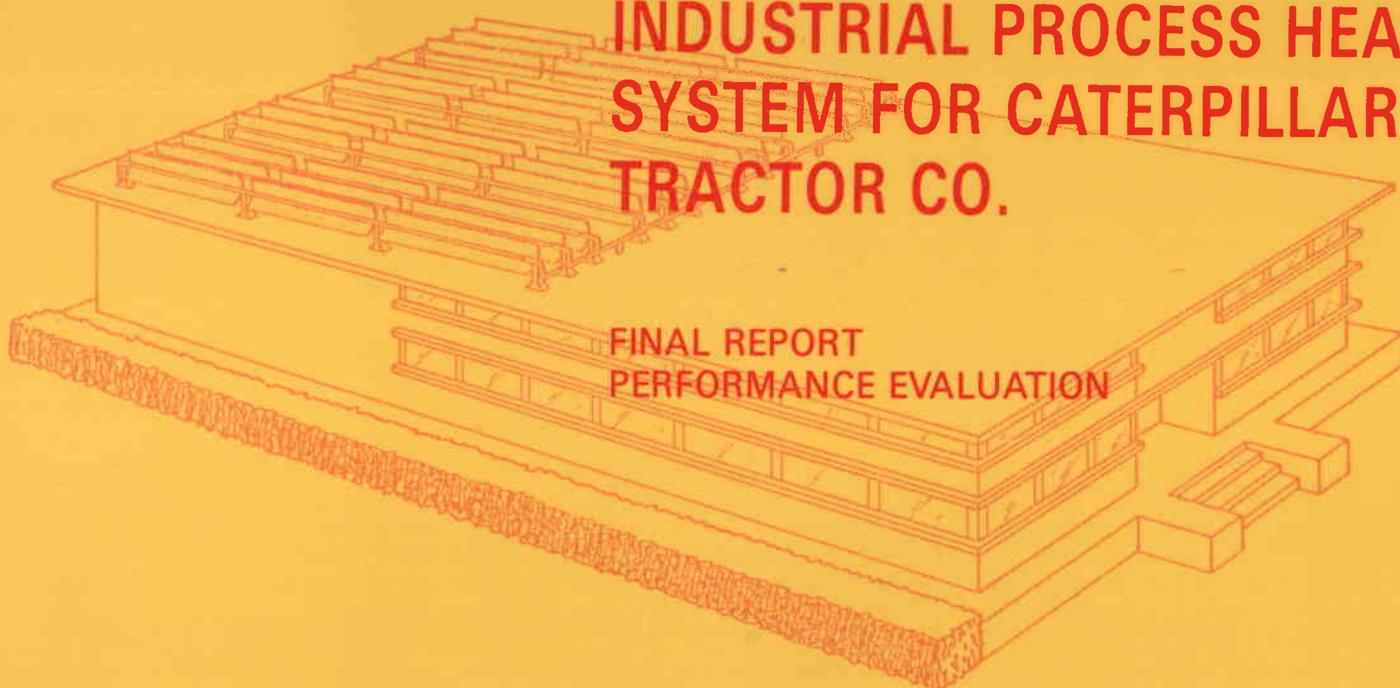
A LARGE-SCALE SOLAR INDUSTRIAL PROCESS HEAT SYSTEM FOR CATERPILLAR TRACTOR CO.



FINAL REPORT
PERFORMANCE EVALUATION

PREPARED FOR:
DEPARTMENT OF ENERGY

JANUARY 31, 1985

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A LARGE-SCALE SOLAR INDUSTRIAL PROCESS HEAT SYSTEM FOR CATERPILLAR TRACTOR CO.: FINAL REPORT–PERFORMANCE EVALUATION

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Approved:

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EXECUTIVE SUMMARY

The objective of this experimental program was to provide a means of assessing the viability of solar energy in an industrial environment. Southwest Research Institute (SwRI Project 06-5821) and Caterpillar Tractor Company (CTCo) jointly undertook one of the projects in DOE's Solar Industrial Process Heat (SIPH) Demonstration Program (DOE Contract DE-FC03-79CS30309) in which the team designed, constructed, and operated a 50,400 ft^2 SIPH system located at CTCo's San Leandro, California plant. DOE funded 75% of the design and construction costs with the remainder being provided by CTCo. DOE provided most of the funding for the evaluation of the system while CTCo made the in-kind contribution of operating and maintaining the solar system after completion of construction.

Specifically, the objectives of this project were to determine (1) performance, (2) installation costs, (3) operation and maintenance (O & M) costs, and (4) reliability of a high quality industrial grade solar system. Prior to this project, estimates of these four parameters were based on the best available information at the time. Thermal performance of this system was estimated to be 240000 Btu/yr-ft^2 with an assumed reliability of 100%. Total installed system costs were estimated to be \$30/ft^2 of collector area and the operation and maintenance (O&M) costs were estimated as 1% of the total installed cost per year.

As a result of this project, these estimates may be refined and the suitability of solar process heat systems may be more confidently determined. The actual thermal performance of the solar system was demonstrated to be 65000 Btu/yr-ft^2 with an observed reliability of 86%. It is possible to increase system performance to its maximum realistic value of 168000 Btu/yr-ft^2 by maintaining the system at peak operating conditions. This could be accomplished by providing a more adequate control system and by washing the collector mirror surfaces at least monthly. The actual O & M costs were \$0.25/yr-ft^2 while it is estimated that this cost would increase to approximately \$0.65/yr-ft^2 if maximum realistic performance levels are maintained. The construction phase of this project showed a total installed cost of $\$50/ft^2$ of which approximately half was the cost of the solar collectors. The remaining $\$25/ft^2$ included mainly labor and a minor amount for the balance of the equipment (piping, pumps, etc.).

The performance and cost parameters are combined in an economic analysis to indicate the value of the system by computing the return on the investment (ROI). At the time the system was designed a 20% ROI was predicted based on the available performance and cost estimates, and the inflation and fuel escalation rates (10-15% each) in effect at that time. Using the present, more realistic values of these parameters, the ROI is less than 1%. Indeed, it appears that, even for the optimistic case of mass-produced solar equipment and more expedient installation, the cost of a solar system could be \$30 to $\$35/ft^2$ yielding an ROI of less than 5%. Of course, there may be unique operating conditions or financing structures which would allow a greater ROI to be realized, but this would be extraordinary. This technology in general, therefore, is not presently a cost-effective investment for energy generation when viewed from a realistic perspective.

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ACKNOWLEDGMENTS

The authors would like to acknowledge the work of several people who were involved in this project.

Don Lucas and Rick Sawyer of the Caterpillar Tractor Co. engineering staff are acknowledged for their efforts in operating and maintaining the solar system. Martha Haywood of SwRI designed and installed the DAS while Jim Hokanson and Brian Bowers, also of SwRI, provided invaluable assistance with DAS software and hardware problems, respectively. The authors would like to also acknowledge Dorothy Endicott for preparing the manuscript of this report.

I. INTRODUCTION

There is little doubt that reserves of conventional fossil fuel energy sources are decreasing at a rapid pace. While the estimates of their untapped amounts are debated, it is generally agreed that at some time fossil fuels must be replaced by other energy sources if we are to maintain a highly technically based society. Solar energy is one of many energy sources being investigated for use in the near and distant future.

Solar energy is abundant; however, as with any energy source it usually requires mechanical equipment to harness its power. This is especially the case for thermodynamically low quality sources such as solar energy. The industrial sector already has much energy-related equipment in use and it has been argued that the addition of solar collectors and ancillary equipment to an existing industrial plant can be one of the more attractive applications of solar energy because many industries have the capital necessary for the purchase and installation of solar equipment and the personnel capable of maintaining its performance. Four basic factors--performance, initial cost, operating cost, and reliability--must be thoroughly investigated, however, before an industry can determine the suitability of solar energy for its energy demands.

First of all the thermal performance of the solar system is of primary importance. Since the purpose of a solar system is to displace part or all of the fossil fuel being consumed by the plant, the thermal performance of the solar system has a direct affect on the expenditures for fossil fuel. Unlike conventional process heat equipment the performance of a solar system is strongly affected by weather conditions. Also, because solar energy is a thermodynamically low quality source, the control of the solar system components strongly affects the performance of the system. It is easily seen that the thermal performance of a solar system is much more difficult to accurately specify than conventional process heating equipment.

The second of these four basic factors is the initial cost of the solar system. This includes material and equipment costs as well as the labor to install a fully functioning solar system. The initial cost of installing most any process heating equipment can be high; so, this cost must be accurately determined before the investment decision can be made.

Next, the cost of operating the solar system is important in the investment decision. This includes the cost of electrical power to control components, move fluid, etc., and the cost of routine maintenance. The annual operating expenses must be less than the cost of the fossil fuel displaced by the solar system if the system is to be economically feasible.

The fourth basic factor in the solar investment decision process is the question of reliability. It is obvious that a solar system can displace fossil fuel only when it is operating properly; so, a highly reliable system is certainly desirable.

It has been historically difficult to determine these four factors and the affects of each on the other three. To provide a body of information on which investment decisions can be based the U. S. Department of Energy embarked on its Solar Industrial Process Heat (SIPH) Demonstration Program. In this program, DOE hoped to provide an assortment of solar systems for various industries so that the cost and performance of industrial grade solar systems could be finally determined. With knowledge of the four factors described above, an investor could use his own investment decision process to determine the suitability of solar energy equipment to his particular case. It will be seen that this project provides information for all four of the investment decision factors--initial cost, performance, operating costs, and reliability--which were discussed above.

The objective of the project described here was to design, construct, and evaluate a high quality solar system as part of DOE's SIPH program. In this particular project the Caterpillar Tractor Company shared a portion of the cost for the design and construction of a solar system at its San Leandro, California plant just south of Oakland. The project was initiated in September, 1979, and the design called for 50,400 square feet of parabolic trough concentrating collectors to be placed on the roof of the CTCo San Leandro plant. Construction was complete in the summer of 1982 and after a brief shakedown period the system was activated for completely automatic operation in November 1982. The design and construction phases of the project are thoroughly discussed by Deffenbaugh [1,2].

This report describes and discusses the operation and performance of the CTCo solar system over a monitoring period of 25 months, November 1982-November 1984. As stated above, the system is fully described elsewhere; however, a brief discussion of the system design and operating procedures is presented in Section II as background for the subsequent sections of this report. The data acquisition system is described in Section III.

In Section IV the operational history and maintenance record of the system is provided for the 25 month evaluation period. This is a valuable aid not only for the purposes of understanding system performance but also for the purposes of designers who can take advantage of the experiences gained here in the design of new systems. Hopefully, problems which were encountered and solved during the course of this project may be avoided in the future.

The performance of the solar system over the monitoring period is presented and discussed in Section V. The performance of the system is defined in terms of its efficiency to convert solar energy to useful thermal energy along with the magnitude of this energy delivered to the plant. The detailed performance data are used to verify a quasi-steady numerical model of the solar system. This model is then used to predict the system performance based on typical weather data for the Oakland, California area. These performance predictions are compared to the actual, observed performance for a one-year period. The differences between collector test stand performance tests and operation in a "real-world" environment are discussed.

Section VI of this report contains an economic analysis of the solar system. This analysis, based on assumed financial factors, includes actual construction costs and operation and maintenance (O & M) costs. This analytical method is presented as an example of typical investment analyses and shows the relationship between initial system cost and system performance.

A statement on the environmental impact and a discussion of system safety is provided in Section VII.

Finally, concluding remarks are located in the last section of this report along with recommendations for improving the CTCo solar system. A discussion of the suitability of solar energy to meet energy demands is presented, as well.

II. SOLAR SYSTEM DESCRIPTION

A. Overview

The process heat system at the Caterpillar Tractor Plant in San Leandro, California is used to heat pressurized water to approximately 235°F for a variety of plant needs. The hot water is used primarily for heating parts washers used for cleaning machined engine parts during various steps in the manufacturing process. The heating system piping encircles the manufacturing facility so that equipment may be easily connected to both the supply and return header at convenient locations. This also ensures a reverse-return piping network, thereby prohibiting the need for extensive flow balancing equipment.

The solar system, shown schematically in the P & I Diagram of Figure 1, is connected to the return line of the plant's piping network. The solar system was designed to heat approximately 60% of the water in the return line to the heater outlet temperature at design conditions. In this way, a large portion of the energy required by the process heat system may be supplied by the solar system. It will be seen below that the plant thermal load was decreased substantially after construction was started. As a result of this lowered thermal load the solar system was capable of providing more than 100% of the hot water requirements of the plant in the summer months. Each of the components of the solar system will be discussed in detail below.

B. Collectors

The CTCo solar system, Figure 2, comprises 360 Solar Kinetics Model T-700A line-focus parabolic trough collectors which provide 50,400 ft^2 of area for receiving solar radiation. It can be seen that the collector array is divided into two fields. The north field has 13440 ft^2 of collector area (96 collectors) while the south field has 36960 ft^2 of

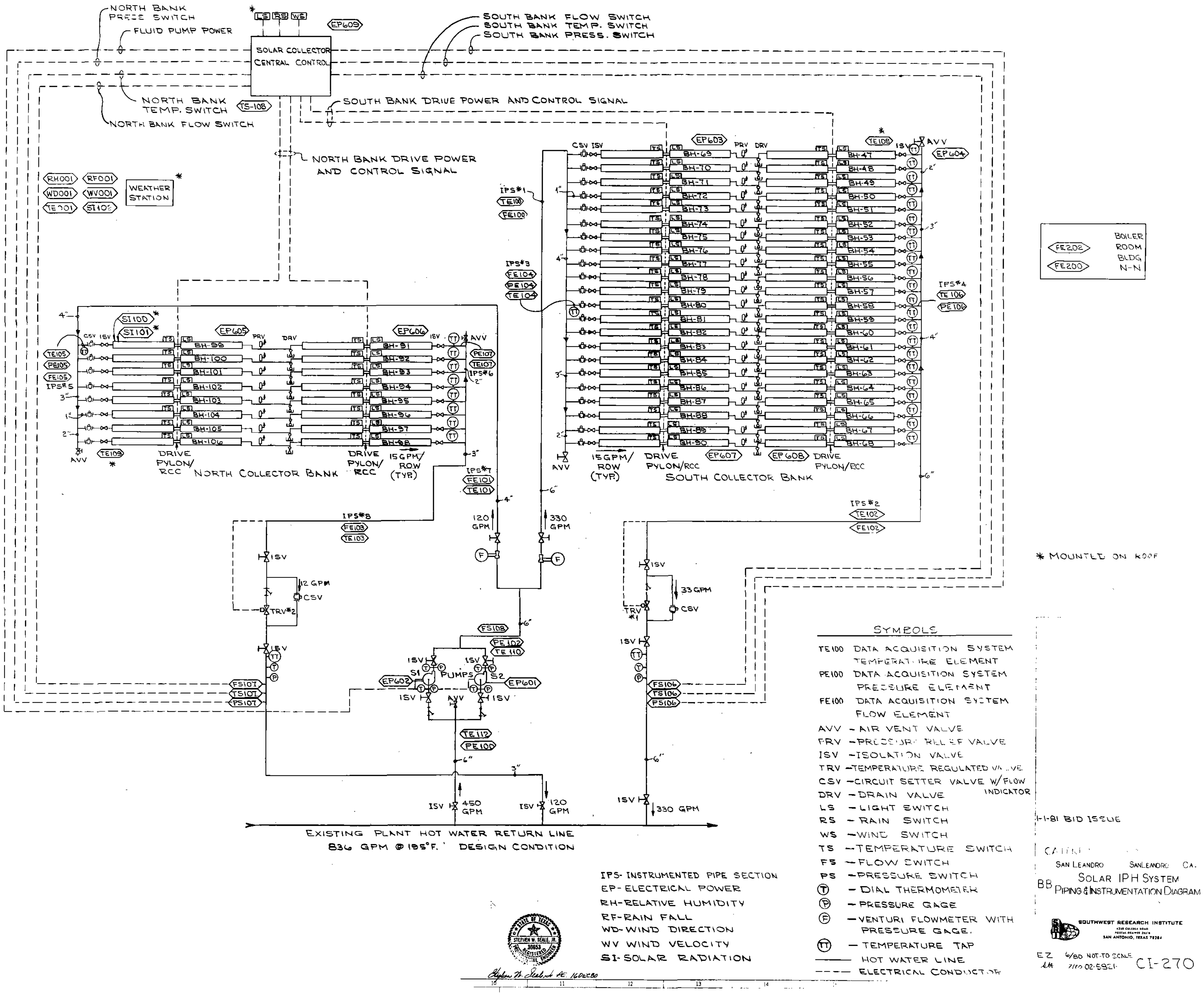

FIGURE 1. SOLAR SYSTEM P & I DIAGRAM

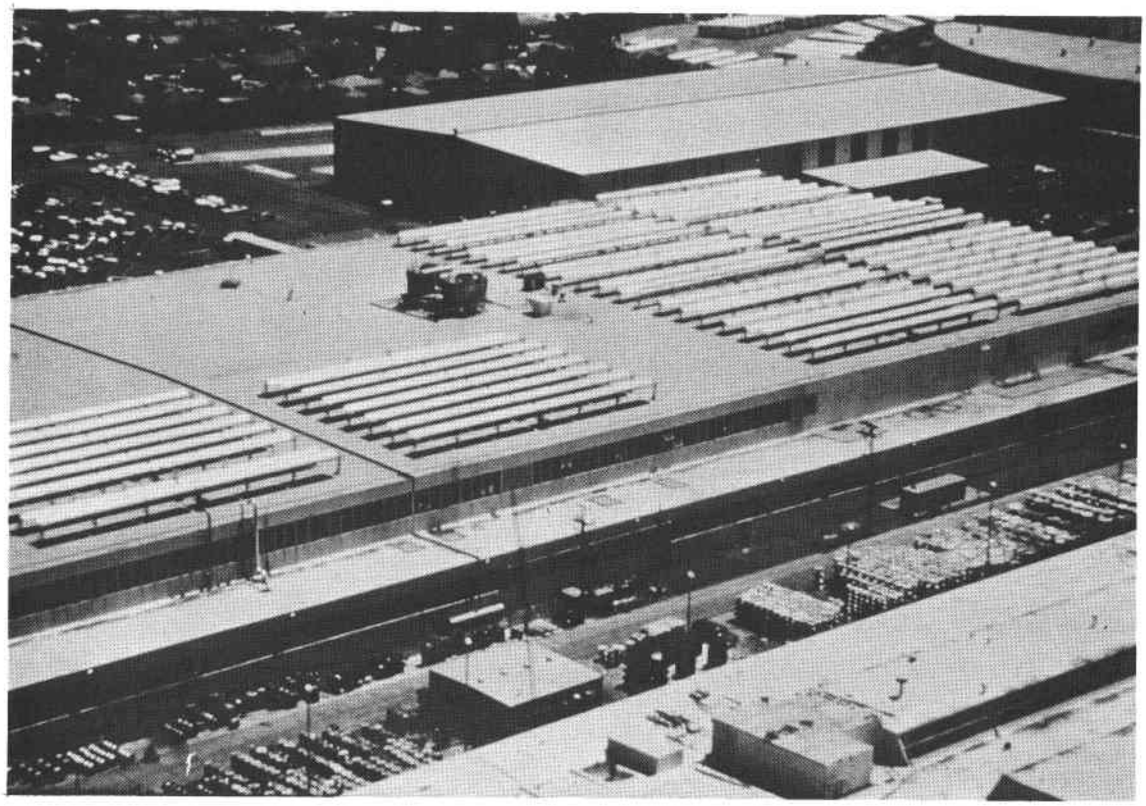

FIGURE 2. AERIAL VIEW OF CTCo SOLAR SYSTEM COLLECTOR ARRAY

collector area (264 collectors). The collectors are attached to the roof structure of the plant's main building. The rotational axis of each of the collectors is horizontal and is oriented 22° west of true north. Each of the two fields has its own inlet and outlet headers so that the 30 ΔT-strings (north: 8, south: 22) are piped in parallel between the inlet and outlet headers. Each of the ΔT strings is made up of 2 drive rows piped in series. A drive row is a set of six collector modules mechanically attached to form a row approximately 120 feet long and is rotated by a hydro-mechanical drive system located at the middle of the row. The physical characteristics of a single T-700A module are listed in Table I. The performance of a T-700A module is graphically depicted in Figure 3 which is the result of the tests performed by Dudley and Workhoven [3].

C. Piping Interface

It can be seen in Figure 1 that the dual pump inlet piping is connected to the plant heating system return line. The pump which is operating moves the fluid through the collector field and returns it to the return line. The fluid from the north collector field is returned approximately 10 feet downstream from the pump inlet piping connection. The south field connection is approximately 300 feet downstream from the north field connection. These two connections are similar, with the north one being depicted in Figure 4.

It can be seen in Figure 4 that a small parallel piping run is taken from the main downcomer. As shown in Figure 1, this leg of the downcomer is used during startup. If the collector field outlet temperature, sensed by the probe of the temperature regulating valve, TRV #1 or TRV #2, respectively, is less than a predetermined minimum valve, then TRV #1 and TRV #2 are closed. This forces the fluid through the small downcomer which limits the flow rate during the system startup period so that any thermal shock caused by the cold fluid stored in the collector receiver tubes is minimized. Once the fluid temperature at the field outlets has reached the valves' set points, the valves will open and the system will operate at its design flow rate.

TABLE I. T-700A PHYSICAL CHARACTERISTICS

Module Width	- 89 in.
Module Length	- 20 ft.
Mirror Width	- 84.5 in.
Solar Area Ft^2	- 140
Mirror Reflectance	- .84
Mirror Shape	- 90° Parabolic
Maximum Height (Vertical)	- 102 in.
Mirror Orientation	- 22° west of North
Maximum Tracking	- 260°
Stow Angle	- 78° (from horizontal)
Rotation Axis Height	- 53 in.
System Weight	- 4.0 lb/ft^2
End Pylon Static Load	- 280 lb
Center Pylon Static Load	- 560 lb
Pylon Base Mount Bolts	- 4 ea, 1-in. at 12-in. c-c
Pylon Spacing c-c	- 246 in.
Row Spacing c-c	- 13 ft-4 in. or 20 ft
Maximum Row Length	- 120 ft
Receiver Tube	- 1-5/8-in. Carbon Steel
Selective Surface	- Black Chrome
Absorptivity	- 0.94
Emissivity (400°)	- 0.18
Receiver Cover	- Pyrex Glass (7740)
Cover Transmissivity	- 0.91
Annulus Size	- 0.25 in.
Annulus Medium	- Dry Air
Pumping Loss (T-66)	- 4 psi/100 ft at 5 gpm
Plumbing Connections	- 1-in. Std. Pipe
Maximum Operating Temperature	- 500°F
Maximum Operating Pressure	- 250 psi

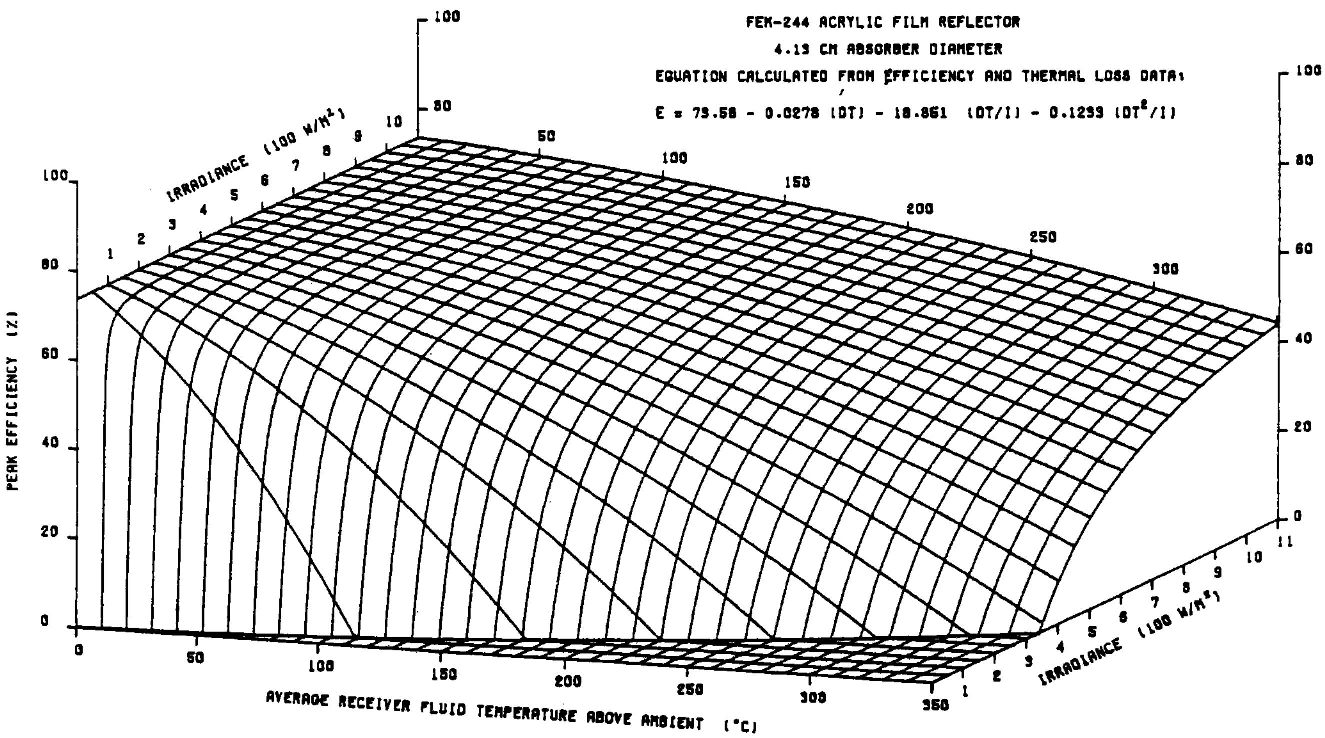

FIGURE 3. SKI T-700A TEST STAND EFFICIENCY
(Figure 60 by Dudley and Workhoven [3])

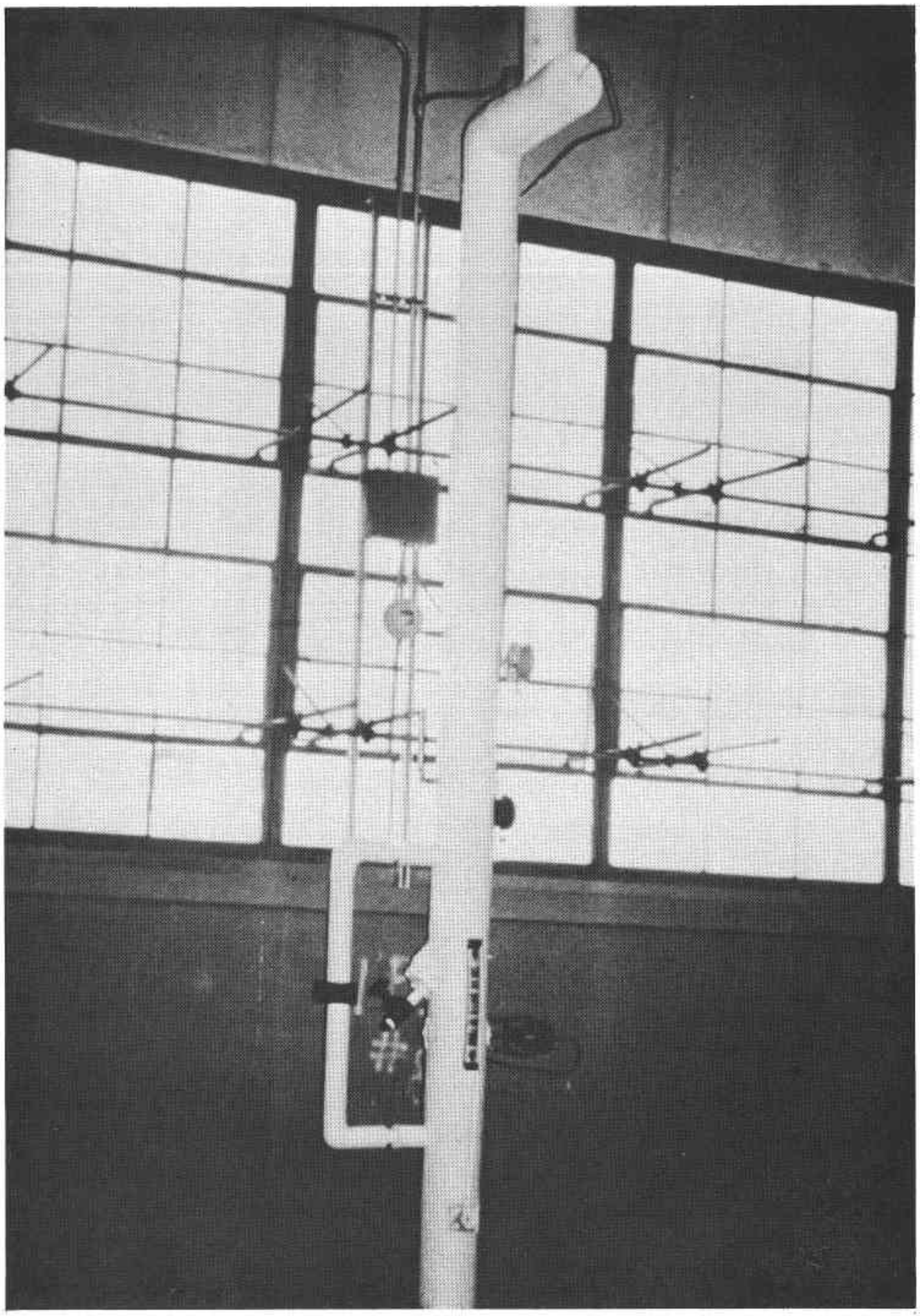

FIGURE 4. COLLECTOR OUTLET MANIFOLD/RETURN LINE PIPING CONNECTION

D. Pumps

There is a dual pump arrangement in the CTCo solar system with one of the two pumps selected as the lead pump with the other one serving as a backup. The operation of the pumps is described below under "Controls".

Both pumps are Paco Type L, Model 11-30121, end-suction pumps designed to deliver 450 gpm at 100 feet of head. They are fitted with 20 hp motors and operate at 460 V-3ϕ.

E. Controls

The control of the solar system is relatively simple and straightforward. The control system is designed to operate the collectors in such a way that energy is delivered to the process heat system if adequate radiation is available and if the process heat system requires an energy input.

The control system logic diagram, Figure 5, is separated into 3 sections. The first section, "Solar Master Control Panel Elementary Diagram" describes the collector array central control panel. The main component of this panel is the Minarik Electric Model WP6000 programmable microprocessor controller. The program for the controller is found in Appendix A. The controller monitors the status of a light level indicator, rain indicator, wind indicator, flow switches, and a hazard loop of temperature and pressure switches. If the light level is above a threshold value and the rain and wind sensors indicate favorable weather conditions the controller checks the status of the hazard loop. This is a series of temperature and pressure switches located at the outlets of the north and south fields. If the temperature and pressure of the collector loop fluid is below the acceptable limits, the pump is activated. If flow is established at the two flow switches, the collectors are activated by sending "high" signals on the Logic 1 and Logic 2 lines to each of the 60

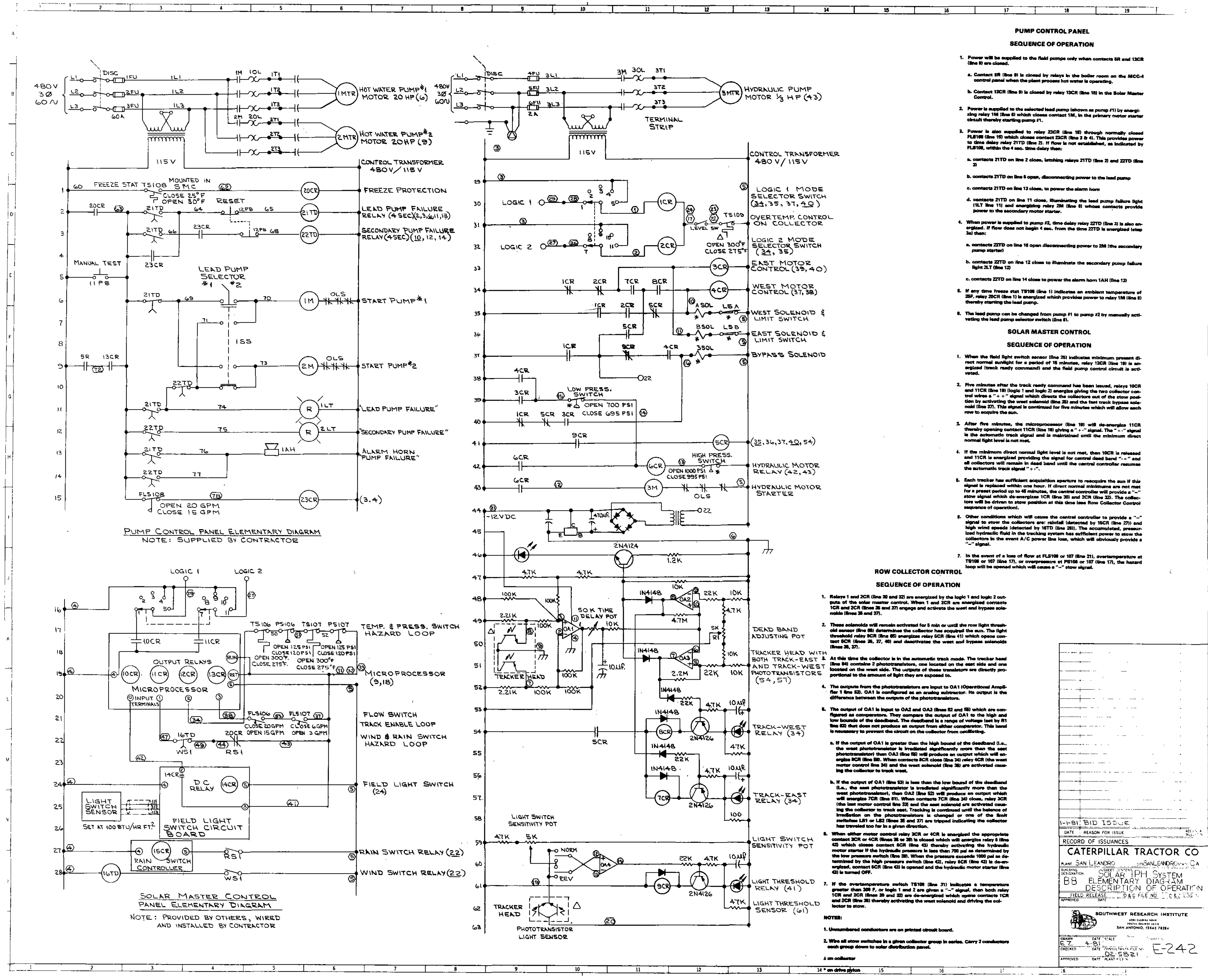

FIGURE 5. CONTROL SYSTEM LOGIC DIAGRAM

drive rows. If any of the system safety switches indicate a hazard, the collectors are immediately stowed. If the light level indicator senses a low level of solar radiation the collectors are halted for several minutes to allow the clouds to pass. If the sensor still indicates no available radiation, the collectors are stowed and the startup sequence is repeated.

If, while the collectors are operating, the collector outlet temperature becomes greater than 250°F, the collectors are unfocused until the fluid temperature decreases to a safe level. This prevents the solar system from overheating the process heat system if there is only a small thermal load in the plant.

The "Pump Control Panel Elementary Diagram" illustrates the operation of the pump control panel. It is seen that this control system allows the choice of one of the two pumps as the lead pump, while the other will serve as a backup in the event that the lead pump experiences a failure. Appropriate lamps and an alarm horn are activated in the event of a pump failure. This arrangement has the advantage of allowing the system to operate even when pump maintenance is being performed.

The "Drive Row Control Elementary Diagram" describes the operation of each of the 60 drive row control circuits. These circuits allow the drive rows to track the sun independently of the operation of each of the other rows as long as "high signals" are present on Logic 1 and Logic 2 as provided by the control controller.

III. DATA ACQUISITION SYSTEM

A. Overview

A highly automated data acquisition system (DAS) was designed and installed to closely monitor the operation of the solar system so that its performance could be accurately measured. The objective of the DAS was to provide the following information:

- Energy delivered to the process heat system
- Electrical energy consumed by solar system equipment
- Weather conditions

To provide the above information, pertinent system operating conditions, such as temperature, flow, electrical power, etc. are measured and reported.

A block diagram of the DAS components is shown in Figure 6. The heart of the DAS is the PDP 11/23 minicomputer. This computer is used to acquire the raw data, convert signals to meaningful values and provide the first level of data reduction by computing energy transfers for the various parts of the solar system. All raw data and computed data are stored on portable magnetic disk media which are transferred to a large off-site computer. A brief report of daily performance was provided by the computer at the end of each day which was printed on the on-site line printer.

In January, 1983 an Acurex Autodata Ten/10 datalogger was installed to serve as backup to the PDP 11/23 system. The datalogger scanned a limited number of transducers in order to provide enough data for the daily performance reports. The Autodata Ten/10 has the capability to reduce data; so, rather than store raw data, the signals are reduced on-line

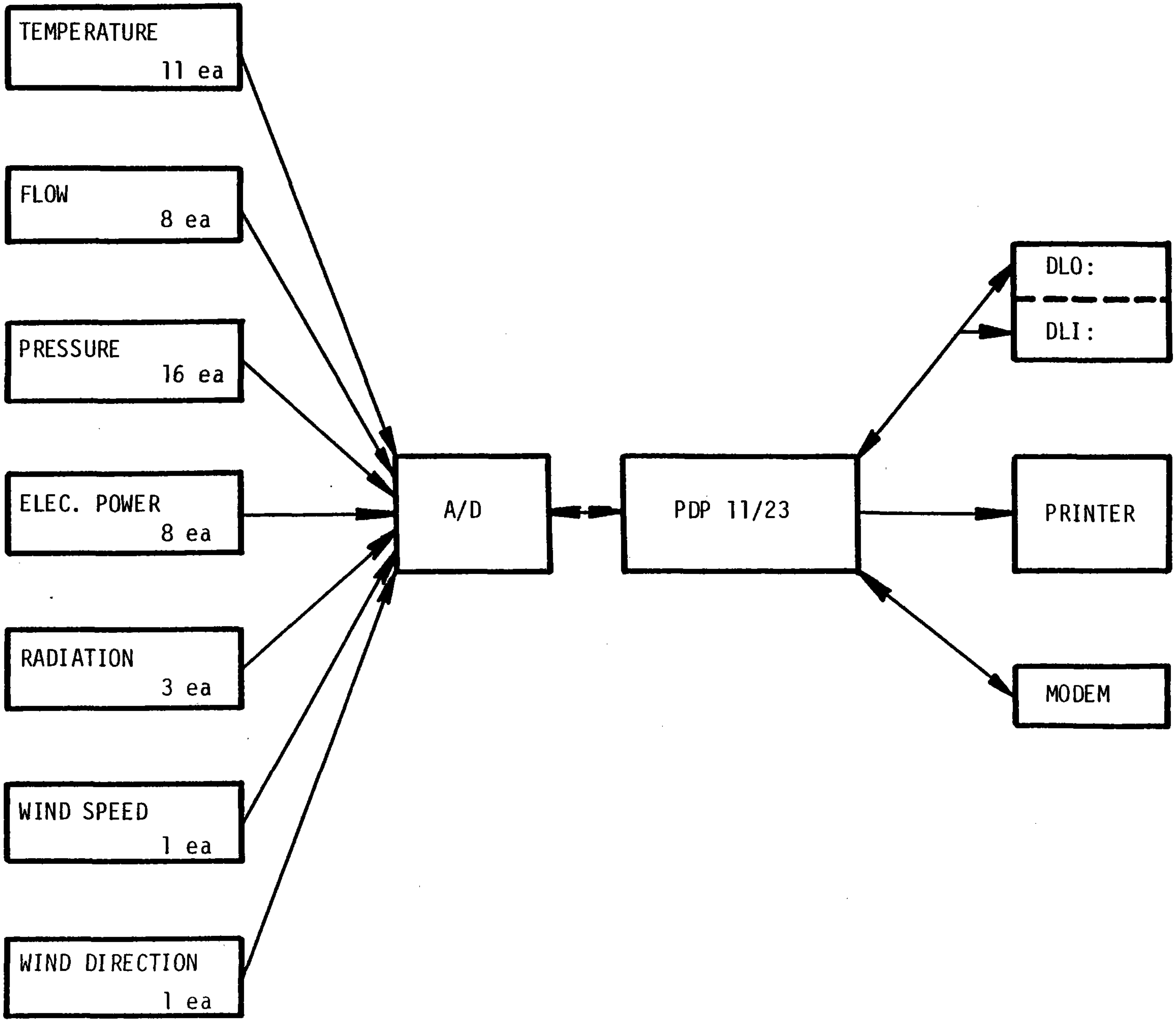

FIGURE 6. DAS BLOCK DIAGRAM

and stored on a cassette tape for later retrieval. The datalogger system was utilized in reporting performance a very few times during the course of the project.

Each of the major DAS components are described below in detail. These descriptive sections are then concluded by a discussion of the overall uncertainty in the results reported with the use of this DAS.

B. PDP 11/23 Computer and Software

The major components of the PDP 11/23 are shown in the photograph in Figure 7. This computer system consists of

- o PDP11/23 CPU with 48 K words of memory and a hardware bootstrap module. Since the backplane is separated into two sections, the necessary backplane terminators are included with the system.
- o 2 RL01, 5 MB, disk drives with controller.
- o 4 port asynchronous RS232 interface.
- o Modem interface.
- o LA36 terminal with graphics modifications.
- o VT100 with graphics modification, used as system controller.
- o A/D cards (2 each).

All of this equipment is Digital Equipment Corporation (DEC) equipment with the exception of the A/D cards which are made by Analog Devices.

The 11/23 CPU has floating point processing capability and is operated by version 3.1 of the RSX-11M operating system. One of the two disk drives is utilized as the system disk and contains all of the software and temporary data storage files necessary for executing the DAS data processing functions. The second disk drive is used for permanent storage of the raw and computed data. This disk is replaced each month so that

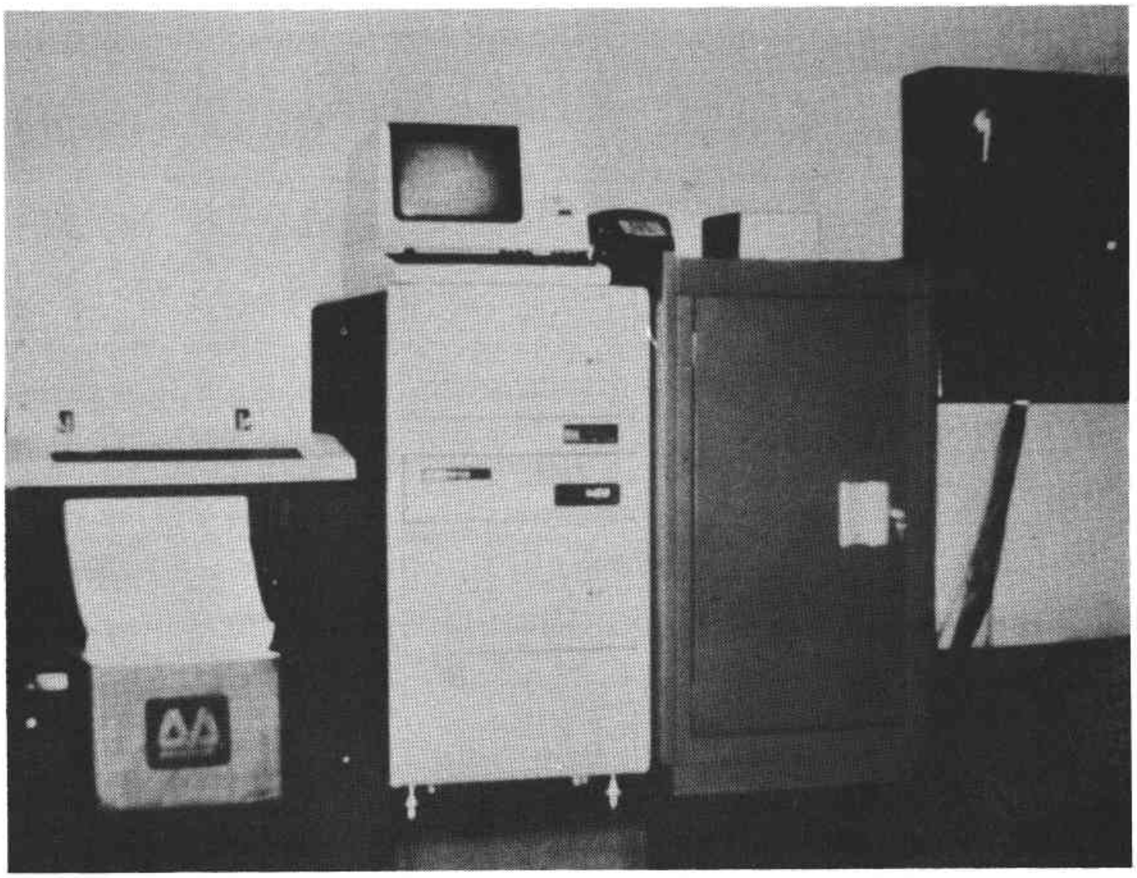

FIGURE 7. PDP 11/23 COMPONENTS

further analysis of the data may be carried out on an off-site computer. The LA36 terminal is connected to the RS232 interface card to provide an output device for occasional real-time data tabulations and graphs as well as the daily performance summary compiled by the computer at the end of each day. The A/D cards provide 64 channels of input from various sensors which the computer can scan.

A flow chart of the DAS software is shown in Figure 8. The actual listings of the software are not presented here for reasons of brevity, however, copies of this software are maintained on file by SwRI for archival purposes. It is seen that the routine, CON, is invoked to begin the DAS software. The initialization routine, INT, is called which sets up the appropriate files and clears the necessary flags for the rest of the routines. Control is passed back to CON which then calls DIS, the terminal display routine. DIS places a grid on the console monitor on which the real-time data will be displaced as the DAS acquires and processes data. After the display grid is completed, CON enters a timing loop. The routine, REC, is called at specific time intervals - usually 10-seconds - from this loop. REC first scans the A/D channels and converts the raw data to engineering units and computes all necessary heat transfers, efficiencies, etc. These data are averaged over 5-minute periods and stored on file by the routine, QUS, activated by REC. After completing the data acquisition tasks for a particular time interval, CON waits until the next set of data are to be gathered.

Other routines not in this basic process allow for the routine CON to be halted and restarted, the display to be cleared and restarted, and listings and graphs of various data to be compiled and transmitted to the LA36 line printer.

