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**A HIGH TEMPERATURE PROCESS STEAM APPLICATION AT THE
SOUTHERN UNION REFINING COMPANY, HOBBS, NEW MEXICO**

Solar Energy in the Oil Patch
Final Report, Phase I Design

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Energetics Corporation
Richardson, Texas

U.S. Department of Energy

Solar Energy

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CONTRACT # EM-78-C-03-2223

A HIGH TEMPERATURE PROCESS STEAM APPLICATION
AT THE
SOUTHERN UNION REFINING COMPANY
HOBBS, NEW MEXICO

(SOLAR ENERGY IN THE OIL PATCH)

FINAL REPORT

Phase I Design

Prepared by

Energetics Corporation
Richardson, Texas
(formerly Monument Solar Corporation)

31 July 1979

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3. SUMMARY

The desires of the Department of Energy with respect to the Southern Union Refining Company's Solar Production of Industrial Steam, as expressed in Contract #EM-78-C-03-2223 with Monument Solar Corporation, have been essentially satisfied. This Phase I Design for an Industrial Process Heat program has moved smoothly to completion while remaining within schedule and cost plans.

Southern Union Refining Company's Famariss Energy Refinery has worked diligently with Monument Solar Corporation in the conceptual and detail design for this unique application of solar generated steam. An area closely adjacent to the refinery and fronting New Mexico State Highway #18 has been designated for the solar collector array giving clear and unobstructed view to the passing public.

Space planned for the demonstration array is sufficiently large to handle an array of 25,200 square feet in size - an array more than twice the size of the 10,080 square feet proposed originally. Since the consensus of opinion at the October, 1978 Industrial Process Heat Work Conference was for a significantly larger demonstration program - up to 50,000 square feet in area - the option of increasing this demonstration from 10,080 square feet to 25,200 square feet was closely considered. Some actual provisions were incorporated into the detail design of the solar system to permit a rather straightforward increase in the demon-

stration array size, if the Department of Energy so chooses. In the system concept and detail design discussed in this volume, the idea presented during the initial conceptual design review (See Figure 3.1) for a 10,080 square foot array-expandable to 25,200 square feet-has been followed. Some minor changes were necessitated from the conceptual design because of availability of components and parts, refinements to the conceptual design encountered after the design review and for safety or environmental reasons.

A proposal covering Phase II effort and associated costs, required during Phase I, has been prepared and submitted in a separate volume.

It is hoped that the efforts of Monument Solar Corporation, supplemented by Bridgers & Paxton Consulting Engineers and New Mexico Solar Energy Institute, is in line with the Department of Energy's wishes. The design of this unique application has been highly rewarding to the participants.

SOLAR ARRAY

3.3

FIGURE 3.1

4. CONCEPTUAL DESIGN

4.1 Introduction

The final design for the Famariss Energy Refinery Solar System and its interface with the refinery is discussed in the following sections. The design follows closely that proposed in the Conceptual Design Review Report (dated 5 January 1979) with special emphasis given to equipment sizing and system operation. Further technical discussion, calculations, and detailed analysis can be found in the above reference.

4.2 Solar System Design

The final solar system design utilizes a linear parabolic trough collector manufactured by Solar Kinetics, Inc. of Dallas, Texas. The system design incorporates 72 model T-700 collectors, each with aperture dimensions of 7 ft. wide by 20 ft. long, to provide 10,080 ft² of solar collector area. Six collector modules will be placed end to end to make collector arrays each with a separate tracking/drive unit. Thus, twelve arrays will make up the total solar field.

The solar process steam application at the Famariss Energy Refinery will be a two loop design. As represented in Figure 4.1, Loop I will be the primary thermal transport loop where heat transfer oil (HTO) will be recirculated by a separate pump, through the solar collectors and solar steam generator (SSG). Loop II will be the interfacing loop between the Famariss Refinery

FIGURE 4.1
APPLICATION DESCRIPTION

and the solar system. It will incorporate feed water supplied by the refinery's boiler feed water pumps to the SSG. Also, steam discharged from the SSG back to the refinery's steam header pipe will be included in this loop. Feed water will be supplied at approximately 220°F while 175 psig dry saturated steam at 375°F will be provided to the Famariss plant.

The system schematic of the Famariss Refinery Solar Process Steam Application is shown in Figure 4.2. Both Loop 1, the solar HTO thermal loop and Loop II, the SSG interface, are represented. The SSG essentially parallels the existing Famariss plant steam boilers. The refinery's steam system is composed of boiler feed pumps, deaerator, steam boilers, steam distribution piping, feed water piping (condensate return), and water treatment. The water treatment, in conjunction with the boiler blow down (not shown in Figure 4.2), controls corrosion and scaling in the boilers and steam system and is critical to continuous efficient operation. The various components of the solar system are the solar collectors, the HTO recirculation loop (piping), the HTO pump, expansion tank, SSG, blow down heat exchanger, and several control valves. These latter items are shown in the solar system flow diagram of Figure 4.3.

The HTO recirculation loop on the solar side of the process interface, Loop I, will be a constant flow system (except for system cold start up). Thus, only oil temperature in the collector field piping will vary in response to variations in the solar input. This will allow oil temperatures at a location

SYSTEM SCHEMATIC

FIGURE 4.2

SOLAR SYSTEM FLOW DIAGRAM

exit the collector field to operate throughout the day with temperatures of 500°F (the maximum collector design temperature) down to about 375°F (the saturated steam temperature in the SSG). The higher temperatures will correspond to the higher steam flow rates out of the SSG and to periods of higher solar insolation. At the SSG, the necessary internal water level will be maintained by a level control valve on the feed water inlet line. In addition, a specified blow down from the SSG (based on the refinery's water quality) will be provided to control scale and corrosion.

The SKI T-700 collector incorporates a reflective parabolic surface of FEK metallized acrylic film and a 1.5 inch outer diameter receiver tube coated with a black chrome selective surface. The receiver tube is surrounded by a Pyrex glass tube to minimize convection losses. The collector is rated for operation up to 250 psig and 500°F . Additional collector details are shown in the manufacturer's literature provided in the appendix.

The solar collector field configuration was arrived at after consideration of the process thermal energy requirement, piping thermal loss, and pumping power requirement. Both East-West and North-South collector row orientations were studied. As indicated in Figure 4.4, the North-South oriented rows deliver approximately 8% more thermal energy on an annual basis but have extreme variations in energy output on a month to month basis (ie, 150% output in August vs 38% thermal output in December).

USABLE SOLAR ENERGY FOR THE
SOLAR PROCESS STEAM APPLICATION
AT THE FAMARISS ENERGY REFINERY

FIGURE 4.4

Comparatively, the thermal output from an East-West oriented collector field is much more consistent throughout the year with variation between only 75% and 109%. Thus, since the Famariss Refinery requires nearly 40% more thermal energy in the winter months than in the summer, the East-West field orientation was selected. Note that this decision would be much more important for a larger field size which supplied a larger percentage of the thermal energy requirements of the plant.

Based on the six collector module array (with a separate tracking/drive unit per array) several field configuration piping arrangements are possible. For the twelve array field (72 collectors) a configuration of either two, three, four, six, or twelve parallel flow loops would be possible. This number of flow loops would also equal the number of East-West collector rows and would contain 36, 24, 18, 12, or 6 collectors in each row, respectively. As identified in the conceptual system design, the selected field configuration would directly effect the field piping thermal loss and pumping power. These items are summarized in Table 4.1 where the total system parasitic losses are listed for the possible East-West row configurations. For the design conditions specified, six East-West rows provide the minimum parasitic losses to the system. Twelve rows are nearly as effective as six but have the additional disadvantage of increased field piping cost (nearly twice the collector header piping length and cost as the six collector row manifold). It should be noted at this point that a field collector area of 25,000 ft²

TABLE 4.1

SOLAR FIELD CONFIGURATION CRITERIA *

<u># E-W Rows or Flow Loops</u>	<u>Piping Thermal Loss, %</u>	<u>Pump Power Factor, %</u>	<u>Total Losses, %</u>
2	0.1	13.2	13.3
3	0.2	3.9	4.1
4	0.3	1.6	1.9
6	0.5	0.5	1.0
12	1.1	0.1	1.2

* Based on percent of clear day energy collection at 425°F; 2" nominal pipe size with 3½" insulation thickness; 16' collector row to row spacing; 125 gpm HTO flow; 12 six-collector modules for 10,080 ft² aperture area.

would be configured by a similar analysis. Most probably, this field size would also be based on two arrays (twelve solar collectors) per individual flow loop. Because of the large increase in parasitic losses as the number of collectors per flow loop increase (or number of flow loops decrease, ie. Table 4.1), fewer than twelve collectors per flow loop would be considered. However, for this process application and these design conditions the twelve collectors per flow loop is the desired design basis.

4.3 Solar System Performance

Detailed solar system performance investigations indicate that the High Temperature Solar Process Steam Application at the Famariss Refinery will provide approximately 3.65 million pounds of steam to the refinery annually (based on 85% clear days). This is the energy equivalent of nearly 4.5 million cubic feet of natural gas for an operating boiler efficiency of 83%. The corresponding solar system annual efficiency is 41.8% (available solar insolation to net steam output) but all system parasitic losses reduce the net energy gain of the installation to 40.2% of the available solar insolation. A system performance summary is listed in Table 4.2. The peak collector thermal output will be about 2 million Btu/hr with a resulting steam flow from the SSG of 1880 pph. This results in a solar noon peak efficiency of 60.2% for insolation to steam output. Additional collector and system performance information is presented in Table 4.2.

TABLE 4.2

SOLAR SYSTEM PERFORMANCE SUMMARY

Peak Collector Thermal Output	- 1.97 million Btu/hr (577 KW _t)
Peak System Steam Output	- 1882 pph
Concentrator	- Solar Kinetics, Inc T-700 Linear Parabolic Trough; 180° Rim Angle; 7 ft x 20 ft Aperture
Concentration Ratio	- 16.4 (based on exposed receiver surface area)
Tracking	- East-West Oriented Collector Field with Active Solar Elevation Tracking; Hydraulic Power Supply
Process Load	- 375 F/175 psig Steam to Famariss Refinery (220 F feed water supplied to the SSG)
Collector Field Size	- 10,080 ft ² Total Aperture Area; 72 Collectors in 12 Arrays
Peak Efficiency	- 60.2% (Insolation to net steam output)
Annual Efficiency	- 41.8% (Insolation to net steam output)
Annual Fuel Savings	- 4.27 Billion Btu*

* Net savings after all system parasitic losses.

The instantaneous energy balance of the SKI T-700 solar collector is represented in Figure 4.5. Approximately 61% of the incident solar insolation can be reflected, concentrated, absorbed, and transferred to the heat transfer fluid in the receiver.

The collector and solar steam generator full day performance is shown in Figure 4.6 where collector output and SSG output are plotted as function of solar time. The direct normal insolation (for a clear vernal equinoxial day) is also shown for comparison. As indicated, the collector daily thermal output is about 1298 Btu/ft^2 of collector aperture area with a corresponding day long efficiency of 43%. The collector peak output at solar noon (195 Btu/hr-ft^2) provides an instantaneous efficiency of over 62%. Based on steam generated, however, the corresponding day long and peak instantaneous efficiencies are 41.8% and 60.2% respectively. The reduction in performance is due to the system parasitic losses of HTO piping thermal losses and steam generator blow down thermal losses. All realistic system performance estimates must include such losses.

Of most importance for any solar system, however, is the annual system performance. This is shown in Figure 4.7 for the Famariss Refinery Solar Process Steam Application. The series of stepping blocks represent all subsystem and collector individual efficiencies with the overall system annual efficiency given in the final block. As indicated, the annual

INSTANTANEOUS ENERGY BALANCE

FIGURE 4.5

FIGURE 4.6

DAILY SYSTEM PERFORMANCE
(CLEAR EQUINOXIAL DAY)

system efficiency is 40.2%. The annual efficiency can also be expressed as the product of the individual subsystem or component efficiencies and factors. This breakdown in component efficiencies is represented in Table 4.3. Thus, nearly 40% of the available annual direct normal insolation can be utilized to reduce the conventional energy consumption of the Famariss Refinery after accounting for all system parasitic, operational, and shut down losses. Therefore, the annual performance of the 10,080 ft² installation with approximately 85% clear days would be to provide nearly 3.54 billion net Btu to the Famariss Refinery, thereby reducing fuel consumption for the generation of process steam by the equivalent of approximately 3.81 million cubic feet of natural gas or 23,788.81 gallons of fuel oil.

The individual component loss factors or efficiencies were determined by hour by hour system performance calculations for four selected days of the year, then averaged to obtain their estimated annual efficiencies. The solar data for the analysis was ASHRAE clear day insolation values for 32°N latitude. The representative four days used in the calculations were the summer and winter solstices and the vernal and autumnal equinoxes. The collector tracking, shading, and row end losses amount to an annual factor of about 0.720 (or 28% of the available insolation is not utilized). This factor is based on row to row spacing of sixteen feet and east-west row lengths of 120 feet (six collector modules). The cosine effect (tracking loss) is

TABLE 4.3

SOLAR SYSTEM ANNUAL LOSS FACTORS

<u>Loss Category</u>	<u>Loss Factor</u>	<u>Product</u>
Tracking	0.732	0.732
Shading (row to row)	0.994	0.728
Collector end loss	0.990	0.720
Reflection	0.830	0.600
Intercept	0.980	0.586
Glass cover transmittance	0.900	0.527
Collector heat loss	0.852	0.431
Field piping heat loss	0.988	0.426
Feed water piping heat loss	0.996	0.424
Blow down	0.986	0.418
Pumping power	0.985	0.412
Field piping cool down	0.990	0.408
Feed water piping cool down	0.990	0.404
Freeze protection	0.996	0.402

the largest loss in this factor with collector shading and row end losses amounting to only slightly over 1% of the available insolation (see Table 4.3).

The collector reflection and intercept losses are based on SKI literature values and provide a combined loss factor of about 0.813. Concentrator surface reflectivity of 83% was the primary loss in this factor with an additional 2% loss due to intercept losses.

The glass cover transmittance (90%) and receiver surface absorptivity (96%) are also based on SKI literature values, with their corresponding annual effects represented in Figure 4.7. It can be seen that after these optical losses, the annual collector optical efficiency should be about 52.7%. Thus, (based on the final system efficiency of 40.2%) only 12.5% of the available solar insolation is "lost" by the system in conversion from absorbed solar radiation to net energy savings to the refinery.

The collector thermal losses (included in the 12.5% annual system losses mentioned in the preceeding paragraph) amounts to approximately 7.5% of the available annual insolation. This results in a collector thermal loss factor of about 0.852 which indicates that nearly 15% of the absorbed solar energy is lost due to collector thermal losses while operating. It should be realized that these collector losses are not based on a constant collector fluid temperature, but on the variation in operating temperature caused by the constant flow

FIGURE 4 7

ANNUAL SYSTEM PERFORMANCE
FAMARISS REFINERY SOLAR PROCESS STEAM APPLICATION

NOTE: 10,080 ft² SKI T-700 COLLECTOR ASHRAE SOLAR
DATA AVERAGE 27,500 PPH HTO CIRCULATION

system design. Note that the operating HTO temperature will nearly always remain between 375°F and 500°F however.

The field piping thermal loss factor was determined to be about 0.988 based on the pipe sizes and insulation thicknesses presented in section 4.4.3. Also, the same variation in operating fluid temperature as discussed for the collector thermal losses applies. The feed water piping heat loss factor, determined similarly, is 0.996.

The blow down thermal losses are an inherent loss for the Famariss Refinery Solar Process Application but is not necessarily indicative of all steam generation applications. This loss, caused by the deliberate release from the SSG of high temperature water, is required for system scale and corrosion control. Generally, this high temperature water is cooled down to near ambient temperatures by incoming boiler makeup feed water and would result in a negligible thermal loss to the system. However, the solar generator in the present system is about 800 feet from the inlet cold makeup water (to the existing steam boilers) and therefore can only exchange heat with the preheated incoming feedwater to the solar steam generator (which is about 220°F). This results in a blow down thermal loss factor of about 0.986 (when a continuous blow down of 10% of the mass of steam generated is maintained).

The pumping power loss factor was determined to be 0.985. This factor was based on a constant operational flow of 125 gpm of HTO through the collector field. The mechanical pumping

energy was weighted by a factor of three in order to compare with the other system thermal parasitic losses. This weighting factor accounts for the actual thermal energy utilized in the thermodynamic conversion to work (or mechanical energy). The pressure drop through the collector field was based on removing the spiral ribbon (flow turbulence inducer) from the collector receiver.

The final system parasitic loss factors of approximately 0.98 and 0.996 account for the piping and collector thermal losses associated with cool down after system shut down and the energy required for freeze protection, respectively. Since the cool down losses occur every evening after a day of operation, they are repetitive and must be accounted for by pre-heating during morning start up. As indicated in Figure 4.7 these losses amount to less than 2% of the annual available solar energy. Energy required for freeze protection was determined from the annual degree days of heating required and the solar control building configuration.

4.4 Detailed Investigations for Conceptual Design

Several detailed studies were completed in the process of finalizing the solar system design for this High Temperature Solar Process Steam Application. These studies included preliminary investigations of alternate concentrating collectors, all water solar system designs (no HTO loop), selection of the feed water supply concept and determination of system

operation for freeze protection. Additional investigations completed were equipment cost/performance and sizing studies. These studies are individually discussed in the remainder of this section.

4.4.1 Alternate Collector Systems

In the conceptual design phase of this contract work, several concentrating collector designs were evaluated for application. Data on four commercially available collectors and one advanced design collector was obtained. All collectors were linear focus, single axis tracking, concentrating collectors with maximum operating temperatures of about 500°F. The collectors evaluated are shown in Table 4.4. In addition to the information of this Table, supplemental information on these collectors was obtained by visiting the Estancia Valley Solar Irrigation Project at Willard, New Mexico and Sandia Laboratory's Collector Test Facility in Albuquerque.

The Accurex and E-Systems collectors were not considered further due to their state of development. The E-Systems collector, while having a substantial improvement in whole day efficiency (due to a polar axis orientation), is not yet offered commercially. Accurex indicated they were modifying their present design to become more cost competitive but had no additional design information presently available.

The Solar Kinetics, Inc., Model T-700 (an improved version of the small Model T-500) parabolic trough was therefore

TABLE 4.4

CONCENTRATING SOLAR COLLECTOR COMPARISON
DATA

<u>Collector</u>	<u>Cost, \$/ft²</u>	<u>Peak Eff @500 F, %</u>	<u>All Day Eff, %</u>
Solar Kinetics, Inc Model T-500	19.25 (1)	49 (3)	30 (3)
Solar Kinetics, Inc Model T-700	19.25 (1)	58 (4)	39 (4)
Hexcel	19.00 (1)	58 (3)	36 (3)
Accurex	27.00 (2)	49 (4)	N.A.
Suntec "Slats"	22.00 (1)	47 (3)	N.A.
E-Systems, Inc Fresnel Lens	25.00 (2)	58 (4)	49 (4)

Notes:

- (1) Manufacturers actual cost data Oct 1978.
 - (2) Manufacturers estimated cost data.
 - (3) Efficiency values obtained or calculated from: Dudley, V.E., and R.M. Workhoven, "Summary Report: Concentrating Solar Collector Test Results Collector Module Test Facility," Sandia Labs, May 1978.
 - (4) Manufacturers estimated performance data.
- N.A. - Not Available

selected as the most cost effective collector for this application. It was anticipated that this "second generation" collector, already utilized in previous solar installations, would minimize system operational problems and provide higher system availability than unproven collectors (an important consideration for this solar process steam application). In addition, the larger aperture area per collector module would minimize field piping connections and cost. Finally, the unplanned but not insignificant fact that the headquarters of both Monument Solar Corporation and Solar Kinetics, Inc., are in Dallas, Texas contributed to the desirability of the SKI collector.

4.4.2 Collector Spacing and Shading

A detailed study was completed to determine the near optimum row to row spacing of the solar collector field. Based on the twelve collector East-West row length and an interconnecting 2 inch nominal pipe size (with $3\frac{1}{2}$ inches of insulation), an energy loss for each collector row was determined as a function of the row to row spacing. The amount of energy lost annually due to collector shading and interconnect piping heat loss was calculated separately then summed to obtain an annual total quantity of energy lost. The annual shading calculations were based on hourly insolation values for the equinox and solstice days of the year. The piping heat loss was based on an average HTO temperature of 450°F and ten hour operational days. Both operating and overnight cool down thermal losses were

accounted for. Results of this analysis are indicated in Figure 4.8. Although 25 feet row to row spacing provides nearly the minimum system energy loss (essentially zero shading loss), a cost/performance trade off indicates that based on a collector capital cost of \$50/million collected Btu (annually), or \$19.25 per ft² collector, the economic optimum spacing becomes approximately 16 feet (for installed interconnect piping and insulation costs of \$20 per linear foot). Thus, the 16 feet row to row spacing was utilized in the final design.

The energy lost due to shading was calculated hourly by multiplying the available insolation (after tracking losses) by the fraction of aperture area shaded. The fraction of collector aperture area shaded was calculated from the following derived equation (for East-West linear tracking collectors on a horizontal plane):

$$\text{Fraction Shaded} = 1 - (D_s/W) \sin\{\tan^{-1}(\tan\{\text{BETA}\}/\cos\{\text{GAMMA}\})\}$$

where,

D_s = distance between adjacent parallel east-west rows

W = collector aperture width

BETA = solar altitude angle

GAMMA = solar azimuth angle measured from due south.

4.4.3 Piping and Insulation

Detailed studies were also completed of the system pipe sizes. In addition to economic consideration, the feed water and steam lines were sized to allow expansion of the solar

FIGURE 4.8

COLLECTOR SYSTEM ENERGY LOSS vs
COLLECTOR SPACING
12 collector/row

collector field to 25,000 ft². Thus, no increase in these pipe sizes would be necessary for increasing the basic case collector area by up to 2½ times.

The feed water line was sized for minimum cost based on heat loss and fixed cost (capital recovery). However, the pipe size was so small (2 inch nominal pipe size selected) that the overriding factor for size selection was the allowance for field expansion to 25,000 ft². Pressure drop was not evaluated due to the current operation of high outlet pressure from the boiler feed pumps.

The steam and HTO piping sizes were determined by evaluating the costs due to operating pressure drop, fixed cost, and heat loss (based on a fixed insulation to pipe diameter ratio). In addition, the steam line size was further penalized for increased backpressure operation in the SSG (caused by reduced steam line sizes). Increased SSG operating pressures reduced the available log mean temperature difference (LMTD) by increasing the saturation temperature in the SSG and thereby requiring larger heat exchange surface areas to transfer equivalent quantities of heat. Based on the estimated price of \$25/ft² of heat transfer area (approximate quoted price), this penalty amounted to an additional capital expenditure of nearly \$100 per psi back pressure in the SSG (or steam line pressure drop). In all these line size evaluations, operating power to overcome pressure drop was converted to equivalent thermal energy (factor of three) for direct cost comparisons.

The cost of the thermal energy was based on the collected energy capital cost of \$50 per million Btu per year (\$19.25 per ft² collector area). The resulting pipe sizes of the steam and main oil lines were 2½ inch and 3 inch nominal pipe sizes, respectively.

The economic optimum insulation thickness was determined similar to the pipe size, except that only the insulation cost and the cost of the heat loss were necessary for the analysis. The capital cost for annual collected insolation (the basis for economic comparison) was again \$50 per million Btu. The insulation cost was the current price obtained from a national manufacturer. Heat loss was calculated for the actual pipe operating temperature and the annual heat loss was based on an operating time of 10 hours per day. Results for the feed water line are indicated in Figure 4.9 for a 12% capital recovery factor). The selected insulation thicknesses were 1½ inches, 3 inches, and 4 inches for the feed water, steam, and larger oil lines, respectively.

4.4.4 Pumps and the Solar Steam Generator

The HTO pump sizing was determined from considerations of parasitic power and heat exchanger LMTD. In addition, the final HTO flow was determined only after completion of the HTO economic pipe size study. Pumping power was based on total system hydraulic losses (collectors, distribution lines, control valves and SSG), pump and motor efficiencies of 0.92 and

FIGURE 4.9
ECONOMIC INSULATION THICKNESS*
METHODOLOGY

1" Feedwater Pipe 220°F
 2½" Steam Pipe 375°F
 2" Oil Pipe 500°F
 3" oil Pipe 450°F

OPTIMUM THICKNESS

1½"
 3"
 3½"
 4"

0.55 respectively (with a factor of 3 used for conversion to equivalent thermal energy), HTO oil properties of Texatherm, and average 10 hour operational days. The SSG cost was determined to be approximately $\$25/\text{ft}^2$ heat exchange surface area while the capital cost of the annual collected insolation was again $\$50/\text{million Btu}$ (constant for this collector and location).

A pictorial representation of what occurs in the SSG is given in Figure 4.10 where local operating temperature versus local steam enthalpy is represented along the heat exchanger surface area. As can be seen, the minimum HTO flow (at a 0° pinch point) is possible only with an infinite size heat exchanger (after calculating surface area with the available LMTD). Conversely, for maximum LMTD (constant HTO oil temperature of 500°F) the SSG has a minimum surface area, but requires an infinite HTO flow rate. Thus, the trade off becomes obvious. However, detailed studies of this relationship soon indicated that the minimum cost point required an abnormally large SSG (which no longer cost $\$25/\text{ft}^2$, but more) and was no longer of a practical design. Therefore, HTO flow was increased to a reasonable rate to further minimize the capital expenditure on this project. It is important to note that the design conditions must be met only at peak solar output conditions in order to prevent overheating in the HTO loop, but that the size optimization study was based on full day operation where the HTO oil temperature (along with the collector efficiency and SSG LMTD) varied hourly. These calculations, along with judgements regarding

FIGURE 4.10

ENTHALPY vs TEMPERATURE FOR THE
SOLAR STEAM GENERATOR

feasible SSG sizes, arrived at the design conditions of 125 gpm HTO flow and a SSG of nearly 600 ft² of heat transfer surface area.

The start up pump was sized on heat transfer considerations within the receiver tube. Design conditions selected were to provide a 1 ft/sec HTO velocity within the collector receiver tube at 32°F. Heat transfer calculations indicated that the maximum oil film temperature would not exceed 350°F under these conditions.

The conceptual design was also concerned with general design problems such as feed water supply to the SSG and required freeze protection operation. These items were decided on after economic and operational consideration, with special emphasis given to reliability and operability by the refinery personnel. Thus, feed water was selected to be provided direct from the refinery boiler feed pumps. This method utilized the existing water treatment facilities and minimized the number of pumps in the solar design. This concept did require about 800 ft of feed water pipe, however, to be connected from the boiler feed pumps to the proposed SSG. Freeze protection was considered for the water containing items (feed water pipe and SSG). It was decided to recirculate a small amount of hot water through the feed water line during freezing weather. Also, the SSG was decided to be kept in a building at 50°F during the winter months. These combined freeze protection functions would amount to an energy loss of only 0.4% of the available annual insolation and is represented in Table 4.3 in the Solar System Performance section.

4.4.5 All Water System

An all water solar system feasibility study was completed during the conceptual design phase. This system involved replacing the HTO loop and the SSG with a water recirculation loop through the collectors and a steam separator. Two methods were considered for the all water design: 1) steam production in the collector field at 375°F and 175 psig; and 2) high pressure hot water production in the solar collector field at 406°F and 250 psig (the maximum collector pressure rating) with flashing across a throttle valve into the steam separator at 175 psig. Both methods had the major advantages of eliminating the HTO in the collector (with improved receiver tube heat transfer) and eliminating the costly solar steam generator. Although, the use of water within the solar collectors was not recommended by the collector manufacturer due to possible corrosion problems, it is felt that future generation collectors must consider this option due to the reduced system cost and complexity and the increased system performance (method 1 above could achieve up to 7% higher efficiency annually than the proposed HTO oil loop design). Additional considerations for all water designs are listed in Table 4.5.

4.4.6. Blow Down Heat Exchanger

The SSG blow down was investigated from a system performance view point where the necessity of a blow down heat exchanger was determined. The blow down heat exchanger transfers heat from

TABLE 4.5

COMPARISON OF ALL WATER AND HTO SYSTEM DESIGNS

<u>Item</u>	Benefit (compared to HTO design)	
	<u>Method 1</u>	<u>Method 2</u>
Operating pressure drop	-	+
Flow imbalance	-	+
Pumping power	+	-
Operating temperature	+	+
Operating pressure	-	-
System performance	+	0
SSG cost	+	+
HTO cost	+	+
Corrosion problems	-	-
Fire hazard	+	+
Start up problems	+	+
Freeze problems	-	-
Cool down losses	-	-

- indicates less desirable
- + indicates more desirable
- 0 indicates little or no difference

the hot water blow down from the SSG at 375°F to the incoming feed water at 210°F. Thus, a blow down heat exchanger reduces the discharged water temperature (and corresponding energy loss) from 375°F to about 220°F. With an ambient temperature of about 100°F, it can be seen that the energy loss when using a blow down heat exchanger is more than cut in half when compared to operating with no blow down heat exchanger. In addition, as shown in Table 4.3 on the Solar System Annual Losses, the blow down annual energy loss can amount to approximately 1.4% of the total collected insolation even when using the blow down heat exchanger. Thus, without the blow down heat exchanger, energy losses could amount to nearly 3% of the total energy available--an entirely unacceptable amount. This heat exchanger thus provides an equivalent capital cost savings of nearly \$3000 in collector area at minimal additional system cost.

It is important to note that the above blow down energy analysis is the "worst case" scenario in that the blow down is set at 10% of the steam flow from the SSG. While this value is presently that being used at the refinery boilers, the SSG is an unfired steam generator and is expected to require a lesser percentage blow down.

5 . FAMARISS ENERGY REFINERY DETAILED DESIGN

5.1 GENERAL DISCUSSION

The Detail Design for the High Temperature Process Steam Application at the Southern Union Refining Company, Department of Energy Contract #EM-78-C-03-2223, is described herein. The design consists of actual details for all the systems involved for installing and interfacing the solar system with the refinery. These different systems will be covered in depth in the pages below.

The bulk of the design is contained in the detail drawings included herein. The drawings are so oriented to allow a contractor or subcontractor to install and interface the proposed solar system to the refinery. The detail design differed from the conceptual design only if the actual hardware used could not satisfy the conceptual needs. Other changes came about due to later developments from the refinery, such as safety, access, and maintenance needs. There were also some modified changes to the original conceptual design which were made after the submitting of the conceptual design. These changes have been incorporated in the detail design.

