and general cleaning.

The second objective was met by arranging the equipment to reflect the flow schematic. The HTF pump, for instance, is located between the steam generator and the collector field in line to recirculate fluid back to the field after it exits the generator.

G. System Draining and Filling

1. Filling

The system will be filled through the expansion tank. The HTF will be delivered in 55-gallon drums and it will be either manually or electrically pumped into the tank. Once the tank is full, the HTF pump will be momentarily turned on until the tank is marginally empty. The tank will be filled again and the process repeated until the full inventory of fluid is in the system and the tank level is at 1/4 full.

Manual air relief valves have been provided at the ends of both pair of supply and return headers. The field will slope up to the west so the ends of the headers are the highest points in the respective loops and entrained air can be released there.

The receiver tubes of the solar collectors will be at a higher elevation than manifolds and due to the design of the flex hose and receiver assembly it is impractical to place an air relief valve in the receiver tube. Fortunately, experience with past systems and tests conducted by Solar Kinetics prove that, when the fluid is forced through the receiver tube, trapped air is pushed out of the receiver and is circulated back to the pump along with the fluid.

To eliminate this entrained air, all return fluid will be deaerated by passing through the expansion tank first. Figure IV-8 illustrates the filling procedure. During system filling, valve A will be closed and valve B opened, forcing the return fluid into the expansion tank and allowing entrained air to bubble out to the top of the tank. After the system is filled, valve B will be closed and valve A opened and flow will bypass the expansion tank.

2. Draining

System draining will not be difficult since the system drain valve is located at the lowest point in the pump house. In addition, the solar field will have a natural slope down to the pump house so draining will be 100% gravity forced.

The manual air vents at the ends of the headers will be opened for vacuum relief. A hose will be attached to the drain valve in the pump house, and the elevation difference will force the fluid into waiting 55-gallon drums.

Manual drain valves have also been provided at collector series connections and these will be sequentially opened (starting from the highest elevation) to allow fluid trapped in the receiver loop to escape.

In summary, the system is completely drainable and fillable.

H. Electrical Design Requirements

The major electrical components of the system are the heat transfer fluid pump, the feedwater pump, the collector tracker hydraulic pumps and the on-line data acquisition equipment. Table IV-10 contains a summary of the average parasitic loads provided by each component.

Electrical power is provided to the solar energy system from the Motor Control Center. A 480 3Ø line is run first to the pump house and then to the solar collector field. A step-down transformer (30 kva) in the pump house provides 120v 3Ø power for the lights, ODAS equipment, system control and convenience outlets. The 480v 3Ø input power also provides

FIGURE IV-8

EXPANSION TANK VALVING

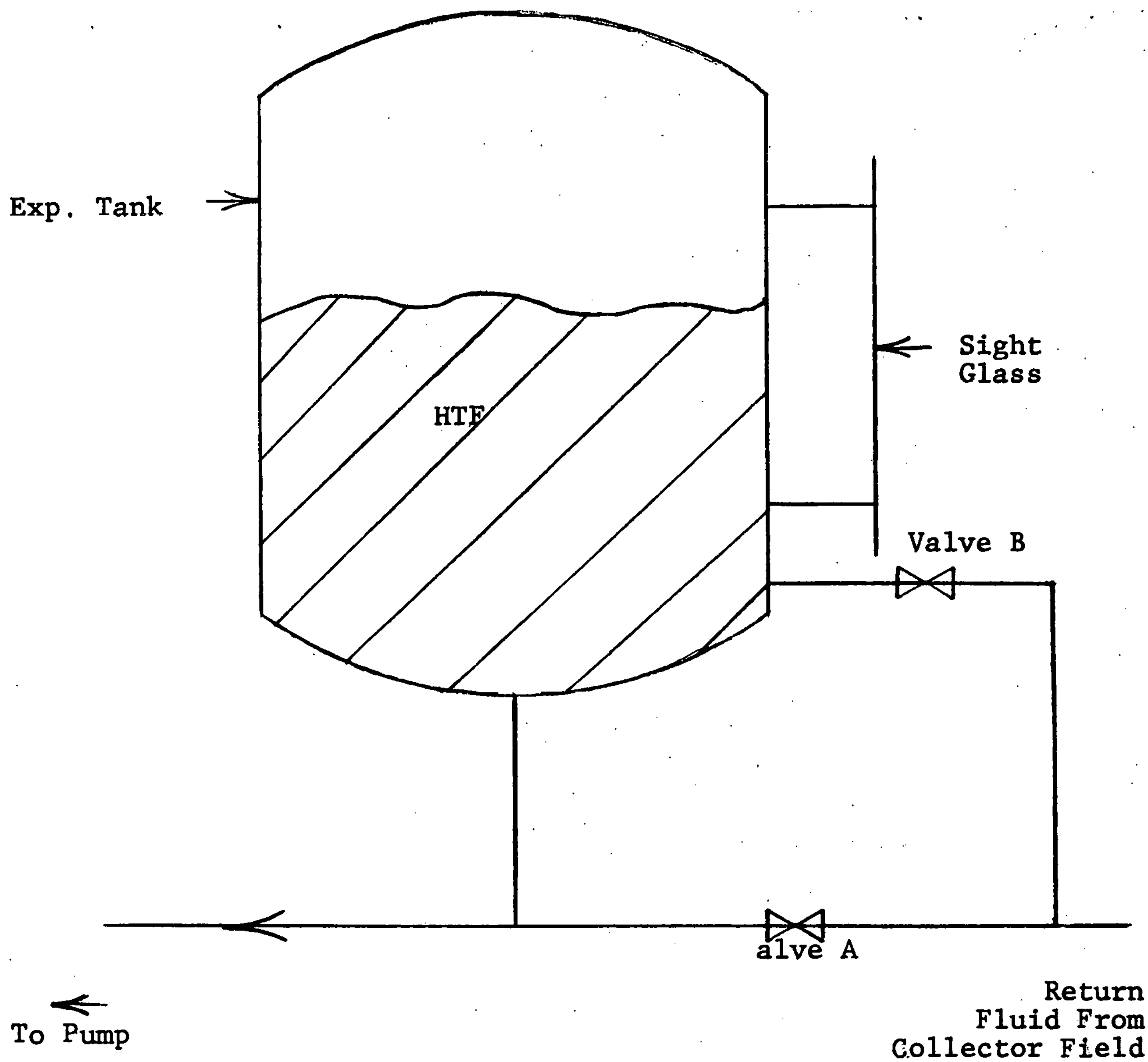


TABLE IV-10

Component	Line Voltage Requirement	Power Consumption
Transfer Fluid pump	440v 3Ø	11.4 kw
Feedwater pump	440v 3Ø	2.5 kw
Collector trackers	120v 1Ø	3.2 kw
ODAS	120v 1Ø	2 kw

power for the 45 hp heat transfer fluid pump in the pump house. A second step-down transformer (45 kva) located in the solar collector array field provides 120v 3Ø power to run the hydraulic pumps at each drive pylon. 120 vac 1Ø 15 amps convenience outlets will be provided at selected pylons throughout the field. This transformer is sized for worst-case conditions, i.e. all hydraulic pumps turning on at the same time. However, the microprocessor controller for the solar field has been designed to start up only one-fifth of the field at a time. Maximum expected field power requirements are therefore less than 10 kva.

The control logic signals for the solar system are 120 vac 1Ø and are routed to the solar field through a relay box mounted adjacent to the master field control box. The field control box is located in the pump room of the pump house. The relay box contains the automatic/manual control interface for each subfield, the total field on/off control, and the emergency control relays. There are two 120 vac 1Ø logic control lines to each of the five subfields. The master field controller, provided by Solar Kinetics, Inc., performs internal relay switching to provide these signals to the relay box.

The automatic/manual control relay drivers and relays, interface with the logic levels as shown in the electrical plans. The control relays are commercially available units and contain the necessary control electronics to respond to high/low voltage levels as provided by the master control panel switches. The units have been interconnected such that all field control functions can be performed under manual control. These include wake-up, normal track, pause, and subfield stow. There is no provision, however, for manual start-up of the heat transfer fluid pump nor will the controls provided on the master control panel override the over-temperature unit stow control located at each drive pylon. Individual collector rows will be controllable in the field at each drive pylon. This will be accomplished by manually closing the appropriate relays located in the pylon control interface provided by Solar Kinetics, Inc.

The heat transfer fluid flow rate through the solar energy system is variable and is controlled using a variable speed pump. A resistive temperature detector (RTD), 100 platinum MINCO RTD, and an Action Pak signal conditioner is used to provide a 4-20 ma control signal to the variable speed motor controller. The unit will be variable from 50% to 100% of full flow. The 50% minimum flow was chosen because below this level the efficiency of the controller decreases and pump operation becomes erratic.

Steam pressure and heat transfer fluid pressure measurements are accomplished using ROSEMOUNT pressure transducers and Action Pak relay controllers and relays. The pressure transducer, powered by a 24 vdc power supply, produces a 4-20 ma signal that opens the relay when the signal exceeds a preset value. The relay is electrically located in the system interrupt circuit of the field control panel. Opening a relay in this circuit causes the total solar energy system to shut down.

Rosemount pressure transducers cannot operate reliably above 200°F. Installation of the transducers is therefore on a stand-off pipe as shown in the piping details in Appendix A. The Action Pak control relay is located in the relay box adjacent to the field control box.

A float switch has been placed in the expansion tank to detect a low-level condition there. The switch is connected electrically to a normally closed relay located electrically in the system interrupt circuit as depicted in the electrical plans. The level switch is normally open and remains open as long as the expansion tank is over one-fifth full. Once the fluid level falls below one-fifth full, the float switch closes and the interrupt relay opens. This action causes the entire solar energy system to cease operation and stow the collectors.

Power to the field and to the pump house will be from a common source located at the adjacent cane cleaner. However, since all three phases will be used to provide power to the field, it is necessary to monitor each phase in the pump house and take corrective action should there be a loss of any phase of power. This is accomplished with a phase loss monitor which opens a relay when any phase of power drops out. Electrically, the relay is in the system interrupt circuit and is normally closed. Physically the device is mounted adjacent to the 120 vac 3Ø service to the pump house.

A normally open flow switch will be installed in the heat transfer fluid line and it will be connected directly to the flow switch terminals on the field control panel. Fluid flow will close the switch completing the circuit to the terminals and allowing the collectors to begin tracking.

I. INSTRUMENTATION AND DATA ACQUISITION SYSTEM

Data acquisition sensors and the resulting measurements are labeled using the following codes and numbering sequence. This nomenclature is carried through ODAS software and the detailed design drawings and specifications provided elsewhere.

Symbol	Designation
EP	Electrical Power
I	Insolation
T	Temperature
V	Velocity
W	Fluid Flow Rate
TI	Time Interval (as acquired from the ODAS)
P	Pressure

Number Sequence	Data Group
001 to 099	Climatology
100 to 199	Collector
200 to 299	Heat Exchangers
400 to 499	Solar Supplied Process
500 to 599	Conventional Process
600 to 699	Parasitic Power (Solar System)
700 to 799	Conventional Power

Table IV-11 provides a complete listing of the nomenclature and location of all the measurement points for the solar energy system. Data from these points will be averaged over an operator-defined period and the results stored on magnetic tape or hard disc. Sampling rate for each sensor shall be under operator control and variable from 10 seconds to 10 minutes.

Table IV-12 provides a complete listing of the derived quantities to be obtained from the above basic measurements. These quantities are to be integrated, averaged and/or summed

TABLE IV-11

DATA ACQUISITION SENSOR

Sensor	Description	Measurement Range	Voltage Range (DC)	Scale Factor	Scanner Channel	Notes
EP101	Pump house and collector parasitic power	0-36 kw	0-10v	3.6 kw/v	1(B-1,R-1)	*B-1 = Relay Bank 1
EP401	Feedwater pump parasitic power	0-10.8 kw	0-10 v 0-10v	1.08 kw/v 1.08 kw/v	2(B-1,R-2) 2(B-1,R-2)	R-1 = Relay 1
W201	Oil flow rate into heat exchanger	0-500 gpm	0-5v	100 gpm/v	4(B-1,R-4)	
W202	Steam flow rate into process	20-200 lb/min	0-5 v	40 lb/min/v	5(B-1,R-5)	
P201	Steam pressure at H.E. outlet	0-300 psi	0-10 v	30 psi/v	6(B-1,R-6)	
V001	Wind speed	0-50 mph	0-500 mv	.1 mph/mv	7(B-1,R-7)	
P001	Atmospheric Pressure	850-950 mb	0-200 mv	.5 mb/mv	8(B-1,R-8)	
I001	Global insolation	0-1000 w/m^2	0-9 mv	111.1 w/m^2/mv	9(B-1,R-9)	
I002	Normal insolation	0-1000 w/m^2	0-8 mv	125 w/m^2/mv	10(B-1,R-10)	
T101	Oil temperature at inlet to field	0-600°F	0-5 v	120°F/v	11(B-2,R-1)	Connected to B-1,R-3 via Signal conditioner SC-1.
T201	Oil temperature at H.E. inlet	0-600°F	0-5 v	120°F/v	12(B-2,R-1)	

TABLE IV-11
(continued)
DATA ACQUISITION SENSOR

Sensor	Description	Measurement Range	Voltage Range (DC)	Scale Factor	Scanner Channel	Notes
T202	Oil temperature at H.E. outlet	0-600°F	0-5 v	120°F/v	13(B-2,R-3)	
T203	Water temperature at H.E. inlet	0-600°F	0-5 v	120°F/v	14(B-2,R-4)	Connected to B-1,R-3 via signal conditioner SC-1.
T204	Steam temperature at H.E. outlet	0-600°F	0-5 v	120°F/v	15(B-2,R-5)	
T001	Ambient air temperature	0-600°F	0-5 v	120°F/v	16(B-2,R-6)	

TABLE IV-12

BASIC DERIVED QUANTITIES

Nomenclature	Quantity	Relationship
TQ101	Thermal Energy Collected by Solar Array	$\int W201 \cdot Cp101 \cdot (T201-T101)\ dt$
CP101	Average Specific Heat in Solar Array	$[L_o\ (T201) + L_o\ (T101)]\ /2$*
TQ102	Thermal Energy Lost by Oil in Heat Exchanger	$\int W201 \cdot Cp103 \cdot (T201-T202)\ dt$
CP103	Average Specific Heat of Oil in Heat Exchanger	$[L_o\ (T201) + L_o\ (T202)]\ /2$
TQ103	Thermal Energy Lost by Oil in Transit to Field	$\int W201 \cdot Cp104 \cdot (T202-T101)\ dt$
CP104	Average Specific Heat of Oil in Transit to Field	$[L_o\ (T202) + L_o\ (T101)]\ /2$
TQ104	Thermal Energy Gained by Water in Process Line	$\int W202 \cdot (H202-H201) \cdot dt$
H201	Enthalpy of Water at T203	Look up table/interpolation
H202	Enthalpy of Steam out of Heat Exchanger	Look up table/interpolation
TQ105	Average Thermal Energy Gained by Process	$\frac{1}{T2} \int TQ104 \cdot dt$
Q201	Quality of Steam on Steam Side of Heat Exchanger	(HG201-H201)/HFG401
Q202	Average Quality	$\frac{1}{TI}\ Q201\ d$
HF201	Enthalpy of Saturated Steam at T203 & P201	Look up table/interpolation

Notes: TI is time interval between measurements and t is period of measurement set.

*L_o is a nonlinear function that relates specific heat of the oil to temperature.

TABLE IV-12
(continued)
BASIC DERIVED QUANTITIES

Nomenclature	Quantity	Relationship
HFG201	Enthalpy of Vaporization at T201	Look up table/interpolation
HFG202	Average Enthalpy	$\frac{1}{TI}\int HFG201dt$
TQ110	Total Direct Insolation Incident on Collector Field	$\int I001 \cdot ECA \cdot dt$ *
TQ111	Average Direct Insolation Incident on Collector Field	$\frac{1}{TI}\int I001 \cdot dt$
TQ115	Average Global Insolation on Collector Field	$\frac{1}{TI}\int I002dt$
TQ116	Total Global Incident on Collector Field	$\int I002 \cdot ECA \cdot dt$
EQ101	Electrical Energy Used by Collectors and Pump House	$\int EP101\ dt$
EQ102	Average Power Used by Collectors and Pump House	$\frac{1}{TI}\int EQ101 \cdot dt$
EQ103	Electrical Energy Used by Water Pump	$\int EP401 \cdot dt$
EQ104	Average Power Used by Water Pump	$\frac{1}{TI}\int EQ103 \cdot dt$
EQ107	Total Parasitic Energy Used	EQ101 + EQ103
EQ108	Total Average Parasitic Power Used	EQ102 + EQ104
N101	Efficiency of Solar Field	TQ101/TQ110*100
N102	Efficiency of Heat Exchanger	TQ104/TQ103*100
N103	Efficiency of Total System	TQ104/TQ110*100

*ECA--Effective Collector Area

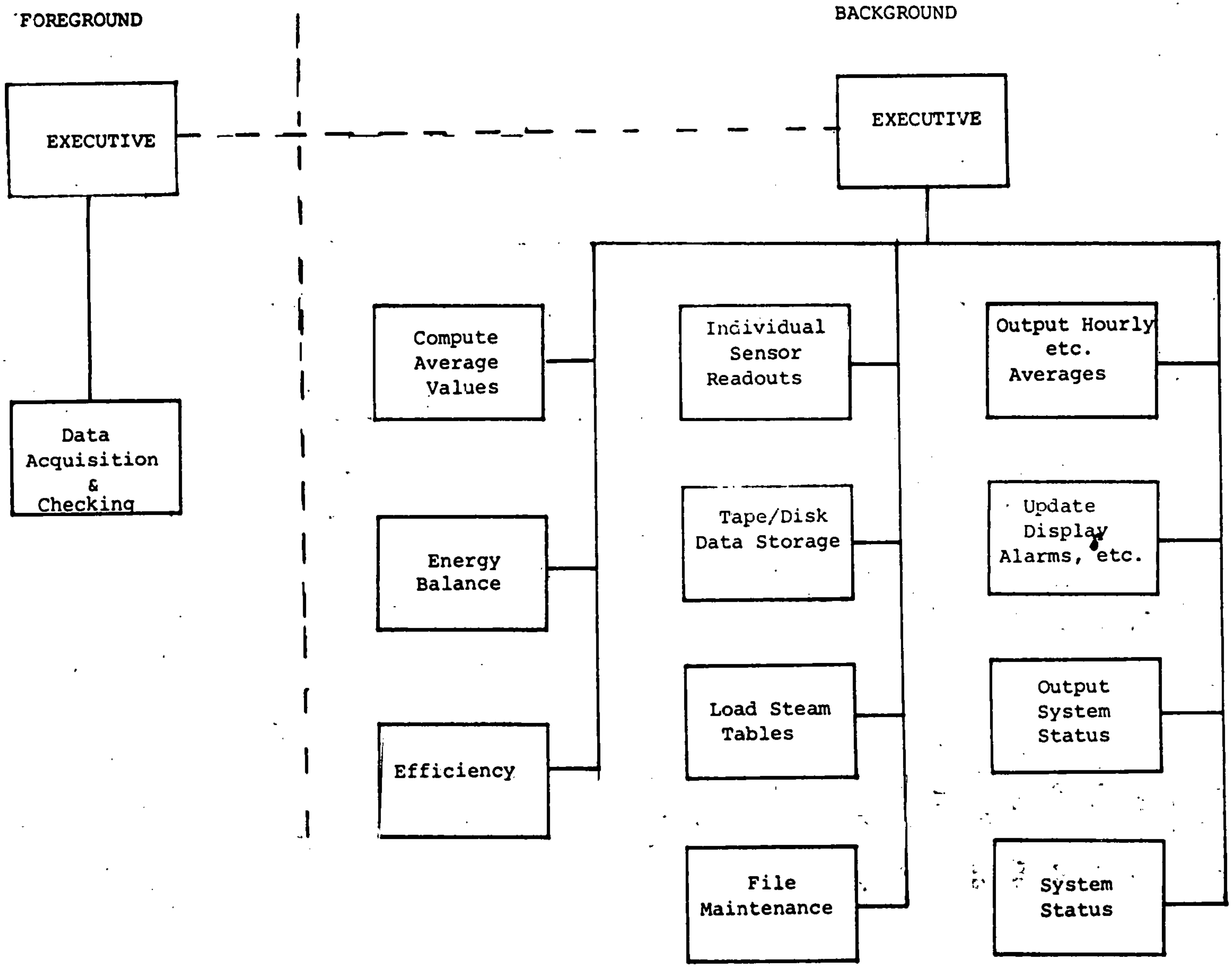
over the same time interval as the sensor averaging interval defined by the operator. These data are to be stored with the basic measurement data. Running averages of all key quantities will be maintained by the system controller and printed out hourly, and at the end of the operational day. Special reports and sensor displays will be available to the operator.

The architecture of the on-line data acquisition system is provided in Figure IV-9. Basically the system is configured to meet system specifications detailed in "Data Acquisition and Analysis Guidelines for IPH Demonstration Projects" with off-the-shelf equipment; readily available maintenance or replacement parts; demonstrated reliability, and at a modest cost. The ODAS consists of a microprocessor computer controller, the data collection instrumentation, a data storage medium, sensors and signal conditioners. The controller, instrumentation and magnetic tape storage medium (if used) are tied together with the IEEE-488 General Purpose Interface Bus. The following is a more detailed description of the above subsystem components.

The system controller is to be an EIA cabinet mount microprocessor computer with at least 64k bytes of user read-write memory. The controller shall consist of a keyboard, CRT display and thermal, dot-matrix printer. The system shall be programmable in Fortran IV and possess dual programming (foreground/background) and multitasking features. The system shall have a disk operating system (DOS) with a Fortran and Assembly Language Compiler. A single drive floppy disk will be available to implement the operating system, restart, reload or modify system programming, or down-load data for storage. The controller will be equipped with a real-time clock and a battery pack to supply power to the clock and the computer memory when utility power fails. An IEEE-488 bus interface and two RS-232 parts will be available. The preferred controller unit is the Data General MP/100 microprocessor and related peripherals.

Figure IV-9

ODAS SOFTWARE STRUCTURE



The data collection instrumentation will consist of a sensor scanner and digital multimeter under control of the system controller via the IEEE-488 bus. The digital multimeter will have at least 4½ digit accuracy. The system controller sets the function and range to be measured by the multimeter and tells the scanner which sensor channel to make available to the multimeters. Typical multimeters available for this application are the Hewlett Packard 3055A and the Fluke 8502A. Typical scanners are the HP 3495A and Fluke 2240A.

Two storage media are possible. The first is a nine-track 1600 BPI P.E. tape system. The second is a 12.5 megabyte sealed hard disk.

A suitable magnetic tape memory system is the Dylon Model 2070-9-1600 consisting of a Dylon Model 1015A Buffered Controller and Dylon Model 2070 tape system. The buffered controller consists of the microprocessor based logic necessary to control any industry standard magnetic tape transport via the IEEE-488 bus. The 2070 tape system features a seven inch reel, IBM/ANSI compatible 9 track, 1600 BPI P.E. tape drive. The reel holds 600 feet of tape.

The preferred data storage unit is the Data General Model 6102 sealed, hard disc system which takes advantage of advanced Winchester-type technology for high transfer rates and reliability. It includes a non-removable, moving head disc with 12.5 megabytes of storage. The unit is sealed in a contamination-free module. The head/disc module has a filtered closed-loop air circulation system. The heads land gently on the disc without disturbing the stored data when the drive is powered down.

Sensors used throughout the system will be in accordance with "Data Acquisition and Analysis Guidelines for IPH Demonstration Projects." In most cases the sensors will be in close proximity to the data collection instrumentation and will not need additional isolation amplifiers. The ability of the digital multimeter to cover a wide range of signal voltages further diminishes the need for such amplifiers. A single RTD signal conditioner will be used by utilizing the multiplexing capability of the scanner under program control. The three leads of each RTD will be connected in turn to the input of the signal conditioner through a relay bank. Output of the signal conditioner will be connected to the multimeter input terminals through contact relays in another relay bank of the scanner.

RTD's, mounted in thermowells, used to measure system temperatures shall be MINCO, 100 Platinum or approved equivalent. For small pipes, i.e., pipes less than 2 inches in diameter, the RTD's will be mounted longitudinally in the pipe with right angle fittings. For pipes with larger diameters, the RTD's can be mounted radially.

Flow meters will be RAMAPO MARK-IV, or equivalent, with a signal conditioner which produces an output signal proportional to the fluid flow rate. The signal produced shall be sampled by the ODAS and shall also provide a visual display of flow conditions in the power plant control room. Flow meters shall have a screened trap located upstream from the target and there will be ten pipe diameters of unobstructed flow upstream from the target. The flow meter will be installed with a valved by-pass around it so that it can be removed without interrupting system operation.

Instruments used to measure solar insolation shall be Eppley normal incident pyroheliometer (NIP) with solar tracker and the Eppley precision spectral pyranometer (PSP). The output of these instruments shall be routed directly to the ODAS through the scanner. Mounting shall be as described in the attached drawings and specifications.

The recommended computer controller for the ODAS is the DATA General Micro NOVA MP/100 with 64k bytes of RAM. The computer is dual-programmable and multitasking. The software performance specifications contained herein is based upon the capabilities of the operating system, the Data General Fortram, and the computer architecture.

Changing computer systems may cause the software requirements to change slightly.

The ODAS software shall be written in Fortran IV is described in Data General Fortran IV Users Manual to the extent possible. Assembly language to interface with the IEEE-488 bus will be allowable but will be kept to a minimum.

The ODAS software shall be developed as two programs, each one with multiple tasks. The first program shall perform the data acquisition function. This program shall be the foreground job and shall have the higher priority. Control is to be passed to the background job only when there are no ready tasks in the foreground. Data collected by the foreground job will be passed to the background job for data manipulation and storage. Control of data acquisition rate is to be accomplished through the background job. No direct inputs to the foreground job will be made.

The background job will handle all other required functions. The background job will be multitasking with an executive routine handling the schedule for all other tasks and subroutines. The executive will handle all operator requests under a password arrangement. Standard keyboard interrupts will be disabled via software routines. The background job shall also provide an automatic recovery capability should utility failure cause the solar system to cease operation.

Outputs from the system software can be divided into four general categories:

- Current status reports
- Calculation reports
- Archived calculation reports
- Alarm communications

At the operator's request the software will generate a current status report. This will contain:

- Time and data
- List of alarm conditions

- List of malfunctioning sensors
- Software status (operating parameters)

Calculation reports will be generated in either of two ways: (1) software interrupt on an hourly, daily, weekly, and monthly basis and (2) by operator requests. Those items listed in the table, or an operator's selected subset thereof, shall be printed out for the hour, day, week, etc., or operator-selected period.

Archived calculation reports may be generated by normal software action at the end of the day, week, or month or at the request of the operator.

High/low limit alarms will be printed on the CRT and printer periodically when it is detected that sensor input is outside acceptable limits. Printer alarms will indicate sensor, time of day, and sensor location. Software will continue to monitor the sensor but no additional messages will be written on the printer until the sensor measurement is within acceptable bounds.

V. SAFETY ANALYSIS

This section presents an analysis of the safety and health aspects of the Hilo Coast Processing Company's (HCPC's) solar industrial process heat (SIPH) system. The purpose of the analysis is to identify potential hazards that may be associated with the project and to ensure that these hazards have been eliminated, reduced to an acceptable level or otherwise controlled.

1. General Discussion

It has been recognized from the beginning of the project that the nature and purpose of the SIPH system entails potential safety hazards. The operating temperatures that the system must attain, the steam and fluid working pressures and the concentrating effect of the solar collectors are some of the hazards that are unavoidable with this type of system. Efforts were made, however, to design a system that minimizes the hazards and maximizes reliable and safe operating conditions.

Industry codes and standards were followed whereever possible. Table V-1 lists the codes and their applicability to the system design that are incorporated into the system. These cover not only equipment specification but installation procedures and practices.

In addition, certain precautions and design details have been included which are not covered by industrial codes but which are necessary to account for unique conditions in the SIPH system. Table V-2 is a listing of the major hazards and proposed solutions associated with the HCPC system. The hazards and solutions listed are covered in depth in the following sections.

2. Solar Collectors

The HCPC system incorporates 42,420 square feet of concentrating solar collectors which will be ground mounted in an open field adjacent to the industrial process.

Table V-1

Applicable Codes and Standards

ASTM - American Society for Testing and Materials
ACI - American Concrete Institute
MBMA - Metal Building Manufacturers Association
ASME - American Society of Mechanical Engineers
ANSI - American National Standards Institute
UL - Underwriters Laboratory
OSHA - Occupational Safety and Health Administration
NEMA - National Electrical Manufacturers Association

Codes	Item Covered
ASTM C31, C39, C231, C42	Concrete test cylinders, air entrainment, core tests
ACI 315	Reinforcing Steel
MBMA	Pump house design loads and instalation
ASTM A106, A53, A105 ANSI B31.1	Pipe and fittings
ASTM C356, UL723	Insulation
ASME Section VIII-VW	Steam Generator
NEMA and UL Standards	Power panelboards, switches, motors, and controllors

Table V-2

General System Hazards

Subsystem	Potential Hazards	Design Solution
Collector/Receiver	Concentrated Sunlight Hot Piping	Warning Signs Personnel Instruction
Heat Transfer Fluid	Fire, Toxicity	Pressure Testing, Handling Precautions Closed Circuit T.V. Sensors
Steam Generater	High Temperature and Pressure	Relief Valves Sensors Pressure Testing
Insulation	Saturation with Spontaneous Combustion	Weep Holes Welded Pipe Closed Cell Insulation Valve Configuration
Personnel	Burns, Moving Equipment, HTF Toxicity	Instruction Protective Equipmenment Overhead Piping

The main safety problems associated with the solar collectors are the high temperatures and concentrated sunlight at the focal point of the collectors. The collector axis is less than 5 feet high from the ground and personnel could be exposed to the concentrating areas. If the skin or eyes of personnel is brought near the focal point during system operation severe burns could result. The effect on the eyes could be temporary or permanenent blindness, while the skin could experience a concentrated sunburn. Burns could also result from contact with exposed portions of the collector receiver.

Since the HCPC system will be ground mounted, the risks of collector exposure are more acute. Fortunately, the HCPC facility is located in the middle of sugar cane fields in an agricultural environment. Access to the plant is strictly controlled and the closest public road is ¼ of a mile away. This fact will restrict the general public's exposure to the solar array. Populations which are most at risk, however, include: personnel involved in the construction, testing, operation and maintenance of the system; HCPC personnel whose duties require that they spend time in the area of the collectors; and visitors to the facility.

The collector/receiver hazards will be eliminated or minimized by (1) providing proper instruction on the hazards and methods of avoiding them to installation and operation and maintenance personnel, (2) installing warning signs around the array, (3) limiting authorized access to the array, (4) providing controls for manual defocusing of individual collector rows for maintenance purposes and (5) insuring that all hot surfaces are labeled and properly insulated.

3. Heat Transfer Fluid

The heat transfer fluid that will be circulated through the collectors is Gulf Oil Company's product Synfluid White Oil 4cs. It is a hydrocarbon base fluid that is accepted as a food grade lubricant. According to the Food and Drug Administration, Synfluid White Oil meets the white mineral oil specifications under 21 CFR 172.878 and may be used as a component of non-food articles intended for use in contact with food. In addition, according to the U.S. Department of Agriculture, 4cs is acceptable with incidental food contact as lubricants, antirust films and tank closure gasket or seal release agents, in Federally inspected meat and poultry establishments. OSHA tests also indicate the product was non-toxic to experimental laboratory animals (reference OSHA material safety data report in section VI - Environment Assessment).

At ambient temperatures the oil poses little hazard. If it is spilled on the skin, it can be removed by washing with soap and water. Prolonged and repeated contact may irritate the skin of some individuals. If the fluid gets in someone's eyes, the eyes should be washed with copious amounts of water.

At elevated temperatures the fluid has a high vapor pressure thus inhalation of fumes, vapors or mists are possible. All personnel, when working around the hot fluid, will be properly protected with an air respirator and safety goggles.

Synfluid 4cs has a relatively high flash point of 445°F. The HCPC system has been designed for a maximum temperature of 450°F during normal operation. Although the fluid will cool rapidly when exposed to air if a leak occurred, the vapor could become mixed with air and an explosion or flammible mixture could result.

The expansion tank is the most likely place that combustible air-vapor mixtures would form. The HCPC design, however, calls for an inert nitrogen vapor blanket over the HTF thus this possibility is eliminiated. In addition, the pump house is well ventilated with two fixed louvers in the walls and an overhead gravity forced ventilator that will provide continous ventilation and prevent a dangerous vapor mixture from developing.

Thermal burns could occur if a pipe ruptures and the HTF sprayed on personnel. The fluid pressure varies through the closed loop from 100 psi at the pump outlet to almost 0 psi at the pump inlet so a fluid stream could occur. Accordingly, personnel will be required to wear eye protection and protective clothing when working in or around the solar energy system.

4. Piping Network

As a further protection against thermal burns during manual operation and/or maintenance, all pipes will be labeled with commercially-available labels. The direction of the flow and the pipe service will be clearly indicated.

The HTF piping network will use carbon steel, ASTM A53 or A106 piping. The design calls for welding as many connections as possible to limit the likelihood of leaks. Raised face 300 lb. flanges have been specified to minimize leakage and increase the thermal stress-bearing ability of the network. All packing and gasketing material are as per manufactures' recommendations so materials compatibility is not a problem.

Pressure relief valves have been provided in all collector series loops, in the expansion tank and on the steam generator. No area in the system that has a heat source can be isolated without a pressure relief valve also being in the loop. This precaution eliminates the potential hazard of explosion due to an overheated and overpressurized pipe.

5. Insulation

The autoignition temperature for synfluid 4cs is 710°F, however, tests indicate that spontaneous combustion does occur at temperatures above 500°F in insulation materials that have been thoroughly soaked with fluid. Such a reaction is believed to occur because the combination of; the large surface area on the insulation fibers, poor heat dissipation conditions, and the formation of low flash point oxidation products, can cause a temperature build-up in the saturated insulation mass resulting in ignition of the material when exposed to air.

This potential hazard has been minimized by (1) welding as many connections as possible, (2) employing impermeable cellular glass insulation around all flanged connections and (3) providing weep holes in the aluminum jacket under expansion joints, flanged connections and control valves. This combination of precautions will reduce the number of locations where a leak could occur and insure that at the locations where a leak could occur, an impermeable insulation is in-place. In addition to these precautions, all valve stems and other protrusions through the insulation will be placed either horizontally or vertically downward to aid in fluid drainage and prevent fluid build-up within the insulation.

6. <u>Steam Generator</u>

The main hazard associated with the steam generator is a steam overpressure condition when the industrial process does not require steam, yet the solar collectors are still functioning. There are three back-up measures that will prevent an explosion or other hazardous event; (1) a pressure relief valve on the generator, (2) an overpressure sensor on the steam line that will disable the HTF pump and stow the collectors under an overpressure condition and (3) overtemperature sensors on the collectors that stow the collectors when the fluid in the receiver tubes is too hot (over $600^{o}F$)

An additional safety feature on the generator is its ability to run completely dry of water without damage to the equipment. Under this condition, the system would eventually shut down since the HTF temperature would exceed acceptable limits and collectors would stow.

7. Visitor Safety and Security Considerations

The HCPC facility is located 10 miles north from the city of Hilo, Hawaii in a predominantly agricultural area. The closest public highway is ¼ of a mile away and access to the plant is strictly controlled via a single access road (the plant is surrounded on 3 sides by sugar cane fields and the ocean on the fourth).

Visitors to the SIPH system will be briefed on the thermal and visual hazards of the system and will be required to wear protective clothing and safety goggles when near the system. They will be accompanied by HCPC personnel at all times.

Unauthorized access and/or vandalism is not expected to be a problem because of the remote facility location and its 24 hour per day operation. A cane truck weighing station overlooks the collector field and is manned 24 hours a day. In addition, a closed circuit television will continuously monitor the collector fields condition during the day with the screen located in the power plant control room. Any unauthorized visitor will be quickly spotted and security actions taken.

VI. ENVIRONMENTAL ASSESSMENT

A. Description of the Proposed Action

The proposed action consists of the installation of 42,420 square feet of parabolic trough, concentrating solar collectors and the integration of the superheated steam that is generated by this solar energy system with the existing industrial process at the HCPC facility.

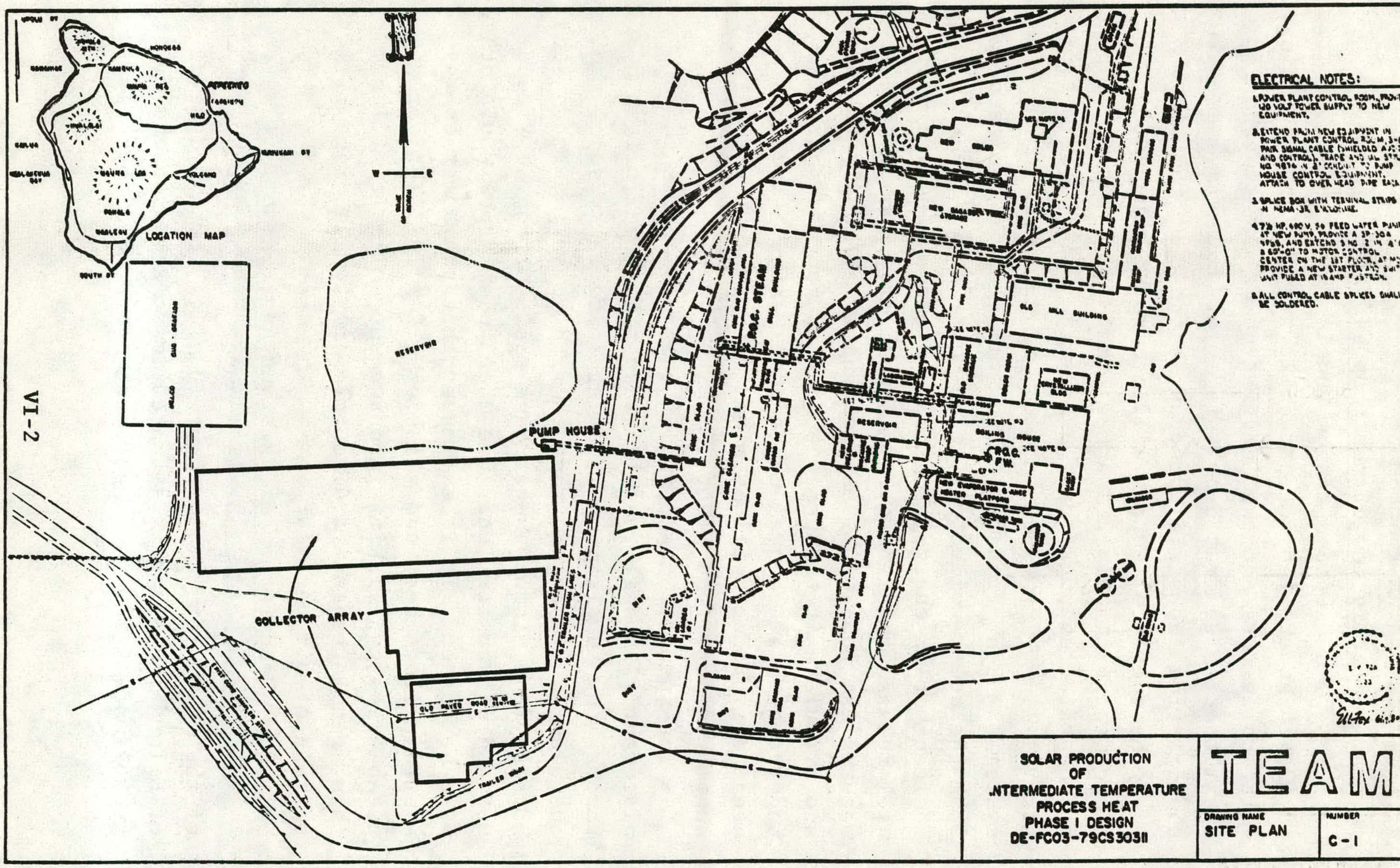
The solar collectors will be ground mounted in a field (approximately 2.5 acres) that is directly adjacent to the existing sugar cane processing buildings (reference fig.VII-1. Figure VI-2 is a flow schematic of the proposed system. A heat transfer fluid will flow in a closed loop from the solar collector field, where it will absorb the incident solar energy, to the heat exchangers where it will release this energy. A second flow loop, the feed-water/steam loop, will use condensate as supply feedwater and circulate it through the heat exchangers where it will undergo a phase change and be superheated. The superheated steam end product will be mixed with the plant's main steam supply to power the plant's mill turbines.

The specific objective of this project is the displacement of fossil fuel (#6 industrial fuel oil at HCPC) through the application of solar energy. By supplementing the plant's steam requirements with solar generated steam, bagasse (the fibrous sugar cane residue) can be "freed-up" and stored for later use when fossil fuel would otherwise be burned. It is estimated that the solar energy system will collect and transfer 7.2×10^9 BTU/Year of useable energy. Taking into account boiler efficiency, this translates into a direct fossil fuel savings of 1489 barrels of oil per year.

B. Description of Existing Environment

The HCPC plant is located on the northeast coast of the island of Hawaii about 10 miles north of the city of Hilo. The plant is situated immediately on the coast approximately 100 feet above the ocean on a rock bluff.

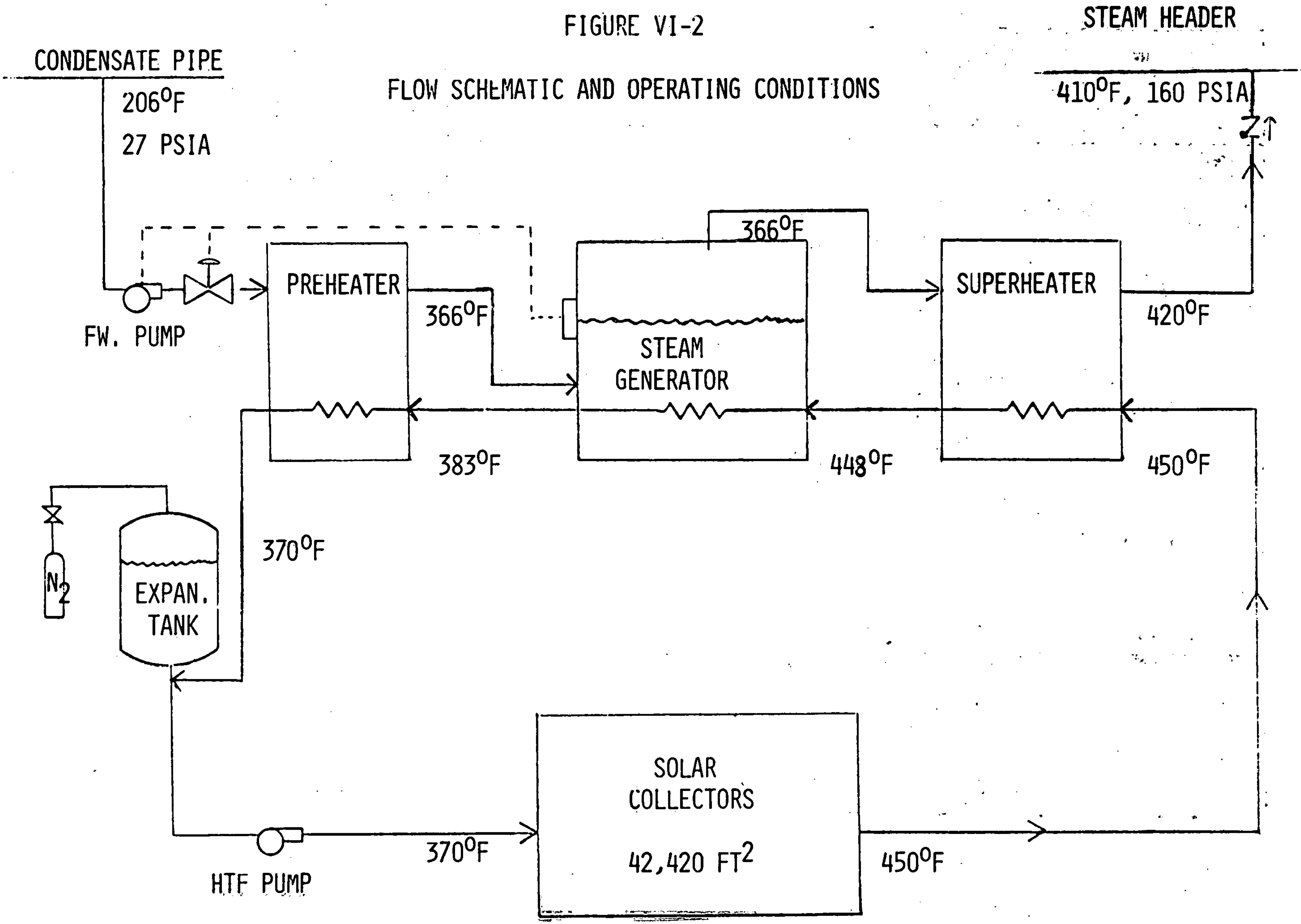
Figure VI-1



LOCATION MAP
RESERVOIR
PUMP HOUSE
COLLECTOR ARRAY
P.O.C. STEAM
OLD MILL BUILDING
ELECTRICAL NOTES:
5. ALL CONTROL CABLE SPLICES SHALL BE SOLDERED.
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
TEAM
DRAWING NAME
SITE PLAN
NUMBER
C-1

FIGURE VI-2

FLOW SCHEMATIC AND OPERATING CONDITIONS



To reduce transportation costs (all cane is trucked to the facility) the plant has been located in the middle of the cane fields which extend almost continuously 8 miles south to the edge of Hilo, 10 miles inland and 30 miles north along the coast. The surrounding area is thus predominantly agricultural.