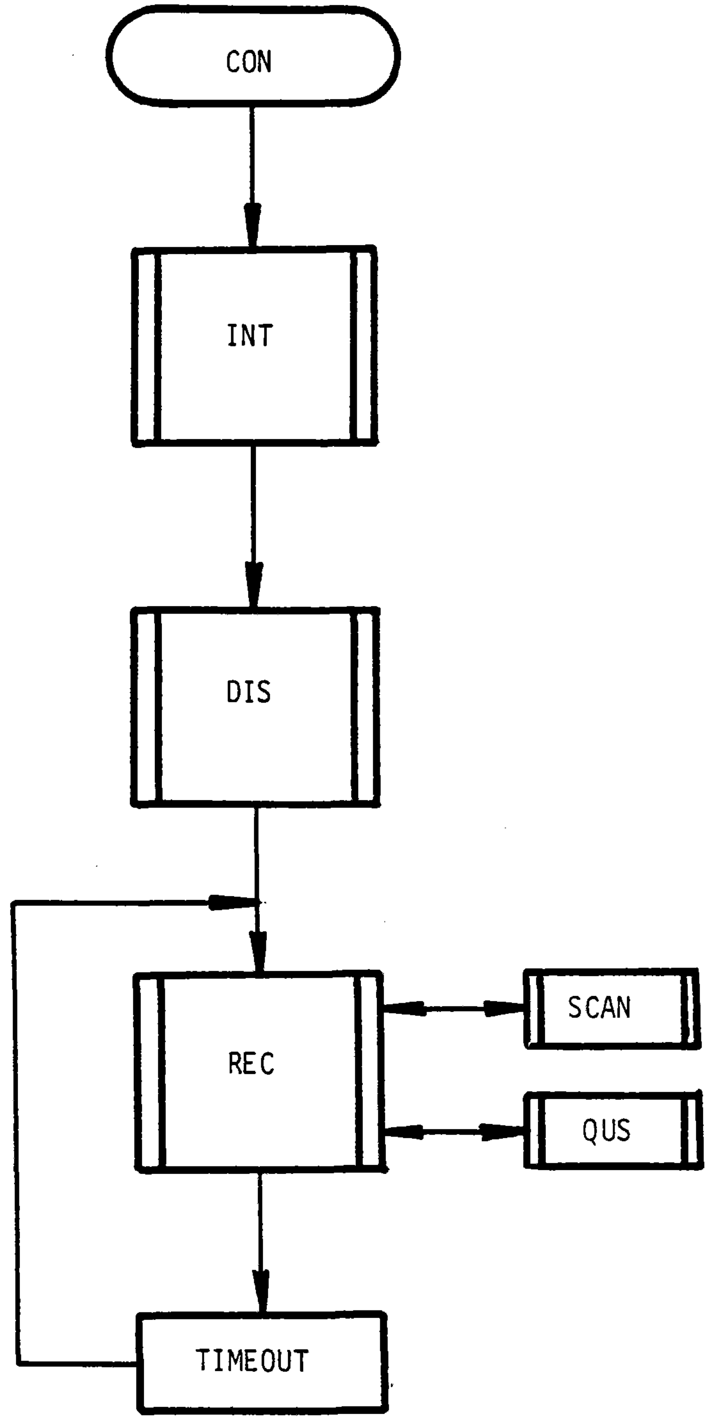

FIGURE 8. DAS FLOWCHART

C. Sensors

All of the primary sensors used in the CTCo DAS are listed in Table II. The sensor locations are shown schematically in the system P & I Diagram, Figure 1, while the actual installations are shown in the As-Built Drawings, see Deffenbaugh [2]. Table II provides the A/D channel number and a brief description of each sensor. The transducer and transmitter accuracy are listed separately while the total instrument accuracy provides an estimate of the error in the measurement recorded by the DAS software. The error associated with the A/D was observed to be negligible in comparison to the transducer/transmitter error level and is ignored here.

All sensors utilize transmitters located near the transducers or integrated with the transducer. These transmitters produce a 4-20 ma output signal proportional to the value of the physical parameter being measured. In this way, errors associated with the transmission of low-level voltage signals are minimized. The current outputs are forced through precision 500 Ω resistors and the A/D's measure the associated voltage drop across the individual resistors.

The power supplies which are used to provide the necessary 28-32 VDC supply voltage to the transmitters are Lambda Model LCS-CC-03. Three power supplies are used with the sensors being evenly distributed among them.

Each of the sensor types is described in more detail below.

Temperature: All process fluid temperatures are measured with Yellow Springs 100 Ω platinum RTD's. Yellow Springs RTD transmitters are mounted with the sensing element to convert the RTD output signal to a 4-20 ma signal proportional to the measured temperature. The transmitter/transducer pair were calibrated as a set at the factory so that each set has the same overall calibration curve. The accuracy of any given

TABLE II. DAS INSTRUMENT ACCURACY

Instrument Number	Data Location	Description/Location	Transducer				Transmitter (4-20 ma)			Total Instrument Accuracy
			Type	Model	Range	Accuracy	Model	Range	Accuracy	
TE101	14	North Field inlet temperature								
TE103	1	North Field outlet temperature								
TE105	5	North Field row outlet Temperature								
TE107	3	North Field row inlet temperature				±(.18 + .002(T-32)) ±0.72°F maximum				
TE100	31	South Field inlet temperature	RTD	Yellow Springs 4150-139AP	-328 - +122°F		Yellow Springs 1260	125-300°F	±0.18°F	±0.9°F
TE102	34	South Field outlet temperature								
TE104	27	South Field row inlet temperature								
TE106	33	South Field row outlet temperature								
TE110	9	Pump Inlet temperature								
TE112	10	Pump outlet temperature								
TE001	17	Ambient temperature	RTD	Hy-Cal RTS-58	-50 - +80°C	±0.9 F @ 32°F	Hy-Cal CT810-C	0-150 F	±0.15°F	±1.05°F
FE101	15	North Field inlet flow	2" Turbine	Halliburton 55 P/g	40-400 gpm	±2 gpm	Moore Ind. FDX/D	0-200/400 Hz	±0.44 gpm	±2.44 gpm
FE103	2	North Field outlet flow	2" Turbine	Halliburton 55 P/g	40-400 gpm	±2 gpm	Moore Ind. FDX/D	0-200/400 Hz	±0.44 gpm	±2.44 gpm
FE105	6	North Field row inlet flow	1" Turbine	Halliburton 870 P/g	5-50 gpm	±0.25 gpm	Moore Ind. FDX/C	0-400/800 Hz	±0.06 gpm	±0.31 gpm
FE100	30	South Field inlet flow	3" Turbine	Halliburton 57 P/g	60-600 gpm	±3 gpm	Moore Ind. FDX/C	0-400/800 Hz	±0.84 gpm	±3.84 gpm
FE102	35	South Field outlet flow	3" Turbine	Halliburton 57 P/g	60-600 gpm	±3 gpm	Moore Ind. FDX/C	0-400/800 Hz	±0.84 gpm	±3.84 gpm
FE104	28	South Field row inlet flow	1" Turbine	Halliburton 870 P/g	5-50 gpm	±0.25 gpm	Moore Ind. FDX/C	0-400/800 Hz	±0.06 gpm	±0.31 gpm
PE105	7	North Field row inlet pressure	Strain gage	Sensotec 811	0-150 psig	±0.38 psi				±0.38 psi
PE107	4	North Field row outlet pressure	Strain gage	Sensotec 811	0-150 psig	±0.38 psi				±0.38 psi
PE104	29	South Field row inlet pressure	Strain gage	Sensotec 811	0-150 psig	±0.38 psi				±0.38 psi
PE106	32	South Field row outlet pressure	Strain gage	Sensotec 811	0-150 psig	±0.38 psi				±0.38 psi
PE100	12	Pump inlet pressure	Strain gage	Sensotec 811	0-100 psig	±0.25 psi				±0.25 psi
PE102	11	Pump outlet pressure	Strain gage	Sensotec 811	0-150 psig	±0.38 psi	Built into transducer	N/A	N/A	±0.38 psi
EP601	18	Pylon power 81-90								±0.015 kw
EP602	19	Pylon power 59-68								±0.015 kw
EP603	20	Pylon power 69-80	Wattmeter	RIS PCE30-P3-E0-C5-XA	066 kw	±0.015 kw				±0.015 kw
EP604	21	Pylon power 47-58								±0.015 kw
EP605	22	Pylon power 99-106								±0.015 kw
EP606	23	Pylon power 91-98								±0.015 kw
EP607	24	Pump power	Wattmeter	RIS PCE30-P3-E0-C10-XA	0-12 kw	±0.030 kw				±0.030 kw
EP609	26	Control power	Wattmeter	RIS PCE15-P1-E0-C5-XA	0-1 kw	±0.003 kw				±0.003 kw
SI100	9	Total Collector plane radiation	Pyranometer	Eppley PSP	0-2800 w/m^2	±8.9 Btu/hr ft^2	Transpak TP601 ±.05%	0-600 Btu/hr ft^2	±0.3 Btu/hr ft^2	±9.2 Btu/hr ft^2
SI101	8	Diffuse collector plane radiation	Pyranometer	Eppley PSP	0-2800 w/m^2	±8.9 Btu/hr ft^2	Transpak TP601 ±.05%	0-600 Btu/hr ft^2	±0.3 Btu/hr ft^2	±9.2 Btu/hr ft^2
SI102	16	Total Horizontal radiation	Pyranometer	Eppley PSP	0-2800 w/m^2	±8.9 Btu/hr ft^2	Transpak TP601 ±.05%	0-600 Btu/hr ft^2	±0.3 Btu/hr ft^2	±9.2 Btu/hr ft^2
WD001	25	Wind direction	Vane	Weather Measure 102P	0-540°	±2.5°	Weather-Measure MD103HF	0-540°	±2.5°	±5°
WV001	38	Wind speed	Anemometer	Weather Measure 102P	0-200 mph	±0.25 mph	Weather-Measure MD104-540	0-200 mph	±0.25 mph	±0.5 mph

temperature measurement is a function of the temperature itself, but, for the range considered here, the maximum error in the measurements is ±0.9°F. For a temperature difference, then, the error is ±1.8°F (maximum). The ambient temperature is measured with a Hy-Cal shielded ambient temperature transmitter with an overall accuracy of ±1.05°F as indicated.

Flow: All water flows are measured by Halliburton turbine flow meters matched to the respective design flows in each pipeline. Moore Industries frequency/current transmitters are used to convert the flow meters output signal to a 4-20 ma signal proportional to the appropriate flow range.

Pressure: All pressures were measured with Sensotec pressure sensors which utilize a strain gage type transducer and a transmitter in an integrated package.

Electrical Power: Rochester Instruments electrical power transmitters are used to measure all electrical power consumption in the solar system. All of these transmitters are designed for use at 460 V 3ϕ for the power ranges indicated, except the control power transmitter, EP607, which measures 120 V-1ϕ power delivered to the central control panel for the collector array.

Solar Radiation: Solar radiation is measured in both the horizontal plane and in the rotating plane of the collectors with Eppley model PSP pyranometers. The horizontal radiation measurement is made by a single stationary pyranometer mounted with the other weather instrumentation. The collector plane radiation is measured with a set of two pyranometers mounted on the edge of a collector module, as shown in Figure 9. One of the pyranometers measures the total hemispherical solar radiation in a plane parallel to the collector aperture. The other one has a shadow band across a portion of the hemisphere which is equal to the area "seen"

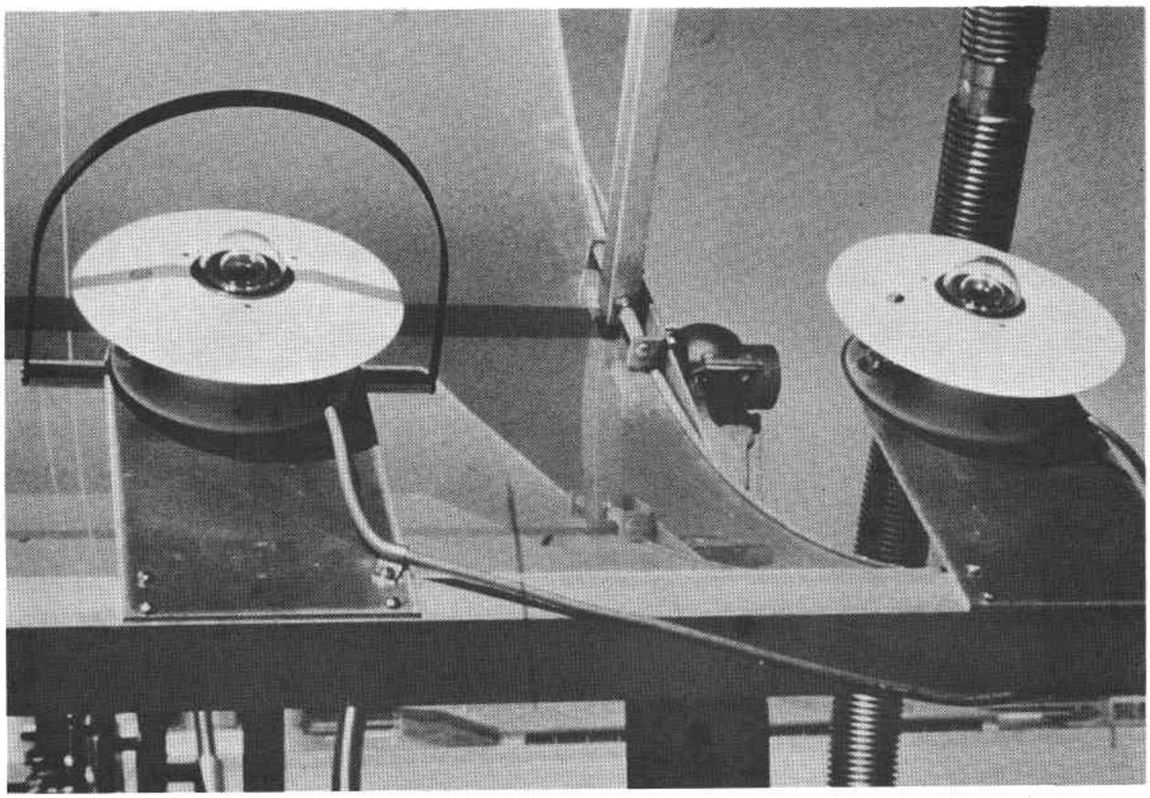

FIGURE 9. COLLECTOR PLANE RADIATION SENSORS

by the collector. This is, therefore, a measure of the radiation which is not utilizable by the collector. By subtracting the latter measurement from the former, the radiation which is used by the collector can be computed.

Wind Velocity: Wind velocity is measured with a Weather Measure 102P propeller anemometer, shown in Figure 10. Wind speed is measured by a tachometer mounted to the propeller shaft while the direction is measured by a rotary potentiometer mounted to the vertical axis of rotation of the vane body.

D. Datalogger and Tape Deck

As mentioned above, an Acurex Autodata Ten/10 and a Techtran 8410 tape deck were used to backup the PDP 11/23 computer. The datalogger and the PDP 11/23 were operated concurrently but did not communicate with each other. The datalogger measured the voltage drop across selected sensor current loop precision resistors to get an independent value for the parameter in question. Since both the datalogger A/D and the computer-based A/D are extremely high impedance devices ($\geq 10\ M\Omega$), they did not interfere with each other when taking voltage readings.

Since the datalogger served only in a backup mode, only those data absolutely necessary for compiling the daily and monthly performance reports were measured. These data were

TE101	North field inlet temperature
TE103	North field outlet temperature
TE100	South field inlet temperature
TE102	South field outlet temperature
FE101	North field inlet flow rate
FE100	South field inlet flow rate
SI100	Collector plane total radiation
SI101	Collector plane diffuse radiation
SI102	Horizontal plane radiation
TE001	Ambient temperature
WV001	Wind speed
EP601-EP609	Electrical power to pylons, pumps, and controls

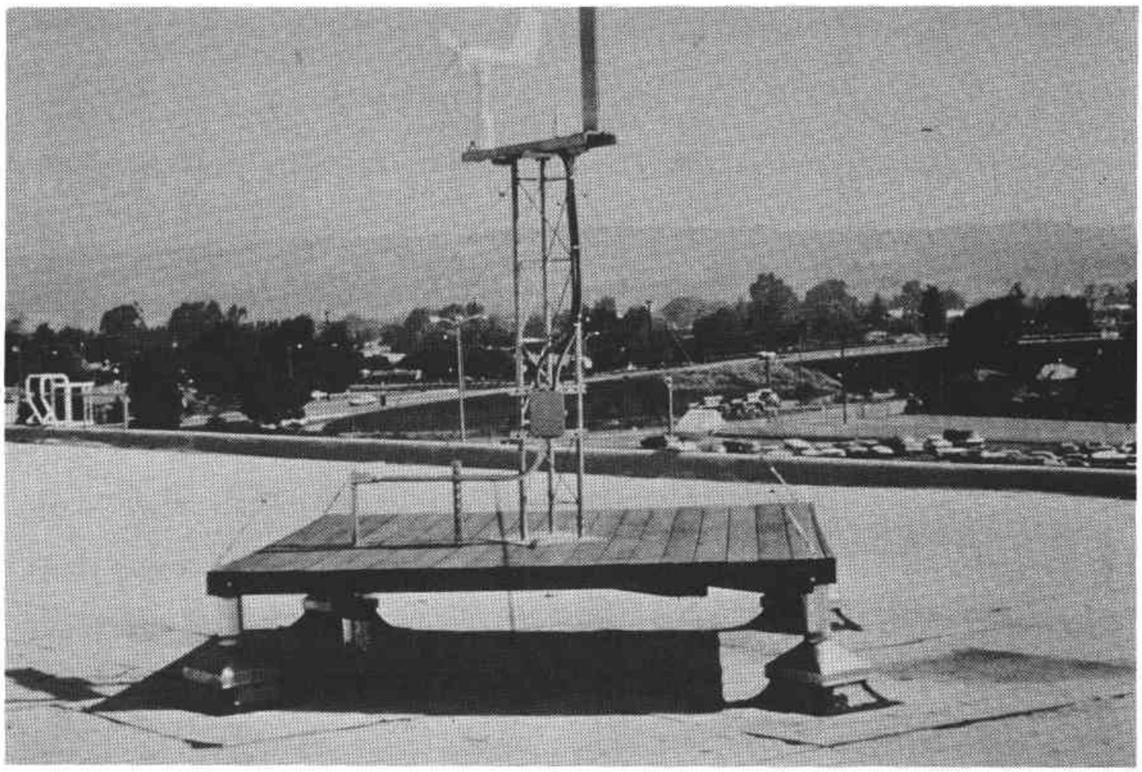

FIGURE 10. WEATHER INSTRUMENTS

The datalogger was programmed to gather these primary data, convert the measured voltages to engineering units, compute all necessary energy transfers and integrate these results over one hour periods. At the end of each hour the integrated data were stored on magnetic cassette tape for later analysis and data reduction.

Since a limited selection of the data are stored at hourly intervals the cassette tapes do not provide the detail that the computer disk data will reveal. However, this method provided a means of gathering data when the 11/23 system was not operational.

E. Uncertainty Analysis

Because this was an experimental program an uncertainty analysis was performed for the CTCo solar system DAS. The details of this analysis are presented in Appendix B and show that the uncertainty in energy computations is nominally ±3.7% based on instrument precision error only.

As pointed out in the discussion in Appendix B, the complete set of data collected during the monitoring period was reviewed and reprocessed because the uncertainty analysis revealed an error in the original data processing software. In short, the DAS was using a correlation for the saturation enthalpy of water which did not closely match accepted values. This bias error introduced an uncertainty which was of the same order as that due solely to the instrument precision error. The data were reprocessed using the actual values of the enthalpy of water; however, because the actual raw data gathered at 10 second intervals are integrated over 5-minute periods for permanent storage, this reprocessing could not exactly duplicate the original conditions. It is estimated that only an additional 1% of uncertainty is introduced by using the integrated temperature rather than the discrete values themselves.

So, the uncertainty in the calculation of energy delivered by the collector array is approximately ±5% at the system design operating conditions.

IV. SYSTEM OPERATION AND MAINTENANCE

A. Overview

The operation of the Caterpillar Tractor Company solar system was closely monitored during the 25 month period from November 1982 to November 1984. The solar system is operated much the same as any other equipment in the plant with careful maintenance and operation records kept for each portion of the system. This record of the operation history and maintenance activities is a valuable source of information for other investigators in that chronic maintenance problems may be avoided in the future.

The following sections summarize the operation and maintenance history of the solar system and the data acquisition. The operating philosophy over the course of the 25 months is described along with a factual summary of the maintenance records during the monitoring period.

B. System Operation History

The CTCo solar system began operating in the summer of 1982 and after an initial shakedown period the system performance monitoring period was begun on 13 November 1982. At that time the DAS was activated to begin closely monitoring the operation and performance of the system and CTCo personnel assumed responsibility for the operation and maintenance of the solar system. Operation and performance were reported monthly until November 1984.

These Monthly Performance Reports, found in Appendix C, describe in detail the operational experience during a given month and summarize the energy delivery of the system. A brief summary of these reports is provided here.

First of all, Table III lists the availability and utilization of the system as a whole and the cumulative availability and utilization if each drive row is individually considered. The system availability and utilization are defined by Kutscher and Davenport [4] as follows

$$\text{system availability} = \frac{\text{no. of days system not down for maintenance}}{\text{no. of days in reporting period}}$$

$$\text{system utilization} = \frac{\text{no. of days of actual system operation}}{\text{no. of days system was not down for maintenance}}$$

In the case of the CTCo solar system it became apparent that, because each row could be isolated from the system, a slightly different definition of availability and utilization was required. This definition provides a truer picture of the operational status of the collector field by considering the status of each individual row for each day of the month.

$$\text{row availability} = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{\text{no. of rows not down for maintenance}}{\text{total no. of rows}} \right)_i$$

$$\text{row utilization} = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{\text{no. of rows actually operating}}{\text{no. of rows not down for maintenance}} \right)_i$$

where N = number of days in the month

The net effective area of the collector array may be computed in the same manner while it can also be shown to be given by

net effective area = (total area)* (row availability)* (row utilization)

TABLE III. SOLAR SYSTEM AVAILABILITY AND UTILIZATION

Month	System		Row		Net Effective Area ft^2
	Availability	Utilization	Availability	Utilization	
11/82	100	100	100.0	100.0	50400
12/82	100	100	100.0	100.0	50400
1/83	100	100	99.8	100.0	50292
2/83	100	100	98.3	100.0	49543
3/83	100	100	99.7	100.0	50240
4/83	100	100	94.9	81.9	39172
5/83	100	100	94.5	44.4	21147
6/83	100	100	96.6	33.1	16115
7/83	100	100	93.5	36.3	17106
8/83	100	100	93.3	40.0	18809
9/83	100	100	93.0	40.9	19171
10/83	100	100	90.0	77.1	34973
11/83	44.4	100	36.0	85.2*	38640*
12/83	100	100	90.0	98.1	44498
1/84	100	100	92.2	100.0	46469
2/84	100	100	92.1	100.0	46418
3/84	100	100	92.0	100.0	46368
4/84	100	100	88.6	100.0	44660
5/84	100	100	82.8	100.0	41756
6/84	100	100	84.7	100.0	42700
7/84	100	100	85.0	100.0	42840
8/84	77.4	100	58.5	100.0	41580*
9/84	100	100	66.7	100.0	33600
10/84	100	100	66.7	100.0	33600
11/84	100	100	66.7	100.0	33600

*Computed only for those days the system was operational

Thus net effective area is the equivalent size of a collector array which operates for an entire month with no down time.

In Table III it is seen that in the period 11/82 - 3/83 the system was fully utilized with only minor maintenance problems on individual rows. This is indicated by the 100% utilization and the high availability for these months. During November, December, and January of this period, the plant was utilizing all of the energy the solar system was capable of producing. Beginning in February 1982, however, it was observed that the system was cyclically focusing and unfocusing as the solar system heated the plant process heating system to a high temperature. At this time the solar system could deliver more energy than the plant could use because the reduction in plant production below design capacity had substantially decreased the thermal load of the plant. So, when the solar system operated it could provide more than 100% of the plant's hot water requirements, as opposed to the 60% portion originally planned.

During the period 4/83 - 12/83 selected drive rows were deactivated and isolated from the solar system, because the CTCo plant personnel were manually matching the capacity of the solar system to the thermal load of the solar system. Since the system efficiency varies during the year with a maximum in the summer months, the row utilization shows a minimum during the summer of 1983. The objective of this type of operation was to allow the solar system to operate in a steady state manner without the cyclical focusing and unfocusing brought on by the control system. Thus, the thermal performance of the system during this time period should indicate the ability of the collector equipment to convert solar radiation to thermal energy better than if the system was rapidly cycling.

It is seen that the entire system was inoperative during more than half of November 1983. On 11/12/83 the central controller lost its program which prevented solar system operation. The plant experienced several power failures during the latter part of the month and the central

To Ed
Date 10-28 Time 3:00

WHILE YOU WERE OUT

M Joel Sitz
of
Phone 404-526-792

Area Code Number Extension

TELEPHONED	✓	PLEASE CALL	
CALLED TO SEE YOU		WILL CALL AGAIN	
WANTS TO SEE YOU		URGENT	
RETURNED YOUR CALL	✓		

Message

W
Operator

s period and required reprogramming
about 12/1/83. So, for 11/83 the
results are listed only for those
able for operation since they cannot

r 1984, CTCo personnel chose to operate
make use of its full capacity. It had
close sometime in the spring of 1985 and
edule was initiated to increase parts
tdown and transportation of equipment to
t although the utilization was 100%
ws cycled between the focused and unfo-
control system. This kept the solar
ssible; however, the system efficiency
portion of the operating period was
d.

It is further seen that the availability decreased steadily from January 1982 till September 1984. This was also a result of the plant shutdown procedures. As maintenance personnel were kept busy servicing highly utilized plant machinery and disassembling other equipment there were fewer personnel available to maintain the solar equipment. Since the solar system could produce more energy than the plant could utilize, the rows which had maintenance problems did not appreciably affect the thermal output of system. At the end of the monitoring period, therefore, the system had a number of minor maintenance problems which could be quickly repaired if parts and personnel could be economically allocated.

The lowered system availability in August 1984 was a result of a check valve failure in the pump piping network. This failed valve decreased fluid flow to the system which caused localized damage to the receiver tubes on a number of rows; however, there was adequate flow to prevent the flow switches signaling a fault condition. The system temperature switches are located downstream from the collectors so that enough time elapsed to cause damage to certain tubes with exceptionally low flow. The system was brought back on line 11/30/84 after the replacement of the pump check valves. It is seen that the row availability suffered as a result of this accident; however, as stated above, the collector array maintenance problems are mostly minor in nature and can be quickly repaired once parts and personnel are allocated.

C. Solar System Maintenance Summary

The summary of solar system maintenance will be discussed in two sections. First, general activities will be described while maintenance activity on the individual rows is described in the following section.

Overall System Maintenance

Over the course of the performance monitoring period, very little effort was required to keep the system, as a whole, operational. A chronological journal of maintenance activities was maintained by CTCo personnel on which the following synopsis is based:

1/82 - System monitoring period was started on 11/13/82. The solar pumps momentarily starved the main plant pumps at startup which was sensed by the flow switches. A brief time delay was incorporated to allow operation to stabilize before a failure is detected. N_2 was accumulating in the collector rows overnight. The plant's N_2 overpressure system, which is necessarily at a lower elevation than the collectors, was modified to correct the problem.

12/82 - Central controller light sensitivity circuit modified to more accurately control the light level threshold.

1/83 - Normal operation.

2/83 - Inconsistent startup sequence was observed. Radiation sensor threshold and focusing adjusted. Focusing/defocusing cycles observed.

3/83 - Focusing/defocusing cycles observed.

3/83-6/83 - Deactivated selected rows to prevent transient operation (focusing/defocusing).

7/83 - Plant closed 7/5-8/2. Intermittent operation to provide hot water for maintenance activities.

8/83-10/83 - Plant begins closing down on Saturdays and Sundays because of reduced schedule. Solar system allowed to operate these days if required to keep the system hot for Mondays. Also, collectors were stowed each day at 1500 since shift ends at that time.

11/83 - Power failures caused central controller to lose its program several times. System showed intermittent operation 11/12-12/1, but, since control problem was observed only when weather was good, the data show no energy delivery at all.

12/83-7/84 - Normal operation with focusing/unfocusing cycles observed.

8/84 - Pump check valve failure on 8/16/84 causes minor glass breakage due to overheating. Check valve replaced 8/31/84. System down 8/16-8/31.

9/84-11/84 - Normal operation.

Collector Drive Row Maintenance

Caterpillar Tractor Company maintenance personnel keep extensive maintenance records for each piece of equipment in the plant. Those records show the cause and the duration of any down time. The equipment maintenance records for each collector drive row are located in Appendix D while a summary of these records is given in Table IV.

Table IV shows the maintenance history of the system as a whole as well as for each drive row. The drive rows are numbered BH-47 through BH-106 to correspond with the CTCo equipment numbering scheme. As an example of interpreting the entries in the table, we will use the entry for row BH-94 for October 1983. The upper line in this entry contains a maintenance code, 11, which represents a problem with the tracking circuitry. This problem existed during the period 11/1/83-11/26/83 as indicated. The upper line also contains a code, T, which means the row was manually deactivated to prevent the focusing/unfocusing cycling discussed above. This occurred 11/27/83-11/30/83 as indicated in the second line of the entry. Using this table of codes and dates the status of any drive row at any given time during the period 11/82-11/84 may be determined.

TABLE IV. SYSTEM MAINTENANCE SUMMARY

	Nov 82	Dec 82	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83	Jul 83	Aug 83	Sep 83	Oct 83	Nov 83	Dec 83	Jan 84	Feb 84	Mar 84	Apr 84	May 84	Jun 84	Jul 84	Aug 84	Sep 84	Oct 84	Nov 84
System	u	u	u	u	u	u	u	u	I 5-31 u	u	u	u	C 13-30 D	u	u	u	u	u	u	u	u	V D 6-20,28-31	u	u	u
Row BH- 47	u	u	u	u	u	13 7-31 D	13 1-31 D	13,21 D 1-7,14-30	21 1-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-11 D	u	u	01 25-30 D	01 1-31 D	01 1-30 D	01 1-31 D	01 1-1 D	u	u	u
48	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-9 D	22 28-30 D	22 1-31 D	22 1-30 D	22 1-31 D	22 1-11 D	u	u	u	u	u	u	u	u	u	u
49	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T,11 D 1-3,27-31	11 1-30 D	11 1-31 D	11 1-31 D	11 1-29 D	11 1-5 D	u	u	u	u	u	u	u	u
50	u	u	u	u	u	u	T 19-31 D	T 1-30 D	T 1-6 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
51	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	22 24-30 D	22 1-31 D	22 1-6 D	u	22 16-31 D	22 1-30 D	22 1-31 D	22 1-30 D
52	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
53	u	u	u	u	u	u	T 19-31 D	T 1-30 D	T 1-6 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
54	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
55	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	u	u	22 16-31 D	22 1-30 D	22 1-31 D	22 1-30 D
56	u	u	u	u	u	u	T 19-22 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
57	u	u	u	u	u	u	T 13-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
58	u	u	u	u	u	T 26-28 D	T 13-31 D	T 1-20 D	T 1-6 D	u	u	u	u	u	u	u	u	11 26-30 D	11 1-31 D	11 1-6 D	u	u	u	u	u
59	u	u	u	u	u	T 26-30 D	T 1-12 D	u	T 7-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	21 12-31 D	21 1-29 D	21, D 1-6,9-31	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-6 D	u	u	u
60	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	21 5-30 D	21 1-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D
61	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	u	u	u	u	u	u
62	u	u	u	u	u	T 26-30 D	T 1-12 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
63	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	u	u	u	u	u	u
64	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	12 12-31 D	12 1-29 D	12 1-5 D	u	u	u	u	u	u	u	u
65	u	u	u	u	u	T 28-30 D	T 1-12 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	22 1-30 D	22 1-31 D	22 1-30 D
66	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	21 6-30 D	21 1-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D
67	u	u	u	u	u	T 28-30 D	13 1-31 D	13,T 1-7,8-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	13 6-8 D	u	u	u	u	u	u	u	u
68	u	u	u	u	u	T 28-30 D	T 1-12 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	14 1-30 D	14 1-31 D	14 1-30 D
69	u	u	u	u	u	T 28-30 D	T 1-12 D	u	21 3-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-11 D	12 9-29 D	12 1-6 D	u	u	u	u	01 16-31 D	u	u	u

TABLE IV. SYSTEM MAINTENANCE SUMMARY (CONTINUED)

Row BH-	Nov 82	Dec 82	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83	Jul 83	Aug 83	Sep 83	Oct 83	Nov 83	Dec 83	Jan 84	Feb 84	Mar 84	Apr 84	May 84	Jun 84	Jul 84	Aug 84	Sep 84	Oct 84	Nov 84
70	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-9 D	22 28-30 D	22 1-31 D	22 1-30 D	22 1-31 D	22 1-11 D	u	u	u	u	u	u	u	u	u	u
71	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	u	u	22 16-31 D	21 1-30 D	21 1-31 D	21 1-30 D
72	u	u	u	u	u	T 28-30 D	T D 1-12,19-31	T 1-30 D	T 1-6 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
73	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	22 24-30 D	22 1-31 D	22 1-6 D	u	22 16-31 D	u	u	u
74	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
75	u	u	u	u	u	T 28-30 D	T D 1-12,19-22	T 1-30 D	T 1-6 D	u	u	u	u	u	u	u	u	21 25-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-31 D	u	u	u
76	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
77	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	1-3 D	u	u	u	u	u	u	u	u	u	22 16-31 D	22 1-30 D	22 1-31 D	22 1-30 D
78	u	u	u	u	u	T 28-30 D	T D 1-12,19-22	u	u	u	u	u	u	u	u	u	21 8-31 D	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 D 1-8,16-31	21 1-30 D	21 1-31 D	21 1-30 D
79	u	u	u	u	u	T 28-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
80	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-6 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
81	u	u	u	u	u	14 7-30 D	14 1-10 D	u	T 7-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	14 7-30 D	14 1-10 D	u	u	u	u	u	u
82	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	13 7-30 D	13 1-31 D	13 1-31 D	13 1-30 D	13 1-31 D	13 1-30 D
83	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	21 9-31 D	21 1-30 D	21 1-31 D	21 1-6 D	u	01 16-31 D	21 1-30 D	21 1-31 D	21 1-30 D
84	u	u	u		u	T 26-30 D	T 1-12 D	u	21 3-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-31 D	21 1-29 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-31 D	21 1-30 D	21 1-31 D	21 1-30 D
85	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	u	u	u	u	u	u	u	u	u
86	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
87	u	u	u	u	u	T 26-30 D	T 1-12 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	14 1-30 D	14 1-31 D	14 1-30 D
88	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-3 D	u	u	u	u	13 9-31 D	13 1-30 D	13 1-31 D	13 1-30 D	13 1-31 D	13 1-31 D	13 1-30 D	13 1-31 D	13 1-30 D
89	u	u	u	u	u	T 26-30 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-10 D	u	u	u	u	u	u	u	u	u	u	u	u	u
90	u	u	u	u	u	T 26-30 D	T 1-12 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	21 1-30 D	21 1-31 D	21 1-30 D
91	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	14 1-30 D	14 1-31 D	14 1-30 D
92	u	u	12 28-31 D	12 1-28 D	12 1-6 D	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	22 16-31 D	22 1-30 D	22 1-31 D	22 1-30 D

TABLE IV. SYSTEM MAINTENANCE SUMMARY (CONCLUDED)

Row BH-	Nov 82	Dec 82	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83	Jul 83	Aug 83	Sep 83	Oct 83	Nov 83	Dec 83	Jan 84	Feb 84	Mar 84	Apr 84	May 84	Jun 84	Jul 84	Aug 84	Sep 84	Oct 84	Nov 84
93	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
94	u	u	u	u	u	21 14-31 D	21,11 D 1-10,11-31	11 1-30 D	11 1-31 D	11 1-31 D	11 1-30 D	11,T D 1-26,27-31	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	u	u	u	u
95	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
96	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	u	u	u	u
97	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
98	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	u	u	u	u
99	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
100	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	u	u	u	u
101	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
102	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	01 16-31 D	01 1-30 D	01 1-31 D	01 1-30 D
103	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	01 16-31 D	01 1-30 D	01 1-31 D	01 1-30 D
104	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	u	u	u	u
105	u	u	u	u	u	T 14-24 D	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u
106	u	u	u	u	u	T 14-24 D	T 26-31 D	T 1-30 D	T 1-31 D	T 1-31 D	T 1-30 D	T 1-31 D	T 1-30 D	T 1-4 D	u	u	u	u	u	u	u	01 16-31 D	21 1-30 D	21 1-31 D	21 1-30 D

LEGEND:

Numbered Codes:

01 - Tube Broken - Short (s)
02 - Tube Broken - Long (L)
03 - Tube Defect - Short
04 - Tube Defect - Long
05 - Support Bracket Broken
06 - Mirror Damage - Severe
07 - Mirror Damage - Minor
08 - Interference - Give Clearances
11 - Tracking Problem
12 - Electrical Short
13 - Switch Defect
14 - Circuit Board Problem
21 - Hydraulic Leak
22 - Water Leak
23 - Accumulator Low
24 - Pump Problem
25 - Low Hydraulic Fluid

Letter Codes:

T - row down to prevent unfocusing/focusing cycles
I - intermittent system operation during temporary plant shutdown, Jul '83
C - system down because of central controller failures
V - system down because of pump check valve failure

Example:

Row 94 in Oct '83 was down from 10/1/83-10/26/83 due to circuit board failure and was down from 10/27/83 to 10/31/83 to prevent focusing/unfocusing cycles.

The extent of the maintenance problems with the drive rows is found by reviewing Table V. Electrical problems include any problem with the drive row controller and relays. Hydraulic problems are those dealing with the hydraulic pump, pump motor, or hydraulic circuit components. Receiver tube/flex hose problems encompass water leaks, glass breakage, tube warps, etc. Downtime due to system failures occurred on two occasions: November 1983 and August 1984 and affected only those rows which were available for operation. Finally, there was some row downtime because of manual deactivation of rows to match the solar system energy output to the plant load during 4/83-12/83.

TABLE V. DRIVE ROW DOWNTIME SUMMARY

Problem	Downtime	
	Row-days	Fraction of Total
Electrical	1350	3.0%
Hydraulic	2152	4.8%
Receiver tube and flex hose	757	1.7%
System failure	1114	2.5%
Prevent focusing/ unfocusing	6181	13.8%

Total available = 60 rows * 749 days = 44940 row-days.

Considering only the maintenance problems, there were a total of 5373 row days of downtime (12% of total). While it is difficult to accurately predict the downtime if rows had not been manually deactivated for load matching purposes, it seems reasonable to extend the above ratio to these manually deactivated rows. So, it is likely that if rows had not been manually deactivated the total downtime for this system would have been approximately 6112 row days or 13.6% of the total. Considering the fact that maintenance personnel and replacement parts were not readily available for about the last six months because of the plant shutdown process, this is a reasonably good operational record. Indeed, CTCo plant engineers have estimated that one can still expect 5% downtime for this type of equipment when a rigorous maintenance program is followed.

DAS Operation and Maintenance

The DAS operated continuously from November 13, 1982 to November 30, 1984 with little loss of data. A survey of the CTCo maintenance journal and the SwRI maintenance journal provides the following history of DAS operation.

11/82	DAS activated 11/13/83 TE102 bad
12/82	TE102 bad PDP 11/23 down 12/22/83-12/31/83 due to disk drive failure
1/83	PDP 11/23 repaired 1/20/83, datalogger installed TE102 bad
2/83	TE102 repaired 2/1/83
3/83	FE100 bad PDP 11/23 down 3/1-3/11 due to disk failure datalogger provided data
4/83	FE100 bad
5/83	FE100 bad TE103 bad 5/24-5/31
6/83	FE100 bad TE103 bad 6/1-6/16, repaired 6/16/83 PDP 11/23 down 6/3-6/15, datalogger provided data
7/83	FE100 bad Wattmeters bad when power turned off during plant shutdown

8/83	No DAS operation during SwRI site visit 8/15/83-8/19/83
9/83	FE100, FE101 bad
10/83	FE100, FE101 bad
11/83	FE100, FE101 bad
12/83	FE100, FE101 bad
1/84	FE100, FE101 repaired 1/11/84 PE105 replaced 1/11/84
2/84	FE102, FE103 bad SI100 bad
3/84	SI100 transmitter replaced 3/6/84 FE102, FE103 bad
4/84	DAS room transformer failed, 2 days lost
5/84-9/84	FE102, FE103 bad
10/84	FE101 transmitter erratic at "no-flow" conditions FE102, FE103 bad PDP 11/23 down 10/9/84-10/30/84, datalogger provided data
11/84	FE101 transmitter erratic at "no-flow" condition FE102, FE103 bad PDP 11/23 down 11/1-11/30, datalogger provided data

It can be seen in the above list that the DAS was down at certain times during the monitoring period. Most of the downtime is attributed to disk and/or disk drive problems and line power problems. Some of the downtime is attributed to software maintenance during SwRI site visits and DEC preventative maintenance. Other times the system simply did not record data during certain times for unexplained reasons. Some of these spurious occurrences are probably attributable to on-site operator error which were not recorded.

A summary of DAS downtime is provided in Table VI, which shows that 49 days of data are missing for a downtime ratio of 6.4%. The PDP 11/23 has an overall downtime ratio of approximately 15% which is quite good considering that the computer equipment is in an isolated location and was usually checked only once a day under normal circumstances and sometimes not for several days at a time.

TABLE VI. DAS DOWNTIME SUMMARY

Month	No of Days (749 total)		
	11/23 Data	Datalogger Data	Lost Data
11/82	18	0	0
12/82	22	0	9
1/83	18	0	13
2/83	28	0	0
3/83	31	0	0
4/83	27	0	3
5/83	26	0	5
6/83	17	13	0
7/83	31	0	0
8/83	29	0	2
9/83	30	0	0
10/83	31	0	0
11/83	30	0	0
12/83	31	0	0
1/84	29	0	2
2/84	29	0	0
3/84	28	0	3
4/84	28	0	2
5/84	27	0	4
6/84	26	0	4
7/84	31	0	0
8/84	31	0	0
8/84	29	0	1
10/84	9	22	0
11/84	0	29	1
TOTAL	636	64	49

V. SYSTEM PERFORMANCE

A. Overview

One of the major objectives of this research program was to collect solar system thermal performance measurements over the monitoring period. These actual operating results are used to obtain a measure of equipment performance as a "real-world" application as opposed to idealized test-stand performance.

In this section, the actual system performance results for the 25 month period November 1982 - November 1984 are presented and discussed. The effects of the operational history on system performance are obvious in the data presented below.

A quasi-steady numerical analysis method is used to estimate system performance. The model predictions are compared to the actual hourly performance for a single day and is then used to predict system performance for a period of one year. Again, a comparison with the observed energy output is presented and discussed.

B. Actual System Performance

The CTCo solar system performance was monitored from 13 November 1982 to 30 November 1984. Each of the Monthly Performance Reports which was prepared during this period, located in Appendix C, describe the operational experience of the system during a particular month and discusses the system performance for the month. The monthly system performance will be summarized here.

It must be noted that near the end of the monitoring period the software used to compute the energy transfers in various parts of the collector system was found to contain a slightly erroneous algorithm. This algorithm resulted from linearizing the saturation enthalpy of water over the range of expected temperatures. As shown in the uncertainty analysis in Appendix B this algorithm leads to uncertainties in the computed results which are comparable to the uncertainties due only to instrument accuracy.

The results presented in this section have been obtained by reprocessing the raw data for the entire performance monitoring period. The enthalpy of saturated liquid water over the expected range of temperatures was taken directly from the ASME Steam Tables in the form of tables placed in the corrective software. The objective was to obtain a corrected set of performance results which does not have the computational errors described above.

Also, it was pointed out in the Monthly Performance Report, CTCo-10 (August 1983), that the radiation measurements prior to that time were slightly in error. This problem arose from a faulty calibration correlation placed in the on-site software. All radiation data presented here have been corrected.

These two corrective efforts lead to slight discrepancies between the performance results presented below and those found in the Monthly Performance Reports in Appendix C. The results presented below are the more accurate of the two sets.

First, the monthly totals for radiation and energy transfer are listed in Table VII. When reviewing these data, one should be aware of the operational history of the solar system and the DAS which is discussed in the previous section. It is seen in Table VII that the net efficiency of the solar system ranges from 0% in December 1983 to a maximum of 39% in June of 1983, with an overall efficiency of 25% for the entire monitoring period. The system performance may be more easily observed in the graph of Figure 11. It is easy to see the seasonal variation in system energy output in this graph.

TABLE VII. MONTHLY PERFORMANCE SUMMARY

Month	Solar Radiation Horizontal Plane KBTU	Solar Radiation Collector Plane KBTU	Energy Collected KBTU	Parasitic Energy KBTU	Net Efficiency %
11/82	391810	133711	47608	1585	34
12/82	474678	96163	13484	2014	12
1/83	445067	63158	8789	1617	11
2/83	981288	250873	43543	4930	15
3/83	1694035	363807	82186	5532	21
4/83	1744847	464757	150137	6608	31
5/83	1066238	573525	209656	3367	36
6/83	1178477	932791	359520	3431	38
7/83	1098119	136919	46287	1388	33
8/83	1238806	495661	145575	6761	28
9/83	938506	447359	110716	5374	24
10/83	1144003	567150	81471	6543	13
11/83	664724	114799	20025	2350	15
12/83	644666	139596	3656	3486	0
1/84	712419	589426	51123	10216	7
2/84	289733	469018	115919	8574	23
3/84	1571822	807705	137363	11086	16
4/84	3123990	684755	204418	11295	28
5/84	3020591	1492683	490200	17861	32
6/84	2226525	1224822	396602	13778	31
7/84	2977251	1395342	413970	18097	28
8/84	2420360	1072352	221542	11899	20
9/84	1601544	1060248	222613	12534	20
10/84	1159435	756672	168410	10757	21
11/84	566664	251630	12938	4896	3
TOTAL	33375688	14053922	3757761	185979	25

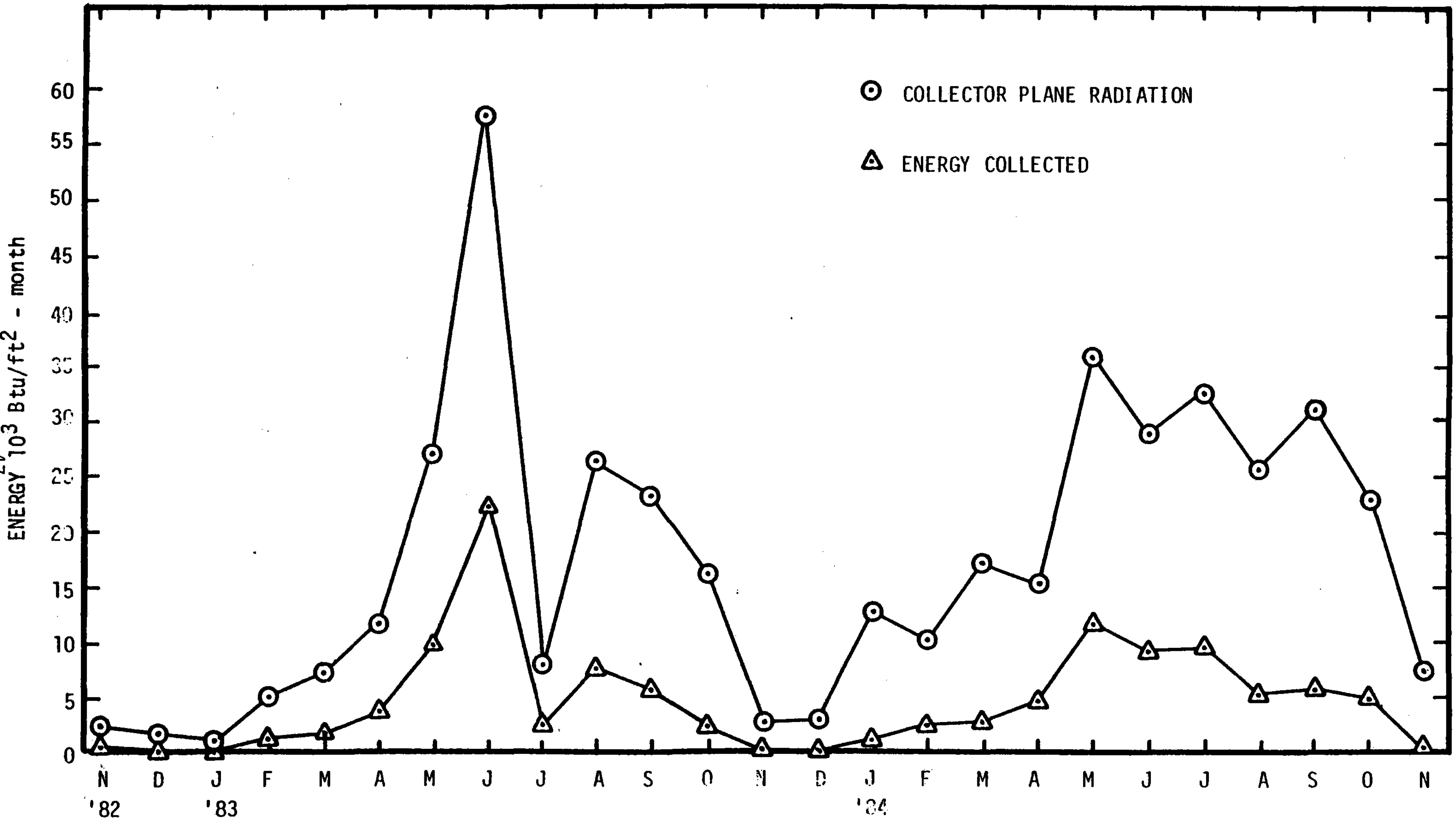

FIGURE 11. THERMAL PERFORMANCE SUMMARY

It can be seen in Table VII that the different operating philosophies for the summers of 1983 and 1984 have a marked effect on the parasitic energy consumption of the solar system. In 1983, portions of the system were deactivated to match the energy output of the solar system to the plant thermal load. Fewer drives were used; hence, less electrical power was consumed to rotate the collectors. In 1984, the energy output of the solar system was maintained as high as possible by activating all drive rows which forced the solar system to operate in a highly transient manner. The drive rows oscillated between a focused and unfocused state which required more total electrical energy to accommodate this movement.