Monument Solar Corporation studied all functions involved, including civil, mechanical, electrical, and architectural

to insure a sound detail design for the proposed system.

Considerable detailed planning by Monument Solar Corporation and the Southern Union Refining Company was involved to assure that a smooth interface between the solar system and the refinery existed. In accomplishing this work, Monument Solar Corporation was assisted on a subcontract basis by Bridgers and Paxton Consulting Engineers, Albuquerque, New Mexico and by New Mexico Solar Energy Institute, Las Cruces, New Mexico.

The conceptual design has been converted into an actual hardware designed system which will produce 1882 pounds/hour of 170 psi saturated steam to be used at the refinery for process steam. Detailed drawings describing the system are included below (reference to drawings will be by Drawing Number rather than Report Figure Number). All energy collected by the solar system (less parasitic losses), will be transferred to the refinery as process steam. In this energy transfer process, a substantial reduction in the amount of fuel consumed by the plant's existing boilers will be realized.

The solar system is a two loop system one being circulated heat transfer oil, and the other a feedwater-steam system. The actual flow diagram and description of operation is shown on Drawing # M-6, System Schematic.

The actual installation layout can be seen on Drawing #M-2,(2 of 5) Plot Plan. The following sections will describe in detail the actual design of the solar system. This will include the Solar Collector Array, Solar Building, Oil System, Steam System, Pump Selection, Control, Data Instrumentation, Power Requirements, Specifications and Drawings.

5.2 SOLAR ARRAY

The detail design of the Solar Collector Array was basically as presented in the conceptual design. The overall layout and dimensions are shown on Drawing # M-5, Plot Plan Collector Field. The actual positioning and design of the array layout took many factors into consideration as presented in sub-topics below.

5.2.1 Civil Works Analysis

a. Soil Analysis - In order to determine the proper foundation designs it was necessary to know the actual soil considerations that existed at the proposed plant site. This information was obtained from a soils testing engineering company which had made a sub-surface exploration at the Southern Union Gas Company (Famariss Refinery). Enclosed as Appendix A is a copy of that report which is segregated into three sections: Part I, Report; Part II, Field Investigation; and Part III, Laboratory Investigation. These findings provided the main foundation design criteria which is described in the next topic.

b. Foundation Designs - The main design consideration for the solar collectors, was the wind load which created an overturning moment to be totally resisted by the piers. A wind speed of 90 mph was used as recommended by the American National Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures (see Figure 5.1). The collector being of a concave shape required that the force obtained be multiplied by a factor of 1.4. The bearing and up lift forces were of lesser concern but were sufficient to be also taken into consideration.

The recommended soil bearing pressure of 7000 lb/sq.ft was used as furnished by the Foster Wheeler Corporation. The "pipe anchors" are in the same soil conditions as the collector piers but the main design consideration in this case was thermal expansion. A force of 7000 pounds was used as directed by the engineer from Monument Solar Corporation.

The "pipe supports" were designed to serve as a weight bearing support with minor consideration given to lateral loads. They were not to be rigidly affixed to the pipe and the only overturning forces resisted are those created by a wind load which is minimal.

For this application, based upon calculations included as Appendix B, it was decided that:

Fig. 5.1
 Basic Wind Speed in Miles per Hour
 Annual Extreme Fastest-Mile Speed 30 Feet Above Ground, 50-Year Mean Recurrence Interval

- o A 24" diameter pier with a 3'0" depth in the calachie layer be used as the foundation for the solar collectors.
- o A 24" diameter pier with a 3'0" depth in the calachie layer be used for the pipe anchors.
- o A 16" (or larger) diameter pier with a 1'0" depth in the calachie layer be used for the pipe supports.
- o A maximum spacing of 14'c-c be used on pipe supports.
- o Portland Cement Concrete Type II will be used.
- o A 3" cover be used on all steel - ACI 7.14.1.1
- o Tops of piers will have a trowel finish and allow no standing water.
- o All drilled piers will be inspected by the Field Inspector to insure proper depth and that no sand pockets are encountered.

These decisions were incorporated into the final installation drawings. For the actual pier layout, see Drawing # M-8, Collector Pier Layout, which shows the actual dimensions between collector piers. For details on the collector piers, pipe supports and pipe anchors, see Drawing # M-7, Collector Field Piping Details. Also listed on this drawing is the detail for the Hydraulic and Electrical Control Pad.

c. Trenching - During initial installation all necessary trenching can be completed. For trenching details see Drawing # M-5, Sheet 3, Underground Collector Field Lines. It should be noted that there is no particular preference as to

how the trenches are dug, however due to the hardness of the soil condition (caprock calachie), a small ditch digging machine will probably be used because it will be more economical. Backfilling of the trenches will be accomplished using the same excavated material if particle size does not exceed 3/4". If excavated material is larger than the 3/4" maximum allowed, then backfill material will be sand (desert blow sand). All trenches will be compacted to avoid any depressions. The trenching design has been laid out to utilize more than one pipe or conduit where possible, thus creating a savings in the installation costs.

d. Site Survey and Grading - A topographical and grading design drawing shall be completed at the beginning of Phase II for this project. However, all foundations, mounting pads and trenches have been referenced to a specific elevation already determined at the plant site. These reference elevations are indicated on the drawing.

At the beginning of Phase II a survey will be made to determine the actual grade and the site shall be graded to a specific elevation. Compaction of the top soil will be done to meet the minimum requirements listed under the Soil Analysis Report (III.A.I.).*

*Note that soil analysis recommendations call for removing original top soil. This will not be required or accomplished due to the nature of this project.

5.2.2. Piping Design

The piping design for the solar field follows very closely the conceptual design, the main exception being that main inlet-outlet header lines planned perpendicular to the field were actually laid out in a parallel direction. The location of the solar building was preferred by the plant personnel and also was in an optimum position for future collector additions.

The piping in the collector field will be schedule 40 ASTM A-53 Grade B ERW or equivalent (commonly called Black Iron) pipe. This particular grade of pipe will meet the requirements and will be used throughout the system. This type of pipe is readily available and very economical.

The main inlet-outlet piping will be 3" diameter while the inlet-outlet manifolds will be 2" diameter. The end connections from the manifold to the collector will be 1" diameter with flexible hoses being used. Use of these pipe sizes allows expansion of the collector field from 10,000 sq.ft to 25,000 sq. ft with no appreciable pressure drops encountered.

Drawing #M-7, Collector Field Piping, shows the actual layouts and dimensions to be used. Also refer to Drawing #M-7, Sheets 2,3,&4 in the actual field piping details. Also shown on these drawings are the location of the pipe supports and anchors.

The field piping plan reveals the collectors will have an isolating gate valve and throttling globe valve located at each collector row (row of 12). The gate valve will be provided for isolation proposed while the globe valve will throttle flow to compensate for header (manifold) pressure drops and these valves will also be isolating valves. No unbalanced flow problems of this nature are anticipated but these valves will correct for this problem. Each row of collectors will also have dial type thermometers mounted on the outlet side to provide an observation of the collector temperatures. Also mounted at each outlet end row will be a safety relief device. All piping in the field will be insulated and covered with a metal jacket. U-type pipe expansion loops will be located in the field for thermal expansion.

The following paragraphs discuss safety relief valves, expansion loops, details, insulation, thermowell design, and collector water usage.

a. Safety Relief Valves - Safety relief valves have been incorporated into the detailed design to protect personnel and property from injury in the remote event a malfunction may occur. This could happen in the event a complete row of collectors (12) were accidentally left in focus with the end valves closed. In that event, a potentially hazardous problem may occur due to overpressure in the receiver and a rupture of

the collector piping may result. This problem was eliminated by providing each collector row with the safety relief devices to prevent such pressure buildup. Proper relief valve sizing was established using the standard calculations.

b. Expansion Loops - Drawing #M-7, Collector Field Piping indicates the locations of the expansion loops that will be used in the system. All the expansion loops have been designed from the calculations procedures shown in "Process Piping Design" by Rip Weaver, section on Piping Flexibility Design, pp. 147-155. All the loops in this system are single plane U-bent type, guided configurations. Calculations for 3" diameter piping manifolds between the collector fields and the solar lab building, and for 2" diameter headers were completed and loop sizes determined. All of the loops are designed in such a way that no formal stress analysis should be required. The calculation procedure compared closely with other references.

c. Field Details - The basic piping details are shown on Drawing #M-7, Sheets 3 and 4. Note that all valves will be mounted where their stems will be in the preferred downward position or alternate horizontal position where possible. In the event of a valve packing leak most of the fluid will not accumulate inside of the insulation jacket thus creating a potential fire hazard if valves are mounted in this fashion. In general, all piping will be welded construction with socket weld fittings used over butt welds. This will help eliminate or significantly reduce the amount of debris, slag, or metal filings, reduce installation time, and increase the installation accuracy on pipe joints and angles. Although socket weld fittings will be somewhat higher in cost, the increased benefits in the above mentioned installation time, cleanliness factor and accuracy should more than offset these additional costs.

There will be places where socket welding will not be desirable and in these cases, 300 pound raised faced flanges will be used for connections. Proper torque will be used on the gasket to provide leak-proof connections.

An isometric collector field drawing, Drawing #M-9, illustrates how the inlet-outlet and mid-row connections will actually be accomplished. With this drawing and the appropriate detailed drawings, installation should be clear and straightforward.

Piping details will be supplemented with product specifications for all pipe and proper piping installation specifications to assume availability during the early part of Phase II.

d. Insulation - The amount of insulation used will be the amounts that were derived from the conceptual design. This provides for optimum insulation values, while being realistic and permitting consideration of pertinent cost factors for making actual selections. The main 3" pipe header will use a 4" insulation thickness with an aluminum metal jacket for protection. The type of insulation to be used will be a snap-on type (heavy density) fiberglass that is rated up to 850°F. This particular insulation will meet government specifications MIL-1-22344B, also ASTM C356, C335-69, ASTM C411, and ASTM-E-84. It will have a flame spread of 25, smoke development of 50, and fuel contribution of 50.

Fiberglass insulation will be used throughout the field except at pipe supports where calcium silicate will be used. The additional strength of calcium silicate will allow the weight of the pipe to actually be supported on the insulation. From other known projects, fiberglass has collapsed, thus creating a problem in the pipe support areas. For actual insulation details refer to Drawing # M-7. Note that the 2" pipe will use 3½" insulation, and the 1" pipe will use 2" insulation. Once again, this follows the original conceptual design.

There is little difference in the cost of fiberglass and calcium silicate, however the insulating qualities of fiberglass are about 5 to 10 percent better than calcium silicate. The snap-on fiberglass insulation will decrease the installation labor cost due to the complete cylindrical sections that snap-on to the pipe instead of handling two or more sections of insulation for each section of pipe.

e. Water Service for Collector Cleaning - Contamination should be a minor problem, however experience from other known solar projects reveal that a good maintenance cleaning program will maintain higher collector efficiency. This cleaning will be accomplished by installing water hydrants in the collector field. These are shown on Drawing #M-5, Underground Collector Field Lines. This water system has adequate pressure and supply to meet the needs for collector cleaning.

There will be inline portable deionizers to make sure that the water used will be free from dissolved solids, such as calcium and magnesium, which accounts for the major part of hard water which is common throughout the area. This will prevent further contamination of the collector due to the cleaning water.

f. Thermowell Designs - Carbon steel thermowells have been selected for inserting a temperature measuring devices,

such as thermometer and thermo couple (J type). Carbon steel thermowells were selected to match the proposed carbon steel pipe. They will be mounted on with proper insertion depth and then welded. The error in the thermowell readings have been studied, using Hilpert's equation and section 13.4 in Heat Transfer, second edition, by Alan J. Chapman. The result showed an insignificant error in reading, since the well and its surrounding would be insulated.

5.2.3 Piping Field and Layouts

Piping field layouts have been designed with consideration of minimum pressure losses and optimum economics. Different layouts were considered and the final selection, which is the current design of the system, was determined (see Field Piping Plan Drawing #M-7). Although a minor problem exists of collectors being completely closed in by the piping which will be installed around them, this problem will be solved using wooden ramps which would allow vehicles to go over the pipe. Once the system is in complete operation, the ramps would be needed only for maintenance reasons. The present design has the minimum number of joints, fittings, turns and expansion joints, thus satisfying the minimum pressure loss requirement along with economic feasibility. Due to the size of the proposed field, this problem does not appear to hinder the future operation of the system, and was more than offset by the economical savings. It should be pointed out that collector cleaning can be accomplished by hand, due to the size of the field.

5.2.4 Collector Details

The conceptual design was validated for the use of the T-700 Parabolic Trough Solar Collector manufactured by Solar Kinetics, Inc. This collector filled the exact needs for the proposed High Temperature Industrial Process Heat project. The conceptual design centers about the use of this collector, so this report will discuss the details of the collector in somewhat more detail. The manufactures actual technical and hardware data is included as Appendix C below.

Solar Kinetics, Inc., has done an exemplary job of describing their collector and supporting equipment and its characteristics and weaknesses. They have well defined their components and their hardware and actual installation instructions for putting together the individual collector systems are included in Appendix C for clarification. A discussion of the tracking drive system and a detailed series of collector parts is also included in this Appendix. An isometric Drawing #M-9 has been provided to show the detail installation connections for the prepared system. Also note that Drawing #M-8 gives the actual pier layouts for mounting of the pylons.

These details were used for interfacing the complete collector field piping arrangements, as can be seen in the list of drawing provided later in this report.

5.3 SOLAR BUILDING

The Solar Building proposed will be a pre-fab metal building with approximately 400 sq.ft of room. The building will be divided into three areas:

- 1) Visitor and Demonstration.
- 2) Control Room.
- 3) Equipment Room.

Referring to Drawing A-1, Architectural Floor Plans and Evaluations show the actual size and layout of the building and its rooms. Also included in this drawing is the actual fabrication details. The building will be insulated as shown and there will be a sound barrier located between the visitor-control rooms and the equipment room. There will be access between these two rooms via a doorway and there will be an observation window to allow visitors to see into the equipment room. Large double doors will be located in the equipment room for maintenance access. All areas will be provided with lighting, heating, cooling and ventilation. The design of these items are covered in sub-topics below.

The estimated building cost and installation will be only 1.8% of the total job cost. The building will provide many advantages over the equipment being exposed to the outside environment. But the most important point will be the aesthetic value to the solar project that the building will provide, remembering this is a demonstration project in which many visitors are anticipated.

5.3.1 Lighting Design

The lighting design was completed for the building by using the standard zonal cavity method (from Standard Handbook for Electrical Engineers, Tenth Edition). The levels of illumination was from a standard recommendation chart for different types of areas. The following footcandle recommendations were used:

- 1) Control Room - 70 footcandles
- 2) Visitor & Demonstration Room - 70 footcandles
- 3) Equipment Room - 50 footcandles

The calculations were found using the zonal-cavity method and using an industrial 2 lamp, 40 watt, 4ft. florescent - 6400 lumens, 10% uplight fixture.

The actual lighting layout can be seen on Drawing E-7, Solar Building Conduit Layout.

5.3.2 Heating Design

The heating of the solar building will be accomplished by using standard electrical heaters or by hot water heaters. The actual installation cost of the electric heater will be half the cost of using the water heaters. However, on an energy basis the water heater would account for a substantial savings. These two items are presently being weighed and compared against each other in order to determine which system to go with.

As was pointed out in the conceptual design, this heating of the solar building will only account for .4% of the total energy collected.

5.4 OIL SYSTEM

The oil system, or Loop I as mentioned in the conceptual design, was designed for the purpose of receiving energy from the collector system and transporting this energy to the steam generator where, through a heat transfer process, steam is generated to be used in the Southern Union Refinery. This discussion will be broken down into four main parts:

- 1) Oil Selection
- 2) Oil Reservoir and Expansion Tank Design
- 3) Filterings and Make-up System
- 4) Recommendations

These will be discussed in detail later on in this report.

The total oil system will be capable of holding approximately 380 gallons fully charged.

5.4.1 Oil Selection

Monument Solar Corporation believed it imperative that the industrial steam process of the refinery not be contaminated in any way by the supplying of solar generated steam. To ensure this, a two loop system was chosen with Loop I connecting the solar system to a heat exchanger (SSG) to the refinery. To obtain optimum heat transfer capabilities and simultaneously counteract the liklihood of freezing during cold weather, an

oil was tentatively selected for Loop I. Because of their availability, low cost, and extensive long term service, a heat transfer oil was chosen.

Typical heat transfer oils which could be used as an energy transferring media were identified for potential use in the solar industrial process heat application. Several man hours were spent collecting and reviewing the different types of heat transfer oils available on the market today.

Even though a two loop system and a heat transfer oil had been tentatively identified during the conceptual design stages of the project, water to steam conversion was thoroughly reviewed. It was quickly ascertained that this would have presented inherent problems such as high pressure, freezing conditions, water treatment considerations, and high corrosion in the collectors. It was more firmly decided that a heat transfer oil would better fit the needs of the project, based upon this detailed study. The remainder of this section will be dedicated to design considerations and the selection process.

a. Project Specifications - The primary design considerations were connected with the solar collectors. These collectors have certain limits requiring the rest of the system to be designed around them, with emphasis placed on the maximum collector temperature being 500°F and maximum pressure 250 psi. The oil selection had to be comparable with these considerations, but there were many more pieces of equipment that

also had similar design considerations and therefore, the proper oil had to match these conditions also. The different parameters that had to be satisfied in selecting the heat transfer oil are discussed below.

Solar Collectors

1. Maximum temperature 500 degree F
2. Maximum pressure 250 psi
3. Good heat transfer capabilities

Steam Generator

1. Must have good heat transfer capabilities
2. Must be compatible with metal construction

Pump

1. Must have a pumpability range over a wide temperature range of 0 - 500 degree F
2. Must not form vapors thus causing cavitation
3. Must have known specific gravities for proper sizing of pumps

Mechanical Piping

1. Must be compatible with metal construction
2. Must have low-vaporization to maintain lower pressures

Oil Reservoir and Expansion Tank

1. Must not have an excessive thermal expansion.

Safety Precautions

1. Must have low volatility
2. Must have high flash point

System Reliability and Cost

1. Oil must perform continuous without being replaced

b) Oil Specifications - As shown above the oil had to match several parameters in order to qualify. Listed below are several factors considered which gave a set of guidelines to be met to satisfy the needs of the system:

1. High Thermal - Conductivity - enabling it to transfer heat effectively
2. High Specific Heat (heat capacity) - capacity to supply or remove heat effectively
3. Low Viscosity Range - for high rate of circulation over a wide range of operating temperatures
4. Low Specific Gravity - to reduce pump power requirements
5. Low Pour Point - to insure pumpability in cold weather start-ups
6. High Flash Point - reduces the danger of fire or explosions
7. High Thermal Stability - Improves its resistance to oxidize or thermal cracking at high temperatures
8. Low Volatility - prevents oil from vaporizing and causing excessive pressure in closed systems.

c. Selection Process

The selection process mainly consisted of gathering data and presenting this data in a comparison chart form. Some of the items mentioned in the previous section were not considered if it was apparent they would not have an adverse effect on the system.

Referring to the comparison chart, the GE silicone fluids were ruled out due to their high cost and were not competitively considered.

Referring to paragraph b, the three oils which matched these considerations are listed in order of preference:

1. Texaco Regal R&O 46
2. Therminol 55 (product of Monsanto)
3. Exxon Caloria HT-43

It appears that any of the above three could be used in the system, however the Texaco Regal R&O 46 was favored mainly because of the lower pour point. The thermal capabilities on the above are almost identical as seen from the comparison chart. The cost of Texaco and Exxon are almost identical, and therminol being somewhat higher. Therefore, the final selection was Texaco Regal R&O 46 (Texatherm) as listed in the order of preference above.

5.4.2 Oil Reservoir and Expansion Tank Design

The design of the oil reservoir and expansion tank considered a number of important and essential criteria. The most important considerations were 1) the system must operate over a broad temperature range in which a large expansion factor had to be offset

	TEXACO REGAL R&O 46	MOBIL THERM LIGHT	MOBIL THERM 600	MOBIL THERM 603	EXXON CALORIA HT43	DOW THERM J	DOW THERM LF	DOW THERM G	DOW THERM A	THERM- INOL 44	55	60	66	GE SILI- CONE FLUIDS
THERMAL CONDUCTIVITY														
BTU/HR/SQ. FT./°F/FT. 500°F	.067	.059	.061	.067	.068	.065	.063	.070	.064	.058	.066	.065	.063	
HEAT CAPACITY														
BTU/LB/°F 500°F	.656	.620	.621	.656	.70	.649	.550	.510	.550	.607	.67	.593	.580	
VISCOSITY RANGE SUS														
°F 10000	10000	380	90000	3500	3500	32	130			600	7500	300	100000	
400°F 31	31	0	10	10	20-30	0	0	17	7	0	10-15	10	15	
SPECIFIC GRAVITY														
60°F .88	.88	.983	.966	.865	.859									
77°F .72	.72					.64	.85			.78	.72	.83	.80	
500°F														
POUR POINT	5°F	-20°F	0°F	20°F	15°F	-100°F	-25°F	+20°F	+54°F	-80°F	-5°F	-60°F	-18°F	-13°F/ -100°F
FLASH POINT	430°F	250°F	350°F	380°F	420°F	145°F	260°F	305°F	255°F	405°F	355°F	310°F	355°F	125°F/ 500°F
MAXIMUM TEMPERATURE														
CLOSED SYSTEM	600°F	400°F	600°F	600°F	600°F	575°F	600°F	700°F	750°F	425°F	575°F	600°F	650°F	400°F/ 600°F
COST \$/GALLON	1.60	1.55	1.79	1.61	1.52	5.27	7.56	8.00	7.00	7.50	2.75	6.60	8.18	16.00/ 80.00

Table 5.1

Comparison Chart

and 2) at the higher temperatures the oil could vaporize and would be above the flash point thus creating a fire hazard.

These problems were handled by using a vertical pressurized tank with sufficient capacity to allow expansion and to be pressurized with a nitrogen blanket to prevent any air-oil vapor mixture, thus eliminating any possible fire hazards. The pressurized system will also prevent vaporization of the oil and will provide a positive suction pressure on the system pumps, which will ensure that pump cavitation does not occur.

The nitrogen blanket also prevents the oxidation reaction with air which causes the breakdown and formation of oxidation sludges that may otherwise insulate the lines and heat exchanger tubes against efficient heat transfer and also may cause obstruction to the fluid flow. The vessel will also have high and low alarms for protection on low oil level which would indicate a leak in the oil system. The high level alarm will indicate a leak into the oil system. In either case these devices will adequately protect the system.

Major concern has been indicated on the possibility of an oil leak in the steam system which could possibly cause contamination in the process of the refinery. The position of the low alarm device has been designed to shut down the system upon a 40 gallon loss of oil. This amount of oil contamination was

introduced at the refinery and found to have a minor contamination effect upon the actual refinery process. Actual details of the expansion and reservoir tank can be seen on Drawing #M-4, Mechanical Details.

As mentioned earlier, the vessel will be pressurized with nitrogen. This nitrogen will be provided by using a standard nitrogen bottle (2200 psi, 275 scf) with a reducing pressure regulator to maintain the pressure at 15 psi. As per the ASME codes, this vessel required a tank safety relief which has been provided. However, the main concern for the tank was in care of a nitrogen regulator failure and thermal expansion in which the tank could be subject to full bottle pressure and high gas pressure due to thermal expansion.

The relief valves should probably be sized for set pressure 55 psig with very small capacity, i.e. 1000 scfh minimum. This could be satisfied by a NUPRO "4CA" Series adjustable inline relief valve (pp 4&5 of Brochure) or NUPRO "4CA" or "8CPA" Series valves. NUPRO "R" Series Safety Relief Valves are slightly too small, but a preferred since they are externally adjustable (Z on 50 psig expansion tank should be sufficient).

5.4.3 Filtering and Make-Up System

The filtering and makeup system will consist of a 30 gallon open holding tank with a 13 gpm, 100 psi rated positive displacement 3 horsepower pump. Refer to Drawing #M-1, Sheet 1-5,

Equipment Schedule for details. This will allow the system to be filled in approximately 30 minutes. All new oil going into the system will pass through a 50 micron filter. There was some consideration given to the possibility of using in-line filters in the main oil flow system, however this would have been very expensive and could not be justified due to the simplicity of this system. It should be noted that Y-strainers are located in the system which will provide adequate protection to the system hardware. For the actual installation of the make-up system refer to Drawing #M-2, Sheet 3 of 5, Mechanical Floor Plan, piping isometrics. It is shown here that clean oil enters the system and since the system is a closed pressurized system it will remain free of contamination.

The oil will be sampled periodically in order to determine if contamination has occurred and also to check if any degradation has occurred. Commonly the following will be checked to see if this occurs; flash point, viscosity range and solid contents.

3.4.4 Recommendations and Precautions

The Texatherm Heat Transfer Oil cannot be used with copper and its alloys because copper acts as a catalyst and degrades the hot oil. Therefore, in the oil system all piping material is either iron or steel.

5.5 STEAM SYSTEM

5.5.1 Steam Generator

The steam generator will be a packaged type generator manufactured by the Patterson-Kelley company. The generator will be a Series 380 model HTO 369. It will have the capability of producing 0 - 2000 lbs of saturated steam per hour at 175 psig. The oil flow requirements to meet the above peak generation have been set at 125 GPM and 500°F which will be supplied by the solar collector system. The feedwater supply to the generator will be 220°F treated water. The generator shall be a shell and u-tube arrangement with the water-steam being contained in the shell side. The generator is a skid-mounted unit with lift lugs for hoisting into place and it can also be moved by rolling or sliding.

The tank or shell will be amply proportioned to store a large volume of water at saturated steam pressure. Intermittent feedwater injection will then have little or no effect on steam output, however, this will be enhanced even further due to a blowdown-feedwater heat exchanger for pre-heating the incoming feedwater. Water entrainment in the emerging steam will be removed by a steam separator mounted at the outlet steam line.

The shell is designed, constructed and stamped to requirements of the ASME code Section VIII for unfired pressure vessels.

These units are fully x-rayed and stress relieved after fabrication to ensure a sound and safe operating condition.

The tube bundles for circulation of the high temperature oil is of the single tube sheet u-tube design. They are capable of operating without damage in the event the steam generator is run absolutely dry. They will also be able to withstand a sudden injection of cold feedwater while they are at steam-generating temperature. The tubes will be 314" OD #18 BWG stainless steel. The stainless steel tubing was used over copper-nickel due to conditions limiting the use of copper-alloy on systems using the heat transfer oil (the problem was discussed under Section 5.4).

Large tube supports will maintain the proper tube alignment in the tube bundle. These supports rest on tracks inside the shell and whenever the bundle must be pulled for inspection or service, these supports will slide on the tracks for easy tube bundle removal.

The generator will be provided with a safety relief valve mounted on the steam shell side for overpressure protection. This valve has been selected and sized properly per the ASME Section I Boiler code. There will also be tandem blow-off valves installed for blowdown and draining the generator.

The generator will be furnished with a combination water column and feedwater controller for monitoring and controlling the feedwater to the generator. There will be various pressure gauges, temperature devices, alarms, etc., supplied with the system. See Drawing #M-1, Equipment Schedule and Drawing #M-2, Mechanical Floor Plan, Piping Isometrics and Flow Schematic for actual details and installation. See Section VIII, Control System, for the actual control of the steam generator. The steam generator will also be furnished with an insulated cover to provide an almost 100% thermal heat transfer capability.

5.5.2 Blowdown System

The steam generator will be equipped with a continuous blowdown system that will be able to control the total dissolved solids in the steam generator, thus helping reduce the amount of fouling on the generator tubes and maintain peak thermal efficiencies in the generator. More important, the blowdown system will maintain steam purity by preventing solid carry-over into the plant's steam system. The amount of blowdown for a worst case condition can be estimated at 10%. However, it should be noted that unfired generators normally experience much less than this. The feedwater solids content coming into the system will be low because all of the feedwater has already been treated with zeolite water softener and deaerated with the plants existing equipment.

To ensure proper steam conditions a sample coil has been provided to take samples of the blowdown water and main output steam from the generator. These samples will be taken on a periodic basis by the plant chemist to check the quality of steam. If necessary, then the blowdown may be adjusted to correct the problems. Referring to Drawing # M-2, Mechanical Floor Plan, Piping Isometrics and Flow Schematic will show the sample coil installed near the generator.

This sample coil, as seen from the above drawing, will also be used as a blowdown-feedwater heat exchanger which will help preheat the incoming feedwater. The discharge from the blowdown will then be directed to the dry-well seepage tank located outside of the solar building.

The amount of blowdown that is necessary will be determined experimentally after start-up. Basic control of the system blowdown will be slaved off of a steam flow control device which can be set 0 - 2000 lbs/hr to activate a control valve for automatic blowdown. The quantity of blowdown will be manually controlled and once set, will require very little attention. Thus, the blowdown control becomes an automatic function of the basic control scheme

5.5.3 Main Steam Line

The main steam line which connects the steam generator to the plants main steam header will be 2½" schedule 40, grade A53, carbon steel pipe. This particular size was conceived to be the ideal size that was designed during the conceptual design stage of Phase I. As pointed out, this line size will also handle the extra steam requirements if the collector field were increased to 25,000 sq. feet. As in the design of the collector field, all piping will be of the socket weld type. Referring to Drawing # M-2, Mechanical Floor Plan, Piping Isometrics, and Flow Schematic. The steam isometric shows all of the steam piping inside of the solar building. The steam line runs overhead in the building then drops downward into a sump pit where a condensate trap is mounted, then goes under ground to the main plant steam header located near the existing cooling tower. At this point, the line commences out of the ground and upward to the main off-on electrically operated control valve which ties into the main isolation valve on the main plant steam header (see Drawing # M-2, Sheet 2 of 5, Plot Plan and Drawing #M-4, Mechanical Details.

The main steam line was run underground due to the access that must be maintained between the existing cooling tower and the solar installation. This line was sloped going back to the condensate trap in order to catch all condensation during operation and after the system shuts down at night. The remaining condensate from the system is a very important factor and will be covered later on in this report.

The insulation inside of the building and on the vertical pipe run at the cooling tower will be snap-on type heavy density Fiberglass 3½" thick with an aluminum metal jacket. The insulation for the underground piping will be a Zcrete b-t-u-water resistant monolithic conduit. For actual installation details refer to Drawing #M-2, Sheet 1 and 2, Mechanical Details.