The land generally slopes upward toward the west (average grade at the site of 16%) due to Mauna Kea volcano which is approximately 35 miles inland. Soil conditions at the site consist of a surface layer of soft, saturated brown clayey silt (volcanic ash) which extends from 5 to 20 feet. This is underlain by varying layers of medium to stiff clayey silt and decomposed lava rock to about 41 feet.

The climate is generally tropical with hot humid summers and mild winters. Average annual precipitation ranges from 150-160 inches/year, 60% of which falls between November and March. Predominant winds in the area are from the east and northeast (on-shore) with an average daily wind speed of 7 mph (reference NOAA climatic atlas).

Water for the plant processes is supplied via a dammed stream located ½ mile inland from the plant. It is used primarily for feedwater makeup and cane cleaning. (It is also the potable water supply for personnel requirements.) A two-acre reservoir adjacent to the plant and on the north side of the proposed collector field supplies backup cleaning water for the cane cleaning operation.

Wastewater from the cane cleaner is pumped to a land containment area 1000 feet from the plant. The wastewater, which contains soil, rocks, etc. from the washed cane, flows into settling ponds within the land containment area to allow gradual water filtration.

The solar collectors will be ground mounted in a field that is currently unused. The field has a slight downward slope (about 5°) toward the north and rainwater drains into the reservoir at the north edge of the field. The field has an unobstructed east, south and west view and only two or three trees border it on the north. The field is approximately 2.5 acres in area and at its closest point is 800 feet from the edge of the bluff which borders the ocean (the existing plant is located between the field and the bluff).

C. Potential Environmental Impacts

Potential environmental impacts can be categorized as follows:

- impact on air quality
- impact on water quality
- impact on flora and fauna
- noise impacts
- visual impacts

The proposed solar energy system will have no negative effects on local air quality. The system does not take in or expel any gasses and its components will not degrade or outgas in the operating temperature range.

The system will, in fact, have a positive impact on local air quality to the extent that the solar system displaces fuel oil which would otherwise be burned. The combustion of fossil fuels can give rise to a variety of air pollutants, including NO_x, SO_x and particulates, thus by displacing fuel oil, the solar system would reduce air pollutants and improve local air quality.

With respect to water quality, the solar energy system will use a heat transfer fluid as the circulating media through the collectors, so there will be no major increase in demand for water resources. Cleaning of collector reflective surfaces is anticipated on a quarterly basis; however, this will require a high pressure low volume spray of water possibly mixed with a mild biodegradable detergent. Sample reflective films that were placed horizontally face up in the field for five months showed depositions of dust and salt that were easily removed by rubbing the surface gently with one finger.

Thus, collector cleaning will involve only a high pressure surface agitation and will not require an industrial strength detergent that could pose environmental hazards when mixed with ground water.

The proposed heat transfer fluid is a synthetic hydrocarbon base fluid manufactured by Gulf Oil Company and trademarked Synfluid White Oil 4cs. Table VI-1 lists the fluid's major properties. It has negligible solubility in water and is colorless and odorless. Table VI-2 is the material safety data sheet from OSHA and the Department of Labor for the fluid. As indicated therein, prolonged and repeated contact may irritate the skin of some individuals; however, the product was nontoxic to experimental laboratory animals.

According to the Food and Drug Administration, the fluid fully complies with 21 CFR 172.878 and may be used as a component of nonfood articles intended for use in contact with food. Furthermore, according to the U.S. Department of Agriculture the fluid is acceptable with incidental food contact, as a lubricant, antirust film and tank closure gasket or seal release agent in Federally inspected meat and poultry establishments.

During normal use and handling, no special protection is required other than following normal industrial practices. Frequent or prolonged skin contact or inhalation of fumes, mists or vapors will be avoided and oil soaked clothing will not be worn. When working with the fluid under elevated temperatures, the room or enclosure will be well ventilated and air respirators (mechanical filter) will be worn by personnel.

The collector heat transfer loop is under low pressure, is self-contained and, under normal operating conditions, no discharges will be made to the water environment. The only possible exceptions to this would be (1) minor leaks that may occur at pump seals and other connections, and (2) accidental spills resulting from a

TABLE VI-1

GULF SYNFLUID® WHITE OIL, 4CS

PROPERTY	TYPICAL VALUE		METHOD
Viscosity	SUS	cs	D 445
@ 210 F (98.9 C)	39	3.97	
100 (38)	92	18.43	
0 (-17.8)		339	
-40 (-40)		2,514	
Viscosity Index	124		D 2270
Pour Point, F (C)	<-90 (-68)		D 97
Flash Point, F (C)	435 (221)		D 92
Fire Point, F (C)	480 (249)		D 92
Evaporation Loss, 6.5 hrs @ 400 F, wt %	10.10		D 972
Autoignition Temperature, F (C)	680 (360)		D 2155
Specific Gravity, 60/60 C	0.8171		D 1298
Total Acid Number	<0.03		D 974
Color, Saybolt, (min)	+30		D 156
Appearance	Clear & Bright		
Odor	No foreign odor		

Complies with all
requirements of
21 CFR 172.878

TABLE VI-2

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
MATERIAL SAFETY DATA SHEET

Synfluid White Oil 4cs, Gulf 5/17/79 P. D. Guiney

SECTION I

MANUFACTURER'S NAME Gulf Oil Company - U.S.	EMERGENCY TELEPHONE NO. (713) 226-1011
ADDRESS (NUMBER, STREET, CITY, STATE & ZIP CODE) P.O. Box 1519, Houston, TX 77001	
CHEMICAL NAME & SYNONYMS Synthetic Hydrocarbon Base Fluid	TRADE NAMES & SYNONYMS Gulf Synfluid White Oil 4cs
CHEMICAL FAMILY Aliphatic Hydrocarbon	FORMULA Polyalphaolefin Mixture

SECTION II – HAZARDOUS INGREDIENTS

MATERIALS	%	TLV (Units)	MATERIALS	%	TLV (Units)

This product is not classified as a "hazardous material" in normal use as defined in the U.S. Department of Labor Regulations 29 CFR 1915, 1916 and 1917.

DOT HAZARD CLASS: Excepted from regulations

SECTION III – PHYSICAL DATA

BOILING POINT °C (°F) Overpoing (oil base)	>149°C (>300°F)	SPECIFIC GRAVITY (H_2O=1) 15.6°/15.6°C	0.8184
VAPOR PRESSURE (mm Hg.)	Negligible	PERCENT VOLATILE BY VOLUME (%)	0
VAPOR DENSITY (Air = 1)	NA	EVAPORATION RATE	0
SOLUBILITY IN WATER	Negligible		
APPEARANCE AND ODOR	Colorless, odorless fluid		

SECTION IV – FIRE AND EXPLOSION HAZARD DATA

FLASH POINT	FLAMMABLE LIMITS	LEL	UEL
225°C (435°F) COC	ND		

EXTINGUISHING MEDIA

- [ ] ALCOHOL FOAM
- [x] CARBON DIOXIDE
- [x] DRY CHEMICAL
- [x] FOAM
- [x] WATER SPRAY (FOG)
- [ ] OTHER

SPECIAL FIRE FIGHTING PROCEDURES Use foam and water spray carefully to prevent excessive frothing. Use water to keep fire-exposed containers cool. Water spray may be used to flush spills away from exposures.

FIRE AND EXPLOSION HAZARDS Slight when exposed to heat or flame; can react with oxidizing materials. Combustible.

NA = Not Applicable ND = No Data Available Gulf Modified Form OSHA 20

Synfluid White Oil 4cs, Gulf

SECTION V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE
Observe current ACGIH TLV of 5 mg/m^3 for oil mist.

EFFECTS OF OVEREXPOSURE
Prolonged and repeated contact may irritate the skin of some individuals. This product was non-toxic to experimental laboratory animals.

EMERGENCY AND FIRST AID PROCEDURES
SKIN CONTACT-remove by wiping and wash with soap and water. EYE CONTACT-wash with copious amounts of water. INHALATION-remove from exposure to fumes, mists. INGESTION-DO NOT INDUCE VOMITING. Seek medical aid.

SECTION VI — REACTIVITY DATA

STABILITY:	UNSTABLE		STABLE	X	CONDITIONS TO AVOID: NA

INCOMPATABILITY (Materials to avoid)
NA

HAZARDOUS DECOMPOSITION PRODUCTS
NA

HAZARDOUS POLYMERIZATION:	MAY OCCUR		WILL NOT OCCUR	X	CONDITIONS TO AVOID: NA

SECTION VII — SPILL OR LEAK PROCEDURES

- [ ] EVACUATE AREA
- [x] STOP FLOW
- [ ] ELIMINATE ALL SOURCES OF IGNITION, FLAMMABLES
- [ ] AVOID INHALATION
- [ ] AVOID DERMAL CONTACT
- [ ] RESPIRATORY PROTECTION (AS PER SECTION VIII)
- [x] SKIN PROTECTION (AS PER SECTION VIII)
- [x] ABSORB OR SCRAPE UP
- [ ] VACUUM UP
- [ ] EVAPORATE SMALL AMOUNTS IN HOOD
- [x] INCINERATE UNDER CONTROLLED CONDITIONS
- [ ] INCINERATE USING AFTER BURNER & SCRUBBER
- [ ] BURY IN REMOTE AREA OR USE AS LANDFILL
- [ ] NEUTRALIZE AND WASH AWAY WITH WATER
- [x] OBSERVE GOVERNMENTAL SPILL & WATER QUALITY REGULATIONS
- [x] REMOVE SOILED CLOTHING
- [ ] OTHER

SECTION VIII — SPECIAL PROTECTION INFORMATION

	DURING NORMAL USE	FOR GASES, VAPORS, DUSTS, FUMES, MISTS EXCEEDING TLV	SPECIAL (E.G. THERMAL PROCESSING, SPRAY APPLICATIONS)
GENERAL VENTILATION	Usually none	Yes	Yes
LOCAL EXHAUST	Usually none	Yes	Yes
RESPIRATORY PROTECTION (1-3)	Usually none	1 as required	1 as required

1. Particle-Removing Air Purifying Air Respirator (Mechanical Filter) *2. Gas and Vapor-Removing Air Purifying Respirator (Canister)* *3. Full Face Mask Positive Pressure-Demand Type Supplied Air*

EYE PROTECTION	SAFETY GLASSES	X	CHEMICAL GOGGLES		FACE SHIELD		*(E) EXCELLENT*
PROTECTIVE GLOVES	NEOPRENE	G	POLYVINYL ALCOHOL	E	POLYETHYLENE	E	*(G) GOOD (F) FAIR (P) POOR*
	NATURAL RUBBER	P	BUTYL RUBBER	E	POLYVINYL CHLORIDE	F	*(NR) NOT RECOMMENDED*

OTHER PROTECTIVE EQUIPMENT
Protective garment as required.

SECTION IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Avoid frequent or prolonged skin contact or inhalation of fumes, mists, vapors.

OTHER PRECAUTIONS
Do not wear oil-soaked clothing.

FOR TRANSPORTATION SPILLS OR LEAK EMERGENCIES, CALL: CHEMTREC - 800-424-9300 (CHEMICAL TRANSPORTATION EMERGENCY CENTER).

major break in the heat transfer circuit.

Any minor leaks that may be present are expected to be short-lived and/or insignificant in magnitude. For instance, minor leaks (i.e. 5 drips/minute) around pump seals may exist due to the low fluid viscosity at 400^{o}F, yet these small leaks can be identified and a catch pot placed under them, thus recapturing the fluid. The system will be engineered, operated and maintained to eliminate this type of loss to the best extent possible. Flanged and threaded connections have been eliminated wherever possible and a system walk-through, visually inspecting pipe connections for fluid leaks, will be a routine maintenance procedure.

The worst scenario for a major break in the circulation loop would result in the loss of the total inventory of 1100 gallons of fluid. While the scenario is highly unlikely, the incorporation into the system of a fluid retaining, crushed rock berm would mitigate the immediate environmental impact by temporarily containing the spilled fluid and allowing maintenance personnel adequate time to collect, absorb and dispose of it properly.

The crushed rock berm is composed of ½" to 3" diameter gravel and coarse sand that forms a sloped wall 9" tall. The berm runs the full length of the collector field's north edge and encloses the pump house (the field slopes slightly down toward the north with the pump house being at the lowest elevation).

At 80^{o}F, the fluid is approximately 70 times more viscous than water and will require a considerable length of time to filter through the crushed rock berm, thus allowing maintenance personnel adequate time to collect and dispose of the fluid.

Losing the full inventory of fluid is highly unlikely, however, due to (1) a low-level sensor/alarm in the expansion tank, (2) shut-off valves located at each collector row and at major pipe connections, and (3) continuous 24-hour monitoring of the system condition. A more likely scenario for a major break would result in approximately 250 gallons of fluid spilling onto the ground before the low-level sensor in the expansion tank was activated, which would turn off the circulation pump and sound an alarm. Maintenance personnel would respond to the alarm, locate the break, and close the nearest gate valves. In addition, once the low-level sensor was activated and the pump turned off, the system would be unpressurized and any leakage thereafter would be a slow, gravity-fed flow.

Further insurance that a major spill would be quickly recognized and acted on comes from (1) a manned 24-hrs-a-day weighing station which overlooks the entire collector field and (2) the location of an emergency control panel and closed circuit television monitor in the power plant control room which is also manned 24 hours a day.

Any emergency condition that exists in the solar energy system (such as pump failure or expansion tank low-level) will be indicated by a flashing light on the control panel in the power plant control room. In addition, a closed circuit television system has been included which will provide control room personnel with visual access to the condition of the solar collectors. In this way an emergency system condition, along with any errant collector configuration (i.e., a stowed collector due to overtemperature and loss of flow) can be immediately identified and proper action initiated.

The most probable time for a major pipe rupture to occur would be during daylight operating hours due to the thermal and flow pipe stresses of normal operation. At night the collector piping loop is unpressurized and eventually will cool to ambient temperature. However, even an emergency situation at night or on weekends will alert operating personnel since the power plant control room is manned 24 hours a day.

The impact on flora and fauna will be small and short-lived. It will occur primarily when the site is graded and leveled and will dissipate quickly after completion of construction. Grading requirements for the collector field will consist of cutting and filling to develop a two-level, gently sloping W-E grade. The collectors will be level in the N-S direction; however, to minimize grading requirements, the field's natural E-W slope will be maintained. To account for the field's natural N-S slope, the field will be divided into two steps which are level in the N-S direction.

Collector installation will consist primarily of setting concrete footing foundations and mechanically erecting the collectors and piping network. Complete system installation should not take longer than six months.

After installation, the field will be seeded with a local grass called "Hilo Grass" which has the desirable characteristic of only growing 2 feet tall. After several cuttings, the grass develops a thick surface layer matting which stabilizes the soil and still permits periodic light vehicular access to the collectors.

Noise impacts will also be small and short-lived, occurring mainly during system installation. The collectors track and operate via hydraulic drives and the only system noise will be electric motors. The noise of the adjacent plant will far outweigh that of the solar energy system.

Visual impacts will be virtually nonexistent due to the remote location of the plant (closest public highway is ¼ mile from site) and the nature of the solar collectors. The collectors are the parabolic trough, line-focusing concentrating type, which focus the sun's rays on a 1½" diameter pipe that runs the full length of the collector. The collectors have a focal length of less than 2 feet from the reflective surface after which the rays diverge from the focal point. Thus, if a receiver tube was misaligned and not in the focal point, the unintercepted rays would pass through the focal point and diverge in a radial pattern diluting their visual impact. An overhead aircraft would only see an extremely thin line of reflected sunlight which would be much less glare than the reflectance of a lake or swimming pool.

D. Coordination with Federal, State, Regional and Local Plans

The following Federal, State and Local Agencies were contacted during Phase I:

- Planning Department, County of Hawaii
- Department of Health, State of Hawaii
- State Resource conservationist, State of Hawaii
- Environmental Protection Agency, Honolulu and Washington, D.C. Offices
- United States Coast Guard, Honolulu Office

On the local level, the Planning Director for the County of Hawaii, Mr. Sidney Fuke, was contacted regarding zoning and environmental regulations that applied to the proposed project. There is a Special Management Area (SMA) which parallels the coast and extends inland for approximately the first 150 feet, within which an SMA use permit would have to be obtained. The solar array, however, will be located approximately 800 feet inland and thus an SMA permit is not required. The field is currently zoned for agricultural use and would have to be rezoned for urban use (the plant is zoned for urban use). However, Mr. Fuke indicated the solar energy application would present no obstacles to this zoning change.

The State of Hawaii Resource Conservationist, Mr. John Bedish, was contacted regarding the use of prime farmland for the collector site. The field is labeled prime farmland by the Soil Conservation Service. However, Mr. Bedish indicated that the small area required (2.5 acres) would not impact the State's plans and thus would not necessitate State review of the project.

The State of Hawaii, Department of Health, was contacted and copies of Public Health Regulations, Chapters 37 (Water Pollution Control), 43 (Air Pollution Control), and 342 (Environmental Quality) were reviewed for compliance with the regulations contained therein.

In addition, the Environmental Protection Agency was contacted regarding this project and a copy of the oil pollution prevention regulations (CFR 40, Part 112) was obtained. The regulations state that facilities which have an aggregate storage of 1320 gallons or more of oil must have a Spill Prevention Control and Countermeasure Plan (SPCC Plan). The volume of oil in the solar energy system totals 1120 gallons and thus is below the 1320-gallon limit.

HCPC has an SPCC Plan developed for its fuel oil storage tank and operating personnel are familiar with the procedures taken during a fuel oil spill. The solar energy system will draw upon this experience and training when alerting and preparing personnel for the possibility of a heat transfer fluid spill.

Although an SPCC Plan is not required for this system, the incorporation of a crushed rock berm and the familiarity of operating personnel with proper spill control procedures will insure that a major spill is contained and promptly acted on.

5. Description of Alternatives

Major alternatives to the proposed action are listed below:

- o do not install the solar energy system and continue to use bagasse and fuel oil, i.e.: a "no action" alternative.
- o use the solar energy system but with another heat transfer fluid.
- o use another fuel to provide the necessary heat.

From an environmental point of view, the "no action" alternative is the worst possible choice. Continued burning of fossil fuels will result in more air pollution and the depletion of an increasingly scarce resource. From a production standpoint, the "no action" alternative could lead to periodic shutdowns if fossil fuel supplies became erratic. This alternative only postpones facing the problem of substituting an increasingly scarce and costly resource with an acceptable substitute.

Numerous alternative heat transfer fluids were investigated for this project, including water, other synthetic oils and silicone fluids. This tradeoff analysis must be performed on an individual application basis because of the varying characteristics of each fluid. The HCPC tradeoff analysis revealed that fluids which were more environmentally benign (i.e., water and silicone fluids) had extenuating characteristics that either presented safety hazards (a high pressure water piping network) or resulted in increased energy use (silicone fluids require twice the pumping power of oils). The fluid selected offered the best combination of flammability, toxicity, viscosity, specific heat and durability.

The use of another fuel to provide the necessary heat is considered a secondary option primarily because of the time and/or technology constraints on other fuel sources.

Eucalyptus wood chips are one alternative source; however, the long lead time for planting and growth makes this a long-term alternative. In addition, the lower conversion efficiency of photosynthesis means more land area would be required than a solar energy system for an equivalent energy yield.

Other alternative energy sources such as wind, geothermal or ocean thermal are either still in the developmental stages or are not abundant enough at the site to compete with the solar IPH system.

VII. PHASE II - MANAGEMENT PLAN

A. Management Team

As prime contractor, Hilo Coast Processing Company (HCPC) will be responsible to the Department of Energy for all aspects of the project. The project management organization for Phase II is illustrated by Figure VII-1. The Principal Investigator, Mr. Terris Inglett, HCPC Executive Vice President and Chief Executive Officer, will provide overall direction, including planning, corrdination, and integration to ensure that the project goals and objectives are met. In performance of these functions, he will be provided with technical and administrative support from C. Brewer and Company by Mr. Jerry Allen, Vice Pesident, Energy, Research and Development. The day-to-day details of Phase II will be handled by Mr. Larry Iwami, HCPC Power Plant Superintendent. Responsible to Mr. Iwami for the tasks assigned to them will be the C. Brewer and Company Ltd. Purchasing Department located in Hilo and headed by Mr. Ernest Smith; Mr. Andy Golay, TEAM, Inc. Project Director for this program; and Dr. Paul Yuen, Director of the Hawaii Natural Energy Institute at the University of Hawaii at Manoa.

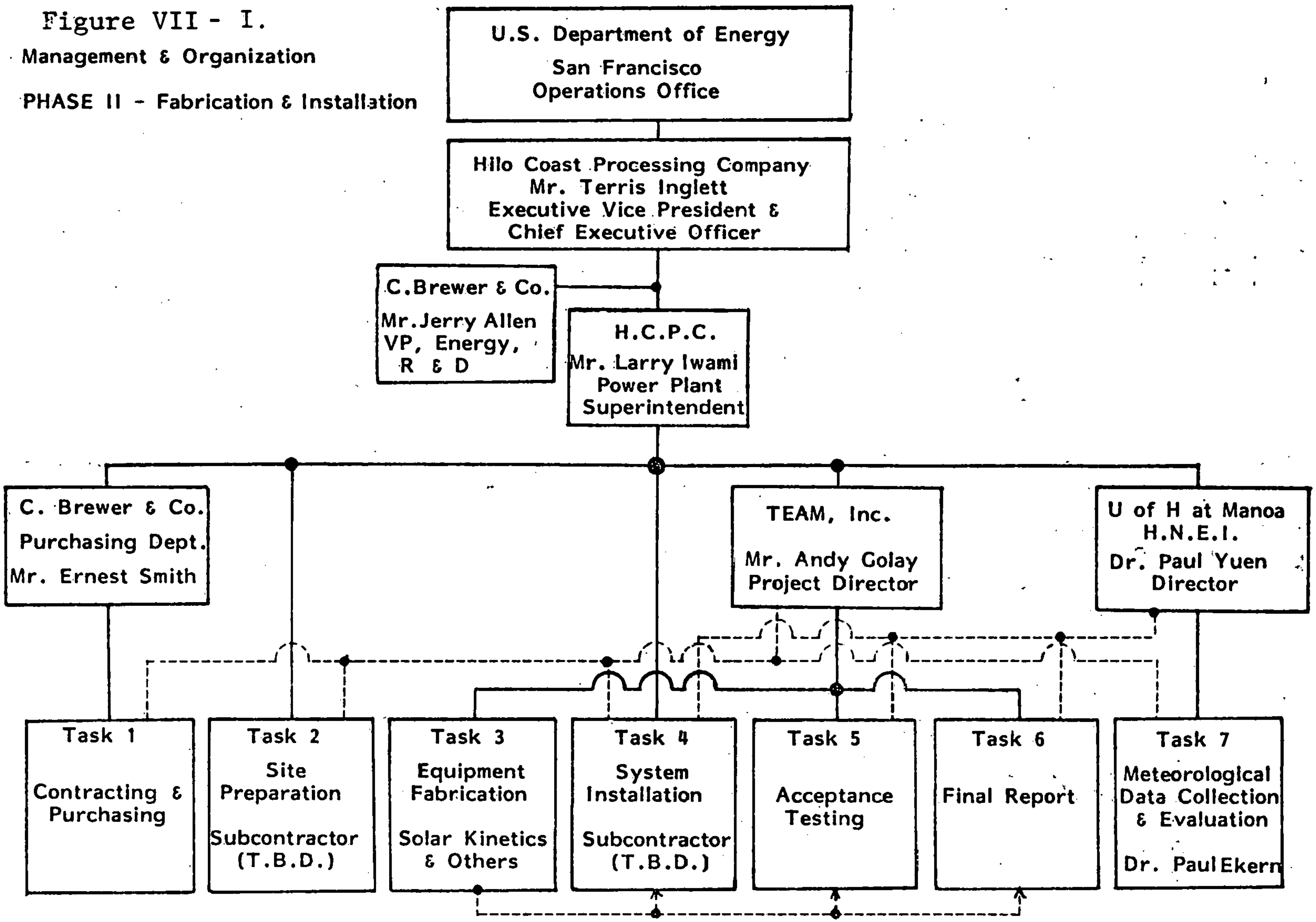
B. Work Breakdown Structure and Management

Phase II, Fabrication and Installation, is shown as being comprised of seven primary tasks described and assigned as follows:

Task 1 - Contracting and Purchasing

The Purchasing Department of C. Brewer and Company will be responsible for the contracting and purchasing of the goods and services for Phase II. They will utilize the final drawings and specifications produced in Phase I of the project. Wherever possible and appropriate, effort will be made to obtain competitive bids. Hilo Coast Processing Company and TEAM will support this effort as appropriate to assure that the project's cost and technical requirements are being met. (This activity was not designated as a separate task in the original proposal.)

Figure VII - I.
Management & Organization
PHASE II - Fabrication & Installation



T.B.D. - To be determined.

DRM:ssi
06/13/80

Task 2 - Site Preparation (including foundations)

Site preparation involves reshaping the project site to new contours, properly compacting the fill areas, installing any underground conduits and water piping, and providing the access roadway through the center of the collector field. This work is to be subcontracted to a local contractor. Larry Iwami, or others on HCPC's staff, will provide the direct HCPC overview and control of this task.

Task 3 - Equipment Fabrication

Once the Brewer Purchasing Department has issued the purchase orders for the various pieces of fabricated equipment, TEAM, Inc. will direct liaison with the manufacturers to insure conformance with the intended design considerations.

Task 4 - System Installation

System installation is to be subcontracted to one or more local contractors and involves the erection and alignment of the collectors, all the associated wiring, plumbing, and insulation, the erection of the pump and boiler house, and the installation and connection of all the equipment housed therein, integration with the existing steam system of the raw sugar factory complex and installation and hook-up of all the controls and data collection equipment. Larry Iwami, assisted by others on HCPC's staff, will provide the direct overview and control of this task. University of Hawaii personnel will be involved in the installation of the controls and data collection subsystems.

Task 5 - Acceptance Testing

Once installed acceptance testing will be conducted to debug the system and insure satisfactory performance. TEAM, Inc., as designers of the integrated system, will be in charge of this task and will be assisted by HCPC and University of Hawaii personnel, as well as representatives of major suppliers if appropriate.

Task 6 - Final Report

TEAM, Inc., as designer of the system and lead party for the acceptance, testing, will be responsible for compiling the final report for Phase II. The various vendors and contractors will be responsible for providing HCPC as-built drawings and specifications for inclusion in the final report. HCPC and the University will provide inputs for the final report as appropriate.

Task 7 - Meteorological Data Collection and Evaluation

The meteorological data collection and evaluation which is underway in Phase I will be continued through Phase II (and Phase III) in order to gain historical data at the site as well as to establish, if possible, a correlation with long-term data collected at the Hilo Cloud Physics Observatory, the nearest site for which data in sufficient depth is available over an extended period. Once the system is operational the meteorological data will provide part of the information needed to evaluate system performance. Dr. Paul Ekern of the University will continue to be responsible for this task. (This activity was not designated as a separate task in the original proposal.)

VIII. PHASES II & III COST PLANS

A. Cost Summaries

Table VIII-1 itemizes the estimated costs for Phase II, Fabrication and Installation. Total Phase II costs are estimated at $1,915,710.00. Table VIII-2 summarizes the Phase II construction management costs.

Phase III costs are broken down by organization and summarized in Table VIII-3 (HCPC), Table VIII-4 (C. Brewer and Co.), Table VIII-5 (Univ. of Hawaii), and Table VIII-6 (TEAM, Inc.). Table VIII-7 summarizes the projected HCPC direct costs for maintenance, operation, insurance, etc. Total Phase III costs are estimated at $91.529.00.

B. Contract Pricing Proposals (Form 60)

Table VIII-8 is the Phase II contract pricing proposal (Form 60) and indicates the level of cost sharing to be undertaken by HCPC, C. Brewer and the University of Hawaii.

Table VIII-9 is the Phase III contract pricing proposal (Form 60) and also indicates the level of cost sharing to be undertaken by HCPC, C. Brewer and the University of Hawaii.

A summary of Phases II & III cost sharing is presented below:

PHASE II	DOE	HCPC	C. BREWER	UNIV.HAWAII
$	1,826,920	72170	6150	10,470
%	95.4	3.8	.3	.5
PHASE III				
$	76,578	90,529	13,589	11,060
%	39.9	47.2	7.1	5.8

TABLE VIII-1

HCPC SOLAR INDUSTRIAL PROCESS HEAT SYSTEM

COST DETAIL - PHASE II

Item	Quantity	Unit Cost Mat'l	Unit Cost Labor	Item Cost Mat'l	Item Cost Labor	Freight	Total
Solar Collectors	42,420 (ft^2)	\$20/ft^2	\$ 3	\$848,400	\$127,260	\$116,100	\$1,091,760
Site Preparation							248,270
Collector Foundations							
Excavation	570 Yd^3		3.45		1,966		
Backfill	131 "		18.75		2,456		
Concrete	439 "	53.10	9.10	23,311	3,995		
Reinforcing	479 Yd^2	1.98	1.35	948	647		
Anchor Bolts	6,300 lb	.75		4,725			
Subtotal				28,984	9,064		38,050
Pump House Building	1	6000.00	3,000.00	6000.00	3,000.00		9,000
Pipe & Fittings							
4" pipe	400 lin.ft.	21.12	29.55	8,448	11,820		20,270
3" pipe	140	14.66	23.04	2,052	3,226		5,280
2½" pipe	880	11.79	19.66	10,377	17,304		27,680
2" pipe	180	8.11	16.22	1,460	2,920		4,380
1½" pipe	1950	7.10	14.61	13,845	28,490		42,330
1" pipe	1190	2.83	4.24	3,368	5,046		8,410

HCPC Solar Industrial Process Heat System, Cost Detail - Phase II (continued)

Item	Quantity	Unit Mat'l	Unit Cost Labor	Item Mat'l	Item Cost Labor	Freight	Total
Truss Support and additional fittings and connections	1 Lot			5,150	2,090		$ 7,240
Insulation							
4" Dia, 2½" Thick	400 ft	20.43	10.21	8,173	4,084		12,260
3" Dia, 2½" Thick	140 ft	19.44	8.70	2,722	1,218		3,940
2½" Dia, 2½" Thick	880 ft	18.08	7.76	15,910	6,829		22,740
2" Dia, 2" Thick	180 ft	16.40	5.81	2,952	1,046		4,000
1½" Dia, 2" Thick	1950 ft	16.02	4.72	31,239	9,204		40,440
Steam Generator	1	41,000		41,000		5,000	46,000
Heat Transfer Fluid Pump	1	4,250	500	4,250	500	425	5,180
Feedwater Pump	1	1,200	500	1,200	500	120	1,820
Expansion Tank	1	1,250	450	1,250	450	1,000	2,700
Heat Transfer Fluid	1300 gal	3.55		4,615		1,000	5,610
Chemical Feed Equipmt.	1	784	200	784	200	224	1,210
Blowdown Equipment	1	1,055	245	1,055	245	106	1,410
System Control Equipmt.				14,717	8,000	736	23,450
Data Acquisition System				45,115	35,500	2,256	82,870
Total Direct Costs							1,756,300
Construction Management							87,220
Hawaii State Excise Tax							72,190
TOTAL SYSTEM COSTS							$1,915,710

TABLE VIII-2

CONSTRUCTION MANAGEMENT COST BREAKDOWN

	Hours	Rate	Total
HCPC			
Project Director	160	$ 34.25	$ 5,480
Project Superintendent	640	21.70	13,890
Travel - 2 people, 2 trips, Hilo to Oakland, California		450.00	1,800
Per Diem - 2 people, 2-day trip, 2 trips		125.00	1,000
SUBTOTAL			$22,170
C. Brewer			
Project Coordinator	160	25.70	4,110
Travel -			
Honolulu/Oakland			
2 trips airfare		450.00	900
4 days per diem		125.00	500
Honolulu/Hilo			
2 trips airfare		120.00	240
4 days per diem		100.00	400
SUBTOTAL			$ 6,150
TEAM, Inc.			
Senior Engineer	160	26.08	4,170
Engineer	880	13.75	12,100
Overhead - 103%			16,760
Travel - 3 trips Tucson/Hilo		506.00	1,520
Per Diem - 36 Days		100.00	3,600
Fee - 10%			3,820
SUBTOTAL			$41,970
University of Hawaii (See Attached Sheet)			
SUBTOTAL			$16,930
TOTAL			$87,220

TABLE VIII-3

Detail of HCPC Phase III Projected Costs

	BASE		1981		1982		1983		TOTAL	
PROJ. MGMT. LABOR	Hrs/mon	'80 $'s/hr	Hours	1981 $'s	Hours	1982 $'s	Hours	1983 $'s	Hours	$
Project Manager	4	34.25	48	1,808	48	1,989	48	2,188	144	5,985
Power Plant Supt.	12	21.70	144	3,437	144	3,781	144	4,159	432	11,377
Power Plant Supv.	15	14.45	180	2,861	180	3,147	180	3,462	540	9,470
Secretary	3	10.70	36	424	36	466	36	513	108	1,403
Subtotal			408	8,530	408	9,383	408	10,322	1,224	28,235
TRAVEL	Units	'80 $'s/Unit								
			Trips		Trips		Trips		Trips	
Air Fare Hilo/West Coast	Man Trip	450	2	990	2	1,089	2	1,198	6	3,277
			Mandays		Mandays		Mandays		Mandays	
Per Diem	Manday	125	5	688	5	756	5	832	15	2,276
Subtotal (Travel)				1,678		1,845		2,030		5,553
			Years		Years		Years			
OPERATION & MAINTENANCE	Year	15,584	1	17,142	1	18,857	1	20,742		56,741

NOTE: Base Figures Escalated 10%/Year

Although 1981 would be only a half year (for Phase III activities) all of the above shown costs reflect a full year for 1981 in expectation of higher costs for first half-year of operations.

TABLE VIII-4

Detail of C. Brewer and Company, Limited Phase III Projected Costs

	BASE		1981		1982		1983		TOTAL	
	Hrs/mon	'80 $'s/hr	Hours	1981 $'s	Hours	1982 $'s	Hours	1983 $'s	Hours	$'s
Project Coordinator	8	25.70	96	2,714	96	2,985	96	3,284	288	8,983
TRAVEL	Units	'80 $'s/Unit								
Honolulu/Hilo/Honolulu										
Air Fare	Man Trips	120	Trips 2	264	Trips 2	290	Trips 2	319	Trips 6	873
Per Diem	Mandays	100	Mandays 2	220	Mandays 2	242	Mandays 2	266	Mandays 6	728
Honolulu/West Coast/Honolulu										
Air Fare	Man Trips	450	Trips 1	495	Trips 1	545	Trips 1	599	Trips 3	1,639
Per Diem	Mandays	125	Mandays 3	413	Mandays 3	454	Mandays 3	499	Mandays 9	1,366
Subtotal				1,392		1,531		1,683		4,606
GRAND TOTAL										13,589

NOTE: Base Figures Escalated 10%/Year

Although 1981 would be only a half year (for Phase III activities) all of the above shown costs reflect a full year for 1981 in expectation of higher costs for first half year of operations.

TABLE VIII-5

HCFC/DOE SIPH PROJECT

UNIVERSITY OF HAWAII AT MANOA

PROPOSED BUDGET

August 1, 1980 - November 30, 1983

	Phase II 10 months 8/1/80 - 5/31/81		Phase III 30 months 6/1/81 - 11/30/83		Total	
	UH	DOE	UH	DOE	UH	DOE
A. SALARIES AND WAGES						
1. Principal Investigator Paul Yuen (Calendar Yr - 5%)	1,950	-	5,460	-	7,410	-
2. Faculty Associates						
a. Paul Ekern (Calendar Yr - 15%)	5,050	-	-		5,050	-
b. James Chou (Academic Yr - 5%)	1,440	-	3,460		4,900	-
Summer - 100% (4 mos.)	-	3,844	-	13,998	-	17,842
3. Graduate Student Academic Year - 50%, Summer - 100%	-	-	-	20,661	-	20,661
TOTAL SALARIES AND WAGES	8,440	3,844	8,920	34,659	17,360	38,503
B. FRINGE BENEFITS	2,025	77	2,140	1,908	4,165	1,985
C. DOMESTIC TRAVEL						
1. One trip to Washington, D.C.	-	-	-	2,000	-	2,000
2. Ten trips to Hilo	-	900	-	2,100	-	3,000
D. COMPUTER COSTS	-	-	-	2,000	-	2,000
E. COMMUNICATIONS	-	100	-	300	-	400
F. TOTAL DIRECT COSTS	10,465	4,921	11,060	42,967	21,525	47,888
G. INDIRECT COSTS 31.30% of Total Direct Costs	-	1,540	-	13,445	-	14,985
H. TOTAL COSTS	$10,465	$6,461	$11,060	$56,412	$21,525	$62,873
TOTALS	$16,926		$67,472		$84,398	

6/5/80

TABLE VIII-6

DETAIL OF TEAM, INC. PHASE III COSTS

	Hours	Rate*	Total
Senior Engineer	120	$26.43	$3,171.60
Engineer	240	13.94	3,345.60
Draftsperson	40	8.66	346.40
Secretary	80	7.39	591.20
			$7,454.80
Overhead @ 103%			7,678.44
Transportation:	2 round trips Tucson/Hilo @ $600 per trip		1,200.00
Per Diem	1 person, 20 days @ $100 per day		2,000.00
	Subtotal		18,333.24
FEE (10%)			1,833.32
	TOTAL		$20,166.00

*Labor escalation rate of 7% per annum assumed.

TABLE VIII-7

Detail of HCPC Phase III Projected Direct Costs (in 1980 $'s)

Routine Maintenance	
mowing, trimming, and/or herbicide	$ 720/yr.
collector cleaning	1,750
mechanical equipment	437
Periodic Maintenance	
collectors (pylon painting and reflective film replacement)	4,437
mechanical equipment (heat exchangers tube bundles)	1,563
Subtotal	$ 8,907
Operating Costs	
personnel and material	$ 860
parasitic power (electrical: 24,700 kwh @ $.09/kwh)	2,220
Subtotal	$ 3,080
Insurance	$ 1,000
Property Tax (exempt if completed prior to 1/1/82)	----
Subtotal	$12,987/yr.
Contingency @ 20%	$ 2,597
Projected Direct Cost (1980 $'s)	$15,584/yr.

TABLE VIII-8

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR: Hilo Coast Processing Company	SUPPLIES AND/OR SERVICES TO BE FURNISHED: Fabrication and Installation of 42,420 feet of Solar Collectors at Hilo Coast Processing Company
HOME OFFICE ADDRESS: P. O. Box 18, Pepeekeo, HI 96783	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Pepeekeo, HI	TOTAL AMOUNT OF PROPOSAL: $ — GOV'T SOLICITATION NO. 03-79-CS30121

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST	REFERENCE
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. PURCHASED PARTS			1,089,350		
b. SUBCONTRACTED ITEMS			666,950		
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				1,756,300	
2. MATERIAL OVERHEAD (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
	160	34.25	5,480		
	640	21.70	13,890		
TOTAL DIRECT LABOR				19,370	
4. LABOR OVERHEAD (Specify Department or Cost Center)	O.H. RATE	X BASE=	EST COST ($)		
(Included in Rate/Hour figures shown above)					
TOTAL LABOR OVERHEAD				---	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			1,800		
b. PER DIEM OR SUBSISTENCE			1,000		
TOTAL TRAVEL				2,800	
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
a. W.A. Hirai & Assoc/TEAM, Inc. Engineering Mgmt.			41,970		
b. University of Hawaii			16,930		
c. C. Brewer and Company, Limited			6,150		
TOTAL CONSULTANTS				65,050	
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				72,190	
10. TOTAL DIRECT COST AND OVERHEAD				1,915,710	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES					
13. TOTAL ESTIMATED COST					
14. FEE OR PROFIT					
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				1,915,710	

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October 1971
General Services Administration
FPR 1-16.806
5060-101

Cost Share		DOE	HCPC	Brewer	U of H	Total
Item 1		1,706,3000	50,000			1,756,300
Item 3,4 & 7			22,170			22,170
Item 8a		41,970				41,970
Item 8b		6,460			10,470	16,930
Item 8c				6,150		6,150
Item 9		72,190				72,190
TOTAL	$	1,826,920	72,170	6,150	10,470	1,915,710
	%	95.4%	3.8%	.3%	.5%	100%

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)* DOE PON 03-79CS30121
Phase II follow on to DOE Agreement No. DE-FC03-79CS30311.
Phase II involves fabrication and installation of 42,420 ft^2 of solar collectors.
and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert H. Hughes Chairman of the Board of Directors	for Jerry E Allen

NAME OF FIRM	DATE OF SUBMISSION
Hilo Coast Processing Company	June 6, 1980

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*		EST COS
1a	Purchase Parts		
	Collectors	848,400	
	Steam Generator	41,000	
	System Control Equipment	14,717	
	Data Acquisition System	45,115	
	Misc. Equipment & Heat Transfer Fluid	13,154	
	Shipping Charges	126,967	
	Subtotal		1,089,
1b	Subcontracted Items		
	Site Preparation	248,270	
	Collector Foundations	38,050	
	Collector & Equip. Installation including controls	137,155	
	Piping & Insulation (including truss across road)	198,970	
	Pump House Building	9,000	
	Data Acquisition System Software and Installation	35,500	
	Subtotal		666,
7a	Travel		
	2 persons, 2 trips Hilo-Oakland AirFare @ 450	1,800	
	2 persons, 2 trips, 2 day/trip Per Diem @ 125	1,000	
	Subtotal		2,
9	Other Direct Costs 4% State Excise Tax (On 1a, 1b, 8a, and Noncontributory Portion of 8b)		72,

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH AN GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☐ YES ☒ NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

☒ YES ☐ NO *(If yes, identify.)*: ☒ ADVANCE PAYMENTS ☒ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

☒ YES ☐ NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM

TABLE VIII-8 (cont'd)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES

NAME OF OFFEROR: Hilo Coast Processing Company	SUPPLIES AND/OR SERVICES TO BE FURNISHED (Phase III) Operation and Evaluation of 42,420 sq. feet of solar collectors at Hilo Coast Processing Company.
HOME OFFICE ADDRESS: P. O. Box 18 Pepeekeo, HI 96783	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Pepeekeo, Hawaii	TOTAL AMOUNT OF PROPOSAL: $
	GOV'T SOLICITATION NO. 03-79-CS30121

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST	REFERENCE
1. DIRECT MATERIAL (Itemize on Exhibit A) Included in Item 9					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD (Rate %X$ base=)					
3. DIRECT LABOR (Specify) See Attachment 1	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Project Manager	144	41.56	5,985		
Power Plant Superintendent	432	26.34	11,377		
Power Plant Supervisors	570	17.54	9,470		
Secretary	108	12.99	1,403		
TOTAL DIRECT LABOR				28,235	
4. LABOR OVERHEAD (Specify Department or Cost Center)	O.H. RATE	X BASE =	EST COST ($)		
(Included on Rate/Hour figures shown above)					
TOTAL LABOR OVERHEAD					
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			3,277		
b. PER DIEM OR SUBSISTENCE			2,276		
TOTAL TRAVEL				5,553	
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
a. C. Brewer Administrative & Technical Assistance			13,589		
b. Univ. of HI at Manoa, Data Collection & Evaluation			67,472		
c. TEAM, Inc. Personnel Training & Manual Prep.			20,166		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A) Operation & Maint. Labor & Materials				57,741	
10. TOTAL DIRECT COST AND OVERHEAD					
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES					
13. TOTAL ESTIMATED COST					
14. FEE OR PROFIT					
15. TOTAL ESTIMATED COST AND FEE OR PROFIT					

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5060-101

Cost Share		DOE	HCPC	Brewer	U of HI	Total
Items 1,3,7,&9		-	90,529	-	-	90,529
Item 8a.		-	-	13,589	-	13,589
Item 8b.		56,412	-	-	11,060	67,472
Item 8c.		20,166	-	-	-	20,166
TOTAL	$	76,578	90,529	13,589	11,060	191,756
	%	39.9	47.2	7.1	5.8	100.0

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.) DOE PON 03-79CS30121

Phase III follow-on to Phase II follow-on to DOE Agreement No. DE-FC03-79CS30311
Phase III involves operation and evaluation of 42,420 ft^2 of solar collectors.