The effects of dust build-up on the mirror surfaces were discussed at length in several monthly reports. Specifically Monthly Report No. 16, February, 1984, shows the effects of manually washing a portion of the field and the effects of a rain rinse. Before washing the North and South field thermal efficiencies were reported as 17% and 19%, respectively. After washing the North field only the efficiencies were 28% (North) and 10% (South). After the rain rinse one month later these values were 35% (North) and 34% (South). Of course, different operating conditions account for a portion of this difference, but the dramatic difference between the performance of dirty collectors and relatively clean collectors makes a strong case for a regular washing cycle.

C. Performance Predictions

The objective of most solar system design efforts is to predict system performance so that the benefits of solar energy can be compared to the costs of system construction and operation. Of course, these analyses must provide results which the designer trusts to be accurate. Actual performance results such as those obtained during this project are, therefore, used to verify the predictive models. The verified performance model can then be used to predict system performance for various operating conditions, climates, and locations.

One such analytical method developed by Treat, et.al. [5] is used by SwRI to model the performance of solar systems. Because solar radiation varies during the day, this model, like many others currently in use, can provide the user with performance computations on an hourly basis as well as a daily and monthly basis. For the purposes of long term predictions, designers are not usually concerned with details of transient temperature profiles throughout the collector array; so, this type of bulk quasi-steady analysis is well suited to systems such as the one described here. While details of the model are described by Treat [5] a brief discussion of this technique will be presented before the results are reviewed.

SIPH Computer Code

As stated above the solar industrial process heat system (SIPH) computer code is a quasi-steady hour-by-hour numerical model. It is quasi-steady because it simulates changes in system operating conditions on an hourly basis; however, operation is steady state during the hour. So, the simulated system moves from one steady state to another throughout the course of its operation. It cannot simulate the transient behavior of very short duration phenomena such as cold startup because thermal capacitance of the fluids and mechanical equipment have not been considered, but correction factors are placed in the model to approximate these transient effects. This is not a serious constraint on the model, however, since process heat systems are typically designed to operate as near steady state as possible. While the model may be exercised over the full 24 hours in a day, only the daylight hours of operation are normally simulated since the solar collectors will only operate if there is sufficient sunlight.

The SIPH model is modular in nature and can be easily adapted to a wide range of applications without modifying the code itself. Basically the code is divided into three sections,

- Simulation control
- Plant equipment simulation
- Collector equipment simulation

The simulation control section contains all of the input/output instructions and routes information between the desired components of the plant and collector equipment sections. The plant equipment section contains code sequences for simulating the operation and performance of pumps, heat exchangers, boilers, and simple piping networks. The model can simulate the operation of flat plate collectors and line-focus parabolic troughs, the two most widely used collector types for process heat ing.

The block diagram in Figure 12 shows the modules used for simulating the performance of the Caterpillar solar system. It is seen that in the model, the solar system pump moves fluid to the inlet of the collectors through a section of insulated pipe. The collectors are used to heat the fluid before passing through another insulated pipe section to the solar system outlet.

The SKI T-700A collector described above has been the subject of several theoretical and experimental investigations of its performance. Dudley and Workhoven [3] have empirically determined a simple relation characterizing the performance of this collector. Deffenbaugh [6] modified this expression to include the effects of dust buildup on the mirror surfaces. The resulting collector efficiency relation is

$$\eta = A_1 F_d^a K + A_2 \Delta T + A_3 \frac{\Delta T}{I} + A_4 \frac{(\Delta T)^2}{I}$$

where

η = collector efficiency

$$\Delta T = \frac{T_i + T_o}{2} - T_\infty$$

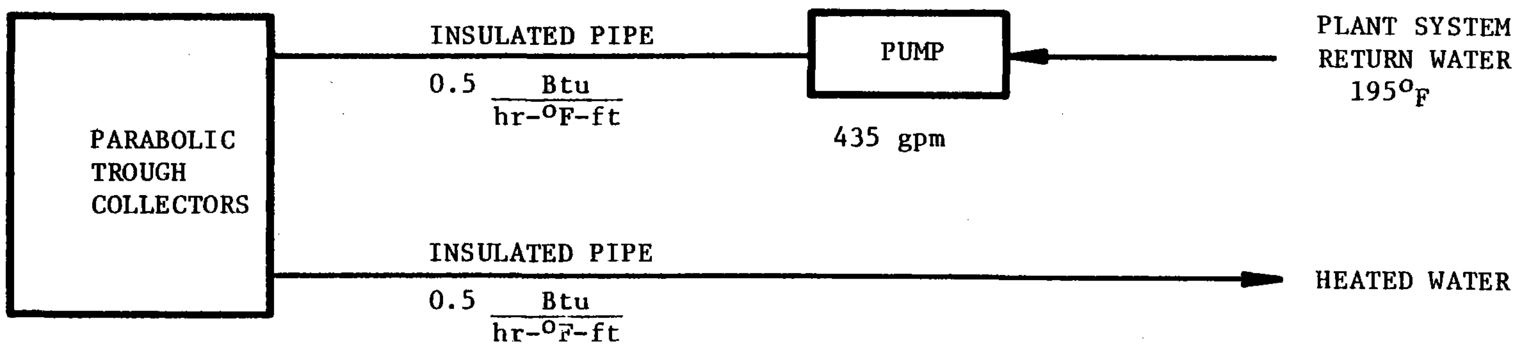

FIGURE 12. SIPH COMPUTER MODEL

T_i = collector inlet temperature, °F

T_o = collector outlet temperature, °F

T_∞ = ambient temperature, °F

I = collector plane radiation, Btu/hr-ft^2

A_1 = 0.7368

A_2 = 1.328 *10^{-4} 1/°F

A_3 = 3.187 *10^{-2} Btu/hr-ft^2-°F

A_4 = 1.283 *10^{-4} Btu/hr-ft^2-°F^2

F_D = dust buildup factor = 0.95 for newly washed surface

a = dust buildup factor exponent = 1.72

K = optical loss coefficient = K_s K_e $K\theta$

K_s = fraction of collector not shaded by adjacent row

K_e = end loss coefficient

$K\theta$ = incidence angle modifier

As indicated, the temperature difference used in this relation is the difference between ambient and the average fluid temperature in the receiver tube. The coefficients, A_1 - A_4, are determined by multiple regression analysis of experimental data for a clean collector operating for short periods at steady conditions. The terms, F_D and a, are determined from long term performance data and historical mirror reflectance degradation measurements. The factor, K_s, involves some rather complicated geometric considerations which will not be discussed here.

In the computer model the dust factor, F_D is chosen by the user to meet his particular needs. A wash cycle can also be specified so that daily variations of F_D may be simulated. The values used below are based on measurements performed by SwRI personnel at the CTCo plant site.

The collector efficiency is determined for each hour of operation and is used to determine the energy output of the collector array and the outlet temperature from the following equations.

$$Q = \eta I$$

$$Q = mc_p (T_o - T_i)$$

where

Q = energy collected, Btu/hr

m = mass flow of collector fluid, lbm/hr

c_p = specific heat, Btu/lbm-°F

It is seen that this process is an iterative one since T_o is not known before η is computed.

The piping runs have been included to account for thermal losses from the fluid between the process water return line and the collector array. The heat loss may be determined from the following

$$Q_L = UL\Delta T$$

where

Q_L = heat loss from pipe, Btu/hr

U = linear heat loss coefficient, Btu/hr-°F-ft of pipe

L = length of pipe run, ft

ΔT = difference between average temperature of fluid in pipe and ambient

This computation is also an iterative one.

Hourly Performance Results

The computer model was used with observed weather data to predict the system performance for August 11, 1983 for comparison to actual system performance. The observed collector field inlet temperature and flow were used as inputs to the model to closely simulate the system operating conditions. The results of this analysis are shown in Figure 13.

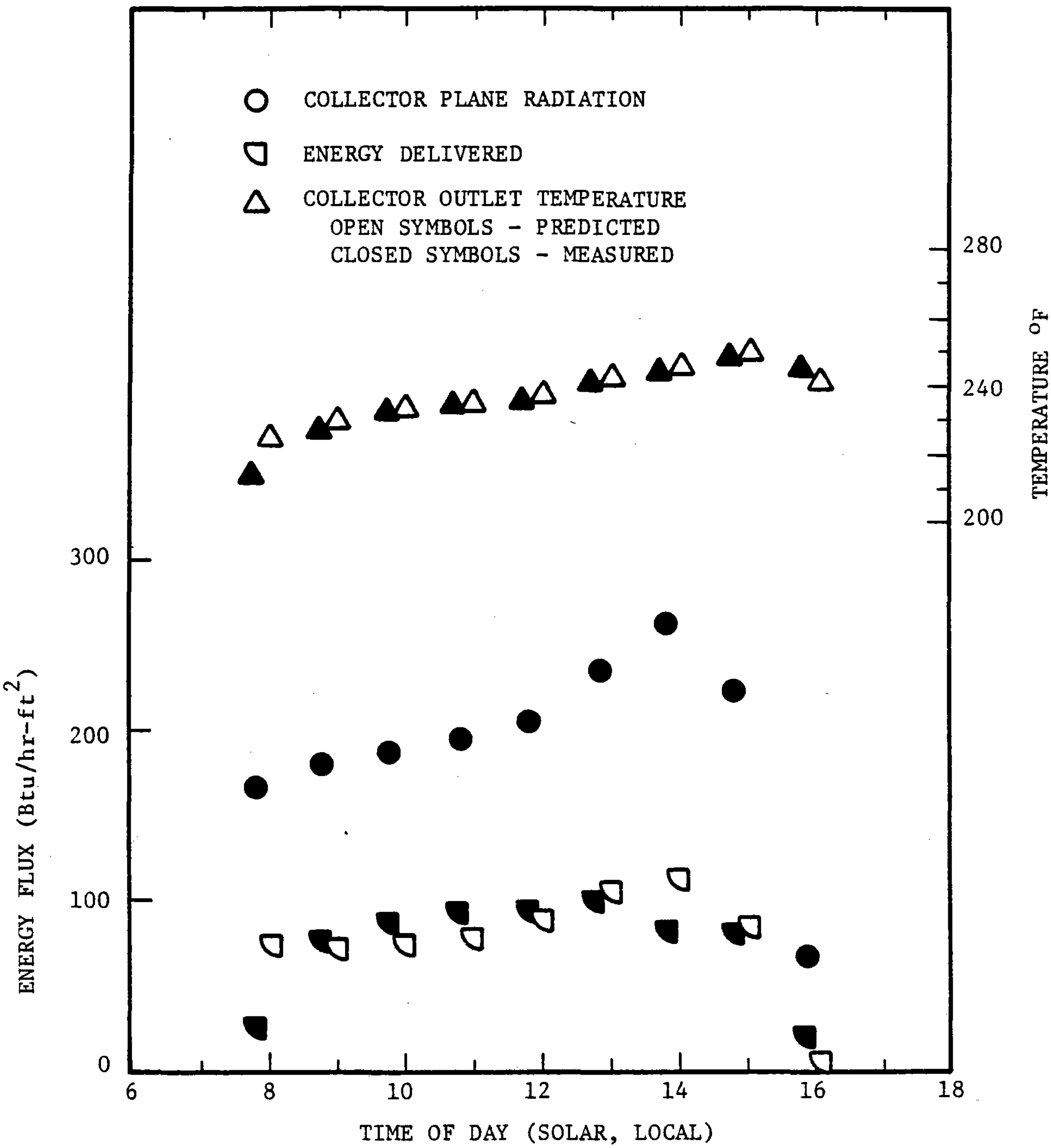

FIGURE 13. ACTUAL AND PREDICTED HOURLY PERFORMANCE FOR AUGUST 11, 1983

It is first seen that the collector plane radiation increases slowly to a maximum at 14:00 (2:00 P.M. PST). The reason the radiation does not peak closer to noon is that the array is oriented 22° from a north-south axis. This slight shift is enough to skew the time distribution of focused collector plane radiation. The collector plane radiation sharply declines in the afternoon because the row tracking sensors are located on the leading edge of the mirror module. This edge is shaded first in the afternoon which causes the rows to unfocus at approximately 1530 in the summer.

The energy output of the collector field follows the radiation curve and shows that the system operates at an efficiency of between 40% and 45% during most of the day. The difference between the predicted and actual values for energy output is between -8.2% and 36% for hourly values during steady operating hours (0900 to 1500). The error in the prediction for total daily energy output is 3.4%. The slight time shift between the actual and predicted curves is due to the difference between local solar time used in the computer model and local standard time which is used by the on-site data acquisition system.

Since the collector mirror modules were not clean at all times during the month, the optical efficiency term, $A_1F_d^a$, was adjusted from the test stand value. The value of $A_1F_d^a$ used in the above comparison was 0.543. This represents a nominal value for the entire collector array computed from mirror reflectance measurements during a site visit by SwRI personnel at that time.

From this comparison, it may be concluded that for steady or, at most, slowly changing operation the predictions of the SIPH model agree with actual performance.

The computer model may now be used to compute system performance for a period of one year. The same collector mathematical model used in the hourly comparison is used here; however, NOAA [7] Typical Meteorological Year (TMY) weather data are used instead of the actual weather data. The results of this analysis are shown in Table VIII and Figure 14.

In Table VIII the actual collector plane radiation measurements are shown along with the collector plane radiation estimates computed from the TMY data. It should be noted that the actual monthly performance data are all taken from 1983 with the exception of July. The entries for July are taken from July 1984 because the plant was shut down in July of 1983. It is seen that the actual and predicted radiation values vary a great deal in the winter months. This is because the model computes the maximum possible radiation available in the collector plane. Actually, the low solar altitudes and radiation intensities in the winter cause control problems during the winter months. Since collector plane radiation is measured only when the collectors operate, this leads to the variations in the tabulated values.

The actual and predicted system performance are also compared in Table VIII where the predicted performance has been adjusted to account for the variation in collector plane radiation. This was done by multiplying the computer program output by the ratio of the actual and predicted collector plane radiation. It is seen that even when this difference is accounted for, there are some operational losses which are not modeled by the SIPH code. The total energy delivery for the months listed show a 20% difference between the actual and predicted values. Most of this disagreement is contained in the latter half of the year.

It is not within the scope of this study to compare other predictive methods to these data and the analysis presented here. It is well worth mentioning, however, that any solar system analytical package such as TRNSYS [8], SOLIPH [9], and others must be used with the correct collector performance model. It was seen here that the test stand value for optical

TABLE VIII. Actual and Predicted Performance for One Year of Operation

Month	Radiation Collector-plane 1983 Actual Btu/ft^2	TMY Btu/ft^2	Ratio	Energy Output 1983 Actual Btu/ft^2	Predicted With Full TMY Radiation Btu/ft^2	Predicted With Scaled TMY Radiation Btu/ft^2
Jan	1256	17800	0.070	175	3510	246
Feb	5064	23500	0.215	879	6040	1299
Mar	7241	33500	0.216	1636	10200	2203
Apr	11864	52600	0.226	3833	18900	4271
May	27121	59400	0.456	9914	22700	10351
Jun	57883	61700	0.938	22310	24100	22606
Jul*	32586	63300	0.515	9668	24700	12721
Aug	26352	60799	0.433	7740	23100	10002
Sep	23335	46500	0.502	5775	16300	8183
Oct	16217	34800	0.466	2330	10100	4707
Nov	2971	22300	0.133	518	4790	637
Dec	3137	19200	0.163	82	3240	528
Total	215027	495399	0.434	64860	167680	77754

* July 1984

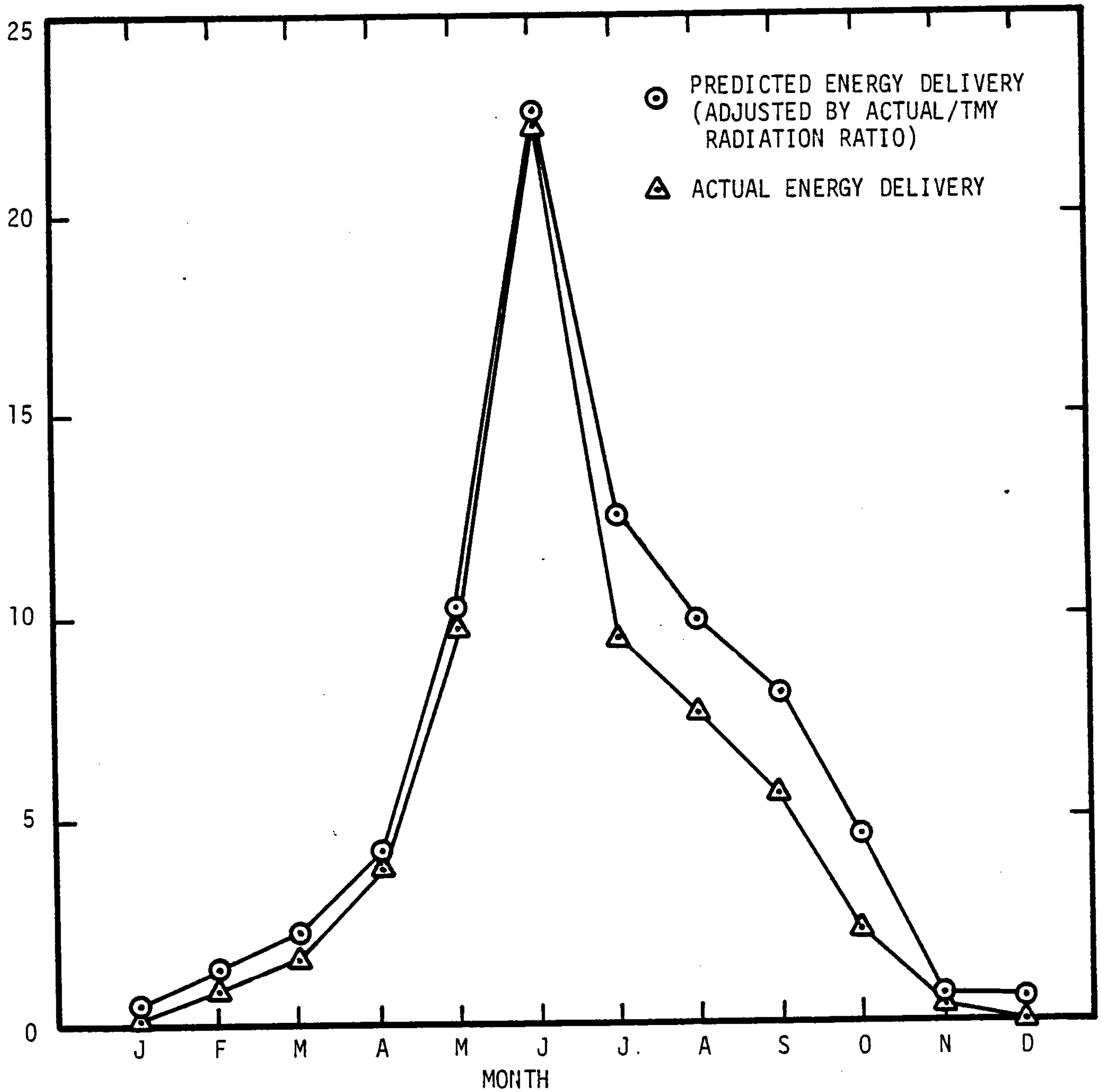

FIGURE 14. ACTUAL AND PREDICTED PERFORMANCE FOR ONE YEAR OF OPERATION

efficiency, $A_1F_d^a$, was substantially different than that computed during a site visit during the time in which the model was verified (8/11/84). This modification to the published empirical correlation was necessary because of the effects of mirror degradation and dust buildup between washings, which are not included in test stand performance correlations.

VI. ECONOMIC ANALYSIS

A. Overview

As in the case of any investment made by industry, the potential benefits of a solar system must be weighed against the costs of the solar system. An economic or investment analysis is performed to provide a basis for the decision of whether to purchase any equipment for the plant. An economic analysis which is well suited for solar systems is presented here to study the cost/benefit situation of the CTCo solar system.

B. System Cost

As pointed out in the Construction Report (Deffenbaugh [2]) the CTCo solar system was constructed at a cost of approximately $2.5 million. Caterpillar Tractor Company was responsible for 25% of this construction cost so that the area specific cost to CTCo was 12.40 $\$/ft^2$ of collector area while the total cost was $\$50/ft^2$ of collector area. The collector array equipment cost was approximately $\$25/ft^2$ while the balance of cost was the remaining materials and the construction labor. These costs will be used in the analysis below to reveal the annual rate of return for the CTCo solar system.

C. Analytical Method

An economic analysis of an investment scenario is usually complex if it is to include most of the important issues. Typically, different methods are applied to different types of problems and Dickinson and Brown [10] have devised a procedure which is well suited to solar systems considered by industry.

In this method, the annual levelized cost of the system is determined using the following equation,

$$C_S = C_O + C_L + C_T + C_E + C_R - C_C - C_S$$

where

C_S = annual levelized cost of the solar energy

C_O = annual operating expenses

C_L = cost of retiring a loan used to purchase the system

C_T = tax on the revenue due to fuel savings

C_E = equity repayment

C_R = cost of major component replacements

C_S = net salvage value

Dickinson and Brown [10] fully define and discuss each of the terms above and this treatment will not be repeated here. Another way of defining C_S is that it is the annual required revenue from fuel savings to meet the rate of return which was assumed to compute the various terms above.

The rate of return on the solar investment is varied in the above computations until the annual levelized cost of the solar system matches the annual levelized cost of the fossil fuel which is saved by using the solar system. This value for the rate of return is termed the internal rate of return. One can see that if the internal rate of return for the solar investment compares favorably with the minimum or hurdle rate set by the investor, then the purchase of the solar system is warranted.

D. Results

The results of the application of the method above will be presented here. Assumptions were made for several financial parameters as follows

corporate tax rate = 50%
solar investment tax credit = 20%
general inflation = 5%
fuel escalation = 5%
system life = 20 yr
depreciation period = 7 yr

loan amount = 0

salvage value = 0

major component replacement = 0

The annual operating costs were held constant at 0.23 $\$/ft^2$-yr. These were actual maintenance costs reported by Caterpillar and are recorded in the Monthly Performance Reports in Appendix C. This value is the average annual maintenance cost over the monitoring period.

The results of the economic analysis are shown in the graph of Figure 15. It can be seen that the rate of return decreases rapidly with an increase in system cost. The graph shows that for the CTCo system, approximately a 2.5% rate of return has been demonstrated based on only CTCo's portion of the system cost and the actual annual energy delivery. This value increases to approximately 10% if the system were to provide the maximum energy that could be realistically expected.

Unfortunately, the rate of return based on the total system cost is negligible, even for the case of maximum realistic performance. It should be noted that the maximum realistic performance, as discussed in Section V is based on nominal, observed values for the performance of the solar collectors. If test stand performance values are used, the energy delivery will increase; however, the cost of maintaining the array at this peak performance would offset the increase in fuel savings. While it is possible to estimate these performance levels, the associated costs are highly speculative and will not be discussed here.

Of course, the objective of this project was not to construct a solar system which would be economically attractive. Instead, the primary objective was to provide a system which could be used to obtain realistic performance measurements from a large solar system and to provide historical data on the maintenance and operating requirements of such a system. In this way, designs and operating procedures will hopefully improve so that economically viable systems may be developed.

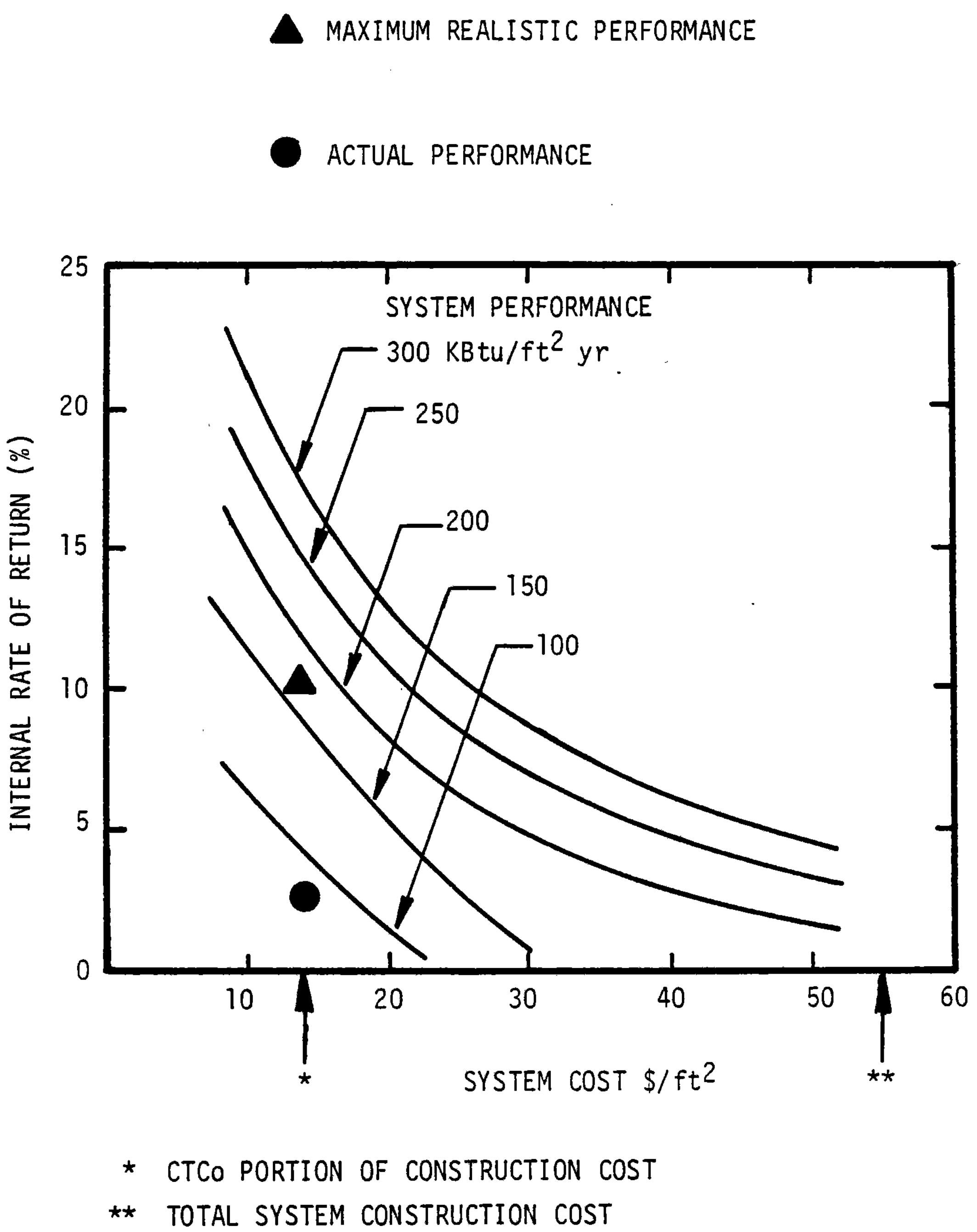

FIGURE 15. INTERNAL RATE-OF-RETURN

VII. ENVIRONMENTAL IMPACT AND SAFETY ANALYSIS

A. Overview

The CTCo solar system was designed to be as unobtrusive as possible in all aspects except from an energy standpoint. Each of the pertinent issues in the assessment of the environmental impact are discussed below which show the system has no unfavorable impact on the surrounding environment. This discussion is concluded by a statement on the safety of the solar system.

B. Environmental Impact

Impact due to System Failures: The heat transfer fluid used in the solar system is the treated water which the plant uses in the rest of the process heating system and is covered by the plant's NPDES license; so, there can be no hazard from the solar system with regards to water leaks which are not already safely allowed. At times there were hydraulic oil leaks from the collector drive mechanism which may have been washed by rain into the local drainage system. The concentration of any such material would have been quite negligible when compared to the amount of hydrocarbon products deposited on streets and parking lots by vehicles and from neighboring industries.

Air Quality: The only impact on the air quality by the solar system would be positive. This occurs because the solar system displaces a portion of the fossil fuel demanded by the process heating system. In doing so, the amount of burner exhaust is actually decreased by the solar system.

Water Usage: The only water used and discarded by the system is that used while washing the mirror modules. During the course of the project the collectors were washed with water only five times in which an estimated 1000 gallons were disposed of each time. No detergents were used during this wash process since it was adequate to only rinse the mirrors followed by air drying and mechanically drying the receiver tubes. The remainder of any washing activities was accomplished with a rain rinse.

Noise Impact: The only noise sources in the solar system are the system fluid pump motors and the hydraulic drive motors in each drive row. These pump motor noise sources are negligible when compared to the heavy machinery in the plant.

Energy Impact: The solar system has a definite impact on the energy usage at the plant. Indeed, it is for this reason that the project was initiated. The energy delivered by the system was approximately $3.8 * 10^9$ Btu during the monitoring period which was used to displace the fossil fuel required by the process heat system.

Geological Impact: The solar system has no impact on the geology of the surrounding area, especially since it is a roof mounted system. Since the solar system is installed in a highly active fault zone (San Andreas system) it is more likely that the geology will have an affect on the solar system. This potential affect was considered in the structural design and meets or exceeds all local seismic codes.

Land-Usage Impact: The solar system is mounted on the roof of the CTCo manufacturing plant so there is no impact on the land usage of the surrounding area. This is an important consideration for industrial interests because land is at a premium in the San Francisco Bay Area.

C. Safety Analysis

Operational Hazards: There are certain hazards which could lead to equipment damage unless properly accounted for. These hazards are:

- Loss of flow in collector system
- Adverse weather conditions
- Severe piping break
- Thermal shock
- Loss of control power

If the collector system suddenly loses adequate flow to either of the two fields because of a pump failure, flow blockage, etc., this could lead to a situation in which sunlight is focused on the receiver tubes with no means of removing this energy input. This is similar to a case in which a boiler tube suddenly loses flow. Temperatures and pressures would rapidly increase causing serious damage to the receiver tubes by warping or breaking them. If there is no flow to either of the two fields, flow switches signal the central controller to immediately "stow" the collectors and turn off the circulation pumps, thereby preventing thermal damage to the collectors and piping. If a single row experiences a flow loss, a temperature and/or pressure switch will cause that particular drive row to move to the "stow" position until the temperature and/or pressure of that receiver tube returns to a safe level.

The only weather condition which might cause damage to the solar system is excessively high winds. The central controller is equipped with an anemometer which signals the controller to "stow" the collectors if winds are above 35 mph for longer than one minute. Other conditions which prevent operation are low direct radiation levels and rainfall; however, these conditions are not hazardous to system operation. They merely prevent the system from delivering energy to the plant.

A severe piping break on the roof would cause a loss of process heating system fluid. This condition is continually monitored by level and pressure sensors placed in the plant's boiler house. Should this condition arise, plant maintenance personnel are dispatched to locate the source of the leak. As with the rest of the process heating system the solar system piping is designed to quickly isolate individual pieces of equipment from the rest of the system in the event of such a failure.

The plant process heating system normally operates 24 hours a day, but the solar system only operates during the daylight hours. Because of this, a substantial amount of cold fluid could be injected to the process heat system piping if full flow was allowed immediately upon solar system startup. To prevent this shock to the system, regulating valves are placed at the outlet of each of the two fields of the collector array. These valves limit the flow through the collector array to 10% of the design condition until the array outlet temperature reaches the design conditions. This allows any cold fluid present in the collectors to be slowly injected into the return line. When heated fluid reaches these valves, they open and allow the full design flow to be established throughout the collector array. This startup period is usually only five minutes in duration, but is important in allowing the solar system and the rest of the process heat system to achieve steady operation in a safe, controlled manner.

The collector drive rows are designed so that in the event of a loss of the control signal from the central controller, the collectors will unfocus. An accumulator is installed in the hydraulic drive circuit to provide hydraulic pressure to the drive piston if the hydraulic fluid pump is not operating. Relays that control the hydraulic circuit valves switch to positions which allow the accumulator to drive the piston causing the row to unfocuses if the control signal is lost to these relays. This prevents the collectors from remaining focused during a time when it is likely that the system pumps will not operate and there will be no water flow through the receiver tubes.

Worker and Visitor Safety: Various precautions have been taken to prevent hazardous conditions for maintenance personnel and visitors. A 20 foot clear area between the collectors and the edge of the roof is provided to allow adequate work area around the array. Virtually all piping is below the roof with penetrations through the roof immediately adjacent to the connections at the collector ends. This minimizes a tripping hazard on the roof. A controlled access walkway is provided to keep visitors from coming into any physical contact with the collectors and safely away from the focal line of the mirrors.

Finally, all pertinent codes and regulations were strictly followed during the design and construction of the solar system. In addition, Caterpillar Tractor Company maintains some of the highest standards in industry with respect to personnel and equipment safety. This solar system is, therefore, considered to be as intrinsically safe as possible.

VIII. CONCLUSIONS AND RECOMMENDATIONS

It was stated in the Introduction that industry requires information in four areas before an investment in solar energy equipment can be made. These four factors are (1) system performance, (2) initial cost, (3) operating costs, and (4) reliability. The project summarized here is one of several projects in the DOE SIPH Demonstration Program which provides industry with a chance to review the benefits of solar energy in actual applications. The Caterpillar Tractor Company solar system performance, operating costs, and reliability have been presented above, while the initial cost is discussed in a previous project report (see Deffenbaugh [2]). Several conclusions can now be drawn regarding the success of this project in each of the four areas listed above as well as meeting the objectives of the overall DOE program.

The observed performance of the CTCo solar system was approximately $65 * 10^3$ Btu/yr-ft^2 of collector area; so, assuming a fuel cost of \$5/10^6 Btu, the fuel savings produced by the solar system were approximately \$0.33/ft^2-yr. It was, seen, however, that the maximum realistic performance of the system could be as high as $168 * 10^3$ Btu/yr-ft^2 of collector area. The difference between these two values is attributed mainly to operational losses due to control system problems. Solar altitude and intensity during the winter months in the San Francisco Bay Area presented unique problems in operating the solar system which could possibly be resolved with a more appropriate control system. Unfortunately, this would likely be a specially designed unit and would carry high cost implications.

At the time of the system design, the best estimates of system performance showed that the plant could receive approximately $317 * 10^3$ Btu/yr-ft^2 from the solar system. Overly optimistic assumptions regarding collector performance and operation were made by many investigators which were usually based on test stand experiments under ideal conditions. It was seen above that the major difference between the actual installation and the test-stand conditions was the condition of the mirror surface. Collector performance models based on test-stand conditions should not be used for predicting solar system performance because industry simply cannot economically maintain collector performance at peak conditions in an industrial environment.

The maintenance costs of the system were shown to be approximately $\$0.23/ft^2$-yr. This figure includes maintenance, labor, and replacement parts costs. The estimated cost of electricity (assuming a rate of 5¢/kwh) for operating the system was $\$0.02/ft^2$-yr; so, the total operating costs were $\$0.25/ft^2$-yr. So, the system was able to save more in fuel costs than the operating expenses which were incurred. It can be shown that if the solar system was to operate at a higher performance level by washing the collectors once a month, the associated maintenance costs would rise to $\$0.63/ft^2$-yr. So, performance and O & M costs are not independent.

It was shown that the CTCo solar system was highly reliable, considering the operating philosophy. A reliability factor of 86.5% was observed and CTCo plant engineering staff estimate that hydro-mechanical equipment such as that in the solar system will exhibit a maximum reliability of 95% with a reasonably rigorous maintenance plan. Since the solar system could usually provide more energy than the plant could use during several months of the year, solar system maintenance was not of high priority to plant personnel. So, the observed reliability factor of 86.5% is considered to be good.

The costs, initial and operating, were combined with the system performance in an investment analysis method typically used for solar systems. It was seen that the Caterpillar Tractor Company could expect a 2.5% rate of return based on actual system performance and their portion of the system construction costs. If the maximum realistic system performance is achieved this rate of return could increase to about 10%. Unfortunately, there can be no rate of return based on total actual system costs and performance. An earlier investigation by Deffenbaugh [1] revealed that a 20% rate of return was possible; however, inflation and fuel cost escalation were assumed to be 15% which were close to the prevailing rates at the time of that analysis. These factors were each estimated to be 5% for the analysis performed here. This leads one to the conclusion that solar systems of this type are feasible only in periods of substantial economic inflation. Of course, there may be other unique situations such as fuel availability, large tax benefits, or innovative financing schemes which would make a solar system cost effective even in relatively stable economic conditions. Also, since the materials used in typical industrial type solar systems (e.g., aluminum, glass, steel, plastics, etc.) rely on relatively energy intensive, high temperature processes, it is not clear what the price of conventional fuels has on the price of solar equipment and whether solar equipment can displace some of the fuel required to make its own components. Treatment of such a complex issue is far beyond the scope of this report.

After operating the system for 25 months several recommendations for improvements can be stated. First, the hydro-mechanical drive mechanisms should be replaced with fully mechanical ones. This suggestion stems from the problems with hydraulic oil leaks onto the roof surface. The oil attacks the roof covering and leads to rapid deterioration of the composition material. Also, the solar collector manufacturer (Solar Kinetics) improved the overall design of the row control system when it offered the mechanical drive option, resulting in a much improved product. Second, the central control system should be improved to account for the weather conditions in the San Francisco Bay area. The low beam component of the solar radiation along with the low solar altitudes presented problems for the current control system. Finally, a thermal storage system would be of benefit to the present system. For much of the time the solar system could provide more energy than the plant needed. A thermal storage system will alleviate the need to unfocus the collectors to match the plant load which will result in increased daily solar energy usage.

While this solar system was only marginally cost effective, it may be said that this project successfully fulfilled its objective as part of the SIPH Demonstration Program. A great deal was learned about the installation of a high quality solar system suitable for an industrial environment. The operation and performance results gathered during the 25-month monitoring period will be of benefit to designers with the aim of improving the economic viability of industrial solar process heat systems.

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APPENDIX A

SOLAR SYSTEM CENTRAL CONTROLLER PROGRAM

The program listed here is for the Minarik Electric Model WP6000 programmable microprocessor controller installed at the Caterpillar Tractor Company's San Leandro plant. This controller operates the roof-mounted solar system. The reader is referred to the project Construction Report and O & M Manual for a complete description of this equipment.

Step	Statement	Output Relay Settings 0 1 2 3	Comment
1	L= 5	- - - -	
2	IF 0 → 6		
3	SS 30.00		
4	IF 0 → 6		
5	GO TO 01		
6	SS 60.00		
7	L → 2		
8	IF 1 → 10		Wind check
9	GO TO 1		
10	SS 01.00	+ + + +	Start all pumps
11	MS 02.00	- - + +	2 min. pump run
12	IF 2 → 14		T & P check
13	GO TO 75		Shutdown
14	IF 3 → 18		Flow check
15	SS 15.00		
16	IF 3 → 18		
17	GO TO 75		Shutdown
18	L = 36	+ + + +	Track from stow (3 minutes)
19	IF 0 → 23		Light check
20	SS 15.00	- + + +	15 sec. light off (dead band)
21	IF 0 → 23	+ + + +	Light check
22	GO TO 49		Shutdown
23	IF 1 → 25		Wind and rain
24	GO TO 75		Shutdown
25	IF 2 → 29		T & P check
26	SS 03.00		
27	IF 2 → 29	+ + + +	Track from stow routine (con't)
28	GO TO 66		
29	IF 3 → 33		
30	SS 03.00		
31	IF 3 → 33		
32	GO TO 75		
33	SS 05.00		
34	L → 19		
35	IF 0 → 39	+ - + +	Auto track
36	SS 15.00	- + + +	
37	IF 0 → 39	+ - + +	
38	GO TO 49		
39	IF 1 → 41		
40	GO TO 75		
41	IF 2 → 45		
42	SS 03.00		
43	IF 2 → 45		
44	GO TO 66		Over temp routine

Step	Statement	Output Relay Settings 0 1 2 3	Comment
45	IF 3 → 35		
46	SS 03.00		
47	IF 3 → 35		
48	GO TO 75		
49	L = 179	- + + +	Dead band
50	IF 0 → 52		
51	GO TO 54		
52	SS 15.00	- + + +	
53	IF 0 → 18		
54	IF 1 → 56		
55	GO TO 75		
56	IF 2 → 60		
57	SS 03.00		
58	IF 2 → 60		
59	GO TO 66		
60	IF 3 → 64		
61	SS 03.00		
62	IF 3 → 64		
63	GO TO 75		
64	GO TO 77		
65	GO TO 75		
66	L = 60	- + + +	Over temp. routine
67	SS 03.00	- - - +	Stow (3 sec.)
68	IF 2 → 18	- + + +	
69	SS 30.00		
70	IF 3 → 74		
71	SS 03.00		
72	IF 3 → 74		
73	GO TO 75		
74	L → 68		
75	MS 10.00	- - - -	Shutdown sequence
76	GO TO 1		
77	SS 05.00		
78	L → 50		

LEGEND:

Function	Output Relay 0	1
Stow	-	-
Deadband	-	+
Auto track	+	-
Track from stow	+	+

Function	Output Relay 2	3
Track ready	+	-
Pump on	-	+

Function	Input Relay
Light	0
Wind/Rain	1
Temp/Press	2
Flow	3

APPENDIX B

DAS UNCERTAINTY ANALYSIS

When reporting the results of an experiment it is usually desirable to report the uncertainty associated with the results. This uncertainty is the result of several factors which are described in detail by Moffat [11] and Abernathy, et.al. [12]. In the case of the measurements made with the CTCo DAS, individual instrument accuracy, calibration errors, and data reduction errors are most important.

The energy delivered by the collector array is determined from

$$Q = \dot{m}\ (h_o - h_i)$$

where

Q = energy delivery

$\dot{m}$ = mass flow of water

h_o = enthalpy of water at outlet

h_i = enthalpy of water at inlet

Since the flow measurement is made in terms of volumetric flow and the enthalpy of water can be expressed as a function temperature the above equation was modified for the CTCo DAS to

$$Q = V\ (\rho C_p)\ (T_o - T_i)$$

where

ρ = density of the fluid

C_p = specific heat of the fluid

Following Moffat [11] and Abernathy [12] the uncertainty, ε_Q, in the computed value of Q is given by

$$\varepsilon_Q = \left\{ \left(\frac{\partial Q}{\partial V} \varepsilon_V \right)^2 + \left(\frac{\partial Q}{\partial (\rho C_p)} \varepsilon_{\rho Cp} \right)^2 + \left(\frac{\partial Q}{\partial T_o} \varepsilon_{T_o} \right)^2 + \left(\frac{\partial Q}{\partial T_i} \varepsilon_{T_i} \right)^2 \right\}^{1/2}$$

where

$$\frac{\partial Q}{\partial V} = (\rho Cp)\ (T_o - T_i)$$

$$\frac{\partial Q}{\partial (\rho C_p)} = V\ (T_o - T_i)$$

$$\frac{\partial Q}{\partial T_o} = V\ (\rho C_p)$$

$$\frac{\partial Q}{\partial T_i} = -V(\rho C_p)$$

ε_V = uncertainty in measurement of fluid flow

$\varepsilon_{\rho Cp}$ = uncertainty in computation of density-specific heat product

ε_T = uncertainty in measuring temperature

The uncertainty in flow measurement, ε_V, and temperature, ε_T, are those values given in Table II for the particular flow meter and temperature sensor in question.

The uncertainty in computing the density-specific heat product, $\varepsilon_{\rho Cp}$, involves not only an instrument accuracy, called precision error, when measuring temperature, but can involve some uncertainty in the method of computation as well. This computational uncertainty can be handled much the same as a bias error.

For example, the PDP 11/23 at CTCo was programmed with the following relation for determining ρC_p

$$\rho C_p = 526.45 - 0.10106\ (T_o + T_i)$$

where temperature is measured in °F and (ρC_p) is given in units of Btu-min/hr-gal for use in the heat transfer equation above.

One can see in the graph of Figure 16, that this relation does a relatively poor job of predicting the value of the (ρC_p) product for water. Even the slope of curve, which is of primary importance here, is not correct. It can be shown that the effect of this large bias error is equal to the effect of all the precision errors on the uncertainty in Q, the energy collected.