5.5.4 Feedwater Line and Return

The design of the feedwater and return system, as shown in the conceptual design, was also sized to handle the collector field of 25,000 sq. feet. The feedwater line will be a 1" schedule 40, carbon steel pipe and the return line will be ½" pipe, same make as above. The insulation on the piping will be a snap-on type heavy density fiberglass 1½" thick with an aluminum metal jacket. The feedwater-return lines will travel the path as the main steam line and will be enclosed in the same type of underground insulation (see Section 6.3). The feedwater-return line will travel approximately 800' on an existing pipe rack and will tie in at the plant's boiler feed pumps. For actual installation details, see Drawing # M-2, Plot Plan and Drawing #M-4, Sheets 1&2, Mechanical Details.

The feedwater will be taken off of the output of the boiler feed pumps at a pressure of 375 psig, 220°F. The return will be tied in at the suction side of the pumps at approximately 25-30 psig. Referring to the Mechanical Details M-4, sheet 4 of

5 (Feedwater Pump Connection Detail) it should be pointed out that a manifold for both the feedwater and return line had to be built in order to tie in to the existing system without a shutdown.

The thermal expansion factors for the two lines will be handled the same as the main steam line mounted in the underground insulation. The expansion factor for the pipes once they are mounted on the pipe rack will be simply anchored at designated positions and expansion will be taken up in the elbows.

During the conceptual design, it was decided to have the steam generator located near the solar collector and install a small feedwater line from the existing boiler area to the solar building. It was obvious that the initial installation cost is considerably cheaper using this method. However, this did present a problem in freeze protecting this pipe. There were three methods considered on protecting this line from freezing.

1. Electric-heat tracing
2. Feedwater re-circulation
3. Feedwater continued circulation and dump

The first method (electric-heat tracing) was readily ruled out due to the inefficiency of using electric energy vs already available hot water. Also, electric-heat tracing is a high maintenance item.

Method three from an energy basis was very acceptable, except that problems arose as to what to do with waste water and the wasting of already treated water at .07 cents per gallon was a major drawback.

The second method was the accepted one and is shown on Drawing #M-2, Flow Schematic. The feedwater will be continually circulated thus preventing the freezing of the line. However, there will be approximately 1% overall energy loss as was shown in the conceptual design. The circulation will be controlled by a fixed orifice in the return line.

5.5.5 Pressure and Flow Control

The steam generator pressure range will be set by the main plant steam header which is maintained at 170psi. The generator will be connected directly to the main header via a swing check valve and electrically operated motor control valve (off-on).

When the solar collector field begins collecting energy, the pressure in the generator will rise until it is slightly higher than the plant pressure (170 psi). At this time, steam flow will commence and will be directly proportional to the amount of energy collected. As the steam flow increases the pressure drop between the steam generator and the plant steam header will increase thus raising the pressure in the generator to establish the proper flow. Figure 5.3 shows how the steam generator pressure will vary with steam flow and solar energy input.

GENERATOR STEAM PRESSURE

DIRECT NORMAL INSOLATION

FIGURE 5.3 STEAM GENERATOR - PRESSURE vs
STEAM FLOW AND ENERGY INPUT

From an instantaneous basis, once the solar steam generator starts injecting steam into the plant process header momentarily the plant's header pressure will slightly rise, thus causing the existing boiler pressure controls to reduce their firing rate and flow rate which would bring the pressure back down to the set point of 170 psi. The response time of the existing boiler controls are very fast and can presently handle a 50% load swing without any ill effects on the plant's process. Therefore, the total effect of the solar system (10%) will have negligible effect on the plant's process boiler pressure controls.

5.5.6. Condensate Trap Design

Condensate removal is an absolute necessity in the steam line. The plant has a number of small turbines that operate from saturated steam lines, thus excessive water in the system can be very detrimental on these turbine blades and the impingement of water particles can cause blade failure. Another important feature is, when condensate remains in contact with hot steam it will cause severe "water hammer" which is annoying and can shorten the life of the equipment and piping systems.

The main steam line has been designed with a gradual slope going back to the solar building sump where the condensate trap is located, thus ensuring the drainage of all condensate during

operation and shutdown periods. This condensate will then be discharged to the drywell seepage tank located outside of the solar building.

From the proper calculations, it shows that "worst case" conditions and added safety factor has been installed in sizing of the steam trap. A model #1011 $\frac{1}{2}$ " inverted bucket trap 400 psi rated, 860 lb/hr at 200 psi has been selected. Also the inverted bucket trap will also vent unwanted non-condensable gas which will help reduce corrosion and blanketing effects in the system.

5.6. PUMP SELECTION

The system will use Viking heavy-duty positive displacement pumps. These pumps will be used for the system start-up capability and another for normal operation. This will allow the pump for normal operation to be sized more nearly the normal running load, thus run more efficiently. The other pump is sized for start-up conditions and will run only during these times. Referring back to the conceptual design, pressure drop considerations for cold oil (start-up) and hot oil (normal) conditions were looked at and calculations revealed the sizing of the pumps. It works out that for a flow of 125 GPM and pressure drop of 35 psi, a 5 horsepower size pump would be proper. Referring to the cold start-up conditions, the other pump would be a $7\frac{1}{2}$ horsepower pump at 35 GPM and pressure drop of 120psi.

The above pressure drops were calculated again after the final detail piping design was completed in order to obtain the corrected motor horsepower requirements. These positive displacement pumps are specifically suited for transporting heat transfer fluids. The actual details and specifications on these pumps can be seen on Drawing #M-1, Equipment Schedule. These pumps will have a high temperature mechanical seal in order to prevent the leakage of oil as would commonly be experienced with a standard packing gland. These pumps also have a built in adjustable high-pressure relief device. In making comparisons with centrifugal pumps' efficiencies, the two are actually about the same. The main advantage of the positive displacement pumps in this case was to ensure a constant flow rate through the collectors where a centrifugal pump would require a throttling valve to control flow, thus requiring more pump power due to the additional pressure drops in the throttling valve. It should be pointed out that other solar projects have used positive displacement pumps with very good success.

One pump could have been used for both cold start-up and normal running operation. However, the larger horsepower motor required for start-up would then run at much lower efficiency during normal operating conditions.

5.7 CONTROL SYSTEM

This system will control the solar process steam to be supplied to the Southern Union Refining Company's Famariss Energy Plant. The solar system as described in the conceptual design is a "two loop" system. Referring to Drawing #M-6, System Schematic, the solar system primary loop (loop I) is that loop containing the fluid moving through the collectors. The secondary loop (loop 2) is the feedwater/steam loop supplying steam to the process as it comes out of the steam generator.

Energy input will be accomplished by solar collectors operating with a typical heat transfer oil circulated through them. This forced circulation will be achieved by a positive displacement oil pump. The heat transfer oil will be transported through a steam generator and give up its energy in the production of steam. This steam will be used in the plant's operation as process steam.

The amount of steam (lbs/hr) produced will depend upon the amount of energy collected taking into account the efficiencies and parasitic losses of the system (see Section 5.5). This will be accomplished by using a direct-acting temperature control valve which will maintain a constant oil flow through the solar collectors but will let a variable flow go through the steam generator.

The oil flow through the generator will be maintained at a minimum temperature of 375°F ensuring steam generation. This generation will increase as the solar energy input increases. During periods when there is very little energy input such as start-up or transient cloud cover, the control valve will by-pass the steam generator completely and circulate the oil until sufficient energy is obtained in the oil to allow normal operation. The by-passing of the generator during cold start-up will also reduce the start-up differential pressure thus requiring less energy on start-ups.

Sequence of System Operation

This system is designed to be completely self-operating. The light sensor detects light and activates the start-up pump after receiving an operating condition signal from high and low oil level sensors, high oil pressure and temperature sensors in the HTO line, high water level sensor in the steam generator, and high steam pressure sensor in the generator. The above tripped signals are reset manually. Momentary wind and rain operating signals also need to be obeyed. The start-up pump would conclude operation when the required temperature is reached, (200-250°F) shifting to the normal operating pump. Simultaneously, when normal oil flow is reached; ensured by a flow switch, hydraulic tracking devices are actuated and start tracking if there is no fault within the system. Steam generation is accomplished when the hot oil line furnishes fluid

to the generator controlled by a 3-way temperature control valve which also bypasses the generator if the temperature of the returning fluid has not reached the required operating temperature (above 250°F). Actual steam injection occurs if the generator pressure is higher than the existing plant pressure. Once this occurs, a differential pressure device activates the main steam valve which is electrically operated. The water level switch controls the input of water to the steam generator. Normal steam flow (0 - 200^olb/hr) is detected by a flow annubar which is connected to the flow recorder. If the flow is over the normal requirement, the blowdown valve is turned on which allows the excess water out through blowdown lines. If high steam generator pressure occurs, it is relieved through the relief valve on the generator if the automatic triggered device (high pressure switch) fails to operate. Relief valves are also provided at the outlet end of each row of collectors for excess pressure in the collector receiving line.

Power input is 220-110V, 3 phase - 60 hz for normal operation of the entire system. In case of power failure, battery operated power supply brings the collectors back to the stow position. The batteries are kept charged all the time by automatic battery charger.

5.7.2 Control Schematic

The control schematic is the standard ladder type electrical control. The control devices are of the relay logic type and the alarm functions are indicating lights. The control system is 120 volt AC. The above section gave a brief explanation on how the control system functions in general. Below will be a detailed description of the complete system. Refer to Drawing #E-1, Electric Control Schematic.

The master run relay (K17)(Line 27) will be the main control logic connected with this system. The K17 relay will be set up as a RUN and TRIP function. The RUN function will be initiated either by a manual start switch (S13) or an automatic light photocell switch. This photocell will provide an automatic start-up every morning when sufficient sunlight is available.

The TRIP function can be initiated by a manual stop switch (S14). The photocell switch, Line 26 will allow automatic shutdown at the end of the day, or an additional TRIP function which will be tied into a trip logic relay (K16) contact line 27. The TRIP functions are interlocked in series from their respective relays to control K16 relay. Note that if any one function is not normal, then relay K16 remains tripped. Also it requires a manual reset and operators attention. These TRIP functions are: low oil level (K1, Line 1), high oil temperature (K4, Line 4), high

oil pressure (K5, Line 5), high water level steam generator (K6, Line 6), high steam pressure (K9 Line 9), and high oil level (K20 Line 22). There will also be rain and wind protection (K14 & K15, Line 15 & 16) which will be provided for collector protection, however note that both of their functions will have the capability of re-starting the system. If K17 on Line 27 is in the ready condition, K14 & K15 are interlocked with K17 on Line 30. When K14, K15 & K17 are normal then the system RUN light comes on and the system now controls the oil pump control logic, the collector tracking system and the steam generator control. The main and start-up oil pump control relays, K18 & K19, Line 31 & 32 are interlocked with each other through a K19 contact to insure that both pumps do not run at the same time. If the oil is below 200-250°F then temperature switch S17 remains open thus preventing the main pump from running. When the oil temperature rises and S17 closes then the main pump starts and shuts down the start-up pump via K19 contact (Line 31) interlock.

The steam generator control is also slaved off of the RUN function line through contact K8 and K10 Line 36 & 37. The main purpose of this control is to determine when the generator has adequate pressure for generation and open and close the main steam valve (Line 40). This is accomplished by a low pressure switch relay (K8 Line 8) and differential pressure switch relay (K10 Line 10). The low pressure steam switch will provide shutdown protection (Line 41 , K8 contact) in case of a plant

emergency shutdown or tripping of the plant steam boilers. The differential pressure will ensure a positive steam flow to the plant. This device will monitor the steam generator pressure and plant steam pressure, making sure the steam generator pressure is always higher than the plant pressure.

The main steam valve is motor operated with a manual override (open and close) push buttons S19, S20 Line 39 & 40 . The main steam valve also has function indicating lights for open and close position, Line 38 & 42 .

The master tracking control is also slaved off of the run circuit. Its main function is to ensure that the collectors have a sufficient oil flow (contact K2, Line 33, K2 oil flow relay line 2) before they are subject to the high intensities of the sun's energy. Therefore, the master run control also gives the command signal to the hydraulic system (Line 33) which drives the collectors. The hydraulic system in turn controls the tracking via K11 relay (hydraulic fault) Line 11 .

The hydraulic and enable tracking controls are interfaced with and actually part of the Solar Kinetics, Inc., (SKI) tracking control system. This will be discussed in detail below.

5.7.3 SKI Tracking System

The SKI tracking system is designed to be a servo loop controlling solar collectors. The SKI system tracks the sun in order to maintain and keep the collectors in focus, thus maintaining maximum efficiency.

The SKI system employs a hydraulic drive system in which hydraulic pressure is obtained by a hydraulic pump and transmitted to hydraulic cylinders for actual movement of the collectors. The hydraulic cylinders are directionally controlled by 3-way electrical solenoid valves. These receive directional controls from the sun tracking servo amplifier. As the sun continues to move during the day the tracking device moves the collectors via hydraulic cylinders and maintains the collectors in focus. Limit switches mounted on the collectors are used for failsafe end travel to prevent any mechanical damage. They also provide a home position in either the North or South directions for the collectors.

The system has a stow relay which is directly controlled by the master tracking relay via the track enable. This relay will automatically position the collectors in a North or South stow position on system shutdown.

The SKI system has a DC voltage back-up system which will insure hydraulic pressure to stow the collector in case of a

power failure or pump failure. SKI also employs mid-row temperature protection on the collectors. If the circulating oil becomes too hot, the system will drive the collectors to stow position. The system also has complete manual control (local or remote). For a more detailed description, the following drawings and operation explanations have been included in Appendix C.

- 1) Automatic Tracking
- 2) Manual Control
- 3) Electrical Schematics, Drawing #78-1-23, 78-1-24
- 4) Master Power Supply Hydraulic Schematic
- 5) Tracker Hydraulic Schematic

Tracking is achieved through the use of two light sensitive transistors positioned equally between a shadow bar. When the shadow bar is pointed directly at the sun the shadow splits each transistor. As the sun moves the shadows become unequal and an electronic imbalance is sensed by the tracker control causing either the east or west relay to be energized. This completes a circuit to the hydraulic fluid control valve which directs pressurized fluid to the tracker drive causing the collector to move until the shadow bar is again pointing at the sun. In this position the tracker control is in dead band and neither relay is activated. A dead band adjustment is provided which will change the sensitivity of the tracker. An adjustment providing accurate tracking during clear days but preventing searching during cloudy conditions is desired. A time delay adjustment is also provided. Proper adjustment of these two

pots will provide accurate pointing and keep the system in dead band during cloudy periods. Limit switches are provided to prevent overtracking in the automatic mode.

There are several conditions under which the collector should be sent to the stow position. They are, over temperature, rain, night fall, high winds and loss of flow. Any number of field contact closure devices can 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 east side.

The stow slave relay is energized when the stow relay loses its signal (open circuit) and the east 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 dead band 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 up to the stow position and remain until all switches are closed.

When the manual (local) position is selected on the local/remote switch at any drive pylon the automatic shadow bar tracker is deenergized and power is directed to the 3 position momentary directional switch next to the local/remote switch. Selection of either direction on the switch will drive the collector either east or west at the rapid stow rate.

If the over temperature switch or any other hazard stow switch opens the circuit to the stow relay the collector will be driven to the stow position whether the local or remote position has been selected. Only in the center off position can the stow mode be overridden. Caution should be exercised when the local/remote switch is in the off position since focus without flow will cause overtemperature resulting in damage to the receiver.

Systems requiring remote manual direction control use relays to replace the action of the 3 position momentary directional switch. With this feature either east or west stow speed control is available from a remote location.

When adjusting the tracking speed rate with the system in automatic (remote) an imbalance may be caused by shadowing one transistor artificially causing the collector to track at the slow speed. Correct tracking speed should be between 0.1 and 0.3 RPM.

5.7.4 Control Rack

The control panel will utilize standard standby-metal racks.

These racks will have panel inserts for the following devices:

- 1) Recorder for measuring steam pressure and flow and oil flow,
- 2) Temperature recorder for measuring up to 12 points in the system,
- 3) Control panel for system control and monitoring,
- 4) Wind Panel - for wind control.
- 5) Additional panels will be used for the data instrumentation.

This control rack will be mounted in the proposed control room. For rack and panel details refer to Drawing #E-5, and #E-6, Sheet 1-4, Control Panel Rack Assembly and Details.

The control panel will be the heart of the system and will provide direct control and monitoring of the system. Referring to Drawing #E-6, Sheet 1-4 shows the actual panel design layout. This panel will indicate all critical and non-critical faults, will give indications by indicating lights on the status of all controlled equipment. The panel is designed to give sequence of operation so an operator may readily understand where a possible problem is occurring.

The detail drawings are available with total equipment list so these drawings may be released to a panel manufacturer for fabrication. The cost of this panel rack will be considerably less because of the use of standard available racks, panels and relays.

5.7.5 Alarm Functions

The following alarm functions will be provided and be classified as critical or non-critical. A critical fault would be a fault that causes an immediate shutdown and requires an operators attention, whereas a non-critical fault would not shut down the system but require attention to a particular area.

The following alarms will have explanations for their use also.

High Oil Temp.	Critical	shutdown system and prevent start-up; for collector protection
High Oil Press.	Critical	shutdown system and prevent start-up; for collector protection
High Water	Critical	shuts down system and prevents start-up; to prevent water carry-over into steam system from generator
High Steam Pressure	Critical	Shuts down system and prevents start-up; to prevent overpressure of steam generator.
High Oil Level	Critical	Shuts down system and prevents start-up; detection of water-steam leak into oil system
Low Oil Level	Critical	Shuts down system and prevents start-up; indicates loss of oil in system
Low Water Level	Non-Critical	Alarms only - indicates loss of feedwater to steam generator
Low DC Volts	Non-Critical	Alarms only - indicates collector hydraulic DC back-up system trouble
Main Oil Pump Off	Non-Critical	Alarms only - indicates status of main pump.

Other noted monitored conditions are as follows:

Trip Light -	Indicates system has experienced a critical fault and will require a manual reset.
Ready Light -	Indicates all system faults are o.k.
RUN Light -	Indicates system (go) to oil system, steam generator, and tracking system.
Hydraulic Enable Light -	Enables hydraulic system.
Hydraulic Fault Light -	Indicates hydraulic problem.
Track Enable Light -	Indicates if tracking exists.
Low Steam Light -	Indicates if proper steam pressure is maintained.
Low Differential- Steam Light	Indicates if required generator pressure is greater than plant pressure.
Steam Valve Close- and Open Lights-	Indicates main steam valve position.
Power Lights -	Indicates if control voltage is available.

All of the above functions are controlled from the main control panel Drawing #E-6, Assembly and Details. The alarm circuits above will be slaved together to provide an alarm contact located in the main plant control room. This will provide necessary information to the plant operator.

5.8 SPECIFICATIONS

Product and procurement specifications will be prepared in the early part of Phase II. These specifications will ensure the proper requirements, restrictions and limits on all material and work.

5.9 ELECTRICAL DESIGN REQUIREMENTS

The electrical design was divided between power and control circuits. Due to the refinery atmosphere, it was required that all electrical switching devices (switches, control contacts, pressure switches, etc) be enclosed in a Class I, Division I, Group D enclosure and provided with a conduit seal to prevent explosive vapors from entering these devices.

Power Requirements

Listed below will be the total power requirements of the system and power and diversity calculations. As will be shown, the system will need a 20kw, 3 Phase Bank, 220/120 volts, 4 wire, Y grounded system. This service will be provided by the local power company at no installation cost up to the solar building (See Drawing #E-4, Incoming Power Details).

This incoming power circuit will then go to the main power distribution panel located in the control room. The schematic for this panel can be reviewed on drawing #E1 and for its actual

location see Drawing #E-7, Solar Building Conduit Layout.

Load Calculations

7½ hp start-up pump 3φ

5 hp main pump 3φ

4 kw unit heater 3φ

4 kw unit heater 3φ

1½ hp hydraulic pump 3φ

1½ hp hydraulic pump 3φ

Total 3φ load = 19.56 kw

$$P = \sqrt{3} I \times V \cos \phi \quad \text{Pf} = .8$$

$$I = \frac{19.56 \text{ kw}}{\sqrt{3} (220)(.8)} = 64 \text{ amps}$$

$$\sqrt{3} (220)(.8)$$

1/3 hp 120V 1φ evaporative cooler

2-30 A 120V 1φ receptacles

960 watts 120V 1φ florescent lamps

19 watts 120V 1φ temperature recorder

15 watts 120V 1φ 3-D/P transmitters

19 watts 120V 1φ flow recorder

240 watts 120V 1φ control circuit

15 watts 120V 1φ blowdown valve

1200 watts 120V 1φ hydraulic battery

15 watts 120V 1φ hydraulic solenoids

1/25hp 120V 1φ exhaust fan

30 AMP 120V 1φ hydraulic receptacle

Total single phase load = 22.19 kw

$$\frac{22.19\text{kw}}{3} = 7.39\text{kw}$$

3 (legs)

$$P = V.I = \frac{7.39\text{kw}}{120} = 61.58 \text{ amps/leg}$$

Diversity Factor

7½ hp start-up pump 3φ

3 hp hydraulic motors 3φ

4 kw unit heater 3φ

Total 11.8 kw

$$P = \sqrt{3} V.I. \times 8 \quad I = 38 \text{ amps}$$

3600 W receptacles 1-30 amps

1200 W battery charger

$$I = \frac{4800 \text{ watts}}{3} = 13$$

3 (120)

Total amps = 52 amps

3φ amps = 84 amps

1φ amps 62 amps

128 amps

-52 amps diversity

76 amps

$$P = \sqrt{3} V.I(.8)$$

$$= 1.73 (220) (76) (.8)$$

$$P = 23 \text{ kw}$$

It should be noted that the diversity factor was calculated conservatively therefore, a 20kw, 3 ϕ , 220/120 volt bank will adequately handle the system load. This total power requirement would amount to about 5 percent on a peak basis, however on any average basis this figure is approximately 2% of the total solar collected energy.

Control Requirements

The control requirements consists mainly of 120 volt AC single phase type control circuits, with the same 24V DC control in the hydraulic control panel. Rigid conduit was used throughout the control system with flexible sealtight conduit for end connections to devices. All circuits are adequately protected with either fuses or circuit breakers. All wiring is sized to withstand normal load or instantaneous short circuits without damage before interrupting device openings.

The national electrical code was used in proper sizing of wire, conduit, and breaker. For conduit and wire information, refer to drawings # E-2, E-3, E-7. All circuits will be provided with a proper means of grounding for safety of all equipment and foremost for operating personnel.

5.10 INSTRUMENTATION

The Instrumentation system has been designed to provide the necessary control and information to ensure the proper operation of the solar system. The Instrumentation system will provide visual means of observing and recording the following information:

- 1) Main Steam Pressure
- 2) Main Steam Flow
- 3) Steam Generator Oil Flow
- 4) Collector Inlet and Outlet Temperature
- 5) Steam Generator Inlet and Outlet Oil Temperature
- 6) Steam Generator Inlet Feedwater Temperature
- 7) Steam Generator Outlet Steam Temperature

The steam flow recorder will provide a variable contact to control the off-on setting of the steam generator blowdown valve.

This control will enhance the operation and give a general background and past experience of the solar collector system. This system will be housed in a permanent manner in the Solar Building control room.

The actual data collection system is presently being designed to meet the DOE instrumentation guidelines. This system will provide a complete data collection system as outlined by the above mentioned guidelines.

5.11 DATA ACQUISITION SYSTEM

5.11.1 Data Systems

The on-site data acquisition system (ODAS) for this industrial process steam application will be utilized to measure the following thermal system parameters:

- o Energy to load (Steam flow, temperature, pressure, feed water temperature)
- o Parasitic Energy (Electircal power consumption)
- o Fossil Fuel Savings
- o Collector array efficiency (energy to heat transfer fluid vs solar direct)
- o Heat exchanger performance (oil and water energy balance)
- o Pipe losses (temperature drops on pipe runs)
- o Array cleaning experiments (efficiency before and after)
- o Evaluate long term performance (monitor collector pointing and system thermal degradation).

The ODAS will also have the capability for on-site data reduction and display (with no interruption of data acquisition), will be capable of cummmunicating with a data reduction computer at NMSEI (to relieve any detailed system monitoring duties from refinery personnel), and will have a power backup system which will circumvent data corruption dut to line power interruption.

Figure 5.3 shows a simplified block diagram of the thermal system with the ODAS sensor locations. The energy supplied to the load will be calculated from temperature T401 and T402 and flow SW401 and pressure P401. The energy supplied by the collectors will be calculated from temperatures T105 to T113

FIGURE 5.3

SIMPLIFIED BLOCK DIAGRAM OF SYSTEM INSTRUMENTATION SENSORS

WIND SENSOR	V004
AMBIENT AIR TEMP.	T003
COLLECTOR ANGLE (6 COLLECTORS PER CONTROLLER, 12 CONTROLLERS)	X101 TO X112
DIRECT SOLAR RADIATION	I001
TOTAL SOLAR RADIATION	I002
ELECTRIC POWER CONSUMPTION	EP6C1, 603

and flow W101. The energy lost through pipe radiation and conduction will be calculated from T112 and T101 and T102. The heat exchanger effectiveness will be calculated from temperatures T103 and T104 and flow W101 and the energy supplied to the load. Collector and system performance will be compared with available solar energy by calculations on the measured solar radiation, ambient temperature and wind speed (I001, I002, T003, and V004). Finally, system tracking performance and electrical power consumption will be evaluated with collector angle sensors X101 and X112 and power sensors EP601 to 603. Table 5.2 details the sensor variable names and their descriptions.

The ODAS hardware to measure these preceding variables will consist of a data logger which scans the analog signals from the sensors and converts the information to digital form, a 9 track tape recorder which will store the raw data in computer-compatible format, and an on-site minicomputer which will provide on-site data reduction and will communicate with remote (to the solar project location) computer systems. Figure 5.4 shows the block diagram for the ODAS.

The data logger will accept signals from the sensors and condition them into digital engineering and numeric representations. The logger will be programmed to scan sequentially energy input at regular intervals. After each scan, the data from the scan (including the date and time and a programmable header identification number) will be transferred to both the tape recorder and the minicomputer. The tape recorder will

TABLE 5.2

SENSORS FOR THE ON-SITE DATA ACQUISITION SYSTEM

Variable Name	Description
T402	Feed Water Temperature
T101	Oil Temperature to Collectors
T102	Oil Temperature from Collectors
T103	Oil Temperature to HX
T104	Oil Temperature from HX
T401	Steam Temperature from HX
T105	Oil Temperature from collector st #1
T106	Oil Temperature from collector st #2
T107	Oil Temperature from collector st #3
T108	Oil Temperature from collector st #4
T109	Oil Temperature from collector st #5
T110	Oil Temperature from collector st #6
I001	Direct Solar Radiation
I002	Total Solar Radiation
T003	Ambient Air Temperature
V004	Wind Speed
X101	Collector Angular Position #1
X102	Collector Angular Position #2
X103	Collector Angular Position #3
X104	Collector Angular Position #4
X105	Collector Angular Position #5
X106	Collector Angular Position #6
X107	Collector Angular Position #7
X108	Collector Angular Position #8
X109	Collector Angular Position #9
X110	Collector Angular Position #10
X111	Collector Angular Position #11
X112	Collector Angular Position #12
W101	Oil Flow from Collectors
SW401	Steam flow to load
W102	Oil Flow through HX
P401	Steam pressure to load
T111	Collector string input, South
T112	Collector string input, Middle
T113	Collector string input, North
EP601	Hydraulic 120 VAC power
EP602	Hydraulic 220 VAC power
EP603	Main Pump 220 VAC power

Figure 5.4 On-Site Data Acquisition System Block Diagram.

store all of the raw data from the sensor and the data will be available for processing at government labs. Each 8½ inch reel of tape will contain at least seven days of raw data in ASCII format. The minicomputer will also receive the data and will be programmed to process the data into daily and weekly summaries of system performance for local analysis. Note that the data logger-tape recorder subsystem can operate completely independently from the minicomputer and therefore, any processing of data on the minicomputer will not interfere with acquiring data from the solar system.

The minicomputer will be programmed in high level language (FORTRAN) and will store compressed data on minifloppy disks. It will be programmed to communicate via a direct dial modem coupled with the common carrier phone system to NMSEI's computer facility. This arrangement will enable solar system monitoring by personnel at NMSEI and will enable easy transfer of data from the solar site to NMSEI for detailed processing. In the event of a line power failure, the uninterruptible power supply (UPS) will provide a continuous source of power to the ODAS. The minicomputer will monitor the AC line and when the AC line drops out, the minicomputer will initiate a controlled power down sequence after a time delay equal to approximately 2/3 of the UPS battery capacity. This action will be to wait for a data transfer from the data logger and a signal from the tape recorder signifying that the data block has been recorded. The minicomputer will then cause an end-of-file to be recorded

and a record gap to be inserted in the tape. The power to the recorder will then be removed. The minicomputer will also type out a power fail message on the line printer which includes the day and time. The power to the CRT, lineprinter and minicomputer will then be removed. The only piece of equipment left powered-up will be the data logger. This is done since the data logger contains the real time clock. The minicomputer will control a "ODAS DOWN" pair of relay contacts which will activate an alarm in the refinery control room whenever either a power failure or system crash occurs. Of course, if the line power is restored to the UPS before a significant fraction of its battery capacity has been consumed, the power down timer will be reset and the ODAS will continue normal operations. NMSEI is also planning on querying the system via telephone on a daily basis to transfer data and monitor solar system operation. These fault detection schemes and the soft power-down through the use of a UPS will ensure data integrity and rapid detection of system crashes and component failure.

This ODAS is essentially identical to an ODAS currently being constructed (and soon to be installed in the field) by NMSEI for data acquisition from solar water heating projects. The software for the system is approximately 90% complete and all of the hardware has been received and is currently being configured. NMSEI is therefore in a position to say that this ODAS is a cost effective and reliable system for remote data acquisition.

5.11.2 Hardware

Data logger and tape recorder - The data logger must accept the following signals from the system sensors:

- o Temperature sensors 16 RTD
- o Insolation sensors 2 (millivolt level)
- o Wind speed sensor 1 (volt level)
- o Angular position sensors 12 (volt level)
- o Flow sensors 3 (volt level)
- o Pressure sensors 1 (volt level)
- o Electrical power snesors 3 (volt level)

Therefore, the total recording requirement is 38 analog signals. The data logger found by NMSEI to be the most cost effective and versitile is the Doric Scientific Model 230A data logger. This data logger will accept up to 80 analog inputs into the main frame through "Front End Modules" (FEMS) which accept 20 analog inputs each. One can purchase a FEM configured for RTD's or a FEM configured for thermocouples and straight voltages. Since we need 16 channels of RTD inputs, one RTD FEM will be needed. Since we need 22 channels of voltage inputs, two thermocouples/ voltage FEMS will be needed. Therefore, a total of 60 analog inputs will be purchased, leaving plenty of room for expansion of the system. The following lists the Doric 230A options needed for the ODAS.