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert H. Hughes Chairman of the Board of Directors	

NAME OF FIRM	DATE OF SUBMISSION
Hilo Coast Processing Company	June 13, 1980

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☐ YES ☒ NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

☒ YES ☐ NO *(If yes, identify.)*: ☒ ADVANCE PAYMENTS ☒ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

☒ YES ☐ NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

2

IX. ECONOMIC ANALYSIS

A. INTRODUCTION

The economic analysis herein is based on the publication UCRL-52814, Economic Analysis of Solar Industrial Process Heat Systems published August 17, 1979 by the Lawrence Livermore Laboratory. Certain input variables to the analysis have been fixed by the Department of Energy (DOE) in an attempt to normalize the analysis for different SIPH projects. While this method may not accurately reflect the economic situation for a particular project (since every firm has different financial characteristics) it does ensure a true "apples to apples" comparison when ranking the economic merits of different SIPH projects.1/

Following the procedures outlined in the above publication, M-Factors (see nomenclature) for a variety of discount rates (10%, 15% and 20%) were developed for the HCPC project. These values were utilized in turn to develop the following economic characteristics:

- internal rate of return assuming the entire system cost represents an investment by the contractor;
- internal rate of return assuming the solar investment consists only of the equity portion ($78,320) of total projected project costs of $1.92 million.
- the levelized price of the solar thermal process heat energy produced under varying discount rates;
- the levelized price of the alternative conventional energy under varying discount rates;
- expected annual fossil fuel savings; and,
- payback period.

1/ In particular, the four "fixed" variables, tax credits (TC), general inflation rate (g), fuel inflation rate (g^1), and replacement of 25% of the system in year 10 $M(t_c)$, do not reflect current economic conditions or expectations at HCPC and the assumed values of these variables markedly understates the cost effectiveness of the system.

B. Nomenclature

M =	$\frac{C_s}{I}$ Levelized required revenue per total investment dollar, the M - factor.
E_s =	Annualized energy provided (saved) by new system at point of use.
C_s =	Levelized required revenue for solar-generated energy or energy conservation.
I =	Total initial system component investment.
SOYD:	Sum-of-Years-Digits Depreciation calculation technique.
DP:	Depreciation Period
$\mathcal{E}$ =	Solar effectiveness factor (fuel energy saved by new system divided by new energy delivered).
f =	Portion of investment financed by loan.
g =	General inflation rate.
g^1 =	Fuel inflation rate.
$m(t_c)$ =	Major component replacement cost in year t_c (as a proportion of I in zero-year dollars).
N =	System life.
$OMPI_o$ =	Average annual operating, maintenance, property tax and insurance costs (as a proportion of I in zero-year dollars).
P_{fo} =	Price of conventional fuel in zero-year.
S =	Salvage value of new system (net).
TC =	Investment tax credit rate.
$\underline{r}$ =	Marginal composite tax rate.
R =	Market discount rate.
R* =	Internal rate of return.
DEP:	Present value of depreciation charges (as a fraction of I).

Nomenclature (continued)

DP = Depreciation period.

P_s = Levelized price of solar energy (or energy saved) produced by the prospective project.

εE_s = Expected annual fossil fuel savings from the solar system.

T_p = Payback period for initial investment.

CRF(R,N)= Capital recovery factor at (R) market discount rate over (N) system life.

LP = Loan period (where LP=N in this analysis).

C. INTERNAL RATE OF RETURN ANALYSIS

The following parameters were inputs to the internal rate of return analysis:

1. SOYD
2. DP = 7 years
3. E_s = 7.21 billion Btu (See Table IX-3)
4. $\mathcal{E}$ = 1.28 1/
5. f = 0
6. g = 6%
7. g^1 = 8%
8. I = Case I = $1.915 **million** (See Table IX-1
   Case II - $78,320
9. $M(t_c)$ = .25 (10)
10. N = 20 years
11. $OMPI_o$ = .006 (Case I) and .143 (Case II). (See Table IX-2)
12. P_{fo} = $4.07/million Btu's.
13. S = 0
14. TC = 20%
15. r = 50%
16. R = 10%; 15%; 20%
17. r = 0

System capital costs on solar investment are presented in Table IX-1. Variable costs (OMPI) are presented in Table IX-2, and energy information in Table IX-3.

1/ HCPC would utilize number 6 fuel oil and bagasse in lieu of the projected solar thermal system. The fuel oil is currently priced at $25.22 per barrel ($4.07 per million Btu's); the present system requires the consumption of 1.28 Btu's to yield 1 Btu of delivered process steam.

Table IX-1

Projected Initial Capital Costs

Item	Installed Costs
Solar Collectors (42,420 ft^2 aperture area)	$1,091,760
Site Preparation	248,270
Collector Foundations	38,050
Pump House	9,000
Piping	115,590
Insulation	83,388
Steam Generator	46,000
Heat Transfer Fluid Pump	5,180
Feedwater Pump	1,820
Expansion Tank	2,700
Heat transfer Fluid	5,610
Chemical Feed Equipment	1,210
Blowdown Equipment	1,410
System Control Equipment	23,450
Data Acquisition System	82,870
Hawaii State Excise Tax	72,190
Total Direct Costs	$1,828,490
Construction Management	87,220
Total	$1,915,710

Table IX-2

Projected Operating, Maintenance, Property Tax and Insurance Costs.

Item	
Routine Maintenance	
collector cleaning	$ 1,750/yr.
mechanical equipment	437
Periodic Maintenance	
collectors (pylon painting and reflective film replacement)	4,437
mechanical equipment (heat exchangers tube bundles)	1,563
Subtotal	$ 8,187
Operating Costs	
personnel and material	$ 860
parasitic power	2,220
Subtotal	$ 3,080
Insurance	$ 1,000
Property Tax	-0-
Total OMPI	$11,267/yr.

Table IX-3

Projected Net Annual Energy

Available Tax Incentives	Fed. - 15% Solar Credit - 10% Invest Credit State - 10% Solar Credit
Total Land Area	2.3 acres (approx)
Number of Collector Module	303
Net Area of Single Module	140 Ft^2
System Lifetime	20 Yrs.
Salvage Value in yr. 20	0
System Energy Storage	0 BTU
Number of Days Plant Can Use Solar Generated Steam	305 Days/Yr.
Unit Price of Fuel Displaced by Solar System	$4.07/MBTU
Inflation Rate	6%
Fuel Escalation Rate	8%
Energy Breakdown	
- Gross Energy Collected	10,190 MBTU/Yr
- Piping Losses	471 MBTU/Yr
- Start-up and Shut-down Losses	1087 MBTU/Yr
- Freeze Protection Losses	0
- Storage System Losses	0
- Net Solar Energy Delivered to Process*	7213 MBTU/Yr
System Parasitic Power Requirements	82.4 MBTU/Yr

*Value has been adjusted by 305/365 for HCPC operation.

Case I

Under the assumption that the entire projected project cost of \$1.915 million represents an owner's unamortized investment, an internal, after-rax rate of return or R* was derived graphically utilizing a recast version of equation (9) from UCRL-52814, viz:

$$\frac{M(R^*)}{\mathcal{E}} \cdot \frac{I}{E_s} - P_{fo} \cdot LF(R^*) = 0 \qquad (1)$$

$$\frac{M(R^*)}{\mathcal{E}} \cdot \frac{I}{E_s} = P_{fo} \cdot LF(R^*) \qquad (2)$$

The value of R* represents the internal rate of return where the relevant levelized fossil fuel price ($P_{fo} \cdot LF$) equals the levelized price of the solar energy provided by the investment $\frac{MI}{\varepsilon E_s}$ or Ps. These values were developed in the following fashion:

Levelized fossil fuel price: $R^* = P_{fo} \cdot Lf(R)$ was plotted (Fig. IX-1) for R = .10, .15 and .20. Values of the leveling factor LF(R) were developed assuming a constant rate of fuel price escalation (g^1) using equation (7) from UCRL-52814; presented here as equation (4).

$$Lf = \frac{CRF(R,N)}{CRF(R''',N)} \qquad (3)$$

$$Lf = CRF(R,N)\ \frac{1 + g^1}{R - g^1} \left[1 - \left(\frac{1 + g^1}{1 + R} \right)^N \right] \qquad (4)$$

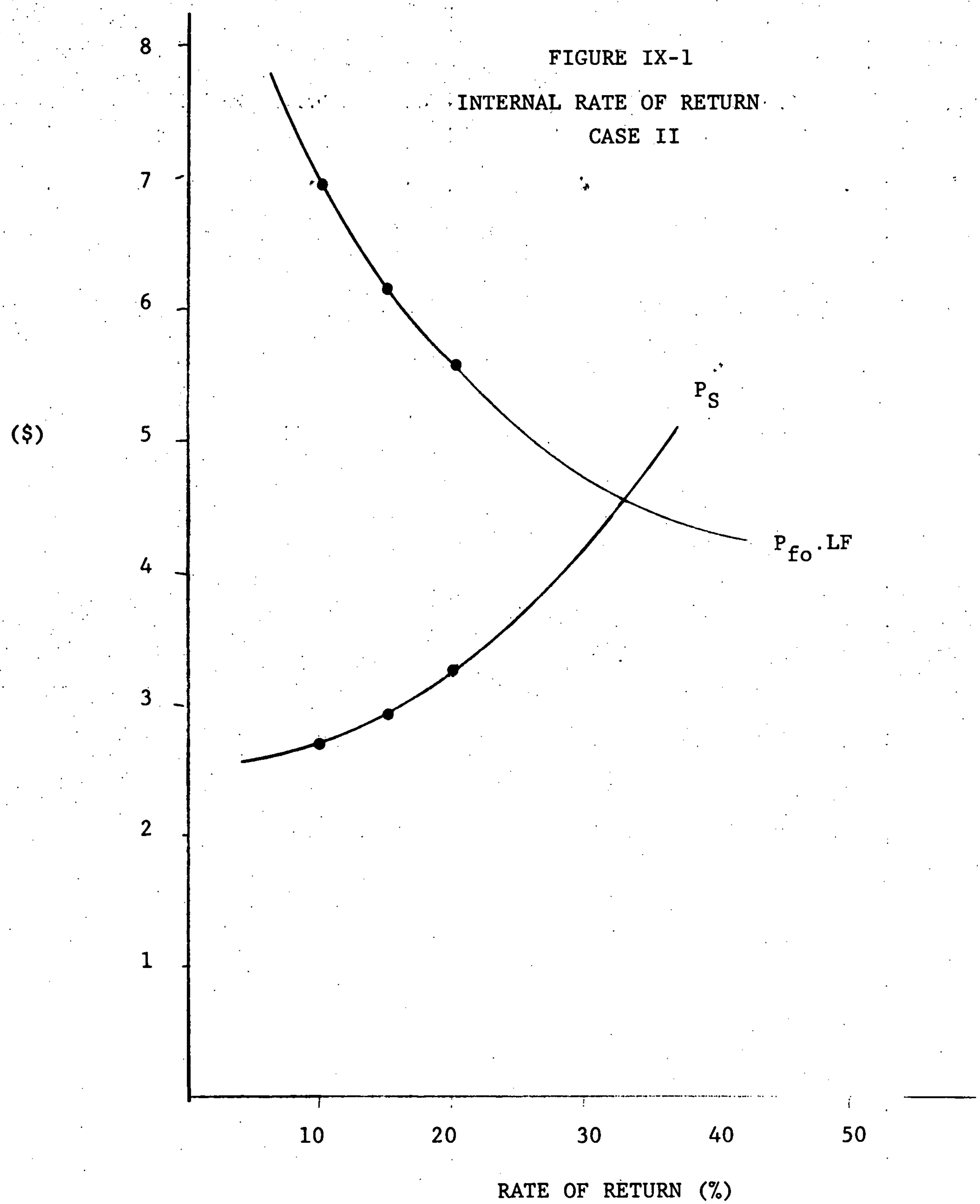
The value of P_{fo} was derived based on HCPC current number 2 fuel oil cost of \$25.22/barrel, and is \$4.07/MBtu's.

Levelized solar energy price (Ps): The equation $Ps = \frac{MI}{\mathcal{E} E_s}$ was plotted for R = .10, .15, and .20. The three values for the required revenues per total investment dollar or M-factor were developed using equation (1) from UCRL-52814:

FIGURE IX-1

INTERNAL RATE OF RETURN

CASE II



$$M = \frac{C_s}{I} = OMPI + \frac{CRF(R,N)}{1 - \underline{r}} \left[(1 - f) + f(1 - \underline{r}) \frac{CRF(\underline{r},LP)}{CRF(R,LP)} + \frac{f^{\underline{r}}}{1 + r} \cdot \frac{CRF(r,LP) - r}{CRF(R,LP)} - \frac{TC}{1 + R} - \underline{r} \cdot DEP + \left(\frac{1 + g}{1 + R}\right)^{t_c} m(t_c) \cdot \left(1 - TC - \underline{r} \cdot DEP\right) - \left(\frac{1 + g}{1 + R}\right)^{N} S \right] \quad (5)$$

Under the Case I assumption that I is the total projected project cost of $1.915 million, a slightly negative R* was derived.

Case II

Under the assumption that the solar investment consists only of the HCPC equity investment ($78,320), a positive R* of 40 percent was derived and is presented graphically in Figure 1. The entire solar investment level assumed for purposes of Case II analysis consists of equity funds.

The value of , the solar effectiveness factor, was derived from data on the conventional fuel oil energy system to be supplanted by the proposed solar thermal system. Included in the assumptions used for developing values for M is that a major replacement of solar system components is necessary in year 10, comparable to some 25 percent of projected project cost.

The levelized fossil fuel prices ($P_{fo} \cdot Lf$) and levelized solar energy prices (P_s) for both Cases I and II are presented in Table IX-4.

Table IX-4

Levelized Fossil and Solar Energy Prices*

(Cases I and II)

	P_s	$P_{fo} \cdot LF$	M
Case I			
R = .10	$22.55	$7.94	.130
R = .15	31.56	7.16	.182
R = .20	41.97	6.59	.242
Case II			
R = .10	$ 2.70	$7.94	.381
R = .15	2.93	7.16	.413
R = .20	3.27	6.59	.462

*All prices in dollars per million Btu's.

D. PAYBACK PERIOD

Case I

To permit inclusion of a fuel escalation rate in payback calculation which differs from the general inflation rate, equation (6) was utilized to calculate the payback period for the HCPC project. This equation is variation (T_3) presented in Appendix A ("Determination of Payback Period") of publication UCRL-52814.

$$1 - TC = T_p \cdot \frac{r}{N} + \frac{(1 - r)\varepsilon E_s P_{fo}}{I} \sum_{t=1}^{T_p} (1 + g^1)^t - (1 - r)\ OMPI_o \sum_{t=1}^{T_p} (1 + g)^t \qquad (6)$$

Using system values presented earlier, in particular $g = 6\%$, $g^1 = 8\%$, $OMPI_o = .0064$, $P_{fo} = \$4.07$/million Btu's, and $I = \$1.915$ million, a lengthy payback period for the proposed project of 17.6 years was derived. A plot of this equation for Case I is presented in Figure IX-2.

Case II

A similar calculation using differing variables applicable to Case II ($OMPI_o = .16$, $I = \$78,320$) yield a much shorter payback period ($T_p = T_n$) of 2.9 years. Figure IX-3 presents this calculation graphically.

FOSSIL FUEL SAVINGS

With a value of 9.25 billion Btu's for the variables (εE_s), annual projected fossil fuel savings are 9,250 MBtu or 1,492 barrels of oil equivalent (with 6.2 MBtu's per barrel).

FIGURE IX-2

PAYBACK ANALYSIS

CASE I

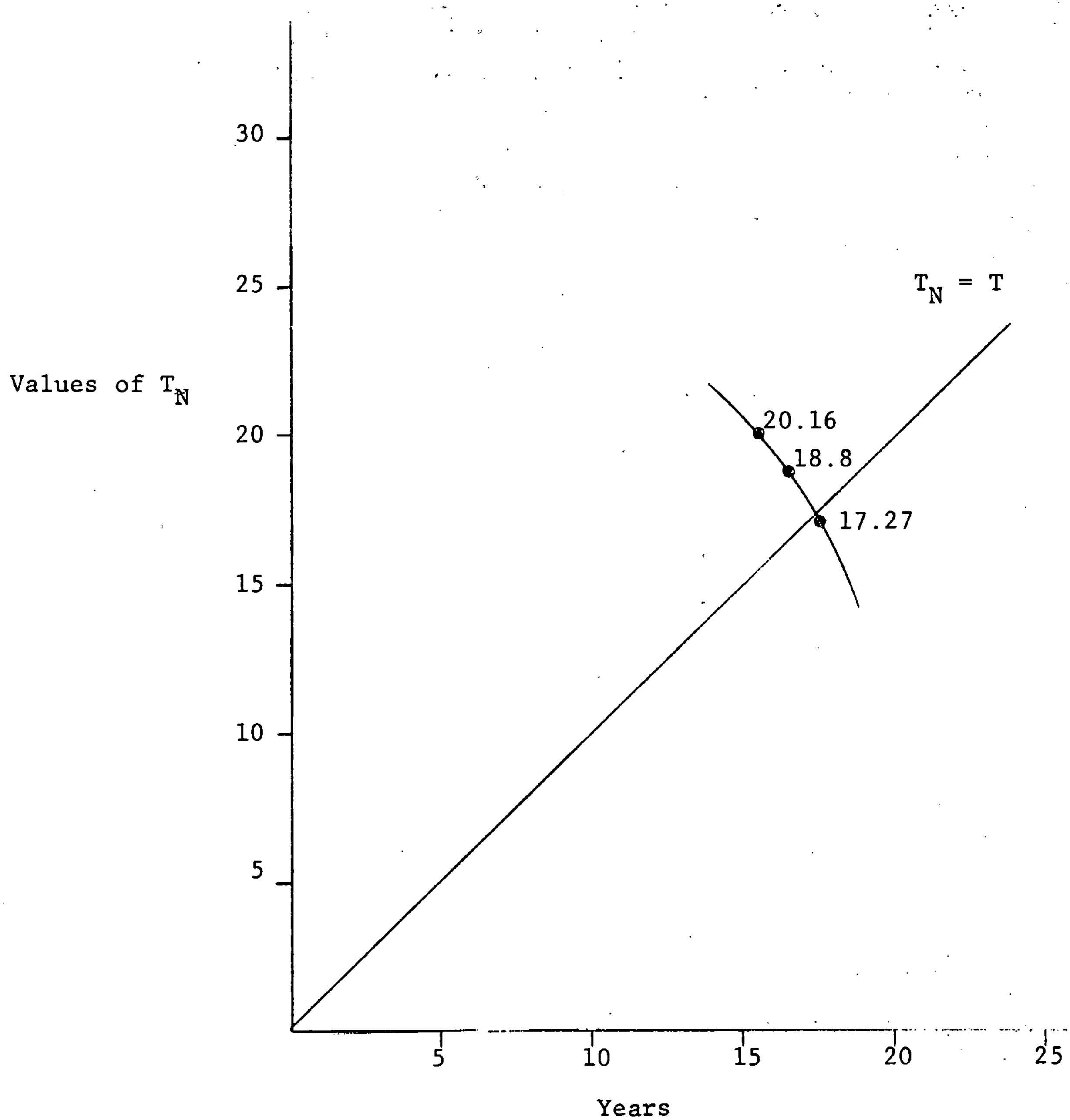
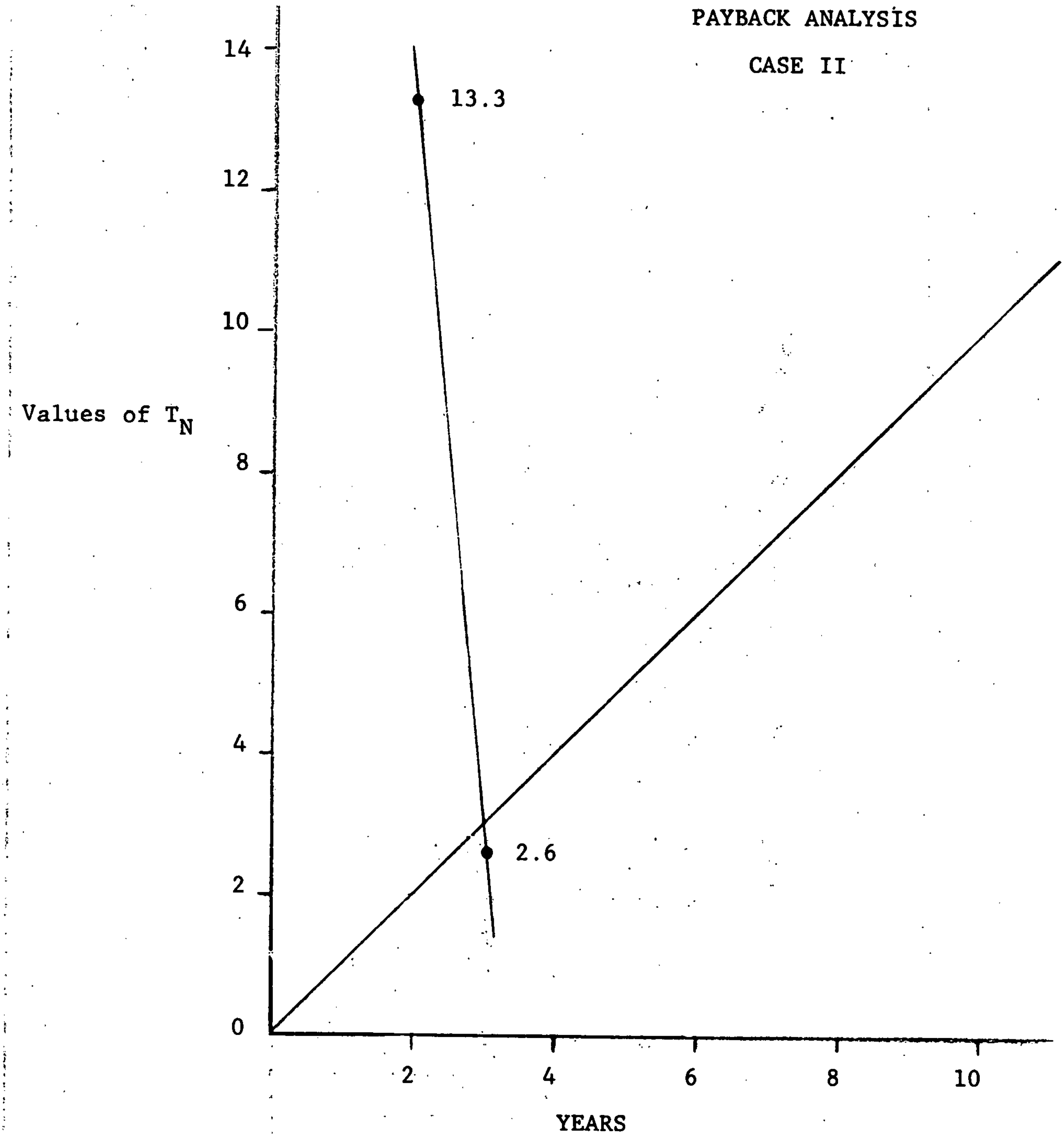


FIGURE IX-3
PAYBACK ANALYSIS
CASE II

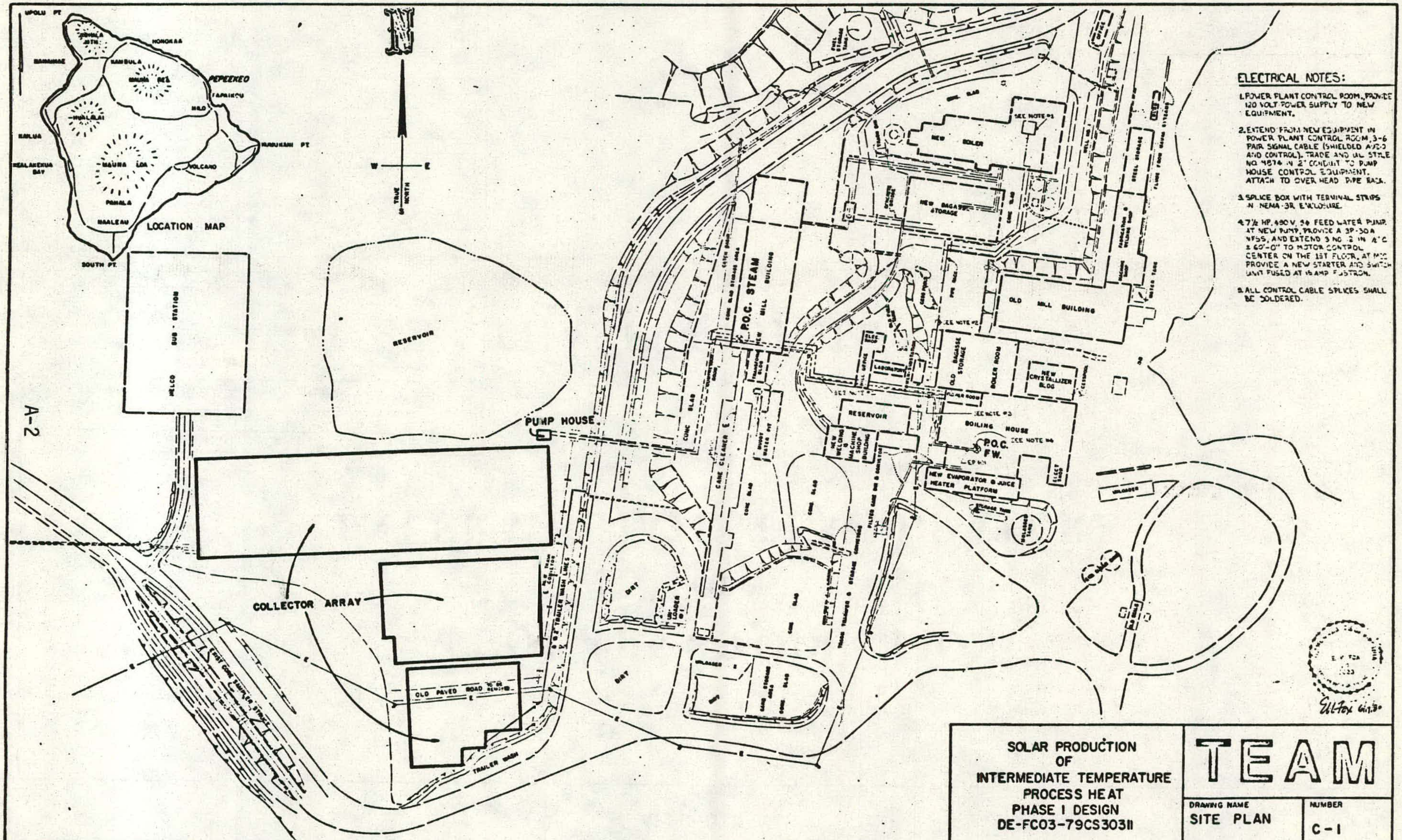


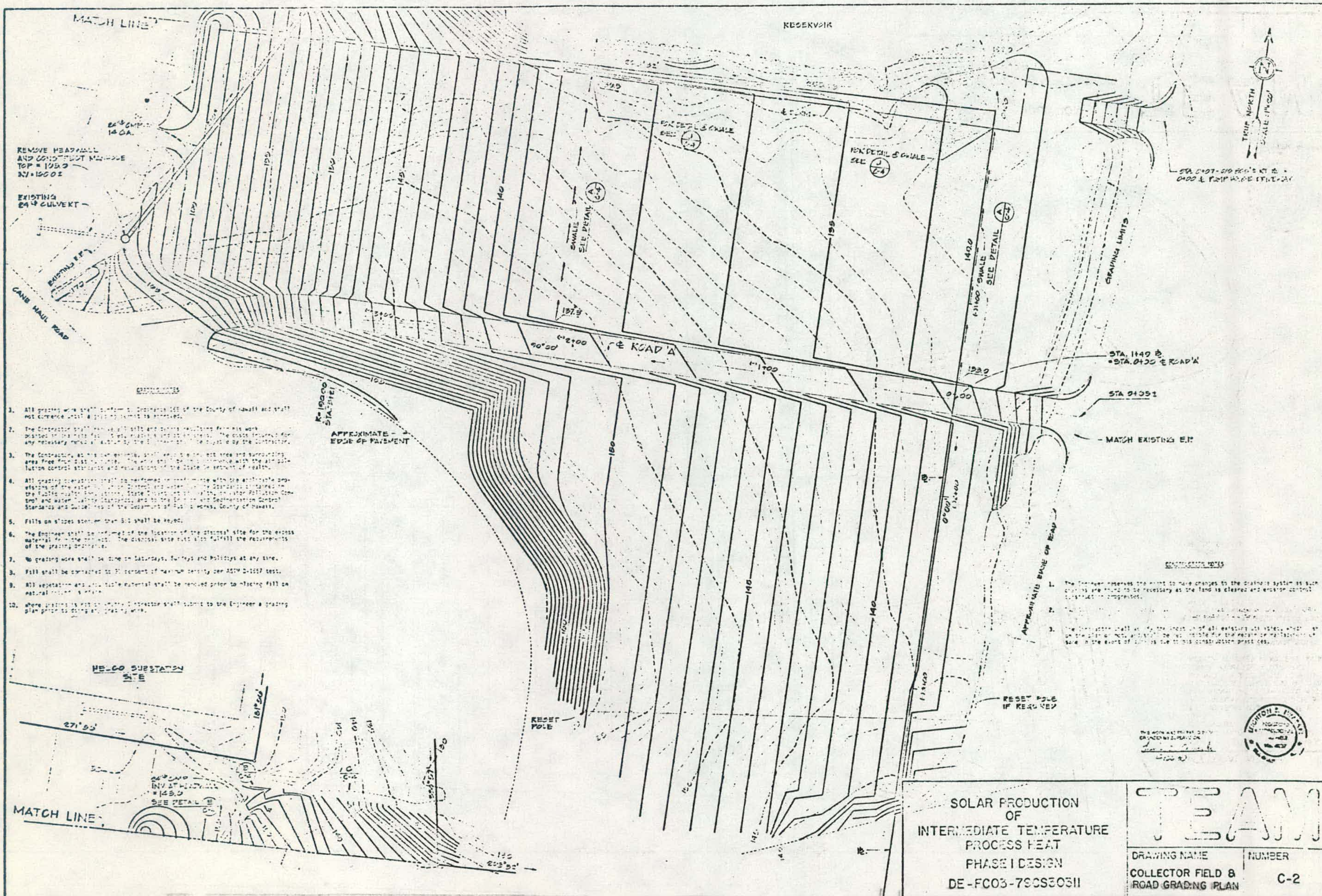
APPENDIX A

SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN

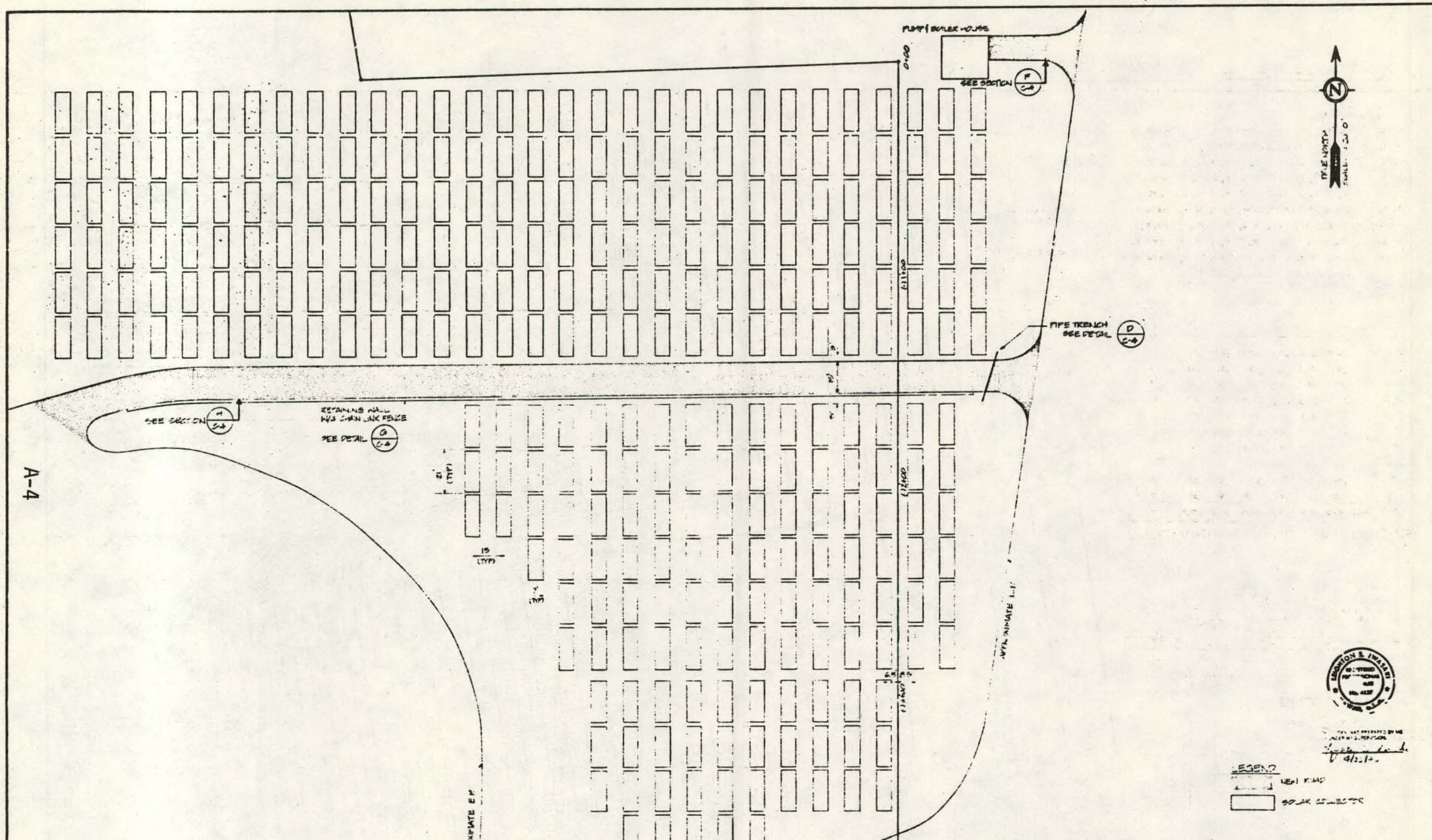
DRAWING INDEX	
DWG NO.	TITLE
C-1	SITE PLAN
C-2	COLLECTOR FIELD AND ROADWAY GRADING PLAN
C-3	ROADWAY PLAN
C-4	SITE DETAILS
C-5	DRAINAGE DETAILS
C-6	ROADWAY & RETAINING WALL PROFILES
C-7	CROSS SECTIONS
C-8	CROSS SECTIONS
C-9	CROSS SECTIONS
C-10	FOUNDATION DETAILS
M-1	P & I DIAGRAM
M-2	SOLAR COLLECTOR FIELD
M-3	PUMP AND BOILER HOUSE PLAN
M-4	PUMP AND BOILER HOUSE SECTION
M-5	PIPING DETAILS
M-6	PIPING DETAILS
M-7	PIPING DETAILS
M-8	WATER PIPING
M-9	PUMP HOUSE DETAILS
M-10	PUMP HOUSE DETAILS
M-11	PIPING PLAN & DETAILS
M-12	PIPING PLAN
M-13	MISCELLENEOUS DETAILS AND DIAGRAMS
E-1	SOLAR FIELD ELECTRICAL LAYOUT
E-2	FIELD CONTROL PANELS - ELECTRICAL LAYOUT
E-3	PUMP HOUSE - ELECTRICAL PLAN
E-4	DATA ACQUISITION INTERCONNECTS
E-5	CONTROL & POWER DISTRIBUTION INTERCONNECTS
E-6	MASTER CONTROL PANEL AND RELAY BOX LAYOUT
E-7	POWER DISTRIBUTION DIAGRAM, SCHEDULE AND NOTES

DOE CONTRACT NO. DE-FC 0379CS 30311
CONTRACTOR: Hilo Coast Processing Company
Hilo, Hawaii
DESIGNER: TEAM INC.
MAY 1,1980


LOCATION MAP
UPOLU PT.
HONOKAA
PEPEEKEO
HILO
KAILUA
MAUNA LOA
VOLCANO
SOUTH PT.
W
E
TRUE NORTH
HELCO SUB - STATION
RESERVOIR
PUMP HOUSE
COLLECTOR ARRAY
OLD PAVED ROAD
TRAILER WASH
P.O.C. STEAM
NEW MILL BUILDING
NEW BOILER
NEW BAGASSE STORAGE
OLD MILL BUILDING
OLD BAGASSE STORAGE
BOILER ROOM
NEW CRYSTALLIZER BLDG
RESERVOIR
BOILING HOUSE
P.O.C. F.W.
NEW EVAPORATOR & JUICE HEATER PLATFORM
CANE CLEANER
CONC SLAB
ELECTRICAL NOTES:
1. POWER PLANT CONTROL ROOM., PROVIDE 120 VOLT POWER SUPPLY TO NEW EQUIPMENT.
2. EXTEND FROM NEW EQUIPMENT IN POWER PLANT CONTROL ROOM, 3-6 PAIR SIGNAL CABLE (SHIELDED AND CONTROL). TRADE AND UL STYLE NO 4874 IN 2" CONDUIT TO PUMP HOUSE CONTROL EQUIPMENT. ATTACH TO OVER HEAD PIPE RACK.
3. SPLICE BOX WITH TERMINAL STRIPS IN NEMA-3R ENCLOSURE.
4. 7½ HP, 480 V, 3Φ FEED WATER PUMP. AT NEW PUMP, PROVIDE A 3P-30A NFSS, AND EXTEND 3 NO. 12 IN ¾" C ± 60'-0" TO MOTOR CONTROL CENTER ON THE 1ST FLOOR. AT MCC PROVIDE A NEW STARTER AND SWITCH UNIT FUSED AT 15 AMP FUSTRON.
5. ALL CONTROL CABLE SPLICES SHALL BE SOLDERED.
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
TEAM
DRAWING NAME
SITE PLAN
NUMBER
C-1



MATCH LINE
RESERVOIR
REMOVE HEADWALL AND CONSTRUCT MANHOLE
EXISTING 24" CULVERT
CANE HAUL ROAD
SWALE SEE DETAIL
℄ ROAD 'A'
APPROXIMATE EDGE OF PAVEMENT
GRADING NOTES
GRADING LIMITS
STA. 1149 ℄
MATCH EXISTING E.P.
CONSTRUCTION NOTES
RESET POLE IF REQUIRED
RESET POLE
HELCO SUBSTATION SITE
MATCH LINE
TRUE NORTH
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
DRAWING NAME
COLLECTOR FIELD 8 ROAD GRADING PLAN
NUMBER
C-2

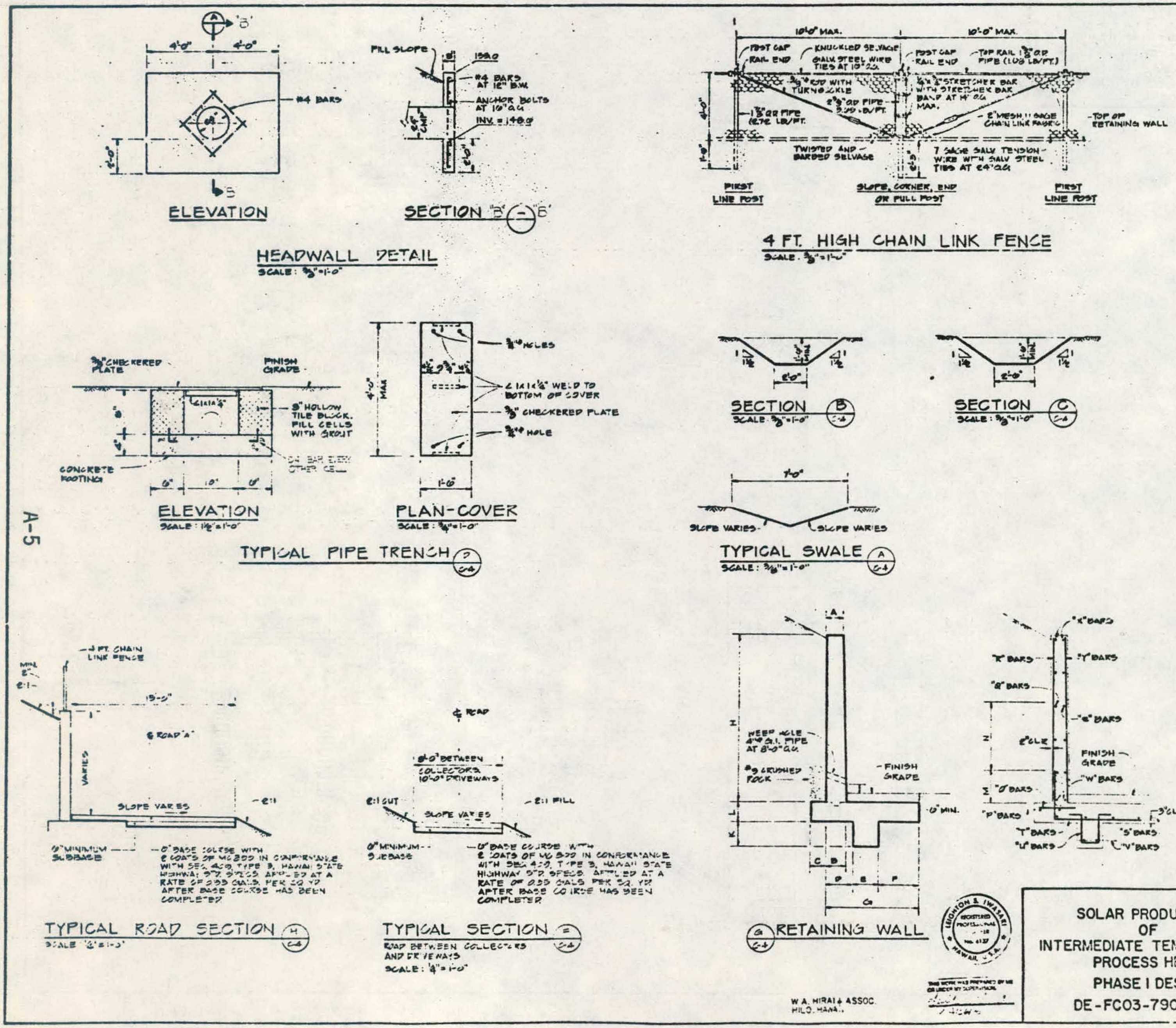


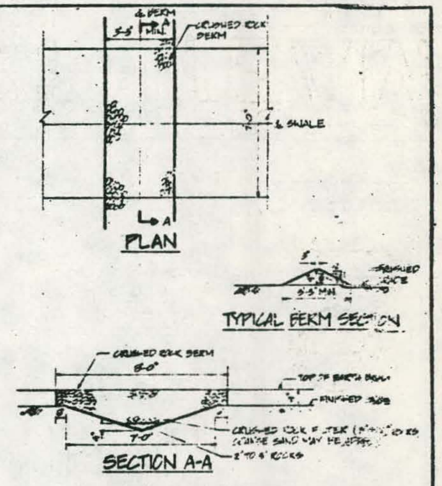
A-4

SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
ROADWAY PLAN	C-3





BERM DETAIL
SCALE: 3/8"=1'-0"