It was for this reason that the data collected by the DAS were re-processed for this report using the following relation for energy collected

$$Q = V\left[(\rho h)_o - (\rho h)_i\right]$$

where ρh = volumetric enthalpy

In this case the uncertainty in Q, ε_Q, is given by

$$\varepsilon_Q = \left\{\left(\frac{\partial Q}{\partial V}\varepsilon_V\right)^2 + \left(\frac{\partial Q}{\partial(\rho h)_o}\varepsilon_{\rho h}\right)^2 + \left(\frac{\partial Q}{\partial(\rho h)_i}\varepsilon_{\rho h}\right)^2\right\}^{1/2}$$

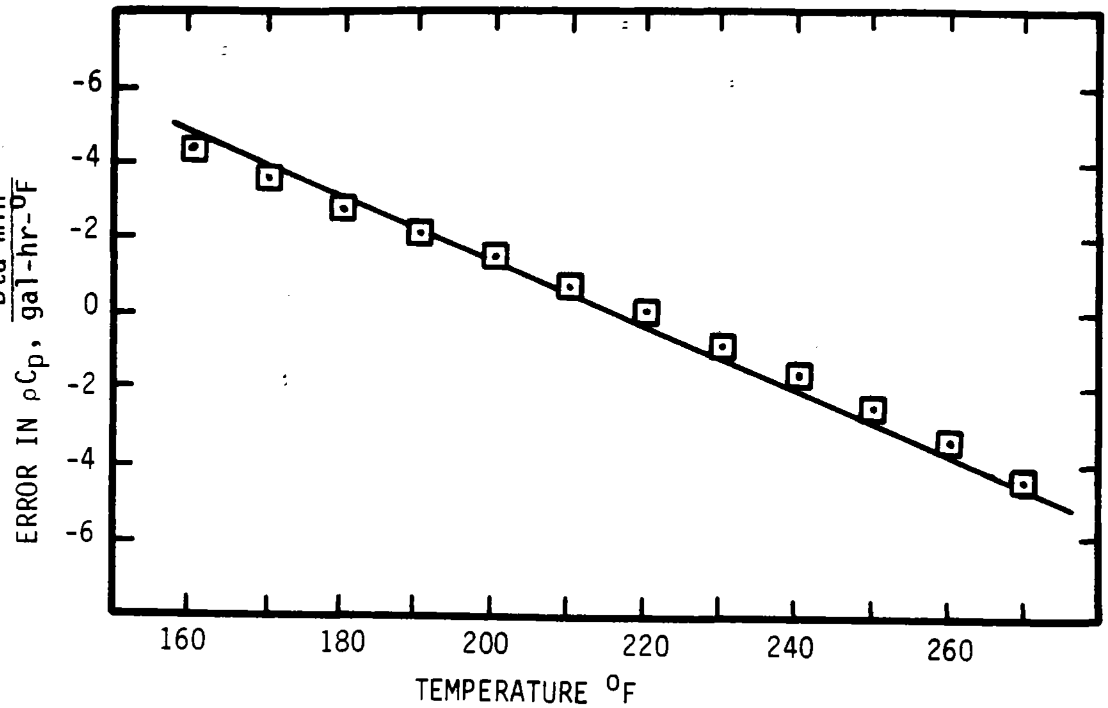
where

$$\frac{\partial Q}{\partial V} = (\rho h)_o - (\rho h)_i$$

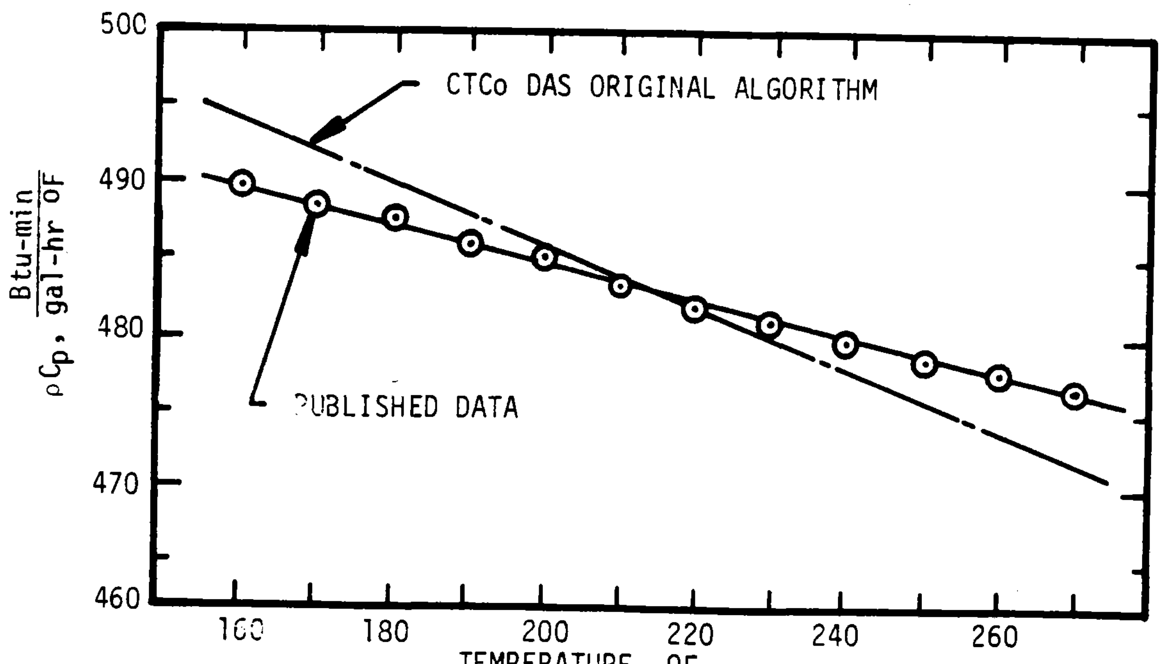
$$\frac{\partial Q}{\partial(\rho h)_o} = V$$

$$\frac{\partial Q}{\partial(\rho h)_i} = -V$$

The currently accepted values for the thermodynamic properties of water are the ASME Steam Tables. These data were used in a computer routine to perform a "table look-up" so that no enthalpy-temperature correlation is required. The uncertainty associated with the tabulated values of enthalpy is less than ±0.05 Btu/lbm, which is negligible when compared to the results given below.



(b)



(a)

FIGURE 16. DENSITY AND SPECIFIC HEAT OF WATER

To estimate the error in choosing a volumetric enthalpy from the tabulated values because of the uncertainty in the temperature measurement the sensitivity, $\frac{\Delta(\rho h)}{\Delta T}$, must be computed. The results of this procedure are shown in Figure 17. These values are based on the saturation properties of water. It is seen that in the expected range of the data, the sensitivity, $\frac{\Delta(\rho h)}{\Delta T}$, of volumetric enthalpy to temperature has a maximum of approximately 460 $\frac{\text{Btu-min}}{\text{gal-hr F}}$. So, if the precision error in temperature is ±0.9°F as listed in Table II the maximum error in volumetric enthalpy $\varepsilon_{\rho h}$ is estimated to be ±414 $\frac{\text{Btu-min}}{\text{gal-hr}}$.

The following conditions represent the design conditions for the solar system:

$$V = 450 \text{ gpm}$$
$$T_i = 195°\text{F}$$
$$T_o = 235°\text{F}$$
$$\varepsilon_{(\rho h)} = \pm 414 \ \frac{\text{Btu-min}}{\text{gal-hr}} \text{ from above}$$
$$\varepsilon_V = \pm 6.28 \text{ gpm from Table II}$$

Substituting these values into the equations above yields

$$Q = 450\ (96601.7-78769.0) = 8024715 \text{ Btu/hr}$$

$$\frac{\partial Q}{\partial V} = 96601.7 - 78769.0 = 17832.7 \ \frac{\text{Btu-min}}{\text{gal-hr}}$$

$$\frac{\partial Q}{\partial(\rho h)_o} = 450 \ \frac{\text{gal}}{\text{min}}$$

$$\frac{\partial Q}{\partial(\rho h)_i} = 450 \ \frac{\text{gal}}{\text{min}}$$

$$\varepsilon_Q = \pm \left\{\left[(17832.7)(6.28)\right]^2 + \left[(450)(424)\right]^2 + \left[(-450)(414)\right]^2\right\}^{1/2}$$

$$\varepsilon_Q = \pm 286281 \text{ Btu/hr } (\pm 3.6\%)$$

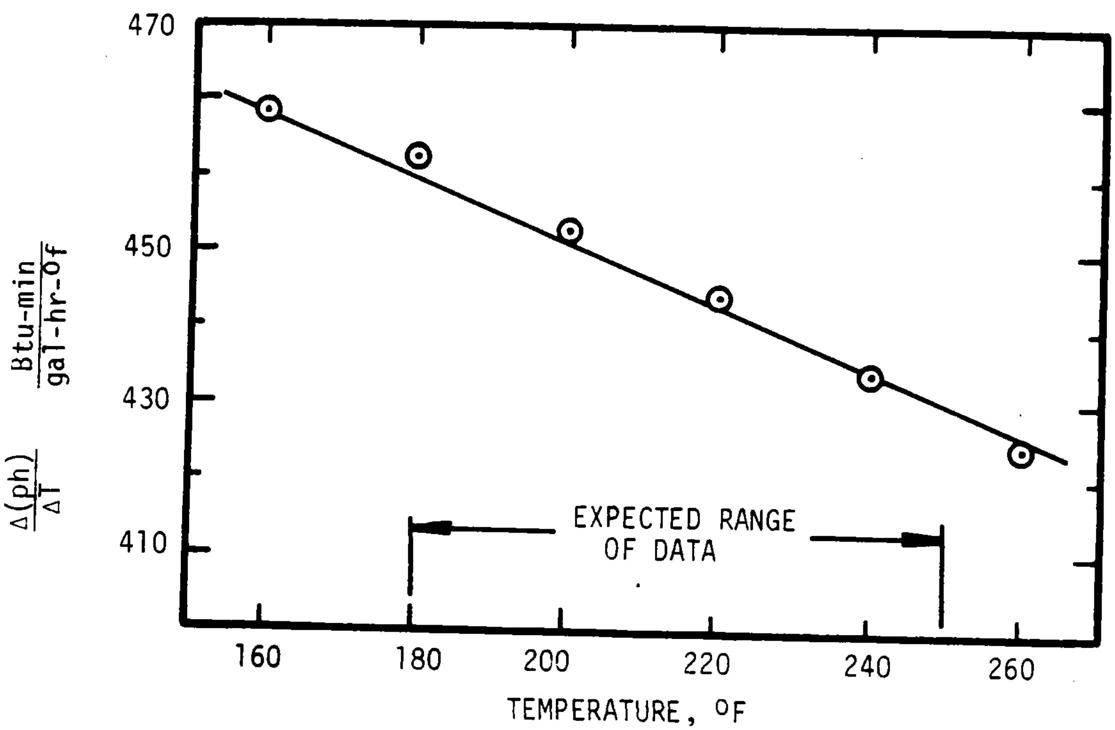


FIGURE 17. SENSITIVITY OF VOLUMETRIC ENTHALPY OF WATER TO TEMPERATURE

APPENDIX C

MONTHLY PERFORMANCE REPORTS

Monthly performance reports were compiled by SwRI to transmit the operational experience and thermal performance of the CTCo solar system. These reports form an important historical record of the activity of the system. As such, they are presented here in full.

It must be noted that the thermal performance results presented in these reports will possibly conflict with those presented in the body of the report. The reason for these discrepancies is that the data were reviewed and reprocessed as discussed in Appendix B, Uncertainty Analysis. The results presented in these reports are slightly in error, but it was not deemed important to change the details of these monthly reports. While they are slightly in error by approximately +6%, the tables and graphs may still be used to show the trends of system performance over the course of the monitoring period.

More importantly, these reports provide discussions of the problems encountered with the system and their probable causes. So, these reports form a record which chronicles in detail the operation and maintenance of a large solar system.

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Department of Mechanical Sciences
January 10, 1983
Monthly Progress Report No. 34
Reporting Period November 20, 1982
through December 17, 1982

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The procedures for processing data gathered at the site have been installed. Monthly performance reports and data analysis can now be performed. Although these performance reports are presently behind schedule, they will be brought up-to-date shortly.

An acceptance test is tentatively scheduled for late January so that Phase III can be officially started.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The central controller light switch problem cited in the previous report has been isolated and resolved by CTCo personnel. The solution involved replacing the 1-turn, 10k light sensitivity trim pot with a 10-turn, 10k trim pot. The result is that the light threshold is now less sensitive to the trim pot setting; thereby allowing better control over the light threshold.

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A problem of gas entrainment in the collector loop piping has been identified. This problem manifests itself in decreased collector loop flow rates until all the gas is purged. No equipment damage is expected; however, CTCo personnel are attempting to resolve the problem since it appears that system efficiency suffers with these mixed flow conditions.

No other mechanical problems have been reported by CTCo.

Very truly yours,

Steven T. Green
Research Engineer

APPROVED:

Danny M. Deffenbaugh
Project Manager

SF/pn

Enclosures

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

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Department of Mechanical Sciences
February 18, 1983
Monthly Progress Report No. 35
Reporting Period December 18, 1982
through January 21, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The acceptance test was rescheduled to the week of February 1, 1983 because of bad weather.

A visit to the site was made by SwRI personnel between January 12 and January 18, 1983 to prepare for the acceptance test. The CTCo plant engineers expressed concern over the operation and documentation of the DAS hardware and software during this visit. These changes will be implemented as soon as possible.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The DAS failed on December 22, 1982 due to disk problems. The problem was not repaired until January 12, 1983. At this time the DAS was brought in line and normal operation was resumed.

During the site visit mentioned above a flow meter transmitter problem was identified. The proper replacement parts were not in hand, so that repairs were delayed until SwRI returned for the acceptance test on February 1, 1983. This flow meter is redundant so no data were lost

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during the interim. Also, a potential temperature transmitter problem was identified. As in the case of the flow transmitter, proper repairs were delayed until the acceptance test trip by SwRI.

Due to CTCo's concern for the DAS, changes will be made in the software to make the on-site data processing procedures more useful. Due to changes in the DAS software over the course of the past several months, the operator's manual is no longer adequate for any new user. The DAS operator's manual will be extensively revised to remedy this situation.

Very truly yours,

Steven T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

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Department of Mechanical Sciences
March 16, 1983
Monthly Progress Report No. 36
Reporting Period January 22, 1983
through February 18, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The solar system passed its acceptance test during the week of February 1, 1983. No major problems were observed during this test.

Work is progressing on the changes to the DAS software which were requested by CTCo personnel during the last site visit. These should be in place by the end of March.

SUMMARY STATUS ASSESSMENT AND FORECAST:

A row control board failure was noted on February 1, 1983 by CTCo personnel. There is, therefore, a row which is not operational. The problem is being investigated by CTCo. Other than this, no other problems have been observed with the solar system in the past month.

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A site visit is planned in March to install the new DAS software. As this work progresses a firm date will be identified for this visit.

Yours very truly,

Steve Green

Steven T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

for Edgar B. Bowles, Jr.
Danny M. Deffenbaugh
Project Manager

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Department of Mechanical Sciences
April 4, 1983
Monthly Progress Report No. 37
Reporting Period February 19, 1983
through March 18, 1982

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The DAS software changes requested by CTCo personnel are complete and ready to install. A new DAS user's manual has been prepared which reflects the changes in the software and the DAS operation.

The monthly performance reports have been prepared and brought up to date. These are being sent under separate cover.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The row control board failure identified on February 1, 1983 was resolved and the disabled row was brought back up on February 23.

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Caterpillar Tractor Co.
DE-FC030CS30309, SwRI Project 06-5821

April 4, 1983
Page 2

A site visit is planned for April 4. The objectives of this trip are:

- o Install new version of DAS software
- o Instruct CTCo personnel on operation of DAS
- o Install new model central controller light switch
- o Inspect collector field for proper performance

Respectfully submitted,

Steven T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

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Department of Mechanical Sciences
April 15, 1983

Mr. Stan Herron
U. S. Department of Energy
Albuquerque Operations Office
Energy Programs Division
P. O. Box 5400
Albuquerque, NM 87115

SUBJECT: Monthly Performance Reports No. 1-4, Caterpillar Tractor Company Solar Process Heat System, San Leandro, California
SwRI Project 06-5821

Dear Mr. Herron:

Please find enclosed copies of the subject reports. These reports summarize the performance of the solar system at the Caterpillar Tractor Company, San Leandro, California.

These reports have been withheld from distribution pending our own review of the collector system operation and the operation of the data acquisition. The intent of this review was to verify system operation at the performance levels indicated in the reports. A site visit was recently made by SwRI to perform this review which revealed certain areas for improvement in overall system operation. These problem areas were resolved as of that time with plans made to monitor their status for future action. These problems included

- misaligned central controller light switch,
- unfocused collector rows,
- faulty flowmeter operation,
- overtemperature conditions.

The above topics are discussed in the February report (#4) enclosed herein.

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April 15, 1983

If you have any questions regarding these reports or the solar system installation at Caterpillar, please call me at (512) 684-5111, extension 3519, or Danny Deffenbaugh, Project Manager, at extension 2384.

Respectfully submitted,

Steve Green
Research Engineer

SG:dle
Enclosure

cc: R. L. Bass, SwRI
D. M. Deffenbaugh, SwRI
Bill Belke, CTCo, Peoria
Don Lucas, CTCo, San Leandro
J. M. Greyerbiehl, DOE Washington
V. A. Chavez, DOE Albuquerque
J. A. Leonard, Sandia
P. J. Eicker, Sandia
E. L. Harley, Sandia
J. K. Roberts, ETEC
W. D. Grant, Tech Reps

MONTHLY REPORT #1

REPORT PERIOD:	November 12, 1982 - November 30, 1982
REPORT NO.:	CTCo-1
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Rd. San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis St. San Leandro, CA

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

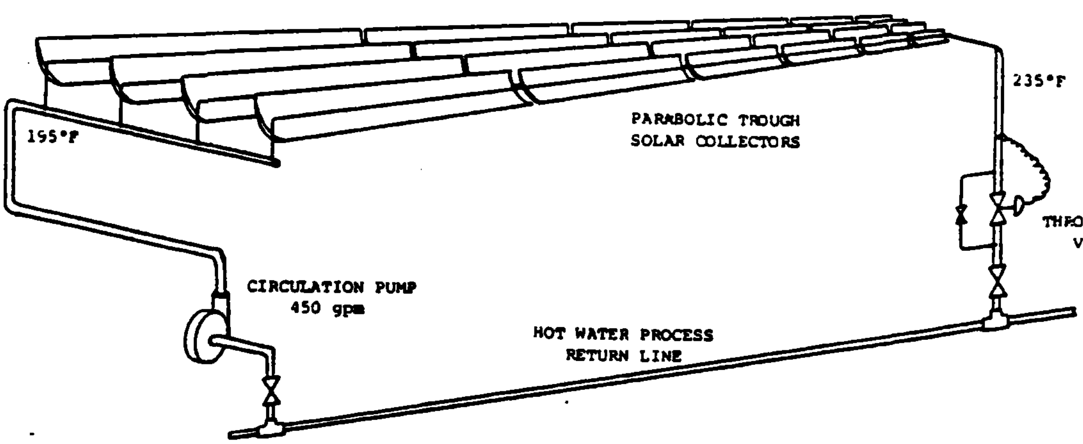

FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The collector system was available for use during the entire reporting period; however, poor weather conditions prohibited extensive operation.

A problem was observed in setting the lower radiation limit on the central controller light switch. This caused inconsistent operation in the early morning. Plant maintenance personnel are reviewing the problem and will implement a solution in the next report period, pending approval. The tentative solution is to replace a one-turn trim pot with a 10-turn pot to decrease the sensitivity of the controller to pot position.

A second problem was observed in the fluid flow rate. Apparently, gas is being trapped in the collector loop. The source of this gas is presently unknown, but appears to be nitrogen from the nitrogen cover system. This problem is being investigated by CTCo personnel.

IV. Performance

A. Monthly Summary

Table I gives a summary of the system's thermal performance for the period 11/12/82 to 11/30/82. The data start at 11/12/82 because that was the time the data system was activated to start monitoring system performance.

The system's performance is shown graphically in Figure 2.

Both Table I and Figure 2 show acceptable operation in the period 11/13 to 11/21. Operation was halted during the period of good weather from 11/25 to 11/26 due to plant holidays.

B. Clear Day Performance

Figure 3, and Table II show the hourly performance for 11/13/82.

As can be seen, the collectors were not brought up until 11:00 a.m. This is related to the central controller problem cited above. Also, the flow does not reach its design point until late in the day. As stated above, this is due to the presence of air in the piping. The plant engineers are currently trying to trace the source of this problem.

As the system reaches its design point, it operates well, exhibiting acceptable efficiencies. The two problems cited above shall be positively identified and resolved shortly.

TABLE I. MONTHLY PERFORMANCE SUMMARY TABLE - 11/82

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) KBTU/SQFT	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) KBTU/SQFT	ENERGY COLLECTED KBTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED KBTU/SQFT	PARASITIC ENERGY USED KBTU/SQFT
305	11/ 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
306	11/ 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
307	11/ 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
308	11/ 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
309	11/ 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
310	11/ 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
311	11/ 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
312	11/ 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
313	11/ 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
314	11/10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
315	11/11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
316	11/12	0.0	0.0	0.0	0.0	0.0	0.0	0.4
317	11/13	1005.0	752.3	272.4	27.1	36.2	272.4	1.7
318	11/14	976.8	501.5	210.5	21.6	36.2	210.5	1.7
319	11/15	896.7	503.3	154.1	17.2	30.6	154.1	1.6
320	11/16	822.8	632.5	238.5	29.0	37.7	238.5	1.6
321	11/17	131.6	0.0	0.0	0.0	0.0	0.0	1.2
322	11/18	108.0	0.0	0.0	0.0	0.0	0.0	1.4
323	11/19	886.6	406.1	154.2	17.4	38.0	154.2	2.1
324	11/20	894.4	502.7	195.6	21.9	38.9	195.6	1.9
325	11/21	736.5	120.9	41.4	5.6	34.3	41.4	1.5
326	11/22	144.5	0.2	0.0	0.0	0.0	0.0	1.2
327	11/23	529.3	0.4	0.0	0.0	0.0	0.0	1.3
328	11/24	450.6	11.8	0.0	0.0	0.0	0.0	1.3
329	11/25	885.6	0.6	0.0	0.0	0.0	0.0	1.4
330	11/26	476.3	0.3	0.0	0.0	0.0	0.0	1.3
331	11/27	234.4	0.6	0.0	0.0	0.0	0.0	1.3
332	11/28	211.9	0.0	0.0	0.0	0.0	0.0	1.3
333	11/29	151.7	0.0	0.0	0.0	0.0	0.0	0.7
334	11/30	145.4	0.2	0.0	0.0	0.0	0.0	0.1
TOTALS		9688.1	3513.3	1266.7	13.1	36.1	1266.7	25.1
AVG		509.9	104.9	66.7			66.7	1.3

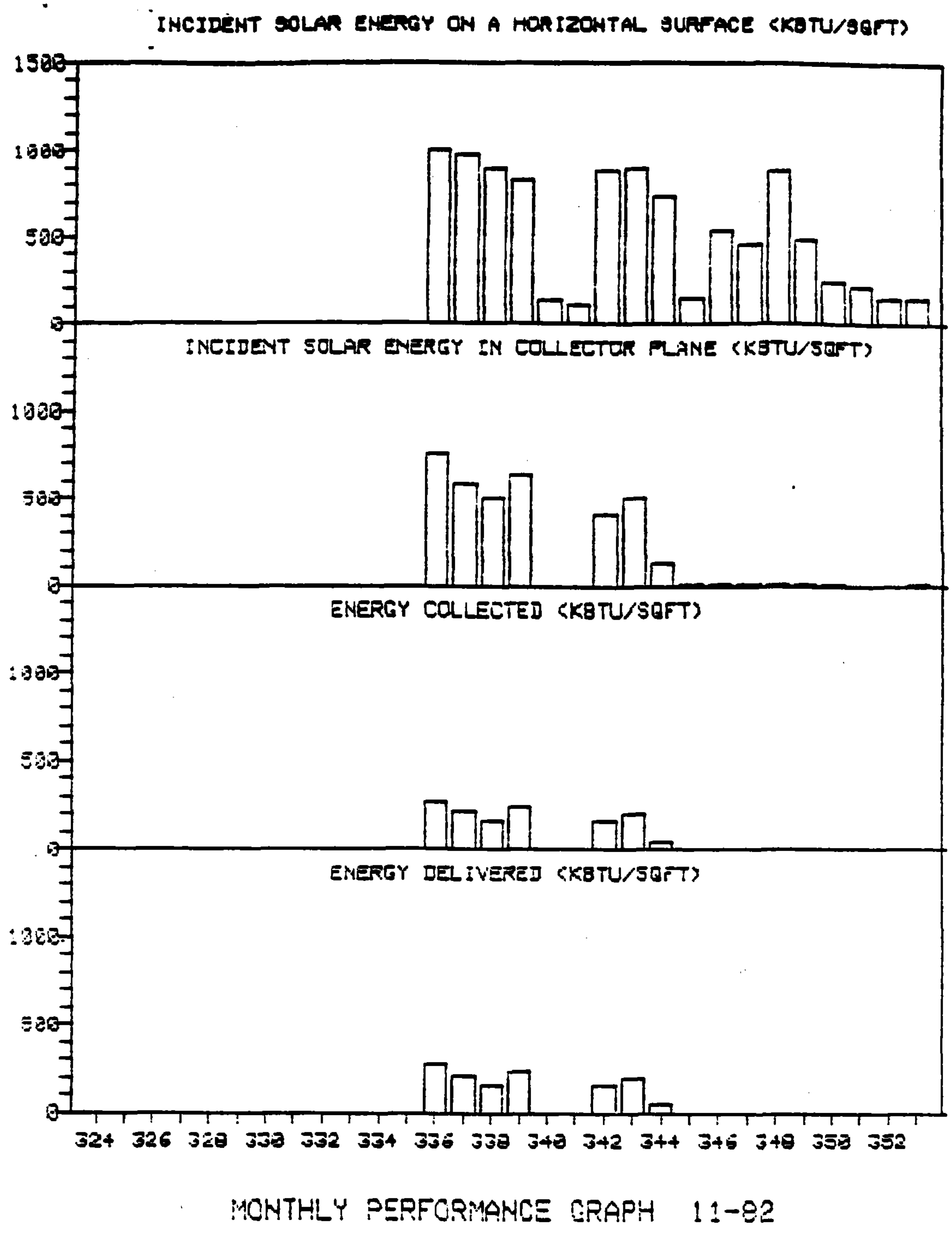

FIGURE 2. CATERPILLAR TRACTOR CO. MONTHLY PERFORMANCE SUMMARY GRAPH

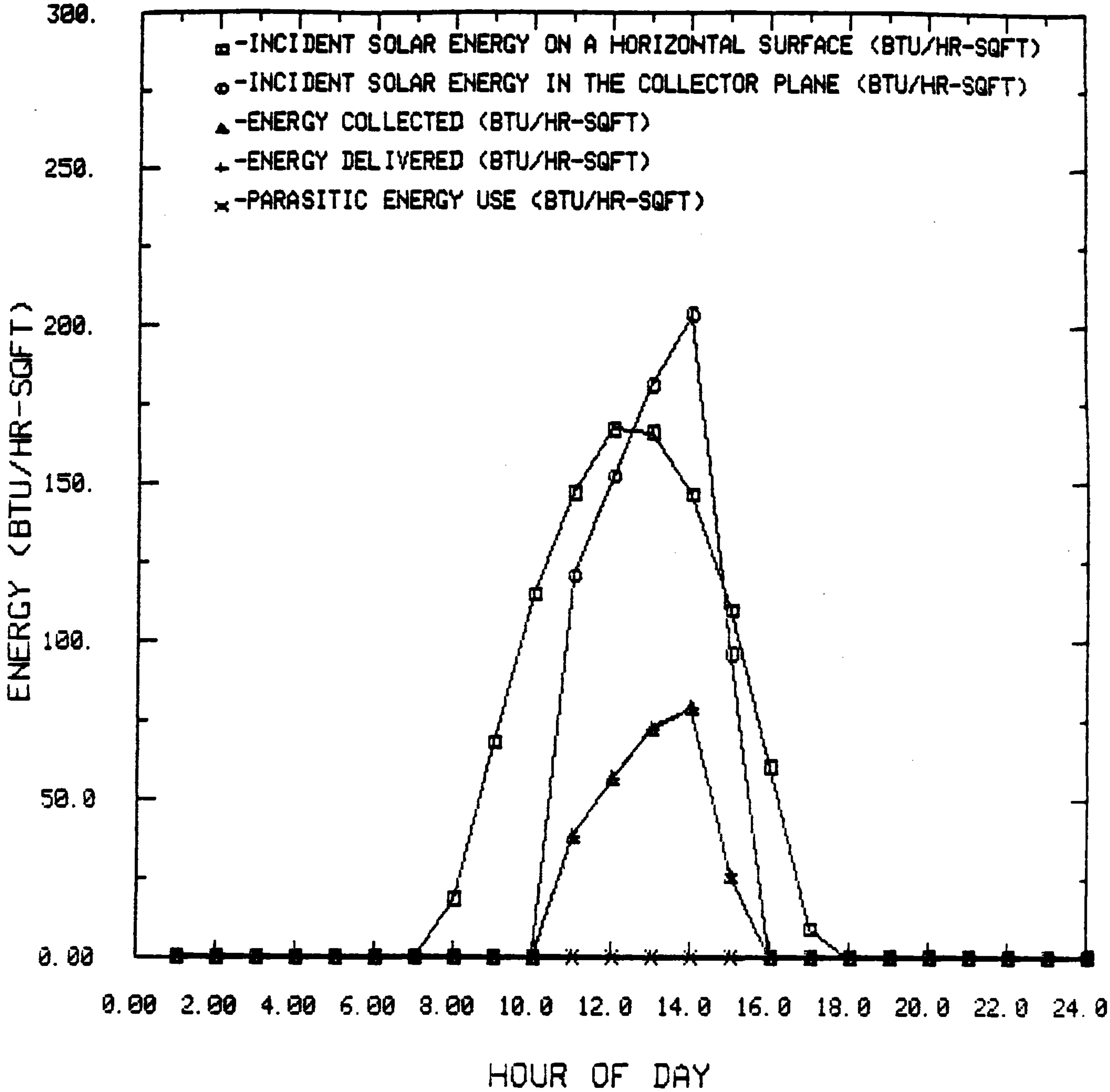

FIGURE 3. CLEAR DAY PERFORMANCE GRAPH 11-13-82

TABLE II. CLEAR DAY PERFORMANCE TABLE - 11/13/82 (JULIAN DAY 317)

HOUR	AMB TEMP F	WIND SPD MPH	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/HR-FT2	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/HR-FT2	NORTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	NORTH FIELD: COLLECTOR ARRAY TEMP IN F	NORTH FIELD: COLLECTOR ARRAY TEMP OUT F	SOUTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	SOUTH FIELD: COLLECTOR ARRAY TEMP IN F	SOUTH FIELD: COLLECTOR ARRAY TEMP OUT F	TOTAL SYSTEM: ENERGY COLLECTED BTU/HR-FT2	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (1) %	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (2) %	TOTAL SYSTEM: PARASITIC ENERGY BTU/HR-FT2
1.	42.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
2.	45.2	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
3.	44.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
4.	44.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5.	44.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6.	43.6	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
7.	41.4	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
8.	45.2	2.4	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9.	49.0	3.1	67.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10.	54.7	0.8	114.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
11.	58.2	2.4	147.0	120.3	58.5	133.1	147.7	158.1	134.0	148.0	38.2	26.0	31.7	0.2
12.	58.8	5.8	166.8	152.1	71.4	140.9	162.3	172.2	141.3	147.7	56.5	33.9	37.1	0.1
13.	62.6	6.4	165.7	180.9	101.6	162.9	182.0	235.7	162.7	184.1	72.6	43.8	40.1	0.1
14.	61.9	7.4	146.2	203.0	118.9	189.8	207.7	305.4	189.2	212.2	79.1	54.1	38.9	0.1
15.	62.3	5.0	109.6	95.7	101.5	190.3	197.2	263.3	190.3	194.0	26.1	23.8	27.3	0.2
16.	61.0	5.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
17.	58.9	2.4	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
18.	53.8	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
19.	50.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
20.	48.2	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
21.	47.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22.	46.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
23.	46.8	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
24.	45.6	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TOTALS			1004.9	752.1							272.4	27.1	36.2	2.1
AVG	50.7	3.1	100.5	150.4	90.4	163.4	179.4	226.9	163.5	177.2	54.5			0.1

MONTHLY REPORT #2

REPORT PERIOD:	December 1, 1982 - December 31, 1982
REPORT NO.:	CTCo-2
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, CA

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

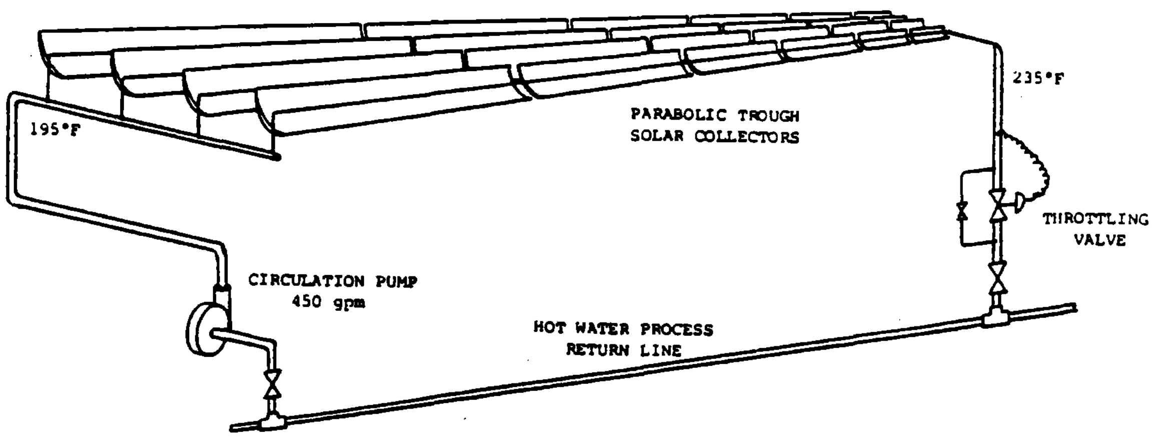

FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The collector system was operational throughout the entire month of December. No mechanical failures were reported by CTCo. personnel.

The 1-turn trim pot in the central controller light switch circuitry was replaced with a 10-turn pot. This allows more sensitive control of the threshold light level. The problem of inconsistent light switch operation was described in the previous report. CTCo personnel have stated they have witnessed smoother operation at morning turn-on time; however, the collectors still are not coming up until relatively late in the morning, as shown below.

The DAS failed on 22 December 1982 due to disk problems. The problem was still unresolved by the end of the month due to the holiday schedule. Also, there appears to be an intermittent problem with the south field outlet temperature probe. The problem seems to be the current transmitter associated with the RTD, and a new one will be installed at the earliest convenience. Meanwhile, south field performance shall be estimated from the north field performance in relation to the single row performances. This is, at best, an approximation of the south field outlet temperature, but until the problem is resolved, there is little else that can be done without the missing data.

IV. Performance

A. Monthly Summary

Table I and Figure 2 show the daily performance of the solar system for the month of December. The reported data extend only to 22 December due to a failure in the DAS on 22 December. The system was functional in the period 23-31 December, but its performance was not monitored.

Disregarding the data for 1 December 1982, the average efficiency of the solar system appears to be approximately 25% if the collector plane radiation is considered. Preliminary performance modeling indicates that this efficiency is an acceptable value. The total energy output, however, appears to be somewhat lower than could be expected. The cause of this low performance is being investigated.

B. Clear Day Performance

Figure 3 and Table II show the hourly performance for 8 December 1982.

In Table II, we can see how the bad transmitter affects the south field outlet temperature measurement. As pointed out above, this effect is removed by estimating the south field performance by other means.

The relatively high efficiency at 15:00 is suspect in view of the low values of radiation and energy output. The daily total efficiency of 23.1 is expected for this system.

It can be seen that, for some days, the daily totals listed in the monthly performance summary differ markedly from the total listed in the daily summary. This is due to a difference in the integration algorithms for the routines which produce the two different summary tables. The monthly summary routine will try to "smooth" in any missing data; whereas, the daily summary routine portrays the true situation of the raw data.

TABLE I. MONTHLY PERFORMANCE SUMMARY TABLE - 12/82

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) KBTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) KBTU/SQFT	ENERGY COLLECTED KBTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED KBTU./SQFT	PARASITIC ENERGY USED KBTU/SQFT	NO. OF CHANCES OF MISSING DATA
335	12/ 1	771.2	192.7	92.9	12.0	48.2	92.9	2.1	2.0
336	12/ 2	245.2	0.1	0.0	0.0	0.0	0.0	1.2	0.0
337	12/ 3	753.2	251.6	63.7	8.5	25.3	63.7	2.0	2.0
338	12/ 4	441.2	83.4	5.1	1.2	6.2	5.1	1.9	2.0
339	12/ 5	433.5	77.1	1.6	0.4	2.0	1.6	1.7	0.0
340	12/ 6	246.9	0.2	0.0	0.0	0.0	0.0	1.1	0.0
341	12/ 7	814.7	278.6	75.8	9.3	27.2	75.8	1.9	0.0
342	12/ 8	847.7	475.3	109.6	12.9	23.1	109.6	2.1	0.0
343	12/ 9	761.3	63.8	11.2	1.5	17.6	11.2	1.5	1.0
344	12/10	772.9	6.7	0.0	0.0	0.0	0.0	1.4	0.0
345	12/11	707.3	0.0	0.0	0.0	0.0	0.0	1.3	0.0
346	12/12	539.8	0.5	0.0	0.0	0.0	0.0	1.2	0.0
347	12/13	711.2	387.6	97.5	13.7	25.2	97.5	1.9	0.0
348	12/14	383.8	0.7	0.0	0.0	0.0	0.0	1.1	0.0
349	12/15	233.4	0.2	0.0	0.0	0.0	0.0	1.1	0.0
350	12/16	378.5	16.8	0.2	0.1	1.3	0.2	1.3	0.0
351	12/17	622.9	420.9	118.3	19.0	28.1	118.3	1.5	0.0
352	12/18	739.2	0.7	0.0	0.0	0.0	0.0	1.3	0.0
353	12/19	743.1	0.5	0.0	0.0	0.0	0.0	1.3	0.0
354	12/20	146.5	0.1	0.0	0.0	0.0	0.0	1.2	0.0
355	12/21	18.8	0.1	0.0	0.0	0.0	0.0	1.2	0.0
356	12/22	117.8	0.0	0.0	0.0	0.0	0.0	0.8	0.0
357	12/23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
358	12/24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
359	12/25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
360	12/26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
361	12/27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
362	12/28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
363	12/29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
364	12/30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
365	12/31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS		11430.1	2257.5	575.8	5.0	25.5	575.8	32.1	7.
AVG		519.5	102.6	26.2			26.2	1.5	

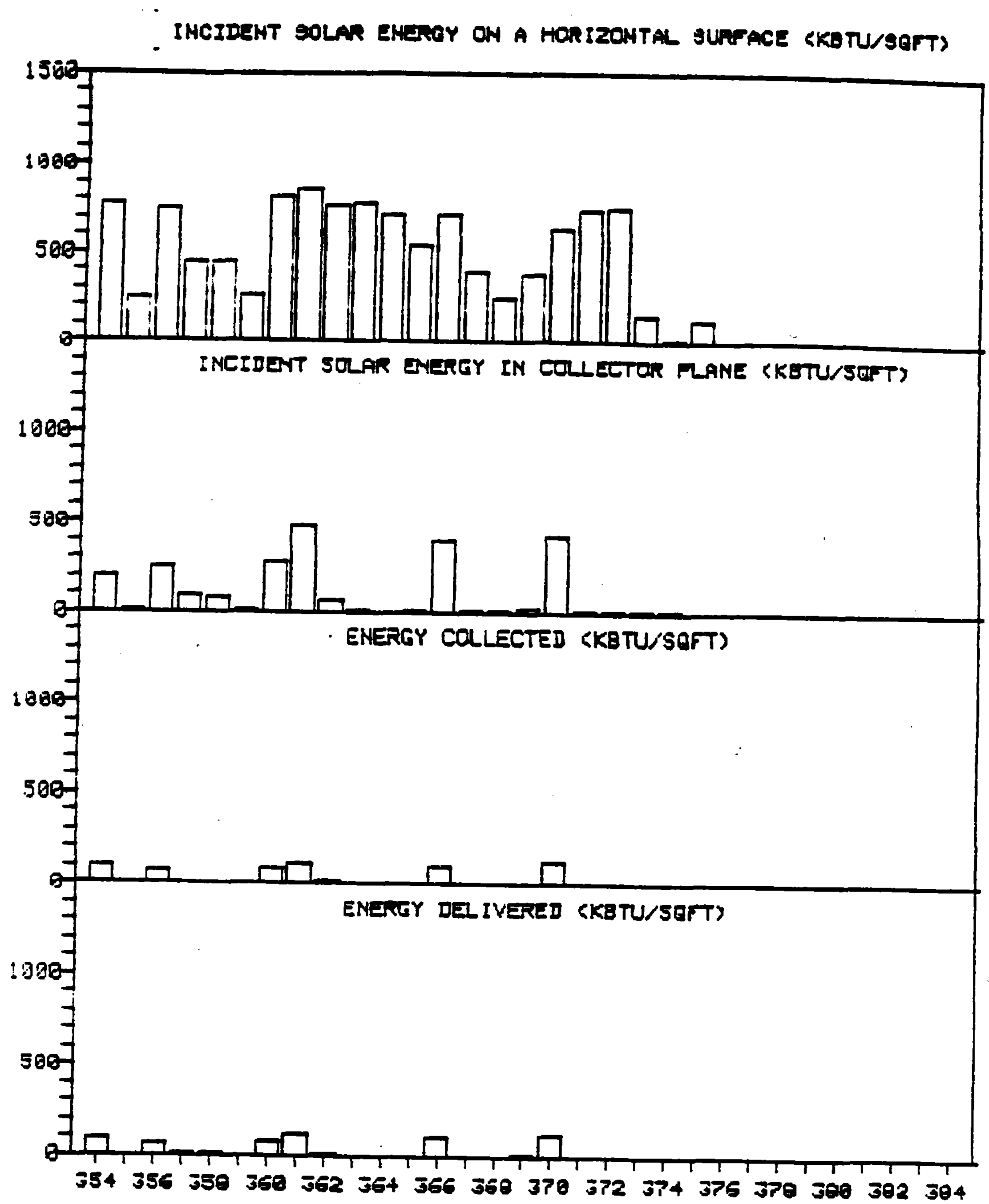

FIGURE 2. MONTHLY PERFORMANCE GRAPH 12-82

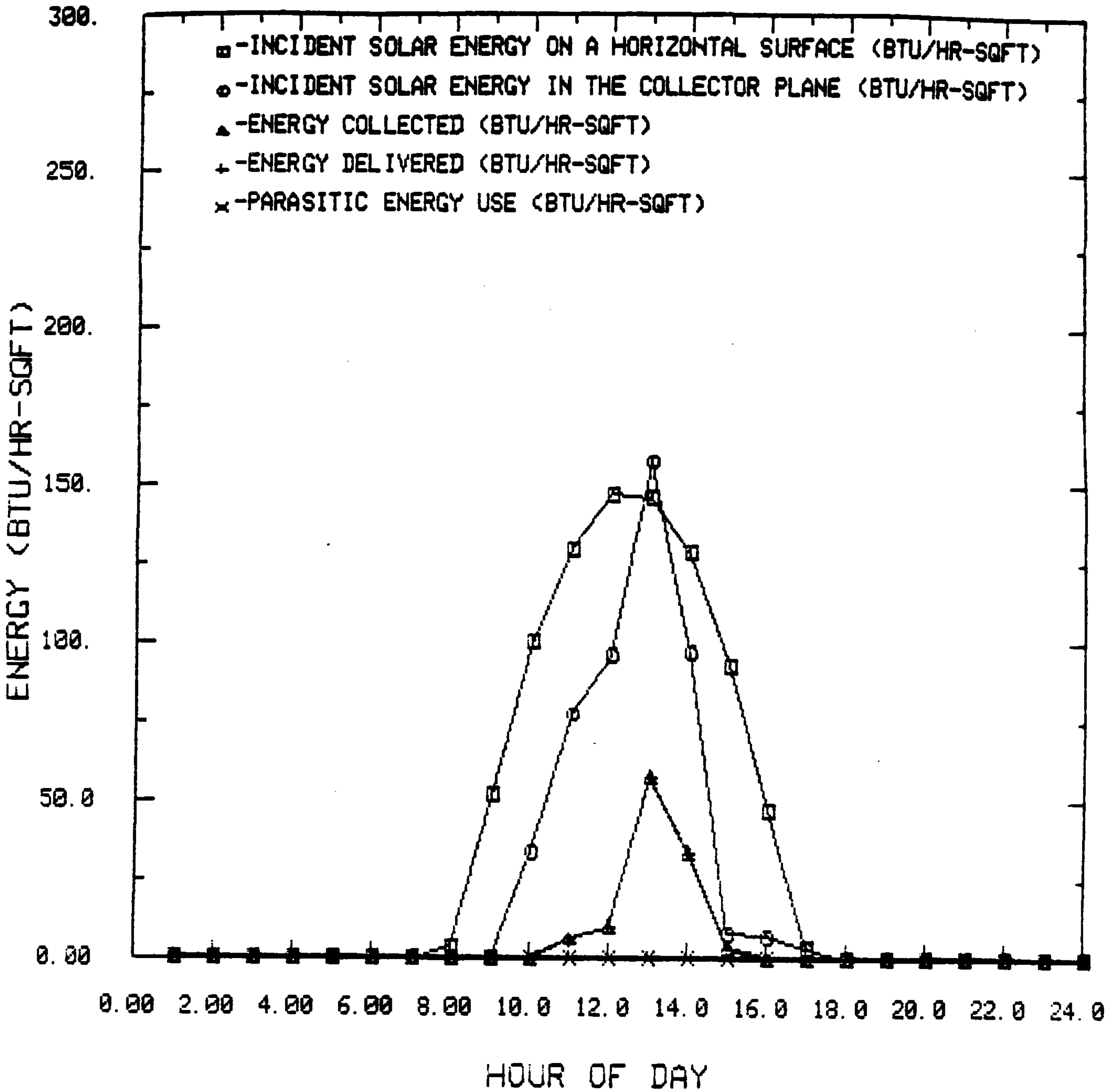

FIGURE 3. CLEAR DAY PERFORMANCE GRAPH 12-8-82

TABLE II. CLEAR DAY PERFORMANCE TABLE - 12/8/82 (JULIAN DAY 342)

HOUR	AMB TEMP F	WIND SPD MPH	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/HR-FT2	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/HR-FT2	NORTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	NORTH FIELD: COLLECTOR ARRAY TEMP IN F	NORTH FIELD: COLLECTOR ARRAY TEMP OUT F	SOUTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	SOUTH FIELD: COLLECTOR ARRAY TEMP IN F	SOUTH FIELD: COLLECTOR ARRAY TEMP OUT F	TOTAL SYSTEM: ENERGY COLLECTED BTU/HR-FT2	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (1) %	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (2) %	TOTAL SYSTEM: PARASITIC ENERGY BTU/HR-FT2
1.	43.9	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
2.	47.0	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
3.	46.6	16.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
4.	46.5	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5.	46.6	11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6.	46.5	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
7.	46.6	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
8.	47.7	9.6	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9.	50.8	10.1	51.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10.	55.0	6.9	100.0	33.5	51.3	126.5	110.0	130.6	126.1	90.2	0.2	0.2	0.5	0.2
11.	56.2	14.7	129.4	77.1	103.4	214.8	215.4	267.5	214.3	175.6	6.3	4.9	8.2	0.3
12.	57.6	11.3	146.8	95.5	93.1	184.1	186.4	269.1	202.8	204.1	9.8	6.7	10.3	0.3
13.	60.8	13.6	145.7	157.0	120.1	226.9	239.2	328.0	226.1	237.7	57.2	39.3	36.4	0.1
14.	60.6	12.9	128.1	96.4	118.1	228.8	237.1	329.5	229.4	143.9	33.4	26.1	34.6	0.3
15.	59.9	9.9	92.5	7.5	118.6	223.8	226.8	328.0	223.4	208.2	3.4	3.6	44.4	0.1
16.	58.0	9.8	47.0	6.8	116.4	218.8	217.6	312.4	218.4	213.7	0.0	0.1	0.7	0.1
17.	56.5	7.5	3.2	3.1	40.1	87.2	86.1	111.3	87.0	85.5	0.0	0.0	0.0	0.2
18.	55.2	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
19.	52.6	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
20.	52.2	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
21.	51.1	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22.	50.1	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
23.	49.1	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
24.	49.3	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TOTALS			847.8	477.0							110.3	13.0	23.1	2.5
AVG	51.9	9.9	84.8	59.6	95.1	188.9	189.8	259.6	191.0	169.9	15.8			0.1

MONTHLY REPORT #3

REPORT PERIOD:	January 1, 1983 - January 31, 1983
REPORT NO.:	CTCo-3
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

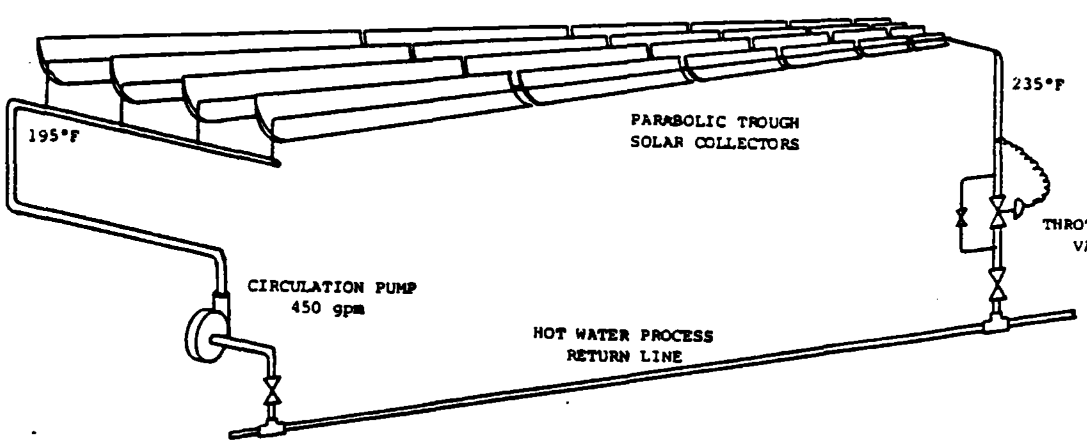

FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The collector system was available for use during the entire reporting period with the exception of row BH92. This row developed a control problem which was observed on January 28, 1983.