Data Logger & Tape Recorder

<u>Quantity</u>	<u>Description</u>	<u>Option #</u>	<u>Total</u>
1	Mainframe	2301 (F)	\$ 2095
1	High Sensor Option	05	195

<u>Quantity</u>	<u>Description</u>	<u>Option</u>	<u>Total</u>
1	RTD input FEM	12(2)	\$ 995
2	Reed relay input FEM	11(1),11(3)	1390
1	Terminal I/O	31(2)	195
1	Mag Tape Interface	34	895
1	Mag Tape Reforder	1600/360	<u>5595</u>
TOTAL			\$11360.

The magnetic tape recorder (record only) will also be purchased from Doric since their tape interface is specifically designed for the recorder. The unit will be a Kennedy 9 track NRZI format 800 BPI unit with a 8½" tape reel (the 10½" reel recorder costs over \$1000 more). We propose that if it is a requirement that the government receive 1600 BPI PE tapes that the 800 BPI tapes be translated to 1600 BPI by NMSEI facilities

The minicomputer must be able to receive data from the data logger via an RS 232 communications line, must communicate with a CRT terminal, modem and a line printer, and must operate with a high level language (preferably FORTRAN). NMSEI has surveyed the low-end market for mini-micro computers and has settled on the Northstar Horizon computer as a standard. The Horizon is a S100 Bus based microcomputer with a Z80 cpu and Shugart minifloppy disk operating system. The following lists the Northstar model numbers and prices for the required system.

MINICOMPUTERS & PERIPHERALS

<u>Quantity</u>	<u>Description</u>	<u>Model #</u>	<u>Cost</u>
1	Minicomputer mainframe with 2 disk drives and 16K Bytes RAM	HRZ-2-16K	\$2300.
2	32K Bytes RAM	RAM-16-A	800.
1	Serial I/O	HRZ-SIO	60.

<u>Quantity</u>	<u>Description</u>	<u>Model #</u>	<u>Cost</u>
1	Parallel I/O	HRZ-PIO	\$ 60
1	Serial I/O Board	Vector Graphic Bit Stramer	180
1	Auto Answer Modem	D.C. Hayes 80-103A	260
1	CRT Video Terminal	Soroc IQ 120	995
1	Line Printer	Digital Eqpt. DEC LS120-HE	1900
1	Software FORTRAN & CP/M	Microsoft F80 and CP/M	500
TOTAL			\$7055.

Uninterruptible Power Supply - The AC load on the UPS can be estimated from the foll
be estimated from the following data:

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>POWER CONSUMPTION</u>
1	Data Logger	25 watts
2	Tape Recorder	150 watts
3	Minicomputer	400 watts
4	Line Printer	300 watts
5	CRT Terminal	150 watts

The total power required is therefore, 1025 watts. An estimate of the cost of a 150 watt UPS complete with batteries was obtained from Computer Power, Inc., of High Bridge, N.J. and is \$2,737.00. This unit would provide approximately 2 hours of backup power and should therefore carry the ODAS over most power interruptions.

Total Cost for ODAS

o	Data logger and tape recorder	\$ 11,360.00
o	Minicomputer and peripherals	7,055.00
o	UPS	<u>2,737.00</u>
TOTAL		\$ 21,152.00

5.12 DETAIL DRAWINGS

The detail drawings are listed in the following drawing list.

There were two main categories of drawings, mechanical and electrical. The mechanical drawings also included various civil details and the electrical drawings covered the data and control instrumentation as well. There was also one architectural drawing to cover the design and installation of the solar building.

All drawings were designed to provide clarification in order to ensure an easy understanding and prompted installation.

It should be noted that many details were provided in order to achieve the above comments, but also to more clearly define actual installation cost that will be experienced.

TABLE 5.2
DRAWING LIST- MSC

Power Supplies Electrical Schematic	78-123	1	1
Pylon Electrical Schematic	78-124	1	1
Building Architecture	A-1	1	1
Equipment Schedule	M-1	1	5
Mechanical Plot Plan	M-2	2	5
Solar Building Piping and Equipment Diagram	M-2	3	5
Mechanical Details	M-4	4	5
Mechanical Details	M-4	4	5
Plot Plan Collector Field	M-5	1	3
Plot Plan Collector Field	M-5	2	3
Underground Collector Field Lines	M-5	3	3
System Schematic	M-6	1	1
Collector Field Piping	M-7	1	4
Pipe Support Details	M-7	2	4
Collector Field Piping Details	M-7	3	4
Collector Field Piping Details	M-7	4	4
Collector Pier Layout	M-8	1	1
Collector Field Isometric	M-9	1	1
Electrical Control Schematic and Power Distribution	E-1	1	1
Electrical Conduit Schedule	E-2	1	1
Underground Conduit Plan	E-3	1	1
Incoming Power Detail	E-4	1	1
Rack Assembly & Weather Station	E-5	1	1

Control Panelrack Assembly & Details	E-6	1	4
Control Panelrack Assembly & Details	E-6	2	4
Control Panelrack Assembly & Details	E-6	3	4
Control Panelrack Assembly & Details	E-6	4	4
Solar Building Conduit Layout	E-7	1	1
Wind Panel	E-8	1	1

POWER SUPPLIES ELEC. SCHEMATIC

SCALE: NONE

APPROVED BY:

DRAWN BY JDW

DATE: 2-21-78

REVISED 4-18-78

SOLAR KINETICS INC.

DRAWING NUMBER
78-1-23

PYLON ELEC SCHEMATIC

SCALE: NONE

APPROVED BY:

DRAWN BY JDW

DATE: 2-22-78

REVISED 9-28-78

SOLAR KINETICS INC.

DRAWING NUMBER

78-1-24

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO		CONTRACT NUMBER EM-18-C-03-2223	
ARCHITECTURAL FLOOR PLANS & ELEVATIONS		DESIGNED BY: <u>U</u>	
		CHECKED BY: <u>C. G. G</u>	
		APPROVED BY: <u>S. L. H</u>	
SCALE: AS NOTED			
SUBMITTED I. D. Clark	RECOMMENDED	APPROVED	
DATE 2/13/79	DWG. NO. A-1	SHEET 1	OF 1

SYMBOL LEGEND		EQUIPMENT SCHEDULE	
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	Switch or Device (see Floor Plan)		18 FLOW SENSING DEVICE (STEAM): Annubar Model ASR 73, 2-1/2" schedule 40 HL (horizontal line only) primary flow sensing device for steam, or approved equal.
	Ceiling Diffuser (Arrows Denote throw pattern, 4-way, 3-way, etc.)		19 FLOW SWITCH: Magnetrol Model F-1000-F flow switch for schedule 40, 3" IPS, rated 1000 psi service on liquid temperature to 450°F, complete with NEMA 7 explosionproof switch enclosure, or approved equal.
	Return Air or Exhaust Air Grille		20 DIFFERENTIAL PRESSURE SWITCH (STEAM): Marcoild Type DPAE-533-3, range 64, rated for 170 psi at 380°F saturated steam, adjustable D/P 2-30 psi, Code B electrical contacts, circuit suffix (S), explosionproof enclosure, complete with pigtail syphon, or approved equal.
	Transfer Grille		21 STEAM CONTROL VALVE: Worchester Model No. 446-PM-300, OFF-ON electric-manual override control valve, 2" ball valve, rated for 300 lb. saturated steam, valve body to be carbon steel construction with socket weld ends, model C73X explosionproof valve operator, 120 volt, 1 phase, 60 Hz, or approved equal.
	Supply Duct (Cross Section)		22 STEAM PRESSURE SWITCH: Mercoild Type DAH-31-3, range 9, Code A, rated for 170 psi at 380°F steam pressure, adjustable operating range 10-300 psig, set at 200 psi, complete with pigtail syphon.
	Return Air or Exhaust Air Duct (Cross Section)		23 STEAM PRESSURE SWITCH: Mercoild Type DAH-31-2, range 9, Code A, rated for 170 psi at 380°F steam pressure, adjustable operating range 10-300 psig, set at 150 psi, complete with pigtail syphon.
	Indicates New to Existing Connection		24 TEMPERATURE SWITCH: Asco Tri-Point, Catalog No. SA12A, 350°F to 510°F, with catalog No. QUILA-4 stainless steel 6 ft. capillary bulb, catalog No. QP07-1/2" NPT - 2-1/2" stainless steel well for bulb mounting (High oil temperature shutdown.)
	Solar Collector Supply		25 TEMPERATURE SWITCH: Asco Tri-Point, Catalog No. SA12A, 160°F to 260°F, with catalog No. QUILA-4 stainless steel 6 ft. capillary bulb, catalog No. QP07-1/2" NPT - 2-1/2" stainless steel well for bulb mounting. (motor change over switch.)
	Solar Collector Return		26 SAMPLE TESTING COIL: Bailey Meter Company, Model No. 8-16-12 x 195118A1, 1/2" OD Inconel inner sampling coil, 1" OD copper outer coolant coil, 1/2" tube inlet and outlet sampling coil connections, 3/4" tube inlet and outlet coolant coil connections, or approved equal.
	Three-Way Control Valve		27 DIFFERENTIAL PRESSURE TRANSMITTER: Foxboro Model E13DL, electronic d/p cell transmitter, explosionproof, Class I, Group C, Division 1, 120 volt, 1 phase, 60 Hz, or approved equal.
	Blow-Down Valve		28 PRESSURE TRANSMITTER: Foxboro Model E11GM-1SAC2, steam pressure transmitter, explosionproof, Class I, Group C, Division 1, 120 volt, 1 phase, 60 Hz, or approved equal.
	Gate Valve		29 FILTER - MAKE-UP UNIT: AMF-Cuno, Model No. 3ALI, complete with 3 Ametek glass fiber element cartridges, 1-1/2" I.P.S. connections, rated 150 psi at 250°F, or approved equal.
	Check Valve		30 THERMOWELLS: Tertrice Model 7-3GC6, 1/2" N.P.T. separable socket connection, stainless steel type 316 socket, depth dimension as required, or approved equal.
	Angle Relief Valve		31 THERMOMETERS: H. O. Tertrice Model A00510, Industrial Thermometer, Catalog No. BX91403-1/2, range 100°F - 500°F, complete with No. A126, Catalog No. 3-4F6 stainless steel type 316 - 3/4" N.P.T. separable socket, or approved equal.
	Butterfly Valve		32 PRESSURE GAUGES: H. O. Tertrice Model 625, Hydraulic Gauge, type 316 stainless steel bourbon tube and alloy steel socket, 4-1/2" dial, range 0 - 400 psi. For steam use include No. 006 Tertrice coil syphon, or approved equal.
	Strainer		33 FIRE EXTINGUISHER: Standard Fire Equipment Model C-5, 5 lb. carbon dioxide (CO ₂) fire extinguisher complete with wall bracket, factory charged, or approved equal.
	Union		34 CEILING DIFFUSER: Carnes Model No. 47 - 18" x 18", complete with No. 4743 damper, for use with gypsum ceiling, duct mounted, aluminum construction, or approved equal.
	Concentric Reducer		35 CEILING TRANSFER GRILLE: Carnes Model No. 6295AN, 24" x 24", for use with gypsum ceiling, duct mounted, aluminum construction, or approved equal.
	Solenoid Valve		36 DOOR TRANSFER GRILLE: Carnes Model No. 6155H, heavy duty steel construction, fixed horizontal bars set at 40", sized as shown on drawings, or approved equal.
	Valve in Rise		
	Pipe Orifice		
	Flex Connection		
	Nitrogen		
	Inverted Bucket Steam Trap		
	Steam, High Pressure 8# or Over		
	Gravity Condensate		
	Angle Valve		
	Pipe Anchor		
	Thermowell		
	Adapter and Line for Transmitter Device		
	Pressure Gauge		
	Electric Power Line		
	Domestic Cold Water		
	Fence		
	Feedwater Supply		
	Blow Down Line		
	Feedwater Return		
	Hose Bibb		
	Floor Drain		
	Steam Control Valve		
			1 STEAM GENERATOR: Furnish and install, where shown on plans, one unfired steam generator. Generator shall generate 2000 lbs/hr. of saturated steam at a pressure of 175 psig from feedwater at 220°F when supplied with 125 gpm of high temperature oil at 500°F. Fouling factor - .001, pressure drop of high temperature oil (Texatherm) not to exceed 20 psig. Generator constructed and stamped in accordance with the ASME Code with Insurance Company certification. The shell and tube circuit shall be flange grade steel and the tubes shall be 3/4" O.D. x 18 BWG stainless steel. The U-tube bundle shall be supported on heavy steel tracks. The shell shall be constructed of SA 285 Grade C steel or SA 515 Grade 70 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 at 500°F. The tube side shall be designed for a pressure of 400 psig at 500°F and ASME stamped. Packaged generator shall include the following listed items: Steam-moisture separator. Full length steel skid foundation to support the generator 18" above the floor. Steel lifting lugs. Steam pressure gauge 6" dial with shut-off cock and syphon. High limit level alarm device. Low limit level alarm device. Shell side ASME 200 lb. steam safety relief valve. Combination water column and feedwater controller (Magnetrol). ASME reflex gauge glass and try cocks. Two (2) high temperature oil thermometers, bi-metal, adjustable dial type with separable #304 stainless steel wells installed in the HTO inlet and outlet nozzles. Independent steam pressure safety system 1/2" tapping for remote high/low pressure alarm device. Two (2) ASME tandem blow-off valves, 1-1/4 ips. Fibre-type high density insulation 2" thick with heavy gauge anodized zinc coated steel jacket or aluminum. Fully descriptive certified scale drawing shall be submitted for approval showing all instrumentation, controls and design details as herewith specified. Patterson-Kelly Series 380 Model HTO 369, or approved equal.
			2 COLD START PUMP: Viking Model K-4124 R pump with 3" flanged ports, carbon graphite bushings, standard Buna N mechanical seal, relief valve at 150 psi. Pump of cast iron construction with a Viking Model "B" 5.06:1 gear reducer with a 7-1/2 horsepower, 1800 rpm, 3 phase, 60 Hz, 230/460 volt TEFC motor. Unit complete with base, couplings, and coupling guards. (Flooded suction, 32 gpm at 120 psi, fluid temperature 32°F - 100°F, fluid viscosity 10,000 to 229 ssu.) Viking, or approved equal.
			3 OPERATION PUMP: Viking Model QR4124R Pump with 4" flanged ports, high temperature carbon graphite bushings, asbestos gaskets, nitralloy idler pin with teflon and cast iron seal in stuffing box with quench and cooling gland, relief valve at 50 psi; pump of cast iron construction with Viking Model "C" 6.24:1 gear reducer with a 5 horsepower, 3 phase, 60 Hz, 230/460 volt TEFC motor. Unit complete with base, couplings, and coupling guards. (Flooded suction 125 gpm at 35 psi, fluid temperature 100°F - 500°F, fluid viscosity 229-10 ssu.) Viking, or approved equal.
			4 EXPANSION TANK: Base mounted vertical expansion tank, ASME Code, working pressure 250 psi, complete with 12" x 8" inspection manhole. Tappings as per detailed drawing, flanged connections, units as manufactured by Texas Tank, Inc., or approved equal.
			5 NITROGEN CYLINDER: Airco or Linde Cylinder (lease purchase or rental, Owner furnished).
			6 NITROGEN PRESSURE REGULATOR: Victor Model VTS 400A, 2200/0-15 psi, 2 stage regulator, 1/4" NPT discharge line.
			7 HIGH TEMPERATURE OIL CONTROLLER: Sybron/Taylor Model 36RN817, direct acting, 3-way valve controller with ANSI 300 lb. flanged end, cast steel construction, teflon asbestos stem packing, double seated, beveled disc, 316 stainless steel trim, 3" valve size, controller range 355°F - 460°F, or approved equal.
			8 SOLAR OIL MAKE-UP FEEDER: Furnish and install an oil feeder unit complete with 30 gallon open tank, gear design pump, coupling, coupling guard and motor all mounted on 12 gauge steel base. Furnish tank with drain and make-up float valve. Pump to have 13 gpm at 100 psig capacity, 3 horsepower motor, 1750 rpm, 240 volt, 3 phase, 60 Hz power. Lobee Model 6LOL, or approved equal.
			9 BLOW-DOWN VALVE: Strong CRDV continuous blow-down system, 300 psi at 600°F maximum, complete with orifice block, with 1/16 orifice, valve size 1/2" IPS inlet, 3/4" IPS outlet, or approved equal.
			10 BLOW-DOWN CONTROL VALVE: Worchester model 446 PM Miser Ball Valve, series A31X Explosion Proof Operator, 1/2" IPS rated 170 lbs @ 380°F hot water service, normally closed, 120 volt, 1 phase, 60 Hz. Worchester Valve Co. or approved equal.
			11 STEAM TRAP: Armstrong Model No. 1011, 1/2" inverted bucket trap, 400 psi rated, 860 lb. water/hr. at 200 psi, 304-L stainless steel body construction, or approved equal.
			12 EVAPORATIVE COOLER: Arctic Circle Model No. AD 330, bottom discharge evaporative cooler complete with Model No. 870A, 1/3 horsepower, 120 volt, 1 phase, 60 Hz, 2-speed motor rated 3000 cfm high speed, 2000 cfm low speed, or approved equal.
			13 HORIZONTAL UNIT HEATER: Emerson Chromalox Model No. LUH-04-U2-TK, 240 volt, 3 phase, 60 Hz, rated 13,700 Btu/hr., 4 kw, 10 amps. Unit complete with Model No. WUH-01 wall swivel mounting bracket, built-in thermostat, temperature range 55°F to 105°F, or approved equal.
			15 EXHAUST FAN: Jenn-Air Model No. 71CR, direct drive centrifugal roof exhaust, 1/25 horsepower, 120 volt, 1 phase, 60 Hz. Unit complete with bird screen, backdraft damper, or approved equal.
			16 DELETED 17 FLOW SENSING DEVICE (HEAT TRANSFER OIL): Annubar Model ANR 73, 3" schedule 40 C-21, primary flow sensing device for heat transfer oil, or approved equal.

MONUMENT SOLAR CORPORATION	
DALLAS	TEXAS
SOUTHERN UNION REFINING CO.	
SOLAR PROJECT	
HOBBS, NEW MEXICO	
EQUIPMENT SCHEDULE	
SUBMITTED J.D. Clark	RECOMMENDED
DATE 4/25/79	DWG. NO. M-1
	SHEET 1
	CF

5.74

PLOT PLAN SCALE: 1" = 40'-0"

MONUMENT SOLAR CORPORATION		
DALLAS TEXAS		
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER
SOLAR PROJECT		EM-78-C-03-2223
HOBBS, NEW MEXICO		DESIGNED BY: H.B.
		CHECKED BY: F.H.B.
		APPROVED BY: W. Price
PLOT PLAN		SCALE: As Noted
SUBMITTED	RECOMMENDED	APPROVED
L.D. Clark		
DATE 2/12/79	DWG. NO. M-2	SHEET 2 OF 3

5.75A

MONUMENT SOLAR CORPORATION	
DALLAS	TEXAS
SOUTHERN UNION REFINING CO.	CONTRACT NUMBER
SOLAR PROJECT	EM-78-C-03-2220
HOBBS, NEW MEXICO	DESIGNED BY: HBS
MECHANICAL FLOOR PLAN,	CHECKED BY: FHS
PIPING ISOMETRICS, AND	APPROVED BY: W. A. H.
LOCAL SCHEMATIC	SCALE: As Noted
SUBMITTED	RECOMMENDED
L.D. Clark	
DATE: 5/15/79	DWG. NO. M-2
	SHEET 3 OF 3

DRIP TRAP DETAIL SCALE: NONE
 Note: Gate valve & strainer enr. trap not req'd on equip. w/ gate valve and strainer at control valve.

FEEDWATER PUMP CONNECTION DETAIL SCALE: NONE

CYLINDER ANCHOR DETAIL SCALE: NONE

TYPICAL BURIED PIPING DETAIL SCALE: NONE

FEEDWATER PIPING INSULATION DETAIL SCALE: NONE

THERMOWELL DETAIL SCALE: NONE

DRYWELL DETAIL SCALE: NONE

ASME Code - Expansion Tank (vertical)
 Working Pressure - 150 P.S.I.
 Test Pressure - 250 P.S.I.
 Maximum Pressure - 250 P.S.I.

EXPANSION TANK SCALE: NONE

NEW COLD WATER CONNECTION AT COOLING TOWER SCALE: NONE

MONUMENT SOLAR CORPORATION			
DALLAS TEXAS			
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER	
SOLAR PROJECT		EM-78-C-03-2223	
HOBBS, NEW MEXICO		DESIGNED BY: MS	
MECHANICAL DETAILS		CHECKED BY: PMS	
(1 OF 2)		APPROVED BY: AL Price	
		SCALE: As Noted	
SUBMITTED	RECOMMENDED	APPROVED	
L.D. Clark			
DATE	DWG. NO.	SHEET	OF
6/15/79	M-4	4	4

NOTE: Feedwater Supply and Feedwater Return located on existing pipe support structure. Located in permissible space on support structure. The anchor also centered to nearest existing crossmember. See sheet M-2.

ABOVE GRADE

ANCHOR DETAIL SCALE: NONE 14 M4

NOTE: For additional dimensions, see Expansion Loop Detail (this sheet) and Typical Buried Piping Section 2 MA.

EXPANSION 'L' DETAIL SCALE: NONE 13 M4

NOTE: For additional dimensions, see Typical Buried Piping Section 3 MA.

EXPANSION LOOP DETAIL SCALE: NONE 12 M4

TRANSMITTER MOUNTING DETAIL 17 M4 SCALE: NONE

STEAM LINE AND VALVE CONNECTION SCALE: NONE 16 M4

SAMPLE TEST COIL DETAIL 11 M4 SCALE: NONE

NOTES:
1) For pipe sizes, trench dimensions, and location, see other details, this sheet, and sheets M-2, M-3, and M-4 (1 of 2)
2) This detail indicates two-pipe anchoring. Three pipe anchoring similar.

SECTION A ANCHOR DETAIL SCALE: NONE 15 M4

MONUMENT SOLAR CORPORATION		
DALLAS TEXAS		
SOUTHERN UNION REFINING CO.	CONTRACT NUMBER	
SOLAR PROJECT	EM-78-C-03-2223	
HOBBS, NEW MEXICO	DESIGNED BY: HSB	
MECHANICAL DETAILS (2 OF 2)	CHECKED BY: PHB	
	APPROVED BY: W. Price	
	SCALE: AS NOTED	
SUBMITTED	RECOMMENDED	APPROVED
1.0 Clark		
DATE 5/2/79	DWG. NO. M-4	SHEET 5 OF 5

UNDERGROUND COLL. FIELD LINES PLAN

SCALE: 1" = 10'-0"

SECTION

WATER LINE TRENCH DETAIL

SCALE: 1/2" = 1'-0"

NOTE:
BACKFILL MAT'L CAN BE SAME AS EXCAVATED
IF PARTICLE SIZE DOES NOT EXCEED 3/4". SAND WILL
BE USED AS SUITABLE REPLACEMENT. ALL TRENCHES
WILL BE BACKFILLED AND COMPACTED IN LAYERS NOT
EXCEEDING 6" IN DEPTH WITH PROPER MOISTURE

① WATER OUTLET DETAIL

SCALE: AS SHOWN

NOTE: ALL FITTINGS ARE WITH NPT.
PIPE THREADED END.

HYD & ELEC LINES TRENCH DETAIL

SCALE: 1/2" = 1'-0"

MCNUMENT SOLAR CORPORATION			
DALLAS TEXAS			
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER	
SOLAR PROJECT		EM-78-C-03-2223	
HOBBS NEW MEXICO		DESIGNED BY: AHB	
UNDERGROUND COLL. FIELD LINES.		CHECKED BY: SLH	
		APPROVED BY: W.P.	
		SCALE: AS NOTED	
SUBMITTED	RECOMMENDED	APPROVED	
L.D. Clark			
DATE 3/13/79	DWG NO M-5	SHEET 3	OF 3

MONUMENT SOLAR CORPORATION		
DALLAS TEXAS		
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBES NEW MEXICO	CONTRACT NUMBER EM-78-C-03-2223	
	DESIGNED BY: AHB	
SYSTEM SCHEMATIC	CHECKED BY:	
	APPROVED BY:	
	SCALE : NONE	
SUBMITTED L.D. Clark	RECOMMENDED	APPROVED
DATE 5/15/79	DWG NO M-6	SHEET 1 OF 1

COLLECTOR FIELD PIPING PLAN
SCALE: 1"=10'-0"

KEYED NOTES:

- ① SEE "T" CONNECTION DETAIL
- ② INLET END CONNECTION SEE DETAIL
- ③ FIELD DRAIN. SEE DETAIL
- ④ MID-ROW CONNECTION SEE DETAIL
- ⑤ SEE NOTE ON DETAIL
- ⑥ CUT THE PIPE 0.5" SHORTER THEN NORMALLY REQD. TO ABSORB THERMAL EXPANSION.
- ⑦ FIELD VENT. SEE DETAIL
- ⑧ OUTLET END CONNECTION SEE DETAIL
- PIPE SUPPORT SEE DETAIL
- PIPE ANCHOR SEE DETAIL
- ⑨ MAIN LINE OVERLAP SEE DETAIL
- EXPANSION LOOP PIPE SUPPORT

GENERAL NOTES

- ALL CONNECTIONS ARE FILLET WELD, UNLESS SPECIFIED.
- MAIN LINE IS 3" NOM. A.S.T.M. A-53 GRADE B.
- BRANCH OR HEADER IS 2" NOM. A.S.T.M. A-53 GRADE B.
- COLLECTOR CONNECTION LINE IS 1" A.S.T.M. A-53 GRADE B.
- ALL EXPANSION LOOPS ARE TYPICAL U-BENT SINGLE PLANE.
- ALL PIPING IS INSULATED AFTER THE LEAK TEST. SEE INSULATION SPECS. FOR SIZES.
- PIPE SUPPORTS ON MAIN LINE ARE 14FT C.C., ON EXP. LOOPS PLACE SUPPORT IN CENTER OF EACH LEG AS SHOWN.
- ANSI B31.1, 127.3.3. CODE IS APPLIED TO ALL CONNECTION & JOINTS, WHICH ARE SOCKET WELD. LEAVE 1/16" CLEARANCE BETWEEN MAXIMUM DEPTH OF ANY SOCKET AND THE INSERTED END OF PIPE IN THAT SOCKET, WHEN WELDED.
- USE CALCIUM SILICATE INSULATION ON PIPE WHERE SUPPORTED, 15" IN LENGTH. ALL OTHER SPECS. HOLD.

MONUMENT SOLAR CORPORATION			
DALLAS TEXAS		CONTRACT NUMBER	
SOUTHERN UNION REFINING CO.		EM-78-C-03-2223	
SOLAR PROJECT		DESIGNED BY: AHB	
HOBBS, NEW MEXICO		CHECKED BY: SLH	
COLLECTOR FIELD		APPROVED BY: W.P.	
PIPING		SCALE 1"=10'-0"	
SUBMITTED	RECOMMENDED	APPROVED	
L.D. Clark			
DATE 5/15/79	DWG. NO. M-7	SHEET 1	OF 4

PLAN

ELEVATION

DETAILS
COLLECTOR SUPPORT PIER
SCALE: 1" = 1'-0"

DETAILS
PIPE SUPPORT
SCALE: 1.5" = 1'-0"

NOTE:
FOR 2" HEADER LINE SUPPORT, EXTEND 2" I.D. BLK. STL. SUPPORT PIPE FROM 1'-0" TO 1'-2" IN LENGTH. ALSO CHANGE 10 GA. STL. BENT PLATE (SADDLE) FROM 6"x29" TO 6"x27".
FOR EXP. LOOP SUPPORT, USE 18"x18", 10GA-36 STL. R. WLD. TO 2" SUPPORT PIPE

PLAN

SECTION

DETAIL
HYDRAULIC & ELEC. CONTROL PAD
SCALE: 3/4" = 1'-0"

DETAILS
PIPE ANCHOR
SCALE: 1.5" = 1'-0"

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO		CONTRACT NUMBER EM-78-C-03-2223	
PIPE SUPPORT DETAIL.		DESIGNED BY: AHB	
		CHECKED BY: SLH	
		APPROVED BY: W.P.	
SUBMITTED 1.0. Clark		RECOMMENDED	
DATE 5/15/79		APPROVED	
DWG NO. M-7		SHEET 2 OF 4

TYPICAL PIPE CONNECTION (SOCKET WELD COUPLING)

SCALE: 1" = 2"

NOTE:
ABOVE CONNECTION IS COMMON TO ALL DIFFERENT SIZE PIPES IN THE COLL. FIELD USE WHERE APPLICABLE.
1/16" CLEARANCE REQD. BETWEEN INNER SOCKET WALL AND PIPE.

TEE CONNECTION DETAIL

SCALE: 1" = 2"

NOTE:
USE 3' LONG 3" SCH 40 PIPE TO CONNECT TEE WITH REDUCER

COLLECTOR FRONT VIEW

COLL MID-ROW CONNECTION DETAIL

SCALE: 1" = 5"

INLET END CONNECTION DETAIL

SCALE: 1" = 5"

NOTE:
FOR FAR END COLLECTORS USE 2" 90° ELBOW WITH 2x1" REDUCER INSERT, INSTEAD OF 2" TEE.
CLAMP TIED ABOVE SWAGelok IS CONNECTED TO 1/2" A-36 STL. GALV. ROD, PINNED ON END SUPPORT PLATE, WITH 2" OF ALLOWABLE MOVEMENT (BACK & FORTH) TO ABSORB THE LINEAR MOVEMENT OF 2" HEADER

COLLECTOR SIDE VIEW

OUTLET END CONNECTION DETAIL

SCALE: 1" = 5"

NOTE:
• ALL CONNECTIONS & FITTINGS ARE FILLET WELD.
• ALL PIPES, FITTINGS, ETC. ARE INSULATED AFTER LEAK TEST. SEE INSULATION SPECS.
• USE 2' LONG 1" SCH 40 AS NIPPLE FOR INTER-CONNECTION BETWEEN FITTINGS, VALVE, ETC.
• ROTATE THE SAFETY RELIEF VALVE 26° AS SHOWN, TO ALLOW 1" PIPE CONNECTED TO VALVE LEAN ON INSULATED 2" HEADER.