RETAINING WALL DIMENSIONS

H	4'-0"	5'-0"	6'-0"	7'-0"	8'-0"	9'-0"	10'-0"	[illegible]
A	8"	8"	8"	10"	10"	10"		12"
B	8"	12"	1'-2"	1'-2"	1'-2"	1'-4"		1'-6"
C	0"	0"	0"	0"	0"	0"		0"
D	12"	12"	1'-6"	1'-0"	1'-6"	[illegible]		[illegible]
E	12"	12"	12"	1'-0"	1'-2"	1'-6"		1'-6"
F	8"	1'-6"	1'-8"	2'-0"	3'-2"	3'-10"		5'-[illegible]
G	2'-8"	3'-0"	4'-2"	5'-0"	5'-10"	6'-10"		[illegible]
K	12"	12"	12"	1'-0"	1'-2"	1'-6"		[illegible]
L	12"	12"	12"	1'-2"	1'-2"	1'-4"		[illegible]
M	1'-6"	1'-6"	2'-0"	2'-0"	2'-0"	2'-0"		2'-0"
N	—	—	—	—	—	3'-0"		4'-6"
"O" BARS	—	—	—	—	—	—		—
"P" BARS	—	—	—	—	—	—		
"Q" BARS	#4@24"	#4@24"	#4@24"	#4@24"	[illegible]	[illegible]		[illegible]
"R" BARS	#4@10"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
"S" BARS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
"T" BARS	#4@10"	#4@12"	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
"U" BARS	[illegible]	#4@24"	#4@24"	[illegible]	[illegible]	[illegible]		[illegible]
"V" BARS	2-#4	2-#4	2-#4	2-#4	2-#4	2-#4		2-#4
"W" BARS	2-#4	2-#4	2-#4	2-#4	2-#4	2-#4		2-#4
"X" BARS	2-#4	2-#4	2-#4	2-#4	2-#4	2-#4		2-#4
"Y" BARS	—	[illegible]	[illegible]	#4@24"	[illegible]	[illegible]		[illegible]
"Z" BARS	—	[illegible]	#4@24"	[illegible]	[illegible]	[illegible]		[illegible]

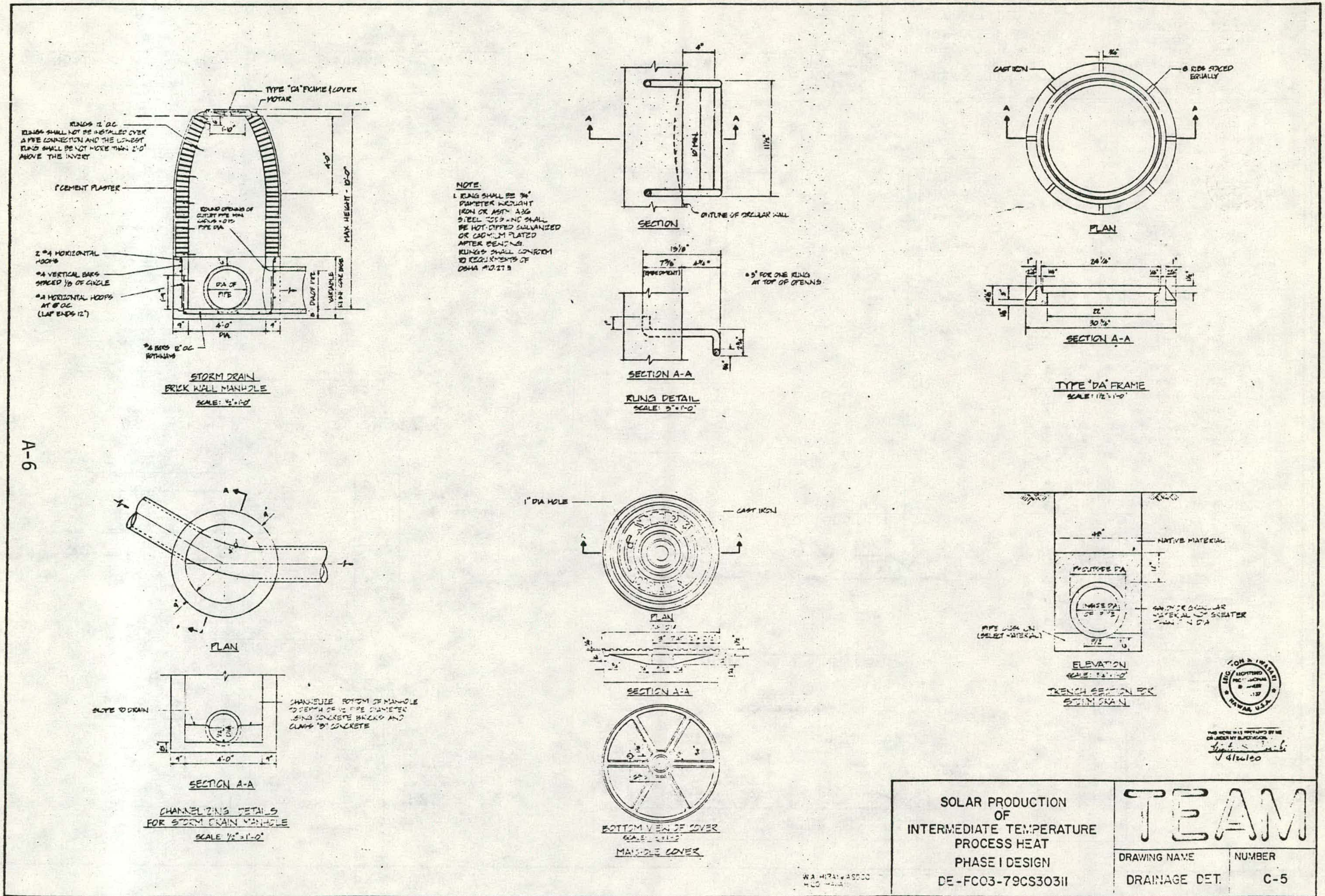
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT

PHASE I DESIGN

DE-FC03-79CS30311

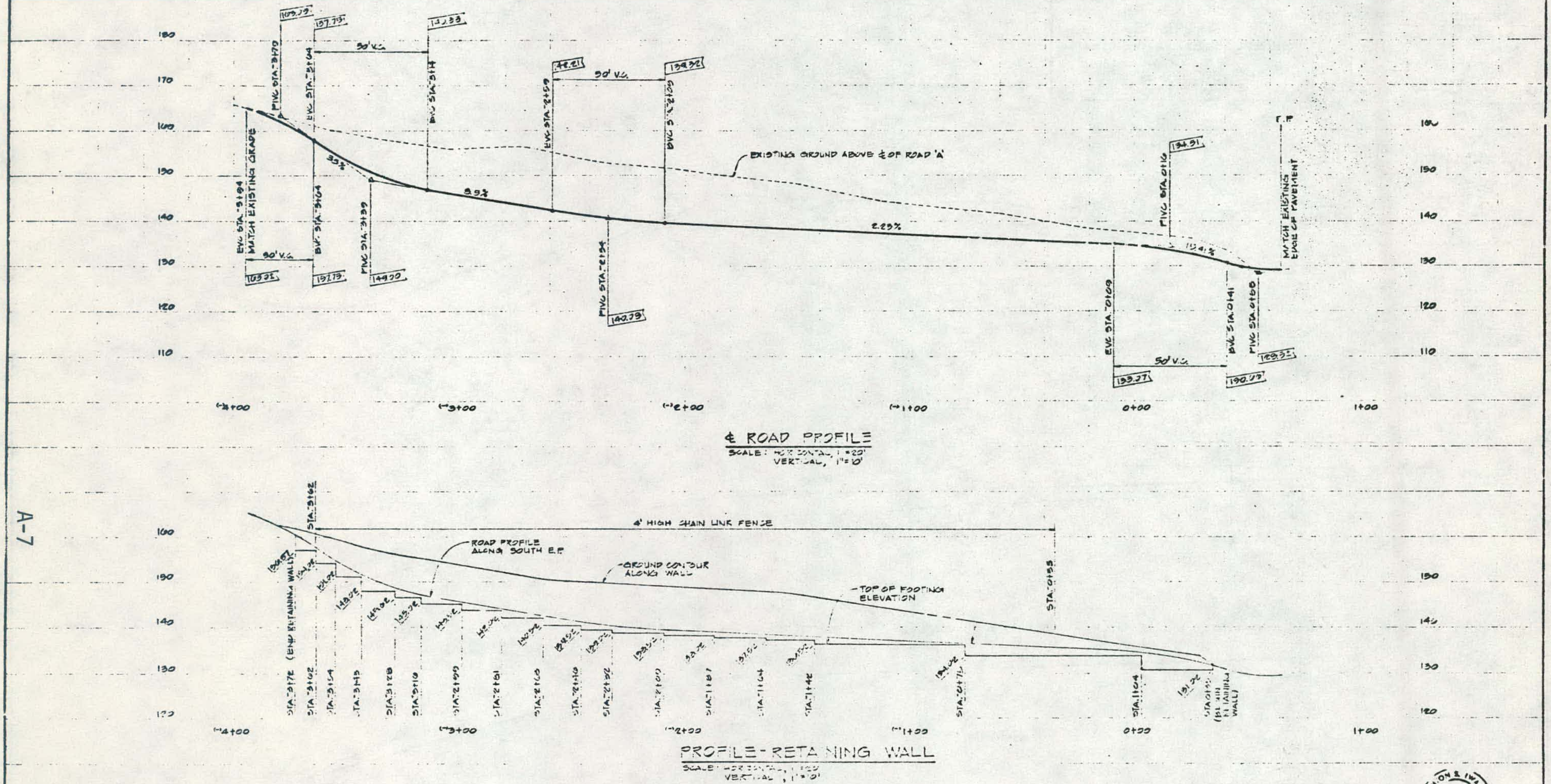
TEAM

DRAWING NAME	NUMBER
SITE DETAILS	C-4



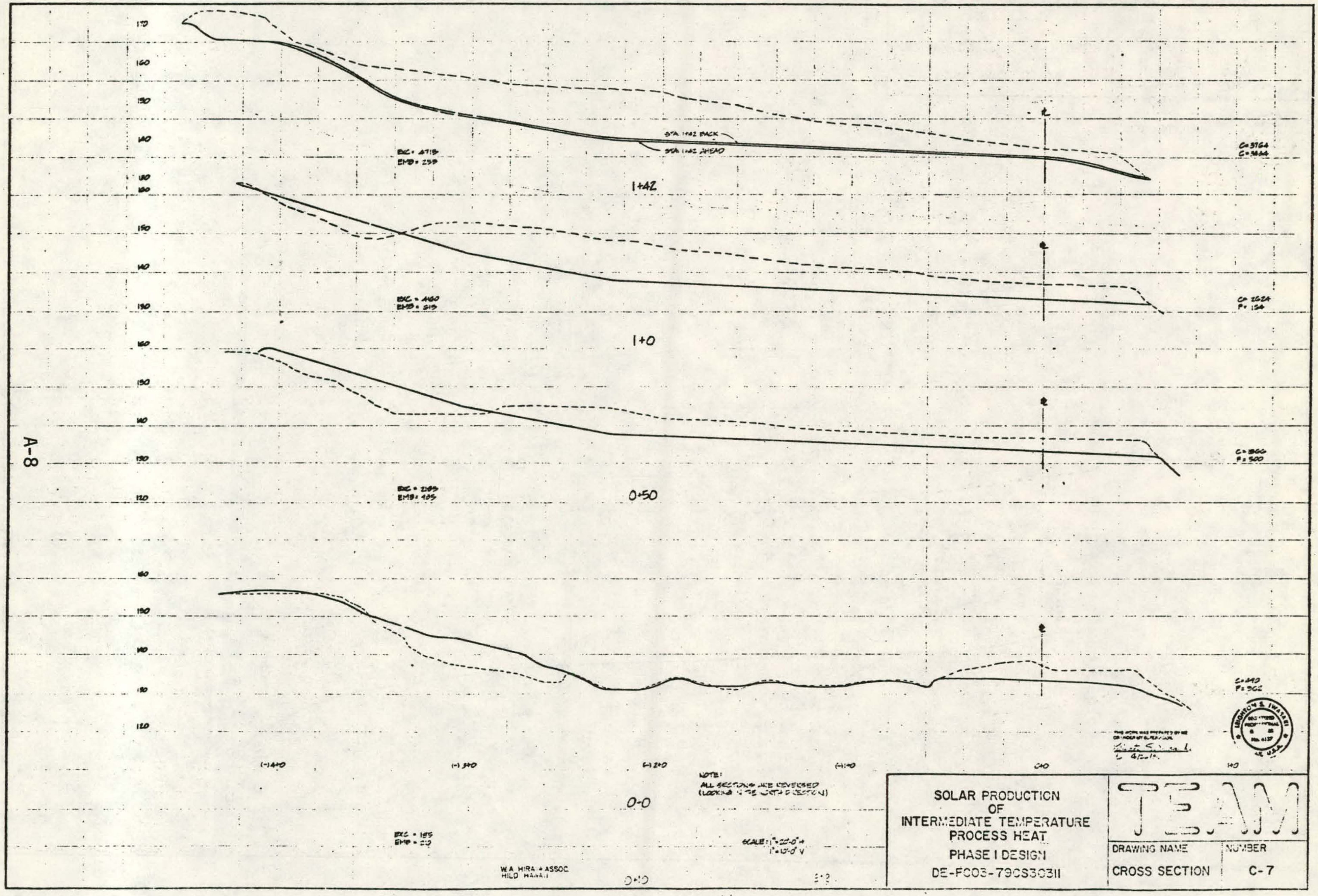
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME	NUMBER
	DRAINAGE DET.	C-5

A-7



SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME	NUMBER
	PROFILES	C-6

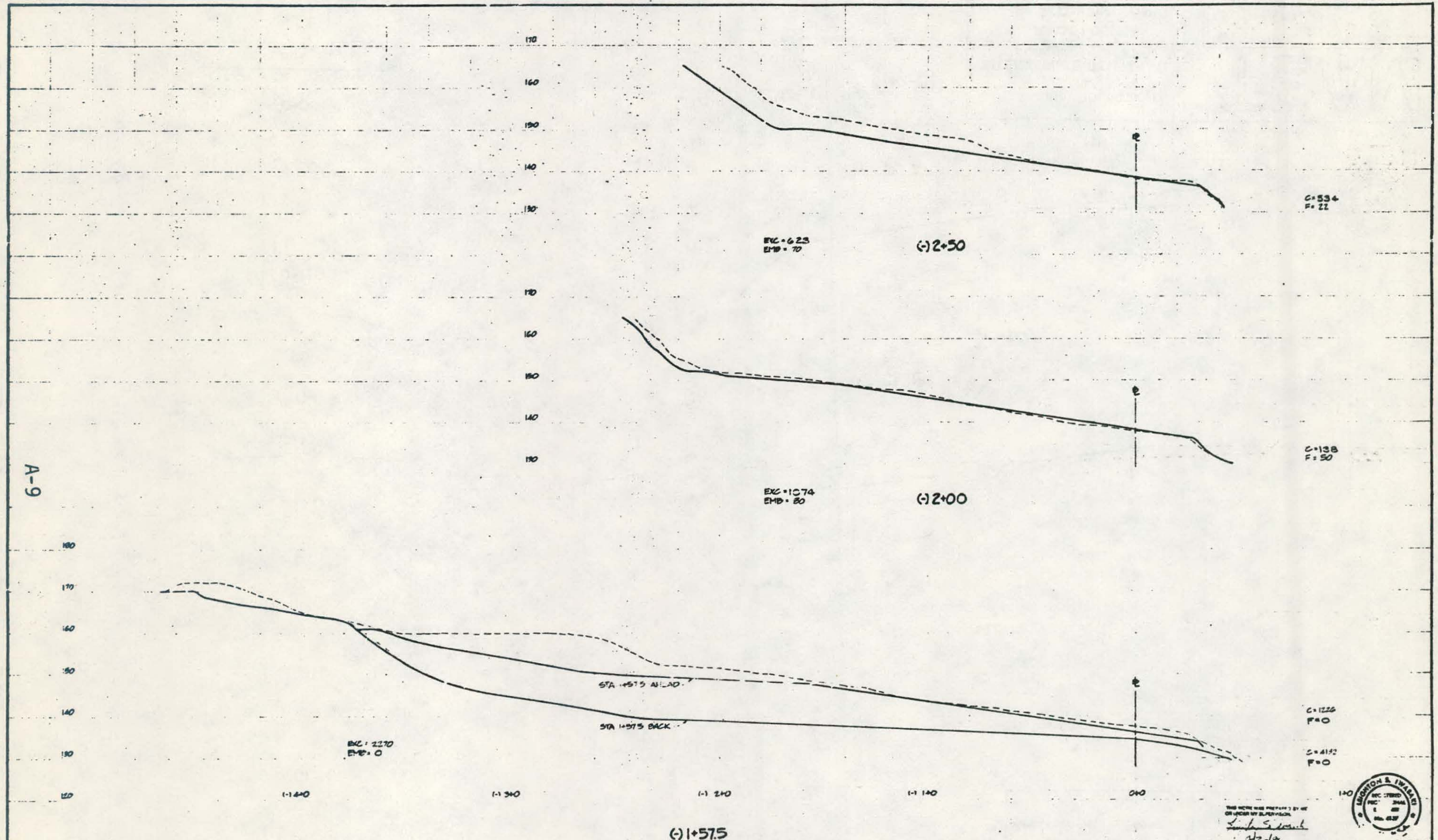
A-8



SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
CROSS SECTION	C-7



NOTE:
ALL SECTIONS ARE REVERSED
(LOOKING IN THE NORTH DIRECTION)

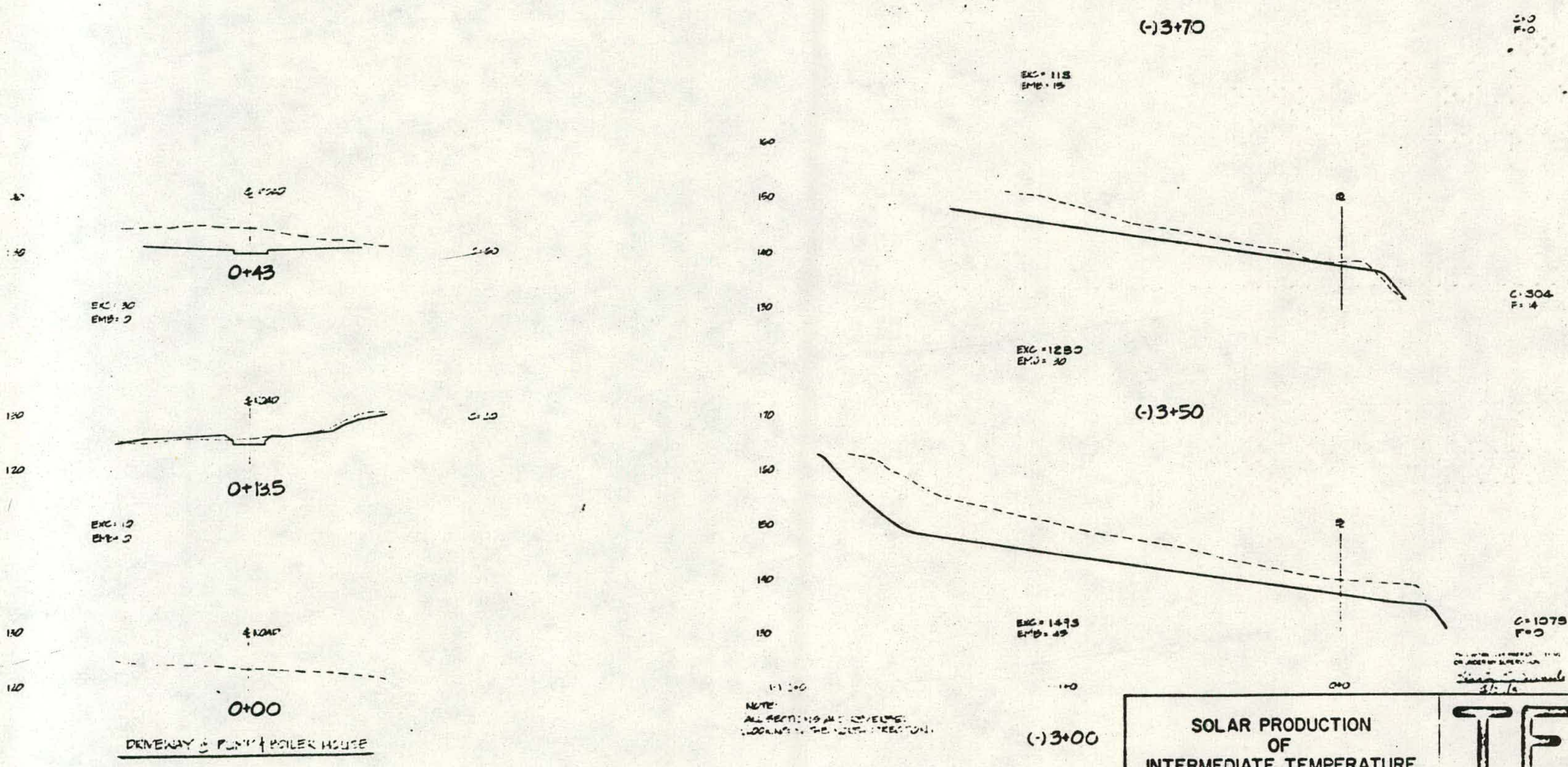
SCALE: 1" = 20'-0" H
1" = 10'-0" V

W.A. HIRAI & ASSOC
HILO HAWAII

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME	NUMBER
	CROSS SECTION	C-8

EARTHWORK SUMMARY

	EXC.	EMB
GRADING, ROAD, DITCH	18140	2655



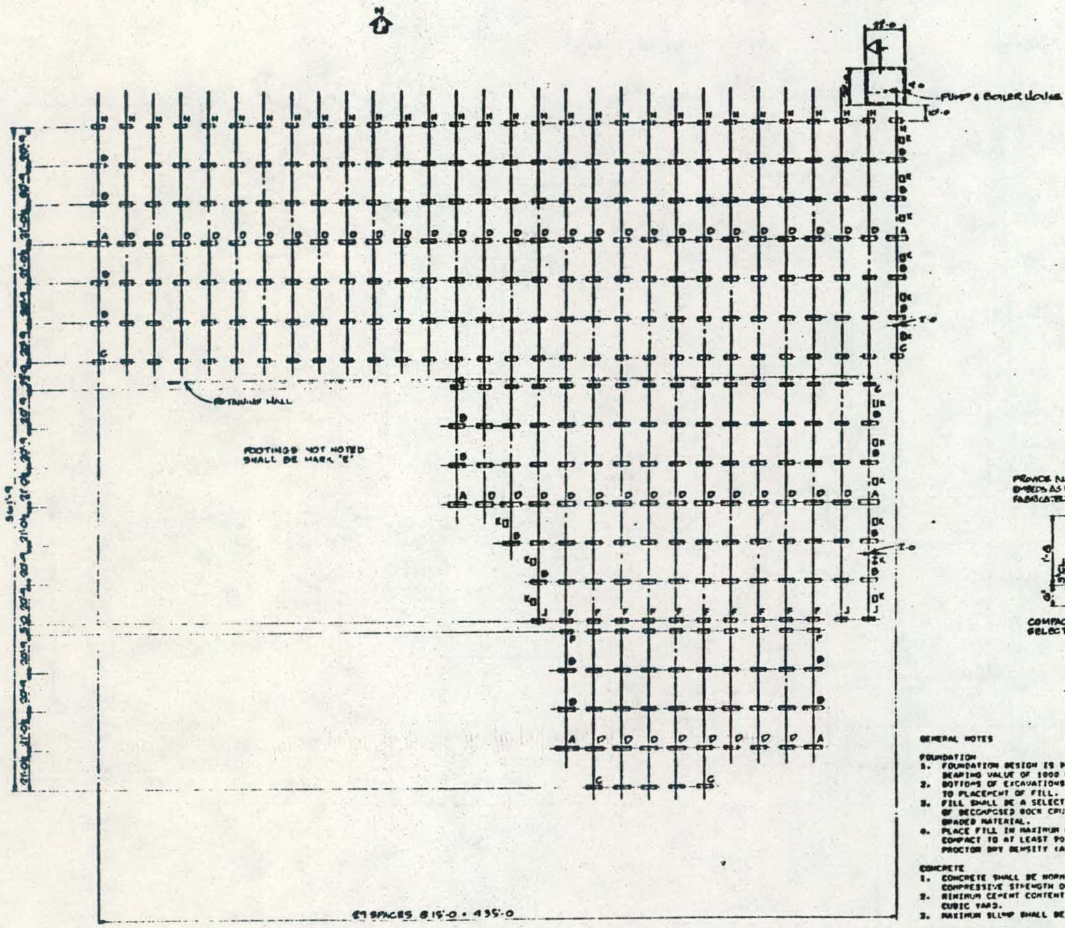
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT

PHASE I DESIGN

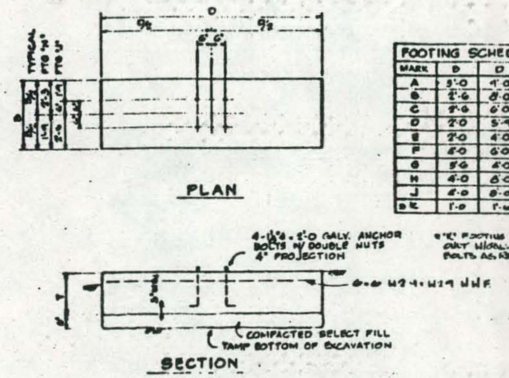
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
CROSS SECTION	C-9



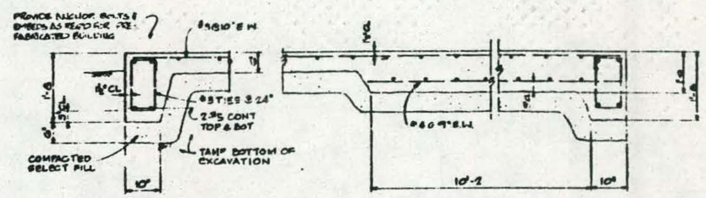
SOLAR COLLECTOR FIELD LAYOUT
SCALE 1" = 30'



FOOTING SCHEDULE			
MARK	D	D	T
A	3'-0	4'-0	'-9
B	2'-6	8'-0	1'-8
C	2'-6	6'-0	'-3
D	2'-0	5'-9	'-3
E	2'-0	4'-0	'-0
F	6'-0	6'-0	'-3
G	5'-6	4'-0	1'-0
H	4'-0	8'-0	'-0
J	4'-0	8'-0	1'-0
*K	1'-0	1'-0	2'-3"

*"K" FOOTING FOR PIPE SUPPORTS ONLY W/GALVANIZED ANCHOR BOLTS AS REQ'D

COLLECTOR FOOTING DETAILS



SECTION 1

GENERAL NOTES

FOUNDATION
1. FOUNDATION DESIGN IS BASED ON AN ALLOWABLE BEARING VALUE OF 1000 P.S.F.
2. BOTTOMS OF EXCAVATIONS SHALL BE TAMPED PRIOR TO PLACEMENT OF FILL.
3. FILL SHALL BE A SELECT MATERIAL CONSISTING OF DECOMPOSED ROCK CRUSHED TO A FAIRLY WELL-GRADED MATERIAL.
4. PLACE FILL IN MAXIMUM 8 IN. LOOSE LIFTS AND COMPACT TO AT LEAST 90% OF THE STANDARD PROCTOR DRY DENSITY (ASTM D-698).

CONCRETE
1. CONCRETE SHALL BE NORMAL WEIGHT WITH A MINIMUM COMPRESSIVE STRENGTH OF 3000 P.S.I. AT 28 DAYS.
2. MINIMUM CEMENT CONTENT SHALL BE FIVE SACKS PER CUBIC YARD.
3. MAXIMUM SLUMP SHALL BE FIVE INCHES.

REINFORCING STEEL
1. REINFORCING STEEL SHALL BE ASTM A615, GRADE 60.
2. PROVIDE CORNER BARS SAME SIZE AS HORIZONTAL BARS WITH 2'-0" LEGS.
3. WELDED WIRE FABRIC SHALL CONFORM TO ASTM A185 AND SHALL BE FURNISHED IN FLAT SHEETS.

ANCHOR BOLTS
1. ANCHOR BOLTS SHALL BE ASTM A36. BOLTS AND NUTS SHALL BE HOT-DIP GALVANIZED.
2. BOLTS SHALL BE PLACED WITH TEMPLATES AT SUFFICIENTLY CLOSE TOLERANCE TO INSURE THAT SOLAR COLLECTOR PYLONS CAN BE ERECTED WITHOUT ENLARGEMENT OF HOLES IN BASES.

FOOTINGS
1. SET ELEVATIONS OF TOPS OF FOOTING AS FOLLOWS:
   a. FOOTINGS FOR EACH ROW OF FOOTINGS SUPPORTING INTERCONNECTING COLLECTORS SHALL BE AT THE SAME ELEVATION.
   b. ELEVATIONS OF FOOTINGS IN PARALLEL ROWS SHALL BE STEPPED WITH FINISH GRADE.
   c. SET UP SLOPE ENDS OF FOOTING AT OR SLIGHTLY ABOVE GRADE.
2. FORM EDGES OF FOOTINGS ABOVE GRADE.
3. SLOPE TOPS OF FOOTINGS 1/4" PER FOOT IN SAME DIRECTION AS GRADE SLOPE.
4. FINISH TOPS OF FOOTINGS WITH A FLOAT FINISH.

GEORGE T. MAYES
CONSULTING ENGINEERS
DALLAS, TEXAS

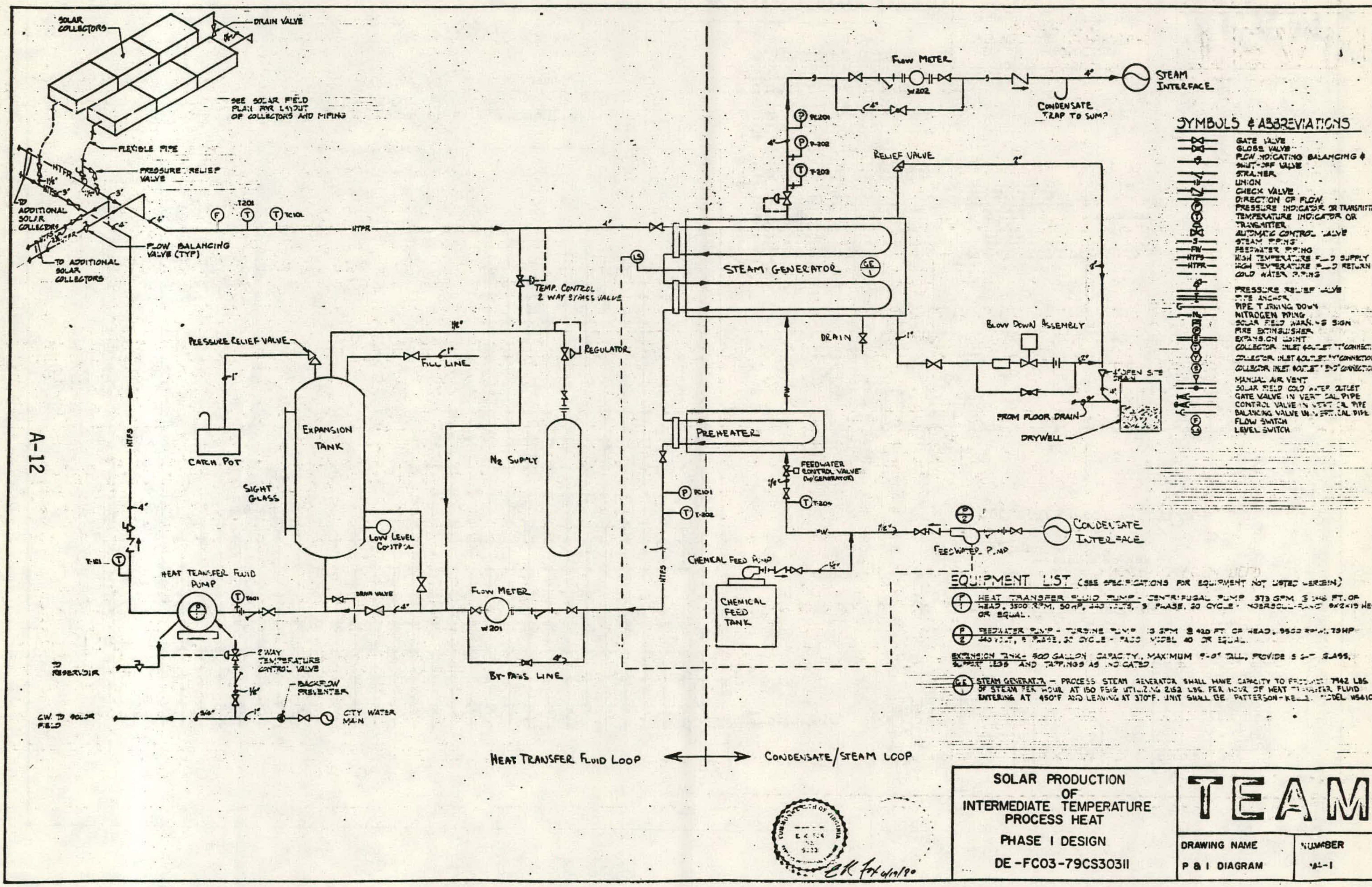
DATE: 6-19-80

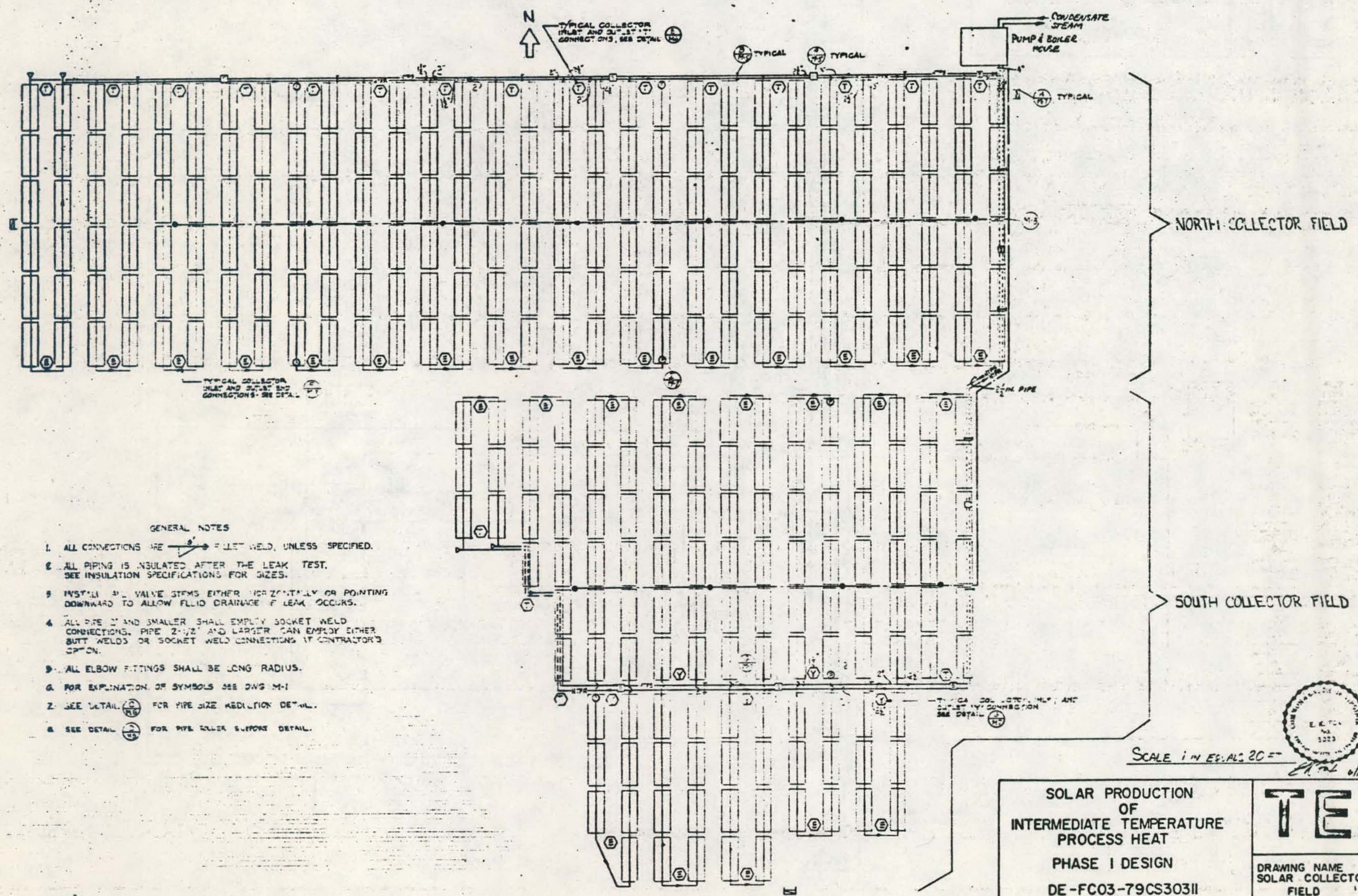
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME: COLLECTOR FOUNDATIONS

DRAWING NO: C-10

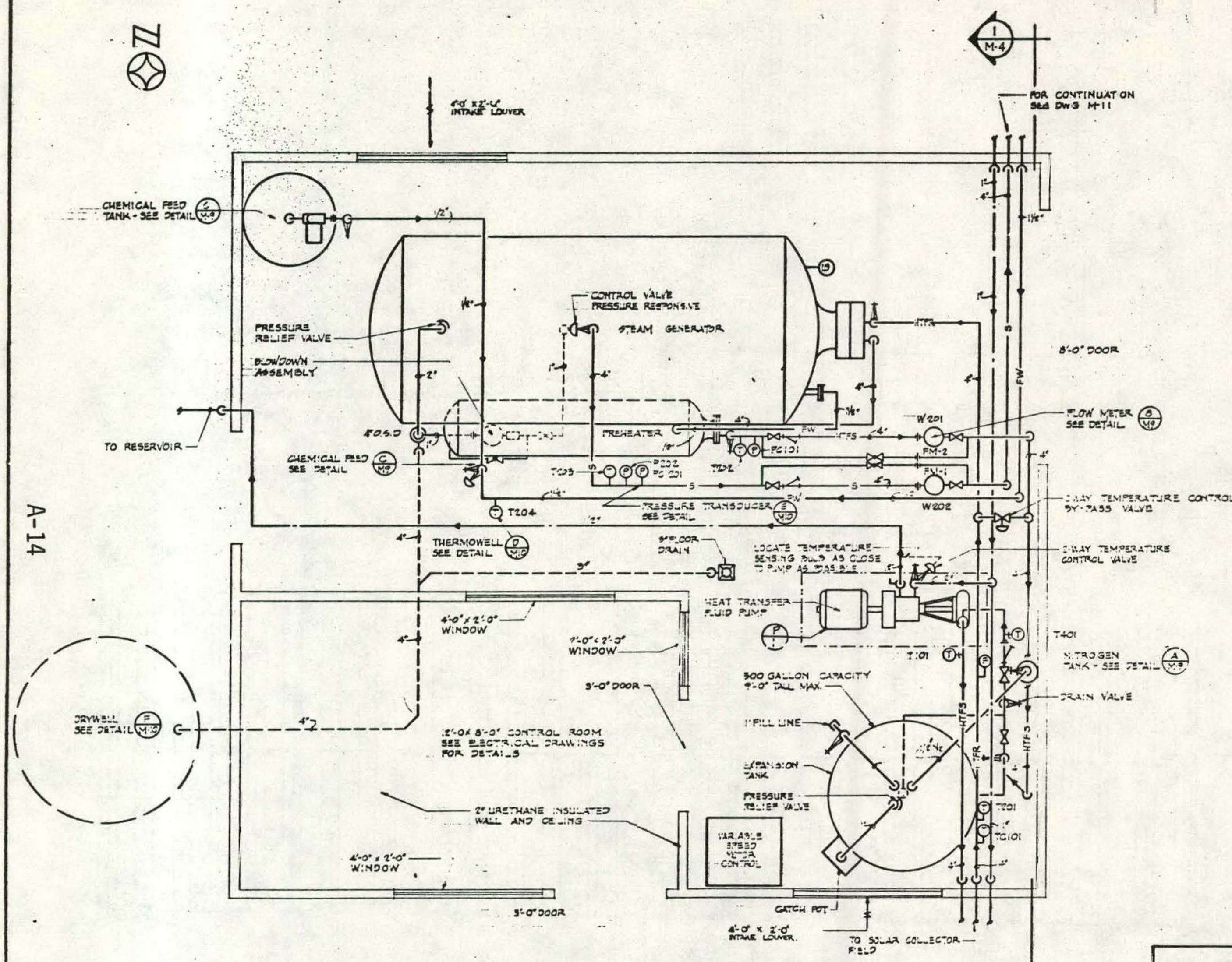

SOLAR COLLECTORS
DRAIN VALVE
SEE SOLAR FIELD PLAN FOR LAYOUT OF COLLECTORS AND PIPING
FLEXIBLE PIPE
PRESSURE RELIEF VALVE
TO ADDITIONAL SOLAR COLLECTORS
FLOW BALANCING VALVE (TYP)
TO ADDITIONAL SOLAR COLLECTORS
HTPR
HTPS
TEMP. CONTROL 2 WAY BYPASS VALVE
PRESSURE RELIEF VALVE
FILL LINE
REGULATOR
CATCH POT
EXPANSION TANK
SIGHT GLASS
LOW LEVEL CONTROL
N2 SUPPLY
HEAT TRANSFER FLUID PUMP
DRAIN VALVE
FLOW METER
W 201
BY-PASS LINE
2 WAY TEMPERATURE CONTROL VALVE
TO RESERVOIR
BACKFLOW PREVENTER
C.W. TO SOLAR FIELD
CITY WATER MAIN
FLOW METER
W 202
STEAM INTERFACE
CONDENSATE TRAP TO SUMP
RELIEF VALVE
STEAM GENERATOR
DRAIN
BLOW DOWN ASSEMBLY
OPEN SITE DRAIN
FROM FLOOR DRAIN
DRYWELL
PREHEATER
FEEDWATER CONTROL VALVE (by GENERATOR)
CHEMICAL FEED PUMP
CHEMICAL FEED TANK
FEEDWATER PUMP
CONDENSATE INTERFACE
SYMBOLS & ABBREVIATIONS
GATE VALVE
GLOBE VALVE
FLOW INDICATING BALANCING & SHUT-OFF VALVE
STRAINER
UNION
CHECK VALVE
DIRECTION OF FLOW
PRESSURE INDICATOR OR TRANSMITTER
TEMPERATURE INDICATOR OR TRANSMITTER
AUTOMATIC CONTROL VALVE
STEAM PIPING
FEEDWATER PIPING
HIGH TEMPERATURE FLUID SUPPLY
HIGH TEMPERATURE FLUID RETURN
COLD WATER PIPING
PRESSURE RELIEF VALVE
PIPE ANCHOR
PIPE TURNING DOWN
NITROGEN PIPING
SOLAR FIELD WARNING SIGN
FIRE EXTINGUISHER
EXPANSION JOINT
COLLECTOR INLET & OUTLET "T" CONNECTION
COLLECTOR INLET & OUTLET "Y" CONNECTION
COLLECTOR INLET & OUTLET "END" CONNECTION
MANUAL AIR VENT
SOLAR FIELD COLD WATER OUTLET
GATE VALVE IN VERTICAL PIPE
CONTROL VALVE IN VERTICAL PIPE
BALANCING VALVE IN VERTICAL PIPE
FLOW SWITCH
LEVEL SWITCH
EQUIPMENT LIST (SEE SPECIFICATIONS FOR EQUIPMENT NOT LISTED HEREIN)
P1 HEAT TRANSFER FLUID PUMP - CENTRIFUGAL PUMP 373 GPM @ 146 FT. OF HEAD, 3500 RPM, 50 HP, 440 VOLTS, 3 PHASE, 60 CYCLE - INGERSOLL-RAND 3x2x13 HEC OR EQUAL.
P2 FEEDWATER PUMP - TURBINE PUMP 13 GPM @ 420 FT. OF HEAD, 3500 RPM, 7.5 HP 440 VOLT, 3 PHASE, 60 CYCLE - PACO MODEL 40 OR EQUAL.
EXPANSION TANK - 500 GALLON CAPACITY, MAXIMUM 9'-0" TALL, PROVIDE SIGHT GLASS, SUPPORT LEGS AND TAPPINGS AS INDICATED.
GE1 STEAM GENERATOR - PROCESS STEAM GENERATOR SHALL HAVE CAPACITY TO PRODUCE 7942 LBS OF STEAM PER HOUR AT 150 PSIG UTILIZING 2152 LBS. PER HOUR OF HEAT TRANSFER FLUID ENTERING AT 450°F AND LEAVING AT 370°F. UNIT SHALL BE PATTERSON-KELLEY MODEL WS410.
HEAT TRANSFER FLUID LOOP
CONDENSATE/STEAM LOOP
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
TEAM
DRAWING NAME
P & I DIAGRAM
NUMBER
A-1



GENERAL NOTES

1. ALL CONNECTIONS ARE FILLET WELD, UNLESS SPECIFIED.
2. ALL PIPING IS INSULATED AFTER THE LEAK TEST. SEE INSULATION SPECIFICATIONS FOR SIZES.
3. INSTALL ALL VALVE STEMS EITHER HORIZONTALLY OR POINTING DOWNWARD TO ALLOW FLUID DRAINAGE IF LEAK OCCURS.
4. ALL PIPE 2" AND SMALLER SHALL EMPLOY SOCKET WELD CONNECTIONS. PIPE 2-1/2" AND LARGER CAN EMPLOY EITHER BUTT WELDS OR SOCKET WELD CONNECTIONS AT CONTRACTOR'S OPTION.
5. ALL ELBOW FITTINGS SHALL BE LONG RADIUS.
6. FOR EXPLINATION OF SYMBOLS SEE DWG M-1
7. SEE DETAIL (C/M5) FOR PIPE SIZE REDUCTION DETAIL.
8. SEE DETAIL (D/M5) FOR PIPE ROLLER SUPPORT DETAIL.