The data acquisition system was reactivated on January 14, 1983 after servicing by the vendor, Digital Equipment Corporation. It was discovered that one of the disk drives had a defective head, which was replaced at that time.

IV. Performance

A. Monthly Summary

Table I and Figure 2 present the performance of the system for the period January 14, 1983 to January 31, 1983.

It is seen that the solar system performance for the month of January is not as high as might be expected. This poor performance is symptomatic of various operation problems, which include (1) inconsistent central light switch operation and (2) defocusing of collectors.

Inconsistent central light switch operation has been observed several times and has been subsequently investigated. It is suggested that the switch be replaced by one of more recent design. Solar Kinetics will make a new switch available for installation at Caterpillar.

The CTCo process heat load has recently been lower than the collector field steady state output. This causes the collector field outlet temperature to exceed safety limits, so the central controller defocuses the collectors for short periods of time until the temperature at the collector field outlet returns to a safe level. It is thought that this transient operation severely affects long term system performance, resulting in the performance levels shown in Figure 2 and Table I. This problem is being monitored by CTCo and SwRI personnel.

Table II and Figure 3 present the system performance for the day of January 31, 1983. These figures show that while the long term performance suffered for the month, the performance for this day is relatively good. It can be concluded, then, that once the problems cited above can be resolved, system performance can be markedly improved.

TABLE I. MONTHLY PERFORMANCE SUMMARY TABLE - 1/31

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) KBTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) KBTU/SQFT	ENERGY COLLECTED KBTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED KBTU./SQFT	PARASITIC ENERGY USED KBTU/SQFT	NO. OF CHANCES OF MISSING DATA
1	1/ 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1/ 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1/ 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1/ 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1/ 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1/ 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1/ 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1/ 8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1/ 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	1/10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1/11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	1/13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	1/14	444.5	151.7	17.1	3.8	11.3	17.1	-0.1	0.0
15	1/15	484.7	0.0	0.0	0.0	0.0	0.0	1.1	0.0
16	1/16	615.4	0.0	0.0	0.0	0.0	0.0	1.1	0.0
17	1/17	626.7	1.0	-21.3	-3.4	*****	-21.3	1.6	0.0
18	1/18	126.7	0.0	0.0	0.0	0.0	0.0	1.0	0.0
19	1/19	778.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0
20	1/20	1026.9	280.0	48.7	4.7	17.4	48.7	3.0	0.0
21	1/21	272.7	0.8	0.0	0.0	0.0	0.0	1.1	1.0
22	1/22	137.9	0.3	0.0	0.0	0.0	0.0	1.0	0.0
23	1/23	624.1	0.2	0.0	0.0	0.0	0.0	1.1	0.0
24	1/24	827.6	297.0	16.5	2.0	5.6	16.5	5.5	0.0
25	1/25	706.7	51.0	-18.4	-2.6	-36.2	-18.4	2.4	0.0
26	1/26	216.0	0.3	0.0	0.0	0.0	0.0	1.0	2.0
27	1/27	679.2	243.4	28.2	4.2	11.6	28.2	3.2	0.0
28	1/28	244.0	4.9	0.5	0.2	9.4	0.5	1.0	0.0
29	1/29	709.6	0.4	0.0	0.0	0.0	0.0	1.3	0.0
30	1/30	966.6	19.3	-0.2	0.0	-1.3	-0.2	1.5	0.0
31	1/31	1149.3	585.4	166.5	14.5	28.4	166.5	5.4	0.0
TOTALS		10637.0	1635.7	237.4	2.2	14.5	237.4	33.3	3.
AVG		590.9	70.9	13.2			13.2	1.8	

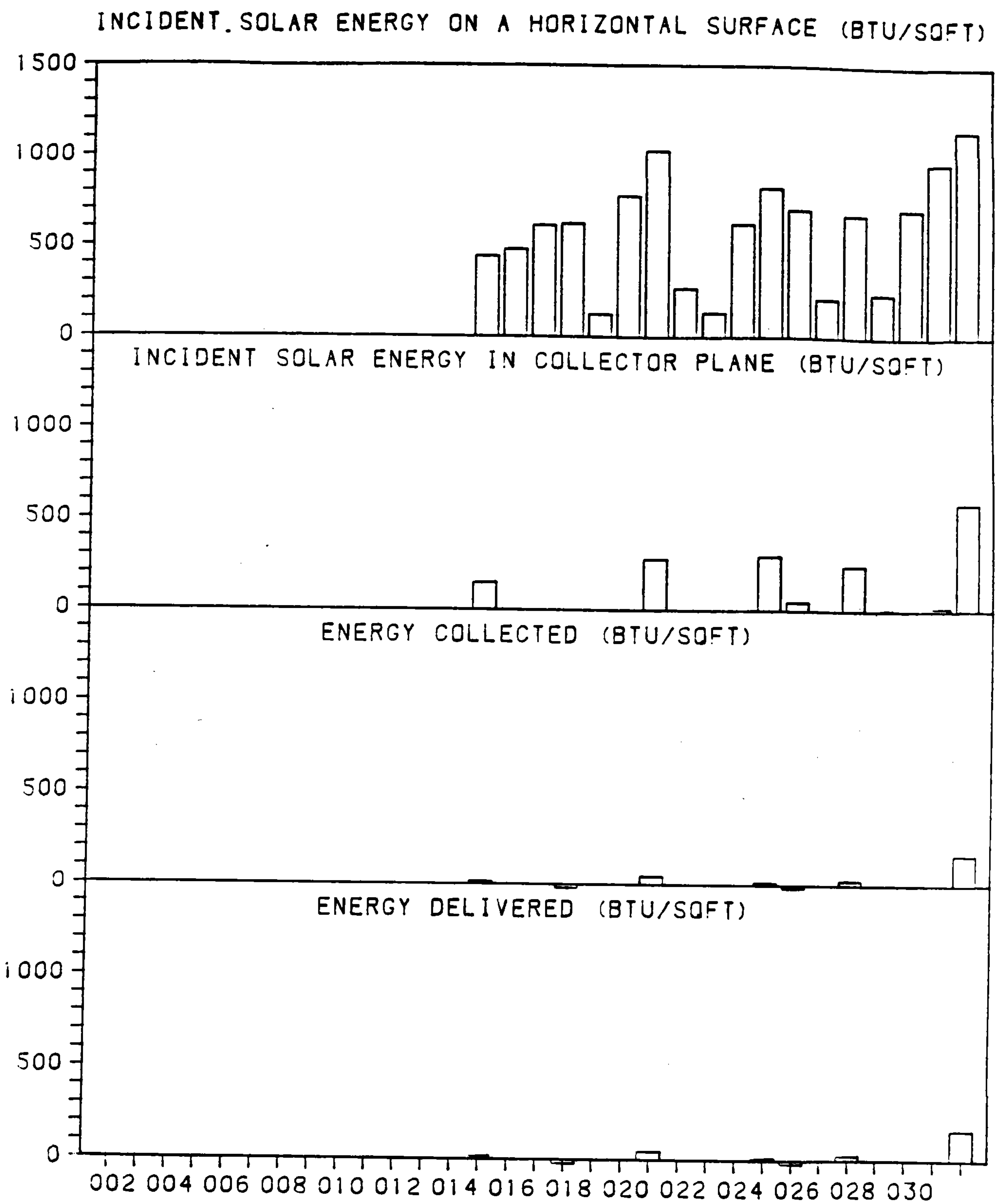

FIGURE 2. MONTHLY PERFORMANCE GRAPH 1-83

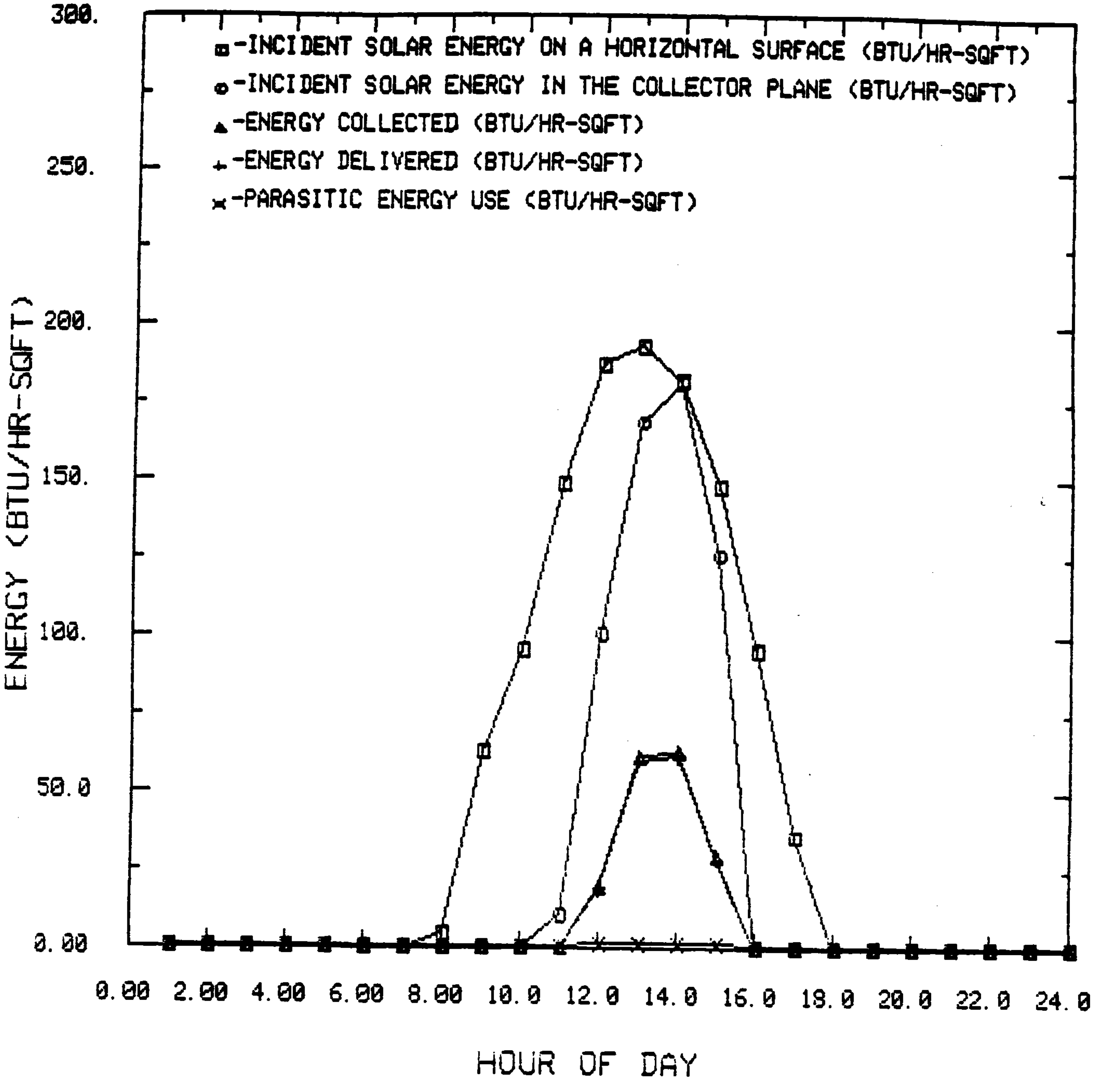

FIGURE 3. CLEAR DAY PERFORMANCE GRAPH 1-31-83

MONTHLY REPORT #4

REPORT PERIOD:	February 1, 1983 - February 28, 1983
REPORT NO.:	CTCo-4
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

III. Operating Experience

The collector system was available for use during the entire month of February. The defective row, BH92, was repaired and returned to operation on February 23.

While compiling the data for the month of February, the south field inlet flowmeter was found to be yielding faulty data. The performance computations were performed with the flowmeter readings at the south field inlet, so no performance results are missing. The faulty flowmeter will be repaired at the earliest convenience. Other than this problem, the DAS was operational for the entire month.

CTCo personnel still observe inconsistent startup from day to day and rapid defocusing/focusing cycles during the day (~10 minutes). The inconsistent startup is attributed to a faulty central controller light switch. Solar Kinetics is to supply a replacement.

The focusing/defocusing sequence of the collectors is normal when the collector outlet temperature exceeds ~240 F. This occurs when the collector inlet temperature is increased because the plant process heat load is low so the hot water return temperature is not lowered to the design point. The plant load has indeed been low recenlty, resulting in the rapid cycling of the focus/defocus sequence. This means that when the collectors operate, they can oversupply the plant load. While this is acceptable from the energy supply standpoint, the collector efficiency is decreased, as evidenced in the results shown below.

IV. Performance

A. Monthly Summary

Table I and Figure 2 present a summary of the collector system operation for the month of February. It is seen in this table and figure that the collector system has a daily efficiency between 24% and 39% when the collectors are operating. There are several days, however, when the collectors do not operate. This is due to the direct interaction between the plant heating system and the collector system cited above.

B. Daily Summary

Table II and Figure 3 depict the performance for the single clear day of February 1983.

It is seen that operation begins between 9:00 and 10:00 a.m. and stops between 3:00 and 4:00 p.m. For this day the peak efficiency is 30.8% with a daily efficiency of 25.1%.

II. Project Description

Application: Preheat of process hot water for parts washing.

Site: 37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.

Process Schedule: Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.

Auxiliary Fuel: Natural gas.

Collectors: 50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).

Fluid Type, Flow: Treated water, North field - 330 gpm, South field - 120 gpm.

Design Energy Delivery: 14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.

Phase 1 Cost (Design): $143,045

Phase 2 Cost (Construction): $2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

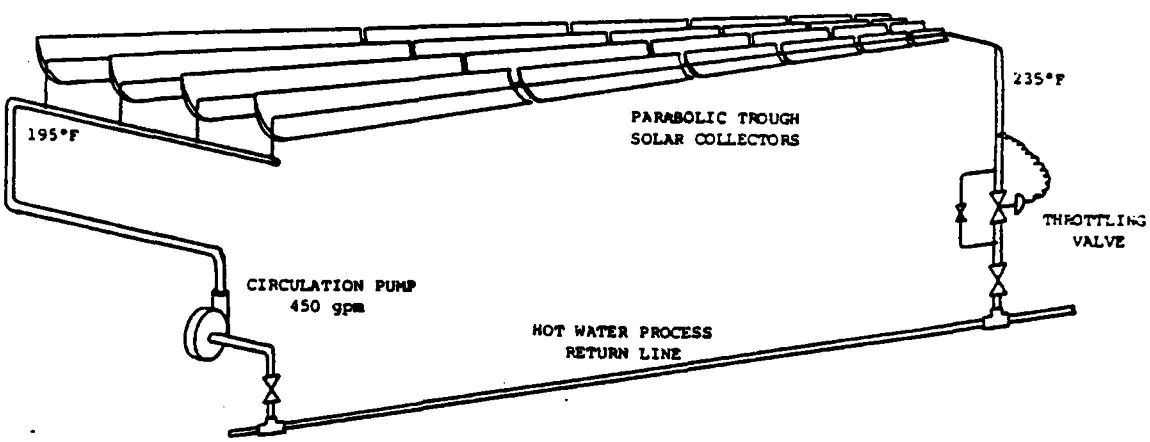

FIGURE 1. SYSTEM SCHEMATIC

TABLE I. MONTHLY PERFORMANCE SUMMARY TABLE - 2/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT	NO. OF CHANCES OF MISSING DATA
32	2/ 1	1169.8	625.4	121.2	10.4	19.4	121.2	7.8	0.0
33	2/ 2	372.6	1.6	-20.8	-5.6	*****	-20.8	1.9	1.0
34	2/ 3	1094.4	502.5	144.8	13.2	24.9	144.8	7.2	1.0
35	2/ 4	866.7	302.6	115.1	13.3	30.1	115.1	4.1	0.0
36	2/ 5	509.6	0.5	0.0	0.0	0.0	0.0	1.7	0.0
37	2/ 6	170.7	0.4	0.0	0.0	0.0	0.0	1.7	0.0
38	2/ 7	176.7	0.0	0.0	0.0	0.0	0.0	1.6	1.0
39	2/ 8	483.6	0.6	0.0	0.0	0.0	0.0	1.6	0.0
40	2/ 9	732.6	141.1	-30.9	-4.2	-21.9	-30.9	4.1	0.0
41	2/10	913.8	255.7	29.9	3.3	11.7	29.9	4.3	0.0
42	2/11	892.6	156.8	-25.9	-2.9	-16.5	-25.9	4.8	0.0
43	2/12	383.1	1.2	0.0	0.0	0.0	0.0	1.6	0.0
44	2/13	1319.9	1.1	0.0	0.0	0.0	0.0	1.4	0.0
45	2/14	1061.6	373.2	39.8	3.7	10.7	39.8	6.2	0.0
46	2/15	470.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0
47	2/16	1411.7	997.6	267.8	19.0	26.8	267.8	10.1	0.0
48	2/17	1194.4	549.3	125.2	10.5	22.8	125.2	7.7	0.0
49	2/18	990.1	292.4	18.2	1.8	6.2	18.2	6.6	0.0
50	2/19	1446.8	444.2	138.8	9.6	31.2	138.8	5.1	0.0
51	2/20	1325.8	732.4	285.5	21.5	39.0	285.5	5.8	0.0
52	2/21	1009.4	0.0	0.0	0.0	0.0	0.0	0.9	0.0
53	2/22	1065.4	230.1	15.8	1.5	6.9	15.8	4.5	0.0
54	2/23	186.9	14.2	-34.5	-18.5	*****	-34.5	1.4	0.0
55	2/24	1574.2	29.4	-39.8	-2.5	*****	-39.8	1.2	1.0
56	2/25	188.3	0.7	0.0	0.0	0.0	0.0	0.8	0.0
57	2/26	901.0	1.0	0.0	0.0	0.0	0.0	0.8	0.0
58	2/27	872.5	1.0	0.0	0.0	0.0	0.0	0.8	0.0
59	2/28	212.5	14.2	40.1	18.9	282.3	40.1	0.7	0.0
TOTALS		23056.7	5828.4	1091.7	4.7	18.7	1091.9	97.8	4.
AVG		823.5	208.2	39.0			39.0	3.5	

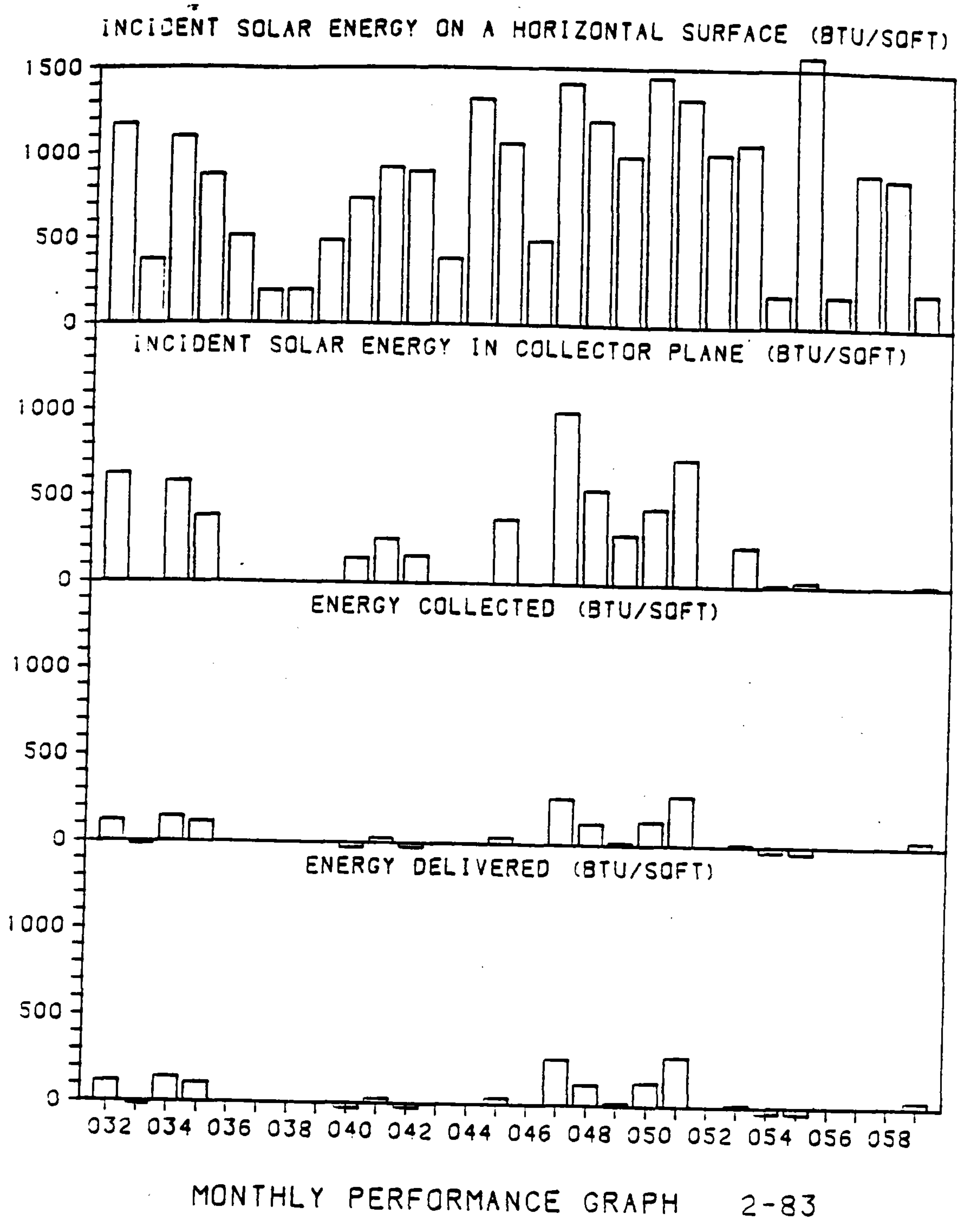

FIGURE 2. MONTHLY PERFORMANCE GRAPH 2-83

TABLE II. CLEAR DAY PERFORMANCE TABLE - 2/16/83 (JULIAN DAY 31)

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED BTU/HR-FT2	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY BTU/HR-FT2
1.	46.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	49.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	47.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	47.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	46.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	46.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	47.6	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.	48.4	1.5	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.	53.9	1.9	76.8	63.6	47.7	128.4	111.5	137.7	127.6	116.9	-9.1	-11.8	-14.2	0.7
10.	58.3	1.2	133.7	136.6	117.7	219.4	227.5	324.4	218.9	228.5	38.7	28.9	28.3	1.1
11.	59.8	2.7	183.1	115.4	115.7	223.7	229.4	325.2	223.4	229.9	26.4	14.4	22.9	1.1
12.	58.6	4.2	213.0	165.3	117.8	225.6	235.7	324.8	225.1	236.4	45.8	21.5	27.7	1.1
13.	60.7	6.0	222.1	188.4	117.8	228.3	240.7	324.9	227.8	242.2	58.0	26.1	30.8	1.1
14.	62.6	5.1	208.5	121.3	116.3	231.6	239.2	324.1	230.9	240.3	37.0	17.7	30.5	1.3
15.	63.8	3.0	173.2	137.8	117.5	230.2	239.4	323.1	229.8	239.3	39.1	22.6	28.4	1.3
16.	61.0	5.6	121.8	67.6	116.2	228.8	233.4	320.2	228.4	231.2	13.6	11.1	20.1	1.1
17.	64.7	0.9	61.4	-0.2	19.4	52.5	52.8	57.4	52.4	52.3	0.0	0.0	-5.4	0.4
18.	58.6	3.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
19.	53.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
20.	53.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
21.	51.8	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
22.	51.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
23.	49.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
24.	48.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TOTALS			1411.5	995.8							249.5	17.7	25.1	10.2
AVG	53.7	2.4	120.3	110.6	98.4	196.5	201.1	273.5	196.0	201.9	27.7			0.4

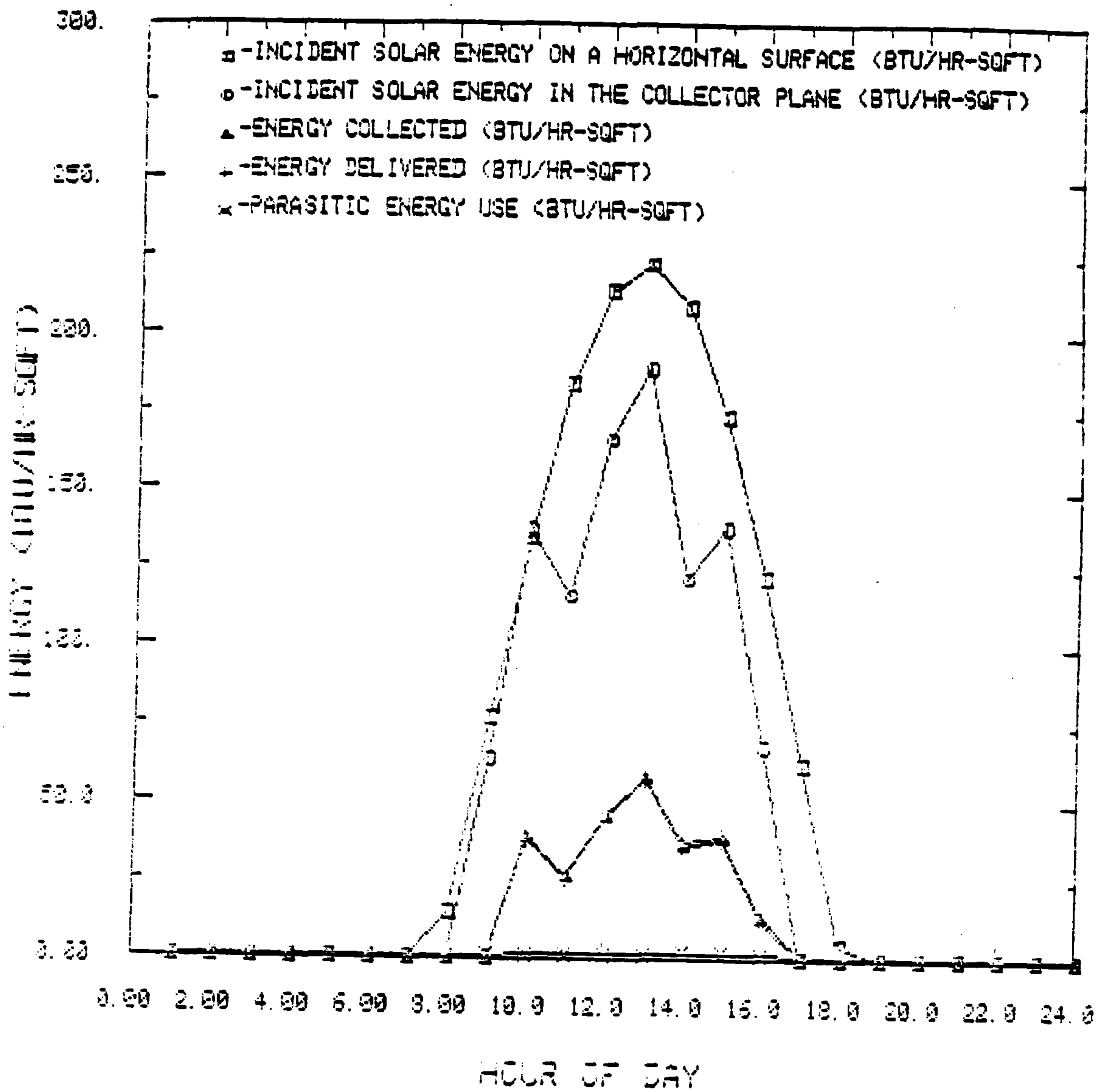

FIGURE 3. CLEAR DAY PERFORMANCE GRAPH 2-16-83

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
May 18, 1983
Monthly Progress Report No. 38
Reporting Period March 19, 1983
through April 15, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

A site visit was made by SwRI personnel on April 4-8. The following tasks were performed at that time:

- New version of DAS software installed.
- New central contoller light switch installed.
- Collector field operation observed in detail.

The new version of the DAS software allows for more efficient off-site processing of the data. It also allows CTCo personnel to observe hourly performance without disturbing the DAS operation. This is accomplished by having the DAS produce a report of hourly performance at the end of each operating day. There are still some details in the new version that have to be resolved but these do not detract from the primary function of data acquisition.

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

When the SwRI personnel arrived on site, they discovered that the central controller light switch was not properly aligned. The new light switch was properly mounted and was seen to properly function while the SwRI personnel were there.

Data were taken at short intervals (i.e., 15 sec.) for a day's operation to observe the operation of the solar system in detail. It was seen that the solar system presently operates in an oscillating state very soon after being activated. This non-steady operation severely degrades collector field performance from that predicted for steady state operation. This problem is described in detail in the enclosed performance report for March.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Operation is continuing at the site with minimal maintenance problems. One row, however, is down due to row controller problems.

For the present time, the non-steady operation of the field will be allowed to continue; however, it may be necessary to disable a portion of the collector field to prevent the temperature oscillations being observed. This possibility is being discussed with Caterpillar.

Respectfully submitted,

Steve Green

Steven T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

D. M. Deffenbaugh

Danny M. Deffenbaugh
Project Manager

MONTHLY REPORT #5

REPORT PERIOD:	March 1, 1983 - March 31, 1983
REPORT NO.:	CTCo-5
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

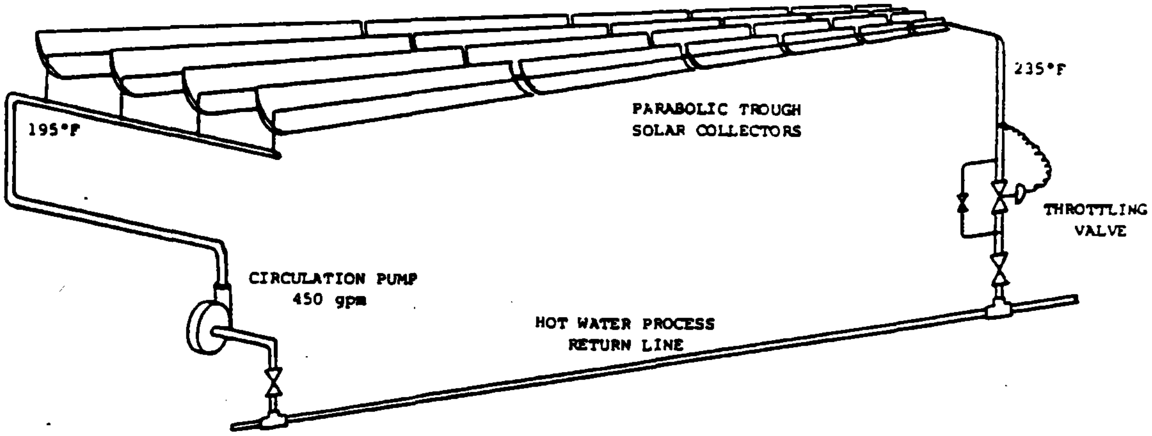


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was operational for the entire month of March. A visit to the site, however, on April 4, revealed several maintenance problems to be resolved. Also, during this site visit the operation of the solar system was observed in detail in an effort to better understand the system performance. These items are all discussed below.

The maintenance problems are listed below by row number (see Figure 2 for collector field layout):

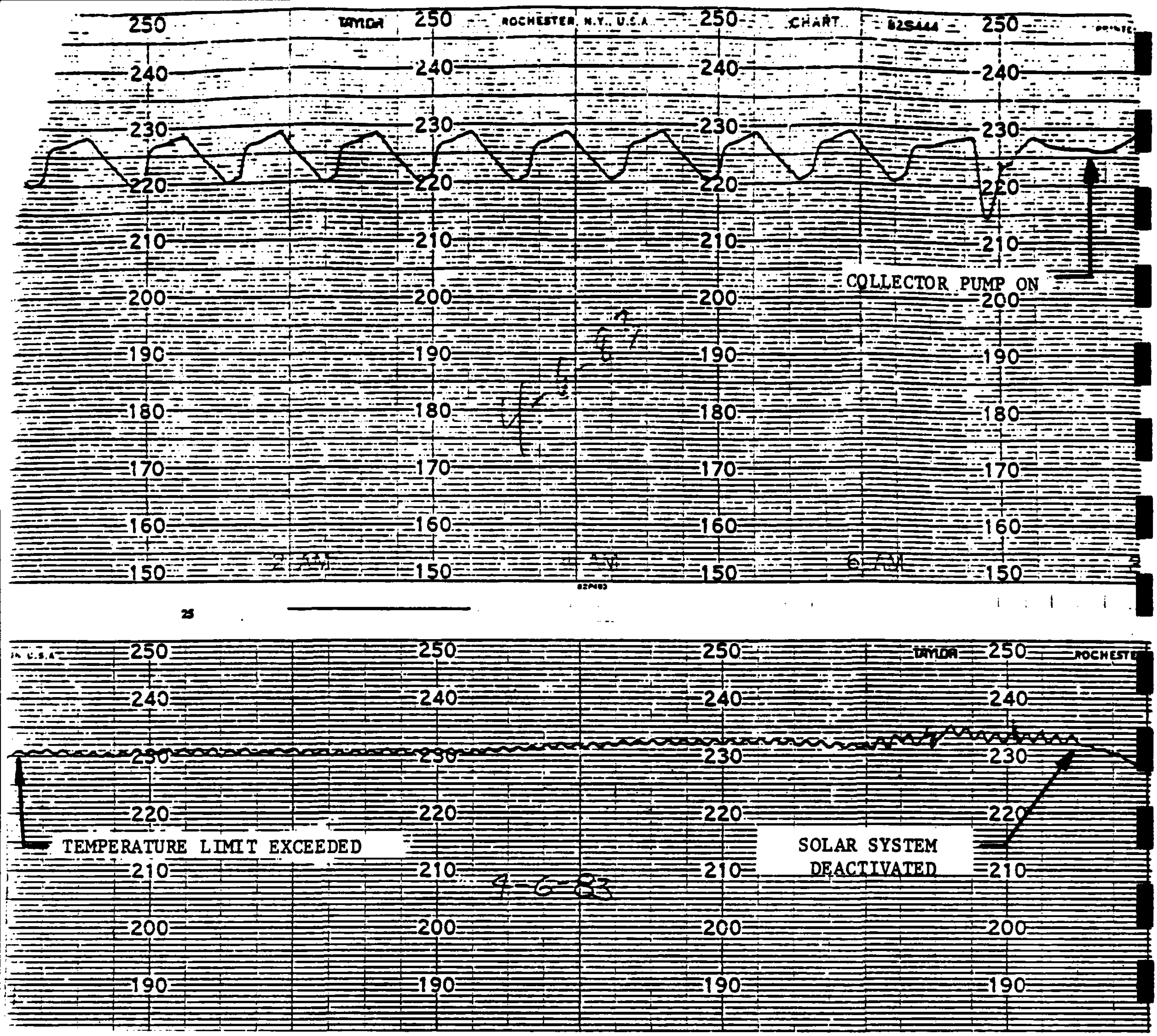
BH-84	leak at receiver tube temperature switch
BH-71	leak at receiver tube flange near drive pylon
BH-49	water in tracker head
BH-58	water in tracker head
BH-94	small hydraulic fluid leak
BH-93	water in tracker head
BH-81 (down)	row control board failure
BH-47 (down)	defective hydraulic pressure switch

Figure 3 shows a time history of the plant boiler inlet temperature (collector field outlet temperature) for April 6, 1983. It can be seen in Figure 3 that the boilers will maintain a minimum process fluid temperature of approximately 225 F. This may be deduced from the nighttime portion of the graph. The collectors are seen to come on line about 7:30 a.m. It is seen that after the collector system is activated the boiler does not fire again until the collectors are shut down at about 4:00 p.m.

During the period of collector operation, the collector outlet temperature is seen to oscillate. Data were collected by the DAS at 15-second intervals during the startup period to characterize this oscillatory performance. Figure 4 shows a graph of the collector field inlet and outlet temperatures during the period 7:30 a.m. to 8:40 a.m. Several interesting observations can be made from Figure 4.

First, it is seen that the average process fluid temperature increases after system startup (the data shown in Figure 4 begin approximately 20 minutes after system startup). The slight temperature drop at 7:40 was caused by the activation of a small process load. After this load was brought on line, it is seen that the average collector fluid temperature increases at approximately 0.6 F per hour.

Since the plant boilers are deactivated as long as the boiler inlet temperature exceeds approximately 225 F, the fact that the process fluid temperature increases beyond this point indicates that the collector field is supplying more energy than the plant load can dissipate. The process fluid temperature increases until the temperature at the collector field outlet exceeds approximately 250 F.



TAYLOR
ROCHESTER N.Y. U.S.A.
CHART
82S444
250
240
230
220
210
200
190
180
170
160
150
COLLECTOR PUMP ON
TEMPERATURE LIMIT EXCEEDED
SOLAR SYSTEM DEACTIVATED
4-6-83

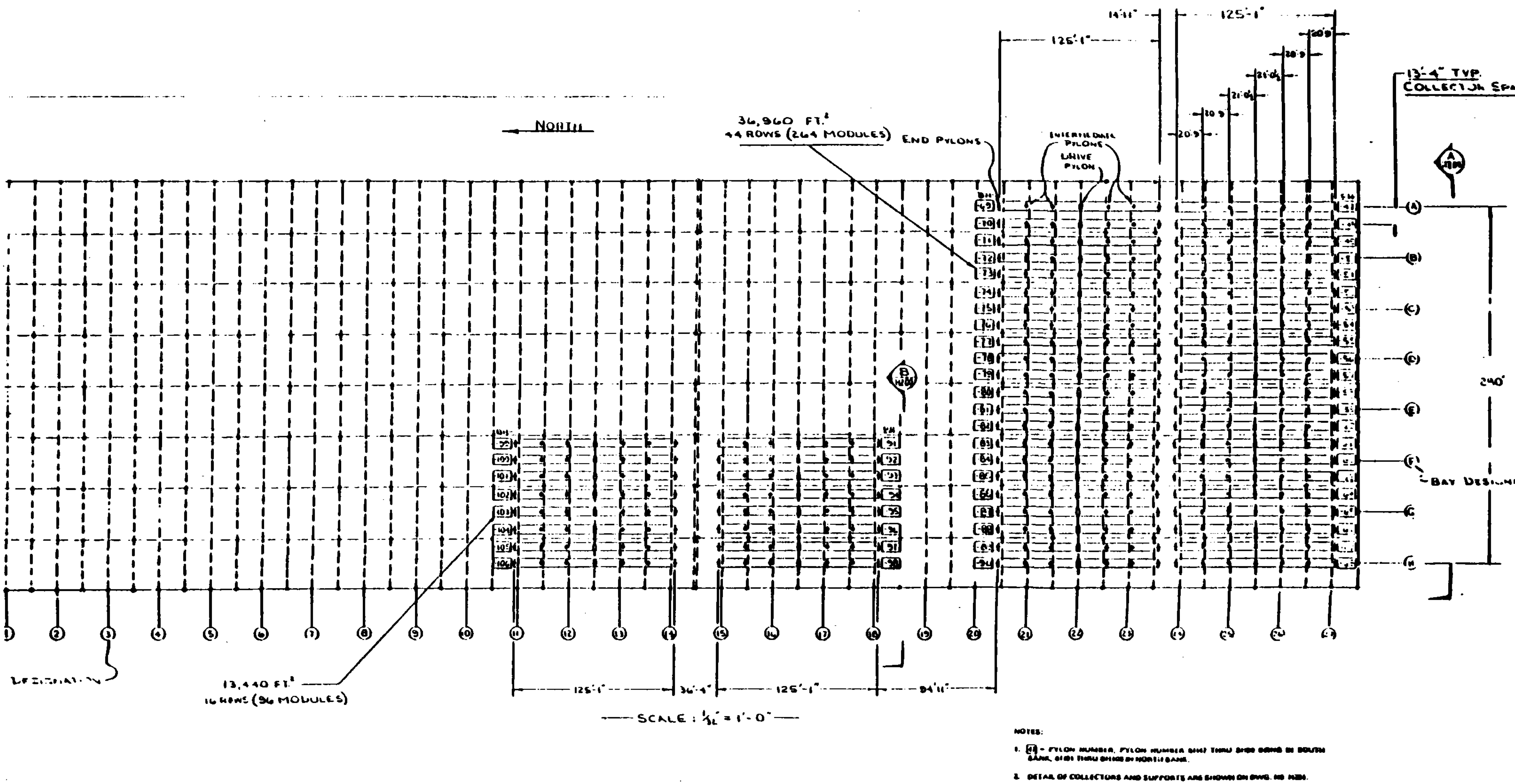
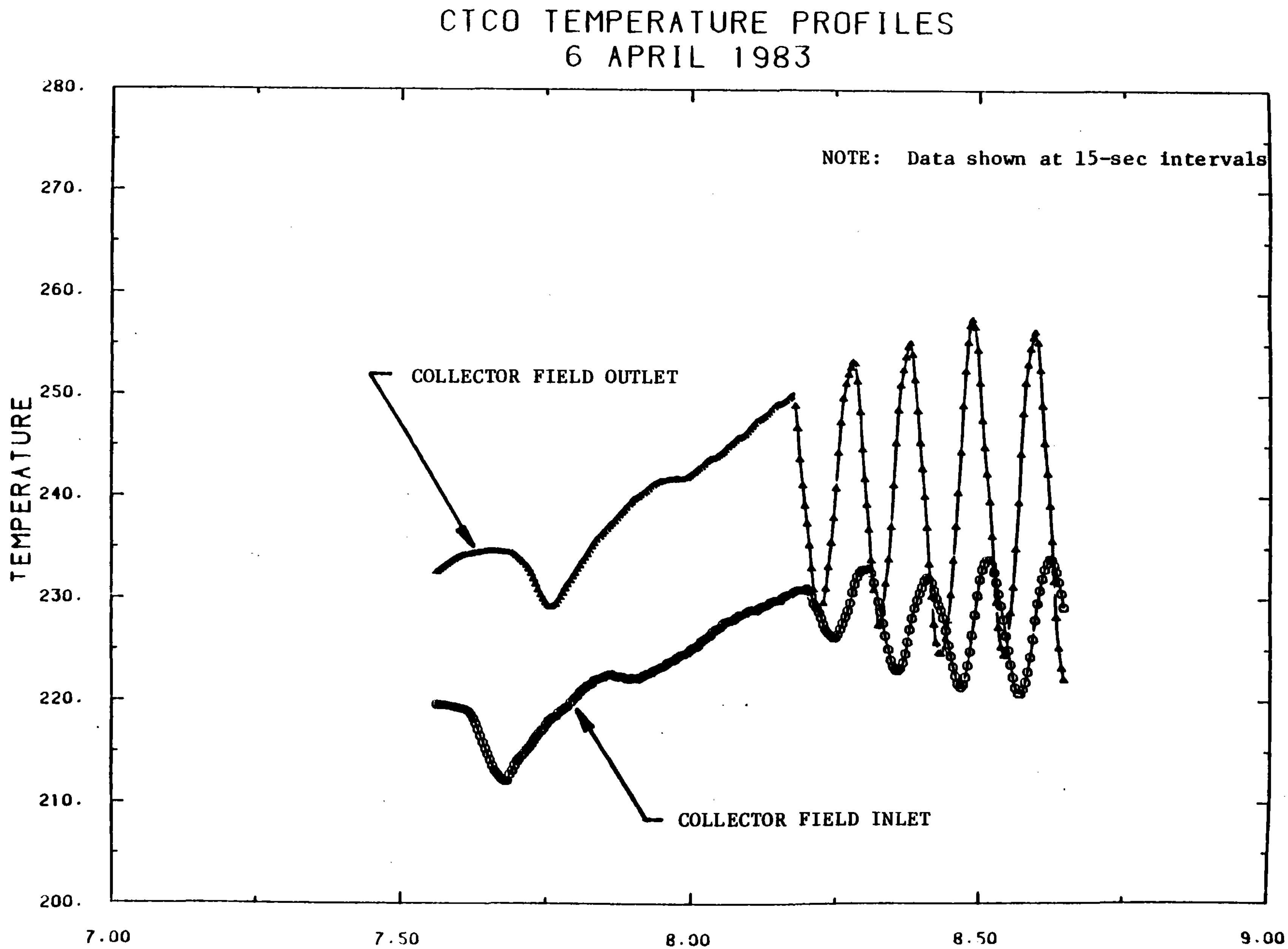


FIGURE 2. COLLECTOR FIELD LAYOUT



CTCO TEMPERATURE PROFILES
6 APRIL 1983
NOTE: Data shown at 15-sec intervals
COLLECTOR FIELD OUTLET
COLLECTOR FIELD INLET
TEMPERATURE
280.
270.
260.
250.
240.
230.
220.
210.
200.
7.00
7.50
8.00
8.50
9.00
TIME OF DAY

FIGURE 4.