MONUMENT SOLAR CORPORATION			
DALLAS TEXAS		CONTRACT NUMBER	
SOUTHERN UNION REFINING CO		EM-78-C-03-2223	
SOLAR PROJECT		DESIGNED BY: AHB	
HOBBS NEW MEXICO		CHECKED BY: SLH	
COLLECTOR FIELD		APPROVED BY: W.P.	
PIPING DETAIL		SCALE: AS NOTED	
SUBMITTED	RECOMMENDED	APPROVED	
L. D. Clark			
DATE	DWG NO	SHEET	OF
5/15/79	M-7	4	4

MONUMENT SOLAR CORPORATION			
DALLAS TEXAS			
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER	
SOLAR PROJECT		EM-78-C-03-2223	
HOBBS, NEW MEXICO		DESIGNED BY: AHB	
COLLECTOR PIER LAYOUT		CHECKED BY: SLH	
		APPROVED BY: W.P.	
		SCALE AS NOTED	
SUBMITTED		RECOMMENDED	
L.D. Clark		APPROVED	
DATE 5/14/79		DWG NO M-8	
		SHEET 1 OF 1

MONUMENT SOLAR CORPORATION DALLAS TEXAS		
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO		CONTRACT NUMBER EM-78-C-03-2223
		DESIGNED BY: AHB
		CHECKED BY: SLH
		APPROVED BY: W.P.
		SCALE: 1/2" = 4'-0"
SUBMITTED L.D. Clark	RECOMMENDED	APPROVED
DATE 5/15/79	DWG NO M-9	SHEET 1 OF 1

LINES OF LOGIC
 THIS COLUMN

LINES OF LOGIC
CONT.

SYMBOLS

- DENOTES COMPONENT CONNECTION
- DENOTES TERM. BOARD CONNECTION

POWER DISTRIBUTION

<h1 style="text-align: center;">MONUMENT SOLAR CORPORATION</h1> <div style="display: flex; justify-content: space-around;"> DALLAS TEXAS </div>			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO ELECTRICAL CONTROL SCHEMATIC AND POWER DISTRIBUTION		CONTRACT NUMBER EM-78-C-03-2233 DESIGNED BY: JDH CHECKED BY: _____ APPROVED BY: _____ SCALE: NONE	
SUBMITTED L.D. CLARK	RECOMMENDED	APPROVED	
DATE 5/15/79	DWG. NO. E-7	SHEET 1	OF 1

NOTES:

1. FOR WIRING DETAILS SEE DWG'S E1 AND E2
2. SEE MECHANICAL DRAWINGS FOR TRENCHING DETAILS
3. EXACT ROUTING TO BE DETERMINED ON SITE
4. INSTALLATION HARDWARE AND WORKMANSHIP PER "NATIONAL ELECTRICAL CODE 1979" AND GOOD COMMERCIAL PRACTICE.
5. SEAL OFF (CLASS I, DIV I GROUP D) TO BE INSTALLED IN CONDUIT WITHIN ONE FOOT OF EACH DEVICE HAVE SPARK POTENTIAL.

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO		CONTRACT NUMBER EM-78-C-03-2223	
DESIGNED BY: J.D.H.		CHECKED BY:	
APPROVED BY:		SCALE: 1"=25'	
SUBMITTED L.D. CLARK	RECOMMENDED	APPROVED	
DATE 5/15/73	DWG. NO. E-3	SHEET 1	OF 1

PYLON J-BOX DETAIL
(TYP EACH COLLECTOR)

INCOMING POWER DETAIL
(SEE SITE PLAN FOR LOCATION)

NOTES:

1. SEE MATERIAL LIST DWG FOR PARTS
2. FULL GROUND WIRE THROUGH POLYPHASE WATT-HOUR METER BOX AND TIE TO GROUND LEADING TO CONTROL ROOM - USE MECH
3. INSTALLATION HARDWARE AND WORKMANSHIP PER NATIONAL ELECTRICAL CODE AND GOOD COMMERCIAL PRACTICE

MONUMENT SOLAR CORPORATION			
DALLAS TEXAS			
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER	
SOLAR PROJECT		SM-78-C-03-2289	
HOBBS, NEW MEXICO		DESIGNED BY: JDH	
INCOMING POWER AND		CHECKED BY:	
PYLON J-BOX DETAIL		APPROVED BY:	
		SCALE: NONE	
SUBMITTED	RECOMMENDED	APPROVED	
L.D. CLARK			
DATE 5/15/79	DWG NO E-4	SHEET 1	OF 1

NOTES: (CONT.)
4. INSTALLATION HARDWARE AND WORKMANSHIP PER "NATIONAL ELECTRICAL CODE 1979" AND GOOD COMMERCIAL PRACTICE.

WEATHER STATION DETAIL

PANEL SCHEDULE

ITEM	PART NO	COLOR	MFG	SIZE	FUNCTION	NOTES
PANEL #1	PS-1251	WHITE	BUD	3 1/2"	BLANK	
#2	PS-1255			10 1/2"	STEAM FLOW	
#3	PS-1257			14"	TEMP RECORDER	
#4	PS-1261			21"	ST PRES REC/CONT.	
#5	PS-1257			14"	BLANK	
#6	PS-1257			14"	BLANK	
#7	PS-1255	WHITE	BUD	10 1/2"	BLANK	
#8	SEE DRAWING NO E-6-1 (M.S.C.)					
#9	SEE DRAWING NO E-8-1 (M.S.C.)					
#10	PS-1255	WHITE	BUD	10 1/2"	BLANK	
#11	PS-1257			14"	BLANK	
PANEL #12	PS-1257	WHITE		14"	BLANK	
RACK #1	RR1369HG	HAM GRAY		80 3/8"		
RACK #2	RR1369HG	HAM GRAY	BUD	80 3/8"		
PANEL SCREWS (FOR ABOVE) QTY: 100 EA						
WIRE DUCT			78FSG (NEWARK)			
			FAN DUCT 1 1/2 x 1 1/2 x 24'			

NOTES:
A OPENING TO BE MACHINED PER RECORDER MFG. INST.
B WIRE DUCT INSTALLED AS REQUIRED ON ASSY.
C INSTALL 2" CHASE NIPPLE, LOCK NUTS AND BUSHINGS THRU ADJACENT RACK WALLS NEAR TOP AND BOTTOM

(CONTROL ROOM)
RACK ASSY
SCALE: 1/16

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO		CONTRACT NUMBER EM-78-C-03-2223	
RACK ASSEMBLY AND WEATHER STATION		DESIGNED BY: JDH	
		CHECKED BY:	
		APPROVED BY:	
		SCALE: NOTED	
SUBMITTED L.D. CLARK		RECOMMENDED APPROVED	
DATE 5/15/79		DWG NO E-5	
		SHEET 1 OF 1	

12
18R

11
1R

CRITICAL FAULTS

- (R) LOW OIL
- (R) OIL TEMP
- (R) HIGH OIL PRES
- (R) HIGH WATER
- (R) HIGH STEAM PRES
- (R) HIGH OIL LEVEL

NON CRITICAL FAULTS

- (R) MAIN OIL PUMP OFF
- (R) LOW WATER
- (R) LOW DC VOLTAGE

POWER

(R) TRIP

(R) TRIPPED

(R) RESET

AUTO OFF (B) START
MANUAL (R) STOP

(W) READY

(R) RAIN

(R) WIND

(W) RUN

OIL PUMP

(R) LOW OIL FLOW

(W) HYDRAULIC ENABLE

(R) HYDRAULIC FAULT

(W) TRACK ENABLE

(R) LOW STEAM

(R) LOW Δ STEAM

(R) STEAM VALVE
CLOSED

(W) STEAM VALVE
OPEN

5.93

NOTES:

1. MATERIAL: 6061-T6 ALUMINUM
2. FINISH: ALDOLINE
3. MATERIAL: CLEAR ACRYLIC PLASTIC
4. HOOK UP WIRE #18 AWG STRANDED EXCEPT #14 AWG STRANDED FROM CIRCUIT BREAKER TO TERMINAL BOARDS
5. CIRCUIT WIRED PER SHT E1, SCHEMATIC

22
2R (W)

23
2R (W)

21
1R

13
5R

2
REF

SEE SHT. 2

QTY	ITEM	PART NUMBER	DESCRIPTION	NOTES
2	26	1N4720	DIODE (CR1, CR2), MOTOROLA	
2	25	SW53AAB3	BLK SW. CAP	
2	24	SW53AA32	RED SW. CAP	
2	23	SA25SAT1	SWITCH, N.O. MOM. CUTLER-HAMMER	
2	22	SA25SBT1	SWITCH, N.C. MOM. CUTLER-HAMMER	
1	21	7563KS	SWITCH, DDPDT, CUTLER-HAMMER	
2	20	27E122	SOCKET, 8 PIN, P/B	
1	19	CSL58-30010	RELAY, DC VOLTAGE SENSOR, P/B	
1	18	CRB38-70010	RELAY, 0.1-10S DELAY, P/B	
1	17	27E123	SOCKET, 11 PIN, POTTER (BRUNFIELD)	
1	16	KAPI4AY-120V	RELAY, 3PDT, POTTER (BRUNFIELD)	
4	15	TYPE MS16-141	MARKER STRIP, C. JONES	
1	14	TYPE 16-141	TERM. BLK, CINC. JONES	
5	13	1050QC4	WHITE PILOT LIGHT, OMNIGLOW	
1	12	1050QC1	RED PILOT LIGHT, OMNIGLOW	
1	11	W67X2Q1-2-10	10A. BREAKER, WOOD	
1	10			
1	9			
1	8	PA-1112-WHITE	1/8x12x21 PANEL, BUD	
4	6	-06	MOUNTING POST 1/2x5/8x2"	1, 2
1	5	-05	GUARD, 1/8x4 1/8x17	3
4	4	-04	MOUNTING POST 1/4x3/8x6"	1, 2
1	3	-03	PANEL, 1/8x17x20 1/2	1, 2
1	2	-02	PANEL, (MAKE FROM ITEM 8)	
1	1	-01	ASSEMBLY	

MONUMENT SOLAR CORPORATION

DALLAS TEXAS

SOUTHERN UNION REFINING CO.
SOLAR PROJECT
HOBBS, NEW MEXICO

CONTROL PANEL

CONTRACT NUMBER

EM-78-C-03-2133

DESIGNED BY: JDN

CHECKED BY: W.P.

APPROVED BY: LDC

SCALE: FULL

APPROVED

SUBMITTED

7/11/79

RECOMMENDED

DATE

5/15/79

DWG. NO.

E-6

SHEET

OF 4

MONUMENT SOLAR CORPORATION		
DALLAS TEXAS		
SOUTHERN UNION REFINING CO.		CONTRACT NUMBER
SOLAR PROJECT		EM-78-C-03-2233
HOBBS, NEW MEXICO		DESIGNED BY: JCH
CONTROL PANEL		CHECKED BY:
		APPROVED BY:
		SCALE: FULL
SUBMITTED	RECOMMENDED	APPROVED
L.D. CLARK		
DATE 5/15/79	DWG NO E-6	SHEET 2 OF 4

-01 ASSY
SCALE 1/2

(TO BE ADDED, SEE DWG 00001 SHT E1)

WIRING DIAGRAM

5.95

MONUMENT SOLAR CORPORATION		
DALLAS TEXAS		
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO CONTROL PANEL	CONTRACT NUMBER	
	EM-78-C-03-2229	
	DESIGNED BY: JDM	
	CHECKED BY:	
SUBMITTED	APPROVED BY:	
	SCALE: 1/2	
L.D. CLARK	RECOMMENDED	APPROVED
DATE 5/15/79	DWG. NO. E-6	SHEET 3 OF 4

-04 POST

-05 GUARD
SCALE 1/2

-06 POST

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS NEW MEXICO		CONTRACT NUMBER EM-78-C-03-2223	
DESIGNED BY: JDM		CHECKED BY:	
APPROVED BY:		SCALE: FULL	
SUBMITTED: L.O. Clark		RECOMMENDED	
DATE 5/15/79	DWG NO E-6	SHEET 4	OF 4

NOTES:

- 1. SEAL-OFF CONDUIT FITTINGS TO BE INSTALLED WITHIN ONE FOOT OF EACH ELECTRICAL DEVICE HAVING SPARK POTENTIAL. SEE CONDUIT SCH. (E-2)
- 2. INSTALLATION HARDWARE AND WORKMANSHIP PER "NATIONAL ELECTRICAL CODE 1979" AND GOOD COMMERCIAL PRACTICE.

CONTROL AND INSTRUMENTATION
SCALE: 1"=2'

LIGHTING AND POWER
SCALE: 1"=4'

MONUMENT SOLAR CORPORATION DALLAS TEXAS			
SOUTHERN UNION REFINING CO. SOLAR PROJECT HOBBS, NEW MEXICO SOLAR BLDG. CONDUIT INSTL		CONTRACT NUMBER EM-78-C03-2223 DESIGNED BY: JDH CHECKED BY: APPROVED BY: SCALE: NOTED	
SUBMITTED L.D. CLARK	RECOMMENDED	APPROVED	
DATE 3/18/79	DWG. NO. E-7	SHEET 1	OF 1

NOTES :

1. MATERIAL : CLEAR ACRYLIC PLASTIC
2. HOOK UP WIRE # 18 AWG STRANDED

NOTE: DASHED LINE INDICATES
WIRING OUTSIDE THIS UNIT

	19			
	18			
	17			
	16			
	15			
	14			
2	13	27E122	SOCKET	8 PIN POTTER & BAMFIELD
1	12	CCR48.7A000A	INTERVAL ON DELAY	170 VAC, 1.0-10 MIN, POTS & BAMFIELD
1	11	CUBS1-10120	DELAY ON RELAY	120 VAC, 1-10 SEC, POTTER & BAMFIELD
1	10	MS-8-141	MARKER STRIP	NO'S 1 THRU 8 CINCH JONES
1	9	TYPE A-41	TERM. BLOCK	8 TERM CINCH JONES
	8	PA-1104-WHITE	PANEL	15" W X 7" H, ALUM., BUD
	7			
4	6	-06	POST, MOUNTING	1/2" SQ X 2" 6061-T6 ALUM
4	5	-05	POST, MOUNTING	3/4" SQ X 6" 6061-T6 ALUM
1	4	-04	GUARD	1/8 X 4 X 13" NOTE 1
1	3	-03	PANEL, REAR	
1	2	-02	PANEL, FRONT	MAKE FROM ITEM 8
✓	1	-01	ASSY	
QTY	ITEM	PART NO	DESCRIPTION	MAT'L, SIZE, MFG

MONUMENT SOLAR CORPORATION
DALLAS TEXAS

SOUTHERN UNION REFINING CO.
SOLAR PROJECT
HOBBS, NEW MEXICO
WIND PANEL

CONTRACT NUMBER
EM-78-C-03-2223

DESIGNED BY: JDH

CHECKED BY:

APPROVED BY:

SCALE: 1

APPROVED

SUBMITTED
L.D. CLARK

RECOMMENDED

DATE 5/15/79

DWG. NO.	F-8
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SHEET	OF
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6. SAFETY

6.1 General Discussion

The system has been designed with considerations to follow the Safety Rules and Regulations by OSHA, Power Piping Codes for Industrial Applications by ASME, ASTM Standards, National Electric Code and State of New Mexico Standard Codes.

The use of hot transfer oil is one of the major hazards, thus the following procedures were used to combat the hazards.

All piping joints will be welded where possible, properly tested for leaks and then a fire retardant fiberglass insulation will be used. All valves will be located with their stems in the downward vertical position where possible.

Due to possible hazardous vapors, all personnel entering any vessel with heat transfer oil shall be adequately protected with proper equipment.

Protective clothing shall be worn when working around hot oil lines. These protective clothing devices will be in accordance with the normal uniforms worn at the refinery.

Possible environmental problems due to an oil spillage has been considered to have negligible effect, thus present no inherent problems.

The system will be adequately protected with safety relay devices, by pass, etc. These safety devices will protect the equipment and provide safety margins for operating personnel.

The area will be provided with various safety and warning signs to provide safety to visitor and operating personnel.

The complete system will be provided with sufficient electrical grounding to ensure the proper grounds for equipment grounding and personnel safety. The complete solar system will adhere to a Class I, Division I, Group D of the National Electric Code to provide explosion proof protection.

The system is located near an existing fire hydrant, thus ensuring proper fire protection for the solar system. The solar building will also be provided with additional CO₂ bottles for in-house protection.

The main plant control room, only a few hundred feet away, offers added security, in that this is the hub of the refinery and offers the most protection in case of needed first aid.

The solar system is completely surrounded and enclosed by the total plant system which is already enclosed by a standard security fence to provide adequate security protection.

6.2 Hazards of Heat Transfer Oil (HTO) Leaks

The liquid to be used in the steam generating system will be Texaco's "Regal R&O 46". (This has recently been superseded in Texaco's product line by "Texatherm" which is nearly identical to "R&O 46"). The dangers are those typically found in petroleum refineries: explosion or fire if the liquid is ignited, thermal burns if the hot (500°F) oil contacts human skin, toxicity of hydrocarbons if inhaled or ingested.

6.2.1 Source of Information - The physical and chemical properties of the oil were provided by the manufacturer. The toxicity information was obtained from an authoritative reference. The data reported here were not evaluated by a physician, however.

6.2.2 Chemical Nature of the Oil - "Regal R&O 46" (or "Texatherm") is a high-boiling paraffinic petroleum fraction that has been extensively refined to ensure purity. Oxidation inhibitors and rust inhibitors have been added in small amounts.

6.2.3 Other Physical Properties - Selected data are summarized in Table 6.1. More information can be obtained from the manufacturer's product brochure which has been reproduced and included in the Appendices of this report.

6.2.4 Danger of Fire - At the expected operating temperature (500°F), the oil has appreciable vapor pressure and is well above its flash point (see Table 6.1). Thus, if the hot oil vapors became mixed with air an explosive or flammable mixture might be found.

TABLE 6.1

PHYSICAL PROPERTIES OF TEXACO'S HEAT - TRANSFER OILS

PROPERTY		REGAL	TEXATHERM
		R&O 46	
Thermal Conductivity			
Btu/Hr/Sq.Ft/°F/Ft. 500°F		.067	.067
Heat Capacity			
Btu/Lb/°F	500°F	.656	.655
Viscosity Range			
SUS	0°F	10,000	
	210°F		47.2
	400°F	30	
Specific Gravity			
g/cc	60°F		.871
	500°F	.72	
Pour Point		-15°F	50°F
Flash Point		430°F	430°F
Max. Temperature			
Closed System		500°F	600°F
Autoignition			
Temperature			675°F
Vapor Pressure			
at 500°F, mm Hg.			25

The HTO storage tank is the most likely place that combustible air-vapor mixtures would form. Thus, the design calls for the oil in the tank to be blanketed with nitrogen.

The oil will not be so hot that if it began to leak it would start burning when it contacted the air. However, the manufacturer agrees that at 500°F the oil would burn readily if it were to contact a spark or flame. Accordingly, any leak from the system should be treated with the same caution as a petroleum leak in the refinery. Smoking or flames near the HTO system will be prohibited.

Another, more subtle, potential for fire exists when HTO leaks beneath insulation and the insulation becomes saturated with the oil. In such a case, the oil oxidizes slowly, the temperature rises; and if the insulation is torn away so the oil is exposed to air, the oil may start burning. Accordingly, pipe joints, flanges, valves, and other likely sources of leaks will not be covered with insulation until after the HTO system has been in operation at 500°F awhile, and these connections have been checked. The piping and fittings will be insulated with glass fiber insulation covered by an aluminum jacket. This insulation meets fire safety requirements. Valves will be installed with their stems in a horizontal or downward position so any oil leaking past the seals will drip away from the insulation.

6.2.5 Nearest Source of Spark or Flame - The nearest source of heat or spark would be in either the field of collectors

(where electric motors position the mirrors) or in the project control room. All motors and switches in the refinery process area and at the cooling tower are explosion proof. Accordingly, all switches, receptacles, lights, motors and other electrical devices in the project area will meet Class I, Division I, Group D of the electrical code.

6.2.6 Fire Protection - The fire hydrant nearest the project site is about 100 feet away and the refinery has suitable fire hoses. In addition, two portable fire extinguishers for A,B, and C-class fires will be mounted in the project control room to protect against small fires.

6.2.7 Toxicity - If the oil is cool, it poses little hazard, unless it is ingested. It cannot be absorbed through the unbroken skin. If it is spilled on the skin, it can be removed by washing with soap and water. For some individuals, repeated or prolonged contact with the skin may cause inflammation. If the oil gets into someone's eyes, the eyes should be flushed with copious volumes of water. If irritation persists, medical advice should be sought.

The vapor from the hot oil poses the same hazard as hydrocarbon vapor generally. According to Sax (1), inhalation of concentrated vapor may cause intoxication similar to that produced by alcohol, as well as headache, nausea and coma; and hemorrhages in vital organs have been reported. Accordingly, if a man is to enter a tank or vessel which contains or contained HTO, he will be equipped with a breathing-air supply.

Drinking the oil would be extremely dangerous. The toxicology according to Sax for hydrocarbon liquids is: "orally by ingestion: causes burning sensation, vomiting, diarrhea, drowsiness, pulmonary edema". There is also the danger that if the victim vomits the liquid may be aspirated into the lungs. Accordingly, the operators will be cautioned about the hazards and instructed in safe handling techniques.

6.2.8 Thermal Burns - If a leak developed in the HTO line, the oil might shoot out as a stream, because it would be under pressure. The oil could cause severe thermal burns to the skin. Accordingly, personnel who must work near the HTO lines or pumps will wear eye protection and protective clothing and equipment as the refinery operators. Visitors will be required to wear eye protection at any time they go into the vicinity of pumps and HTO valves.

6.2.9 Labels on Pipes and Valves - In the event the system must be controlled manually, or an operating problem must be corrected in an emergency, it will be a tremendous help to the operators if they can easily identify the pipes and valves. To facilitate this, the various pipes will be labeled with large commercially - available labels. The direction of the flow will be clearly indicated. Control valves and control devices will be labeled as to the fluid they control.

6.2.10 Compatibility with Materials of Construction - As stated in the Appendix, the important consideration in choosing materials is the operating temperature, not the chemical

nature of the oil. The oil, if dry, is non-corrosive. Carbon steel, ASTM A53 or A106 piping, is commonly used. Packing materials are discussed in the Appendix.

6.3 Designing the HTO System to Minimize Leaks

6.3.1 Alarm System - The HTO storage tank will have high-low level alarms and will shut down the system if more than 40 gal of oil is lost. This would prevent more oil from getting into the steam system, in the event there was a leak inside the steam generator. It would also isolate the pressurized expansion tank system steam generator, steam and feedwater lines.

6.3.2 Small leaks into steam system - The HTO from such leaks would get into the refinery's products, because there are several places in the process where steam is introduced directly for stripping. Although this contamination will not ruin the products, it can be detected by analyzing the products in the laboratory. Such analyses will be performed regularly and the leaks corrected if any contamination is detected.

6.3.3 HTO Storage Tank - The largest spill is potentially from the storage tank where the largest volume of oil is contained. This will be prevented by capping or plugging a drain valve outlet when not in use.

Similarly, other points where the system might be accidentally left open will be capped or plugged.

6.4 Guarding Against Overpressures

6.4.1 Start-Up - It is likely that there will be air and traces of water in the pipes when the HTO is introduced. As the temperature

of the oil is raised, the water will vaporize and the steam must be bled off. This will be facilitated by locating vent valves at several places in the HTO loop, especially at high points. Initially the tank will contain only the minimum volume of oil needed for start-up.

6.4.2 Pluggages in pipes - If the HTO line becomes blocked at a point downstream of the pump, the pressure may rise rapidly as the pump continues to try to circulate the oil. The pressure may become high enough to cause leaks at fittings or to rupture the piping. A by-pass loop around each pump will guard against this. Each loop will have a check valve that will open if the pressure becomes too high, thus permitting oil to circulate from the discharge side of the pump to the suction side.

6.4.3 Vent System Design - Expansion of the HTO will cause a rise in the oil level in the storage tank. If the oil is above 350°F, the concentration of oil vapor in the nitrogen may be significant. The vapor can be cooled and condensed by providing a cold seal. A long vent line serves as a condenser, and a drum containing a small volume of HTO serves to catch any drips. The drum of oil will also prevent air from being sucked into the vapor space in the event the oil level drops and the nitrogen blanketing system fails.

Pluggage of lines is always a possibility, and the vent line is no exception. Accordingly the tank will be provided with a properly sized emergency vent line and rupture disk (or relief valve) to serve as a back up to the small vent line. No

vent line will have a valve except its pressure relief valve. A redundant valve might be accidentally closed, rendering the protection system ineffective.

6.5 Decontamination

In the event of a spill, the bulk of the spilled liquid may be pumped into closed-head drums for subsequent reclamation or disposal. Small spills may be removed by spreading absorbent (dry) sand or dirt on them, then sweeping up the sand or dirt.

Surfaces that have been stained can be steam-cleaned or washed with a strong detergent. Because the hot oil oxidizes rapidly in air and becomes a black carbonaceous deposit, some stains may have to be removed with a dry-cleaning solvent, e.g., perchloroethane.

6.6 Steam Generator

6.6.1 Leaks into HTO System - The steam generator is expected to produce 175 psig steam. The oil pressure in the tubes will normally be much lower than this. Consequently, if crack or hole develops in a heat exchanger tube, boiling water will be forced into the HTO system. The loss of oil into the generator will be practically nil. When the water contacts the 500°F oil (or as its pressure drops to that inside the tubes), the water will vaporize and expand. This steam will displace the oil, pushing it from the HTO loop and into the HTO storage tank. This could require an oversized emergency relief valve.

The abrupt rise in oil level in the tank will be one of the first indications of trouble. The high-level alarm will sound and the system will be shut down automatically.

6.6.2 Precautionary Measures - The steam generator will be hydrostatically tested after manufacture. This is standard procedure. Thus, the most likely cause of leaks will be corrosion. To guard against this, the outside surfaces of the tubes will be inspected annually. A detailed procedure for removing the tube bundle is presented in the attached appendices.

6.6.3 Corrosion due to the HTO - This seems less likely than corrosion caused by the boiler water. When new and unweathered, the oil is not corrosive if dry. At the expected operating temperature (500°F), it will remain dry. When partly oxidized, "Texatherm" may be slightly corrosive, but it contains rust inhibitors to counter this.

6.6.4 Steam pressure - relief system - Assuming the line and pressure-relief valve are properly sized, there are two additional considerations. First, the line from the steam chest must have no valves in it besides the pressure-relief valve. A valve might be left closed accidentally, thus rendering the system ineffective. Second, the steam should discharge at least 8 feet above the highest walkway, grating or personnel access way to prevent the possibility of scalding personnel. This may also be prevented by running the vent line through the roof of the solar building so any steam will go harmlessly into the atmosphere.

6.7 Hazards from Solar Collectors

6.7.1 Reflected Sunlight - If someone were to stand near the focus of the parabolic collectors when they were pointed toward the sun, the intense light could severely damage his eyesight and could cause both sunburn and thermal burns. However, if the person were 40 feet away, the light would be diffused and there would be little danger (See Figure 6.1). The intensity would be less than that reflected from a flat mirror. Moreover, when the collectors are in use, they will be pointed skyward at an angle of 15° above the horizon or greater.

The refinery is surrounded by a high fence, so unwary persons are in no danger of wandering too near the collectors. Visitors to the facility will always be accompanied by refinery personnel, who will prevent them from approaching the collectors too closely.

There may be occasions when visitors or maintenance personnel must approach the collectors when they are in operation. In such cases, special safety glasses will be provided. The lenses will be opaque to ultraviolet light and provide adequate protection against visible light. Moreover signs will be posted about the collector field warning people to avoid looking directly toward the reflectors.

6.8 Safety of Visitors

6.8.1 Danger from Refinery Operations - Normally, visitors to the solar project will not be touring the refinery. Thus, they will be in no danger from this source.

Profile of Parabolic Collector Showing
Directions of Reflected Sunlight

FIGURE 6.1

6.8.2 Control of Visitor Movement - Visitors will enter the refinery property at the main gate and register at the office. Safety rules pertaining to the refinery and solar project will be explained.

Because parking inside the gate is limited, visitors will usually leave their autos in the refinery parking lot near the office. Large groups that arrive by bus can proceed by bus to the project site. Parking space for several buses will be provided near the solar project's control room. Adequate cleared area will be provided so buses can turn around.

6.8.3 Supervision - Visitors will be accompanied by refinery personnel at all times.

6.8.4 Safety Rules - The refinery strictly forbids smoking beyond the office, and forbids any vehicle having a catalytic converter in its smog-control system from entering the refinery gate. In addition, visitors will be cautioned to avoid snakes should they find any, because some may be poisonous. Also, visitors will be advised not to touch exposed pipes, because some may be hot.

6.8.5 Safety Equipment - Ordinarily, visitors to the solar project will not be visiting the refinery so they will not need protective glasses and hard hats.

6.8.6 Availability of Medical Care - Complete emergency medical care is available in the city of Hobbs which is near-by.

The refinery has no facilities for treating a serious illness or injury beyond calling the local ambulance service

and alerting the hospital's emergency room. This will not change since the cost of establishing such facilities for occasional and infrequent visitors to the solar project is unwarranted.

6.9 Security Considerations - Vandalism

The fence around the refinery property is adequate to deter most vandals from entering. Moreover, the distance between the fence and the solar collectors is great enough that thrown rocks would seldom reach them.

REFERENCES

1. Sax, "Dangerous Properties of Industrial Materials", Reinhold Publishing Company, 1968.
2. "Therminol Heat Transfer Fluids", Monsanto, St. Louis, MO, publishing, IC/FP-31.

7. ENVIRONMENTAL IMPACT ANALYSIS

7.1 Description of Proposed Action and Alternatives

The proposed action involves the application of solar energy to the generation of process steam at the Southern Union Company's Famariss Energy Plant (refinery) located near Hobbs, New Mexico. The solar system will interface the petroleum refinery through a heat exchanger with a high temperature oil serving as the heat transfer medium. The collector array is planned to utilize parabolic trough solar collectors having a total aperture area of 10,080 ft² on the Famariss Energy Plant site.