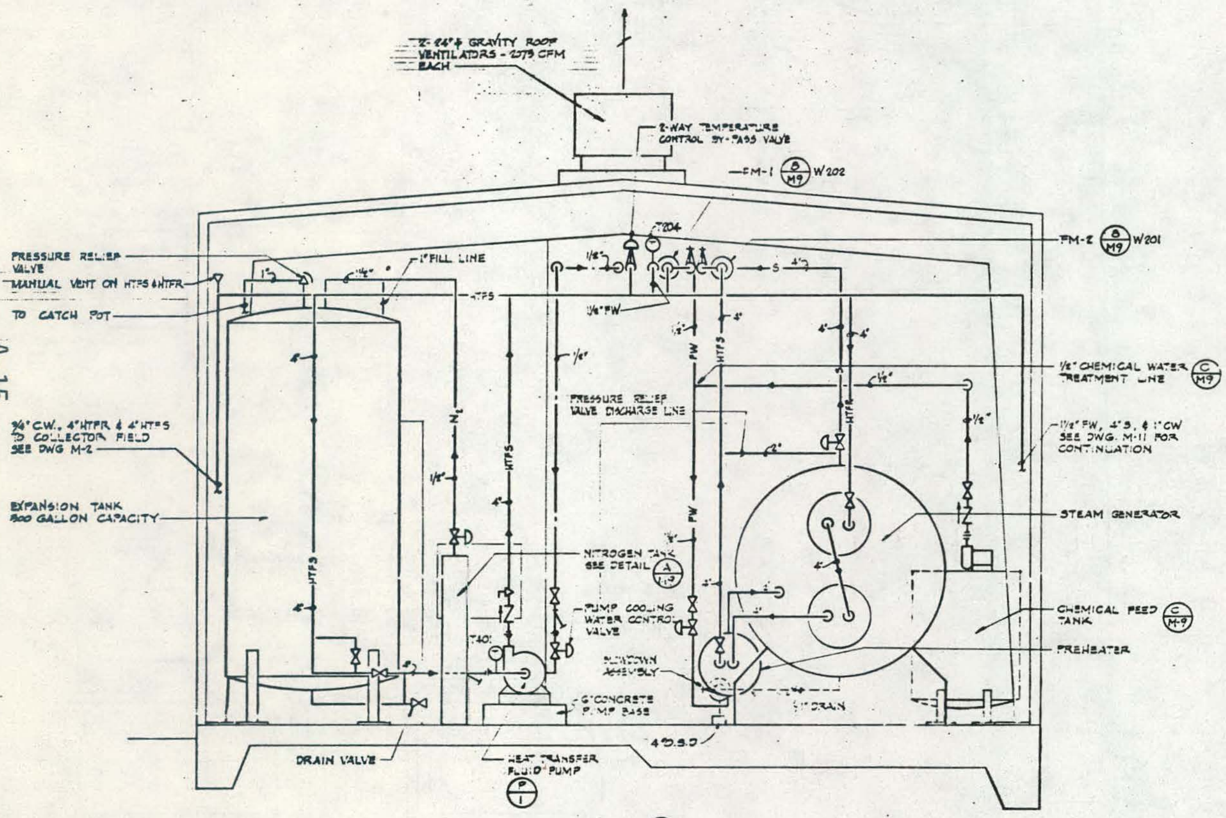
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM		
		DRAWING NAME SOLAR COLLECTOR FIELD	NUMBER M-2



PUMP AND BOILER HOUSE
MECHANICAL PLAN

SCALE 3/4"=1'-0"

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME: PUMP AND BOILER HOUSE PLAN	NUMBER: M-3



SECTION

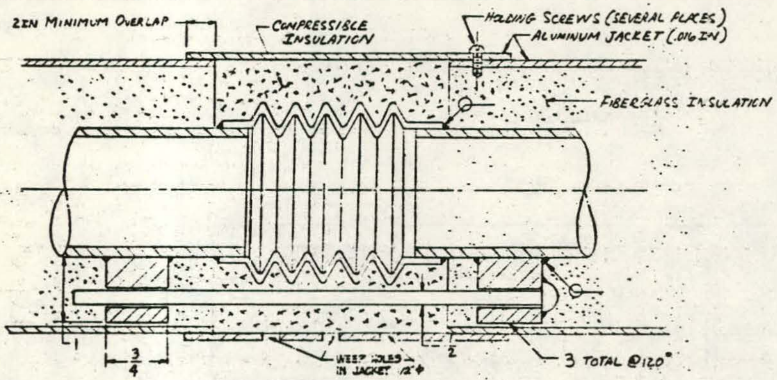
PUMP AND BOILER HOUSE - MECHANICAL

SCALE 3/4" = 1'-0"

SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
PUMP & BOILER HOUSE SECTION	M - 4

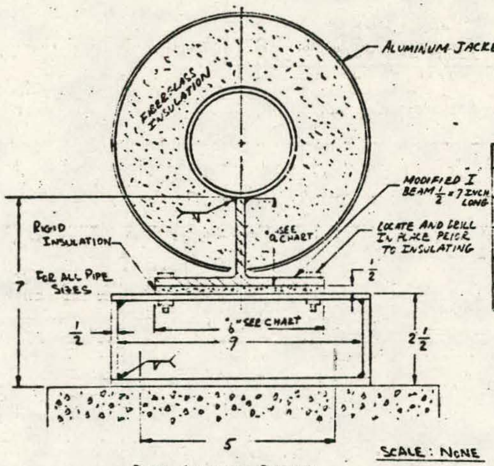


EXPANSION JOINT WITH SUPPORT & GLIDE DETAIL

SCALE: NONE

A / M-5

NOTE
SEE DWG No FOR PIPE SUPPORT FOUNDATION DETAILS

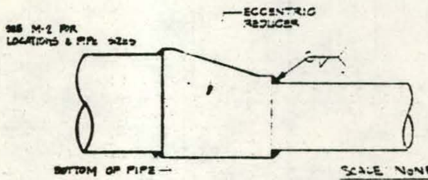


PIPE SIZE	"a"	"b"
1 1/2	4	4 1/2
2	4	5
2 1/2	4	5 1/2
3	4	6
4	4	7

SCALE: NONE

PIPE ANCHOR DETAIL

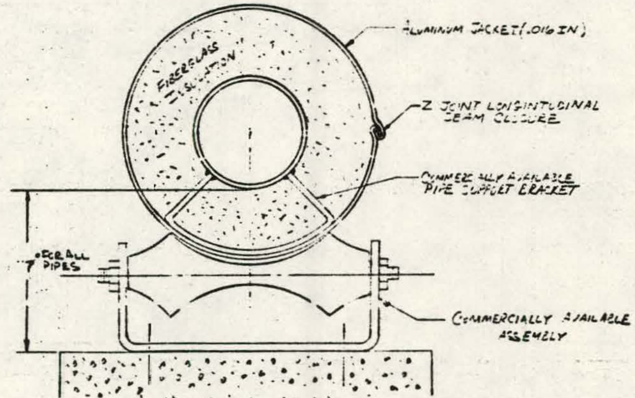
B / M-5



SCALE: NONE

MANIFOLD PIPING REDUCER

C / M-5

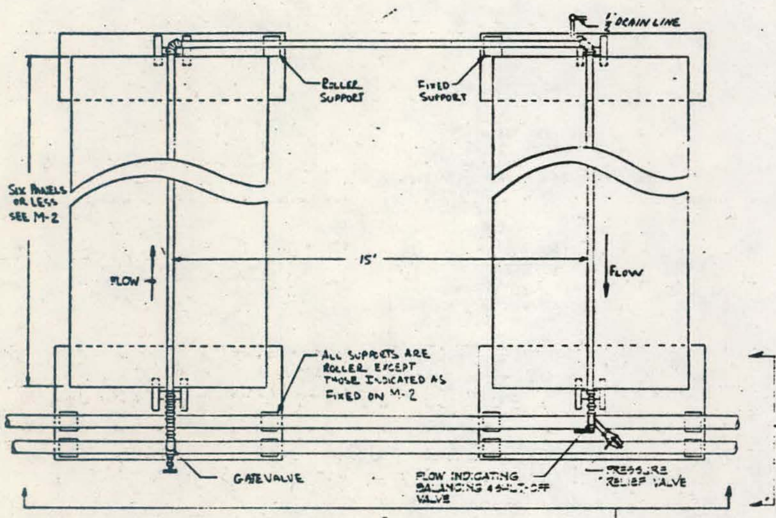


SCALE: NONE

MOVEABLE ANCHOR DETAIL

D / M-5

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT	TEAM	
PHASE I DESIGN	DRAWING NAME	NUMBER
DE-FC03-79CS30311	PIPING DETAILS	M-5



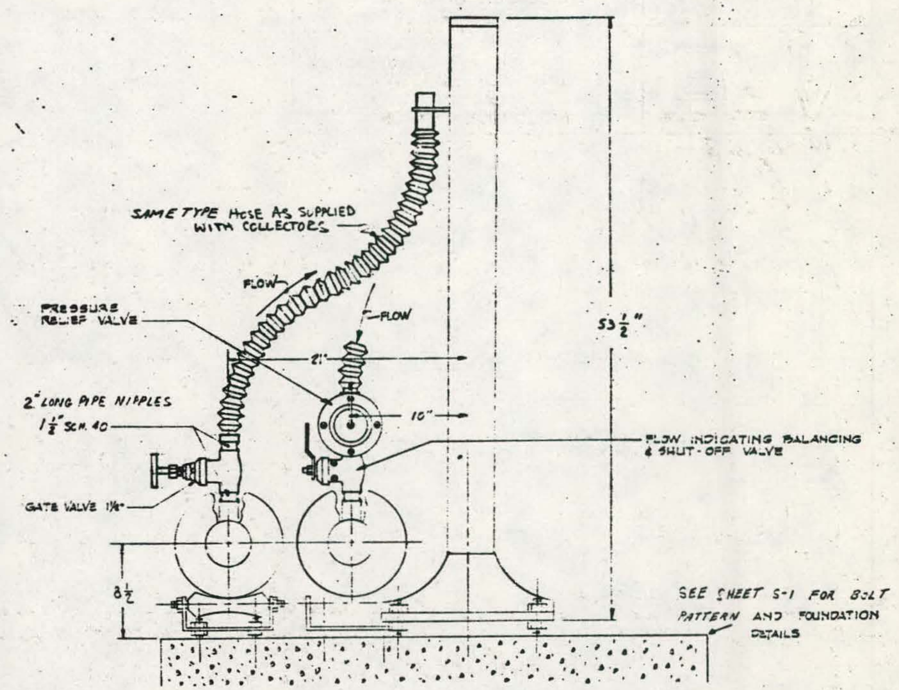
NOTE:

DETAIL AS SHOWN IS TYPICAL FOR SOUTH COLLECTOR FIELD "T" CONNECTIONS FOR NORTH FIELD CONNECTIONS ARE OPPOSITE HAND. IN ALL INSTALLATIONS COLLECTOR DISCHARGE IS ALWAYS CLOSER TO PUMP HOUSE THAN COLLECTOR INLET.

PLAN VIEW COLLECTOR SERIES "T" CONNECTIONS

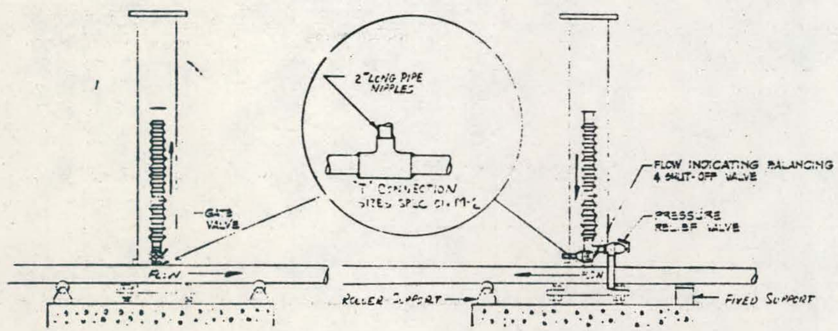
SCALE: NONE

E / M-6



SCALE: NONE

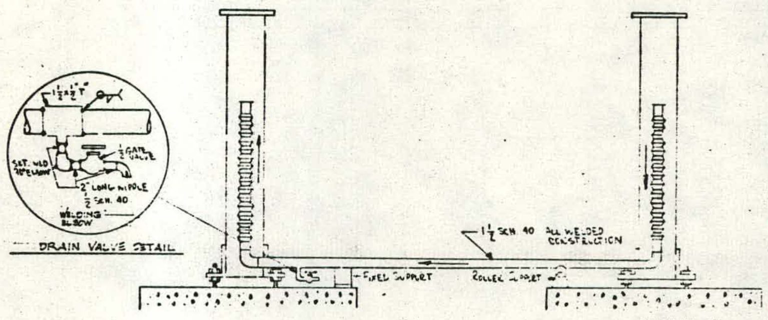
COLLECTOR INLET & OUTLET "T" CONNECTIONS
VIEW A



SCALE: NONE

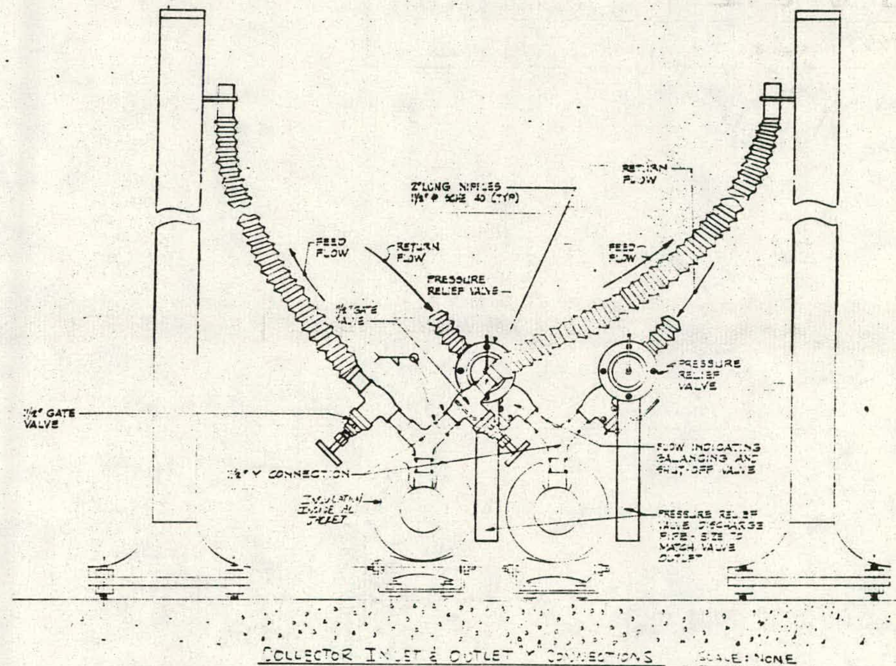
COLLECTOR INLET & OUTLET CONNECTIONS
VIEW B

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME PIPING DETAILS	NUMBER M-6



COLLECTOR INLET & OUTLET END CONNECTIONS

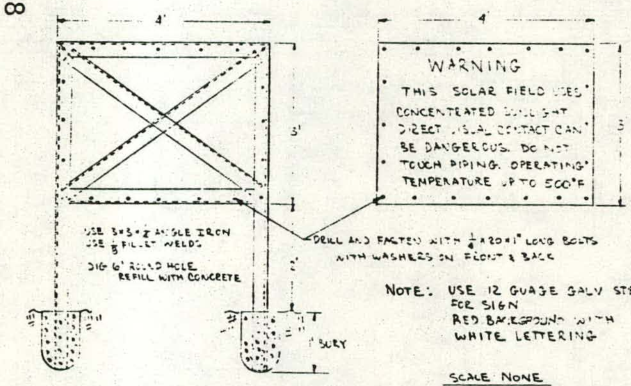
F / M-7



COLLECTOR INLET & OUTLET "Y" CONNECTIONS SCALE: NONE

G / M-7

NOTE
BOND ALL ALUMINUM JACKET INSULATION EACH SIDE OF VALVES

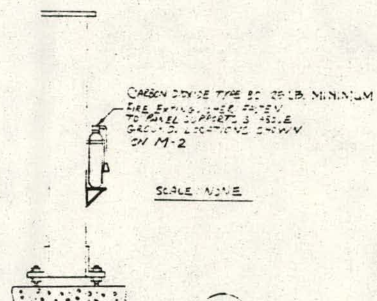


NOTE: USE 12 GUAGE GALV STEEL FOR SIGN
RED BACKGROUND WITH WHITE LETTERING

SCALE NONE

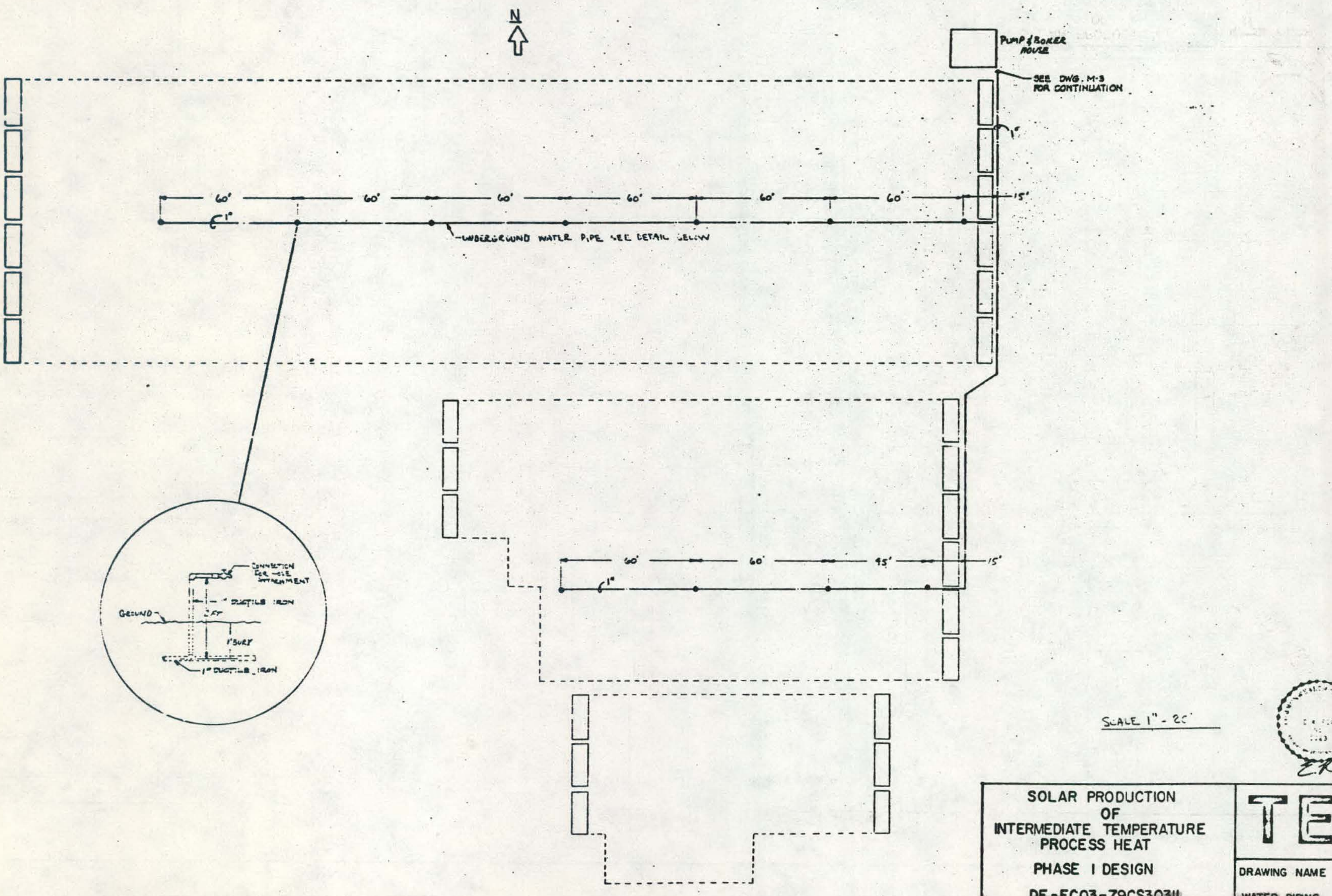
WARNING SIGN

H / M-7



FIRE EXTINGUISHER I / M-7

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT	TEAM	
PHASE I DESIGN	DRAWING NAME	NUMBER
DE-FC03-79CS30311	FIELD DETAILS	M-7



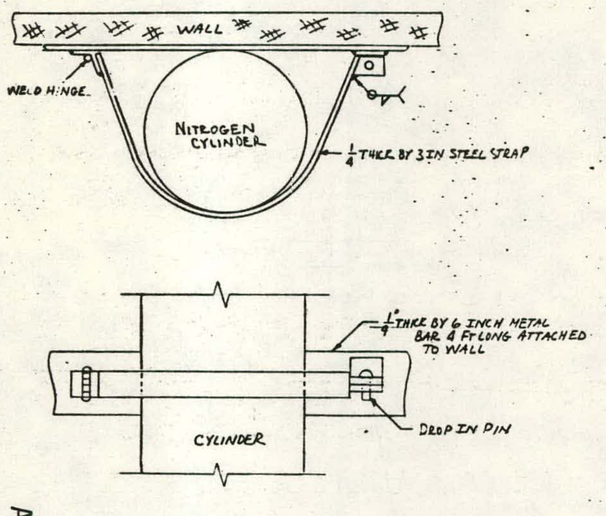
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT

PHASE I DESIGN

DE-FC03-79CS30311

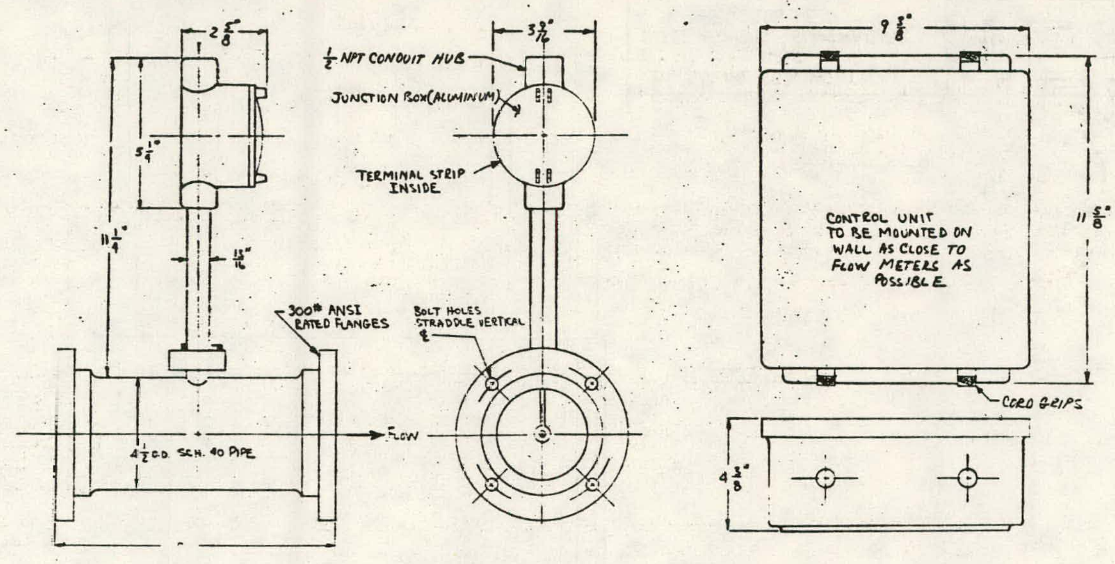
TEAM

DRAWING NAME	NUMBER
WATER PIPING	M-8



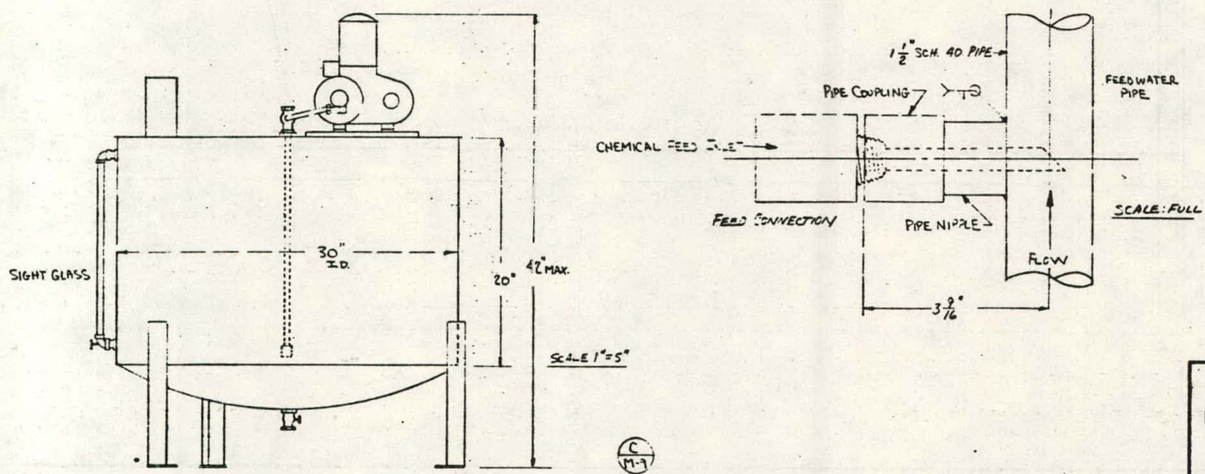
NITROGEN CYLINDER ANCHOR DETAIL SCALE: NONE

A / M-9



FLOW METER & CONTROL UNIT SCALE: 1" = 2"

B / M-9

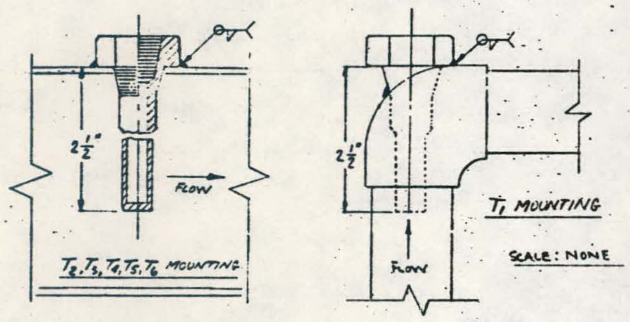


C / M-9

CHEMICAL FEED TANK & FEED CONNECTION

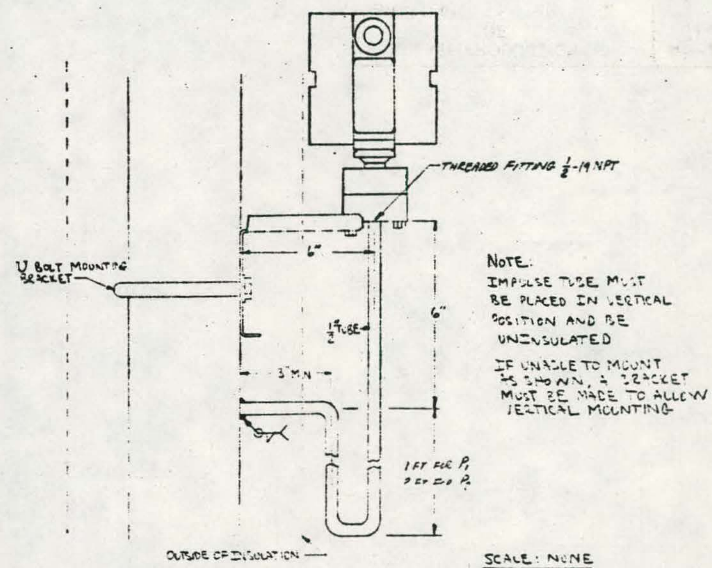
E. R. Fox

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT	TEAM	
PHASE I DESIGN	DRAWING NAME	NUMBER
DE-FC03-79CS30311	PUMPHOUSE DETAILS	M-9



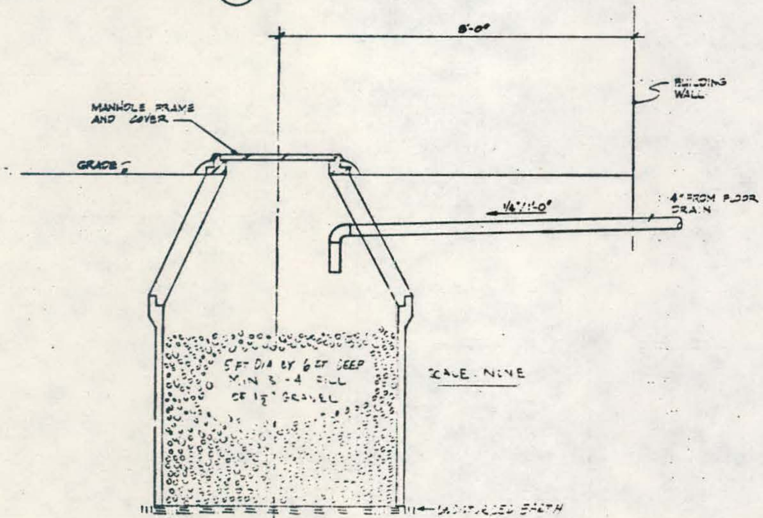
THERMOWELL DETAILS

D / M-10



PRESSURE TRANSDUCER DETAILS

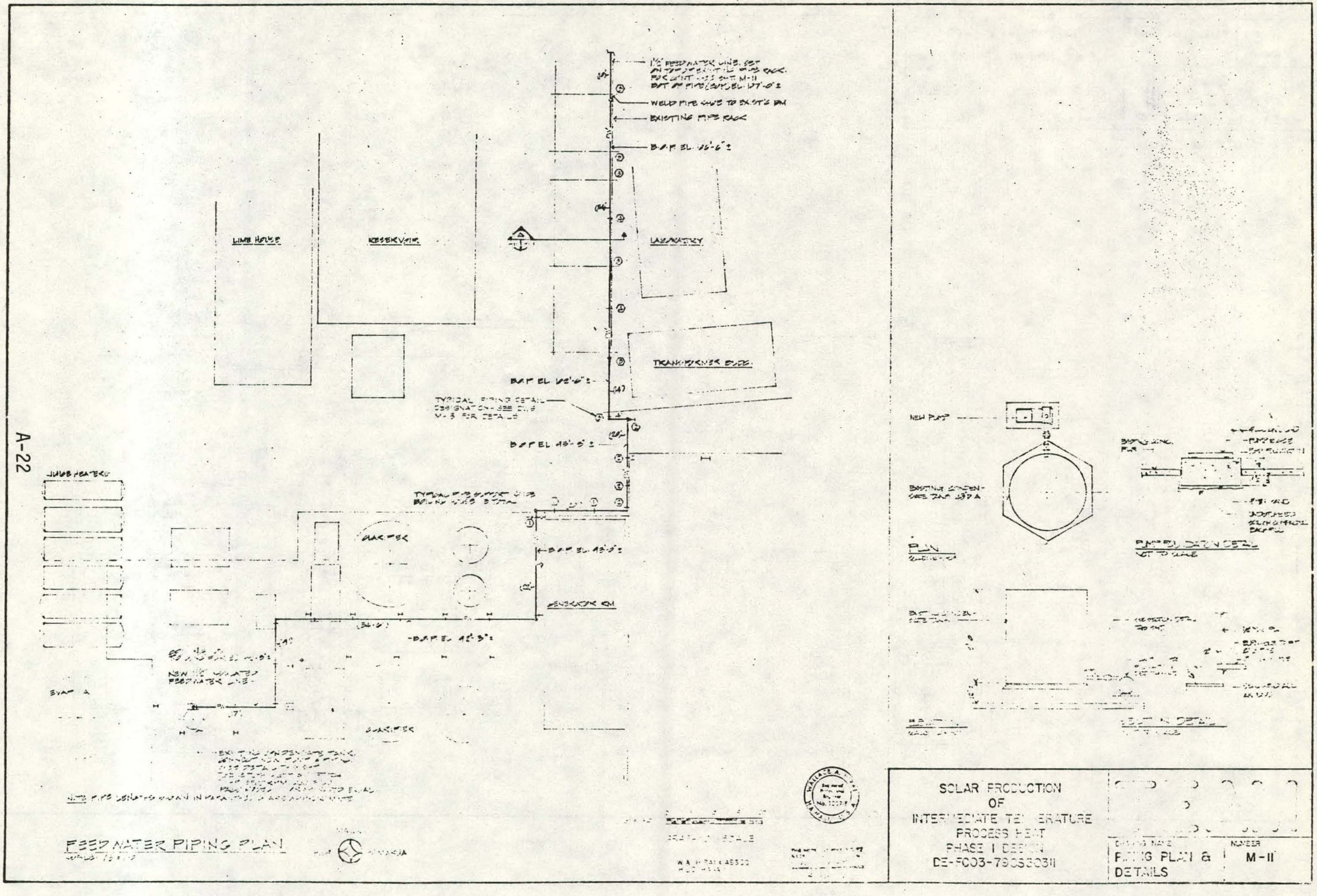
E / M-10



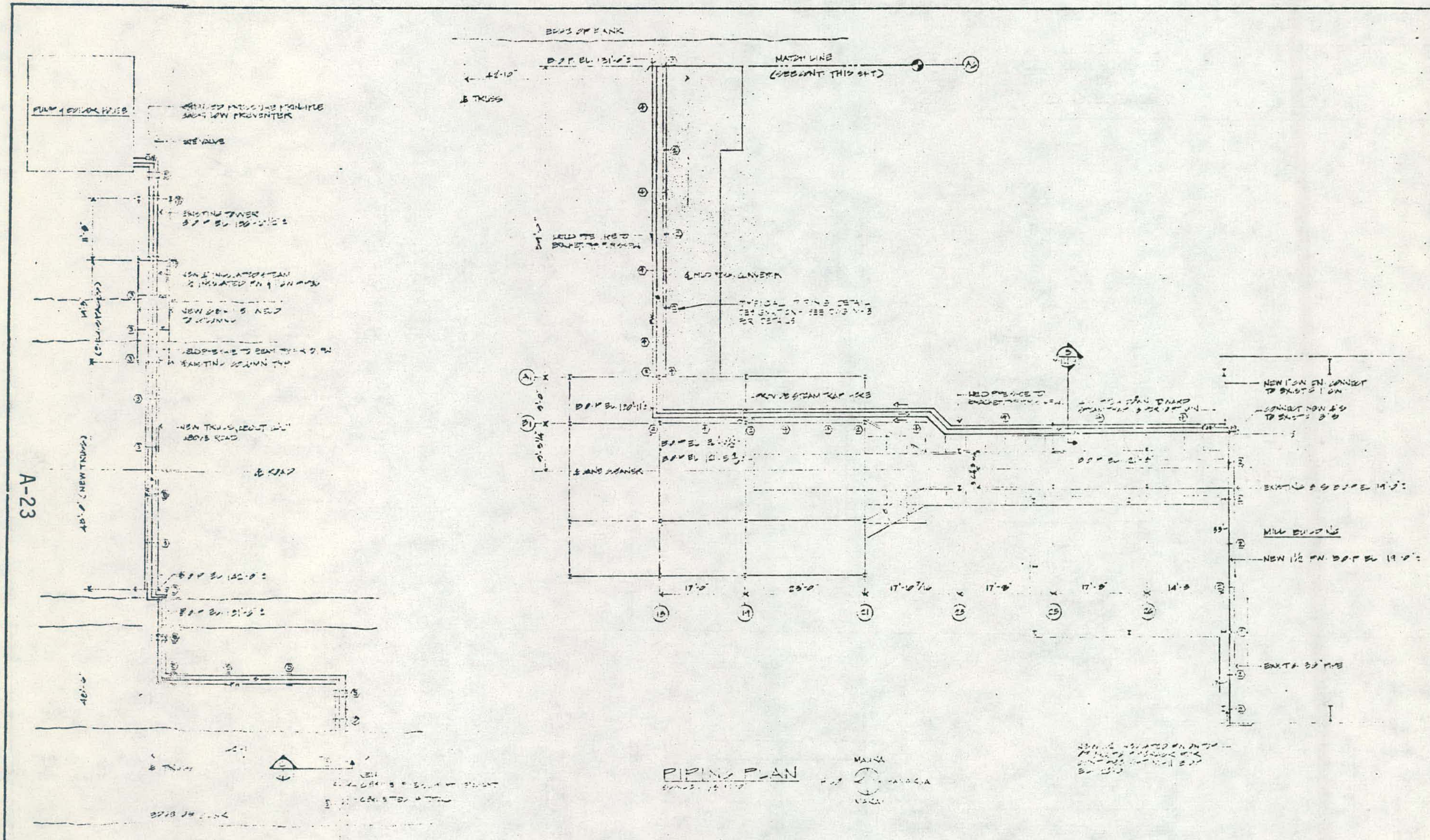
DRYWELL DETAIL

F / M-10

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT	TEAM	
PHASE I DESIGN	DRAWING NAME	NUMBER
DE-FC03-79CS30311	PUMPHOUSE DETAILS	M-10

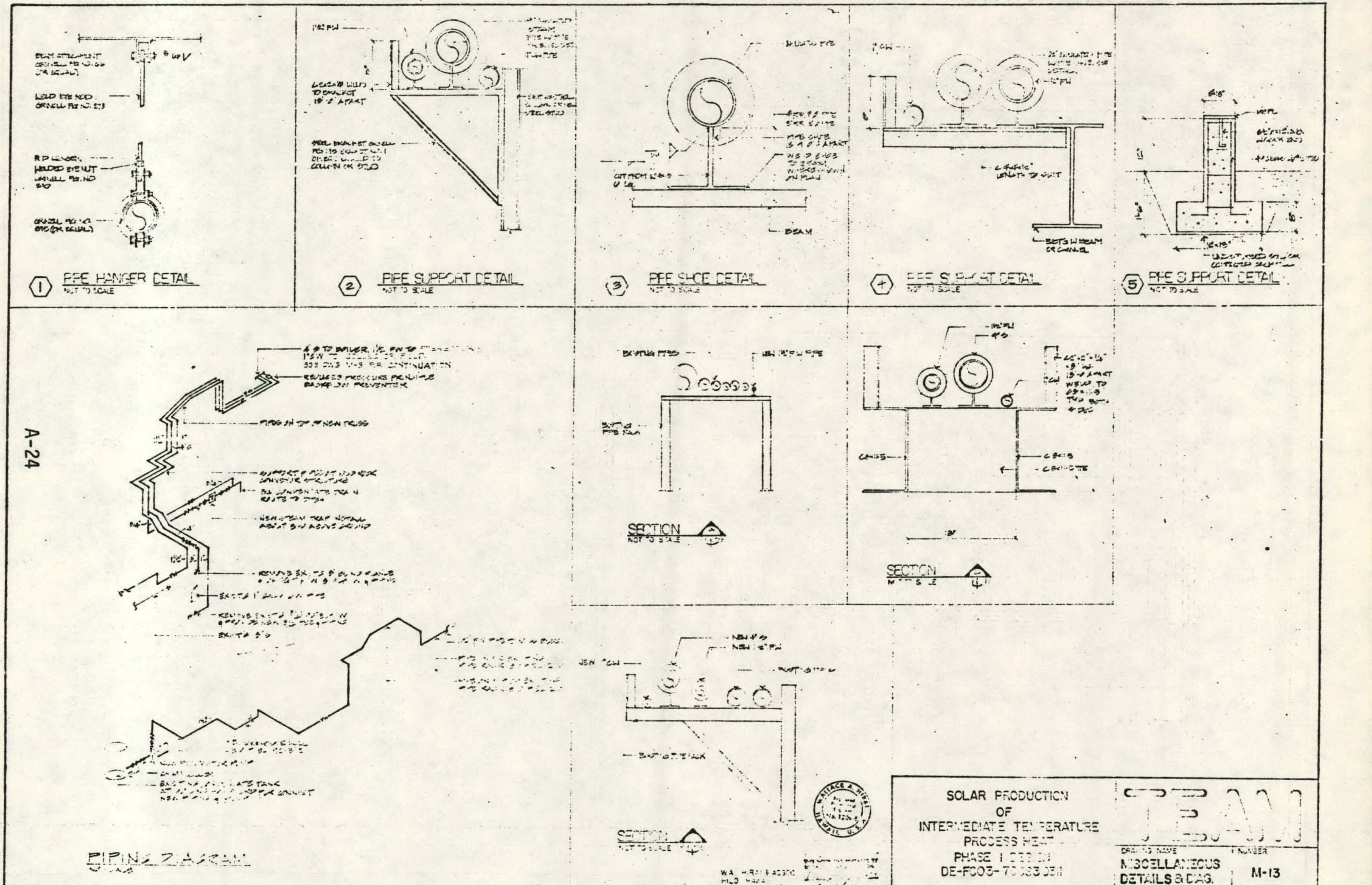


LIME HOUSE
RESERVOIR
LABORATORY
TRANSFORMER BLDG.
CLARIFIER
EXISTING PIPE RACK
NEW PUMP
PLAN
PUMP FOUNDATION DETAIL
NOT TO SCALE
FEEDWATER PIPING PLAN
GRAPHIC SCALE
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
DRAWING NAME
PIPING PLAN &
DETAILS
NUMBER
M-11

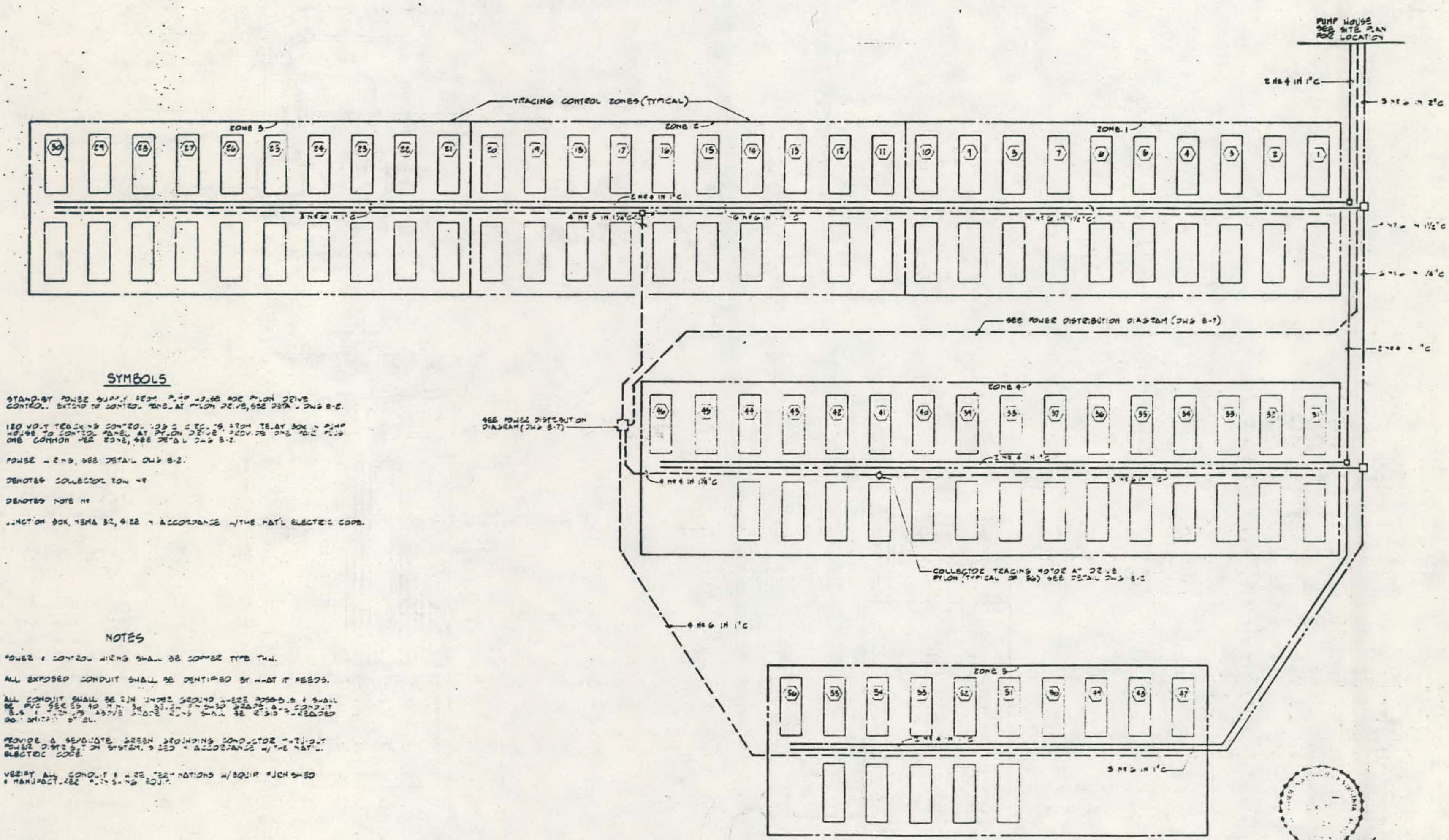


SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

DRAWING NAME	NUMBER
PIPING PLAN	M-12



PIPE HANGER DETAIL
NOT TO SCALE
PIPE SUPPORT DETAIL
NOT TO SCALE
PIPE SHOE DETAIL
NOT TO SCALE
PIPE SUPPORT DETAIL
NOT TO SCALE
PIPE SUPPORT DETAIL
NOT TO SCALE
SECTION
NOT TO SCALE
SECTION
NOT TO SCALE
SECTION
NOT TO SCALE
PIPING DIAGRAM
SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311
DRAWING NAME
MISCELLANEOUS
DETAILS & DIAG.
NUMBER
M-13



A-25

SYMBOLS

—·— STAND-BY POWER SUPPLY FROM PUMP HOUSE FOR PYLON DRIVE CONTROL. EXTEND TO CONTROL PANEL AT PYLON DRIVE, SEE DETAIL DWG B-2.