At this point, as a safety precaution, a temperature switch is activated which causes the collector central controller to defocus the entire collector field. As the collector outlet temperature decreases below the limit of 250°F, the collectors are allowed to refocus. Since the collector field energy ouput is greater than the plant load, the collector outlet temperature soon exceeds the limit condition again causing the oscillating condition pictures. The period of oscillation is seen to be approximately six minutes. So, in a period of six minutes, the collectors are defocused and then refocused.

Finally, the collector field inlet temperature is seen to oscillate with the same frequency of the collector field outlet temperature. The north collector field outlet connection to the hot water return header is close to the collector pump suction piping connection. At the time the system piping was designed, the hot water return flow was at such a capacity to prevent any recirculation of north field outlet flow directly back into the pump suction piping. At present, the plant load is significantly less than the design condition which leads to the recirculation of fluid through the collector field.

As might be expected, this oscillatory type of operation directly affects the thermal performance of the collector system. It can be seen in Figure 4 that the average temperature difference across the collector field during the oscillating period of operation is much less than the temperature difference during the near steady conditions just prior to the oscillating period. The corresponding transient heat supply is less than that possible during steady state operation.

It is concluded here that the collector field energy output should be decreased to allow the system to achieve more nearly steady state conditions. Although transient operation is not necessarily harmful in itself, the transient operation of the collector drive mechanisms could possibly lead to premature maintenance problems or even failures.

The possibility of deactivating a portion of the collector field is being discussed with CTCo personnel. At the same time, the flow through the field should be decreased to prevent the recirculation problem cited above. Since plant production is expected to increase in the near future, this activity will be postponed until the plant process heat load stabilizes.

IV. System Performance

A. Monthly Summary

Figure 5 and Table 1 show the daily performance of the solar system for the month of March 1983.

It should be noted here that the on-site DAS experienced disk problems between March 1, 1983 and March 10, 1983. The performance results for this period are taken from data gathered by the backup Acurex data logger. From March 11, 1983 the data are from the DEC 11/23 system.

A point should also be made here about the method of measuring the radiation in the plane of the collector. This measurement is made by taking the difference between two total hemispherical pyranometers mounted on a collector mirror parallel to the aperture plane. One of these pyranometers is shaded with a shadow band while the other is fully exposed. In this manner, only the radiation in the collector aperture window is measured whether the collectors are focused or defocused. Considering the oscillatory nature of the collector operation described above, this measure of radiation is truly the radiation "seen" by the collector and not a measure of the available direct radiation.

B. Daily Summary

Figure 6 and Table II show the performance of the solar system for a clear day, March 25. It is seen that the all-day efficiency of the the collector field is 37%. Disregarding the system shut down period from 1400 to 1500, the peak efficiency is 49% for this day.

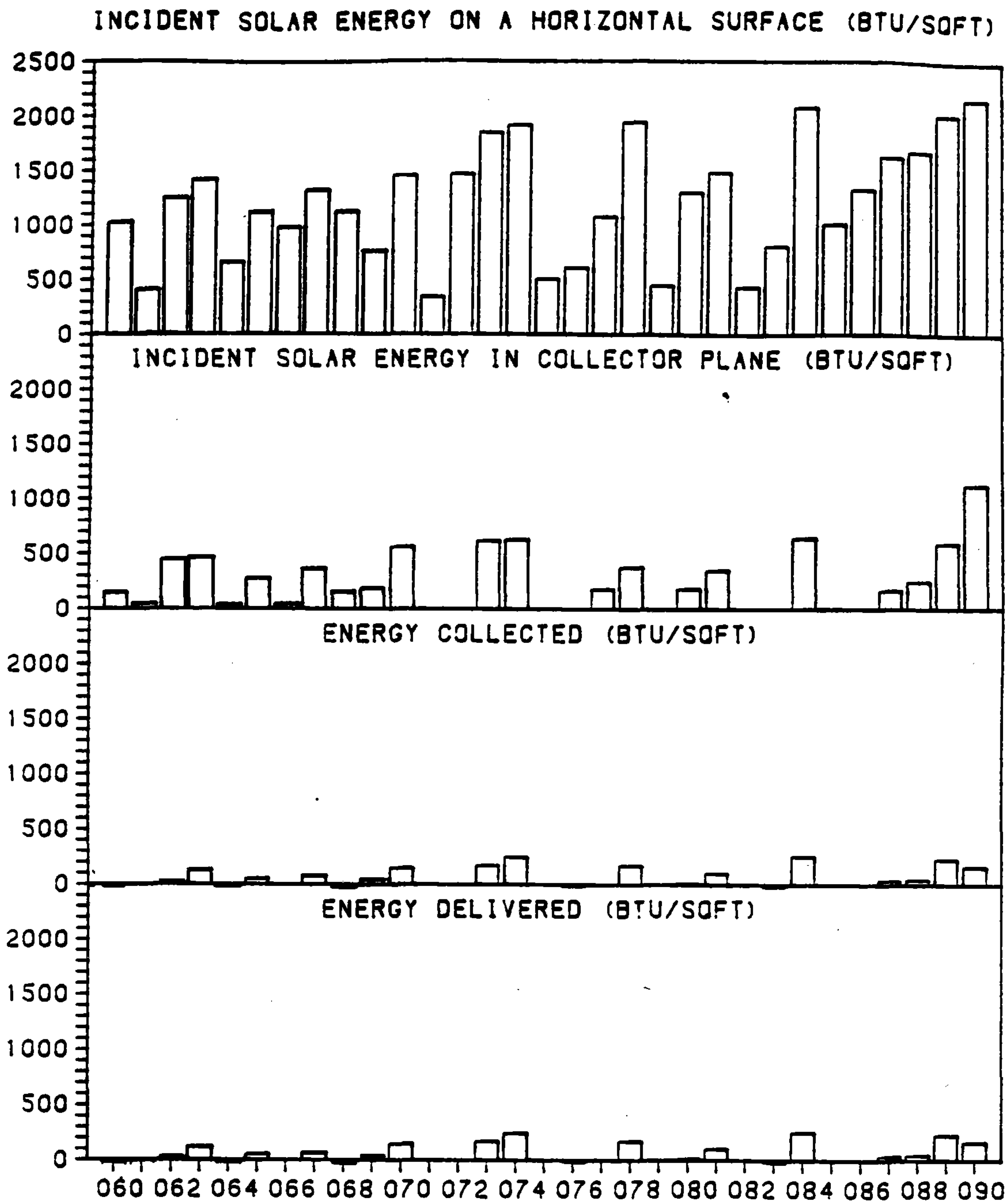


FIGURE 5. MONTHLY PERFORMANCE GRAPH 3-83

TABLE I. MONTHLY PERFORMANCE SUMMARY TABLE - 3/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT	NO. OF CHANCES OF MISSING DATA
60	3/ 1	1010.7	153.6	-24.1	-2.4	-15.7	-24.1	2.7	10.0
61	3/ 2	396.1	42.6	-4.9	-1.2	-11.5	-4.9	1.0	10.0
62	3/ 3	1255.5	478.8	16.6	1.3	3.5	16.6	6.1	10.0
63	3/ 4	1431.8	486.7	135.4	9.5	27.8	135.4	5.7	10.0
64	3/ 5	673.7	50.6	-2.9	-0.4	-5.7	-2.9	0.5	10.0
65	3/ 6	1139.4	273.4	65.6	5.8	24.0	65.6	2.9	10.0
66	3/ 7	970.9	51.5	-13.6	-1.4	-26.5	-13.6	0.4	10.0
67	3/ 8	1268.4	362.9	81.1	6.4	22.4	81.1	5.2	10.0
68	3/ 9	1091.1	264.8	-24.8	-2.3	-9.4	-24.8	3.4	10.0
69	3/10	720.0	273.4	33.1	4.6	12.1	33.1	2.8	10.0
70	3/11	1454.4	566.3	150.7	10.4	26.6	150.7	6.4	0.0
71	3/12	345.0	1.2	0.0	0.0	0.0	0.0	1.0	0.0
72	3/13	1464.7	2.7	0.0	0.0	0.0	0.0	1.1	0.0
73	3/14	1848.6	625.2	174.4	9.4	27.9	174.4	7.9	0.0
74	3/15	1920.6	634.9	249.9	13.0	39.4	249.9	8.5	0.0
75	3/16	504.7	0.4	0.0	0.0	0.0	0.0	0.9	0.0
76	3/17	608.5	4.7	-15.2	-2.5	*****	-15.2	1.6	0.0
77	3/18	1072.0	184.6	4.7	0.4	2.6	4.7	3.9	0.0
78	3/19	1941.9	382.0	173.4	8.9	45.4	173.4	3.4	0.0
79	3/20	448.5	0.0	0.0	0.0	0.0	0.0	0.9	0.0
80	3/21	1298.0	186.9	14.7	1.1	7.9	14.7	3.3	0.0
81	3/22	1484.0	354.5	103.8	7.0	29.3	103.8	5.5	0.0
82	3/23	437.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
83	3/24	808.6	3.2	-23.4	-2.9	*****	-23.4	1.3	0.0
84	3/25	2080.6	648.4	256.7	12.3	39.6	256.7	7.9	0.0
85	3/26	1009.0	1.4	0.0	0.0	0.0	0.0	1.1	0.0
86	3/27	1323.0	0.5	0.0	0.0	0.0	0.0	1.0	0.0
87	3/28	1625.6	170.1	41.4	2.5	24.3	41.4	3.4	0.0
88	3/29	1677.4	248.6	49.2	2.9	19.8	49.2	4.4	0.0
89	3/30	2020.4	599.1	231.7	11.5	38.7	231.7	7.1	0.0
90	3/31	2165.6	1131.5	164.4	7.6	14.5	164.4	6.5	0.0
TOTALS		37528.6	8189.4	1836.9	4.9	22.4	1836.9	109.1	100.0
AVERAGE		1210.6	264.2	59.3			59.3	3.5	

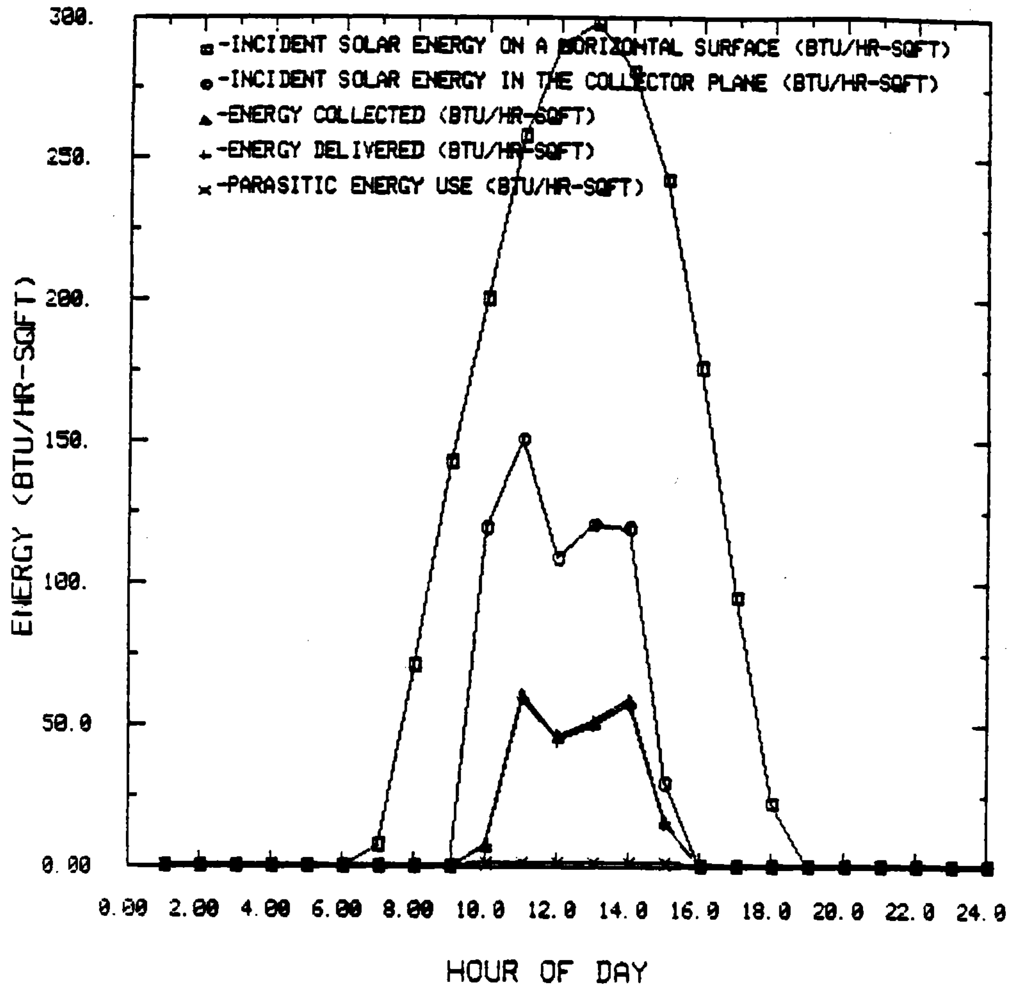


FIGURE 6. CLEAR DAY PERFORMANCE GRAPH 3-25-83

TABLE II. CLEAR DAY PERFORMANCE TABLE - 3/25/83 (JULIAN DAY 84)

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED BTU/HR-FT2	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY BTU/HR-FT2
1.	45.8	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	46.5	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	46.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	46.5	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	44.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	45.4	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	46.2	1.4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.	50.6	3.8	70.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9.	50.6	13.0	142.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10.	53.1	11.8	200.0	119.2	79.6	185.1	179.5	212.7	184.3	181.2	7.8	3.9	6.6	1.1
11.	54.0	11.6	257.4	150.5	117.4	225.2	239.7	327.2	224.6	239.0	60.4	23.5	40.1	1.3
12.	55.1	9.0	289.4	108.5	115.3	228.3	239.1	331.4	227.5	238.3	45.6	15.7	42.0	1.3
13.	58.4	7.9	297.5	120.4	116.8	227.8	238.6	335.2	227.3	239.6	50.8	17.1	42.2	1.3
14.	59.2	7.3	280.3	118.9	117.9	229.0	240.1	339.4	228.2	242.6	58.5	20.9	49.2	1.3
15.	57.3	9.2	242.0	29.2	70.5	157.1	159.4	203.1	156.9	161.1	16.1	6.6	55:0	0.9
16.	57.1	11.1	175.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17.	54.8	13.5	94.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.	52.4	10.2	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
19.	50.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.	49.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.	47.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.	46.5	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	45.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	45.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2079.9	646.6							239.2	11.5	37.0	8.0
AVG	50.3	6.7	173.3	107.8	102.9	208.8	216.0	291.5	208.1	217.0	39.9			0.3

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Department of Mechanical Sciences
June 1, 1983
Monthly Progress Report No. 39
Reporting Period April 16, 1983
through May 13, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The new version of the DAS software was closely monitored. A few minor problems were noted and are being resolved.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Operation is continuing at the site; however, a portion of the field has been deactivated to prevent overheating the plant process heating system. This activity is discussed in the accompanying performance report for April.

Respectfully submitted,

Steven T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT #6

REPORT PERIOD:	April 1, 1983 - April 30, 1983
REPORT NO.:	CTCo-6
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

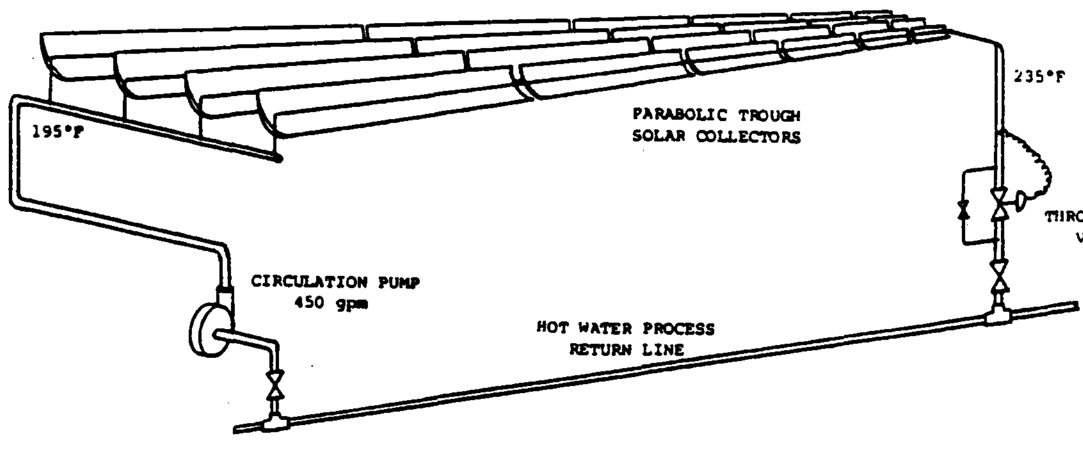

FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The collector system operation was varied throughout the month of April. Table I briefly summarizes this operation. It is seen in Table I that three rows were down with various problems. These failures are all being attended to by the CTCo maintenance staff.

Secondly, it is seen that the field was down for inspection and detailed performance measurements during the period April 5-7. These activities were reported in the previous report, CTCo-5, for March, 1983.

Finally, it is seen that throughout the month, various portions of the collector field were deactivated. This was done in an attempt to decrease the overtemperature situation described in the previous report. The collector rows that were left stowed still had water flowing through them so that full flow was maintained throughout the field. The rationale for this was to keep the collector outlet temperature below the controller limit by mixing the solar heated water with the unheated water.

During May, parts of the collector field will be valved off to decrease the total flow through the field as a further attempt to bring the solar system performance closer to the current plant load. A review of these activities will be presented in a subsequent report.

It can also be seen that the DAS was not operable during April 5-7. The DAS software was updated during this time to make its operation more efficient. No data can be reported during this period.

IV. System Performance

A. Monthly Summary

Figure 2 and Table II show the system performance for the month of April.

It should be noted that the results presented for the collector system energy output are normalized on a unit area basis. These results have been obtained by considering only the operable portion of the collector field which is found in Table I. To determine total energy output from the collector field, the appropriate operable collector area must be taken from Table I.

It can be seen in Table II that the overall system efficiency for April was 32.6%. The system efficiency for March was 22.4%, so a substantial improvement in performance has been attained. This can be attributed to: (1) installation of new central controller light switch to improve the startup sequence, and (2) efforts to bring the system operation closer to steady state.

B. Daily Summary

Figure 3 and Table III show the hourly performance for April 10, 1983.

TABLE I.

CATERPILLAR SOLAR SYSTEM OPERATION

April 1983

Date	Drive Rows Down	Active Area (ft^2)	Comments
1-4	47,81,94	47880	Normal Operation, except: 47-Hydraulic pressure switch failure 81-Row controller failure 94-Hydraulic oil leak
5-7			Field Maintenance - intermittent operation DAS Maintenance - no data
8	47,81,94	47880	Normal operation after 10:00 AM
9-13	47,81,94	47880	Normal operation
14	47,81,94 continuous	47880	Normal operation
	91,106 after 13:00	35280	North field shutdown in attempt to inhibit transient operation, flow maintained throughout entire field
15-24	47,81,94,91,106	35280	Same as 4-14
25	47,94,58-63,80-90	30240	North field activated, one-half of South field deactivated in attempt to inhibit transient operation
26-28	47,94,58-63,80-90	30240	Same as 4-25
29	47,94,59-90	21840	North field activated except row 94, one-fourth of South field (48-58) activated
30	47,94,59-90	21840	Same as 4-29

TABLE II. MONTHLY PERFORMANCE SUMMARY TABLE - 4/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT	NO. OF CHANCES OF MISSING DATA
91	4/ 1	2087.6	473.8	57.5	2.8	12.1	57.5	5.9	0.0
92	4/ 2	2260.1	609.5	81.7	3.6	13.4	81.7	6.0	0.0
93	4/ 3	2353.7	646.2	70.4	3.0	10.9	70.4	5.3	0.0
94	4/ 4	1385.0	523.6	202.6	14.6	38.7	202.6	5.6	0.0
95	4/ 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	4/ 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	4/ 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
98	4/ 8	1684.7	1189.7	284.0	16.9	23.9	284.0	8.0	0.0
99	4/ 9	1042.8	0.2	0.0	0.0	0.0	0.0	0.5	0.0
100	4/10	2175.8	963.1	387.1	17.8	40.2	387.1	6.3	0.0
101	4/11	2006.2	1085.1	324.2	16.2	29.9	324.2	10.7	1.0
102	4/12	1983.3	840.0	245.0	12.4	29.2	245.0	10.1	0.0
103	4/13	2457.2	1381.5	394.2	16.0	28.5	394.2	14.2	0.0
104	4/14	2344.9	534.7	229.7	9.8	43.0	229.7	11.0	1.0
105	4/15	2038.5	0.0	304.4	14.9	*****	304.4	8.9	10.0
106	4/16	1886.6	0.0	6.6	0.4	*****	6.6	1.6	0.0
107	4/17	1279.6	0.0	83.4	6.5	*****	83.4	2.5	0.0
108	4/18	1347.7	0.0	-38.0	-2.8	*****	-38.0	4.7	0.0
109	4/19	971.5	0.0	-10.2	-1.0	*****	-10.2	2.8	0.0
110	4/20	1477.7	0.0	146.4	9.9	*****	146.4	7.3	0.0
111	4/21	1345.3	0.0	54.1	4.0	*****	54.1	3.4	0.0
112	4/22	1172.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
113	4/23	619.3	0.0	0.0	0.0	0.0	0.0	1.1	0.0
114	4/24	1784.1	0.0	145.1	8.1	*****	145.1	3.3	0.0
115	4/25	2428.5	1323.0	178.4	7.3	13.5	178.4	9.8	0.0
116	4/26	2160.3	638.9	170.8	7.9	26.7	170.8	7.9	1.0
117	4/27	1030.7	96.4	-14.7	-1.4	-15.3	-14.7	1.9	0.0
118	4/28	1357.0	238.8	0.9	0.1	0.4	0.9	3.5	0.0
119	4/29	1474.5	403.4	262.7	17.8	65.1	262.7	-0.4	0.0
120	4/30	909.3	0.0	0.0	0.0	0.0	0.0	-8.9	0.0
TOTALS		45063.8	10947.7	3566.4	7.9	32.6	3566.4	134.0	13.
AVG		1669.0	405.5	132.1			132.1	5.0	

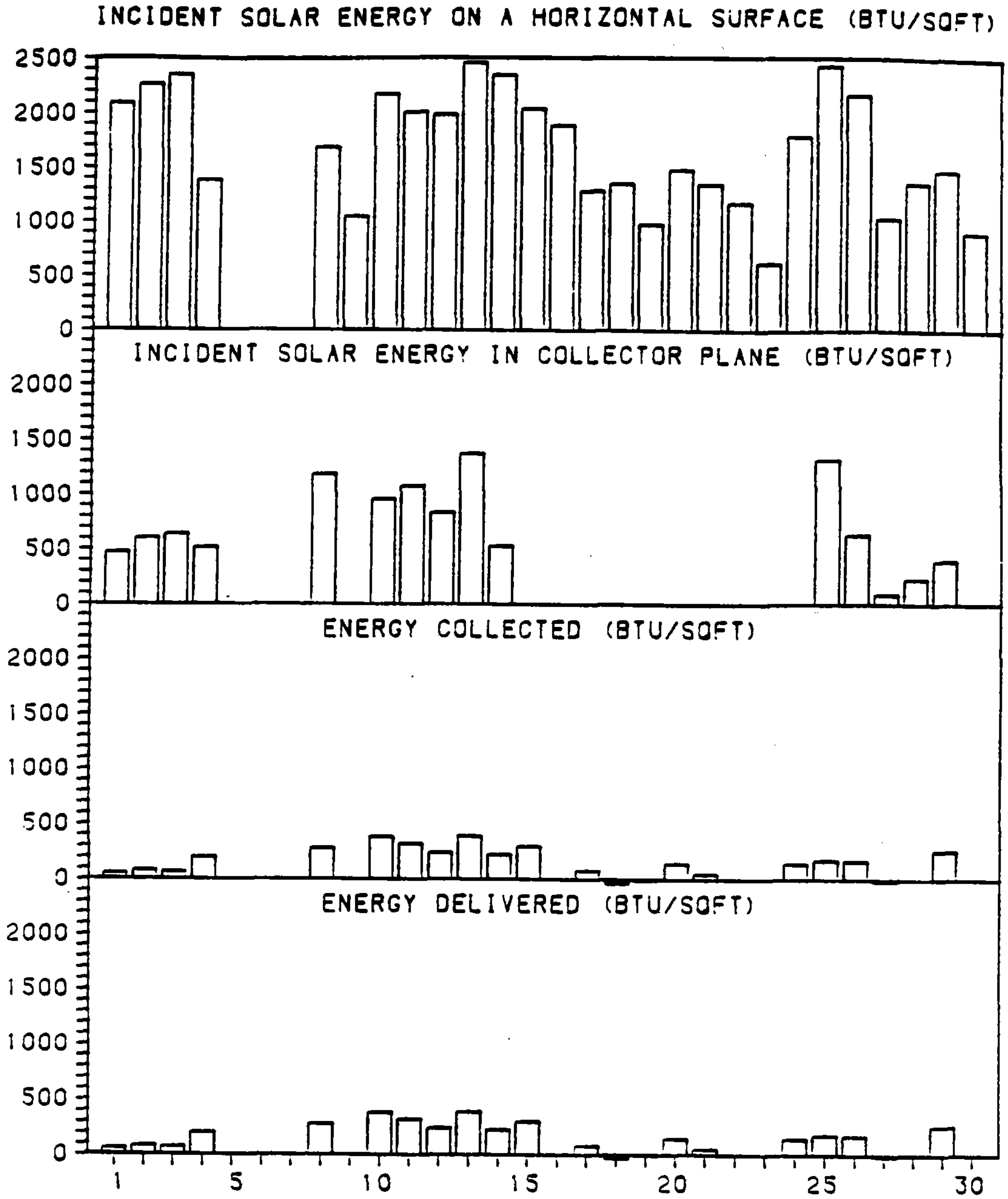

FIGURE 2. MONTHLY PERFORMANCE GRAPH 4-83

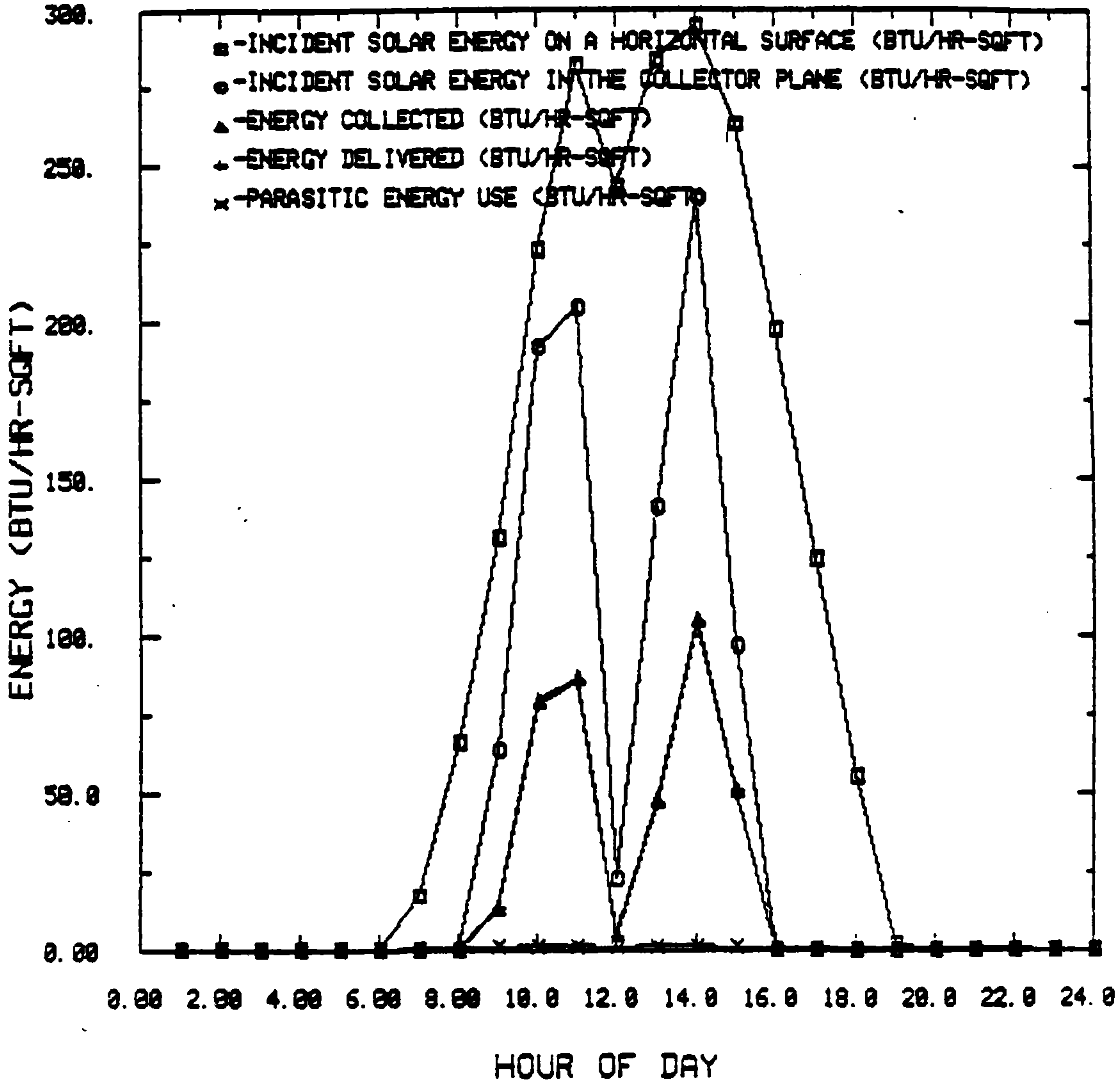

FIGURE 3. CLEAR DAY PERFORMANCE GRAPH 4-10-83

TABLE III. CLEAR DAY PERFORMANCE TABLE - 4/10/83 (JULIAN DAY 100)

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED BTU/HR-FT2	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY BTU/HR-FT2
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	41.2	-0.2	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.	49.6	1.0	65.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.	51.3	7.3	130.6	63.4	55.0	73.4	76.1	83.0	73.0	78.8	13.5	10.4	21.4	0.6
10.	54.4	6.1	222.7	191.4	126.9	149.0	164.3	227.0	149.1	174.6	79.2	35.5	41.4	1.1
11.	53.8	7.5	281.7	204.2	124.6	169.1	186.3	271.6	169.0	192.6	86.4	30.7	42.3	1.2
12.	54.0	7.4	242.6	22.6	34.1	48.3	49.0	70.8	48.3	49.7	4.5	1.9	20.1	0.5
13.	54.8	11.1	283.4	140.7	108.6	163.5	173.6	242.6	163.6	175.4	47.5	16.8	33.7	1.1
14.	55.2	11.4	294.4	239.5	120.3	198.8	219.8	334.5	198.4	222.2	105.1	35.7	43.9	1.2
15.	54.7	12.5	263.0	96.9	47.1	79.6	88.1	147.8	79.3	89.4	50.7	19.3	52.3	0.6
16.	54.2	13.9	197.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
17.	53.0	13.7	124.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
18.	51.0	13.4	55.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.	48.1	13.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.	47.2	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.	46.9	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.	46.9	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2179.8	958.8							386.9	17.7	40.4	6.7
AVG	51.0	9.7	167.7	137.0	88.1	125.9	136.7	196.8	125.8	140.4	55.3			0.4

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
July 12, 1983
Monthly Progress Report No. 40
Reporting Period May 13, 1983
through June 10, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The solar system was closely monitored to observe the effects of operational changes. These changes, described in the accompanying performance report, now allow the solar system to operate in a steady state manner. This mode of operation will allow investigators to more accurately compare performance predictions with actual performance results.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Current operation will continue until long-term changes in the plant heat load require changes in the operation of the collector system.

Respectfully submitted,

Steve Green

Steven T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT #7

REPORT PERIOD:	May 1, 1983 - May 31, 1983
REPORT NO.:	CTCo-7
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

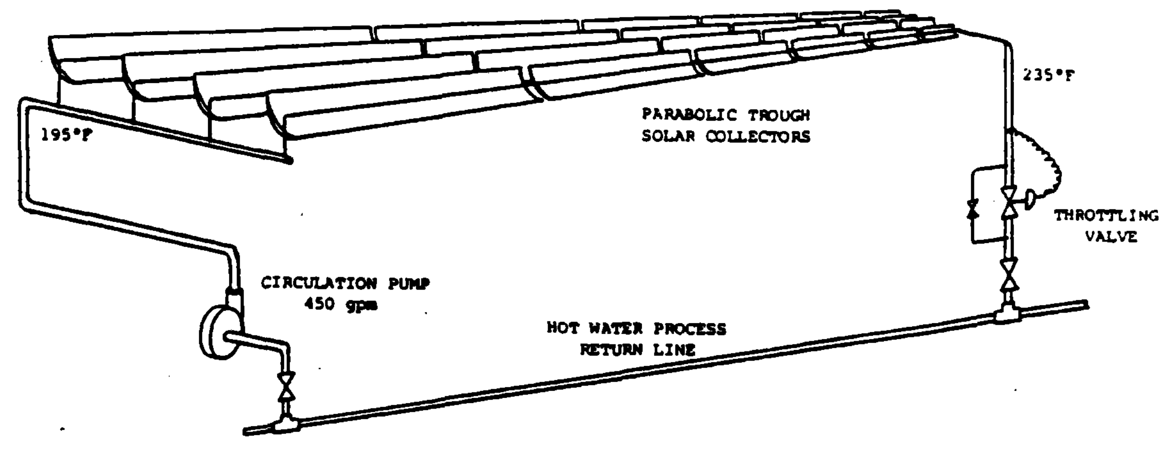


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The operational status of the collector field was changed several times during May in an attempt to prevent the overtemperature problem in the past (see previous monthly reports). During May some DAS problems were experienced and some maintenance items were dealt with as well.

First of all, the operational status of the collector field is summarized in Table I and Figures 2-7. Table I describes the operating scenario and lists the active portion of the total collector area while Figures 2-7 graphically portray the status of each of the 60 collector drive rows. According to CTCo personnel, the overtemperature problem was finally prevented on May 26. The collector field is now operating such that any delta-T strings which are down intentionally do not have any flow through them. It is seen that at present two-thirds of the collector field has been deactivated and isolated to prevent overdriving the plant process heat system.

As plant heat load increases and available solar energy decreases, more delta-T strings will be activated to maintain the portion of the load carried by the collector field.

During the period 5/10 - 5/15, the DAS experienced disk drive problems. At the same time, the tape drive on the backup datalogger was not properly functioning, so that no data at all were collected during this period. The source of the disk drive problem was in software and was resolved on 5/15. A switch failure prevented operation of the datalogger tape drive which was disabled during the remainder of the month.

Finally, the collector field maintenance is summarized in Table II. It is seen that for the period 5/1 - 5/10, up to four drive rows were out of service for maintenance related problems. During the period 5/10 - 5/31, three drive rows were out of service. The drive rows down for maintenance are considered in the active area summary in Table I.

Also shown in Table II are the expenditures to date for maintenance. A record of these costs is being maintained by Caterpillar and represent total expenditures (i.e., labor and materials) by CTCo in maintaining the solar system.

IV. System Performance

A. Monthly Summary

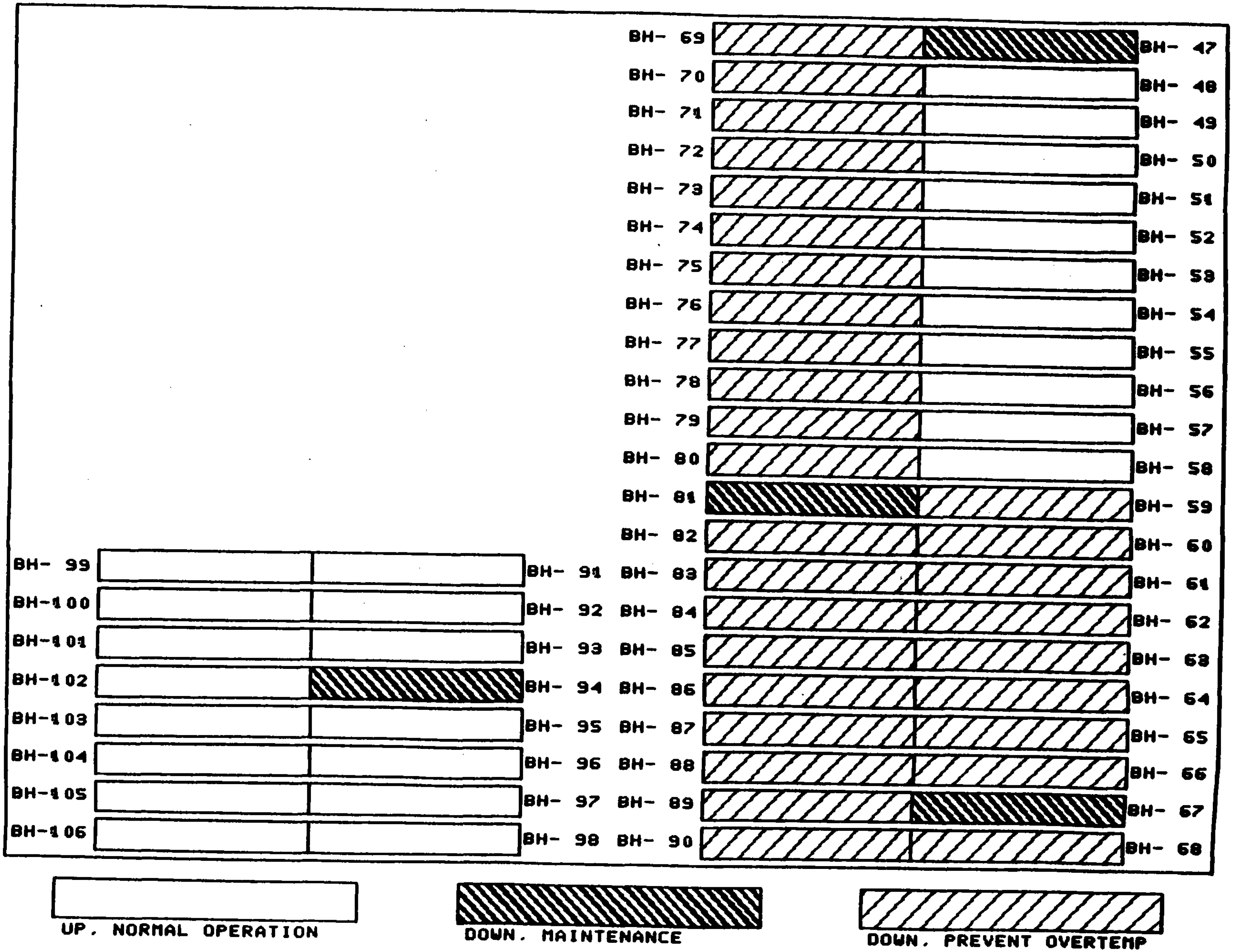
Figure 8 and Table III summarize the performance of the solar system for May 1983. Recall that, at any given time of the month, only a portion of the collector field is active. To determine the total collector field energy ouput the appropriate value for the array active area shown in Table I must be used with the performance results tabulated in Table III.

B. Daily Summary

Figure 9 and Table IV summarize the collector system performance for May 18. As a result of controlling the desteering problem by deactivating portions of the collector field, the performance of the remainder of the field approaches the maximum efficiency possible for this collector model. This can be seen by reviewing the efficiency values listed in Table IV.