The specific objective of this project is the displacement of fossil fuel (natural gas in the case of the Famariss Plant) through the application of solar energy. The magnitude of the fossil energy saved is predicted to be approximately 1.5 percent of the total natural gas used on an annual basis (taking into account boiler efficiency). Of the total 716 million cubic feet of natural gas annually consumed by the plant, forty percent (about 280 million cubic feet) is used for steam generation. Thus, the solar contribution is the displacement of about 4.3 million cubic feet of natural gas on an annual basis.

7.2 Description of the Existing Environment

The Famariss Plant is located in Lea County between Hobbs and Lovington, New Mexico. Lea County is the extreme southeastern

county within New Mexico. The topography is predominantly plains or rolling hills where the elevation is approximately 3,000 ft above sea level.

The major natural resources in the region are good farm and range lands, and extensive deposits of oil and natural gas and potash. This area contains the most extensive croplands in New Mexico. Most irrigated farming occurs along the Pecos River. There is some dry farming.

In general, very little manufacturing is done in this region. Economically, the region depends on agriculture and the mineral industry. The major agricultural activity includes cattle and hog production and, where irrigation is possible, crops such as grain, sorghums, cotton, wheat, alfalfa, and peanuts. Oil and gas production and potash mining are the major mineral industries in this region.

The characterization of the local environment at the location of the refinery is difficult to determine in that no ambient air quality surveys have been conducted at the plant site. With water quality, only the wells supplying the Hobbs municipal water supply system have been analyzed.

However, the New Mexico Air Quality Division of the Environmental Improvement Agency has published summaries of ambient air quality data. The closest sampling stations are located at the Lea County General Hospital in Hobbs and the Lea County Health Department in Lovington (1). The data available for these sites are given for 1976 as:

SO₂: 0.0057 ppm, annual arithmetic mean

(Federal Standard = 0.03 ppm)

(State Standard = 0.02 ppm)

Total Suspended Particulates: 66 µg/m³) annual geo. mean

(Federal Standard = 76 µg/m³)

(State Standard = 60 µg/m³)

NOx, CO total hydrocarbons (THC) and ozone were not measured.

The ground water analysis and the Human Health Standards (2) are given in Table 7.1. The ground water supply wells for Hobbs are well within the standards. This is in contrast to the air quality which is near the standards for SO₂ and total suspended particulates.

7.3 Analysis of Proposed Action

An analysis, limited in depth, is presented where the environmental impacts of the proposed solar steam generation system are assessed. First, the anticipated impacts are outlined; then the appropriate mitigating or enhancing measures are presented. Finally, the residual impacts are discussed.

The major impact of this study is the displacement of fossil fuel - natural gas - which is the primary objective of the proposed action. Approximately 4.8 million cubic feet of gas will be displaced annually by the application of the solar system at the Famariss Plant. In addition to the diversion of natural gas to another application, the following is the predicted reduction in emissions from the two process steam boilers based on emission factors for the combustion of natural gas (3).

TABLE 7.1

HUMAN HEALTH STANDARDS AND GROUND WATER
ANALYSIS FOR THE HOBBS MUNICIPAL WATER SUPPLY

<u>ITEM</u>	<u>STANDARD CONCENTRATION</u>	<u>MEASURED CONCENTRATION</u>
Arsenic (As)	0.1 mg/1	<0.01
Barium (Ba)	1.0 mg/1	<0.500
Cadmium (Cd)	0.01 mg/1	<0.010
Chromium (Cr)	0.05 mg/1	<0.050
Cyanide (CN)	0.2 mg/1	-----
Flouride (F)	1.6 mg/1	0.95
Lead (Pb)	0.05 mg/1	<0.010
Total Mercury (Hg)	0.002 mg/1	-----
Nitrate (NO ₃ as N)	10.0 mg/1	10.5
Selenium (Se)	0.05 mg/1	0.16
Silver (Ag)	0.05 mg/1	-----
Uranium (U)	5.0 mg/1	-----
Radioactivity: Combined (Radium 226 and Radium 228)	30.0 pCi/1	-----
Chloride (Cl)	250 mg/1	45
Copper (Cu)	1.0 mg/1	<0.25
Iron (Fe)	1.0 mg/1	<0.25
Manganese (Mn)	0.2 mg/1	<0.25
Phenols	0.005 mg/1	-----
Sulfate (SO ₄)	600 mg/1	85
Total Dissolved Solids (TDS)	1000 mg/1	650
Zinc (Zn)	10.0 mg/1	0.6
pH	between 6 and 9	7.7

<u>Pollutant</u>	<u>Annual Emission Reduction</u>
Particulates	65 lb
Sulfur Oxides (SO ₂)	2.6 lb
Carbon Monoxide (CO)	75 lb
Hydrocarbons (as CH ₄)	15 lb
Nitrogen Oxides (NO _x)	900 lb

Although emission data for the Famariss Plant are not available, the average emission rates for 262 refineries are given below to illustrate the relative magnitudes.

<u>Pollutant</u>	<u>Daily Emission Rate</u>
SO ₂	23 tons/day
NO _x	0.6 tons/day
Hydrocarbons	24 tons/day
CO	25 tons/day
Particulates	0.6 tons/day

These average emission rates are so large that the proposed solar system will have virtually no impact on the ambient air quality near the plant site or the population centers of Hobbs and Lovington.

The impact of the proposed action on water quality can only occur through an unforeseen accident in which the heat transfer fluid within the collector loop would spill onto the ground. Because the area surrounding the refinery lacks any rivers or streams and is largely flat, the oil would be absorbed into the soil immediately below the collectors. Surface runoff would not transport the oil to another location. Therefore, the direct effect would be sterilization of the soil in the vicinity of the collector array thus preventing any plant-life for a long time. The planned site for the collector field has

been plowed and graded, eliminating any negative environmental impact relative to the naturally occurring plant-life by the proposed action.

Contamination of the Ogalla Basin (the freshwater basin supplying both Hobbs and Lovington) as well as the drinking water supply for the refinery itself (on-site well), is possible. However, calculations (4,5) indicate contamination resulting from an oil discharge from the solar system is only a remote possibility. The Ogalla Basin is located approximately 70 ft below the surface with a substantial thickness of bedrock (limestone) above it. Firmly cemented to the bedrock is indurated caliche which is several feet thick and lies just below the soil (5). For contamination to occur, the amount of oil spilled would have to be much greater than the amount of oil in the solar system. Moreover, the oil would have to be replenished at the surface to maintain the driving force.

Cleaning the collector's reflective surface may be necessary to maintain acceptable performance. Deionized water will be used to rinse them periodically. The environmental impact will be negligible.

Solid waste disposal through the proposed action will not present any significant environmental impact. The solid waste generated will involve the normal materials associated with the maintenance and operation of any mechanical system. The Famariss Plant's normal disposal procedures can accommodate the additional solid wastes.

The impact of the solar system on the surrounding area's aesthetics is muted by its close proximity to the refining equipment. From all vantage points, the solar system's components will be below the "sight" profile of the refinery complex.

Public attitude is anticipated to generate positive support for the proposed action. The solar system will be visible to the public and should encourage the expanded use of solar generated process steam, both at the Famariss Refinery and other refineries.

The area of land involved with the proposed solar system is about two acres. The effect on land use is, therefore, inconsequential particularly in view of the fact that the land is presently idle. However, expansion of this proposed action or the addition of solar systems to other refineries must separately consider the land-use impact relative to alternative uses.

During the construction phase of the project, activities not characteristic of the completed system will exist. These include:

- o Labor market impact
- o Emissions due to construction activity

Construction of the solar system will involve little on-site work because the major components (collectors and heat exchanger) will be fabricated at the manufacturer's plant. The required ground work will involve the installation of concrete pads to support the collector modules. The on-site construction labor is anticipated to have no impact on the surrounding labor market.

The construction crew will involve fewer than ten full-time men on a continuous basis over the duration of the nearly one-year construction phase.

The impact on air quality during construction includes the emissions from internal combustion engines operated at the construction site, automotive emissions resulting from commuting to the construction site, and fugitive dust emissions caused by the usual ground activity. The anticipated total emission rates during the construction phase are (3,6,7):

<u>Pollutant</u>	<u>Daily Emission Rate, lb/day</u>
CO	21
Hydrocarbons	4
NOx	10
Particulates	0.6
SO ₂	0.2

Compared to the refinery's emission rates, these are negligible.

Site generated solid wastes will be easily accommodated by the refinery's normal disposal procedures. No impact on water quality is anticipated, because no liquid discharges are expected during construction.

The irreversible and irretrievable impacts and commitment of resources associated with the proposed action are insignificant due to the project's small scale. But, the installation of concrete pads to support the collector array is an irreversible impact on the land, because their removal is unlikely. The proposed solar system does not involve the extraction of minerals, the destruction of archeological sites, or changes in ecosystems.

In summary - the proposed installation and operation of the solar system will have no significant environmental impact on the operation of the Famariss petroleum refinery operated by the Southern Union Company. However, future expansion of the proposed solar system and the associated environmental impacts must be considered separately at the time such expansion is contemplated.

7.4 Potential Environmental Impact Assessment

The project environmental impact assessment was restricted to the activity associated with the solar system planned at the Famariss Refinery. Tables 7.2 and 7.3 extend that analysis to include all refineries within the United States having a total production capacity less than 50,000 bbl/day. In determining which refineries met the production criteria, the refineries under construction as of 1974 as well as those currently producing at that time were counted. Refineries constructed after 1974 are not included in the Tables. However, a qualitative observation is possible from the 1974 data, because the majority of new refinery construction was directed toward capacities exceeding the 50,000 bbl/day criterion. Small refinery construction usually involved improving or expanding of the existing refinery. Consequently, Table 7.3 is believed to be a reasonable assessment of current U.S. refinery capability.

The smaller collector area that is given in the totals corresponds to a 10,080 ft² collector array installed at each

TABLE 7.2
SUMMARY OF TOTAL ENVIRONMENTAL IMPACTS
RESULTING FROM INSTALLTION OF SOLAR SYSTEMS
ALL SMALL REFINERIES*

<u>COLLECTOR AREA (ft²)</u>	<u>TOTAL ENERGY SAVED (GBTU/YR)</u>	<u>AIR POLLUTION REDUCTION (tons/yr)</u>	<u>LAND USED (acres)</u>
1,683,360	617	136	34
4,208,400	1522	339	301

*For 167 refineries in 50 states, and Puerto Rico processing 2,239,880 bb./day crude oil.

TABLE 7.3

ESTIMATION OF ENVIRONMENTAL IMPACT OF PROPOSED SOLAR SYSTEM

<u>State</u>	<u>Number of Refineries*</u>	<u>Total Operation Capacity of All Refineries (BPD)*</u>	<u>Collector Aperature per Installation (ft²)</u>	<u>Fossil Fuel Displaced (G BTU/yr)</u>	<u>Reduction of Air Pollution Emission** (tons/yr)</u>	<u>Required Acreage</u>
Alabama	5	42,500	10,080 25,200	18.0 27.0	4.0 9.9	4.0 9.0
Alaska	3	65,400	10,080 25,200	7.8 19.2	1.7 4.3	2.4 5.4
Arizona	1	9,000	10,080 25,200	4.5 11.2	1.0 2.5	0.8 1.8
Arkansas	3	13,000	10,080 25,200	10.8 27.1	2.4 5.9	2.4 5.4
California	22	370,458	10,080 25,200	77.9 195.0	17.1 42.8	17.6 39.6
Colorado	4	48,200	10,080 25,200	16.8 42.1	3.7 9.2	3.2 7.2
Delaware	0	--	--	--	--	--
Florida	1	5,000	10,080 25,200	4.1 10.4	0.9 2.3	0.8 1.8
Georgia	2	17,000	10,080 25,200	7.3 14.6	1.6 4.0	1.6 3.6

* Includes only those refineries with total capacity less than 50,000 BPD on a per calender day basis.

**Based on the combination of natural gas and includes both gaseous and particulate emissions.

TABLE 7.3 cont.

State	Number of Refineries*	Total Operation Capacity of All Refineries (BPD)*	Collector Aperture per Installation (ft ²)	Fossil Fuel Displaced (G BTU/yr)	Reduction of Air Pollution Emission** (tons/yr)	Required Acreage
Hawaii	0	--	--	--	--	--
Illinois	2	2,200	10,080 25,200	6.6 16.5	1.5 3.6	1.6 3.6
Indiana	6	59,400	10,080 25,200	19.6 49.0	4.3 10.8	4.8 10.8
Kansas	5	146,659	10,080 25,200	18.8 46.9	4.1 10.3	4.0 9.0
Kentucky	3	40,300	10,080 25,200	11.5 28.6	2.5 6.3	2.4 5.4
Louisiana	11	111,100	10,080 25,200	33.9 84.8	7.5 18.6	8.8 19.8
Maryland	2	23,500	10,080 25,200	6.9 17.1	1.5 3.8	1.6 3.6
Michigan	5	56,000	10,080 25,200	16.1 40.3	3.5 8.9	4.0 9.0
Minnesota	1	35,000	10,080 25,200	3.2 7.9	0.7 1.8	0.8 1.8
Mississippi	3	21,000	10,080 25,200	11.7 29.3	2.6 6.4	2.4 5.4
Missouri	0	--	--	--	--	--

* Includes only those refineries with total capacity less than 50,000 BPD on a per calendar day basis.

**Based on the combination of natural gas and includes both gaseous and particulate emissions.

TABLE 7.3 cont.

<u>State</u>	<u>Number of Refineries*</u>	<u>Total Operation Capacity of All Refineries (BPD)*</u>	<u>Collector Aperture per Installation (ft²)</u>	<u>Fossil Fuel Displaced (G BTU/yr)</u>	<u>Reduction of Air Pollution Emission** (tons/yr)</u>	<u>Required Acreage</u>
Montana	6	29,683	10,080 25,200	21.0 52.4	4.5 11.6	4.8 10.8
Nebraska	1	8,000	10,080 25,200	3.5 8.6	0.8 1.9	0.8 1.8
Nevada	1	500	10,080 25,200	4.6 11.6	1.0 2.5	0.8 1.8
New Jersey	1	3,000	10,080 25,200	3.4 8.5	0.8 1.9	0.8 1.8
New Mexico	8	135,450	10,080 25,200	39.2 98.0	8.6 21.6	6.4 14.4
New York	0	--	--	--	--	--
North Carolina	1	12,000	10,080 25,200	3.7 9.3	0.8 2.0	0.8 1.8
North Dakota	2	13,100	10,080 25,200	6.2 15.5	1.4 3.4	1.6 3.6
Ohio	1	20,400	10,080 25,200	6.7 16.7	1.5 3.7	0.8 1.8
Oklahoma	6	137,735	10,080 25,200	25.0 62.5	5.5 13.8	4.8 10.8
Oregon	1	14,000	10,080 25,200	3.1 7.8	0.7 1.7	0.8 1.8

* Includes only those refineries with total capacity less than 50,000 BPD on a per calendar day basis.

**Based on the combination of natural gas and includes both gaseous and particulate emissions.

TABLE 7.3 cont.

State	Number of Refineries*	Total Operation Capacity of All Refineries (BPD)*	Collector Aperture per Installation (ft ²)	Fossil Fuel Displaced (G BTU/yr)	Reduction of Air Pollution Emission** (tons/yr)		Required Acreage
Pennsylvania	7	52,035	10,080 25,200	23.7 59.2	5.2 13.0		5.6 12.6
Rhode Island	1	7,500	10,080 25,200	3.0 7.4	0.4 1.1		0.8 1.8
Tennessee	0	--	--	--	--		--
Texas	26	370,860	10,080 25,200	103.0 259.0	22.7 56.7		20.8 46.8
Utah	6	98,900	10,080 25,200	22.2 55.6	4.9 12.2		4.8 10.8
Virginia	0	--	--	--	--		--
Washington	3	27,800	10,080 25,200	9.6 24.0	2.1 5.3		2.4 5.4
West Virginia	3	26,160	10,080 25,200	11.0 27.6	2.4 6.1		2.4 5.4
Wisconsin	1	5,000	10,080 25,200	3.3 8.3	0.7 1.8		0.8 1.8
Wyoming	11	145,040	10,080 25,200	41.0 102.0	9.0 22.6		8.8 19.8

* Includes only those refineries with total capacity less than 50,000 BPD on a per calendar day basis.

**Based on the combination of natural gas and includes both gaseous and particulate emissions.

TABLE 7.3 concluded

<u>State</u>	<u>Number of Refineries*</u>	<u>Total Operation Capacity of All Refineries (BPD)*</u>	<u>Collector Aperature per Installation (ft²)</u>	<u>Fossil Fuel Displaced (G BTU/yr)</u>	<u>Reduction of Air Pollution Emission** (tons/yr)</u>	<u>Required Acreage</u>
Hawaiian Foreign Trade Zone (Ewa Beach)	0	---	---	--	--	--
Puerto Rico	2	66,100	10,080 25,200	8.2 20.5	1.8 4.5	1.6 3.6

* Includes only those refineries with total capacity less than 50,000 BPD on a per calender day basis.

**Based on the combination of natural gas and includes both gaseous and particulate emissions.

of the 167 refineries. The larger collector area is the total area resulting from installing a 25,200 ft² collector array at each refinery.

The environmental impacts are still relatively small compared to any major industry. For example, the 1522 GBTU/year saved by installing the larger solar system at all eligible refineries would be about 0.1% of New Mexico's total energy production in 1975. The reduction in the emission of effluence would likewise be small. The daily emission rate from an average U.S. refinery exceeds the total reduction (for the 25,200 ft² arrays) in five days.

Land use impact is also small, but can be important depending on local circumstances. For example, uses other than agriculture could be highly significant and outweigh the benefits of saving non-renewable fuels. This aspect can only be investigated on a case-by-case basis.

7.5 Influence of Cooling and System Performance

Because the cooling tower plume will shade a portion of the collector field depending on the local meteorology, an estimate of this shading is required. With the annual fraction of the array shaded, the overall effect on performance can be estimated. The approach used here is to establish an upper bound on the anticipated shading fraction for both the 10,080 ft² array and the larger 25,200 ft² array. The analysis disregards the details associated with the development of a moist

plume as the calculation of the plume trajectory is extremely complex and requires considerable on-site meteorological data and computational effort (digital computer).

In general, meteorological conditions fall under four classifications: very unstable, unstable, neutral, and stable. These conditions govern the development of the plume and are used to define the crosswind and vertical plume standard deviations. In the absence of meteorological data, stable and unstable conditions are assumed for this preliminary estimate. However, it is expected these conditions are the most prevalent in the Hobbs area. The dispersion equation is based on the assumption that the concentration distribution of a plume is Gaussian. This assumption has been supported by numerous investigations (9,10,11,12). The equation yielding ground-level concentrations from an elevated point source is:

$$X(x,y,o) = \frac{Q}{\pi\sigma_y\sigma_z\bar{u}} \exp -\left(\frac{h^2}{2\sigma_z^2} + \frac{y^2}{2\sigma_y^2}\right) \quad (1)$$

where,

X = concentration (units/m³)

Q = source release rate (units/sec)

σ_y, σ_z = crosswind and vertical plume standard deviations (m)

$\bar{u}$ = mean wind speed (m/sec) at h

h = effective stack height (m)

x, y = downwind and crosswind distances (m)

Along the centerline of the plume, the concentration is given by:

$$X(x,o,o) = Q/(\pi\sigma_y\sigma_z\bar{u}) \quad (2)$$

For the horizontal variation of X from the plume centerline,

$$X = \frac{Q}{\pi\sigma_y\sigma_z\bar{u}} \exp \left(\frac{-y^2}{2\sigma_y^2}\right) \quad (3)$$

and can be used to estimate plume width.

In order to perform the estimate, the characteristics of the source must be determined. A list of these calculations is given in Table 7.4 with several appropriate calculations. Because the cooling tower plume is near ambient temperature, bouyant effects can be neglected. Hence, the effective stack height is due to the exit speed at the top of the cooling tower.

The meteorological data available from the Lea County airport were measured at an elevation of 10.7 m above ground with no nearby obstructions (14). This elevation is nearly the same as the cooling tower's height, 9.1 m. The wind data pertinent to the plume dispersion calculations are given in Table 7.5. For the four wind directions, the average effective stack height is 21.0 m with the maximum variation about 8 percent. In addition, corrections to wind speed and direction at the effective stack height are negligible relative to the approximate nature of the plume calculation.

For the unstable and stable meteorological conditions, the following relations were used to approximate the plume standard deviations (2):

	<u>$\sigma_y(m)$</u>	<u>$\sigma_z(m)$</u>
UNSTABLE	0.36×0.86	0.33×0.86
STABLE	0.31×0.71	0.06×0.71

These relations were determined empirically and are reasonable in comparison to corresponding values reported elsewhere.

Calculations have been made and the normalized

TABLE 7.4

COOLING TOWER SYSTEM PARAMETERS (13)

Stack height = 9.1 m

Stack diameter = 3.05 (2 stacks)

Stack effluent velocity = 15.2 m/sec (estimated)

Effluent temperature = ambient temperature = 288°K

Effluent density: Void fraction = 0.01 (assumption)

$$(0.01) \times (1 \text{ gm/cm}^3) = 0.01 \text{ gm/cm}^3$$

Ambient air density = $1.2 \times 10^{-3} \text{ gm/cm}^3$

$$Q = (2)\left(\frac{\pi}{4}\right)(3.1^2)(15.2)(0.01)\left(\frac{10^4}{10^3}\right)\left(\frac{288}{273}\right) = 24 \text{ kg H}_2\text{O sec}^{-1}$$

The effective stack height is given by:

$$\Delta h = (V_s/\bar{u}_s)^{1.4}$$

where,

Δh = height of the plume centerline above the source (m)

D = diameter of stack (m)

V_s = Vertical exit velocity at release temperature (m/sec)

$\bar{u}_s$ = mean wind speed at actual stack height (m/sec)

TABLE 7.5

WIND ROSE DATA FOR LEA COUNTY AIRPORT
Hobbs, New Mexico (14)

Direction	Average Annual Wind Speed (mph)	Standard Deviation (mph)	Annual Wind Rose Percent
SSW	12.4	1.7	13%
SW	12.8	2.8	16%
WSW	14.8	3.3	4%
W	11.7	2.5	5%

plume half-width, $W_{\frac{1}{2}}/D$ are plotted against downwind distance. The centerline concentration for unstable meteorological conditions is much less than for stable conditions due to the difference in atmospheric mixing. Likewise, the plume half-width for stable conditions is considerably less than for unstable conditions. It should be noted that the influence of the two points of discharge are disregarded due to their close proximity to each other. However, the source emission rate accounts for the total discharge rate.

To consider the worst case, we assumed that the plume is unstable (thus its thickness equals twice the calculated half-width) and it fully attenuates the direct beam radiation. This would be the widest plume and thus would shade the greatest portion of the collector array. Using this plume, we determined the annual fractional reduction of collector area, taking into account the wind direction probability. The results are given below in Table 7.6.

TABLE 7.6
ANNUAL FRACTIONAL
REDUCTION IN WORST CASE

<u>ARRAY FT²</u>	<u>REDUCTION</u>
10,080	0.024
25,200	0.035

The higher fractional reduction for the larger array is due to the SW wind which has a 16 percent chance of occurring.

The fractional reductions presented in Table 7.6 serve as an upper bound. Realistically, the cooling tower plume may or may not be visible depending on the relative humidity. In addition, the relatively vigorous mixing of the unstable plume enhances dilution and the evaporation of water droplets. These two factors greatly influence the visibility of the plume. In other words, the stable plume is likely to be visible whereas the unstable plume may not be visible. In addition, unstable conditions are apt to occur on sunny days, whereas stable conditions generally occur on overcast days and at night. Factoring all these items together without on-site meteorological data is not possible. However, it may be expected that the actual area fractional reductions will be only half as great as the maximum values given in Table 7.6.

There may be a greater problem associated with the cooling tower plume, namely, the deposition of water droplets onto the reflective surface of the collectors. Although the major impurities in this water are the naturally-occurring dissolved minerals, additives are used in small amounts to control pH and corrosion. These additives include: sulfuric acid, zinc chromate, dispersants, surfactants and chlorine (15). Because the mean size of the emitted droplets is likely to be over 100 μm , deposition or "fall-out" from the plume will occur. The effects on the collector's reflective surface could be significant.

In considering the problem of droplet deposition, it is proposed that when the collector module is being tested on-site, careful examination of the reflective surface be conducted. Also, electron-microscope grids should be installed on the surface for varying time periods and examined under a scanning electron-microscope having elemental analysis capability to identify particle composition. Corrosion activity can also be investigated by the electron-microscope through analysis of the reflective material itself.

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8. ECONOMIC ANALYSIS

8.1 General Discussion

The introduction of solar energy into the petrochemical industry by this DOE sponsored demonstration program appears to be exceedingly meaningful. The petrochemical refining industry is one which has one of the highest potentials for a solar thermal energy application. This is true because the thermal energy demand is nearly constant over a daily 24-hour period when the refining plant is operated continuously. Such a steam demand profile provides an excellent application for supplemental solar steam generation.

Due to a depletion in the available or known natural gas reserves, the oil-refining industry is looking for alternative energy sources for steam generation. This demonstration program is to illustrate by actual installation and operation, the suitability of solar generated steam to partially supplant the steam generated using natural gas or fuel oils, and to show that this can be done in an economically acceptable fashion if done in a sufficiently high level of activity. In the following, therefore, the economic viability of the solar thermal system is reviewed and compared with the conventional existing refining system. Recognition of the demonstration nature of this system is noted by looking, in a limited fashion, to somewhat larger arrays and a look at the projected 100th production system.

In performing this economic analysis, the life-cycle economic models have been used for comparisons and evaluations. This is

considered to be realistic and emphasizes the rising prices of the fossil fuel imparting a steadily increasing benefit through the lifetime of the solar system. Since it may be more proper to present the economic results on a comparative basis instead of giving a single value from a specific method, three methods were employed in this analysis: 1) JPL Method - levelized energy cost calculation (Reference 1); 2) Dickinson's Method - payback period calculation with levelized fuel price (fuel escalation included) (Reference 2); 3) Present Worth Method - determine the breakeven point (i.e. payback period at equal present values of conventional system and solar-augmented system).

The economic factors that were considered for this analysis include system capital costs, operation and maintenance costs, taxes, investment tax credit incentives, and cost of fossil fuel. In determining the levelized thermal energy cost, the financial factors of the existing refining company were used for analytic simulation.

The solar collector of a solar system is actually the source of energy supply. However, for the proposed solar system (10,080 square feet collector area), the cost of solar collectors is only 37% of the total cost of the system. In a larger size solar system or in the mass production process, the cost of solar collectors will go up to 57% of the total cost. The impacts of large size solar systems, as well as mass production on the economic values are presented in this analysis. This will provide more realistic economic values than those for the demonstration solar system.

Finally, by using a general rule of thumb, an optimum size solar system for the Southern Union Refining Plant has been determined.

8.2 Energy Supply by Solar System

Figure 8.1 shows the energy flow diagram of the Famariss Refining plant. The annual energy consumption is 716 billion Btu in natural gas and 3.17 megawatts in electricity. Approximately 40% of the gas is used for steam generation. The steam at 375°F, 170 psi is used for the oil-distillation process, with a small amount of additional steam used for storage tank heating in the winter season. The efficiency of the boiler was calculated to be 83%, i.e. about 17% of the gas has been lost through the exhaust system. Therefore, the high temperature steam generated by solar system will reduce a significant amount of gas consumption as well as reduce the level of the air pollution.

Table 8.1 presents the annual energy supplied by the solar system in terms of the amount of fossil fuel which has been replaced. The efficiency of the boiler has been included in the calculations. The proposed solar system will provide 3.54 billion net Btu to the Famariss Refinery, thereby reducing fuel consumption for the generation of process steam by the equivalent of 3.81 million cubic feet of natural gas or 23.8 million gallons of fuel oil. This is about 3.66 percent of the annual gas consumption for steam generation during the daylight hours (average 10 hours per day) or equivalent to 1.53 percent of their natural gas consumption during the 24-hour period.

FIGURE B.1

REFINERY ENERGY USE, ANNUAL

TABLE 8.1

ENERGY SUPPLIED BY SOLAR
(10,070 ft² System)

QUANTITY OF ENERGY SUPPLIED, BTU/YR	3.54×10^9
FUEL REPLACED ANNUALLY:	
NATURAL GAS (\$2 MM Btu)	3.81 MM SCF (4.27×10^9 BTU)
FUEL OIL (\$18/BBL)	23,788 M Gallon
% OF TOTAL INDUSTRIAL STEAM	
DURING DAYLIGHT HOURS	3.66%
DURING 24-HOUR PERIOD	1.53%

8.3 Cost Estimates of the Solar System

Table 8.2 shows the estimated installed costs of the nominal project size (10,000 square feet) and the proposed project sized (10,080 square feet) solar systems. The installed cost of the proposed solar system was estimated to be \$571,878, or \$56.73/square feet of collector area. By applying appropriate learning curves, the installed costs of solar systems in a large scale and in mass production are presented in Table 8.3. The reduction in the cost of the solar system will be dominated in the economic analysis in terms of the levelized energy cost and the payback period of the solar system.

8.4 Operation and Maintenance Cost

Because of lack of operating experience with the proposed solar system, it is difficult to predict the operation and maintenance costs and large variations can be expected from one application to another as well as one climatic region to another region. However, the solar thermal irrigation system located in Willard, New Mexico uses the same type of solar collector and has been operated about one year. The maintenance cost for this system, mainly repairing and troubleshooting and excluding the collector cleaning, amounts to about 0.55% of the total installed investment. For the Famariss refinery, the annual insurance premium as a ratio of capital investment was estimated by Southern Union Refining Company to be 0.72%. Thus, a total of 2% of the investment is a reasonable value for the operating

TABLE 8.2

INSTALLED COST

<u>CATEGORY</u>	<u>PROJECT SIZE: AREA OF COLLECTORS</u>	
	<u>10,000 FT²</u>	<u>ACTUAL PROJECT 10,080 FT²</u>
COLLECTOR	219,016	220,768
STEAM GENERATOR	19,800	19,800
PIPING & PUMPS	74,757	74,757
STRUCTURAL SUPPORT	12,233	12,331
CONTROLS	34,000	34,000
ELECTRICAL	10,000	10,000
OVERHEAD, CONTRACTORS FEES, OTHER COSTS	200,000	200,222
	569,806	571,878

TABLE 8.3

SOLAR SYSTEM COSTS

System Size Collector Size in Ft ²	One Unit		100 Units*	
	Capital Cost	Cost/Ft ²	Capital Cost	Cost Ft ²
10,080	\$571,878	\$56.73	\$331,861	\$32.92
25,200	\$935,277	\$37.18	\$530,594	\$21.50

*Assumptions used when scaling the system production from 1 to 100 units:

- a) 90% of learning curve in labor cost.
- b) 50% reduction in collector cost
- c) 10% reduction in piping components cost due to mass purchase
- d) all costs are based on 1979 dollars with no escalation
- e) 100 units will be built in five years.

and maintenance cost of the solar system. This is the same value estimated by Dickinson. However, a sensitivity study has been done in this analysis as shown in Figure 8.2 below.