—··— 120 VOLT TRACKING CONTROL WIRE CIRCUITS FROM RELAY BOX IN PUMP HOUSE TO CONTROL PANEL AT PYLON DRIVE. PROVIDE ONE PAIR PLUS ONE COMMON PER ZONE, SEE DETAIL DWG B-2.

– – – – POWER WIRING, SEE DETAIL DWG B-2.

⟨3⟩ DENOTES COLLECTOR ROW NO

(5) DENOTES NOTE NO

□ JUNCTION BOX, NEMA 3R, SIZE IN ACCORDANCE W/THE NAT'L ELECTRIC CODE.

NOTES

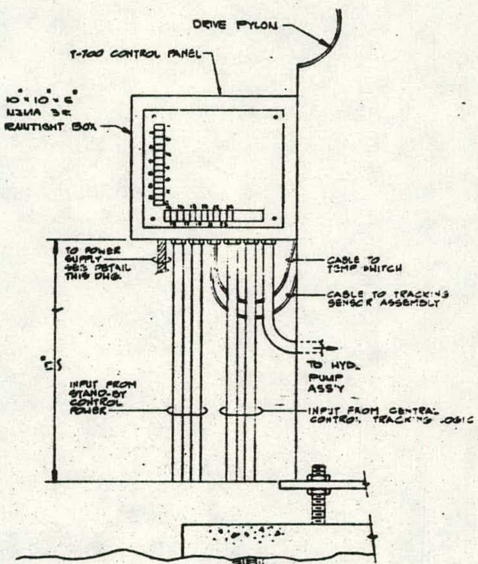
1. POWER & CONTROL WIRING SHALL BE COPPER TYPE THW.
2. ALL EXPOSED CONDUIT SHALL BE IDENTIFIED BY WHAT IT FEEDS.
3. ALL CONDUIT SHALL BE RUN UNDER GROUND WHERE POSSIBLE & SHALL BE PVC SERIES 40 MIN. 30 BELOW FINISHED GRADE. ALL CONDUIT ELS & TURNUPS ABOVE GRADE RUNS SHALL BE RIGID THREADED GALVANIZED STEEL.
4. PROVIDE A SEPARATE GREEN GROUNDING CONDUCTOR THROUGHOUT POWER DISTRIBUTION SYSTEM, SIZED IN ACCORDANCE W/THE NAT'L ELECTRIC CODE.
5. VERIFY ALL CONDUIT & WIRE TERMINATIONS W/EQUIP. FURNISHED & MANUFACTURER FURNISHING EQUIP.

SOLAR FIELD-DRIVE PYLON PLAN
SCALE 1/16" = 1'-0"

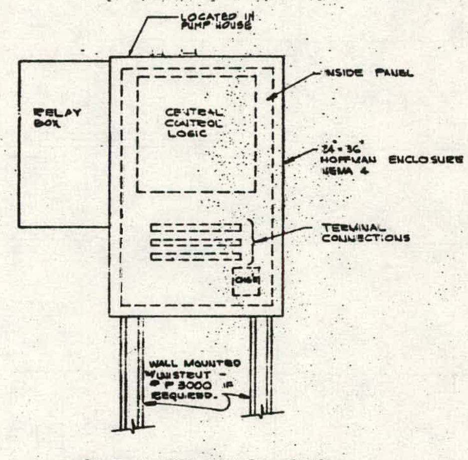
E. P. Fox 6/19/80

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME: SOLAR FIELD ELECTRICAL LAYOUT	NUMBER: B-1

No.	DESCRIPTION
1	LOGIC 1
2	LOGIC 2
3	120 VAC IN (INVERTER)
4	120 VAC IN
5	120 VAC RETURN
6	GROUND
7	TR'K SENSOR (GRN. LEAD)
8	TR'K SENSOR (BLUE LEAD)
9	TR'K SENSOR (ORN. LEAD)
10	DIRECTION SOLENOID (EAST)
11	DIRECTION SOLENOID (WEST)
12	HYD. MOTOR
13	HYD. PRESS. SW. (HI SIDE)
14	HYD. PRESS. SW. (LOW SIDE)
15	" " " "
16	BYPASS RELAY COIL
17	HAZ'D INTERRUPT
18	" "
19	LT. SENSOR (WHITE LEAD)
20	LT. SENSOR (RED LEAD)
21	V-TO LT. SEN'R BD.
22	STOW POS. IND.
23	" " "
24	CONTROL NEG.

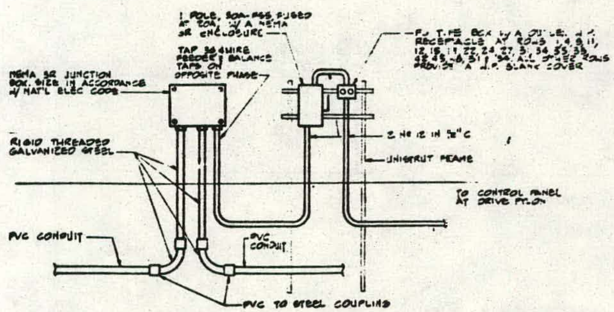


DRIVE PYLON CONNECTION DETAIL
NO SCALE



FIELD MASTER CONTROL PANEL
NO SCALE

No.	DESCRIPTION
1	LOGIC 1 SUBFIELD 1
2	" 2 " 1
3	" 1 " 2
4	" 2 " 2
5	" 1 " 3
6	" 2 " 3
7	" 1 " 4
8	" 2 " 4
9	" 1 " 5
10	" 2 " 5
24	CONTROL NEGATIVE (LOGIC 1&2 RETURN)
25	SPARE
26	"
27	RAIN SWITCH
28	" "
29	WIND SWITCH
30	" "
31	FLOW SWITCH
32	" "
33	SPARE SWITCH
34	" "
35	FIELD READY SWITCH
36	" " "
37	TRACK ENABLE (OPERATOR READY)
38	(EXTERNAL SYSTEM INTERRUPT)

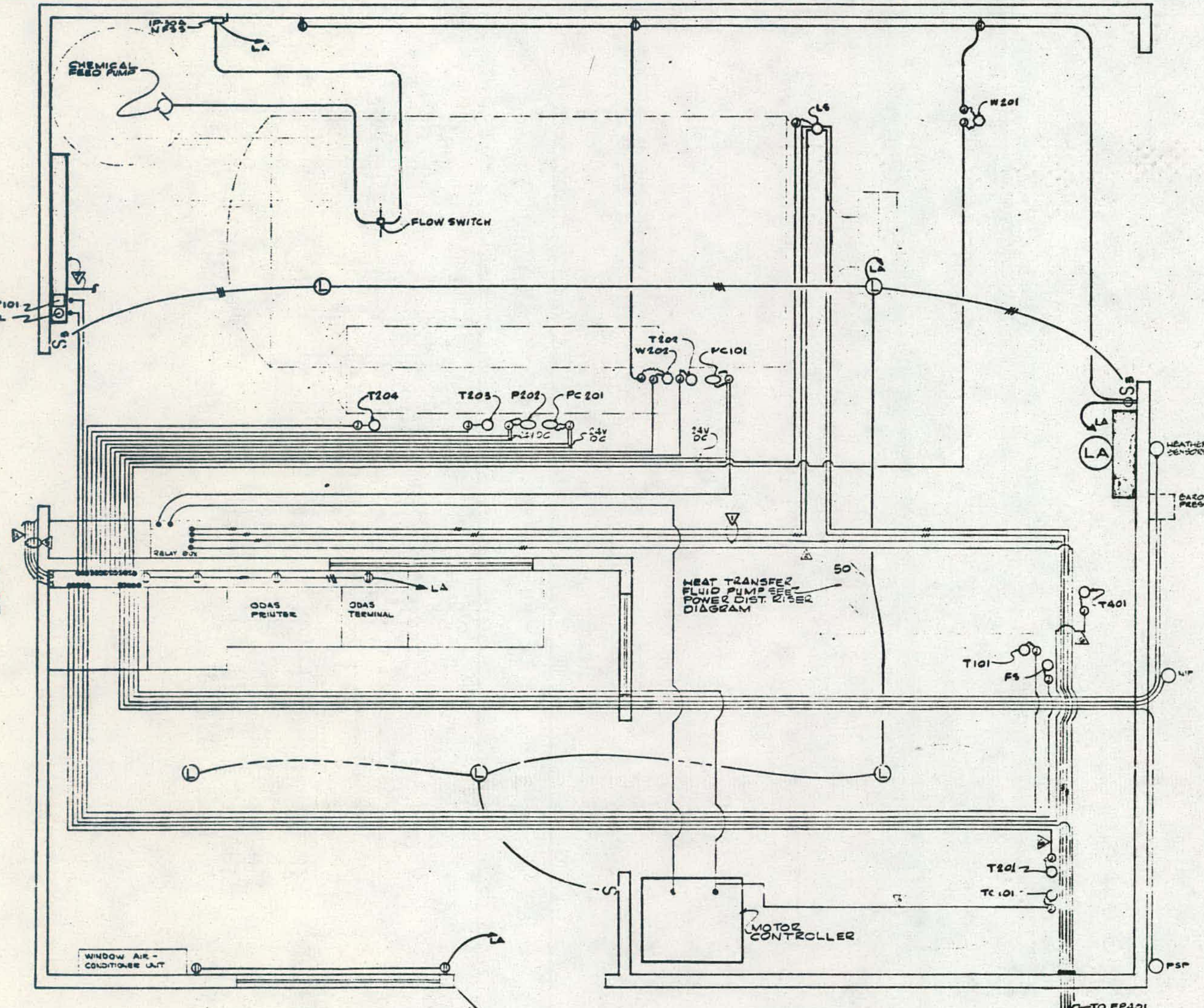


DRIVE PYLON POWER SUPPLY DETAIL
NO SCALE

A-26

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM
DRAWING NAME: FIELD CONTROL PANELS ELECTRICAL LAYOUT	NUMBER: E-2

A-27



PUMP HOUSE FLOOR PLAN
SCALE: 1" = 1'-0"

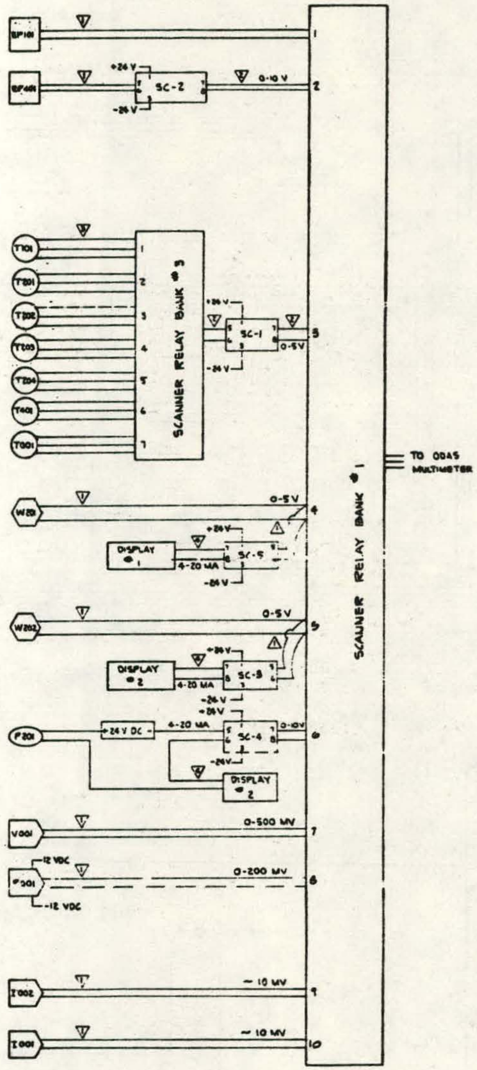
SYMBOLS

- INCANDESCENT LIGHTING FIXTURE PENDANT MOUNTED. HUBBLE CATALOG NO. RP-216-AL-4-RG WITH 200 WATT LAMP. MOUNT 9'-0" ABOVE FINISHED FLOOR.
- SINGLE POLE FLUSH TUMBLER SWITCH 4'-6" AFF OR AS NOTED.
- THREE-WAY FLUSH TUMBLER SWITCH 4'-6" AFF OR AS NOTED.
- JUNCTION BOX-CEILING OR WALL MOUNTED.
- DUPLEX RECEPTACLE 2P-3W-15A-125V. 42" AFF OR AS NOTED.
- MOTOR OUTLET-NUMERAL INDICATES HORSEPOWER.
- SAFETY SWITCH (FSS=FUSIBLE NFSS=NON-FUSIBLE).
- BRANCH CIRCUIT PANELBOARD-NUMERAL IN CIRCLE INDICATES PANEL DESIGNATION.
- BRANCH CIRCUIT HOMERUN TO PANELBOARD-NUMBER OF ARROWHEADS INDICATE NUMBER OF CIRCUITS IN RUN.
- BRANCH CIRCUIT WIRING CONCEALED IN CEILING OR WALLS-CROSSMARKS AND NUMERALS INDICATE NUMBER AND SIZE OF CONDUCTORS RESPECTIVELY, 2 NO. 12 IN 1/2" CONDUIT NOT NOTED.
- TURN UP OR TURN DOWN.
- AFF ABOVE FINISHED FLOOR.
- EC EMPTY CONDUIT.
- WP WEATHERPROOF.
- CONDUCTOR RUN IN CONDUIT OR SIGNAL WIRE TRAYS OR BUNDLES AS APPROPRIATE. 120 VAC LINES IN CONDUIT. 24 VDC LINES IN CABLES SEPARATE FROM OTHER SIGNAL CABLES. SIGNAL CABLES IN TRAYS, BUNDLES OR CONDUIT.
- PROTECTED FLEXIBLE LINE. BULEX FOR 120 VAC LINES. HARD RUBBER COVER FOR SIGNAL LINES.
- TEMPERATURE SENSOR. INSTALLED BY MECHANICAL, HOOKED UP BY ELECTRICAL SIGNAL. REQUIRES BELDEN TRADE & UL STYLE 8771 OR EQUIVALENT SIGNAL CABLE.
- PRESSURE TRANSDUCER, INSTALLED BY MECHANICAL, HOOKED UP BY ELECTRICAL. REQUIRES 24 VDC POWER. REQUIRES 2 BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.
- FLUID AND STEAM FLOW METER. INSTALLED BY MECHANICAL, HOOKED UP BY ELECTRICAL. REQUIRES 120 VAC TO WALL MOUNTED TRANSMITTER. SIGNAL WIRE TO BE BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.
- FLOW SWITCH. REQUIRES 1 BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.
- PHASE LOSS SWITCH. REQUIRES 1 BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.
- LEVEL SWITCH. REQUIRES 1 BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.
- WATT TRANSDUCER. INSTALLED AND HOOKED UP BY ELECTRICAL. REQUIRES 1 BELDEN TRADE & UL STYLE 8761 OR EQUIVALENT.

NOTES

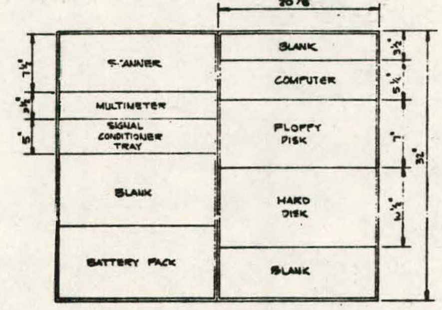
1. ONE OF FIVE PAIR OF 120 VAC FIELD CONTROL LINES SHOWN. EACH PAIR IS NO. 6 AWG COPPER OR EQUIVALENT. A COMMON RETURN IS TO BE RUN FOR EACH PAIR.
2. INVERTER OUTPUT LINES TO FIELD. NO. 4 AWG COPPER OR EQUIVALENT WITH RETURN.
3. ALL SIGNAL LINES IN PUMP HOUSE TO BE BELDEN TRADE & UL TYPE 8761 OR EQUIVALENT. DRAIN WIRES TERMINATED AS DESCRIBED ELSEWHERE.
4. BELDEN TRADE & UL TYPE 8761 OR EQUIVALENT FROM EP 401 TO DDAS [illegible]. DRAIN TERMINATED [illegible].
5. BELDEN TRADE & UL TYPE 9874. SIX TWISTED PAIRS IN SINGLE CABLE. EACH PAIR WITH SEPARATE DRAIN. DRAINS TERMINATED AT SIGNAL CONDITIONER TRAY. THREE CABLES REQUIRED.
6. BELDEN TRADE & UL TYPE 8771. THREE CONDUCTOR, SHIELDED CABLE WITH DRAIN. DRAIN TERMINATED AT SIGNAL CONDITIONER OR SCANNER RELAY ONLY.
7. ELECTRIC SERVICE. SEE POWER DISTRIBUTION DIAGRAM. DRAWING NO. E-7.

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM DRAWING NAME PUMP HOUSE ELECTRICAL LAYOUT	NUMBER E-3

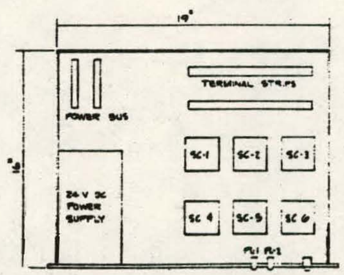


NOTES:

1. BELDEN TRADE & UL TYPE 8761. TWO CONDUCTOR, SHIELDED W/DRAIN. DRAIN CONNECTED AT SIGNAL CONDITIONER OR SCANNER RELAY BANK ONLY.
2. SAME SIGNAL WIRE AS 1 ABOVE EXCEPT DRAIN TERMINATED AT BOTH ENDS.
3. BELDEN TRADE & UL TYPE 8771. THREE CONDUCTOR, SHIELDED W/DRAIN. DRAIN TERMINATED AT SCANNER RELAY BANK ONLY.
4. BELDEN TRADE & UL TYPE 9874. ONE OF SIX TWISTED PAIRS IN COMMON CABLE. EACH PAIR WITH DRAIN WIRE. DRAINS TERMINATED AT SIGNAL CONDITIONER ONLY.

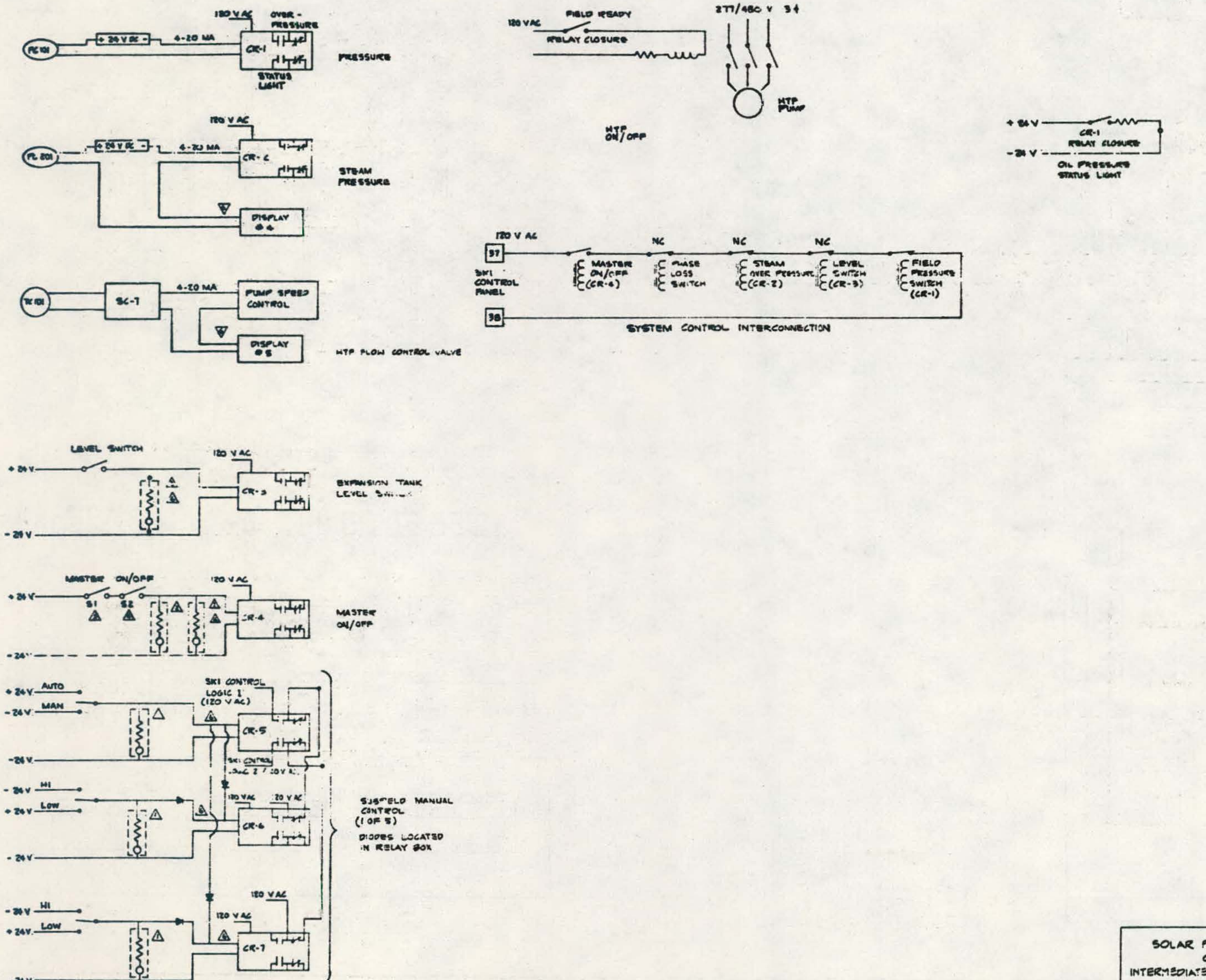


EQUIPMENT RACKS



SIGNAL CONDITIONER TRAY LAYOUT

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME: DATA ACQUISITION INTERCONNECTS	NUMBER: E-4

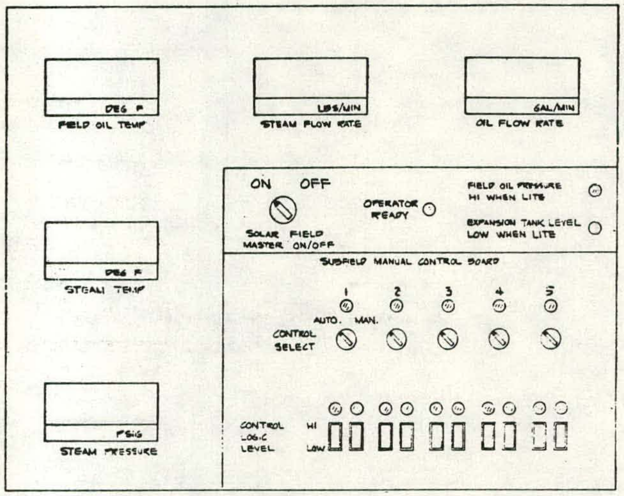


NOTES:

1. ON MASTER CONTROL PANEL
2. ON SIGNAL CONDITIONER PANEL
3. S1 ON MASTER CONTROL PANEL
4. S2 ON SIGNAL CONDITIONER PANEL
5. BELDEN TRADE # TYPE 8761. TWO CONDUCTOR SHIELDED WITH DRAIN. DRAIN TERMINATED AT RELAY BOX ONLY.
6. BELDEN TRADE # TYPE 9874. ONE OF SIX TWISTED PAIRS IN COMMON CABLE. EACH PAIR WITH INDIVIDUAL DRAIN. ALL DRAINS TERMINATED AT RELAY BOX.

E. K. FOX No. 5023

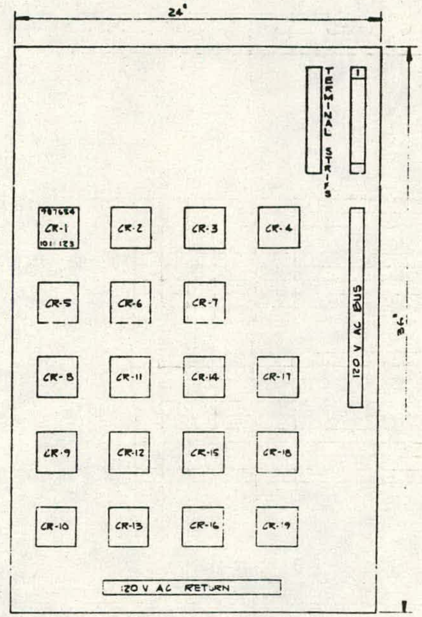
SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT PHASE I DESIGN DE-FC03-79CS30311	TEAM	
	DRAWING NAME: CONTROL & POWER DISTRIBUTION INTERCONNECTS	NUMBER: E-5



MASTER CONTROL PANEL LAYOUT

NO SCALE

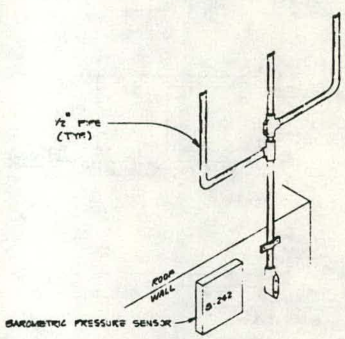
NOTE : LOCATED IN NEW BOILER BLDG SEE SITE PLAN FOR LOCATION



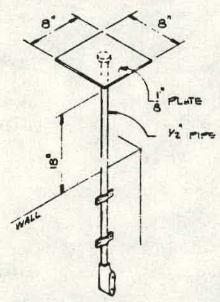
RELAY BOX LAYOUT

NO SCALE

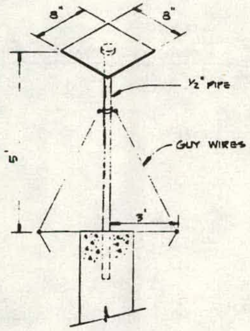
NOTE : LOCATED IN PUMP HOUSE



ENVIRONMENTAL SENSOR MOUNT



FSP ROOF MOUNT



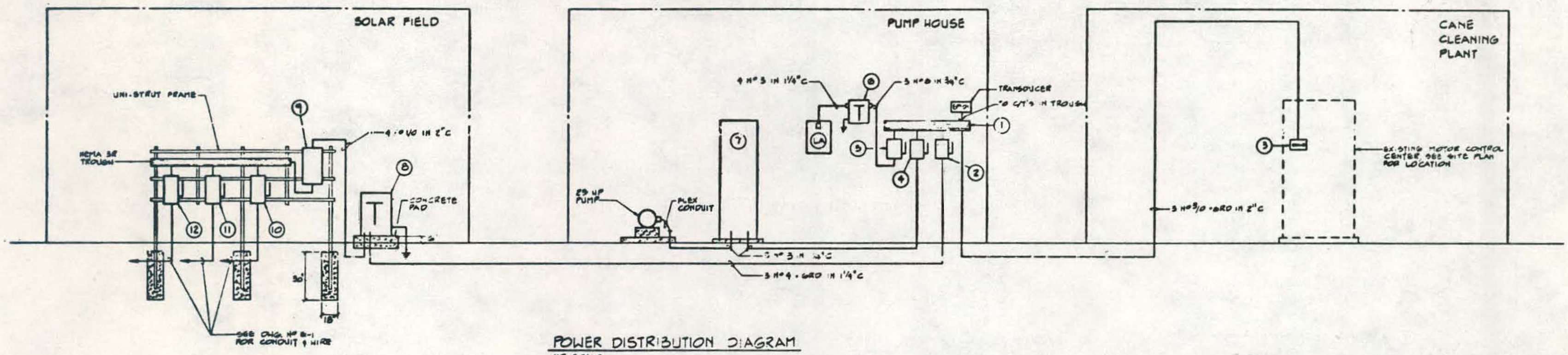
NIP GROUND MOUNT

E. K. FUX No. 5023

SOLAR PRODUCTION OF INTERMEDIATE TEMPERATURE PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30305.1

TEAM

DRAWING NAME	NUMBER
MASTER CONTROL PANEL & RELAY BOX LAYOUT	E-6



POWER DISTRIBUTION DIAGRAM

NO SCALE

NOTES

1. EXTEND CABLE FULL LENGTH OF TROUGH & PROVIDE W/CURRENT TRANSFORMERS COMPATIBLE W/RECORDING EQUIPMENT.
2. 3 POLE, 100 AMP, FSS; FUSED AT 70 AMPS, W/CURRENT LIMITING FUSES.
3. PROVIDE & INSTALL IN EXISTING SPACE A NEW 3 POLE 200AMP SWITCH UNIT & FUSE AT 200AMPS W/CURRENT LIMITING FUSES.
4. 3 POLE, 100AMP FSS; FUSED AT 100 AMPS, W/CURRENT LIMITING FUSES.
5. 3 POLE 60AMP FSS; FUSED AT 40 AMPS, W/ CURRENT LIMITING FUSES.
6. 30 KVA DRY TYPE TRANSFORMER, WALL MOUNTED. 480 VOLT △ PRIMARY TO 120/208 VOLT, 3φ, 4W, Y SECONDARY W/ 2-2/2% TAPS ABOVE & BELOW NORMAL.
7. MOTOR STARTER - WINCOM VARIABLE SPEED CAT. NO VSMC-555-480-60-50-MCC-OPTION 6.
8. 45 KVA DRY TYPE TRANSFORMER PAD MOUNTED W/ NEMA 3R ENCLOSURE. 480 VOLT PRIMARY, TO 120/208 VOLT. 3φ, 4W Y SECONDARY W/2-2/2% TAPS ABOVE & BELOW NORMAL.
9. 3 POLE 200AMP FSS; FUSED AT 150 AMPS W/ CURRENT LIMITING FUSES & W/ NEMA 3R ENCLOSURE.
10. 3 POLE 100AMP FSS, FUSED AT 70AMPS W/ CURRENT LIMITING FUSES & W/ NEMA 3R ENCLOSURE.
11. 3 POLE 60A FSS; FUSED AT 40 AMPS W/ CURRENT LIMITING FUSES & W/ NEMA 3R ENCLOSURE.
12. 3 POLE 30AMP FSS, FUSED AT 30AMPS, W/CURRENT LIMITING FUSES & W/ NEMA 3R ENCLOSURE.

PANELBOARD SCHEDULE

PANEL Nº	TYPE CABINET	PANEL MAINS			BRANCHES					ITEM FED OR REMARKS
		AMPS	VOLTS	PHASE	1P	2P	3P	TRIP	FRAME	
LA	SURFACE	100A	120/208	3φ,4W	20	-	-	20A	70A	LTS RECEPTS & SPARES
SQUARE D TYPE NQOB W/3P-100A MAIN CIRCUIT BREAKER					10	-	-	-	70A	PROVISIONS ONLY

A-31

SOLAR PRODUCTION
OF
INTERMEDIATE TEMPERATURE
PROCESS HEAT
PHASE I DESIGN
DE-FC03-79CS30311

TEAM

DRAWING NAME	NUMBER
POWER DISTRIBUTION DIAGRAM SCHEDULE & NOTES	E-7

APPENDIX B

SPECIFICATIONS

HILO COAST PROCESSING COMPANY

SOLAR

INDUSTRIAL PROCESS HEAT SYSTEM

DOE CONTRACT NO. DE-FC03-79CS30311

June 20, 1980

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DIVISION 2 - SITE WORK

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PART 1.00 - GENERAL

1.01 SCOPE OF WORK

Furnish all labor, materials, services, equipment and appliances required for site grading, excavation, backfilling and compaction work indicated on the drawings.

PART 2.00 - PRODUCTS

2.01 MATERIALS FOR FILLING AND BACKFILLING

A. On-site materials shall be decomposed rock crushed to a well-graded consistency.

B. Select borrow soils shall be well-graded clinker or cinders.

C. Maximum size shall be 1-1/2 inch for collector footings and 3/4 inch elsewhere.

PART 3.00 - EXECUTION

3.01 GRADING

Establish grades by means of grade stakes and grade to nearest .1 foot.

3.02 EXCAVATION

A. Excavate to the lines, elevations and limits indicated with sufficient distance and space to permit erection of forms.

B. Inspect bottoms of excavations. Where soil is too soft to support indicated bearing pressures, over-excavate a minimum of one foot.

3.03 PLACEMENT OF FILL AND BACKFILL

A. Place fill in uniformly thick layers not exceeding eight (8) inches of loose measurement.

B. Compact to a density of at least 95% of the Standard Proctor dry density (ASTM D-698) at or within 2% of optimum moisture content.

3.04 SURFACE DRAINAGE

Keep excavations free of water.

DIVISION 3 - CONCRETE

SECTION 03100 - CONCRETE FORM WORK

PART 1.00 - GENERAL

1.01 SCOPE OF WORK

Furnish all labor, materials, services, equipment and appliances required for concrete form work indicated on the drawings and specified herein.

1.02 REFERENCE STANDARDS

A. Material Standards

American Society for Testing Materials (ASTM)

B. Concrete Standards

American Concrete Institute (ACI)

PART 2.00 - PRODUCTS

2.01 FORM MATERIALS

A. Wood

No. 2, or better, southern pine dressed lumber or Douglas fir, non-stress grades.

B. Plywood

DFPA Plyform, Exterior B-B, edge sealed.

2.02 FORM ACCESSORIES

Gateway, Superior or equal, catalog items selected for form loadings encountered.

PART 3.00 - EXECUTION

3.01 FORM CONSTRUCTION

A. General

Design, construct and maintain forms so as to insure that after removal finished concrete members will have true surfaces, be free of waves or bulges, and conform accurately to indicated shapes, dimensions, lines and positions of concrete members shown. Forms shall be readily removable without impact, shock or damage to concrete. Clean all form surfaces before each use.

B. Deflection and Leakage

Space walers, ties, bracing, etc. to prevent form deflection. Form joints shall be sufficiently tight to prevent leakage of grout and cement paste during placing.

3.02 CURING CONCRETE WITHIN FORMS

If certain surfaces are to be cured within forms, curing shall be accomplished by keeping the forms continuously wet. If forms are removed before end of curing period, curing must be continued as described in CAST-IN-PLACE CONCRETE.

3.03 REMOVAL OF FORMS

A. Timing

Forms shall not be removed until concrete has adequately hardened and in any event not earlier than two (2) days after concrete is placed.

B. Method

Form removal shall be accomplished as a hand operation, with due care to avoid damage to any finished concrete work or any reinforcing passing through the forms being removed.

3.04 CLEAN-UP

A. Upon completion of the work of this section, remove all debris relating to the conduct of this portion of the work from the premises.

DIVISION 3 - CONCRETE

SECTION 03300 - CAST-IN-PLACE CONCRETE

PART 1.00 - GENERAL

1.01 SCOPE OF WORK

A. Furnish all labor, materials, services, equipment and appliances required for Cast-In-Place Concrete work indicated on the drawings and specified herein.

1.02 INTENT

A. All concrete shall be ready-mixed, or transit-mixed, obtained from a plant, the operation of which conforms to requirements of ASTM C94. Job-mixed concrete shall not be used except where particularly authorized by Project Director in small quantities such as may be needed to affect patching and repairs.

1.03 REFERENCE STANDARDS

A. Materials Standards

American Society for Testing Materials (ASTM)

B. Concrete Standards

American Concrete Institute (ACI)

1.04 SHOP DRAWINGS AND MILL TEST REPORTS

A. Submit shop drawings of concrete reinforcement to Project Director for approval prior to the start of fabrication. Shop drawings shall consist of reinforcing lists and placing drawings. Reinforcing lists shall cover all reinforcing and accessories complete with quantities, sizes, bends, dimensions and notes required for fabrication and placement. Placing drawings shall include placing plans, elevations, details and sequence of placement as required for proper location in the structure. Insofar as possible, member marks on shop drawings shall be the same as on the structural drawings. Certified copies of mill test reports evidencing compliance with these specifications shall be submitted to the Project Director if requested.

1.05 INSPECTION AND TESTING

A. Independent Testing Laboratory

The Contractor shall employ and pay for, as part of the contract price, the services of a Project Director approved independent testing laboratory to perform all the following:

1. Concrete Mix Design

Testing laboratory shall determine design mix based on compressive strengths of concrete shown on the structural drawings, or specified herein. For design mix tests use aggregates, cement additive where specified, and water to be actually used in mixing concrete.

2. Cylinder Tests

Test cylinders shall be taken, cured and tested by the testing laboratory for each different class of concrete poured in any one day. Cylinders shall be taken in accordance with ASTM C31, and cured and tested in accordance with ASTM C39. One set of three cylinders is required for each 50 cubic yards of concrete or less, placed in any one day. One cylinder shall be tested at 7 days, one cylinder shall be tested at 28 days, and one cylinder shall be held as a spare from each set of three cylinders as specified above. Testing laboratory shall furnish three copies of the test reports to the Project Director indicating results of the cylinder test.

B. Contractor Tests

1. Slump Tests

Slump tests shall be taken by the testing laboratory when cylinders are taken, and shall show maximum slump 5" and minimum slump 3".

2. Air Entrainment

Air content by volume: 3 to 5% based on measurements made in concrete mixtures at point of discharge at job site at time slump tests are made. Air content by volume: determined in accordance with ASTM C231.

C. Special Testing

If quality of concrete is questioned, for any reason whatsoever, Project Director may direct that core tests conform to ASTM C42. The cost of such tests to be borne by the Contractor.

D. Time Limit for Use of Ready-Mixed Concrete

Concrete not placed within specified maximum time interval, after adding mixing water, shall be rejected and removed, or wasted where directed.

Temperature, Mix or Air	Maximum Time Interval
Up to 75°F	90 minutes
75°F to 89°F	60 minutes
Over 90°F	45 minutes

PART 2.00 - PRODUCTS

2.01 CONCRETE MATERIALS

A. Portland Cement

ASTM C150, Type I for general purpose concrete which includes concrete exposed to view outside building, and concrete for use in piers.

B. Aggregates

1. Fine Aggregates

ASTM C33, washed sand.

2. Coarse Aggregates

ASTM C33

3. Water

Fresh, potable tap water.

2.02 REINFORCING STEEL

A. Bars

ASTM A615, grade 40 or as called out in notes on the drawings.

B. Wire Fabric

ASTM A185, welded steel wire fabric as noted on drawings.

C. Accessories

AC315, chairs, stools, spacers, etc., Superior Manufacturing Company, 1054 Florida Street, Memphis, TN 38106, or equal.

2.03 FLOOR FINISHING MATERIALS

A. Floor Sealing Compound

Master Builders "Master Seal" or approved equal.

2.04 CURING MATERIALS

A. Curing Compound

Resin-base, transparent, not incompatible with On-Grade Flooring Adhesives, equal to CLEARSEAL made by A. C. Horn Products Co.

B. Plastic Sheet Curing Membrane

ZENDEL-FILM or VISQUEEN, plastic sheeting 4-mil thick, with joint sealing tapes furnished by membrane manufacturer.

C. Burlap for Moist Curing

Federal Specification CCC-C 467, standard grade burlap.

PART 3.00 - EXECUTION

3.01 PLACING REINFORCING

A. General

Place reinforcing bars accurately and securely saddle-tied at intersection with #16 ga. black, annealed wire. Support bars rigidly in place with metal chairs, spacers or other supports permitted by ACI-315. Number of inches of concrete protection at reinforcement shall be in accordance with 1977 ACI Building Code unless otherwise noted on drawings.

B. Shop Drawings and Splicing

Place reinforcing bars and wire mesh in accordance with approved shop drawings, bending and placing diagrams, and schedules shown on structural drawings. When splicing welded wire fabric, lap in both directions shall be not less than distance between wires, and the two transverse wires for any splice shall be securely wire-tied. Splice bars as noted on drawings.

C. Inspection Before Coverings

Project Director will inspect and approve inserts and reinforcing in place before concrete is poured, and no work of this kind shall be concealed by poured concrete until this inspection has taken place and the Project Director has given permission to proceed with the placing of concrete.

3.02 PLACING CONCRETE

A. General

Deposit concrete as nearly as practical to final position to avoid segregation due to rehandling or flowing. Deposit concrete at such rate that it is at all times plastic and flows readily into spaces between inserts and reinforcing and completely fills forms. Temperature of fluid concrete at time of placing shall be between 50°F and 90°F.

B. Discharge and Layering

Stacking or piling of concrete in one place and then removing it any appreciable distance into position with hoes, rakes, shovels, and/or compactors is prohibited. Placing shall be essentially a pouring procedure and concrete which has begun to set before being poured will be rejected.

C. Anchor Bolts

Set anchor bolts, furnished by and/or for the work of other trades, in freshly placed concrete. Set bolts plumb and true and in complete accord with approved anchor bolt plan, shop drawings and as required by the drawings and other sections of these specifications. Finished placement of bolts shall be sufficiently accurate to receive solar collector pylons and other construction.

3.03 FINISHING CONCRETE

A. Slabs

Smooth finish floor slab of pumphouse shall be finished (unless otherwise noted on the drawings) as follows:

1. Tamping

   While placing concrete, tamp with special tools to force coarse aggregate away from surface, then screed with straight edges to bring surface to finish level shown on drawings.

2. Floating

   Wood float to true plane with no coarse aggregate showing while concrete is still green but sufficiently hard to bear a man's weight without imprint. Plane shall be level or slope to drain as required. Use sufficient pressure while wood floating to bring moisture to surface.

3. Troweling

Steel trowel not less than two passes. Begin troweling with power trowel as soon as little or no cement sticks to blades. Dusting with dry cement or aggregate to absorb moisture or to stiffen mix will not be permitted. Hand trowel third pass, or final steel troweling, to remove slight imperfections and produce smooth impervious face. Continue hand troweling until ringing sound is heard as trowel burnishes surface.

4. Tolerance

Finished slabs to receive applied finished floor coverings or to be sealed shall be level with tolerance of 1/8" in ten feet, when tested with ten foot straight edge at 3 ft. intervals in both directions.

5. Depressions

Depressed slabs, if indicated on the drawings, to receive waterproofing and topping, fill or mortar beds for tile application, etc., need to be finished only through wood floating.