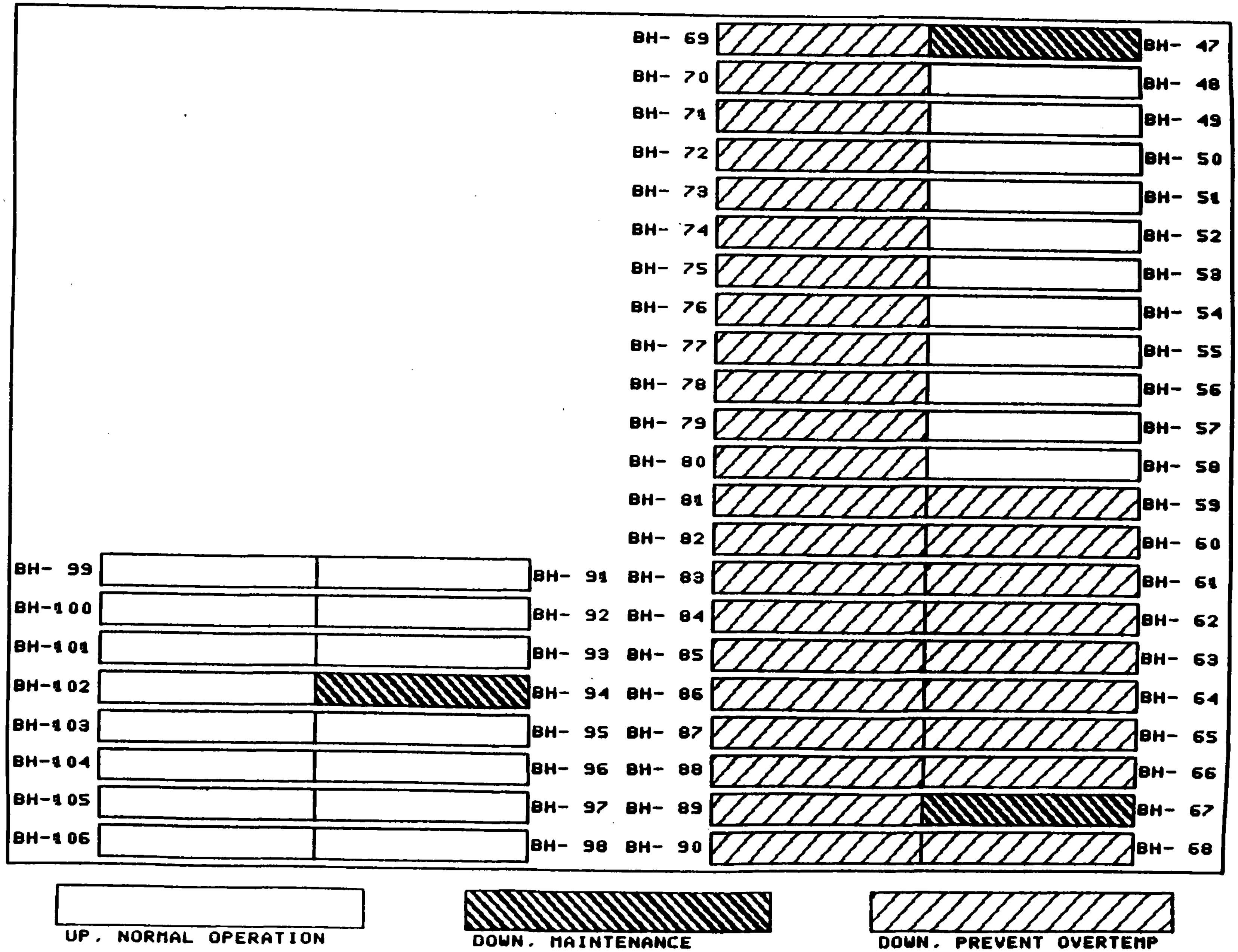
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
May 1983

Date	Active Area (ft^2)	Comments
1-12	21840	South Field: 11 drive rows up North Field: 15 drive rows up Full flow to entire field.
13	25200	South Field: 15 drive rows up, no flow to down delta-T strings. North Field: 15 drive rows up, full flow.
14-18	25200	Same as 5/13
19	20160	South Field: 9 drive rows up, no flow to down delta-T strings. North Field: 15 drive rows up, full flow.
20-22	20160	Same as 5/19
23	21840	South Field: 11 drive rows up, no flow to down delta-T strings. North Field: 15 drive rows up, full flow.
24-25	21840	Same as 5/23
26	15960	South Field: 11 drive rows up, no flow to down delta-T strings. North Field: 8 drive rows up, no flow to down delta-T strings.
27-31	15960	Same as 5/26



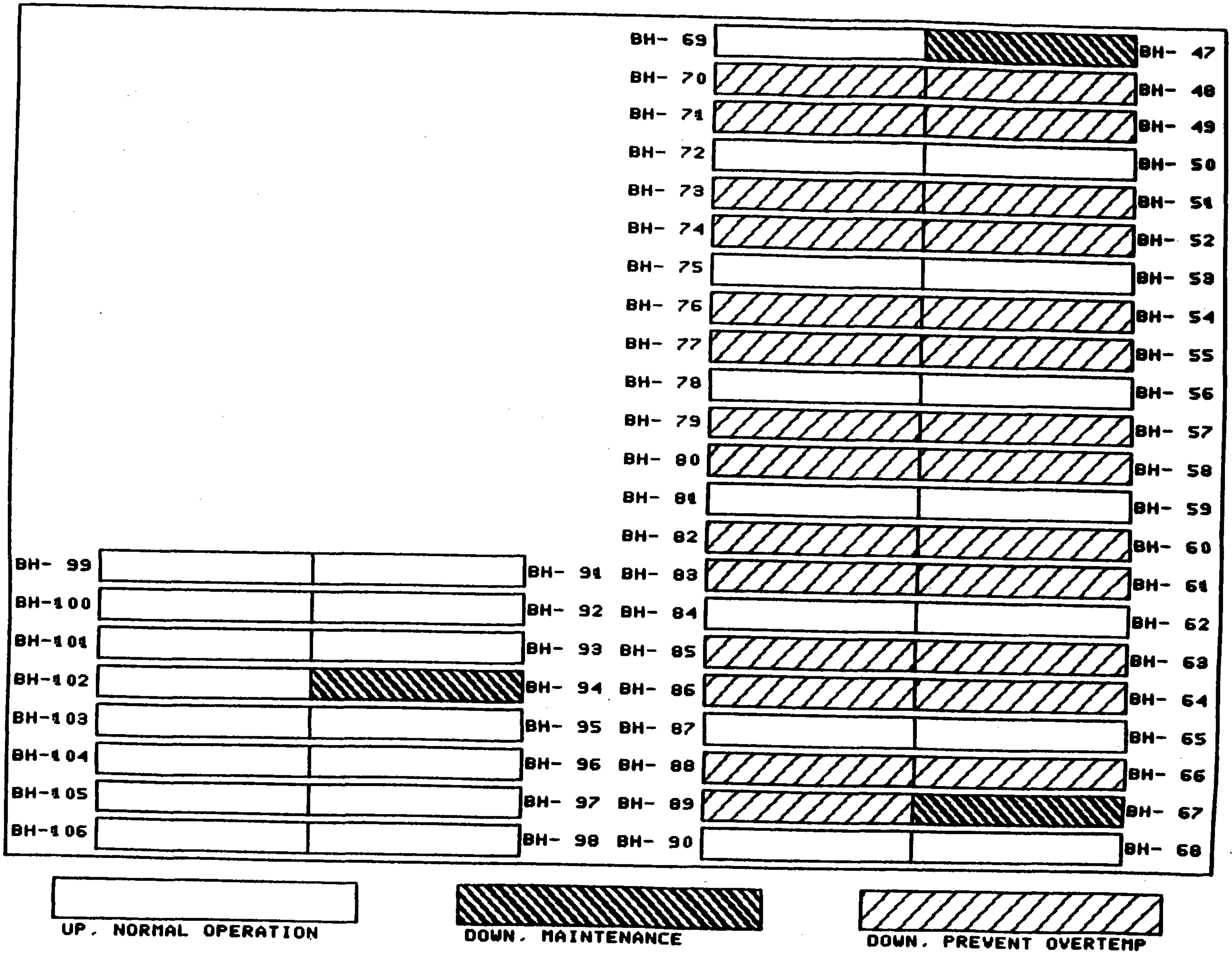
TIME PERIOD: MAY 1-10

FIGURE 2. COLLECTOR DRIVE ROW STATUS



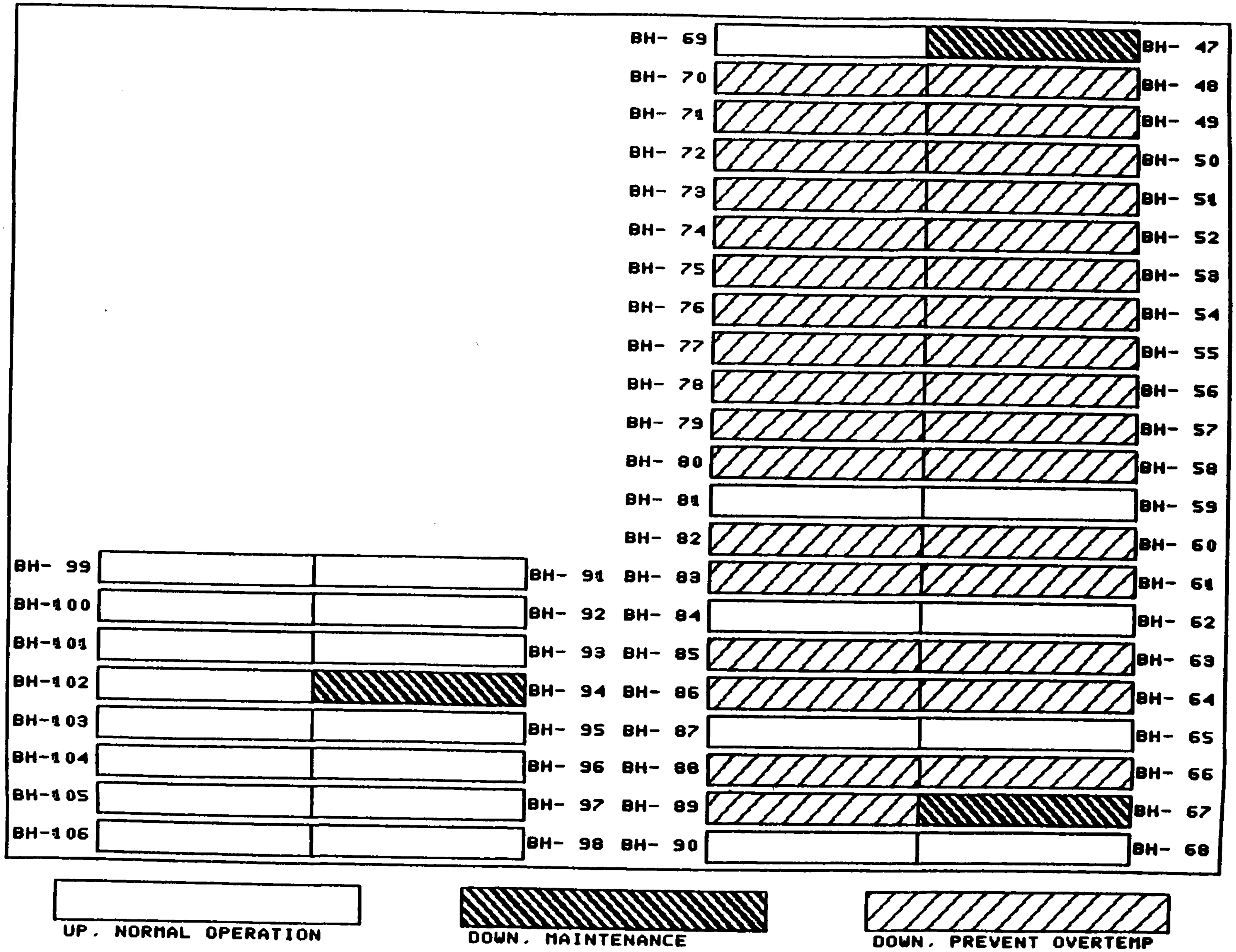
TIME PERIOD: MAY 11-12

[redacted] GUR [redacted] C [redacted] ECT [redacted] RIV [redacted] W S [redacted] S [redacted]



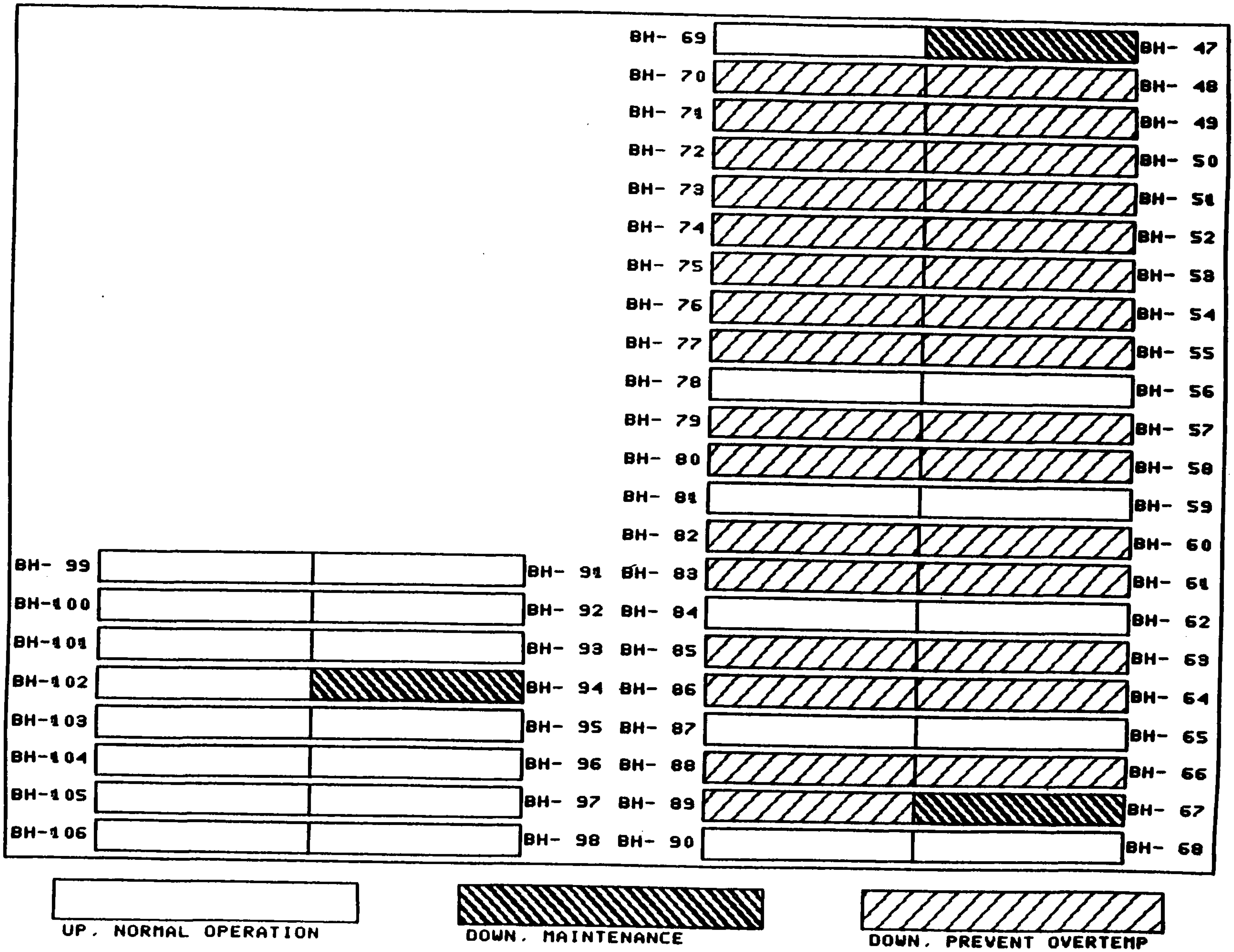
TIME PERIOD: MAY 13-18

FIGURE 4. COLLECTOR DRIVE ROW STATUS



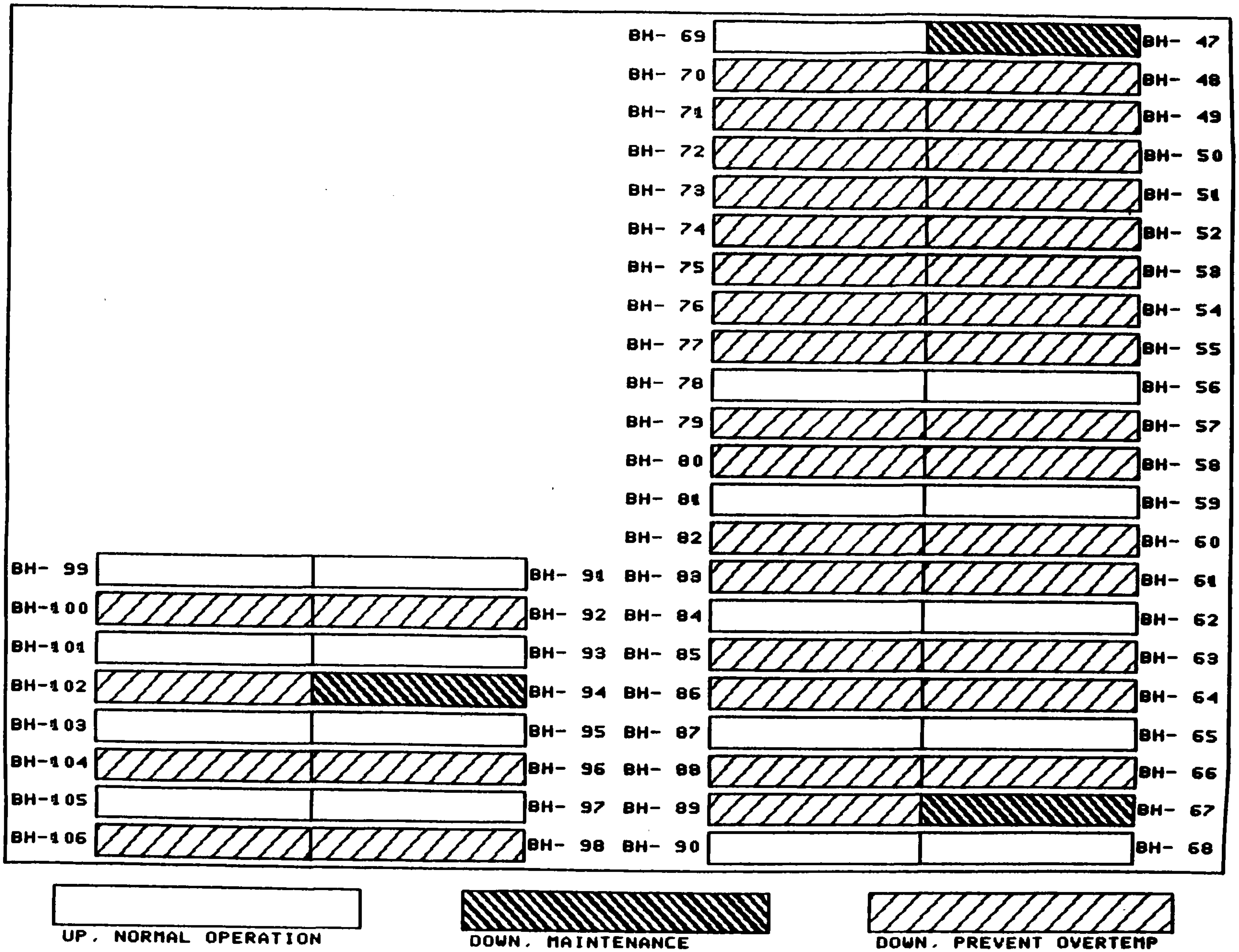
TIME PERIOD: MAY 19-22

FIGURE 5. COLLECTOR DRIVE ROW STATUS



TIME PERIOD: MAY 23-25

FIGURE 6. COLLECTOR DRIVE ROW STATUS



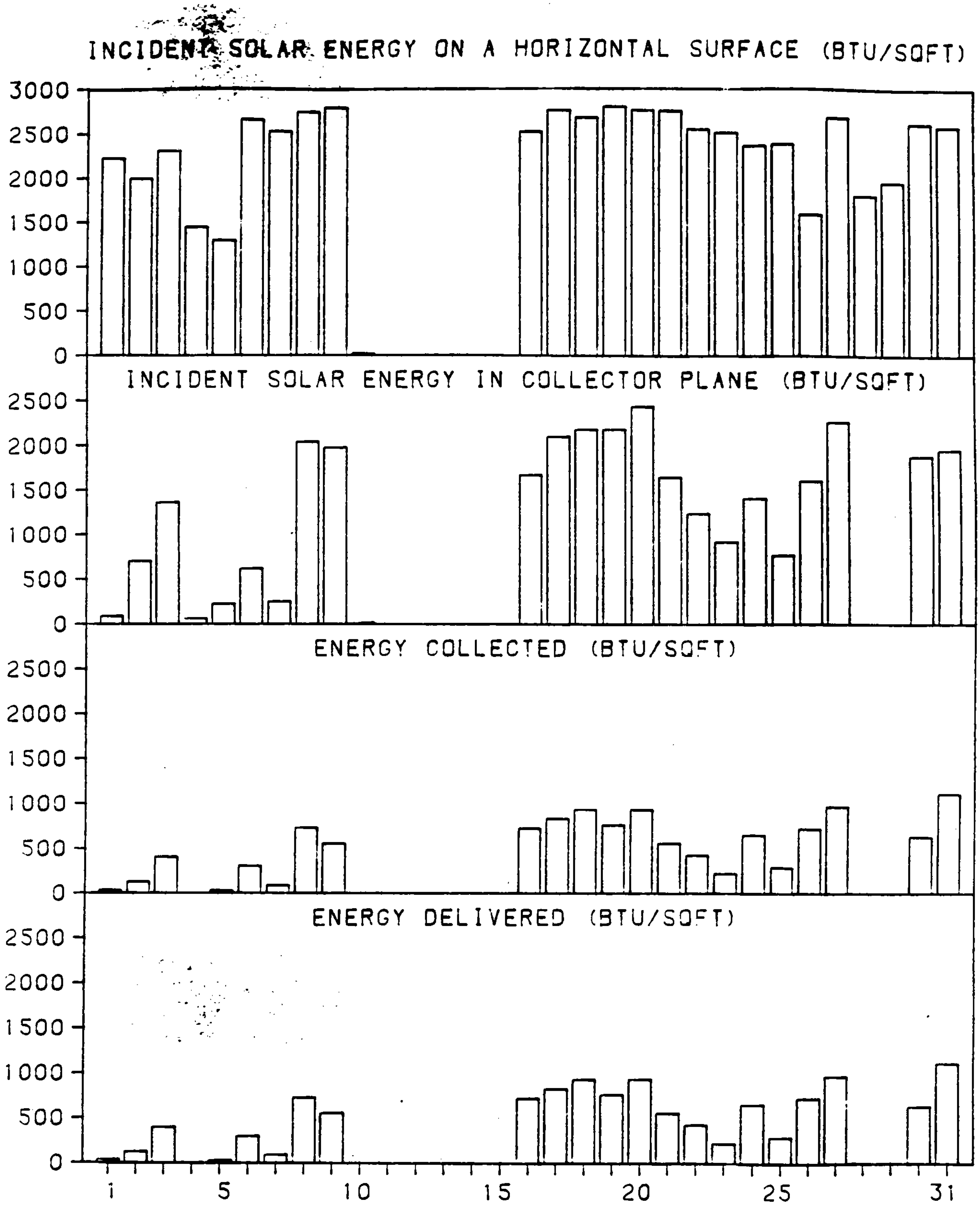
TIME PERIOD: MAY 26-31

FIGURE 7. COLLECTOR DRIVE ROW STATUS

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY

Drive Row	Date	Observation/Action
BH-81	5/10	24 V transformer repaired, row returned to service.
BH-94	5/10	Oil leak repaired, tracker head failure, row left out of service.
BH-47	4/7	Pressure switch failure, row still out of service during May 1983.
BH-67	5/10	Pressure switch failure, row out of service before 5/10.

Maintenance expenditures, May 1983: $1053.24
Maintenance expenditures, February-May, 1983: $2456.11



MONTHLY PERFORMANCE GRAPH 5-83

FIGURE 8

TABLE III. MONTHLY PERFORMANCE SUMMARY TABLE - 5/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT
121	5/ 1	2232.3	95.5	38.1	1.7	39.9	38.1	1.2
122	5/ 2	2000.4	707.4	129.5	6.5	18.3	129.5	5.2
123	5/ 3	2314.0	1366.8	407.1	17.6	29.8	407.1	6.6
124	5/ 4	1450.0	70.7	14.7	1.0	20.8	14.7	1.7
125	5/ 5	1300.1	232.8	35.8	2.8	15.4	35.8	3.2
126	5/ 6	2667.0	625.5	306.6	11.5	49.0	306.6	10.3
127	5/ 7	2538.0	259.2	93.2	3.7	36.0	93.2	5.4
128	5/ 8	2753.0	2045.2	734.7	26.7	35.9	734.7	8.7
129	5/ 9	2797.8	1982.3	561.5	20.1	28.3	561.5	11.1
130	5/10	26.8	21.6	0.5	2.0	2.4	0.5	0.2
131	5/11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
132	5/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
133	5/13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
134	5/14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
135	5/15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
136	5/16	2520.5	1674.6	728.8	28.9	43.5	728.8	8.1
137	5/17	2760.2	2103.8	835.0	30.3	39.7	835.0	10.2
138	5/18	2682.2	2182.6	939.5	35.0	43.0	939.5	9.5
139	5/19	2800.6	2185.5	768.8	27.4	35.2	768.8	7.8
140	5/20	2762.5	2441.5	940.2	34.0	38.5	940.2	8.8
141	5/21	2755.4	1649.7	564.1	20.5	34.2	564.1	6.4
142	5/22	2552.6	1245.2	434.1	17.0	34.9	434.1	4.5
143	5/23	2516.9	923.2	227.7	9.0	24.7	227.7	4.5
144	5/24	2370.3	1410.8	624.1	26.3	44.2	624.1	5.1
145	5/25	2390.3	774.7	268.2	11.2	34.6	268.2	3.9
146	5/26	1592.2	1602.6	723.1	45.4	45.1	723.1	5.4
147	5/27	2688.8	2264.9	926.5	34.5	40.9	926.5	8.0
148	5/28	1807.5	0.6	0.0	0.0	0.0	0.0	0.0
149	5/29	1953.3	0.0	0.0	0.0	0.0	0.0	0.0
150	5/30	2621.8	1881.2	633.7	24.2	33.7	633.7	6.3
151	5/31	2587.0	1948.1	1057.9	40.9	54.3	1057.9	7.3
TOTALS		59413.8	31673.8	11992.9	20.2	37.8	11992.9	149.4
AVG		2376.6	1377.1	521.4			521.4	6.2

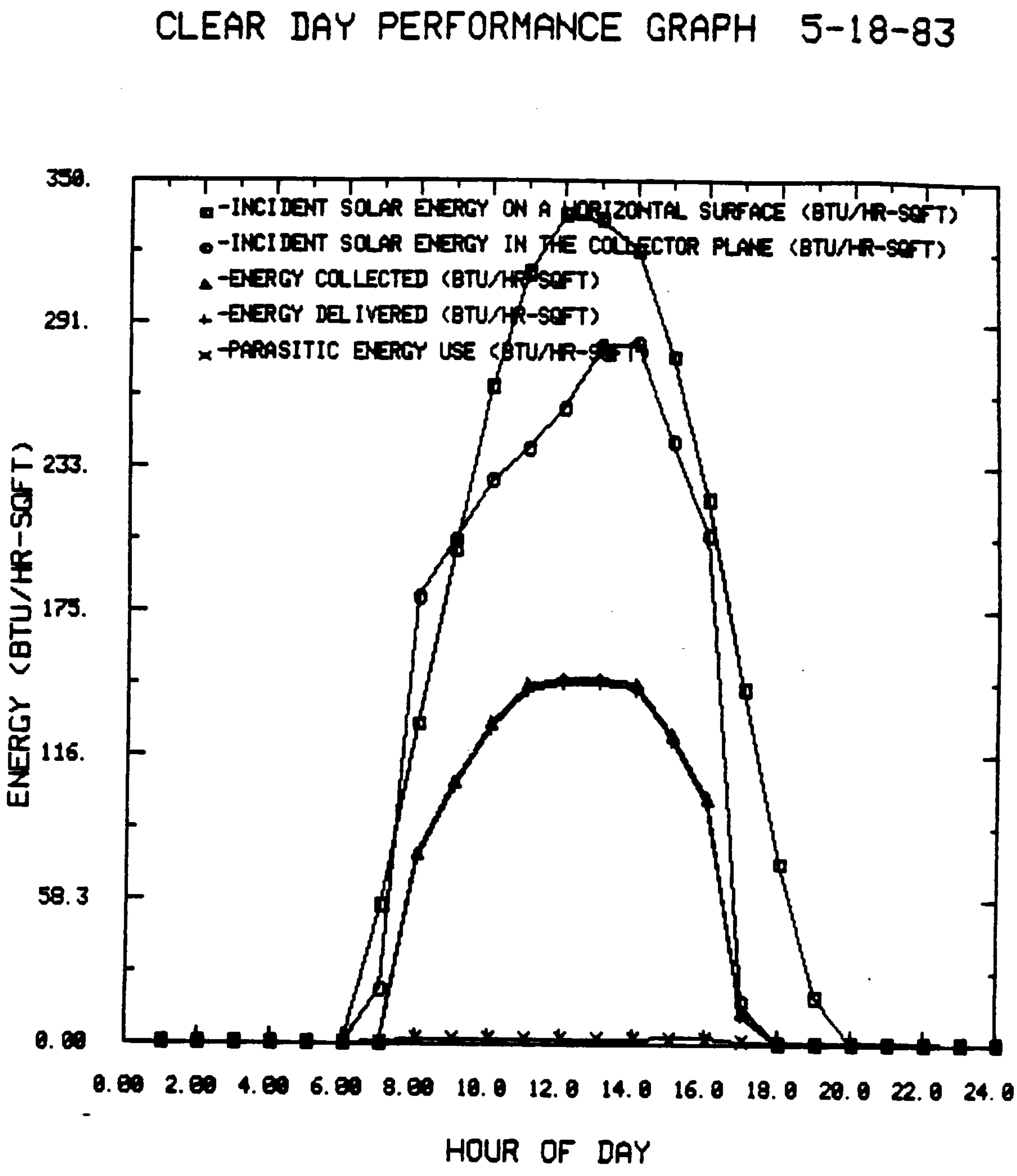

CLEAR DAY PERFORMANCE GRAPH 5-18-83
-INCIDENT SOLAR ENERGY ON A HORIZONTAL SURFACE (BTU/HR-SQFT)
-INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (BTU/HR-SQFT)
-ENERGY COLLECTED (BTU/HR-SQFT)
-ENERGY DELIVERED (BTU/HR-SQFT)
-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
291.
233.
175.
116.
58.3
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 9

TABLE IV. CLEAR DAY PERFORMANCE TABLE - 5/18/83 (JULIAN DAY 138)

HOUR	AMB TEMP F	WIND SPD MPH	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/HR-FT2	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/HR-FT2	NORTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	NORTH FIELD: COLLECTOR ARRAY TEMP IN F	NORTH FIELD: COLLECTOR ARRAY TEMP OUT F	SOUTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	SOUTH FIELD: COLLECTOR ARRAY TEMP IN F	SOUTH FIELD: COLLECTOR ARRAY TEMP OUT F	TOTAL SYSTEM: ENERGY COLLECTED BTU/HR-FT2	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (1) %	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (2) %	TOTAL SYSTEM: PARASITIC ENERGY BTU/HR-FT2
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	56.6	0.8	55.2	21.5	24.8	194.1	132.3	26.3	182.5	129.7	-7.8	-14.1	-36.3	0.4
8.	69.4	2.7	128.8	180.0	135.0	220.9	230.3	176.6	220.0	229.9	76.3	59.2	42.4	1.9
9.	72.9	2.9	199.3	203.4	135.7	222.2	238.8	178.1	221.9	236.2	105.4	52.9	51.8	1.9
10.	73.5	4.0	265.1	227.2	136.2	226.5	245.9	179.4	225.6	242.8	129.0	48.7	56.8	1.9
11.	74.1	4.2	311.9	240.3	136.6	231.8	253.2	181.6	230.9	250.7	144.8	46.4	60.3	1.9
12.	76.4	4.9	335.3	257.0	136.4	232.1	253.5	180.0	231.2	251.7	147.2	43.9	57.3	1.9
13.	76.6	8.1	333.1	281.7	135.9	232.2	253.6	179.1	231.7	251.9	147.3	44.2	52.3	1.9
14.	76.0	9.0	321.0	283.2	135.6	228.3	248.3	179.3	227.2	246.5	145.2	45.2	51.3	1.9
15.	75.2	9.4	277.6	242.9	135.2	230.8	247.9	177.4	230.1	247.1	124.5	44.8	51.3	2.0
16.	73.5	9.4	219.7	205.3	135.1	237.5	250.6	177.3	236.6	250.2	99.3	45.2	48.4	2.1
17.	71.5	8.6	142.7	16.3	49.0	229.2	227.6	63.9	230.0	231.5	12.3	8.6	75.5	0.8
18.	70.8	6.6	72.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.	66.9	7.1	18.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.	60.9	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.	59.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.	59.4	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2680.8	2158.8							1123.4	41.9	52.0	18.9
AVG	69.6	6.1	206.2	196.3	117.8	226.0	234.7	154.4	224.3	233.5	102.1			1.2

SOUTHWEST RESEARCH INSTITUTE

POST OFFICE DRAWER 28510 • 6220 CULEBRA ROAD • SAN ANTONIO, TEXAS, USA 78284 • (512) 684-5111•TELEX 76-7357

Department of Mechanical Sciences
July 20, 1983
Monthly Progress Report No. 41
Reporting Period June 11, 1983
through July 8, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The solar system operated smoothly for the month of June with only minor problems being observed. These are described in the accompanying performance report.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Current operation will continue until long-term changes in the plant heat load require changes in the operation of the collector system. A site visit is being planned for early August to check the DAS calibration and operation. This activity will be coordinated with the CTCo plant personnel.

Respectfully submitted,

Steven T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT No. 8

REPORT PERIOD:	June 1, 1983 - June 30, 1983
REPORT NO.:	CTCo-8
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

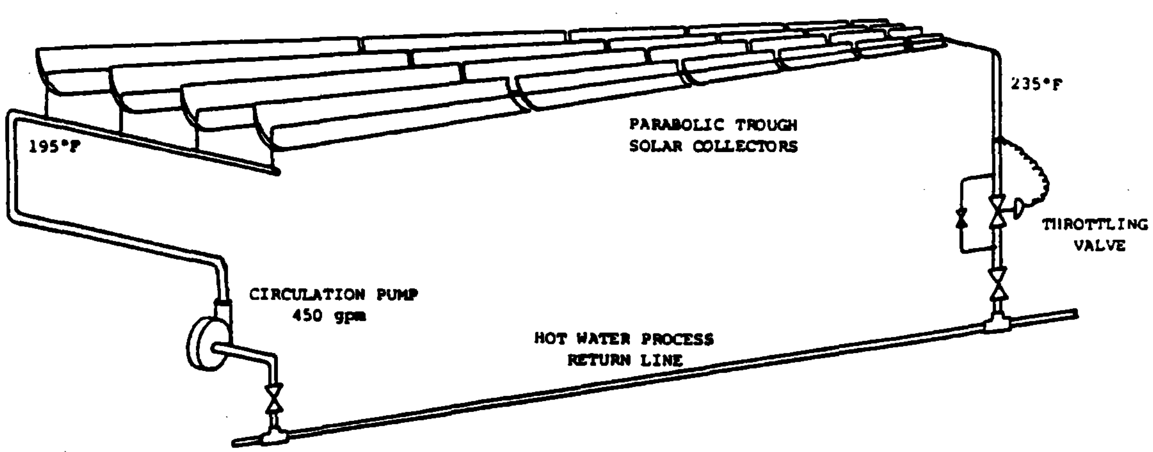


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system operated in much the same configuration as during the latter part of May, with changes being made in the maintenance status of some of the rows. The DAS again experienced problems in June.

Table I and Figures 2-4 summarize the operation of the collector field for June 1983. It was found that the collector operation mode for the month of June prevented the over-temperature and defocusing problems; therefore, the current status will be maintained until the plant heat load warrants the use of an additional portion of the field.

It should be noted that on June 23 and June 30 it was discovered that most of the active collectors had missed focusing on the sun at start-up. The central controller light switch was adjusted on both occasions in attempts to prevent future occurrences.

Table II summarizes the maintenance activity for June. Of the current maintenance problems, the ones related to the hydraulic circuit are the most troublesome. Because the hydraulic oil being used attacks the roofing material, CTCo plant personnel are sensitive to any leak problems. It is hoped that the petroleum based oil can be replaced by a water based hydraulic fluid to prevent damage to the roof material. This upgrade is being investigated by CTCo and SwRI personnel.

The summary in Table II also reveals that two glass receiver tube covers have recently been chipped. It is hoped that these are isolated problems; however, this situation shall be closely monitored so that a more widespread problem, if present, can be prevented.

The DAS experienced data disk problems in June. This was due to the installation of a bad disk for the period June 3 to June 16. The performance results reported below for this period have been rehabilitated from data taken by the backup datalogger. The datalogger, however, was using a faulty flowmeter in the south field flow loop so that the flow in the south field had to be estimated from the north field flow rate. It is seen that at other times of the month, the relation between the north and south field flow rates is very consistent; therefore, it is assumed that the performance reported for June 3 to June 16 is a sound estimate. This flowmeter is backed up by a redundant flowmeter; unfortunately, only the computer is connected to both sensors. It is difficult to assess the accuracy of these results, but are presented rather than providing no results at all during this 13 day period.

IV. System Performance

A. Monthly Summary

Table III and Figure 5 summarize the performance of the collector field for June 1983. As indicated in Table IV, the efficiency results for June 9, June 14, and June 17 are in error. This is due to incorrect measurements of the collector plane radiation for those three days. A review of the detailed data reveal that the readings for the remainder of the month are acceptable. This is an intermittent problem that will be more closely monitored.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
June 1983

Date	Active Area (ft^2)	Comments
6/1-6/7	15960	South Field: 11 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
6/8-6/13	16800	South Field: 12 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
6/14-6/30	15960	South Field: 11 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
6/23	-	Most of active rows missed focusing at startup.
6/30	-	75% of active rows missed focusing at startup.

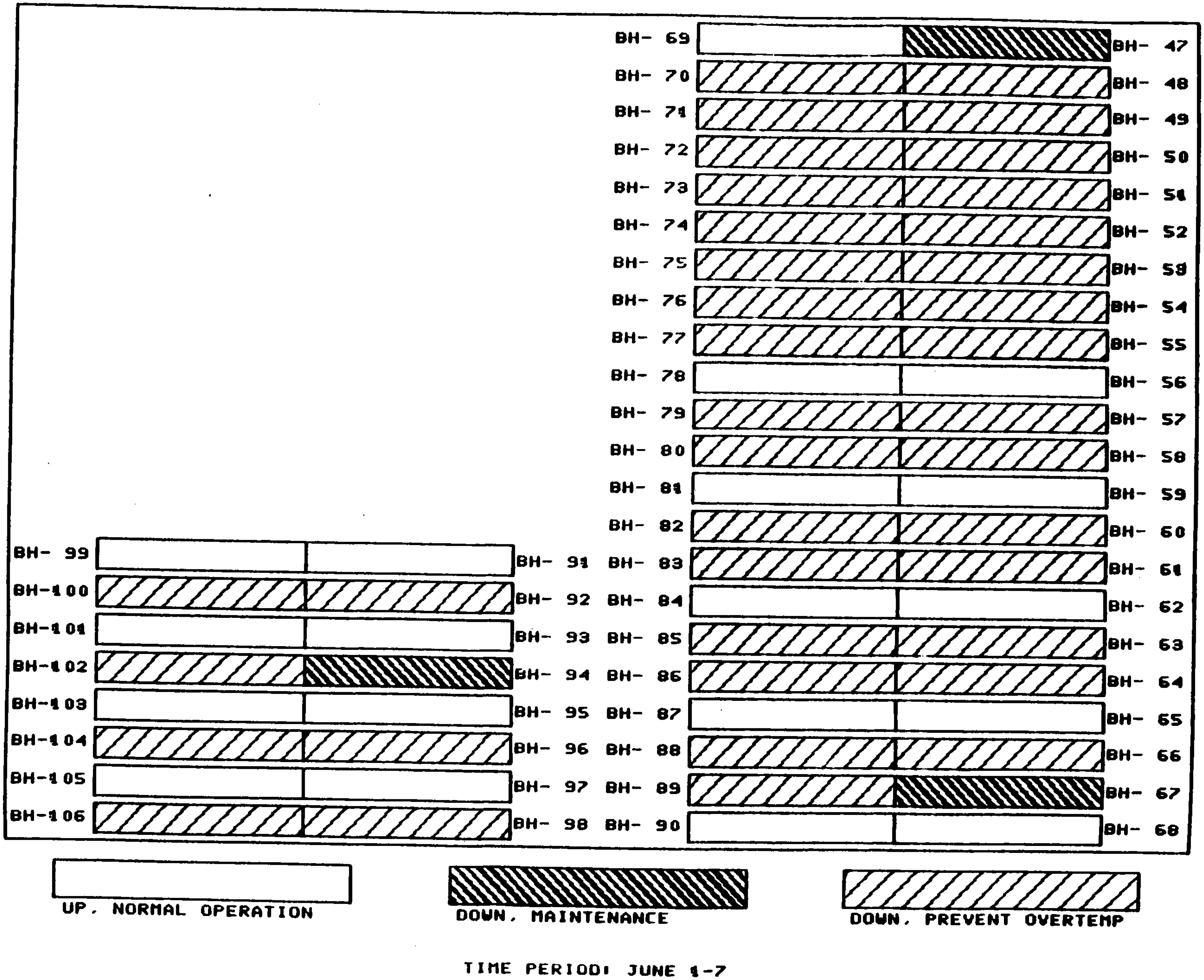
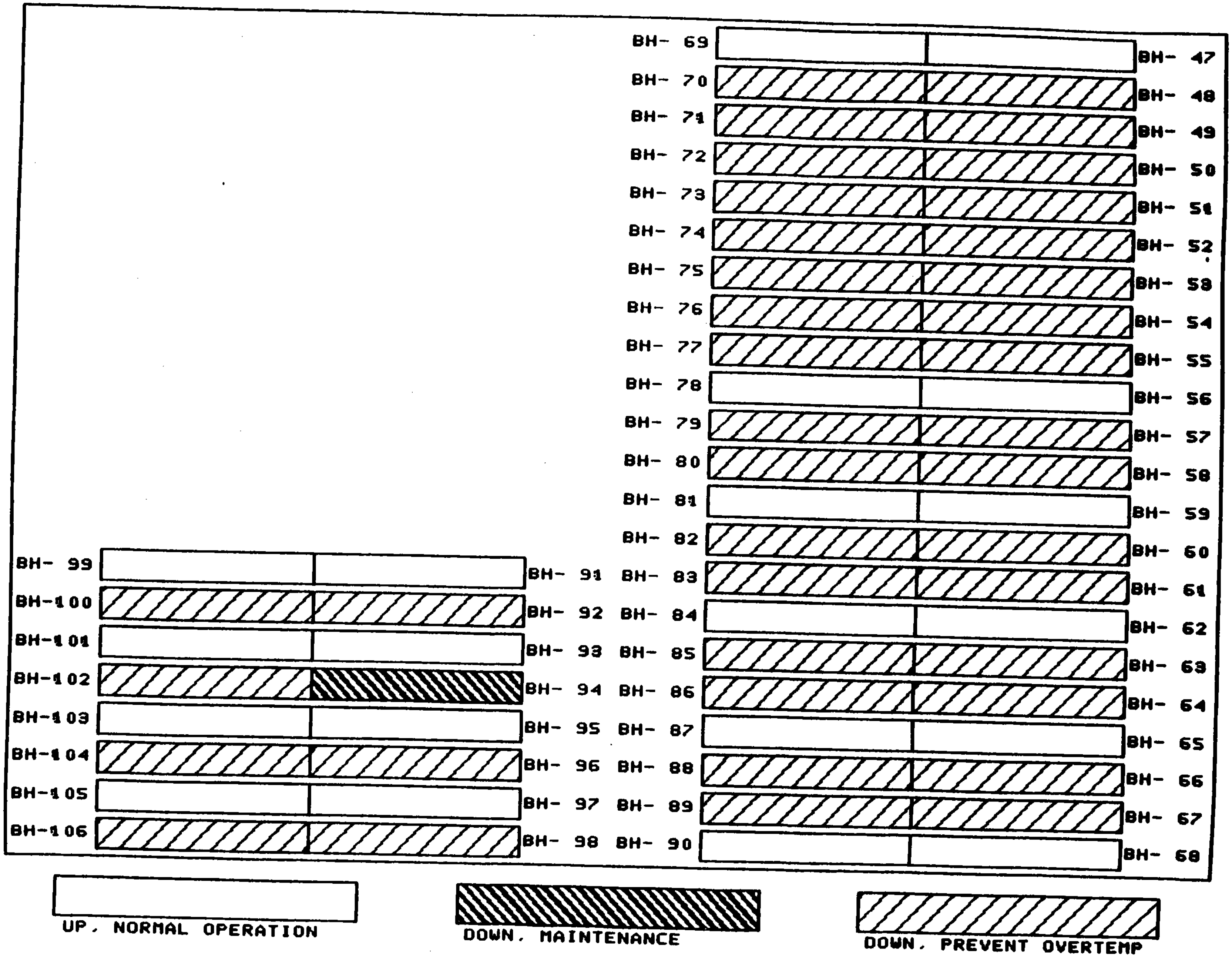


FIGURE 2. COLLECTOR DRIVE ROW STATUS



TIME PERIOD: JUNE 8-13

FIGURE 3. COLLECTOR DRIVE ROW STATUS

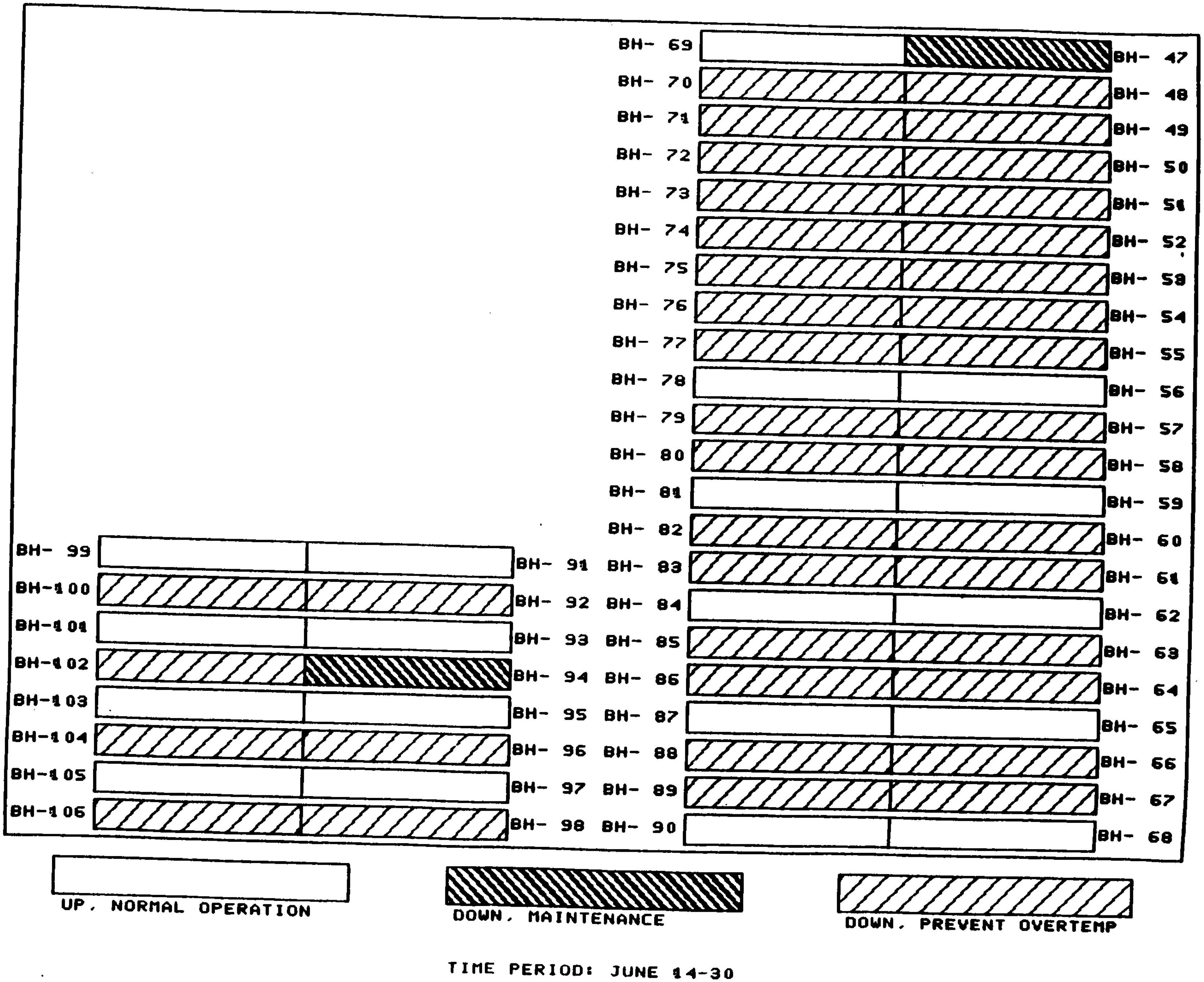


FIGURE 4. COLLECTOR DRIVE ROW STATUS

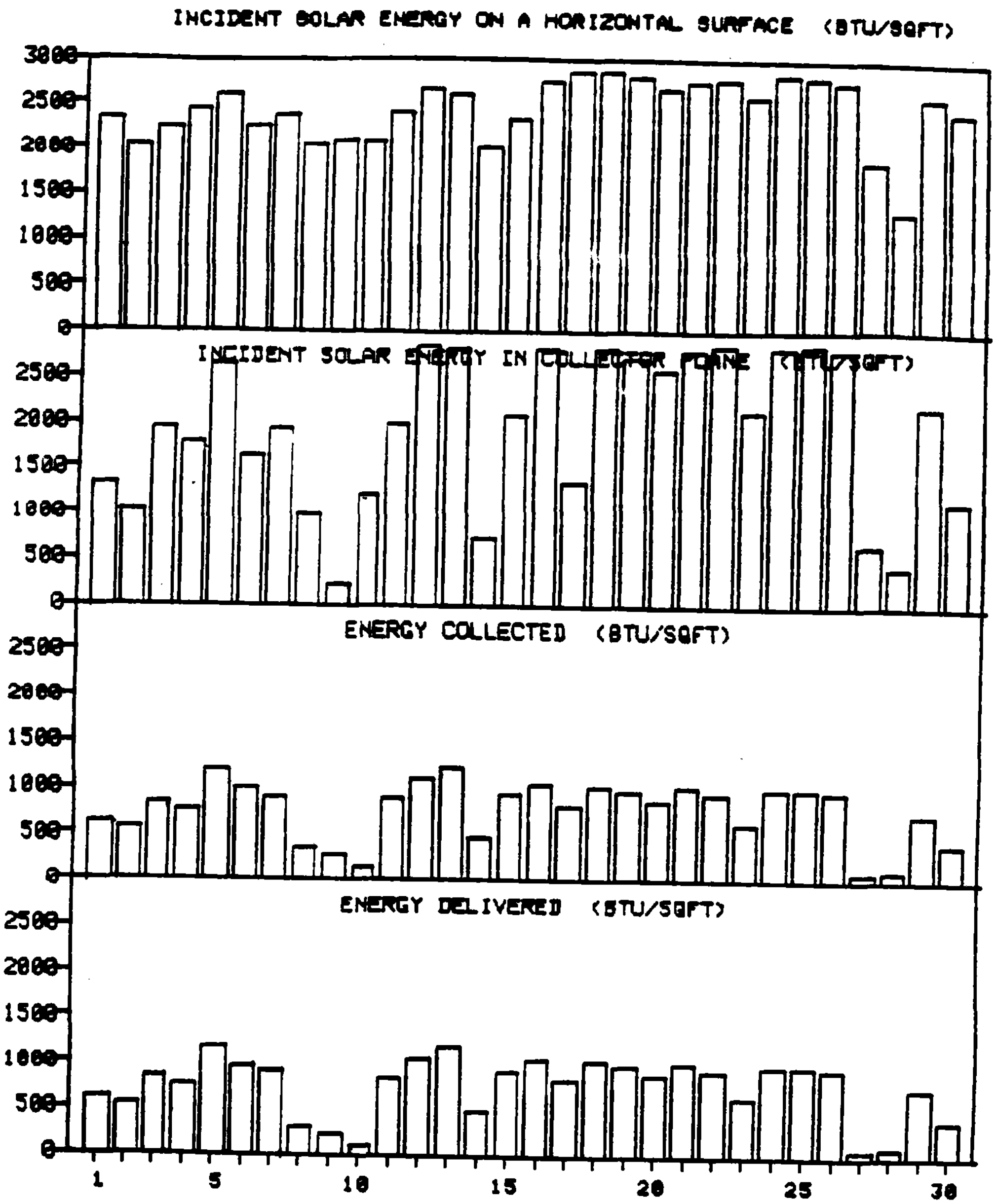
TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
June 1983

Drive Row	Date	Observation/Action
BH-94	5/10	Tracker head failure, row deactivated
BH-69 BH-81	6/6	Receiver tube glass chipped, rows remained activated.
BH-47 BH-67	6/8	Replaced faulty hydraulic pressure switch Rows brought back to service
BH-47	6/13	Oil leak through seal on new pressure switch, row deactivated

TABLE III.