8.5 Optimization of the Solar System

The optimization of the solar system was executed to find out the optimum size of the solar collector array. A rule of thumb of "three times the size of the solar collector array will double the cost of the installation and auxiliary equipment" was adopted. Under these assumptions the optimum size of the solar collector array was found to be about 180,000 square feet. Such an array will supply about 10 percent of the total thermal energy consumption as shown in Figure 8.3, or 27% of the energy consumption for steam generation at the Famariss refinery.

8.6 Results and Discussion

Table 8.4 shows the levelized energy cost of the solar systems, large reduction in the cost from small size to large size and from one unit to 100 units. The financial factors appropriate to the Southern Union Refining Company are listed in Table 8.5.

Figure 8.4 and 8.5 present the payback period for a small demonstration system, a large demonstration system and the optimum system by using the Dickinson's method and present worth method respectively. On these figures, the upper line of the shaded area is referred to the cost of one unit sized solar

Sensitivity Study of the O & M Cost of the Solar System on Payback Period.

FIGURE 8.2

Optimization of the Solar System by
Levelized Busbar Energy Cost
(Analysis period = 20 years)

FIGURE 8.3

TABLE 8.4

LEVELIZED ENERGY COSTS OF THE PROPOSED SOLAR SYSTEMS

System Size Collector Size in ft ²	ENERGY COST (\$/MMBTU)	
	One Unit	100 Units
10,080	25.35	17.76
25,200	16.63	11.49

** 32% reduction from one unit to 100 units.

** 34% reduction from 10,080 ft² to 25,200 ft².

TABLE 3.5
ECONOMIC ASSUMPTIONS

<u>FACTOR</u>	<u>VALUE USED</u>
Annual Other Tax as Fraction of Capital Investment	0.0334
Annual Insurance Premiums Fraction	0.0072
Effective Income Tax	0.484
Ratio of Debt to Total Capitalization	0.227
Ratio of Preferred Stock to Total Capitalization	0.0
Ratio of Common Stock to Total Capitalization	0.642
Annual Rate of Return on Debt	0.0899
Annual Rate of Return on Common Stock	0.038
Annual Rate of Return on Preferred Stock	0.0
General Cost Inflation	0.08*
First Year of Commercial Operation	1980
Base Year for Constant Dollars	1979
Capital Cost Inflation Ration	0.099
Year of Capital Expenditure	1979
Federal Income Tax Rate	0.46
State Income Tax Rate	0.05
Investment Tzx Credit Rate	0.10
Accounting Life for Depreciation	Straight Line
Fuel Costs: Gas = \$2/MM Btu	
#5 resid. oil = \$18/BBL	
= \$2.95/Btu	
Annual Fuel Consumption = 716×10^9 Btu (excluding electricity)	

*This value was obtained from Chemical Engineering Index, April 1979.

Payback Period of Solar Systems versus Fuel Escalation Rate
Using Dickinson's Method

FIGURE 8.4

Payback Periods of Solar Systems Versus Fuel Escalation Rate Using Present Worth Method

FIGURE 8. 5

system array and the lower line is referred to the cost of building 100 unit solar system arrays. The payback period of the small demonstration solar system is in the range of 17-23 years at 20% of fuel escalation rate. The optimized system and the larger 25,000 square foot demonstration system show a comparative payback period of about 10 to 14 years.

8.7 Existing Steam Plant

Among the data needed for the economic evaluation of the solar project were the fuel consumption rate, efficiency, and installed cost of the existing gas-fired boiler at the Famariss Refinery.

The replacement cost (1979 dollars) was estimated at \$187,000. The gas consumption rate was determined to be 40,000 scf/ht (40 MM Btu/hr) during the winter months and 30,000 scf/hr during the other seasons. The thermal efficiency was calculated at 77%. In performing the economic analysis, however, an efficiency of 83% was used in order to be more conservative. This is because the greater the efficiency of the boiler, the less gas is required to produce a given amount of steam. Thus, the amount of gas saved by using solar energy is less.

8.7.1 Gas Consumption & Boiler Efficiency

The following data were provided by personnel at Famariss Refinery:

boiler steam generation rate = 30,000 lb steam/hr (winter)

boiler gas consumption rate = 40,000 scf/hr

heating value of natural gas = 1,000 Btu/sch

Calculations:

$$(1) \quad \text{Heat input to boiler} = \frac{40,000 \text{ scf/hr}}{30,000 \text{ lb/hr}} \frac{(1000 \text{ Btu})}{\text{scf}} \\ = 1,333 \text{ Btu/lb}$$

$$(2) \quad \begin{array}{ll} \text{Heat added to water (Btu/lb steam)} & \\ \text{Enthalpy of (sat'd) steam at } 375^{\circ}\text{F} & = 1197.2 \\ \text{Enthalpy of feed water at } 200^{\circ}\text{F} & = 168.1 \\ \text{Net Heat} & = 1029 \text{ Btu/lb} \end{array}$$

$$(3) \quad \begin{array}{l} \text{Efficiency:} \\ \frac{\text{heat going to yield steam}}{\text{total heat input to boiler}} = \frac{1029 \text{ Btu/lb}}{1333 \text{ Btu/lb}} = 77\% \end{array}$$

This result was confirmed by the vendor who reported (3) the thermal efficiency is (78%).

8.7.2 Replacement Cost

The original vendor, Foster-Wheeler, estimated (3) the existing package boilers would cost \$150,000 each to replace today. This figure includes \$7,000 freight from the factory to Lovington. The vendor further estimated it would cost \$15,000 each to off-load a boiler and connect it to utilities (electricity, gas, steam and water lines).

To provide for foundation and other site preparations, an additional \$22,000 should be added to calculate the installed cost of each boiler. The latter is based on the vendor's experience with boilers.

TOTAL INSTALLED COST OF ONE BOILER

Purchase Price	\$150,000.00
Site Preparation	22,000.00
Installation	<u>15,000.00</u>
TOTAL	\$187,000.00

REFERENCES

1. "The Cost of Energy from Utility-Owned Solar Electric Systems," ERDA/JPL-1012-76/3, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.
2. "An Economic Methodology for Solar-Assisted Industrial Process Heat Systems," W.C. Dickinson, H.J. Freeman, Lawrence Livermore Laboratory.
3. Downham, A.F., Foster-Wheeler Energy Corporation, Livingston, New Jersey, Private Communication, April 9, 1979.

SOILS REPORT
for
FAMARISS ENERGY REFINERY

APPENDIX A

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SUB-SURFACE EXPLORATION

FOR

LOVINGTON TERMINAL FACILITIES

SOUTHERN UNION GAS COMPANY

PREPARED FOR:

FOSTER WHEELER CORPORATION
P. O. BOX 22395
HOUSTON, TEXAS 77027

LAB NO. 73L-2029

RICHARD R. PETTIGREW AND ASSOCIATES

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PART I
REPORT

SCOPE

This Report presents the results of a Soils and Sub-Surface Investigation for Southern Union Gas Company's Proposed Terminal Facilities, located at Lovington, New Mexico. The purpose of this Investigation is to determine the physical characteristics of the sub-soils to provide recommendations for Foundation Design.

The Investigation was performed and this Report based on information received from Mr. R. P. Adams, Project Engineer, Foster Wheeler Corporation:

- 1) Key Plot Plan, Drawing No. 1290-1-01-1
- 2) Tankage Summary Sheet No. 1, Drawing No. 1290-4-11-1, Revision 0
- 3) Grid Coordinates of Borings, Letter of September 14, 1973
- 4) Elevation of Grid Coordinates per telephone conversation from Sherman & Jones
- 5) Basis of Soils Report, Foster Wheeler Foundation Standards - verbal from Mr. Adams

INVESTIGATION

Five (5) Test Borings were made on the site employing a rotary drilling rig using air. The locations of the Test Borings were selected by the Laboratory, relying upon the Key Plot Plan, Drawing No. 1290-1-01-1, supplied by Foster Wheeler Corporation. The locations of the Test Borings

were selected to be in the areas of individual tanks and were spaced to give maximum coverage of the area covered by the tank farm without drilling a test hole at each tank location. The locations and elevations of individual Test Borings are given in the Log of Boring.

During Test drilling, the soils encountered were continuously examined, visually classified, and where applicable, sampled. Standard Penetration Tests were performed at varying elevations as shown in the Log of Boring. Penetration resistance was measured by driving a 2" split tube sampler, having a 30" free fall drop hammer weighing 140 pounds. The cores were removed from the sampler tube in the field, logged and sealed to maintain the field conditions while being transported to the Laboratory.

Mechanical analysis and soils constant determination were made on the soils to help establish classification and identification of each soil. These Tests were also used to establish plasticity qualities and to give indication of the swell and settlement characteristics of the soils.

DISCUSSION OF RESULTS

The proposed site is located in grass land and in the midst of an oil field. There is no evidence of prior structures or deep site disturbance which would influence

performance of the foundation for proposed construction. The ground surface was firm and presented no mobilization problem for the drilling and should present no mobilization problem during construction.

As disclosed by the Test Borings, Caliche is predominate throughout the depth of the investigation. Caliche is a formation consisting of calcium carbonate and silica, and a form of clays, sand and gravel, cemented into a conglomerate by calcium carbonate.

The penetration resistance of the soils within the depth of the Test Borings are high. As shown in the Log of Borings, the Top Soil has a thickness of 6-10 inches and the Caliche Caprock a thickness of 22-48 inches.

In most areas where Caliche is the predominant formation, pockets of material of a sandy nature are often encountered. These pockets are generally small in area, up to six feet in diameter. The problems that arise in the Sub-Surface Analysis is when these pockets of material are not encountered during the Sub-Surface Exploration. Past experience has shown us that the bearing capacity of this material will generally vary from 2,000 to 4,000 lbs./sq.ft., which is considerably lower than the 7,000 to 12,000 lbs./sq.ft. bearing capacity of the solid Caliche. Although these pockets of material were not encountered during the Sub-Surface Exploration

for this Project, it is conceivable they can, or will, be encountered during the progress of construction. These pockets do not follow any set pattern as to location and/or depth or thickness.

CONCLUSIONS

The Log of Boring shows four (4) distinct Stratas encountered within the depth of the Test Holes. These Stratas are as follows:

- 1) Top Soil -- 0" to 10" (No classifications or tests were run on this Strata.)
- 2) Caliche Caprock -- Soil Classification SM-SC
- 3) Caliche -- Soil Classification SM-SC
- 4) Sandy Caliche -- Soil Classification SW-SP

With the exception of the Top Soil, the soil bearing capacity remained relatively uniform throughout the full depth of the Test Holes. Some variation in the moisture content of the material was noted; however, the moisture content of all materials tested is well below the liquid limit of the material.

Excavations for footings can be made vertical without the use of lateral support; however, the nature of the material excavated will probably present an irregular face.

With the exception of vibratory loading, settlement will not be a factor using the allowable soil bearing capacity

as outlined under "Recommendations", unless the sandy material described in "Discussion of Results" above, is encountered.

Frost line depth is one foot below existing ground elevation.

RECOMMENDATIONS

It is recommended that:

- 1) The allowable soil bearing capacity of 7,000 lbs./sq.ft. be used for all footings to elevations of 3810, with the exception of pockets of sandy material -- if they are encountered during construction.
- 2) Should these pockets of sandy material be encountered in construction the Contractor should contact the Soils Engineer for further testing and consultation.
- 3) The allowable sliding friction is $0.20 \times$ allowable bearing pressure.
- 4) All Top Soils in construction area be removed.
- 5) Holes or depressions caused by removal of underground utilities or by over excavation to the bottom of footings should be backfilled and compacted in layers not exceeding 6" in depth at approximately optimum moisture to at

RICHARD R. PETTIGREW AND ASSOCIATES

least 95% of Laboratory Density as determined by ASTM D-1557.

- 6) Excavated material (maximum particle size $\frac{1}{2}$ ") should be considered as suitable backfill material.
- 7) Excavated material, Soil Classification SM-SC, (Maximum particle size $\frac{1}{2}$ ") should be considered as suitable material for tank retainage dikes.
- 8) A minimum of 4" of cohesionless, non-expansive material be used beneath concrete slab on grade (desert blow sand has proven to be acceptable for this material). This material should be compacted at approximately optimum moisture to not less than 95% of Laboratory Density as determined by ASTM D-698.
- 9) Portland Cement Concrete foundations should be in accordance with ACI 318.
- 10) Aggregates for Portland Cement Concrete should conform to ASTM C-33.
- 11) Portland Cement should be Type II.
- 12) All Exposed Portland Cement Concrete should have a minimum air content of 5% by volume

plus or minus 1%
RICHARD H. PETTIGREW AND ASSOCIATES

PART II

FIELD INVESTIGATION

LOG OF BORING		
PROJECT: Lovington Terminal Facility Southern Union Gas Company		BORING NO.: 1
CLIENT: Foster Wheeler		LOCATION: 3+41(s) 18+08(W)
DATE: 9/24/73		GROUND ELEVATION: 3823.8
DEPTH, FEET	SYMBOL	LEGEND:
		<div> SAMPLE <div> PENETRATION <div> WATER </div> </div> </div>
DESCRIPTION OF STRATUM		
0"-6"		Top Soil
8"-32"		Caliche Caprock
32"		Penetration - 8" in 50 Blows - Moisture Content-3.6%
6'2"		Caliche
	Penetration - 10" in 50 Blows - Moisture Content-3.3%
	Moisture Content - 5.8%
10'		Sandy Caliche
	Penetration - 8" in 50 Blows - Moisture Content-6.6%
15'

Moisture Content - 4.1%
20'		Total Depth of Hole - 20'

PROJECT: Lovington Terminal Facility
CLIENT: Southern Union Gas Company
Foster Wheeler
DATE: 9/24/73

LOCATION: 4+47(S)
13+08(W)
ELEVATION: 3823.3

LEGEND:		
DEPTH, FEET	SYMBOL	SAMPLE
<div style="display: flex; justify-content: space-around;"> == SAMPLE * PENETRATION △ WATER </div>		
DESCRIPTION OF STRATUM		
0"-10"	///	Top Soil
10"-36"	•	Caliche Caprock
36"	•	Penetration - 1" in 50 Blows
5'	•	Caliche
	•	Penetration - 7" in 50 Blows - Moisture Content-6.3%
	•	Penetration - 6" in 50 Blows - Moisture Content-4.8%
10'10"	•	Sandy Caliche
	•	Penetration - 5" in 50 Blows - Moisture Content-4.2%
	•	Total Depth of Hole - 12'

PROJECT: Lovington Terminal Facility
CLIENT: Southern Union Gas Company
DATE: Foster Wheeler
9/24/73

LOCATION: $\begin{matrix} -8+89(S) \\ 13+20(W) \end{matrix}$

GROUND ELEVATION: 3820.9

LEGEND:		
DEPTH, FEET	SYMBOL	SAMPLE
	SAMPLE
	PENETRATION
	WATER
DESCRIPTION OF STRATUM		
0"-6"		Top Soil
6"		Caliche Caprock
4'6"
5'		Caliche
	Penetration - 12" in 44 Blows - Moisture Content-12.1%
		Moisture Content - 5.4%
10'8"		Sandy Caliche
	Penetration - 8" in 50 Blows - Moisture Content-6.8%
		Total Depth of Hole - 13'

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LOG OF BORING

PROJECT: Lovington Terminal Facility

BORING NO.: 4

CLIENT. Southern Union Gas Company

LOCATION: 13+61 (S)

CLIENT: Foster Wheeler

13+44 (W)

DATE: 9/24/73

GROUND ELEVATION: 3820.4

LEGEND:		
DEPTH FEET	SYMBOL	SAMPLE
<div style="display: flex; justify-content: space-around;"> SAMPLE PENETRATION WATER </div>		
DESCRIPTION OF STRATUM		
0'-8"		Top Soil
8"		Caliche Caprock
4'-2"		Penetration - 1 1/2" in 50 Blows
5'		Caliche
		Penetration - 1 1/4" in 50 Blows
		Penetration - 8" in 50 Blows - Moisture Content-6.1%
		Penetration - 5" in 50 Blows - Moisture Content-4.6%
10'		
14'		
15'		Sandy Caliche
		Moisture Content - 3.3%
		Total Depth of Hole - 15'

PROJECT: Lovington Terminal Facility
Southern Union Gas Company
CLIENT: Foster Wheeler
DATE: 9/24/73

BORING NO.: 5
LOCATION: 13+61(S)
10+85(W)
ELEVATION: 3820.5

LEGEND:		
DEPTH, FEET	SYMBOL	SAMPLE
	SAMPLE
	PENETRATION
	WATER
DESCRIPTION OF STRATUM		
0"-9"		Top Soil - Moisture Content-10.1%
9"		Caliche Caprock
30"		Penetration - 1 1/2" in 50 Blows
	Caliche
5'		Penetration - 3" in 50 Blows
	Penetration - 12" in 49 Blows - Moisture Content-11.8%
10'		Penetration - 5" in 50 Blows - Moisture Content-7.7%
	Sandy Caliche
	Penetration - 8" in 50 Blows - Moisture Content-5.2%
	Total Depth of Hole - 14'

PART III

LABORATORY INVESTIGATION

RICHARD R. PETTIGREW AND ASSOCIATES

P. O. DRAWER 807
CLOVIS, NEW MEXICO 88101
505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:

SIEVE ANALYSIS

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 1 (8"--16")
" " 5 (9"--12")
% PASSING

1 1/2"	100 %
1 1/4"	78.7
3/4"	65.2
1/2"	53.0
3/8"	46.1
No. 4	36.3
No. 10	26.8
No. 20	21.3
No. 40	18.3
No. 80	15.4
No. 200	9.8

LAB. NO. 73L-2029

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BY

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P. O. DRAWER 807
CLOVIS, NEW MEXICO 88101
505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:
SOIL ANALYSES & CLASSIFICATION
BORING Nos. 1, 2 & 4

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 1 (6'2"--7'3/4")
" " 2 (5'1"--5'7-3/4")
" " 4 (4'8"--5'3-3/4")
% PASSING

1 1/2"	100 %
1 1/4"	90.3
1/2"	81.3
3/8"	74.8
No. 4	63.2
No. 10	50.5
No. 20	41.6
No. 40	35.4
No. 80	25.6
No. 200	14.9
Liquid Limit	29.4
Plastic Limit	25.3
Plasticity Index	4.1
Linear Shrinkage	2.3

Soil Classification

SM-SC -- Silty Sands, Sand-Silt Mixtures, Clayey Sands, Sand-Clay Mixtures

LAB. No. 73L-2029

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A-17

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P. O. DRAWER 807
CLOVIS, NEW MEXICO 88101
505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:
SOIL ANALYSES & CLASSIFICATION
BORINGS No. 3 & 5

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 3 -- (5'--6')
" " 5 -- (5'--6')
% PASSING

1/2"	100 %
3/8"	99.8
No. 4	97.2
No. 10	94.6
No. 20	90.7
No. 40	87.6
No. 80	66.8
No. 200	35.5

Liquid Limit	30.7
Plastic Limit	23.5
Plasticity Index	7.2
Linear Shrinkage	3.7

Soil Classification

SM-SC -- Silty Sands, Sand-
Silt Mixtures, Clayey Sands,
& Sand-Clay Mixtures

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LABORATORY TEST REPORTS

RICHARD R. PETTIGREW AND ASSOCIATES

P. O. DRAWER 807
CLOVIS, NEW MEXICO 88101
505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:
SOIL ANALYSES & CLASSIFICATION
BORINGS NO. 3 & 4

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 3 (9'-10')
" " 4 (9'2"-9'4-3/4")
% PASSING

3/4"	100 %
1/2"	98.6
3/8"	95.0
No. 4	81.0
No. 10	65.4
No. 20	58.8
No. 40	54.1
No. 80	39.8
No. 200	19.2

Liquid Limit	30.0
Plastic Limit	23.0
Plasticity Index	7.0
Linear Shrinkage	3.0

Soil Classification

SM-SC -- Silty Sands, Sand-
Silt Mixtures, Clayey Sands, &
Sand-Clay Mixtures

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505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:
SOIL ANALYSES & CLASSIFICATION
BORINGS NO. 1 & 4

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 1 (15'--20')
" " 4 (14'--15')
% PASSING

3/4"	100 %
1/2"	99.0
3/8"	97.6
No. 4	94.0
No. 10	91.6
No. 20	90.1
No. 40	88.9
No. 80	69.3
No. 200	11.1

Linear Shrinkage

U

Soil Classification

SW-SP -- Well-Graded to
Poorly-Graded Sands, Gravelly
Sands with little or no Fines.

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CLOVIS, NEW MEXICO 88101
505 762-3716

TO: FOSTER WHEELER CORPORATION

TYPE OF TEST:
SOIL ANALYSES & CLASSIFICATION
BORINGS NO. 2, 3 & 5

PROJECT: LOVINGTON TERMINAL FACILITIES
SOUTHERN UNION GAS COMPANY

DATE OF TEST: September 26, 1973

SIEVE SIZE

COMBINATION OF SAMPLES
BORING NO. 2 (11'4"--11'9")
" " 3 (10'8"--11'3-3/4")
" " 5 (13'--13'7-3/4")
% PASSING

3/4"	100 %
1/2"	98.5
3/8"	98.1
No. 4	95.9
No. 10	94.0
No. 20	91.8
No. 40	90.0
No. 80	55.4
No. 200	10.6

Linear Shrinkage

0

Soil Classification

SW-SP -- Well-Graded to
Poorly-Graded Sands, Gravelly
Sands with little or no Fines.

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A-21

CALCULATIONS RELATED

to

CIVIL WORK

on the

SOLAR GENERATION OF INDUSTRIAL STEAM

for the

FAMARISS ENERGY REFINERY

APPENDIX B

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Calculations.

Collector Pier

$$\frac{6M}{bd^2} = P$$

$$d = \sqrt{\frac{6M}{bP}}$$

P = Soil bearing capacity (PSF)

M = Moment on Structure (FT-LB)

b = width of Pole (FT)

d = Depth of Pole (FT)

$$M = 4300 \text{ lb} \times 4.75 \text{ FT} = 20425 \text{ FT-LB}$$

$$P = 7000 \text{ lb/sf}$$

$$d = \sqrt{\frac{6 \times 20425 \text{ FT-LB}}{2 \text{ FT} \times 7000 \text{ LB/sf}}}$$

$$d = 2.96' \quad \text{use } 3'0''$$

For Pipe Anchors

$$M = 7500 \text{ lb} \times 1.5 \text{ FT} = 11250 \text{ FT-LB}$$

$$b = 14''$$

$$d = \sqrt{\frac{6 \times 11250 \text{ FT-LB}}{1.17 \text{ FT} \times 7000 \text{ LB/SF}}}$$

$$d = 2.87 \quad \text{USE } 3'0''$$

For Pipe Supports

wind Load = 12" pipe 14' long

$$14' \times 1' = 14 \text{ SF}$$

$$14 \text{ SF} \times 22 \text{ LB/SF} = 308 \text{ LB}$$

308 LB Force/support

This amount of Force will yield a pier 14'x14" with a depth of 5"

USE 1'0"

Bearing Strength

Recommended bearing capacity of 7000 lb/sq ft

weight of unit = 700 lb ↓
weight of Pier = 1413.7 lb ↓

wind load in worst possible condition = 3080 ↓

Total 5193 lb

Surface area of Pier = $\pi r^2 = \pi \times (1 \text{ ft})^2$
= 3.14 sq ft.

$5193 \text{ lb} / 3.14 \text{ sq ft} = \underline{\underline{1654 \text{ lb/sq ft}}}$

$7000 \text{ lb/sq ft} > 1654 \text{ lb/sq ft}$

OK!

Consideration of up Lift

Max Up Lift = 3,080 Lb.

Weight of structure	700 Lb
Weight of Pier	1413 Lb
	<hr/> 2113 Lb

↑	3080 Lb
↓	2113 Lb
	<hr/> 967 Lb

Surface area of Pier in Caliche

$$\pi d \times \text{Depth} = \pi 2' \times 2' = 12.57 \text{ sq. ft.}$$

$$967 \text{ Lb} / 12.57 \text{ sq. ft.} = \underline{\underline{76.92 \text{ Lb/sq. ft.}}}$$

The min. average value of adhesion
for concrete & stiff soil is *750 PSF!

* From Soil Mechanics manual; Bureau of Docks
& Harbors

T-700 SOLAR COLLECTOR
WIND LOAD CALCULATIONS

PSF = 22 @ 90mph.

H = 53" or 4.4'

ASSUME:

X = 12" or 1'

$\theta = -45^\circ$ (stow)

Pylon = Drive unit

$$D_f = C_d(\text{psf})(\text{area}) = 1.4(22)(140) = 4,312 \text{ lbs.}$$

$$L_f = C_l(\text{psf})(\text{area}) = 1.0(22)(140) = 3,080 \text{ lbs.}$$

$$T_m = C_{mw}(\text{chord})(\text{psf})(\text{area}) = 0.1(7)(22)(140 \times 3) = 6,468 \text{ ft. lbs.}$$

$$\text{Bolt Force} = \frac{D_f(H) + T_m}{2(X)} + \frac{L_f}{4} = \frac{(4312)(4.4) + 6468}{2(1)} + \frac{3080}{4}$$

$$= 13,490 \text{ lbs.}$$

Pylons = all others

$$D_f = 4,312 \text{ lbs} \quad L_f = 3,080 \text{ lbs} \quad T_m = 0$$

$$\text{Bolt Force} = \frac{(4312)(4.4) + 0}{2} + \frac{3080}{4} = 10,256 \text{ lbs}$$

$\theta = 120^\circ$

Pylon = Drive

$$D_f = 0.78(22)(140) = 2,400 \text{ lbs}$$

$$L_f = 0$$

$$T_m = 0.55(7)(22)(140 \times 3) = 35,574 \text{ ft. lbs}$$

$$\text{Bolt Force} = \frac{2402(4.4) + 35.574}{2} + \frac{0}{4} = 23,072$$

ASSUME WIND LOADS FOR FIELDS TO BE 67% OF STAND ALONE
COLLECTOR WIND TUNNEL DATA EXTENSIONS:

$$\text{MAXIMUM } D_f = 2,900 \text{ lbs} \quad \text{MAXIMUM } L_f = 2,000 \text{ lbs}$$

$$\text{MAXIMUM } T_m = 24,000 \text{ ft. lbs.} \quad \text{MAXIMUM B F} = 17,300 \text{ lbs.}$$

SOLAR COLLECTOR WIND LOADING

Shown in stow position(-45°)

+L_f=lift force

-L_f=down force

θ = pitch angle

Y = yaw angle

D_f = drag force = C_d(psf)(area)

L_f = lift force = C_l(psf)(area)

T_m = torque = C_{mw}(chord)(psf)(area)

$$\text{Bolt Force} = \frac{D_f(H) + T_m + \frac{L_f}{4}}{2X}$$

θ	Y	C _d	C _l	C _{mw}	Unit	Area ft ²	H in	X in	Chord ft
-45°	0°	1.4	1.0	0.1	T-600	80	39	8.5	4.0
0°	0°	1.0	0	0	T-700	140	53	12.	7.0
60°	0°	0.78	-1.5	0.14					
120°	0°	0.5	0.1	-0.28	90 MPH = 22 psf				
120°	40°	0.78	0	0.55	50 MPH = 5 psf slow				
180°	0°	1.6	0	0					
225°	0°	0.78	0	-0.2					

Multiple parallel rows of collectors are subject to lower wind loads than a single row. If it is assumed that loads are two thirds of the single row loads, bolt forces would be reduced accordingly.

COLLECTOR PYLON DETAILS

B-10

T-700

DRILLED CONCRETE PIER 2500 PSI

REINFORCE WITH 4"
VERTICAL REBAR W/3 TIES
@ 16" CEN

DEPTH VARIES
WITH SOIL CONDITIONS
5' MIN

Collector Support Pier

Pipe Anchor Pier

Pipe Support Pier

ASTM, SAE AND ISO GRADE MARKINGS AND MECHANICAL PROPERTIES FOR STEEL FASTENERS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	Yield Strength Min (psi)	Tensile Strength Min (psi)
SAE J429 Grade 5	Bolts, Screws, Studs	Medium Car- bon Steel, Quenched and Tempered	1/4 thru 1 Over 1 to 1-1/2	85,000 74,000	92,000 81,000	129,000 105,000
	ASTM A449			1/4 thru 1 Over 1 thru 1-1/2 Over 1-1/2 thru 3	85,000 74,000 55,000	92,000 81,000 58,000	120,000 105,000 90,000
SAE J429 Grade 5.1	Sems	Low or Med- ium Carbon Steel, Quenched and Tempered	No. 6 thru 3/8	85,000	-	120,000
SAE J429 Grade 5.2	Bolts, Screws, Studs	Low Carbon Martensitic Steel, Quenched and Tempered	1/4 thru 1	85,000	92,000	120,000
ASTM A325 Type 1	High Strength Structural Bolts	Medium Car- bon Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
ASTM A325 Type 2		Low Carbon Martensitic Steel, Quenched and Tempered	1/2 thru 1	85,000	92,000	120,000
ASTM A325 Type 3		Atmospheric Corrosion Resisting Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
ASTM A354 Grade BB	Bolts, Studs	Alloy Steel, Quenched and Tempered	1/4 thru 2-1/2 2-3/4 thru 4	80,000 75,000	83,000 78,000	105,000 100,000
ASTM A354 Grade BC				105,000 95,000	109,000 99,000	125,000 115,000
SAE J429 Grade 7	Bolts, Screws	Medium Car- bon Alloy Steel, Quenched and Tempered ⁴	1/4 thru 1-1/2	105,000	115,000	133,000
SAE J429 Grade 8	Bolts, Screws, Studs	Medium Car- bon Alloy Steel, Quenched and Tempered	1/4 thru 1-1/2	120,000	130,000	150,000
	ASTM A354 Grade BD		Alloy Steel, Quenched and Tempered				

SOLAR COLLECTOR MANUFACTURER'S

DATA ON

PARABOLIC TROUGH COLLECTORS

and

RELATED EQUIPMENT

INCLUDING

DETAILED COLLECTOR PARTS

APPENDIX C

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AIR CONDITIONING
INDUSTRIAL-COMMERCIAL PROCESS HEAT
HOT WATER — STEAM 100-500°F
STRONG — DURABLE — SIMPLE

HIGH PERFORMANCE
LOW INSTALLED COST

SOLAR KINETICS, INC.