B. Surfaces Other Than Slabs

1. Patching and Repairs

Remove honeycomb voids, cracks, and irregularities. Where repair is required, cut back defects not less than 1/2" with square edges, brush out, drench with water and fill with concrete of same mix from which coarse aggregate is removed. When cut-outs have been filled, trowel surface smooth, remove excess grout and after set, grind slightly to uniform color and appearance using neat Portland Cement applied with a power grinder wheel.

2. Collector Footings

Tops shall be screeded and floated to a level surface.

3.04 CURING CONCRETE

A. Requirements

Cure concrete not less than 7 days by protecting it against moisture loss, rapid temperature change, mechanical injury, and injury from weather, rain, or flowing water. Concrete may be cured by any one of the following methods, or combination thereof as approved by the Project Director.

1. Compound

Curing compound may be applied in accordance with manufacturer's instructions. Compound shall be of such formulation that it will remain intact as moisture seal for not less than twenty-eight (28 days. Application on horizontal surfaces: one coat at rate of 150 sf/gal. On slabs protect the curing-compound-formed membrane with 1" of sand, or other approved means.

2. Plastic Sheet

Impervious-sheet curing may be used, consisting of covering surface to be cured with 4-mil thick plastic membrane, edges lapped 4" or more and sealed with tape recommended for the purpose by the membrane manufacturer.

3. Moisture

Moist-curing by keeping concrete surfaces continuously wet or moist during the entire curing period. This may be accomplished by covering the surfaces with wet sand, or with wet burlap, or concrete curing mats, which are kept continuously wet or moist by sprinkling. The means to be employed to apply moisture during moist curing shall be approved by the Project Director.

3.05 SEALING CONCRETE

The pumping house floor shall have sealer applied to the slab in accord with the manufacturer's instructions. Apply sealer during later stages of building construction.

3.06 CLEANING CONCRETE

At completion of concrete work, all concrete surfaces exposed to view shall be washed down with clean water using fiber bristle brushes and then dried to prevent stains forming.

3.07 CLEAN-UP

Upon completion of the work of this section, remove all debris relating to the conduct of this portion of the work from the premises.

SECTION 05500 - METAL FABRICATIONS

PART 1.00 - GENERAL

1.01 SCOPE OF WORK

Furnish all labor, materials, services, equipment and appliances required for metal fabrication work indicated on the drawings and specified herein.

1.02 WORK INCLUDED, BUT NOT INCLUSIVE

A. Miscellaneous steel framing as indicated on the drawings for the support of the work of other trades.

B. Steel pipe supports.

C. Steel anchor bolts.

D. Steel drilled-in anchors.

E. Steel collector field warning signs.

F. Templates as required by other trades.

G. Shop painting and field touch-up painting.

1.03 DESIGN AND FABRICATION

Fabricator shall be responsible for design of connections not specifically shown on the drawings and for member dimensions and fit.

1.04 REFERENCE PUBLICATIONS AND STANDARDS

A. American Institute of Steel Construction (ASCI)

B. American Welding Society (AWS)

1. "Structural Welding Code" AWS D1.1

2. "Standard Welding Symbols" AWS A2.0

C. American Society for Testing Materials (ASTM)

D. Other

All applicable Federal, state and local ordinances and directions.

1.05 SHOP DRAWINGS

Submit shop drawings to Project Director for approval prior to the start of fabrication. Shop drawings shall include complete materials lists and erection, placing and detail drawings of all items, checked before submittal.

1.06 COORDINATION

Contractor shall be responsible for dimensions, detailing, fabrication, fitting and alignment of the work of this section.

PART 2.00 - PRODUCTS

2.01 STEEL

A. Shapes and plates, ASTM A36.

B. Pipe, ASTM A53, Grade B.

C. Anchor Bolts, ASTM A36.

D. Bolts and Nuts

ASTM designation A307, regular hexagon-bolt type.

E. Washers

American Standard B27.2, Type B.

2.02 WELDING ELECTRODES

A. Series E70.

2.03 GALVANIZING (WHERE REQUIRED ON THE DRAWINGS)

A. ASTM A123, A163, or A386, as applicable.

B. All steel items exposed to the weather shall be galvanized.

2.04 SHOP PAINT

A. Concealed Use

Rust inhibiting primer which will not support combustion.

B. Exposed Steel

Primer compatible with finish paint.

PART 3.00 - EXECUTION

3.01 GENERAL

Provide all anchors, supports, braces, connections, sleeves, inserts, bolts, etc. required in conjunction with items of work included under this section and under other trades where necessary for securing work in place. Sizes, kinds and spacing of bolts and/or anchors not indicated or specified shall be as directed.

3.02 SCHEDULING

Deliver bolts, embedded items, etc. along with setting drawings to the job site in ample time for installation in the work of other trades.

3.03 HANDLING AND STORAGE

Perform in a manner to prevent bending, warping, twisting or other damage.

3.04 WORKMANSHIP

Use only skilled and experienced personnel.

3.05 FABRICATION

A. General

Shear and punch parts without leaving ragged or torn edges. Surfaces and edges to be welded shall be smooth, clean, uniform and free from loose scale, fins, tears, cracks and other defects. Provide holes or other provisions for attachment of other materials as required. Fabricate and assemble parts in shop to the greatest extent possible. Assembled pieces shall be taken apart, if necessary, for the removal of any burrs and shavings. Parts not completely assembled in the shop shall be secured by bolts, insofar as practicable, to prevent damage in shipment and handling.

B. Measurements

Verify all measurements and make all field measurements before fabrication.

3.06 INSTALLATION

A. Field Assembly

Properly locate and build into connecting work. Bolts and anchors shall be pre-set to locate anchors and anchor bolts accurately. Align and adjust all parts accurately before fastening.

3.07 CONNECTIONS

A. Welding

Insofar as is possible, weld all connections unless shown otherwise on the drawings. Defective or unsound welds or base metal shall be corrected as provided for under AWS D1.0 at no additional cost to the owner. Welding to or on structural steel shall be in accord with the Code for Welding in Building Construction of the American Welding Society.

B. Miscellaneous

Fastenings shall be concealed where practicable. Thickness of metal and details of assembly and supports shall give ample strength and stiffness. Exposed fastenings shall be compatible materials, shall generally match in color and finish, and shall harmonize with the material to which fastenings are applied. Materials and parts necessary to complete each item, even though such work is not definitely shown or specified., shall be included. Where dissimilar metals are in contact, the surfaces shall be protected with a coat of bituminous paint to prevent galvanic or corrosive action.

3.08 SHOP PAINTING

A. Shop paint all items included in this section. Thoroughly clean steel after fabrication and before leaving the shop, of all loose mill scale, rust, oil, grease, and other foreign matter. Apply one shop coat of primer to all surfaces except those to be field welded.

3.09 FIELD PAINTING

A. After installation, field connections, including welds, bolts, and all abraded places on the shop paint, shall be painted with same material specified for shop coat.

3.10 CLEAN-UP

A. Upon completion of the work of this section, remove all debris relating to the conduct of this portion of the work from the premises.

SECTION 13121 - PREFABRICATED METAL BUILDING FOR PUMP HOUSE

PART 1.00 - GENERAL

1.01 SCOPE OF WORK

This section covers the furnishing and installation of prefabricated metal building complete, including:

1. Main frames and other primary load carrying members
2. Secondary framing
3. Roofing
4. Siding
5. Fasteners
6. Closures
7. Sealants
8. Flashing and trim
9. Insulation
10. Doors
11. Windows
12. Shop drawings
13. Protection of the work of other trades
14. Clean-up

1.02 BUILDING DESCRIPTION

The building shall be 20'0" x 22'0" in plan with a 10'0" eave height and a roof pitch of 1:12. It shall have one 8'0" x 9'0" roll-up door and one 8'0" x 12'0" room with 2" insulated panels for walls and ceilings. Fixed wall louvers and a gravity-fed roof ventilator shall be provided as indicated.

1.03 BUILDING MANUFACTURER

A. The building manufacturer shall be a member of the American Institute of Steel Construction (AISC) and the Metal Building Manufacturers Association (MBMA).

B. The metal building shall be manufactured and erected in conformance with the latest edition of the "CODE OF STANDARD PRACTICES" of the MBMA.

1.04 STRUCTURAL DESIGN

A. General

The basic design criteria, except as modified herein, shall be based on the applicable sections of the following specifications:

1. "SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDING," (AISC).

2. "SPECIFICATION FOR THE DESIGN OF COLD-FORMED STEEL STRUCTURAL MEMBERS," American Iron and Steel Institute (AISI).

3. "RECOMMENDED DESIGN PRACTICES MANUAL," (MBMA).

B. Framing Systems

1. The structural analysis of the primary framing shall be based on linear elastic behavior and shall accurately reflect the final configuration of the structure and all tributary design loadings. Main framing members shall be rigid frame type.

2. The wall girts and roof purlins may be designed as a simple, cantilevered or continuous elastic system. The reactions produced by the selected system shall be used for the design of the primary framing.

C. Design Loads

Include roof live load, wind load building dead load, and auxilliary loads.

1. Roof Live Load: Shall be considered as a uniformly distributed loading acting vertically on the horizontal projection of the roof and shall be 30 p.s.f. minimum.

2. Roof Dead Load: Shall be considered as a uniformly distributed loading acting vertically on the horizontal projection of the roof and shall be equal to the weight of the metal building components.

3. Wind Load: Shall be considered as a uniformly distributed loading acting in accordance with the shape coefficients specified by the "RECOMMENDED DESIGN PRACTICES MANUAL" of the MBMA, and shall be a minimum of 20 MPH.

4. Auxiliary Design Loads: Auxiliary Design Loads are those loads, other than the live, dead and wind loads, which the building must safely withstand, such as ceilings and other construction, electrical systems, mechanical systems, plumbing systems, etc.

5. Combination of Loads: The combination of design loads shall be Roof Life Load plus Building Dead Load, or Wind Load plus Building Dead Load. The Roof Live Load and Wind Load shall not be combined. All specified Auxiliary Loads shall be combined with other design loads in accordance with the "RECOMMENDED DESIGN PRACTICES MANUAL" of the MBMA.

D. Deflection Limitations

1. Structural Framing: The primary and secondary framing members shall be so proportioned that their maximum calculated Roof Live Load deflection does not exceed 1/180 of the span.

2. Covering: The steel roof covering shall be so proportioned that the maximum calculated deflection under the specified design loadings does not exceed 1/240 of the span.

E. Anchorage: The building anchor bolts shall be designed to resist the column forces produced by the specified design loadings. The quantity, size and location of the anchor bolts shall be specified by the building manufacturer.

1.05 CERTIFICATION

A. Prior to the awarding of the contract, the building manufacturer shall, on request, submit a letter certifying that the proposed building conforms to the specified design loads.

B. Subsequent to the awarding of the contract, the building manufacturer shall submit design calculations sealed by a Professional Engineer.

1.06 SHOP DRAWINGS

A. The building manufacturer shall furnish an anchor bolt setting plan showing the size and location of the building anchor bolts, and the column forces showing magnitude and direction.

B. The building manufacturer shall furnish shop drawings identifying all materials in sufficient detail to indicate the proper assembly and installation of the metal building components.

PART 2.00 - PRODUCTS

2.01 FRAMING AND COVERING, GENERAL

A. Primary Structural Framing: The primary structural framing includes the main frames and other primary load carrying members and their fasteners.

B. Secondary Structural Framing: The secondary framing includes the wall girts, roof purlins, endwall columns, other miscellaneous secondary framing members and their fasteners.

C. Roof and Wall Covering: The roof and wall covering includes the exterior metal panels, panel fasteners, sealant, trim and closures, and accessories, as indicated on the drawings and specified herein.

2.02 STRUCTURAL FRAMING

A. All hot rolled structural shapes shall have a minimum yield point of 36,000 psi in conformance with ASTM A36. All hot rolled bar and plate shall conform to the requirements of ASTM A572, grade 45. All hot rolled flat sheet shall conform to the requirements of ASTM A570, grade E except that the minimum yield point shall be 45,000 psi. All cold formed steel structural members shall have a minimum yield point of 40,000 or 50,000 psi in conformance with the AISI specifications.

B. Minimum thickness of framing members shall be:

Flanges of Main Frames	3/16 inch
Webs of Main Frames	12 gauge
Structural Tubing	12 gauge
Secondary Framing Members	16 gauge

C. All framing members shall be manufactured for bolted field assembly. Workmanship will be such that all members are straight and dimensionally accurate.

D. All shop connections shall be welded in conformance with the "Code for Welding in Building Construction" A.W.S. D1.0-69. The flange-to-web welds shall be one side continuous submerged arc fillet welds. Other welds shall be by manual shielded metal arc, gas metal arc, or fluxcored semi-automatic.

E. All steel components, not protected by corrosive resistant coatings, shall be given one prime coat of iron oxide-zinc chromate primer formulated to equal or exceed the performance requirements of Federal Specifications TT-P-636C.

F. Primary Structural Framing

1. Main Frames - Rigid Frame Type

a. The main frames shall be welded "I" shapes with either constant or variable depth fabricated from hot rolled steel bar, sheet, or plate, and/or hot rolled structural shapes.

b. The main frames shall be laterally braced by angles bolted to the inside flange of the frame and to the web of the girt or purlin.

c. The main frames shall be field spliced with butt moment bolted connections. Joints required to resist shear between their connected parts shall be bearing-type connections. Fasteners shall be high strength structural bolts conforming to ASTM A325. Installation of fasteners shall be by the "Turn-of-nut" method in accordance with the "SPECIFICATIONS FOR STRUCTURAL JOINTS" of the Research Council on Riveted and Bolted Structural Joints.

G. Secondary Structural Framing

1. Wall girts: Shall be a cold formed channel 9 inches deep with stiffened flanges 3 inches wide.

2. Roof purlins shall be a cold formed channel 9 inches or 11 inches (as indicated) deep with stiffened flanges 3 inches wide.

3. Supporting Lugs: Shall be used to connect the purlins and girts to the primary framing. The lugs shall be designed to restrain the cold formed sections from tipping or warping at their supports. Each purlin and girt shall be connected to each lug by a minimum of two fasteners.

4. Standard fasteners for all secondary framing: Shall be 1/2 in. diameter bolts conforming to ASTM A307 or ASTM A490 as applicable.

2.03 ROOF AND WALL COVERING (Metal Roofing and Metal Siding)

A. Materials for Metal Roofing and Metal Siding shall be one of the following:

1. Galvanized Steel, 26 U. S. Standard gauge galvanized high strength steel with minimum yield point 55,000 psi in conformance with the AISI specifications. The zinc coating shall be 1.25 ounces per square feet in conformance with ASTM A525.

2. Galvanized steel 24 U. S. Standard gauge high strength steel with a minimum yield point 36,000 psi in conformance with the AISI specifications. The zinc coating shall be 1.25 ounces per square foot in conformance with ASTM A525.

3. Galvanized steel, 26 U. S. Standard gauge high strength steel with a minimum yield point 80,000 psi in conformance with ASTM A525.

B. Roofing and siding panels shall be factory-finished in a baked enamel finish.

C. Panel Configuration

1. Roof Panels: Shall have 1/14 inch deep major ribs spaced at 10 inches on centers with two 3/16 inch deep intermediate ribs equally spaced between the major ribs. The inner rib of each sidelap shall be a full major rib to provide bearing support of the lap, and shall have continuous anti-capillary groove. Each panel shall provide 30 inch net coverage. Panels shall be similar to "multi-rib" roof panel as manufactured by Mesco Metal Buildings Corporation, Grapevine, Texas.

2. Wall Panel: Shall have 1-1/4 inch deep major ribs spaced at 10 inches on centers. Three additional recessed stiffening flutes shall be equally spaced between major ribs. Each panel shall provide 30 inch net coverage. Panels shall be similar to "Boldline" panel as manufactured by Mesco Metal Buildings Corporation, Grapevine, Texas.

D. Flashing and Trim

1. Flashing, metal closures and trim shall conform to ASTM Specification A525, 1.25 ounce zinc and shall be U. S. Standard 26 gauge, galvanized steel.

2. Fascia and gable trim: Shall be sculptured, extending a minimum of five inches beyond the wall covering.

3. Gutters: Shall be sculptured configuration matching fascia and the gable trim. Shall be externally suspended providing overflow outside the building. All gutter joints shall be sealed with a polymer sealant.

E. Sealant and Closure

1. Sealant: Shall conform to MIL-C-18969, be non-shrinking, non-hardening and shall have a service temperature range of 40^{o} to 350^{o}F.

2. Closed cell pre-formed rubber closure matching the configuration of the covering shall be provided in conformance with the manufacturers' standard practice and where indicated on the drawings.

F. Fasteners

1. Self-tapping sheet metal screws: Shall be #14, Type AS threads with 5/8 inch diameter domed metal washer and neoprene sealing washer. Screws and dome washers shall be stainless steel.

2. Self-drilling sheet metal screw: Shall be #12 Type A thread with 5/8 inch diameter domed metal washer and a neoprene sealing washer. Hexhead screws and dome washers shall be stainless steel.

3. (Optional) wall fasteners: Shall be #12 self-drilling Type A threads with special nylon star shaped head color matched to wall panels.

4. Exposed trim fasteners: Shall be stainless steel 1/8 inch diameter dome head blind rivets.

2.04 DOORS

A. Exterior swinging door shall be 1-3/4 inches thick, hollow metal door. Steel bucks shall be manufacturers' standard.

1. Butts - 1½ pair per door, 4½ x 4½.

2. Lockset - Keyed outside, manufacturers' standard.

B. Overhead door, metal - manufacturers' standard with guides, spring balances and interior locking device.

2.05 INTERIOR CONTROL ROOM

A. Partitions around control room shall be of material similar to the exterior wall system of the main building. Panels shall be insulated not less than 2" thick. Panels shall be finished on both sides. Height of partitions shall be 8 feet.

B. Ceiling shall be acoustic tile, suspended type. Acoustical panels shall conform to Federal specifications SS-S-118a, Class 25, Type III. Size shall be 24" x 48" for lay-in installation.

1. Main tee shall be double web bulb section not less than 0.20-inch cold rolled steel. Tee height shall be not less than 1½ inches with bottom flange of 15/16 inch.

2. Cross tees shall be double web bulb section of not less than 0.018 inch cold rolled steel.

2.06 INTENT

A. It is the intent of these specifications that the Standard products of prefabricated metal buildings manufacturers are acceptable if the above design criteria is met by all components. Slight variations in dimensions and configurations of girts, siding, roofing, etc. shall be acceptable for the work of this section.

PART 3.00 - EXECUTION

3.01 STRUCTURAL FRAME

A. Erection of the metal building and the installation of accessories specified herein shall conform to the "CODE OF STANDARD PRACTICES" of the MBMA.

B. Building erector shall be regularly engaged in the erection of metal buildings and shall perform all work in a skillful and workmanlike manner.

3.02 METAL ROOFING AND SIDING

A. Roof panels shall be continuous from ridge to eave. Where end laps are required, they shall be a minimum of 7 inches and shall occur only at and be fast ened through the secondary framing member.

B. Roof panels shall sidelap one major rib. The inner panel at the sidelap shall have a full major rib to provide bearing support of the lap.

C. End wall panels shall be one piece from 3-5/8 inches below the column base plate to roof line. Where endlaps are required they shall occur only at and be fastened through the secondary framing member. Side wall panels shall be one piece from 3-5/8 inches below the column base plate to 9'0" above column base plate.

D. The quantity and location of panel fasteners shall be in conformance with the manufacturer's drawings.

3.03 FLASHING AND TRIM

Shall be furnished at rake corners, framed openings and where required to provide weather tightness and finished appearance.

3.04 SEALANT

All panel end laps shall be sealed with sealant.

3.05 PROTECTION OF WORK OF OTHER TRADES

Protection of work of other trades shall be the responsibility of the prefabricated metal building contractor.

3.06 CLEAN-UP

Clean up all debris caused by the work of this section, keeping the premises clean and neat at all times.

DIVISION 15 - MECHANICAL

SECTION 15400 - MECHANICAL

PART 1.00 - GENERAL

1.01 DESCRIPTION

A. Includes furnishing all materials, equipment, tools, labor, supervision and performing all operations in connection with mechanical work as indicated on the drawings, specified herein, or as otherwise required to complete the work. The GENERAL CONDITIONS are a part of this section.

B. The work includes, but is not limited to:

1. Solar collectors
2. Heat transfer fluid piping system
3. Steam and feedwater piping system
4. Nitrogen piping system
5. Feedwater pump
6. Solar collector loop circulator
7. Feedwater chemical treatment system
8. Steam generator and feedwater preheater
9. Steam generator blowdown system
10. Expansion tank
11. Controls
12. Gate valves, balancing valves, check valves, strainers, flow meters, and temperature and pressure sensor wells.
13. Insulation of piping and equipment
14. Weather instrumentation
15. Closed circuit television equipment
16. Miscellaneous hangers, supports, anchors, sleeves, escutcheons and other auxiliary equipment for all systems under this section
17. Flushing, cleaning, adjusting and testing
18. Shop and record drawings

C. Related work described elsewhere

1. Concrete work----------------Division 3
2. Metal work-------------------Division 5
3. Special Construction---------Division 13 (Prefab. pump house)
4. Electrical work--------------Division 16

D. Coordination with other work

It shall be the responsibility of the Contractor for the work of this section to coordinate his work with the contractors performing related work under other sections of these specifications.

1.02 CODES AND STANDARDS

All work and materials shall conform to the latest rules and regulations of all applicable state and local codes, laws and ordinances, including OSHA, Uniform Building Code, ASME boiler and pressure vessel codes and ANSI standards for piping.

1.03 WORKMANSHIP

Workmanship shall be of the best standard practice of the trade, installed by journeyman mechanics. If portions of work require mechanics with special registration or certification, such registration or certification shall be delivered to the Project Director prior to the start of such work.

1.04 SUPERVISION

Furnish the services of a superintendent experienced in the work of this section who shall be constantly in charge of the erection of the work, together with all necessary journeymen, helpers and laborers required to properly unload, erect, connect, adjust, start, and operate and test the work involved.

1.05 CLEANING SYSTEMS AND PREMISES

A. The entire premises shall be cleaned of unused materials, rubbish, debris, grease spots, etc., caused by the work of this section, to the entire satisfaction of the Project Director.

B. All piping systems shall be thoroughly flushed in such a manner that all dirt, scale, foreign substances, etc. are removed.

1.06 SUBMITTALS

A. Shop Drawings

Before starting of work, the Contractor shall submit to the Project Director for approval dimensioned shop and installation drawings and itemized equipment brochures, complete in all details, for all items which he proposes to install.

B. The submittal of items to be furnished includes but shall not necessarily be limited to, the following:

1. Equipment------------------------------all types
2. Insulation-----------------------------all types
3. Valves, accessories and devices--------all types
4. Controls-------------------------------all types
5. Hangers and supports-------------------all types
6. Pipe and fittings----------------------all types

C. In the event that the Contractor installs equipment or materials in a manner not acceptable to the Project Director or without having first submitted shop drawings for approval, any changes which are required shall be made at the Contractor's expense.

D. As-Built Record Drawings

Submit As-Built Record Drawings in accordance with the General Conditions.

1.07 PRODUCT HANDLING

A. Protection

Use all means necessary to protect the work and materials of this section before, during, and after installation and to protect the work and materials of all other trades.

B. Replacements

In the event of damage, immediately make all repairs and replacements necessary to the approval of the Project Director and at no additional cost to the Owner.

1.08 REGULATIONS, PERMITS, FEES AND INSPECTIONS

The piping and equipment shall be installed, tested, and approved satisfactory in accordance with requirements of all legally constituted authorities having jurisdiction. The Contractor shall secure and pay for all permits, and arrange for all inspections, as pertains to this section of the specifications, as part of this contract.

1.09 GUARANTEE

In addition to other guarantees required and as a condition precedent to the issuing of the final certificate for completion payment, the Contractor shall deliver to the Owner a written guarantee that all materials, apparatus and equipment furnished and installed hereunder shall be new and free from all defects. Should any trouble develop within one (1) year from date of acceptance of the project, due to faulty or inferior material and/or workmanship, the trouble shall be corrected by the Contractor without expense to the Owner. The Contractor shall guarantee all apparatus and equipment to deliver the capacities as scheduled and/or specified.

PART 2.00 - PRODUCTS

2.01 SOLAR COLLECTORS

The solar collectors shall include single-axis tracking, parabolic-trough, line-focusing reflectors; receiver assemblies; support pylons and hydraulic tracking equipment. Size, capacity and spatial arrangement shall be as shown on the drawings. The collectors shall have a maximum operating temperature and pressure of 650°F and 250 psi respectively. Instantaneous collector efficiency shall be a minimum of 62% based on an average fluid temperature of 410°F ambient air temperature of 80°F and insolation of 300 Btu/ft^2 Hr.

The solar collectors shall be manufactured by Solar Kinetics, Inc. (Model T-700) or approved equal.

A. Reflectors

Reflectors shall be constructed of cast aluminum bulkheads, extruded aluminum edge formers and a sheet aluminum skin. The reflecting surface shall be a metallized acrylic film with an average specular reflectivity of .84.

The reflector shall have a parabolic trough contour with a rim angle of 90° and a focal length of 1.85 ft.

B. Receiver Assemblies

The receiver assembly shall consist of a 1.5 in. I.D. 0.065 in. wall, black chrome-plated steel tube, enclosed by a 1.75 in. I.D. pyrex tube. The steel tube absorptivity and emissivity at 500°F shall be .95 and .18 respectively.

Inlet and outlet connections to the receiver assemblies shall be insulated stainless steel flex hoses that allow a 270° collector rotation with unrestricted flow.

C. Support Pylons

The support pylons shall be hot dipped galvanized steel with an outer coating of Devcon Z or equal zinc-rich paint.

D. Hydraulic Tracking Equipment

The tracking system for the collectors shall be hydraulically driven with two light sensitive transistors and a shadow bar providing the control signal.

A tracking system shall be provided for each collector row and will be located at the middle support pylon in each row.

A back-up battery system shall be provided for emergency stowing in the event of AC line power loss.

Automatic collector stowing shall occur under the following conditions:

- a coolant temperature greater than 600°F
- wind velocities greater than 30 MPH
- loss of coolant flow in the receiver
- insolation less than 95 Btu/ft^2 Hr.

2.02 PIPE

A. Heat Transfer Fluid Piping

1. Pipe: 1-1/2" and smaller: seamless carbon steel tube, plain end, drawn to Schedule 40 nominal pipe size; ASTM A-106, Grade B.
2. Pipe 2" and larger: Schedule 40 seamless carbon steel, plain end, ASTM A-53, Type S, Grade B.
3. Fittings all sizes: Standard weight forged carbon steel welding outlet, ASTM A-105 material.
4. Flanges all sizes: USAS 300 lb. forged steel welding neck, 1/16" raised face, Schedule 40 bore, ASTM A-181 material, USAS B16.5 dimensions.
5. Welding electrodes all: coated, ASTM A-233, E60 series.
6. Gaskets all sizes: .175" thick, 300 lb. Type 304 stainless steel and asbestos spiral wound, API STD 601.
7. Bolting all sizes: Heavy hex nuts, ASTM A-194, grade 2H, with alloy steel continuous threaded studs, ASTM A-193, Grade B7.

B. Steam and Feedwater Piping

1. Pipe all sizes: Standard weight black steel, plain end, ASTM A-53 or A-120, Grade A or B.
2. Fittings: 2" and smaller: 150 lb. black malleable iron screwed fittings, ASA B16.3.

3. Fittings: 2-1/2" and larger: Standard weight seamless welding fittings, ASA B16.9 and B16.25.

4. Unions: 2" and smaller: 250 lb. malleable iron, ground iron to bronze seat. 2-1/2" and larger: use flanges.

5. Flanges: 2-1/2" and larger: 150 lb. raised face forged steel, slip-on or weldneck, ASA B16.5, ASTM A-181, Grade I. 1/16" asbestos gasket. 2" and smaller: use unions.

C. Nitrogen Piping

As specified for heat transfer fluid piping.

2.03 VALVES

A. Manufacturer: Crane, Jenkins, Lunkenheimer, Stockham, Walworth or equivalent. Valves for similar service shall be of one manufacturer.

1. Heat Transfer Fluid System

a. Gate valves all sizes: carbon steel, bolted bonnet, OS&Y, 13 Cr solid wedge disc, stellited seats, asbestos core packing, asbestos contained bonnet gasket, 300 lb. buttweld.

b. Globe valves all sizes: carbon steel, bolted bonnet, OS&Y, 13 Cr plug disc stellited seat, asbestos core packing, asbestos or soft iron bonnet gasket, 300 lb. buttweld.

c. Check valves all sizes: carbon steel swing check, bolted cap, 13 Cr swing disc, stellited seat, soft iron or asbestos gasket, 300 lb. buttweld.

d. Two-way bypass valve: self-actuated, direct acting thermostatic temperature regulator. Valve shall be fully open below 300°F and fully closed at 360°F. Manufacturer shall be Hoffman, Jordon Valve or equal.

2. Steam and Feedwater System

a. Gate valves all sizes: Crane No. 431, solid wedge disc, screwed bonnet, bronze gate valves, 150 lb.

b. Check valves all sizes: Crane No. 27 with No. 1 Cranite disc bronze life check valves, 150 lb.

c. Pump Coolant Control Valve: self actuated, reverse acting, thermostatic temperature regulator. Set valve control such that HTF pump temperature does not exceed 200°F. Place sensor as close to HTF pump possible. Manufacturers shall be Hoffman, Jordon Valve or equal.

d. Steam Control Valve: self actuated, direct acting pressure regulator. Valve shall be fully open at psia and fully closed at psia. Maximum operating temperature of at least 430°F. By Hoffman, Jordon Valve or equal.

3. Nitrogen System

a. High-pressure regulator shall be Linde Specialty Gases Model HP-C, 0-750 psig maximum inlet pressure, self-relieving and venting or approved equivalent.

b. High-pressure valve shall be corrosion-resistant Linde Specialty Gases Model SG-5501, Type 316 stainless steel or equivalent.

c. High-pressure check valve shall be Linde Specialty Gases No. CV-5586, 6000 psig, stainless steel or approved equivalent.

B. Installation

Valve stems shall be installed horizontally or pointing down such that stem leakage does not enter insulation.

Valves shall be installed where shown and where required to permit the proper servicing of the equipment being installed. Valves shall be accessible for servicing and fitted with extension handles for ease of operation where so designated or required.

2.04 SLEEVES AND ESCUTCHEONS

A. All pipes passing through concrete walls shall be sleeved, caulked, and made watertight.

B. Sleeves in concrete shall be Schedule 40 black steel pipe finished flush with wall surfaces. Sleeves in partitions shall be 18-gauge galvanized steel, finished flush with wall finish. Sleeves shall be sized for insulation, piping, and one-half-inch clearance.

C. The Contractor shall provide chrome-plated hinged escutcheon plates with locking device where pipes pierce finished furfaces. Plates shall fit outside of pipe insulation.

2.05 HANGERS AND SUPPORTS

A. Pipe roller supports shall consist of a curved carbon steel protection plate welded to the pipe and a roller chair as indicated on the drawings. Manufacturer shall be Grinnell or equal.

B. Fixed pipe supports shall consist of a steel tee welded to the pipe and a rigid block of insulation as indicated on the drawings. Supports may be field fabricated or procured from Grinnell or equal manufacturer.

2.06 INSULATION

A. General

Insulation shall be applied on clean dry surfaces, and after inspection and release for insulation application.

All insulation shall be continuous through wall openings and sleeves.

B. Outdoor Piping Systems

1. Piping

Heavy density fiberglass pipe insulation with a .016" aluminum jacket. Johns-Manville Micro-Lok 650 ML or approved equal. Insulation shall be 2" thick for all piping 2" and smaller and 2-1/2" thick for all piping 2-1/2" and larger.

Insulation shall be applied over clean, dry pipe with all joints butted firmly together. The insulation and jacket shall be held in place by a continuous friction-type joint, providing a positive weatherproof seal lock over the entire length of the jacket. A pre-formed snap-strap, containing a permanently plastic weatherproof sealant, shall be centered on beads at the ends of the jackets and secured over each circumferential joint with a metal band tightened with a banding tool.

2. Expansion Joints

Expansion joints shall be insulated with same material and thickness as adjoining pipe. Aluminum jackets shall be overlapped a minimum of 2" at nearest connection to expansion joint. Snap-straps shall not be used at the overlap to allow free movement of aluminum jacket. See drawing for details.

C. Indoor Piping Systems

Insulation shall be the same as for outdoor piping systems except an all-purpose paper laminate jacket shall replace the aluminum jacket.

D. Flanges and Strainers in Heat Transfer Fluid Loop

Flanges and strainers in the heat transfer fluid loop shall be insulated with cellular glass or an inside metal shielded insulation, and tight fitting caps at the interface with the pipe insulation to eliminate or minimize potential saturation of the insulating system.

Strainers shall be so insulated as to provide easy removal of strainer screens for inspection and cleaning.

E. Equipment

Equipment shall be insulated with 2" Johns-Manville 1000 Series Spin-Glass or approved equal. Insulation shall be applied over pins welded to the vessel. All joints shall be staggered and tightly butted. Where required, wire shall be laced around the welded pins to secure the insulation. Speed clips shall be applied on pins to secure insulation to the vessel. Over the insulation, glass cloth shall be smoothly adhered with CMC 16-300, B., Foster 30-36 or equal.

2.07 HEAT TRANSFER FLUID CIRCULATING PUMPS

A. Ingersol Rand or approved equal, single stage, end suction centerline discharge, centrifugal, designed to ANSI B73.1 Standards for Chemical Process pumps.

1. Size, capacity and operating conditions as scheduled on the drawings.

2. Cast ductile iron casing, high temperature, mechanical seals with water-cooled stuffing box jacket and closed impeller.

3. Shop drawings required, indicating construction, pump curves and dimensions.

4. Pump and motor alignment to be checked according to standards of the Hydraulic Institute after pump has been installed.

2.08 FEEDWATER PUMP

Regenerative turbine, bronze fitted construction, direct connected to NEMA standard drip-proof motor. Capacity as scheduled on drawings. PACO Model No. 40 or approved equal.

2.09 ELECTRIC MOTORS

A. Solar collector loop circulating pump motor: wound rotor type, synchronous speed, 20 Hp., 480V primary control, and 90% of primary voltage for secondary control.

Over-temperature sensors shall be imbedded in motor windings to interrupt the control circuit and protect motor from overheating.

B. Feedwater pump motor: squirrel cage induction type for three-phase, 60-cycle power supply.

C. In general, motors 1/3 hp and smaller shall be capacitor start, induction run type or split-phase type for single-phase 60-cycle power supply.

D. Motors shall have drip-proof enclosures and shall have continuous duty ratings of 40°C.

E. Single-phase motors shall have built-in overload protection. Overload protectors shall be single pole automatic reset type, except where frequent start stop may constitute a hazard, manual reset type shall be used.

F. All motors shall have UL approved terminal boxes. Except where integral with hermetic equipment, all motors, including mountings and shaft sizes, shall be built to NEMA standard dimensions.

2.10 STEAM GENERATOR

A. Steam Generator System

The system shall include a factory prefabricated steam generator unit complete with horizontal steam generator, preheater, superheater, skid, water level control system, and accessories. Size and capacity shall be as shown on the drawings. Manufacturer shall be Patterson-Kelley or approved equal.

1. Steam Generator

Steam generator shall be the horizontal type. The shell shall be constructed of SA 285 copper-bearing steel. Shell shall be fully X-rayed and stress-relieved according to Section VIII-UW-2(c) of ASME Code and ASME-stamped for a design pressure of 200 psig.

2. Tubes

The shell and tube circuit shall be flange grade steel and the tubes shall be 3/4" O.D. #14 BWG, A214 carbon steel on a 1" square pitch. The U-tube bundle shall be supported on heavy steel tracks for ease in maintenance. The tube joints shall be seal welded with Freon and nitrogen and pressure tested at 500 psi using a halide torch or equivalent leak detector.

The tube side shall be designed for a pressure of 400 psi at 450^{o}F and ASME-stamped. The heat transfer fluid bonnet shall be a one-piece solid steel billet with 300-pound ANSI raised face flanged nozzles elbowed into the radial position. The bolting between the bonnet, tube sheet and shell flange shall be independent on each gasket to allow inspection and replacement of either gasket without disturbing the other gasket. The HTF bonnet gasket shall be the spiral wound metal-asbestos type. The shell side gasket shall be compressed asbestos.

3. Preheater

Preheater shall be intricately mounted to the steam generator package and shall be a water-to-water type heat exchanger with the HTF in the tubes and feedwater in the shell. The shell working pressure shall be 200 psig.

4. Superheater

Superheater shall be a tube bundle located inside the steam generator in the vapor section. Specifications for the tube bundle are the same as for the tubes above.

5. Lugs

Steel lifting lugs shall be integral with shell.

6. Skids

Full length steel skid foundation shall support the generator 18 inches above the floor.

B. Water Level Controller

The water level controller shall consist of a combination water column and pump controller with magnetically actuated mercury switches, ASME reflex gauge glass and trycocks. The level controller shall turn the feedwater pump and two-way feedwater control valve on or off simultaneously depending on the water level in the drum.

C. Blowdown System

Blowdown system shall be automatic in operation and capable of maintaining the drum solids level at 90% of the maximum allowable level. The system shall be a Uniloc No. 747 or approved equal.

1. The controller shall be housed in a weatherproofed, corrosion resistant, enclosure built to NEMA 4X standards. It shall contain a visible conductivity meter, operating status lights and a manual blowdown valve position switch.

2. The flow assembly will contain a 1-inch valve, flow limiting orifice and conductivity sensor. It shall be attached to the steam generator's blowdown valve and piped to drain as indicated on the drawings.

D. Accessories for Steam Generator, Factory Installed

1. Relief valve ASME.

2. Two ASME tandem blow-off valves, minimum size 1-1/4".

3. Surface blowdown connection and internal skimming device factory piped to same through drain valve to blowdown line.

4. High water level alarm for overfill protection.

E. Insulation

Fiber-type high density insulation, 2" thick with 22-gauge anodized zinc coated steel jacket, high quality enamel paint.

F. Drawings

Individual scale drawings shall be provided for the steam generator showing all instrumentation, controls, and design details as herewith specified. Schematic or non-scale representation will not be accepted.

G. Insurance certificates of inspection and test shall be provided to the Project Director after completion.

2.11 FEEDWATER CHEMICAL TREATMENT EQUIPMENT

Packaged chemical feed system manufactured by Milton Roy or approved equal.

A. Pump: cast iron construction, 1/4 horsepower adjustable simplex controlled volume, top mounted on storage tank.

B. Injector: Type 304 stainless steel with ball check, inserted in pipe such that nozzle is in middle of flow stream. See drawings for detail. NALCO No. P4610-304SS or approved equal.

2.12 EXPANSION TANK

A. Size and Capacity

As indicated on the drawings

B. Construction

Welded steel code for 50 psig ASME working pressure.

C. Accessories and Fittings

1. Level indicating sight glass
2. Low fluid level sensor
3. Inlet and outlet connections at bottom of tank
4. Fill, pressure relief and nitrogen gas connections at top of tank

D. Provide fabricated steel support stand with tie-down rods, lifting eyebolts and manhole.

E. Insulate tank with 2" of high density fiberglass and finish as per insulation specifications.

F. Shop drawings and manufacturer's reference data required.

2.13 HEAT TRANSFER FLUID

Specific heat of not less than .62 BTU/lb-^{o}F, @ 300^{o}F, a maximum viscosity of 339 cSt @ 0^{o}F, a flash point not lower than $_{o}$ and an autignition temperature not lower than 710^{o}F. The fluid shall be Gulf Oil Company's synfluid white oil 4 cs or approved equivalent.

2.14 EXPANSION JOINTS

A. Bellows type, 321 stainless steel construction. Metal Bellows Corporation Series 1500 or approved equal.

1. Size and location

   As indicated on drawings.

2. Deflection all sizes

   Capable of deflecting 4-1/2 inches.

3. Support and guides

   Provide support tabs and guide pins as indicated on drawings.

2.15 STRAINERS

Strainers shall be "Y" type with removable screens. Screens shall be stainless steel with 3/64" perforations. Manufacturer shall be Hoffman or equal.

2.16 Resistive Temperature Devices (RTD)

Resistive temperature device shall consist of a thermowell, probe, pressure fitting and weatherproof connection head. Thermowell shall be welded in place. Manufacturer shall be Minco and part numbers as specified below:

Thermowell---------------------------#F222U25
Pressure fitting--------------------#F145
Weatherproof head-------------------#F102-3T
RTD---------------------------------#S87P

2.17 Pressure Gauges

Pressure gauges will consist of an impulse tube and pressure transducer. The length and configuration of the impulse tube shall be as specified on the drawings. The pressure transducer shall provide a 4-20 ma output signal. It shall be a Rosemount Model #1144-G02COAA or equal.

2.18 Flow Meters

Flow meters shall be flanged in place with 300 lb., ANSI raised face flanges and shall include a bypass line for system operation during flow meter removal. Flow meter shall have a temperature range of 65°F to 650°F.

Flow range for the HTF meter shall be 40-400 gpm and for the steam meter the flow range shall be 2-20 gpm.

The strain gauge transmitter shall be mounted securely as close as possible to the flow meter following manufacturer's instructions.

Manufacturer shall be Ramapo Model Mark V with strain gauge transmitter SGA-8300B or equal.

2.19 Weather Instruments

A. Normal Incidence Pyroheliometer

The normal incidence pyroheliometer shall be manufactured by Eppley and shall consist of a Model ST-1 solar tracker and an E6-type wire-wound thermopile with a thermistor temperature compensating circuit. It shall be ground-mounted with an unobstructed view to the east, south and west.

B. Pyranometer

The pyranometer shall be manufactured by Eppley and shall be roof-mounted in the horizontal position.

C. Wind Speed Indicator

The wind speed indicator shall be a cup anemometer manufactured by Weather Measure, Model W103B-355. It shall have a range of 0.6 to 100 mph and shall be roof-mounted on a 1" diameter pipe.

D. Ambient Temperature

Ambient temperature shall be measured with a general purpose platinum resistive temperature detector enclosed in a radiation shield manufactured by Weather Measure, Model TRSS-RM-1. The device will be roof-mounted on a 1" pipe.

2.20 Closed Circuit Television

A. Camera

The closed circuit television camera shall have a 1" standard vidicon image tube with 700 lines resolution and a 25 mm, f/1.4 wide range auto iris lens. The camera shall be enclosed in a weather resistant and tamper resistant housing. The camera and enclosure shall be General Electric Series A Model 4TE45 or equal.

B. Camera/Enclosure Mount

The camera enclosure shall be wall-mounted on the southeast corner of the pump house such that the entire collector field is in view. The mount shall be attached to a structural member of the pump house as per manufacturer's instructions.

C. Monitor

The monitor shall have a 10-inch diagonal screen dimension with solid state circuitry and front panel controls.

The monitor shall be located in the power plant control room such that continuous field monitoring is possible.

PART 3.00 - EXECUTION

3.01 SURFACE CONDITIONS

A. Inspection

1. Prior to all work of this section, carefully inspect the installed work of adjacent trades and verify that all such work is complete to the point where this installation may properly commence.

2. Verify that plumbing shall be installed in strict accordance with all pertinent codes and standards and with the requirements of the Contract Documents.

B. Discrepancies

1. In the event of discrepancy, immediately notify the Project Director.

2. Do not proceed with work in areas of discrepancy until all such discrepancies have been fully resolved.

3.02 PIPING SYSTEM LAYOUT

Lay out the piping systems in careful coordination with the drawings, determining proper elevations for all components of the system and using only the minimum number of bends to produce a satisfactorily functioning system. Follow the general layout shown on the drawings in all cases except where other work may interfere.

3.03 PIPING INSTALLATION

A. Installation shall be the best standard practice of the trade. Inspect all piping prior to installation. Coupled short sections of piping, bushings, close nipples, long screws, bullhead tees, and crosses are prohibited.

B. All piping systems shall be graded and valved to provide complete drainage and control of all systems.

C. Where incompatible materials come in contact, they shall be isolated with the material best suited for that purpose.

D. Inspect each piece of pipe, tubing, fittings, and equipment for defects and obstruction. Promptly remove all defective material from the site.

E. Install pipes to clear all beams and obstructions. Do not cut in to or reduce the size of any load-carrying members without the prior approval of the Project Director.

F. Piping shall be arranged to maintain headroom and keep passageways clear and, where necessary, shall be off-set to maintain the required clearances and conform with structural features of building. All piping shall be run parallel and straight with adjacent walls of ceilings and shall present a uniform appearance.

3.04 CLOSING IN UNINSPECTED WORK

Do not cover up or enclose work until it has been properly and completely inspected and approved. Should any of the work be covered up or enclosed prior to all required inspections and approvals, uncover the work as required and, after it has been completely inspected and approved, make all repairs and replacements with such materials and workmanship as are necessary to the approval of the Project Director and at no additional cost to the Project Director.

3.05 FLUSHING AND CLEANING

All piping shall be flushed clean with potable water until "clear" and all foreign materials flushed out of systems.

3.06 TESTING

A. General

Furnish all test pumps, gauges, equipment, and personnel required and test as necessary to demonstrate the integrity of the finished piping installation to the approval of all pertinent authorities and the Project Director.

B. Heat Transfer Fluid Piping System

Test with water and make tight at 100 psi water gauge. Retain for four hours. Repair all leaking joints as required and then re-test.

C. Feedwater Piping System

Test with water and make tight at 200 psi water gauge. Retain for four hours. Repair all leaking joints as required and then re-test.

3.07 PIPING IDENTIFICATION

Piping systems shall be identified with the name of service and directional arrows on each pipe, insulated or not insulated, using pressure-sensitive type identification, at a maximum spacing of 20 feet in rooms, at branches or changes of direction and on both sides of walls and floors penetrated by the pipe. Service markers and directional arrows shall be similar and equal to Brady Type B-350 Perma-Code thin film pipe markers. Pipe banding tape similar and equal to Brady Type B-500 shall be used around each end of the service marker. Color coding and size of letters and arrows shall conform to ANSI - A12.1, "Scheme for the Identification of Piping System."

3.08 SYSTEM CHARTS

Furnish to Developer two complete charts showing color and designation of pipe identification for each type of service and a valve directory indicating location and functions of valves. One chart shall be suitably framed behind glass and mounted as directed in the Electrical Equipment Room.

DIVISION 16 - ELECTRICAL

SECTION 16400 - ELECTRICAL

Part 1.00 - GENERAL

1.01 Description

A. Includes furnishing all labor, materials, equipment, tools, labor, supervision and services required to construct and/or install the complete and operable electrical, on-line data acquisition and control systems as indicated on the drawings, specified herein, or reasonably required to complete the work. The GENERAL CONDITIONS are a part of this Section.

B. The work includes, but is not limited to:

1. Power panelboard, disconnect switches and motor starters.
2. Powering wiring - conduit, conductors, pull boxes, outlet boxes and devices.
3. Sub-feeders, pull boxes, conduits, conductors and fittings.
4. On-line Data Acquisition System (ODAS) including computer and peripherals, scanner, digital multimeter, sensors and interconnect wiring and necessary equipment racks.
5. Control wiring - including all conduit and wiring for line voltage control and conduit only for low voltage control, instrumentation and monitoring.
6. Wiring and connection of all pumps, including conduit, conductors, fittings, control wiring and final terminations.
7. Wiring and connection of all tracking device drive motors.
8. Provide convenience duplex power receptacles as indicated on the drawings.
9. All grounding as required to meet N.E.C. and local code requirements plus any special grounding required for equipment installed.
10. Lighting wiring - conduit, conductors, outlet boxes, fixtures and switches.
11. As-built drawings, Shop Drawings, operating manuals and guarantee.

C. Related work described elsewhere:

1. Plumbing
2. Painting

1.02 Requirements of Regulatory Agencies

A. Work and materials shall conform to the latest rules and regulations of all applicable State and local codes, laws and ordinances; including the requirements of the latest edition of the National Electrical Code of the National Fire Protection Association, and OSHA

B. All material and equipment shall be approved by Underwriters' Laboratory, Inc.

C. Subcontractor shall apply and pay for all necessary permits and fees required. He shall arrange and pay for any inspections and tests required, and deliver certificates of such inspections to the Owner.

1.03 Drawings

A. Drawings indicate diagrammatically desired locations or arrangement of conduit runs, outlets, equipment, etc., and are to be followed as closely as possible. Proper judgment must be exercised in executing work to secure the best possible installation in the available space and to overcome local difficulties due to space limitations and/or interference with structural conditions. All deviations from the drawings which are required to make the work of this Section conform to the structure as built or to fit the installed work of other trades and contractors shall be made without additional cost to the Project Manager. Such deviations shall be as approved by the Project Manager.

B. Subcontractor shall consult and coordinate with all trades so that no interferences shall occur. No extras will be allowed for changes made necessary by interferences with the work of other trades.

1.04 Inspection of Premises

A. Subcontractor shall examine the premises and satisfy himself as to the existing conditions. Should any discrepancy appear on the drawings or in the Specifications, it shall be brought to the attention of the Project Manager before submitting bids.

1.05 Submittals

A. Shop Drawings: Before starting of work, the Contractor shall submit to the Project Director for approval dimensioned shop and installation drawings and itemized equipment brochures, complete in all details, for all items which he proposes to install.

1. Includes cuts of all equipment, fixtures, materials, etc., from manufacturer's brochures, along with detailed specifications. Shop Drawing submittals shall include data on lighting fixtures, motor starters, circuit breakers, panelboards and switchboards, computer and peripherals, scanner, multimeter, sensors and other electrical components to be used.

B. As-Built Drawings: Submit per requirements in GENERAL CONDITIONS.

1.06 Guarantee

A. Provide written guarantee per requirements noted in GENERAL CONDITIONS.

1. Equipment, materials and workmanship shall be guaranteed against all defects for a period of one (1) year from final acceptance. Guarantee shall state that Subcontractor will replace all defective work and materials without cost to the Project Manager during gurantee period.

1.07 Performance Tests

A. Shall be performed to certify the integrity of the electrical system and freedom from unintentional grounds. Any work showing faults under test, and any work not in accordance with the Specifications and the accompanying drawings, shall be made good by the Subcontractor at his own expense. Should the Subcontractor refuse or neglect to make any tests necessary to satisfy the Project Manager or their representative that he has carried out the true intent and meaning of the Specifications, Project Manager may make such tests and charge the expense thereof to the Subcontractor to be retained out of full final payment as provided in the "GENERAL CONDITIONS" of the contract.

1.08 Protection of Fixtures and Equipment

A. Subcontractor shall be responsible for protection of all fixtures and equipment during construction. He shall replace, at his own expense, any fixture or equipment that is marred, defaced or broken

1.09 Cleaning

A. All fixtures and equipment shall be thoroughly cleaned and left ready for service and for occupancy of the building.

1.10 Cutting and Patching

A. Cutting of structural members shall be done at a location and in a manner approved by the Project Manager. All holes in concrete or masonry shall be coredrilled, or saw-cut, unless sleeves are provided in new construction. Holes which exceed the outside diameter of the conduit shall be packed with untreated oakum. The space between a conduit and the outside surface of a hole shall be clean and dry, and shall be caulked with General Electric Sealant 1300 or Silicone Construction Sealant. Unused holes shall have both ends sealed with plastic plugs and cemented in place with sealant. Openings for conduit entry through concrete or masonry walls and/or roof structure shall be packed, flashed, patched and made watertight.

Part 2.00 - PRODUCTS

2.01 General

A. The electrical materials and components specified herein shall be new and furnished in accordance with specifications of the National Electric Manufacturer's Association, the National Board of Fire Underwriters and the National Electric Code.

2.02 Panelboards

A. Power panelboard shall be 120/240 volts, 1 phase, 3 wire, as noted on the drawings. Panelboards shall meet the latest revision of the Federal Specifications W-P-115a, Type 1, Class 1, listed by the U.L. Bus shall be copper with lugs to permit the termination of copper conductors. Circuit breakers shall be bolt-on and shall meet the latest revision of Federal Specifications W-P-375a, having a minimum interupting capacity of 10,000 RMS symmetrical amperes. Provide neutral bus and a separate ground bus.

B. Panelboard provisions, where two or three pole breakers occur, they shall have common trips, and single operating handles. Single pole breakers with tie-bar between handles will not be accepted.

C. Panelboard shall be furnished with flush locks and key rings. Six keys shall be furnished.

D. Panel Schedules. A typed panel schedule of circuits shall be mounted on the back of panel door. The panel schedule shall have a metal frame with sheet lucite cover.

E. Nameplate shall be furnished for panelboard. Engraving shall be white on black bakelite indicating the panelboard designation.

F. Padlocking bracketes and handle lock-off devices shall be furnished for circuit breakers as indicated on panel schedules and as required by codes.

2.03 Safety Switches

A. Safety switches shall be NEMA Standard, heavy duty, horsepower rated of the size and voltage as indicated. Fused switches shall be provided with dual element, time delay type fuse of size indicated. Where exposed to the weather or in damp locations, enclosures shall be minimum NEMA 3R. Switches shall have interlocked cover and means for locking in the "ON" and "OFF" positions. Provide nameplate identification for each switch.

2.04 Raceways and Fittings

A. Conduit Types

1. Rigid metal conduit shall be rigid galvanized steel, intermediate grade, including couplings and nipples.

2. Electrical metallic tubing, including elbows, shall be galvanized steel.

3. Flexible metal conduit shall be steel with twist-on type connectors. Flexible steel conduit shall be galvanized and with galvanized or plated connectors. Flex may be used for motor connections and connections from J-Boxes to lighting fixtures.

4. Liquidtight flexible metal conduit shall consist of a core of flexible steel conduit with a neoprene jacket and shall be fitted with watertight connectors, with provisions for grounding conductor.

B. Conduit Fittings: All conduit bodies used with steel conduit shall have a cast metal body made of a ferrous metal of high corrosion resistance. Conduit bodies shall be cadmium-plated or zinc-galvanized with gasketed covers. Fittings for EMT shall be threadless raintight type; set screw type are not acceptable.

C. Junction and Pull Boxes: For interior and non-weatherproof use shall be constructed of galvanized steel with ample laps, spot welded, and shall be rigid. Weatherproof pull and junction boxes shall be provided with watertight gaskets and shall be complete with threaded type conduit hubs as required. All box hardware shall be corrosion resistant.

D. Outlet Boxes: In exposed work shall be pressed metal. Exposed outlet boxes shall be fastened securely to walls, ceilings, beams or columns.

E. Gutters and Wireways: Shall be fabricated from code gauge galvanized sheet steel and shall receive a standard factory finish.

2.05 Conductors

A. Conductor Types: For systems below 600 volts, such as lighting and power branch circuits and control circuit wiring, conductors shall be 600 volt copper wire listed by Underwriters' Laboratories as Type THHN, unless otherwise indicated or specified. Conductor sizes are American Wire Gauge (AWG). Minimum conductor sizes shall be #12, except for final connections to small motors and for control, signal and communication wiring.

2.06 Wiring Devices

A. Switches: Local switches shall be toggle, quiet type, conforming to NEMA Standards, premium specification grade, U.L. Listed, 120 volt, AC, 20 ampere rating, with completely enclosing insulation case and brown handle. Where more than one switch is shown at a location, switches shall be ganged in one box, if of same voltage.

B. Convenience outlets shall be 15 ampere, 125 volt, 2 pole, 3 wire, "Specification" Grade, Duplex U.L. tested, with "U" ground. Convenience outlets shall meet the latest revision of Federal Specification W-C-596.

C. Twist-lock receptacles shall be single, 15 ampere, 125 volt, 2 pole, 3 wire, grounding type, NEMA L5-15R configuration.

D. Device Plates: All wiring devices shall be complete with plates. Plates shall be galvanized steel, weather-proof, with spring type, lift cover.

2.07 Lighting Fixtures

Complete with all diffusers, fitters, pendants, canopies, sockets, reflectors and wiring accessories necessary for a complete installation. Fixtures and their appurtenances shall be so designed that the points of screws will not be inside a fixture. Fixtures shall be installed in perfect vertical and horizontal alignment.

A. Ballasts: Shall be high power factor (except where not available for lamps specified), U.L. Listed Class "P" and CBM certified by ETL. Ballasts shall be "A" sound rated in types which are so available, and any ballasts which obviously have more noise than expected from the "A" sound rating shall be replaced. Ballasts shall be self-protected. Ballasts shall be guaranteed for a period of two years.

B. Lamps: Shall be furnished and installed by the Contractor. Incandescent lamps shall be general-service, 130 volts, inside frosted, except as otherwise indicated. Fluorescent lamps shall be rapid-start, standard warm white. Lamps shall be General Electric, Sylvania, Westinghouse or approved equal.

C. Fixture Manufacturers: All fixtures of each type shall be by one manufacturer.

2.08 Nameplates

A. Equipment: Each major component of equipment shall have as a minimum the manufacturer's name, address, shop order number and catalog number, model, style, or type of a plate securely and conspicuously attached to the item of equipment.

B. Nameplates shall be laminated black and white plastic with characters cut through the black bakelite to the white core. Nameplate schedules shall be furnished with panel drawings submitted for approval.

C. Power panel shall have a nameplate bearing the panel designation as: "Panel LA". Nameplate shall be mounted outside panelboard doors and attached to the dead front.

D. Nameplates shall be furnished for: All line voltage control panels, pilot lights, disconnect switches, manual starting switches, and magnetic starters which are furnished for the work.

E. Nameplates shall be attached with machine screws or drive screws.

2.09 Motor Controls and Devices

A. Controllers and motor starters shall conform to the National Electrical Manufacturers' Association Standards. The size of the controller or starter shall be as noted or as required for the particular load. In no case shall a smaller size than No. 1 be used. The starters shall be equipped with externally mounted reset buttons for resetting the thermal overloads. The thermal overloads, one for each phase, shall be rated in accordance with the requirements of the National Electrical Code, and shall be of the ambient compensating type. The actual nameplate value of current for each motor shall be used for rating of the overloads.

B. Pushbutton Stations and Control Devices: All pushbutton stations, switches, pilot lights and other control devices shall be standard heavy-duty oil-type, unless otherwise noted.

C. Control wiring for plumbing and other miscellaneous equipment shall be provided as shown on control diagrams of Electrical, Mechanical and Plumbing Drawings. The Electrical Subcontractor shall be responsible for coordinating with Mechanical and Plumbing Drawings.

D. It shall be the Electrical Subcontractor's responsibility to coordinate with the approved control schemes of the mechanical trades before submitting Shop Drawings. Incomplete control diagrams shall be returned for resubmittal.

2.10 Computer and Peripherals

A. The ODAS computer shall be a Data General Micro Nova MP/100 or equivalent with the following characteristics:

Memory	64K bytes minimum
Address Modes	Absolute, Indexed, Deferred Relative
Bus System	Separate memory on I/O buses
Input/Output	16-level priority interrupt structure
Operating Temperature	$0^{\circ}C$ to $55^{\circ}C$
Operating Relative Humidity	To 90% non-condensing
AC Line Voltage	120V AC
Mounting	EIA Cabinet Mount

Unit shall be provided with the following additional options:

Real Time Clock
Battery backup for memory and clock
IEEE-488 bus interface
Three (3) RS-232 interfaces
Disk Operating System (DOS)
FORTRAN IV & Assembler compiler
Rack mounted chassis (standard EIA cabinet)
Floppy Disk Controller
Hard Disk Controller (as required)
CRT terminal with keyboards
Standard line printer

B. The Floppy disk system shall be the Data General Model 6031 or equivalent. Unit shall be compatable with the computer selected in A above without requiring software development. Unit shall meet or exceed the following specifications:

Number of disk drives	1
Disk Capacity	>512 bytes
AC line voltage	120V AC (300 watts)
Operating Temperature	$50^{\circ}F$ to $100^{\circ}F$
Operating Relative Humidity	20% to 80% non-condensing
Rack mounted chassis	EIA cabinet mount

C. The data storage medium shall be either a 9 track magnetic tape unit or a hard, non-removable disk system. The minimum specifications of each are provided below.

1. Tape Controller and Drive shall meet or exceed the following requirements:

Controller:

Interface	IEEE-488 bus
Buffer Size	2048 characters
Compatability	Any synchronous mag tape drive using industrial standard interface
Mount	EIA rack mount
Temperature (Operating)	$2^{o}C$ to $50^{o}C$
Pressure (Operating)	10% to 95%, non-condensing
Line Voltage	120V AC (125 VA max)

Tape Unit:

Reel size	7"
Data density	9 track, 1600 BPI
Recording Mode	Phase-encoded
Mounting	EIA rack mount
Type specifications	0.5" wide, 1.5 mil thick
Line voltage	120V AC

The controller and tape drive units shall be DYLON series 1015 controller and Series 2000 tape unit or equivalent.

2. Hard disk subsystem shall be Data General Model 6102 or equivalent. System shall be provided as a sealed contamination free module. The head/disc module shall have a filtered, closed-loop air circulation system. When in operation the head shall not contact the disc media surface. During start and stop operations the head shall settle gently on media surface without disturbing the recorded data. Unit selected shall be compatible with the computer and floppy disk system in A & B above without software development requirements.

Capacity	>10 million bytes
Line voltage	120V AC (340 watts)
Temperature (Operating)	$10^{o}C$ to $32^{o}C$
Relative Humidity	10% to 80% non-condensing

2.11 Scanner

The scanner shall be capable of scanning at least 30 channels with modular expansion capability to 120 or more channels. Unit shall be capable of withstanding accidental connection of 120V AC between any two inputs without harm. Scanner shall be rack mounted in a standard EIA cabinet. Scanner shall connect directly to, and be computer controlled by, the IEEE-488 bus. Scanner shall be equivalent to Hewlett Packard 3495A Scanner with three system option 001, ten cahnnel low thermal relay assemblies. The unit selected shall meet or exceed the following additional requirements:

Operating Temperature	0^oC to 55^oC
Relative Humidity	To 95% non-condensing
Line voltage	120V AC (<100 watt)
Compatibility	IEEE-488 bus
Mounting	EIA rack mounting
Relay type	Three pole, low thermal dry reed relays per channel
Relay Contact Ratings	200V peak, 200 ma
Maximum Input Voltage	230V peak between any two terminals
Switching time	10m sec maximum

2.12 Digital Multimeter

The digital multimeter shall meet or exceed the following requirements:

Compatibility	Plug into and controlled through the IEEE-488 bus
Input Voltage Range	Few MV to 20V DC
Voltage Standoff	Unit shall withstand connection to 120V AC without damage
Output (display)	>4½ digit readout
(digital)	>12 bit resolution of input
Mounting	EIA cabinet mounted
Line voltage	120V AC (<60 watt)
Operating Temperature	0^oC to 50^oC
Humidity	95% non-condensing

2.13 Resistive Temperature Device (RTD)

Resistive temperature devices (tagged T101, T201-T204, T401 on attached drawings) shall be Platinum 100 Ω $\pm$1% at 0^oC installed with thermowells. Active temperature range shall be -10^oC to 400^oC. Equipment shall be equivalent to MINCO S87p RTD mounted with F222 Thermowell, F145 pressurefitting and F102-3T weatherproof connection head. Thermowell and RTD to be sized to fit the process pipe. RTD to be procured and installed by others, electrical to hookup to ODAS.

2.14 Fluid and Steam Flow Transducer

A. Oil flow meter (tagged W201) shall be RAMAPO Mark V with 4" schedule 40 line size with 4"-150# ASNI flanged end connections. Temperature range shall be -65°F to 650°F. Flow range 50 gpm to 500 gpm with +5% FS water flow calibration corrected to operating fluid density. Electrical strip in gasketed junction box. Unit purchased and installed by others, electrical contractor to make electrical connection.

B. Steam flow meter (tagged W202) shall be RAMAPO Mark V with 4" schedule 40 line size, 4"-150# ANSI flanged end connections. Operating temperature range shall be -65°F to 650°F and flow range shall be 20 to 200 pounds per minute. Electrical strip in gasketed junction box. Unit purchased and installed by others, electrical contractor to make all electrical connections.

C. Strain gage transmitter which supplies the DC excitation potential to the Mark V flow meter and amplifies the flow meter output shall be RAMAPO SGA-8350B or equivalent. Input power requirements are 115V AC, output signal is 0-5VDC linearly proportional to the flow rate. Instrument is in a weather resistant, wall-mounted enclosure according to manufacturers specifications. Unit to be purchased and installed by others but hooked up by electrical contractor. Two units required.

2.15 Pressure Transducer

A. Steam pressure transducers (tagged P201 & PC201) shall be Rosemount Model 1144 pressure transmitter or equivalent. Unit to be procured and installed by others. Electrical unit will require 24V DC excitation potential and produce a 4 to 20 ma signal. Contractor to make electrical connections in accordance with manufacturers specifications. Two units to be installed, one connects to the ODAS, the second is for a control function. Electrical to clearly lable each unit and related wiring. Operating range shall be 0 to 300 psig for both units.

B. Oil pressure transducer (tagged PC101) shall be Rosemount Model 1144 or equivalent. Unit will require 24V DC excitation potential and produce a 4-20 ma signal. Electrical contractor to make all electrical connections in accordance with manufacturers specifications. Operating pressure range shall be 5 to 50 psig.

2.16 Flow Switch

The flow switch (tagged FS) mounted in the oil return line to the field shall be Delta Controls Corp. Model 621 or equivalent. Switch to be provided with 4" steel body with 150# ANSI flanged end plates. Switch to actuate at 75 gpm and deactuate at 50 gpm. Switch to be capable of functioning when fluid temperatures exceed 450°F. Switch to be procured and installed by others. Electrical contractor shall make all electrical connections.

2.17 Level Switch

The level switch (tagged LS) inserted in the oil expansion tank shall be Delta Controls Corp. type 735 level switch or equivalent. Switch to operate effectively to 450°F. Switch to be purchased and installed by others. Electrical contractor to make all electrical connections.

2.18 Phase Loss Switch

Phase failure switch (tagged PL), Taylor Electronics Model PLVE-120 or equivalent, is to be installed on the input lines of the pump house 120/208 3Ø 4 wire panelboard. Electrical contractor to procure, install and make all electrical connections in accordance with the manufacturers specifications and attached drawings.

2.19 Watt Transducers

Installation of two watt transducers is required. These shall be Ohio Semitronics PCS series transducers or equivalent. Electrical contractor to procure, install and perform electrical connection as indicated on the drawings or otherwiese required. Location and special requirements of each is provided below.

A. Feedwater Pump (tagged ED401): The transducer (PC5-24E) is to be wall mounted in a NEMA enclosure on the input to the Feedwater Pump. Transducer is to provide a 4-20 ma signal to the ODAS.

B. Parasitic Power (tagged EP101): Power to the collector field tracking motors and pump house is to come from 277/480 VAC3Ø power brought to the pump house and then run into the field. A watt transducer is to be installed on the input to the junction box. The transducer is to provide a 0-10 signal to the ODAS. Signal wires to be installed as depicted on attached drawings or otherwise described herein.

2.20 Environmental Sensors

A. Eppley Laboratories, normal incidence pyroheliomet er with solar tracker Model ST-1 (tagged I002) shall be provided and installed on the southeast corner of the pump house. Tracker will require 115V AC - 1Ø, 60 Hz power. Sensor output to be routed to the ODAS.

B. Eppley Laboratories Precision Spectral Pyranomet er (tagged I001) shall be mounted, per the drawings provided, against the east side of the pump house. Sensor output to be routed to the ODAS.

C. Weather measure Cup Aneometer with DC generator, (tagged V001), model W103B-3SS or equivalent, will be installed on the east side of the pump house at least 8 feet from the pyronometer. Sensor output to be routed to the ODAS.

D. Ambient temperature sensor (tagged T001) shall be platinum 100 ohm ± .1% RTD (weather measure part number TRSS-RM-1 or equivalent) enclosed in a radiation shield (weather measure part number IS4 or equivalent) to protect it from the sun. Sensor output to be run to the ODAS. Unit shall be mounted adjacent to the cup aneomometer.

2.21 Digital Display Meters

Digital display meters mounted on the control panel shall be Anologic PI-2455 measureometers, or equivalent, for current loop signals. Five meters will be mounted on the panel. One for oil flow rate (50 to 500 gpm) tagged D-1, one for steam flow rate (20 to 200 lb/min), tagged D-2, one for field outlet temperature (0°F to 600°F), tagged D-3, steam temperature (0°F to 500°F), tagged D-4 and steam pressure (0 to 300 psig), tagged D-5. The instruments shall be powered from 115V AC. Display section shall be red LED or GAS PLASMA (at least .43" segment height). Front of meter shall bear the engineering units of the quantity being displayed. Instruments will have an out of range indicator (blinking display or alarm). Out of range indicator for D-3 and D-5 shall be 550°F and 250 psig respectively.

2.22 Signal Conditioners

A. RTD signal conditioner (tagged SC-1 and SC-7) shall be Action Pak model AP4001 or equivalent. Unit shall be mounted inside EIA cabinet tray with ball bearing slides. Each unit shall take a three wire RTD input. SC-1 shall produce a 0-10V output signal, SC-7 shall produce a 4-20ma current signal. Minimum instrument performance characteristics are:

Nominal Linearity	.1% of max span
Stability	.05% of span per °C
Ripple	.2% of span p-p
Common Mode Rejection	>100db at 60 Hz
Measurement Range	0°F to 650°F
Power Supply Voltage	24V DC

B. DC current and voltage transmitters shall be Action Pak models AP4003 or equivalent. All units input and output levels to be in accordance with the attached drawings or otherwise defined herein. All signal conditioners to be located in the same tray as the RTD signal conditioner.

Nominal Linearity	$\pm$.1% of span
Stability	$\mp$0.05% of span per °C

Common Mode Rejection	>80db at 60 Hz
Maximum Common Mode Voltage	600V DC
Input Impedance (Voltage inputs > 500MV	200k Ω minimum
Voltage drop (current inputs)	< 500 MV
Power Supply Voltage	24V DC

1. Signal conditioners tagged SC-3 and SC-4 shall have current inputs of 4-20 ma and full scale voltage outputs of 10V DC. Outputs to be routed to ODAS scanner inputs as shown in the attached drawings and electrical schematics.

2. Signal conditioners tagged SC-5 and SC-6 shall have voltage inputs in the range 0-5V DC and produce a 4-20 ma current signal to drive the master control panel displays.

2.23 Limit Alarms and Control Relays

All control relays shall be Action Pak Models AP 1000 or equivalent. Units shall be powered by 120V AC and mounted in a NEMA enclosure adjacent to the collector field master control panel. Units shall have single-trip setpoint with DPDT relay. Signal inputs shall be as described in the drawings and below. General performance specifications are as indicated below:

Input Span: Voltage	50MV to 50DV
Current	1MA to 5A
Input Impedance on Voltage Drop	100k minimum (voltage input) 200MV drop current input
Stability	.05% of span per °C
Deadband	.25% of span
Response time	150 MS
Relay Contact Rating	5A to 120V AC (DPDT)
Relay Contact Life	10^7 operation
Temperature	0-60°C
Line Power	120V AC 50-400 Hz 2 wire floating power

Unit relays shall trip off when line power fails. Under normal operation the relay will remain energized until the monitored process exceeds a predetermined limit. Input and output signals and setpoint for each control relay is provided below:

1. Input to the control relay tagged CR-1 shall be a 4-20 ma current signal from pressure transducer

PC101. NC relay closure (when activated) shall be the Field Pressure Switch in series with the master On/Off switch. Relay shall deactivate when the pressure exceeds 40 psig (16 ma).

2. Input to control relay tagged CR-2 shall be a 4-20 ma current signal from pressure transducer PC201. The NC relay closure (when activated) shall be connected in series with the master On/Off switch as shown schematically. Relay to deactivate (open) when pressure exceeds 250 psig (17 ma). Status light (LP1) to be located on front of signal conditioner panel.

3. Input to control relay CR-3 shall be a 0-10V signal produced by closure of level switch (LS) in expansion tank. The NC relay closure (when activated) shall be connected in series with the master On/Off switch. Relay shall deactivate at 9V DC input. Panel lamp LP2 (see drawings) shall be located on the master control panel. Panel lamp LP3 shall be located on the front of the signal conditioner panel.

4. Inputs to control relays CR-4 through CR-13 shall be 0-10V DC signal produced by closure of manual control switch for the logic signal for each of the five collector subfields. Relay closures to be connected as indicated on attached drawings and schematics. Manual switches to be located on master control panel.

2.24 Power Conditioning Power Supply

The 24V DC power supply shall be a Lambda LNS-W-24 or equivalent. Power supply to meet or exceed the following specifications.

Regulation (line or load)	$\leq$0.1%
Output Ripple	$\leq$1.5mVrms
Output Voltage	24V DC
Output Current	5 amp
Overload Protection	Current limited
Temperature Coefficient	$\leq$0.03% per ^{o}C
AC Input	120V AC, 60 Hz

Unit to be mounted in EIA cabinet with signal conditioners.

2.25 Shielded Instrumentation Cables

All instrumentation and low voltage power cables between sensing devices and the ODAS master control panels and/or relay panel shall be two or three or multiconductor shielded cables as required. Cable shall be type Beldfoil as manufactured by Belden Corporation or an approved equal. All cable shall be UL listed. Cable shall be sized as specified in the drawings or under the electrical section of these specifications.

2.26 ODAS, Signal Conditioner and Sensor Interconnects

A. Watt Transducers (see paragraph 2.19)

1. Water pump motor power requirements are monitored by EP401 which produces a 4-20 ma signal. Output of sensor is carried to a signal conditioner SC-3 via Belden Trade & UL style number 8761. Shielded twisted pair with drain in conduit. Only one end of the drain wire is to be terminated, drain to be terminated at signal conditioner. The signal conditioner is to be Action Pak part number AP401D-1242 or equivalent (see paragraph 2.22 for specifications) mounted in the signal conditioning drawer in the pump house control room. Signal conditioners to be supplied and mounted by electrical contractor. Output of signal conditioners to be supplied and mount ed by electrical contractor. Output of signal conditioners are routed to Scanner relay bank #1, relay 2 via Belden Trade & UL style number 8761, shielded twisted pair with drain wire. Drain wire to be grounded at each end.

2. Watt transducer EP101 produces 0-5V DC signal which is routed directly to Relay Scanner Bank #1, relay 1. No signal conditioners are required. Signal cable is Belden Trade & UL style number 8761 or equivalent.

B. Resistive Temperature Devices (RTD): (see paragraph 2.13)

1. Three wire leads of each RTD is extended to Relay Scanner Bank #3 using Belden Trade & UL style 8771, three conductor, shielded and with drain wire. Drain wire to be connected at one end only. RTD T101 is input to Relay #1, RTD's T201 through T204 and T001 input to Relays 2 through 5 respectively. RTD T401 input to relay #6 and RTD T001 is input to relay #7.

2. The output of Scanner Relay Bank #3 is routed via Belden Trade & UL type 8761 to an Action Pac signal conditioner SC-1 (see paragraph 2.22 for specifications). Signal conditioners are located in the signal conditioner tray. Signal conditioner are to be supplied and installed by the electrical contractor.

3. Output of the signal conditioner is to be routed to Scanner Relay Bank #1, relay #5, via Belden Trade & UL type 8761 cable. Both ends of drain wire to be grounded.

C. Flow Transducers

1. Flow meters W201 and W202 require a 120V excitation potential for proper operation. This may be obtained from the nearest duplex convenience outlet. Electrical contractor to supply necessary connection cable and hook up the transducer. Output of each transducer is a 0-5V DC signal. Output is connected to Scanner Relay Bank #1, relays 6 & 7 via Belden Trade & UL type 8761 cable. The drain wire to be terminated at the ODAS end only.

2. The Scanner Relay Bank inputs for the flow meters are also used to drive a display in the master control room. This is accomplished by parallel input of the signal into Action Pak signal conditioners SC-5 and SC-6 (see paragraph 2.22 for specification). This signal conditioner has high impedance input and a 4-20 ma signal output. The 4-20 ma signal is carried to the display via a twisted pair in Belden Trade & UL style 9874. This cable contains six twisted pairs, each pair shielded and with its own drain. Drain for each pair is to be terminated at scanner end only. The signal conditioners will be located in the signal conditioner tray of the ODAS equipment signal conditioner to be procured and installed by electrical contractor.

3. The display is to be an Analogic PI-2455 measurometer, or equivalent, for 4-20 ma current loops (see paragraph 2.21 for specification) The display for W201 will be calibrated to read lbs/min of steam. These displays are to be located in the steam plant control room. Displays are to be purchased and installed by electrical contractor.

D. Pressure Transducers: (See paragraph 2.15)

Pressure transducer tagged P201 provides a 4-20 ma signal to signal conditioner SC-4 (see paragraph 2.22) and Display D01. Signal to D-1 is via twisted, shielded pair in Belden Trade & UL style 9874 or equivalent. Drain to be terminated at ODAS. Do not terminate drain at display. Output from SC-4 is 0-10V DC and connected to relay #8 of Scanner Relay Bank #1 via Belden Trade & UL style 8761 or equivalent. Drain to be terminated at both ends.

E. Environmental Sensors: (See paragraph 2.20)

1. Wind speed aneomometer tagged V001 output of 500MV DC @ 50 mph wind will be routed directly to relay #9 of Scanner Relay Bank #1. Signal cable shall be Belden Trade and UL style 8761 (or equivalent). Drain to be terminated at ODAS end only.

2. Pressure transducer tagged P001 shall be provided with 12V DC excitation potential derived from the 24V DC power supply. Power cable shall be Belden Trade and UL style 8761 or equivalent. Sensor output shall be routed directly to relay #10 of Scanner Relay Bank #1 via Belden Trade and UL style 8761 or equivalent.

3. Eppley NIP tagged I002 output shall be routed directly to relay #1 of Scanner Relay Bank #2. Drain wire to be terminated at scanner only.

4. Eppley PSD tagged I001 output shall be routed directly to relay #2 of Scanner Relay Bank #2. Drain wire to be terminated at scanner only.

2.27 Control Relays, Status Lights and Sensor Interconnects (See Drawing E-4)

A. Oil pressure transducer tagged PC101 produces a 4-20 ma signal with a 24V DC power supply and interconnects with control relay CR-1 (see paragraph 2.23) via Belden Trade & UL style 8761 or equivalent. Connections are made in accordance with drawing E-4.

B. Steam pressure transducer tagged PC201 produces 4-20 ma signal with a 24V DC power supply and interconnects with control relay CR-2 and Display D-4. (See paragraphs 2.23 and 2.21 respectively). D-4 is driven by twisted pair in Belden Trade & UL style 9874 cable or equivalent. Drain terminated at power supply end only. Control relay CR-2 is driven via Belden Trade and UL style 8761 or equivalent. One NC contact (when energized) will be in series with the master On/Off switch. The second NO (when activated) shall turn on a status light on the alternate control panel in the pump house control room. Signal cable from control panel to contact connection shall be via Belden Trade and UL style 8761 or equivalent. Connections to be made in accordance with Drawing E-4.

C. Outlet Fluid Temperature sensor tagged TC201 is a three wire RTD (see paragraph 2.13) and is connected to signal conditioner SC-7 (see paragraph 2.22) via Belden Trade and UL style 8771. Drain wire connected to signal conditioner only. Output of SC-7 is a 4-20 ma signal which drives:

1. Field Pump Spped Control Unit via Belden Trade and UL style 8761 or equivalent. Drain to be terminated at SC-7.

2. Control panel Display D-5 via shielded, twisted pair in Belden Trade & UL style 9874 or equivalent. Drain to be connected to drain wire in 1 above.

D. Expansion tank level switch shall be interconnected with status lights for both master control panel and the front of the signal conditioner tray. Resistors shown in Drawing E-4 to be colocated with status lamps and CR-3. Signal cables to master control panel to be twisted pair in Belden Trade & UL style 9874 or equivalent. Remaining cable to be Belden Trade & UL style 8761 or equivalent. All drains tied to common ground at signal conditioner tray.

E. Subfield manual control circuits in both the main control panel and the alternate control panel shall be fabricated per the attached drawings and as defined herein. Dropping resistors to be coloated with status light. Interconnect between panels to be by twisted pair in Belden Trade & UL style 9874 cable or equivalent. Control relays CR4 through and smaller shall be fastened to the building with approved pipe straps. No perforated tape shall be used to support conduits.

3.08 Miscellaneous Iron Work

A. All miscellaneous iron work required to complete and properly install the electrical work shall be furnished and installed under this Section of the Specifications.

3.09 Junction, Pull and Outlet Boxes shall be accurately placed and accessible and where exposed in finished areas, shall be fitted with covers matching the device plates specified for such areas. Bolts or screws shall be stainless steel. Junction, pull or outlet boxes shall be installed as required and as necessary, whether or not shown on the drawings. Bar hangers or box braces shall be used for all switch, receptacle and other outlets where conduit is exposed. All boxes exposed to weather shall be provided with gasketed weatherproof covers.

3.10 Prefabricated Equipment

A. Installation of all prefabricated items and equipment shall conform to the requirements of the manufacturer's specifications and installation instruction pamphlets. Where code requirements affect installation of materials and equipment, the more stringent requirements, code or manufacturer's instructions and/or specifications, shall govern the work.

3.11 Grounding

A. Metal raceways, metal enclosures of electrical devices, and other equipment shall be completely grounded in an approved manner prescribed by the National Electrical Code. All necessary conduit, conductors, clamps, connectors, etc., for the grounding system shall be furnished, installed and connected by the Electrical Subcontractor.

B. All ground clamps used shall be of an approved type and accessible for inspection.

CR13 to be located in relay rock adjacent to master field control panel. 24V DC power in master control panel to be supplied by 24V power cupply in power conditioner.

Part 3.00 - EXECUTION

3.01 General

All work shall be done in strict accordance with NEC, ESO, OSHA, and all other local codes, rules and requirements of authorities having jurisdiction.

Prior to starting work of this section, carefully inspect the installed work of all other trades and verify that all such work is complete to the point where this installation may properly commence.

Verify that the work of this section can be completed in strict accordance with all pertinent codes and regulations, the approved shop drawings and manufacturers recommendations.

In the event of discrepancy, immediately notify the Program Manager. Do not proceed in areas of discrepancy until all such discrepancies have been fully resolved.

Installation of ODAS and Control System Components

Install all equipment in the locations shown on approved drawings or specified herein, except where specifically otherwise approved on the job by Project Manager. Install equipment in accordance with manufacturers recommendation. Avoid interference with structure and work of other trades.

Workmansip

Install all equipment and devices in a neat and workmanlike manner, properly aligned, leveled and adjusted for satisfactory operation. Install so that connecting and disconnecting of wiring can be readily done, and all devices are readily accessible for inspection, service and repair.

Inspection

Check each piece of equipment and device for defects, verifying that all parts are properly furnished and installed, that all items function properly, and all adjustments have been made.

Installation of computer and peripheral equipment shall be under the supervision of system manufacturer's field engineer or Program Manager.

Upon completion of the installation, all system components shall be tested, adjusted and validated.

All low voltage wiring shall be installed in accordance with the requirements of electrical section.

3.02 Conduit Installation

A. Rigid steel conduit shall be used where embedded in concrete, masonry walls or where subject to physical damage or exposed up to eight feet above floor.

B. Green ground wire of code size shall be installed in all branch conduit runs.

C. Electrical metallic tubing shall be used for all conduit runs within the building except when run in or under floor slab or when run exposed up to 8 feet above floor.

D. Flexible metal conduit shall be used for connection to motors, lighting fixtures, and equipment or where structural conditions make it necessary. Where flexible metal conduit is exposed to moisture, it shall have polyvinyl chloride cover.

E. Wiring systems. All wiring shall be enclosed in rigid conduit, electrical metallic tubing, or raceways.

F. All conduits shall be rigidly supported with conduit straps and shall be exposed unless otherwise indicated. Concealed conduit shall be run in as direct a line and with bends as long as possible. Exposed conduit shall be run parallel to the building lines and bends shall be made with conduit elbows or conduit bent to not less than the same radius as elbows. All bends shall be free from dents of flattening. Not more than the equivalent of four (4) 90^{o} bends shall be used in any run between junction or pull boxes. Boxes shall be located in accessible locations. Joints shall be cut square, reamed smooth and drawn up tight.

G. Conduits shall be capped during construction by means of manufactured conduit seals or caps to prevent entrance of water or debris, and shall remain closed until ready for use. An 1/8" nylon pull cord shall be installed in all empty conduit left for future use or in which wiring is to be installed by other. Crushed or deformed raceways shall not be installed.

H. Flashing: Wherever conduit extends through roof, galvanized iron flashings shall be furnished and installed. These shall consist of a preformed roof jack and packing. Roof jack shall extend 5 inches out on roof and up on conduit at least 8 inches. Installation of flashing shall be coordinated with roofing.

I. Terminals of all conduit shall be installed with locknuts and non-metallic bushings. Conduit shall have supports spaced in compliance with the Code and shall be supported on galvanized wall brackets, ceiling trapeze, strap hangers or pipe straps, secured by means of toggle bolts in hollow masonry units, expansion bolts in concrete, machine screws on metal surfaces and wood screws for one hole straps and nails for two hole straps on wood construction. Nail and plumbers tape shall not be used as a means of fastening boxes or conduit.

J. Conduit shall be kept at least 16" from the covering on hot water pipes, and 18" from the covering on flues and breachings. Use conduit unions where union joints are necessary. Running threads will not be permitted.

K. No conduit or cable shall be run under, on, or in the floor of any boiler room.

L. All empty conduits shall be tagged at all exposed ends with brass tags marked as directed by the Program Manager's representative.

M. Where conduit passes from one type of construction to another, or where there is a possibility of dissimiliar movements, a suitable flexible or expansion device shall be installed.

N. Conduit couplings shall be made watertight with joint sealing compound made specifically for the conduit materials used.

O. Outlet boxes shall be firmly fastened with screws at two opposite sides.

P. All outlet boxes shall be accurately plumbed.

3.03 Conductor Installation

A. Wiring: Wire and cables shall be protected from weather and damage during storage and handling and shall be in perfect condition when installed. Conductors shall be factory color coded, with a separate color for each phase and neutral, used consistently throughout the system. Green coding shall be used for conductors intended solely for grounding purposes. Conductors, #2 and larger, shall be color coded in the field with colored tapes securely attached.

B. Number of conductors: A complete system of conductors shall be installed in the conduit systems regardless of the number shown on the drawings. The Subcontractor shall verify the required number of conductors and the corresponding conduit size. Any discrepancies shall be reported to the Architect who will issue an addendum to all bidders. Submission of a bid shall indicate that the Contractor has made such verification, understands the circuiting and switching and is prepared to install all electrical systems complete with the required number of conductors.

C. Installation of Conductors: All conduits shall be thoroughly cleaned and dried before wires are pulled. Only pulling compounds such as manufactured by Minerallac, Ideal or Burndy shall be used. In panelboard, conductors shall be neatly fanned out and tagged with fiber or linen tags, or stick-on markers, which are marked with the circuit number of usage designated. Feeders shall be tagged in pull boxes and cabinets, to indicate clearly their electrical characteristics, circuit number and panel designation.

1. Splices in conductors #6 and larger shall be made with approved solderless compression connectors.

2. Connections to terminals shall be made with solderless compression connectors.

3. Terminations and splices of straded wire which are accomplished with screw-type lugs or connectors shall be retightened not less than 24 hours after being installed, preferably after having been energized.

4. All circuits and feeder wires for all systems shall be continuous from switch to terminal or farthest outlet. No joint shall be made except in pull, junction or outlet boxes.

3.04 Feeder and Branch Circuits

A. Junction and Pull Boxes: Shall be installed in all conduit runs wherever indicated and/or where necessary to facilitate the pulling of wires and cables. Conduit bodies shall not be substituted for this purpose.

1. All junction and pull boxes shall be rigidly fastened to the structure and shall not depend on the conduits for support.

3.05 Supports for Fluorescent Fixtures

A. Shall have a minimum capacity of 150 pounds and all parts of the support and the fixture and appurtenances shall be arranged to prevent vibrating. Fixtures with a sheet metal backplate shall be provided with a minimum of sic square inches of substantial supporting surface inside the backplate.

B. Fixtures shall be securely attached to structural members or to metal supports which span structural members. Fixtures shall be fastened near each end, and, if a fixture is more than four feet long, it shall be fastened also at the center.

C. Fluorescent fixture stem hangers shall be suspended from ball aligner hangers.

3.06 Equipment Connections

A. Electrical connections to equipment which is furnished under other Sections of the Contract shall be part of the electrical work. The work shall include connections to equipment having internal factory wiring as well as connections of components that do not have factory wiring. Provide line voltage wiring and conduit only for low voltage, mechanical systems requiring control wiring. Provide components necessary for the controls. Provide a stick-on label on each end of each control wire.

B. The location of all conduit terminations to the equipment is approximate. The exact location of these conduit terminations shall be located and installed as directed by the plumbing Contractor.

3.07 Electrical Supports

A. Ring or trapeze hangers shall be used to support conduit larger than one inch. Conduit one inch

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