8120 Chancellor Row Dallas, Texas 75247

SOLAR COLLECTOR

EFFICIENCY vs TEMPERATURE

Solar Flux--290 BTU/ft²/hr
(924 Watt/M²)

Wind Speed--8-12 MPH (13-19 Km/hr)

Fluid--Therminol T-66

Flow Rate--5 GPM (19 L/min)

Aperture --T-700--140 ft² (13M²)
T-600--80 ft² (7.4M²)

Orientation--Normal to Sun

Receiver Annulus--Argon Gas

SOLAR KINETICS INC.

DALLAS, TEXAS

T-600 and T-700 SOLAR COLLECTORS

INSTANTANEOUS EFFICIENCY VS FLUID PARAMETER

T_i = Inlet Temp

T_o = Outlet Temp

$$T_c = \frac{T_o - T_i}{2}$$

T_a = Ambient Temp.

E_s = Direct Normal Solar Flux
(75-310 BTU/ft²/hr)

Clear day conditions with
clean reflector/receiver surfaces

EFFICIENCY VS INSOLATION

at 200°F and 500°F Collector Temperatures

$$\text{Eff.} = \frac{O_e (D_n) - L_r}{D_n}$$

D_n = Direct Normal Insolation

L_r = Receiver Loss Rate

RECEIVER ASSEMBLY

	T-600	T-700
COVER: Pyrex Tube	57mm OD	64mm OD
RECEIVER: 16 Ga. ASTM A-179 Steel	1 1/4 in OD (32mm)	1 5/8 in OD (41.3mm)
SELECTIVE SURFACE: Black Chrome		
TURBULENCE INDUCER: .016 in thk. Ribbon @ 3 twists/ft.		
ANNULUS: Sealed on O-rings and plumbed in series		

PUMPING LOSS THROUGH 120' RECEIVER AND TWO HOSE ASSEMBLIES

Efficiency is flow rate independent with ribbon from 1 GPM up. Without ribbon efficiency falls several percent at rates below 3 GPM.

METHOD USED TO CALCULATE NET THERMAL
OUTPUT FOR SOLAR KINETICS COLLECTORS

SINGLE AXIS HORIZONTALLY MOUNTED IN
NORTH-SOUTH AND EAST-WEST ORIENTATION

1. Determine Solar Declination (d) where

$$d = \sin^{-1}(0.39795 \cos(0.98563(n-172)))$$

where
n = number of Julian days

2. Determine Solar Altitude (a) where

$$a = \sin^{-1}(\cos L \cos d \cos h + \sin L \sin d)$$

where
L = Latitude
h = Hour angle from Noon (.25°/min)

3. Determine Azimuth from Solar South where (b)

$$b = \frac{\cos d \sin h}{\cos a}$$

4. For North-South Orientation calculate net thermal output *
as follows. Where D_{ns} = North-South net ins. & D_n = Direct ins.

$$D_{ns} = D_n \sqrt{1 - \cos^2 a \cos^2 b} \quad \text{Net output} = D_{ns} (\text{Eff.})^{**}$$

For East-West Orientation calculate net output as follows:
Where D_{ew} = Net insolation.

$$D_{ew} = D_n \sqrt{1 - \cos^2 d \sin^2 h} \quad \text{Net output} = D_{ew} (\text{Eff.})$$

* Taken from direct normal pyroheliometer measurements.

** Consult efficiency vs insolation curve.

COLLECTOR FIELD SUPPORT LAYOUT

	T-600		T-700	
	Ft	M	Ft	M
A	4.00	1.20	7.00	2.14
B	123.50	37.7	125.00	38.10
C	20.50	6.25	20.75	6.33
D	20.75	6.33	21.00	6.40
E	12.01	3.66	20.00	6.10

Standard row length is six 20 Ft.(6.1M)
collector modules.

SOLAR COLLECTOR WIND LOADING

Shown in stow position (-45°)

+L_f=lift force

-L_f=down force

θ = pitch angle

Y = yaw angle

D_f= drag force=C_d(psf) (area)

L_f= lift force=C_l(psf) (area)

T_m= torque= C_{mw}(chord) (psf) (area)

Bolt Force= $\frac{D_f(H)+T_m+L_f}{2X+4}$

θ	Y	C _d	C _l	C _{mw}	Unit	Area ft ²	H in	X in	Chord ft
-45°	0°	1.4	1.0	0.1	T-600	80	39	8.5	4.0
0°	0°	1.0	0	0	T-700	140	53	12.	7.0
60°	0°	0.78	-1.5	0.14					
120°	0°	0.5	0.1	-0.28	90 MPH = 22 psf				
120°	40°	0.78	0	0.55	50 MPH = 5 psf				
180°	0°	1.6	0	0					
225°	0°	0.78	0	-0.2					

Multiple parallel rows of collectors are subject to lower wind loads than a single row. If it is assumed that loads are two thirds of the single row loads, bolt forces would be reduced accordingly.

C-11

T-600 & T-700
DRILLED CONCRETE PIER 2500 PSI

	T-600	T-700
A	18	24
B	8 1/2 ± 1/8	12 ± 1/8
C	4 3/4	6
D	4 MIN	4 MIN
E	3/4 Ø	1 1/8 Ø

DIMENSIONS IN INCHES

REINFORCE WITH 4"5
VERTICAL REBAR W/3 TIES
@ 16" CEN

DEPTH VARIES
WITH SOIL CONDITIONS
5' MIN

COLLECTOR PYLON DETAILS

T-600			T-700	
	in.	cm	in	cm.
A	10.4	26.4	15.0	38.1
B	8.5	21.6	12.0	30.5
F	36.0	91.4	53.5	135.9
G	39.0	99.1	57.0	144.8
H	20.5	52.1	34.5	87.6

COLLECTOR FIELD FLOW SCHEMATIC

Typical flow schematic with six loops, twelve collectors per loop.

A customer supplied valve should be installed at the inlet and outlet of each loop to provide flow throttling and for loop isolation for maintenance.

COLLECTOR FIELD INSTALLATION

The collector system consists of individually controlled rows. The standard six module row is slightly longer than 120' and is supported by seven pylons. See Fig. 1.

The installation procedure consists of four steps as follows:

1. Installation and alignment of support pylons.
2. Fastening and alignment of mirror modules.
3. Installation and adjustment of receiver tube assembly and hoses.
4. Connection of electrical controls and hydraulic power supply plumbing.

Step. 1

The Solar field foundations should be complete as per the data sheet or satisfactory roof top pads should be prepared to accept the pylon bolt pattern and spacing. The double nut technique is used to fasten the bottom of the support pylons and allow for adjustment and alignment. See fig. 2. The pylons should be installed and aligned with a standard transit or other suitable optical instrument. Care should be taken to obtain a true line of sight through the center of the axis of rotation. While the parallel alignment of each row is desirable, the exactness of orientation N/S or E/W is not important. Also exact levelness of the row is not critical but is suggested that the pylons be shot level and straight to the next row when ever possible.

When the pylons are aligned and tightened to the foundations the mirror modules are ready for installation. The Drive pylon should be in the stow position and filled with hydraulic fluid to prevent rotation.

Fig. 1

Fig. 2

Step. 2

Mirror modules are installed to the drive pylon first and thence to the end of each row. An intermediate bearing assembly is bolted to one end of the mirror module with the receiver tube stand on the mirror side. The module is then lowered into position and the bearing bolted to the first standard pylon while the other end is bolted to the drive flange. (4-1/2" bolts) See fig. 3.

The procedure is repeated for each module out to the end of the row where an end bearing assembly is attached to the end pylon. Care should be taken to align the modules rotationally. The bolt holes are sufficiently oversized to provide some adjustment.

The counter weights may be bolted to the end of each mirror module before or after installation. The counter weight attaches with two 1 in. bolts and weighs approximately 90lbs. See fig. 4.

Step. 3

The center receiver tube stand is attached with four bolts and the intermediate receiver tube stands are inserted through the mirror module body and fastened with a nut on the back side. Receiver stands are at 10ft. spacing and the receiver adjustment brackets are installed into each stand with 1 bolt and two nuts. The bolt allows height adjustment while the slotted bracket provides side adjustment. Each bracket should be adjusted to put the center of the receiver at the center of the focus. That point is in the center from each edge of the collector and 22.157" (T-700) up from the bottom of the mirror (10.425" for T-600). A simple pattern or fixture will allow rapid adjustment.

Each receiver tube is 20' long and connects to the next with a union that tightens with two wrenches. The glass jacket "O" ring retainer slips over the receiver and is spaced every 10' to correspond to the stand and bracket. Two glass tubes are suspended on each receiver tube by the silicone "O" rings, and the entire assembly is clamped to the bracket. See fig. 5

Fig. 3

Fig. 4

Fig. 5

Fig. 6

The two center receiver tubes should be installed to the special union attached to the central receiver tube stand and thence out to the end of each row. The hoses are fastened to the tube with a union and the expansion bellows are clamped in place. See fig. 6. The lower end of the hose assembly is attached to the end pylon with the hose bracket. Each receiver assembly should be pressure tested for leaks at this point.

Step 4

The shadow bar tracker bracket is bolted on to the collector next to the drive pylon. The shadow bar sensor is bolted to the bracket and aligned lengthwise with the collector.

The hydraulic power supply (Fig.7) is plumbed in parallel to each drive pylon and connected to the hydraulic fittings at the bottom of each control box. Stainless steel tubing is suggested and manifold tubing size should be considered for long runs to avoid pressure drop. Stainless tube of 3/4" diameter is usually adequate for lengths up to 200 feet. Cold weather conditions should be considered and appropriate hydraulic fluid used. The manifold tube size should be selected based on the pressure drop during cold weather operation.

The control wiring should be routed to each drive pylon control box and appropriate connections made.

After all plumbing connections have been accomplished and fluid is flowing through the receiver, the collector automatic focus command may be given. The angular adjustment of the shadow bar tracker is then changed until the receiver is focused to the center of the reflected light. Slight "tweaking" adjustments may be made at each bracket for fine focus. Caution should be taken never to focus the receiver without fluid flow.

TRACKER CONTROL
OPERATION EXPLANATION
AUTOMATIC TRACKING

Tracking is achieved through the use of two light sensitive transistors positioned equally between a shadow bar. When the shadow bar is pointed directly at the sun the shadow splits each transistor. As the sun moves the shadows become unequal and an electronic imbalance is sensed by the tracker control causing either the east or west relay to be energized. This completes a circuit to the hydraulic fluid control valve which directs pressurized fluid to the tracker drive causing the collector to move until the shadow bar is again pointing at the sun. In this position the tracker control is in dead band and neither relay is activated. A dead band adjustment is provided which will change the sensitivity of the tracker. An adjustment providing accurate tracking during clear days but preventing searching during cloudy conditions is desired. A time delay adjustment is also provided. Proper adjustment of these two pots will provide accurate pointing and keep the system in dead band during cloudy periods. Limit switches are provided to prevent overtracking in the automatic mode.

There are several conditions under which the collector should be sent to the stow position. They are, over temperature, rain, night fall, high winds and loss of flow. Any Number of field contact closure devices can 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 east side.

The stow slave relay is energized when the stow relay loses its signal (open circuit) and the east 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 dead band 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.

TRACKER CONTROL

OPERATION EXPLANATION

MANUAL CONTROL

When the manual (local) position is selected on the local/remote switch at any drive pylon the automatic shadow bar tracker is de-energized and power is directed to the 3 position momentary directional switch next to the local/remote switch. Selection of either direction on the switch will drive the collector either east or west at the rapid stow rate.

If the over temperature switch or any other hazard stow switch opens the circuit to the stow relay the collector will be driven to the stow position whether the local or remote position has been selected. Only in the center off position can the stow mode be overridden. Caution should be exercised when the local/remote switch is in the off position since focus without flow will cause overtemperature resulting in damage to the receiver.

Systems requiring remote manual direction control use relays to replace the action of the 3 position momentary directional switch. With this feature either east or west stow speed control is available from a remote location.

When adjusting the tracking speed rate with the system in automatic (remote) an imbalance may be caused by shadowing one transistor artificially causing the collector to track at the slow speed. Correct tracking speed should be between 0.1 and 0.3 RPM.

APPENDIX C

(Reference 3)

Materials of construction (excluding heater coils)

The majority of metals normally encountered in high temperature heating systems can be used with *Therminol* fluids.

Materials of construction are generally selected on the basis of their suitability for operation at the specified maximum temperature. Mild steel is widely used.

The use of copper, aluminum, bronze and brass alloys etc. should be kept to a minimum mainly because of their loss of metallurgical strength at higher temperatures.

The expansion tank and venting arrangements

The expansion tank should be installed at the highest point in the system and connected to the suction side of the pumps. It should serve as the main venting point of the system.

The double drop leg expansion tank (see Figures a and b on page 10) provides greater flexibility of operation than a single leg tank. Venting of incondensibles, water, etc. is often difficult in a heating system. Purging out air on start-up can also be a problem. This particular arrangement eliminates flooded pump suction and uninterrupted flow on start-up and allows venting as required.

It is preferable when designing the expansion tank to minimize air contact with fluid at temperatures exceeding 100°F (40°C) to prevent oxidation.

The most effective way of preventing fluid oxidation is to blanket the system with an inert gas (such as nitrogen) as shown in Fig. a. If this is not desirable, air contact can be minimized by a cold seal trap arrangement as shown in Fig. b. Low boilers and moisture can collect in the cold seal trap and the fluid in the trap should be discarded periodically.

Some systems operate without an allowance being made for oxidation protection of the fluid in the tank. In this case, the temperature in the expansion tank should be kept as low as possible in order to minimize problems which could result from fluid oxidation.

These guidelines are given to maximize fluid life which is particularly important in the case of the higher cost fluids. When using a nitrogen blanket, moisture should be driven off from the fluid before the gas pressure is set. Any vent lines should be led outside of the building so that vapors do not enter the working area.

The expansion tank should be sized so that it is 1/4 full when the system is at room temperature and 3/4 full when the system is at operating temperature. It should be fitted with a sight glass at the full range and with a float operated, minimum level switch to shut off the heater in the event of accidental fluid loss.

Pipework

The most important factors in the piping layout for systems utilizing *Therminol* are: (A) Proper sizing for the required flow rate and (B) minimizing pressure drop. Because the system will undergo temperature changes, adequate loops to relieve expansion and contraction stress are essential. Schedule 40 seamless carbon steel pipe should be used throughout the system. It is characteristic of most organic heat transfer fluids (including *Therminol*) to have a tendency to leak through joints and fittings at high temperatures unless these fittings are very tight. The best way to prevent piping leakage is to weld all connections. Where access is necessary, use raised-face flanges with appropriate gasketing and high-temperature bolting. Control of piping leaks is especially important, since fluid-soaked insulation poses a more serious hazard than the leaking fluid, itself. (See Section on Insulation).

When a flanged connection is made, USAS 300 lb. weldneck or equivalent raised-face flanges are recommended. The flanges should be back welded to the pipe and proper gasketing used, such as spiral wound asbestos and stainless steel gasket. Recommended flange gasketing for high temperature heat transfer fluid systems should be spiral-wound type conforming to API specification 601. Standard materials for spiral wound flange gaskets are Type 304 stainless steel and asbestos.

Important to non-leak performance with spiral wound gaskets is the use of raised-face flanges, alloy steel bolting and even compression of gasket during bolt pull up.

Figure a Suggested Inert Gas Arrangement for Expansion Tank

For startup or venting operations, valves B, C, D & F are opened and valves A & E are closed. All flow passes to expansion tank; degasses; vents; and maintains flooded pump suction.

For normal operation, valves B, C & F are closed and valves A, D & E are open. This arrangement provides normal return flow to pump suction with open static head line from tank to pump. Bypass line through valve D eliminates thermal siphon to expansion tank.

Figure b Suggested Cold Seal Trap Arrangement for Expansion Tank

HEAT TRANSFER FLUID PROPERTIES

APPENDIX D

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Texaco Texatherm

An Outstanding Heat Transfer Fluid

Product Description

TEXATHERM is a highly refined paraffinic oil specially prepared from selected petroleum stocks for use as a heat transfer fluid. It contains an oxidation inhibitor and has outstanding thermal stability at sustained operating temperatures up to 600°F in closed systems. It is rust inhibited and is non-corrosive to copper and steel. It also contains an anti-foamant and air-release agent to improve its circulation and heat transfer properties.

Recommended Operating Conditions

Closed Systems (sealed with either an inert gas or with cold oil). TEXATHERM is recommended for use as a heat transfer fluid in well-designed and properly maintained closed systems with bulk oil temperatures up to 600°F.

Open Systems. TEXATHERM is recommended for use in open systems with bulk oil temperatures up to 400°F.

Maximum Allowable Film Temperature. This is the temperature of the film of oil next to the heater and is the highest oil temperature in the system. The maximum allowable film temperature for TEXATHERM is approximately 640°F.

Heat Transfer Fluid Requirements

TEXATHERM meets all the requirements for a good heat transfer fluid—

- Has good heat capacity and thermal conductivity in order to transfer heat efficiently.
- Has good thermal and oxidation stability to minimize thickening and the formation of deposits, and to permit operation at high temperatures for long periods.
- Has low volatility to minimize evaporation, vapor lock and cavitation.
- Has low viscosity at operating temperatures to minimize pumping effort and maximize heat transfer.
- Is non-corrosive and protects the system from rust and corrosion.
- Has low toxicity and is non-irritating to operating personnel.

Laboratory Tests

Typical laboratory tests on TEXATHERM are given in Table I. Figures 1 through 5 present physical data vs temperature, and flow vs pressure drop and heat transfer rate.

Viscosity (Fig. 1). TEXATHERM circulates easily in heat transfer systems, carrying heat efficiently from the heater to the user with a minimum of pumping power. It also flows easily at low temperatures and facilitates starting a cold system.

Specific Heat, Specific Gravity, and Thermal Conductivity (Fig. 2). TEXATHERM has the ability to carry the large amount of heat needed for efficient operation of a heat transfer process. It can absorb heat quickly from and release heat quickly to metal surfaces. It also removes heat rapidly from the surfaces of the heater, preventing overheating of the tubes with subsequent carbon formation and tube failure.

Vapor Pressure (Fig. 3). TEXATHERM operates at essentially atmospheric pressure up to 650°F; thus it does not require a high-pressure system. Its low volatility also minimizes evaporation and the possibility of vapor lock and pump cavitation.

Flow vs Pressure Drop and Heat Transfer Rate (Figs. 4 & 5). This information is helpful in designing a satisfactory heat transfer system for use with TEXATHERM.

Chemical Stability. TEXATHERM is hydrolytically and oxidatively stable up to 150°F when exposed to air.

Laboratory Stability Data

Thermal and oxidation data on TEXATHERM from several high-temperature laboratory tests are shown in Table II. TEXATHERM withstood all of these rigorous tests very well and showed only minimal degradation. In the Indiana Oxidation Test it lasted longer than three competitive products tested at the same time.

Precautions

As with any heat transfer oil, certain precautions should be taken to ensure satisfactory performance of TEXATHERM in service.

Clean System. The heat transfer system, whether new or used, should be thoroughly cleaned (with chemicals, if necessary) and then flushed with TEXATHERM before being placed in use.

Materials. Iron and steel are the preferred materials. Copper and its alloys should not be used, since copper acts as a catalyst and degrades the hot oil. Packing and gaskets must be designed for hot oil use.

System Seal. The hot oil must be protected from air, since air will rapidly oxidize hot oil. The best way is to use an expansion tank located so the oil in it remains cool (below 130°F).

Hot Spots. The system must not have any hot spots, since these will degrade the oil and cause carbon formation. Oil should circulate in the tubes at about 8 feet per second, $\pm$ 2 fps, using the higher velocities at the higher temperatures. The system should be arranged so that:

1. The circulating pump must be started before heat is applied to the heater.
2. The circulating pump will run for some time after the heater is turned off.
3. The heater will shut down if the circulating pump fails.

Full oil circulation should be provided through the heater whenever it is operating. If variable oil circulation is required through the user to provide temperature control, any oil not sent through the user should be bypassed back to the heater to provide full flow through it. Surface temperatures of heaters must be kept reasonable. For electric heaters, watt densities of 10-15 watts/sq. in. are suggested, with a maximum of 20. Safety controls should be provided to shut down the system in case of excessive temperature or pressure, or circulation failure.

Mixing Oils

While TEXATHERM is compatible with other unused heat transfer oils, it is a good idea not to mix different kinds of oils unless absolutely necessary. Mixing other new oils with TEXATHERM will not give the excellent performance of undiluted TEXATHERM. Adding TEXATHERM as make-up to some other kind of oil (particularly aromatic types) may precipitate sludge which is in suspension in the other oil.

Field Performance

TEXATHERM has been accepted by manufacturers and users of circulating oil heaters. It has been successfully used for periods up to four years without replacement in industrial closed systems sealed with inert gas and operated at sustained elevated temperatures. Some cracking may occur at first; however, after equilibrium is reached, the oil performs most satisfactorily.

Physiological Properties

TEXATHERM is suitable for use within food, feed and drink plants.

Table I—Texatherm Inspection Tests

Appearance	Pale, clear
Color, ASTM	L 0.5
Gravity, °API	31.0
Specific Gravity	0.871
Flash Point (COC), °F	430
Pour Point, °F	5
Viscosity, SUS at 100°F	211
Viscosity, SUS at 210°F	47.2
Viscosity Index	98
Carbon Residue, %	0.01
Sulfur, %	0.1
Neutralization No.	0.04
Ash, %	Nil
Corrosion, ASTM D 130	
Copper	Negative
Steel	Negative
Distillation, °F	
IBP	675
10%	714
50%	808
90%	950
Aniline Point, °F	224
Coefficient of Expansion, per °F	0.0004
Autoignition Temp. (ASTM D 2155), °F	675
Rust (distilled water) (ASTM D 665)	Pass

Figure 1—Texatherm Viscosity vs. Temperature

Figure 2—Texatherm Specific Heat, Specific Gravity, and Thermal Conductivity vs. Temperature

Figure 3—Texatherm Vapor Pressure vs. Temperature

Figure 4—Texatherm Flow Rate vs. Pressure Drop

Figure 5—Texatherm Flow Rate vs. Heat Transfer Rate

Table II—Texatherm Thermal and Oxidation Data

1. British Thermal Stability Test	
(273 hrs, 536°F, nitrogen blanket)	
Viscosity Increase, (SUS at 100°F), %	5.7
Naphtha Insolubles, mg/10g	Nil
2. Modified British Thermal Stability Test	
(273 hrs, 536°F, air blanket)	
Viscosity Increase, (SUS at 100°F), %	18.1
Naphtha Insolubles, mg/10g	0.8
3. Modified British Thermal Stability Test	
(273 hrs, 600°F, nitrogen blanket)	
Viscosity Increase, (SUS at 100°F), %	4.7
Carbon Residue, % increase	0.01
Propane Number, increase	8
Total Acid Number, increase	0.01
Sediment, % by volume	Trace
4. Modified British Thermal Stability Test	
(273 hrs, 600°F, air blanket)	
Viscosity Increase, (SUS at 100°F), %	-12.7
Carbon Residue, % increase	0.04
Propane Number, increase	14
Total Acid Number, increase	0.18
Sediment, % by volume	0.06
5. Indiana Oxidation Test	
(341°F, bubbling air)	
Naphtha Insolubles	
mg/10g at 48 hrs	43
Hours to 10mg/10g	26
6. Modified Indiana Oxidation Test (Static Heat Test)	
(96 hrs, 500°F, air blanket)	
Viscosity Increase, (SUS at 100°F), %	6.5
Naphtha Insolubles, mg/10g	Nil
Thermal Data at 500°F	
Thermal Conductivity	
Btu/hr/sq. ft/°F/ft	0.067
Heat Capacity, Btu/lb/°F	0.656
Viscosity, cs	1.02
Specific Gravity	0.72
Vapor Pressure, mm Hg	25

Insulation (Ref. 3)

Organic heat transfer fluids exhibit a slow oxidation reaction with the air trapped inside the voids of the insulating material when system temperatures reach about 260°C (500°F). Saturated insulation offers a large fuel surface in the face of poor heat dissipation conditions, and this, along with possible catalysis from the insulating material (magnesia, silicate-bonded asbestos or calcium silicate) can cause a temperature build-up in the mass. This temperature build-up can result in ignition of the fluid when the space between the piping and the saturated insulation is exposed to air (i.e., should the insulation be broken for repair, etc.).

This phenomenon is not fully understood but appears to occur less with closed cell insulation than with the insulating materials mentioned above. Closed cell materials, then, are preferred, especially where leakage is a possibility despite all precautions.

The principal problem areas are near instrument connections, valve packing glands, flanges, and where cracks develop in relatively impermeable insulation or cement adjacent to oil-soaked insulation.

To obviate this problem, eliminate any source of leakage promptly. Replace leaky gaskets and oil-soaked insulation, and re-pack valve stems. Cover insulation where leaks might occur with a hydraulic setting, oil-resistant cement. Install valves, where possible, with the stems in a horizontal position so that leaks will drip away from the insulation. And again, use closed cell insulating materials on suspect piping areas.

MATERIALS OF CONSTRUCTION

APPENDIX E

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(Reference 4)

Materials of construction (excluding heater coils)

The majority of metals normally encountered in high temperature heating systems can be used with *Therminol* fluids.

Materials of construction are generally selected on the basis of their suitability for operation at the specified maximum temperature. Mild steel is widely used.

The use of copper, aluminum, bronze and brass alloys etc. should be kept to a minimum mainly because of their loss of metallurgical strength at higher temperatures.

The expansion tank and venting arrangements

The expansion tank should be installed at the highest point in the system and connected to the suction side of the pumps. It should serve as the main venting point of the system.

The double drop leg expansion tank (see Figures a and b on page 10) provides greater flexibility of operation than a single leg tank. Venting of incondensibles, water, etc. is often difficult in a heating system. Purging out air on start-up can also be a problem. This particular arrangement eliminates flooded pump suction and uninterrupted flow on start-up and allows venting as required.

It is preferable when designing the expansion tank to minimize air contact with fluid at temperatures exceeding 100°F (40°C) to prevent oxidation.

The most effective way of preventing fluid oxidation is to blanket the system with an inert gas (such as nitrogen) as shown in Fig. a. If this is not desirable, air contact can be minimized by a cold seal trap arrangement as shown in Fig. b. Low boilers and moisture can collect in the cold seal trap and the fluid in the trap should be discarded periodically.

Some systems operate without an allowance being made for oxidation protection of the fluid in the tank. In this case, the temperature in the expansion tank should be kept as low as possible in order to minimize problems which could result from fluid oxidation.

These guidelines are given to maximize fluid life which is particularly important in the case of the higher cost fluids. When using a nitrogen blanket, moisture should be driven off from the fluid before the gas pressure is set. Any vent lines should be led outside of the building so that vapors do not enter the working area.

The expansion tank should be sized so that it is $\frac{1}{4}$ full when the system is at room temperature and $\frac{3}{4}$ full when the system is at operating temperature. It should be fitted with a sight glass at the full range and with a float operated, minimum level switch to shut off the heater in the event of accidental fluid loss.

Pipework

The most important factors in the piping layout for systems utilizing *Therminol* are: (A) Proper sizing for the required flow rate and (B) minimizing pressure drop. Because the system will undergo temperature changes, adequate loops to relieve expansion and contraction stress are essential. Schedule 40 seamless carbon steel pipe should be used throughout the system. It is characteristic of most organic heat transfer fluids (including *Therminol*) to have a tendency to leak through joints and fittings at high temperatures unless these fittings are very tight. The best way to prevent piping leakage is to weld all connections. Where access is necessary, use raised-face flanges with appropriate gasketing and high-temperature bolting. Control of piping leaks is especially important, since fluid-soaked insulation poses a more serious hazard than the leaking fluid, itself. (See Section on Insulation).

When a flanged connection is made, USAS 300 lb. weldneck or equivalent raised-face flanges are recommended. The flanges should be back welded to the pipe and proper gasketing used, such as spiral wound asbestos and stainless steel gasket. Recommended flange gasketing for high temperature heat transfer fluid systems should be spiral-wound type conforming to API specification 601. Standard materials for spiral wound flange gaskets are Type 304 stainless steel and asbestos.

Important to non-leak performance with spiral wound gaskets is the use of raised-face flanges, alloy steel bolting and even compression of gasket during bolt pull up.

Figure a Suggested Inert Gas Arrangement for Expansion Tank

For startup or venting operations, valves D, C, D & F are opened and valves A & E are closed. All flow passes to expansion tank; degasses; vents; and maintains flooded pump suction.

For normal operation, valves B, C & F are closed and valves A, D & E are open. This arrangement provides normal return flow to pump suction with open static head line from tank to pump. Bypass line through valve D eliminates thermal siphon to expansion tank.

Figure b Suggested Cold Seal Trap Arrangement for Expansion Tank

Procedure for Removing Tube Bundle from Steam Generator

1. Isolate steam generator using the system controller, and close the manually operated valves at A and B (Figure 1).
2. Shut down the boiler and isolate it from the steam system by valving off the steam lines.
3. Allow pressure in both the steam chest and HTO tubes to drop to zero as indicated by the gauges.
4. Vent the steam chest to atmosphere through the pressure relief system.
5. Drain the generator of water by opening the blowdown valve.
6. Drain the tubes of HTO by opening valves at C and D to atmosphere. (CAUTION: Oil is hot. Avoid contact) Catch the oil in a large bucket.
7. After closing the valves at A and B, break the flanges at A and B.
8. Swivel the piping aside.
9. The tube bundle may be withdrawn after removing the circle of bolts around the large flange.

Figure 1. Steam Generator

Side View Showing Manhole and
Flanges on HTO Lines

A and B denote drain valves; C and D denote
manual shut-off valves;

PACKING

APPENDIX F

PACKING

Various types of packing are used to seal valve stems and small pump shafts on high temperature systems. Flexible metal or solid graphite packings give the best service.

Graphite or Teflon* impregnated, short fibre asbestos gasketing is used also, but leak-free service is not always achieved at the higher temperatures.

Generally, five rings of packing are specified on valve stems to assure a reasonable seal.

The use of metal bellows steam seals on valves is increasing and would, of course provide absolutely leak-free service.

*Trademark of E.I. DuPont