MONTHLY PERFORMANCE SUMMARY TABLE - 6/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT
152	6/ 1	2378.2	1322.8	609.3	25.6	46.1	609.3	5.8
153	6/ 2	2032.1	1031.8	531.8	26.2	51.5	531.8	4.7
154	6/ 3	2218.4	1906.4	796.9	35.9	41.8	796.9	6.5
155	6/ 4	2435.1	1773.4	746.8	30.7	42.1	746.8	6.0
156	6/ 5	2605.7	2648.8	1163.3	44.6	43.9	1163.3	8.4
157	6/ 6	2242.6	1619.4	966.6	43.1	59.7	966.6	7.2
158	6/ 7	2379.4	1902.7	881.1	37.0	46.3	881.1	7.3
159	6/ 8	2047.2	1001.7	318.3	15.5	31.8	318.3	4.3
160	6/ 9	2097.1	226.7	224.9	10.7	——	224.9	5.2
161	6/10	2113.7	1223.5	124.0	5.9	10.1	124.0	5.5
162	6/11	2421.1	1999.7	849.1	35.1	42.5	849.1	6.1
163	6/12	2670.1	2855.9	1089.1	40.8	38.1	1089.1	8.6
164	6/13	2623.1	2826.9	1180.0	45.0	41.7	1180.0	8.5
165	6/14	2057.4	759.0	483.5	23.5	——	483.5	5.0
166	6/15	2350.0	2086.3	895.9	38.1	42.9	895.9	6.5
167	6/16	2582.9	2640.7	1043.2	40.4	39.5	1043.2	8.5
168	6/17	2851.1	1336.9	812.3	28.5	——	812.3	9.7
169	6/18	2849.6	2821.7	1018.9	35.8	36.1	1018.9	8.5
170	6/19	2801.9	2707.1	972.9	34.7	35.9	972.9	8.4
171	6/20	2672.8	2562.9	853.6	31.9	33.3	853.6	9.6
172	6/21	2753.1	2785.4	1009.8	36.7	36.3	1009.8	10.1
173	6/22	2778.4	2853.2	924.9	33.3	32.4	924.9	10.1
174	6/23	2581.9	2114.3	618.1	23.9	29.2	618.1	7.2
175	6/24	2815.6	2818.6	983.1	34.9	34.9	983.1	8.7
176	6/25	2811.6	2836.6	975.2	34.7	34.4	975.2	8.9
177	6/26	2755.3	2789.0	950.1	34.5	34.1	950.1	8.7
178	6/27	1875.3	647.4	75.0	4.0	11.6	75.0	2.7
179	6/28	1306.5	400.9	105.5	8.1	26.3	105.5	2.1
180	6/29	2574.9	2164.6	727.5	28.3	33.6	727.5	7.1
181	6/30	2421.8	1145.8	396.7	16.4	34.6	396.7	6.7
	TOTALS	73103.9	57912.1	22327.7	30.5	38.6	22327.7	212.6
	AVERAGE	2436.8	1930.4	744.3			744.3	6.6



MONTHLY PERFORMANCE GRAPH 6-83

FIGURE 5.

Using the active area values for the appropriate periods (see Table II), it is found that the total collector field energy output for June was 360×10^6 Btu.

B. Daily Summary

Table IV and Figure 6 summarize the clear day performance of the collector field for June 26.

TABLE IV. CLEAR DAY PERFORMANCE TABLE - 6/26/83 (JULIAN DAY 177)

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED BTU/HR-FT2	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY BTU/HR-FT2
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	52.7	4.4	55.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.	61.1	5.3	127.2	143.1	53.2	166.2	185.8	85.4	168.3	179.6	6.8	5.4	4.8	1.8
9.	66.1	4.5	209.9	257.9	84.4	186.9	201.6	144.0	188.6	202.7	98.6	47.0	38.2	2.7
10.	71.6	2.6	264.4	263.5	84.7	190.4	206.8	144.9	192.6	206.8	104.0	39.3	39.5	2.7
11.	67.0	6.6	309.5	268.6	84.9	198.7	213.6	145.0	199.1	213.7	101.6	32.8	37.8	2.7
12.	66.0	9.4	342.5	288.9	84.8	205.4	220.2	144.7	205.3	220.3	102.9	30.1	35.6	2.7
13.	66.3	10.9	351.2	301.2	84.7	211.8	226.6	144.6	211.1	226.5	103.8	29.6	34.5	2.7
14.	64.9	11.3	344.7	308.3	84.5	217.9	233.5	143.8	217.1	232.4	104.9	30.4	34.0	2.7
15.	64.9	12.6	302.0	303.8	84.4	223.4	238.9	143.8	222.4	237.5	103.1	34.1	33.9	2.7
16.	67.0	8.0	220.7	287.4	84.0	227.7	242.1	143.4	226.7	240.9	96.4	43.7	33.5	2.6
17.	65.3	11.2	134.3	253.5	83.5	230.1	241.4	142.5	229.1	241.0	78.6	58.5	31.0	2.6
18.	61.5	14.1	68.5	112.6	45.4	228.1	232.3	77.6	227.1	233.2	29.2	42.6	25.9	1.6
19.	59.4	15.4	28.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.	56.3	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.	54.9	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2759.0	2788.7							930.0	33.7	33.3	27.4
AVG	63.0	9.5	212.2	253.5	78.0	207.9	222.1	132.7	207.9	221.3	84.5			1.8

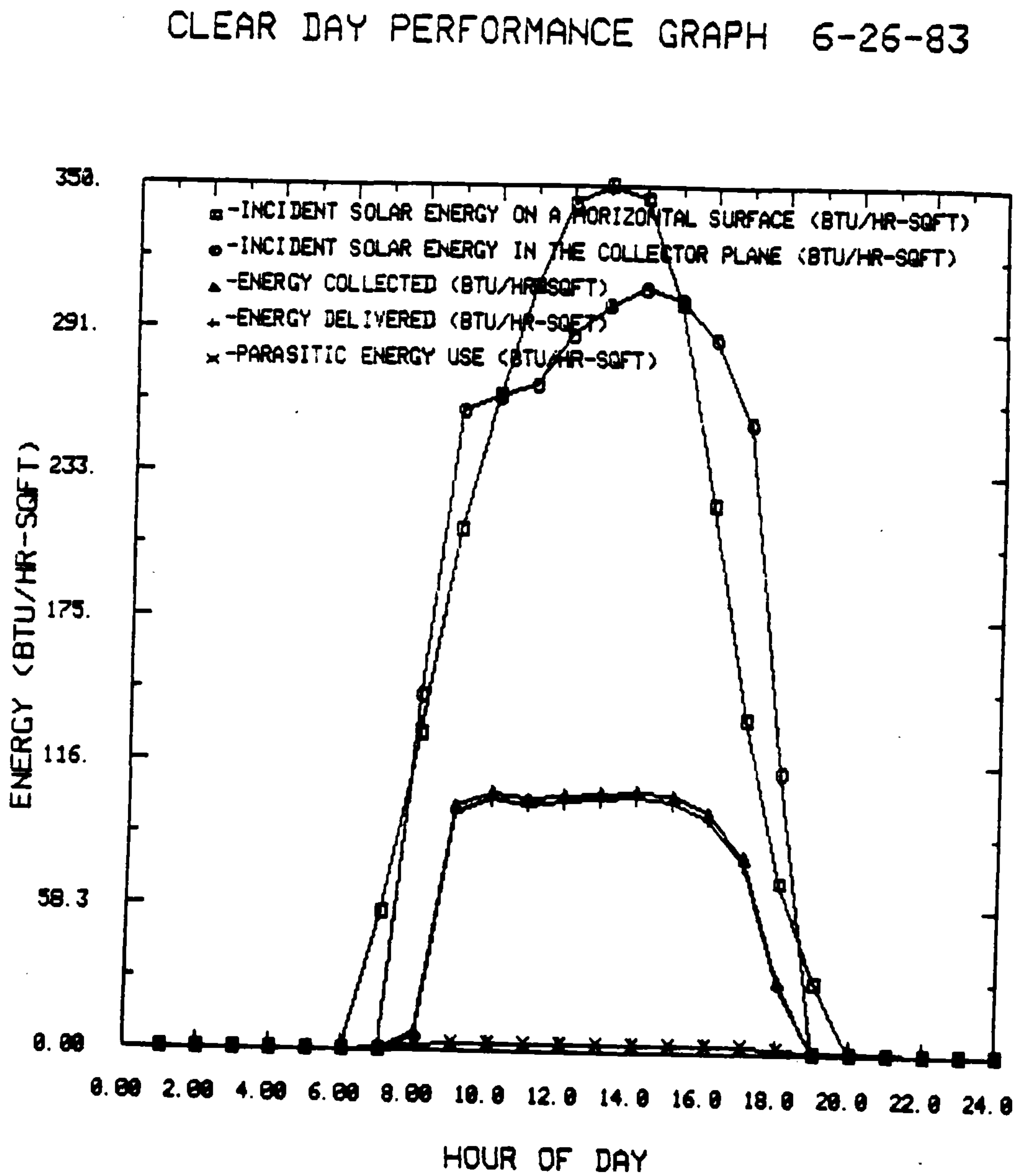

CLEAR DAY PERFORMANCE GRAPH 6-26-83
-INCIDENT SOLAR ENERGY ON A HORIZONTAL SURFACE (BTU/HR-SQFT)
-INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (BTU/HR-SQFT)
-ENERGY COLLECTED (BTU/HR-SQFT)
-ENERGY DELIVERED (BTU/HR-SQFT)
-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
291.
233.
175.
116.
58.3
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 6.

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
August 19, 1983
Monthly Progress Report No. 42
Reporting Period July 9, 1983
through August 5, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The solar system was available throughout the month of July; however, there were only six days of normal operation due primarily to the plant shutdown during the period July 5 to August 2.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The danger of leaking hydraulic fluid destroying the roof material has increased with the failure of two additional drive pylons. SwRI and CTCo personnel will implement a permanent solution to this problem before any more repairs to isolated failures are performed. See the accompanying performance report for a more detailed description of these failures.

Respectfully submitted,

Steven T. Green
Research Engineer

APPROVED:

Danny M. Deffenbaugh
Project Manager

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT No. 9

REPORT PERIOD:	July 1, 1983 - July 31, 1983
REPORT NO.:	CTCo-9
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

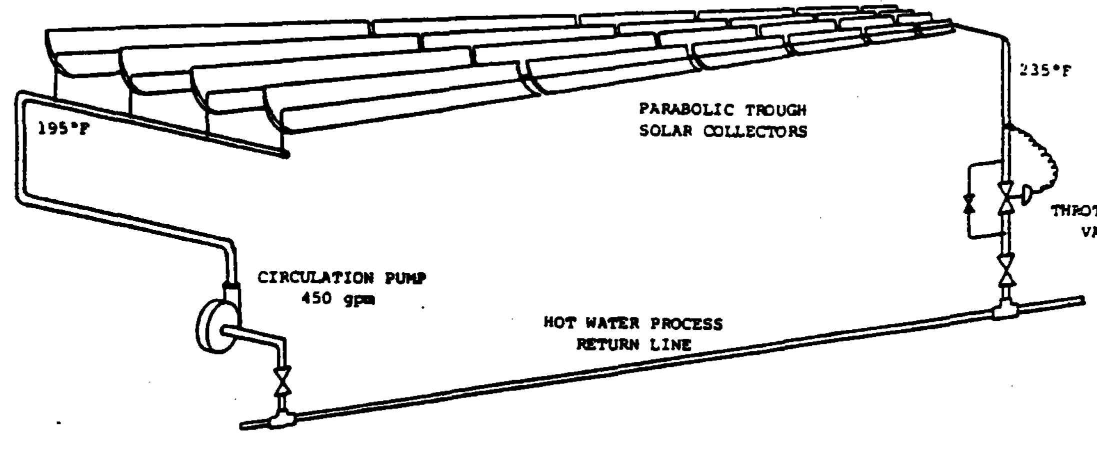


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation throughout the month of July. Minor changes were made to the system to accommodate the several maintenance actions described below. The DAS operated without trouble through the entire month.

Table I summarizes the operation of the solar system for the month of July while Figures 2-4 show the status of all drive rows at various times. It is seen in this table and these figures that two more drive pylons failed on or before July 3. As noted in Table II, these failures are related to problems with the hydraulic drive circuit. On July 7 row BH-81/-59 was replaced with BH-80/-58 as an active delta-T string since the latter is an instrumented row. Also on July 7 rows BH-72/-50 and BH-75/-53 were activated to more closely match collector energy delivery to plant load.

CTCo personnel plan to leave rows with hydraulic oil circuit leaks out of service until a permanent solution to the leak problem and associated problems can be found. Recall that the petroleum-based fluid currently in use destroys the roofing material on the CTCo plant. SwRI and CTCo are investigating changing to a more appropriate fluid which may also require changing some of the hydraulic circuit components.

IV. System Performance

A. Monthly Summary

Table III and Figure 5 summarize the system performance for the month of July. It is seen that there were only six days of normal operation during the month. As mentioned above, the plant was shut down from July 5 to August 2. During this period, the process heat system was operated for occasional plant maintenance needs.

B. Daily Summary

Table IV and Figure 6 summarize system performance for July 5, 1983. It is seen that the system operated from about 8:00 A.M. (PST) to 5:00 P.M. (PST). There were 14280 ft^2 of active collector area so that the energy energy delivered for the entire day was $10.5 * 10^6$ BTU with an all-day efficiency of 32.0%.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
July 1983

Date	Active Area (ft^2)	Comments
7/1-7/2	15960	South Field: 11 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
7/3-7/6	14280	South Field: 9 drive rows up, no flow to down delta-T strings except for string BH69/BH47
		North Field: 8 drive rows up, no flow to down delta-T strings
7/7-7/31	17640	South Field: 13 drive rows up, no flow to down delta-T strings except string BH69/BH47
		North Field: 8 drive rows up. Intermittent operation 7/15 to 7/31 due to plant shutdown

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
July 1983

Drive Row	Date	Observation/Action
BH-94	5/10	Tracker head failure, row deactivated
BH-47	6/13	Oil leak through seal on new pressure switch, row deactivated
BH-69	7/3	Oil leak, BH-69 due to faulty tube connection, BH-84 due to lower seal on hydraulic cylinder

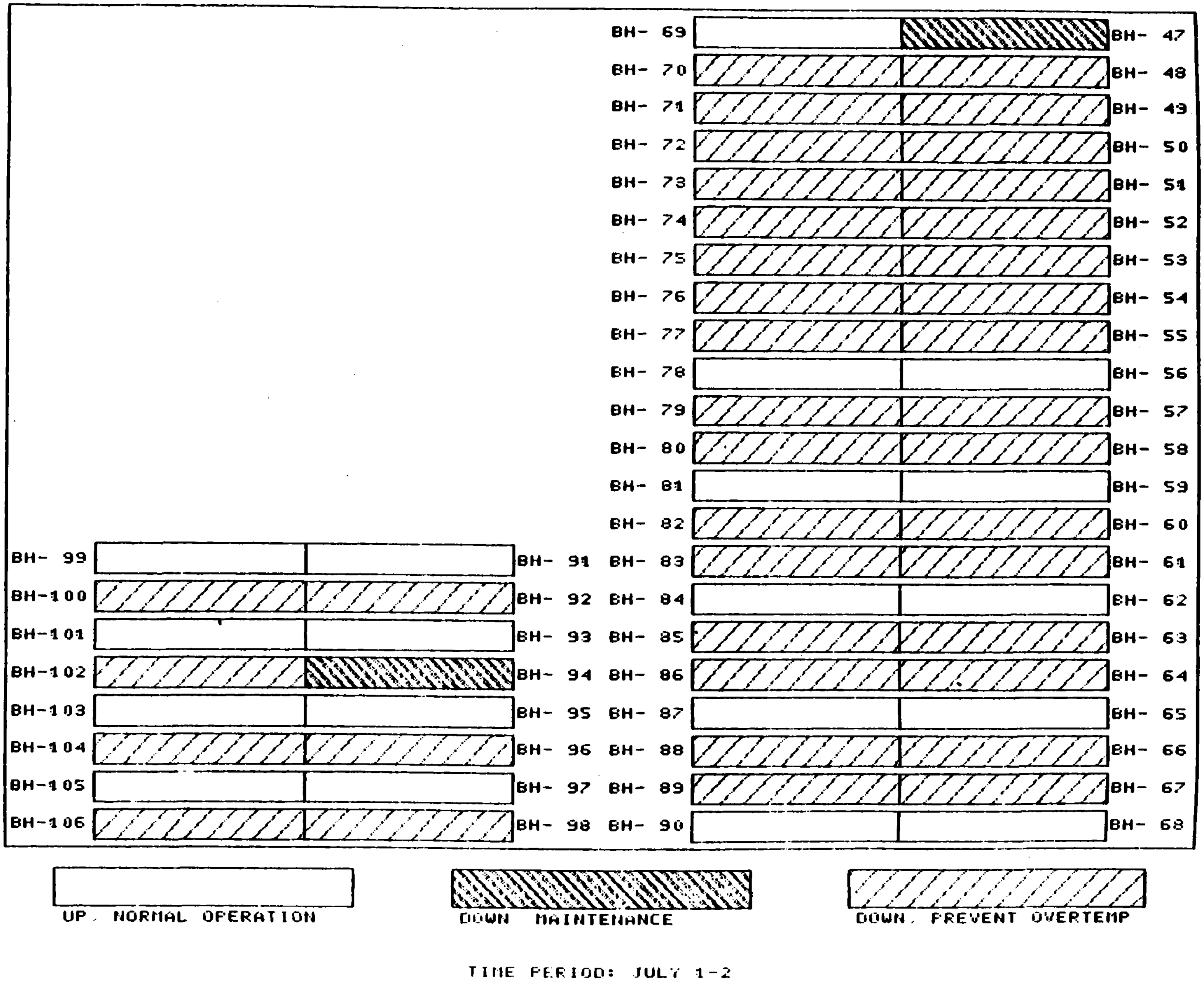
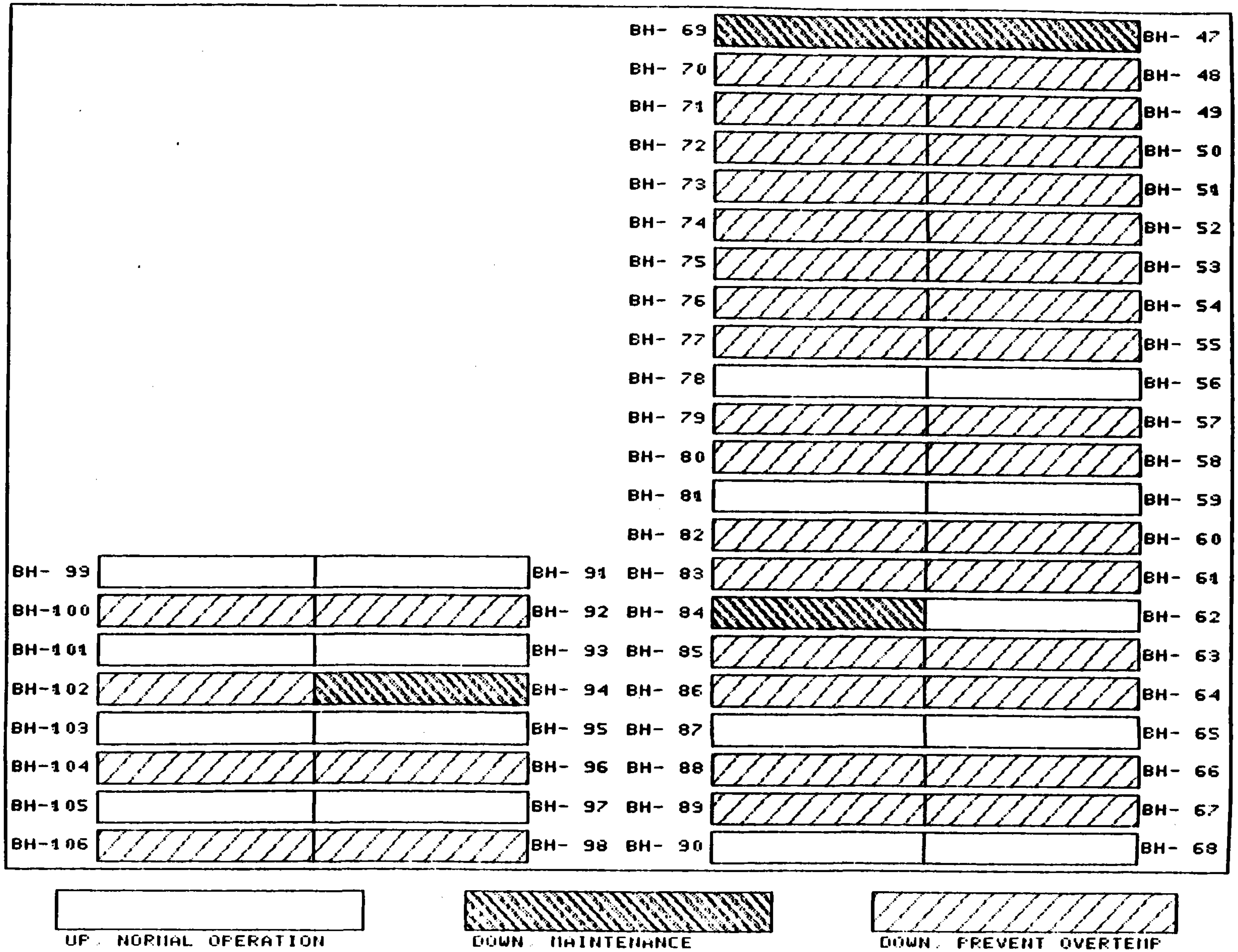
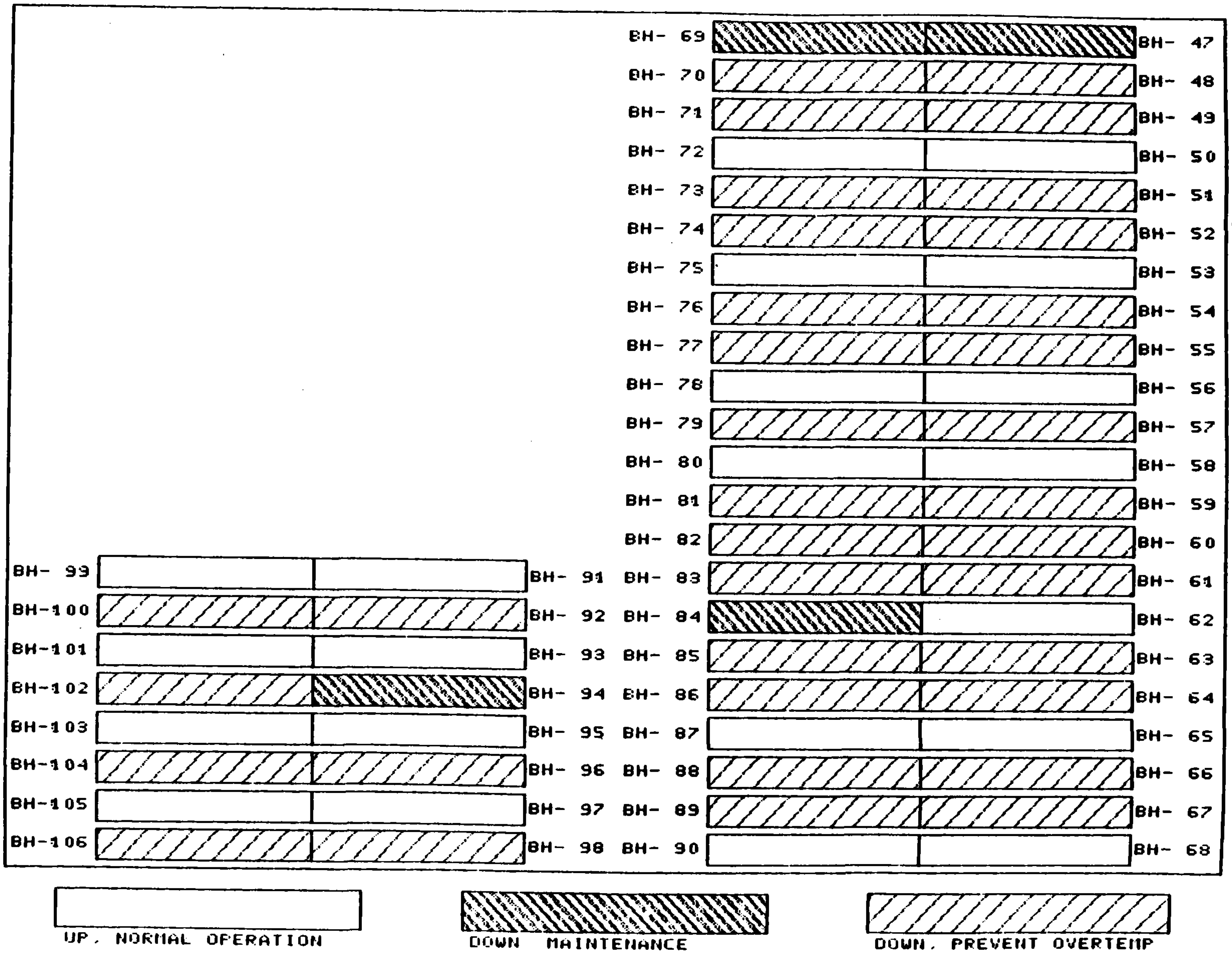


FIGURE 2. COLLECTOR DRIVE ROW STATUS



TIME PERIOD: JULY 3-6

FIGURE 3. COLLECTOR DRIVE ROW STATUS



TIME PERIOD: JULY 7-31

FIGURE 4. COLLECTOR DRIVE ROW STATUS

TABLE III. MONTHLY PERFORMANCE SUMMARY TABLE - 7/83

JULIAN DAY	(DATE)	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (2) BTU/SQFT	ENERGY COLLECTED BTU/SQFT	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	ENERGY DELIVERED BTU./SQFT	PARASITIC ENERGY USED BTU/SQFT
182	7/ 1	341.7	-0.1	0.0	0.0	0.0	0.0	0.1
183	7/ 2	2768.8	0.0	0.0	0.0	0.0	0.0	0.3
184	7/ 3	2792.7	-0.1	0.0	0.0	0.0	0.0	0.3
185	7/ 4	1719.1	0.0	0.0	0.0	0.0	0.0	0.1
186	7/ 5	2776.6	2284.6	731.0	26.3	32.0	731.0	6.7
187	7/ 6	2550.1	2086.6	653.7	25.6	31.3	653.7	6.2
188	7/ 7	2475.1	1422.6	507.5	20.5	35.7	507.5	5.3
189	7/ 8	2822.3	1878.8	673.1	23.8	35.8	673.1	6.3
190	7/ 9	2805.6	-0.3	0.0	0.0	0.0	0.0	0.3
191	7/10	2799.9	0.5	0.0	0.0	0.0	0.0	0.3
192	7/11	2818.8	464.8	106.7	3.8	23.0	106.7	2.0
193	7/12	2917.2	-9.7	8.4	0.3	-86.3	8.4	5.7
194	7/13	2701.3	1524.7	523.9	19.4	34.4	523.9	5.2
195	7/14	2762.0	-0.4	0.0	0.0	0.0	0.0	0.0
196	7/15	2777.7	0.0	0.0	0.0	0.0	0.0	0.0
197	7/16	2547.8	0.0	0.0	0.0	0.0	0.0	0.0
198	7/17	2332.1	0.0	0.0	0.0	0.0	0.0	0.0
199	7/18	2124.2	0.0	0.0	0.0	0.0	0.0	0.0
200	7/19	2598.4	0.0	0.0	0.0	0.0	0.0	0.0
201	7/20	2690.2	0.0	0.0	0.0	0.0	0.0	0.0
202	7/21	2703.6	0.0	0.0	0.0	0.0	0.0	0.0
203	7/22	1740.5	0.0	0.0	0.0	0.0	0.0	0.0
204	7/23	2233.8	0.0	0.0	0.0	0.0	0.0	0.0
205	7/24	982.9	0.0	0.0	0.0	0.0	0.0	0.0
206	7/25	2083.6	0.0	0.0	0.0	0.0	0.0	0.0
207	7/26	2434.8	0.0	0.0	0.0	0.0	0.0	0.0
208	7/27	2317.0	0.0	0.0	0.0	0.0	0.0	0.0
209	7/28	2346.0	0.0	0.0	0.0	0.0	0.0	0.0
210	7/29	2468.4	1.4	1.0	0.0	73.9	1.0	3.0
211	7/30	1832.7	11.0	9.5	0.5	86.2	9.5	3.5
212	7/31	2569.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS		73833.9	9664.3	3214.8	4.4	33.3	3214.8	45.3
AVG		2381.7	311.8	103.7			103.7	1.5

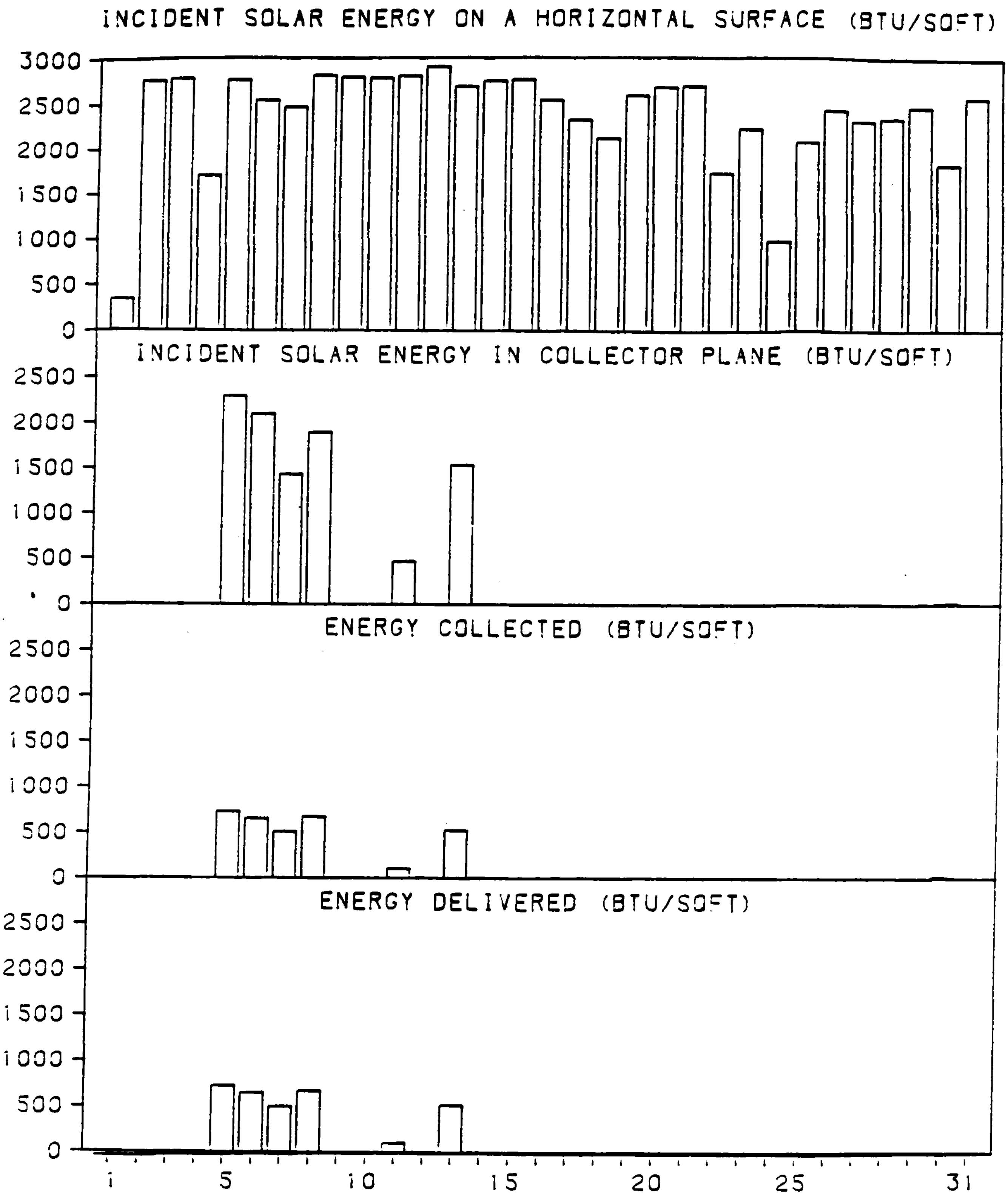


FIGURE 5. MONTHLY PERFORMANCE GRAPH 7/83

TABLE IV. CLEAR DAY PERFORMANCE TABLE - 7/5/83 (JULIAN DAY 186)

HOUR	AMB TEMP F	WIND SPD MPH	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/HR-FT2	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/HR-FT2	NORTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	NORTH FIELD: COLLECTOR ARRAY TEMP IN F	NORTH FIELD: COLLECTOR ARRAY TEMP OUT F	SOUTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	SOUTH FIELD: COLLECTOR ARRAY TEMP IN F	SOUTH FIELD: COLLECTOR ARRAY TEMP OUT F	TOTAL SYSTEM: ENERGY COLLECTED BTU/HR-FT2	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (1) %	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (2) %	TOTAL SYSTEM: PARASITIC ENERGY BTU/HR-FT2
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	52.7	2.3	44.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	60.4	2.5	92.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.	68.4	3.1	213.5	229.8	70.4	124.1	125.2	104.7	124.2	125.0	6.3	3.0	2.7	2.7
10.	69.3	4.3	262.8	274.3	82.0	124.6	136.3	118.7	124.5	134.9	75.9	28.9	27.7	2.9
11.	69.0	5.2	308.2	275.9	83.7	135.2	150.9	124.3	135.3	149.2	104.8	34.0	38.0	2.9
12	69.5	5.8	343.5	296.7	84.6	148.7	165.1	132.6	149.4	162.8	108.4	31.6	36.5	3.0
13.	70.8	8.9	354.8	311.5	84.7	161.6	178.9	138.2	162.9	176.1	111.6	31.4	35.8	3.0
14.	70.2	8.2	340.4	313.9	84.4	170.9	189.9	139.7	173.1	186.8	118.9	34.9	37.9	3.0
15.	67.9	9.5	305.6	308.7	84.1	171.9	190.5	139.7	173.8	186.5	113.0	37.0	36.6	3.0
16.	68.2	9.2	236.7	286.5	83.8	182.9	199.4	140.6	185.5	196.0	96.1	40.6	33.5	2.9
17.	66.2	11.5	154.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.	64.2	9.9	81.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.	61.1	8.5	36.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.	57.2	6.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.	56.4	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2775.9	2297.2							735.0	26.5	32.0	23.5
AVG	64.8	6.9	198.3	287.2	82.2	152.5	167.0	129.8	153.6	164.6	91.9			1.6

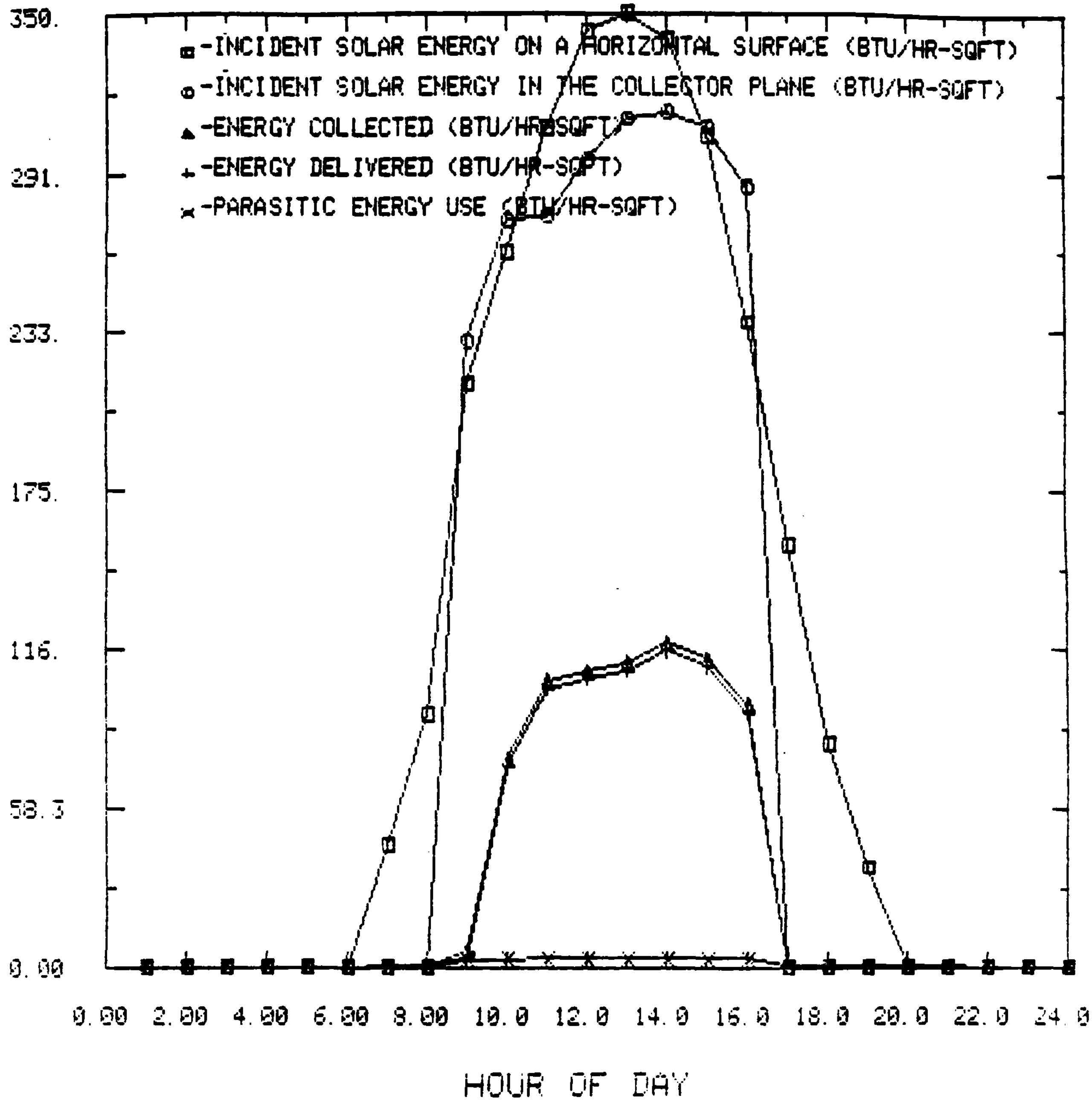


FIGURE 6. CLEAR DAY PERFORMANCE GRAPH 7-5-83

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Department of Mechanical Sciences
September 20, 1983
Monthly Progress Report No. 43
Reporting Period August 6, 1983
through September 2, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 20, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The solar system operated throughout the month of August with no substantial problems encountered. The DAS was inspected and recalibrated during a site visit by SwRI personnel.

SUMMARY STATUS ASSESSMENT AND FORECAST:

A change in the process heat load schedule has forced the solar system to operate for a shorter period each day than it normally would. These shortened operating hours are expected to continue for several months. The accompanying report details the month's operation more completely.

Respectfully submitted,

Steven T. Green
Research Engineer

APPROVED:

Danny M. Deffenbaugh
Project Manager

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 10

REPORT PERIOD:	August 1, 1983 - August 31, 1983
REPORT NO.:	CTCo-10
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

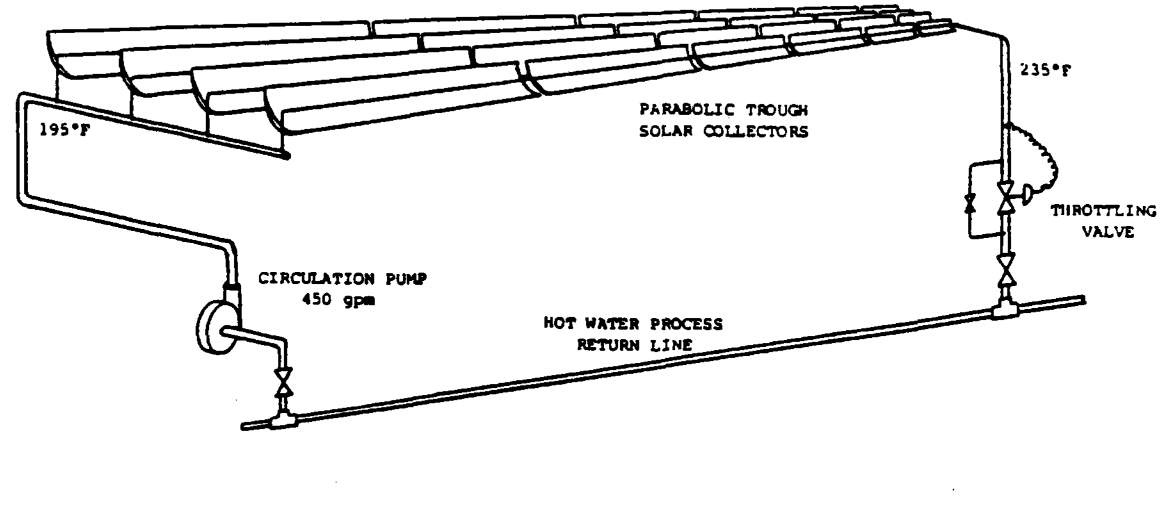


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The operation of the solar system was changed during the month of August to accommodate a new plant load profile. Adjustment to the central controller was also necessary to prevent collectors from missing focusing during startup. The DAS was inspected and modified during August as well.

A summary of the solar system operation is presented in Table I. It is seen that on August 1 the plant began a single shift production procedure so that the plant process heat system is operated only between the hours of 6:00 A.M. and 3:30 P.M. Monday-Friday. At 3:30 P.M. the process loop pumps are deactivated which in turn should force the solar system to shut down. Apparently, the collector loop pump can force a rate of flow through the process loop which is above the threshold of the process loop flow switches, so that the collector loop pump was not always deactivated when the process loop pumps were turned off. Therefore, starting on August 31, the collector field is manually stowed at approximately 3:30 P.M. along with the process loop. If the weather on a Sunday permits collector operation, the solar system will be allowed to operate to preheat the plant process water system prior to Monday morning startup.

It can also be seen in Table I that beginning on August 19, the collector field in whole or in part occasionally missed focusing on the sun at startup. The central controller light switch sensitivity was adjusted on August 22 to solve this problem, but was not totally successful as seen on August 23 and August 29. This is thought to be a seasonal problem with the current light sensor related to variations in the solar altitude angle.

Figures 2 and 3 depict the collector drive row status for the month of August. The active collector area was 17640 ft^2 for August 1-9 and 19320 ft^2 for August 10-31.

The solar system maintenance costs are summarized in Table II. These costs are tabulated by month for the operational phase of the project which began in February. It is seen that maintenance cost, normalized to collector array size, is \$0.15/ft^2/year based on this seven month period. A similar table to the one shown here will be presented each month for the maintenance costs for that respective period.

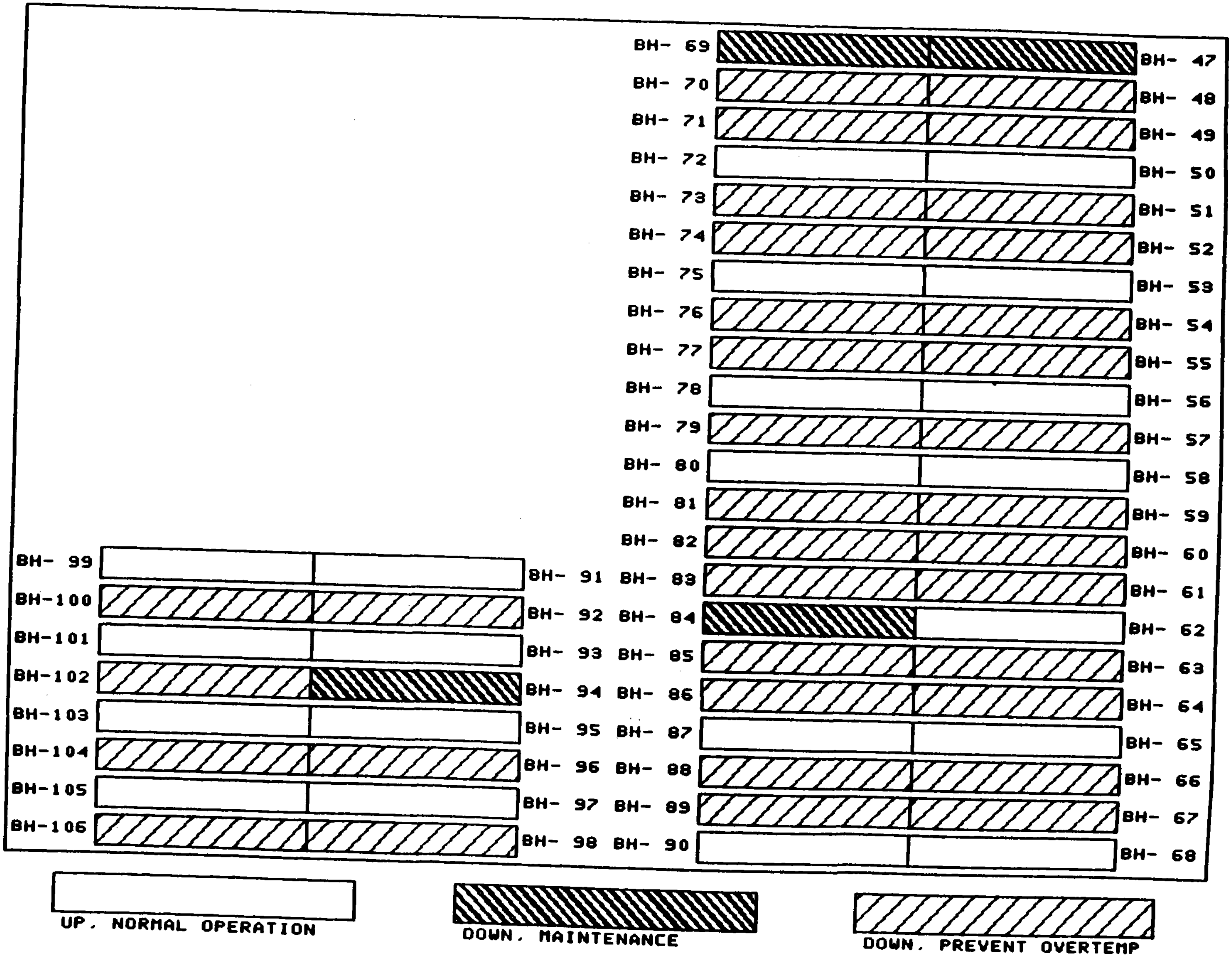
During the period August 15-August 19, the DAS was inspected and sensor calibrations were checked. The only sensors requiring calibration changes were the pyranometers. An incorrect relation was being used to convert pyranometer output to physical units since DAS initiation. The incorrect and correct equations are as follows:

Incorrect:		$S = 44.054\ (V) - 176.21$
Correct:	Horizontal Plane	$S = 38.3275\ (V) - 153.310$
	Collector Plane Total	$S = 38.4766\ (V) - 153.910$
	Collector Plane Diffuse	$S = 37.7437\ (V) - 150.975$

S = radiation, Btu/ft^2/hr V = sensor output, mA

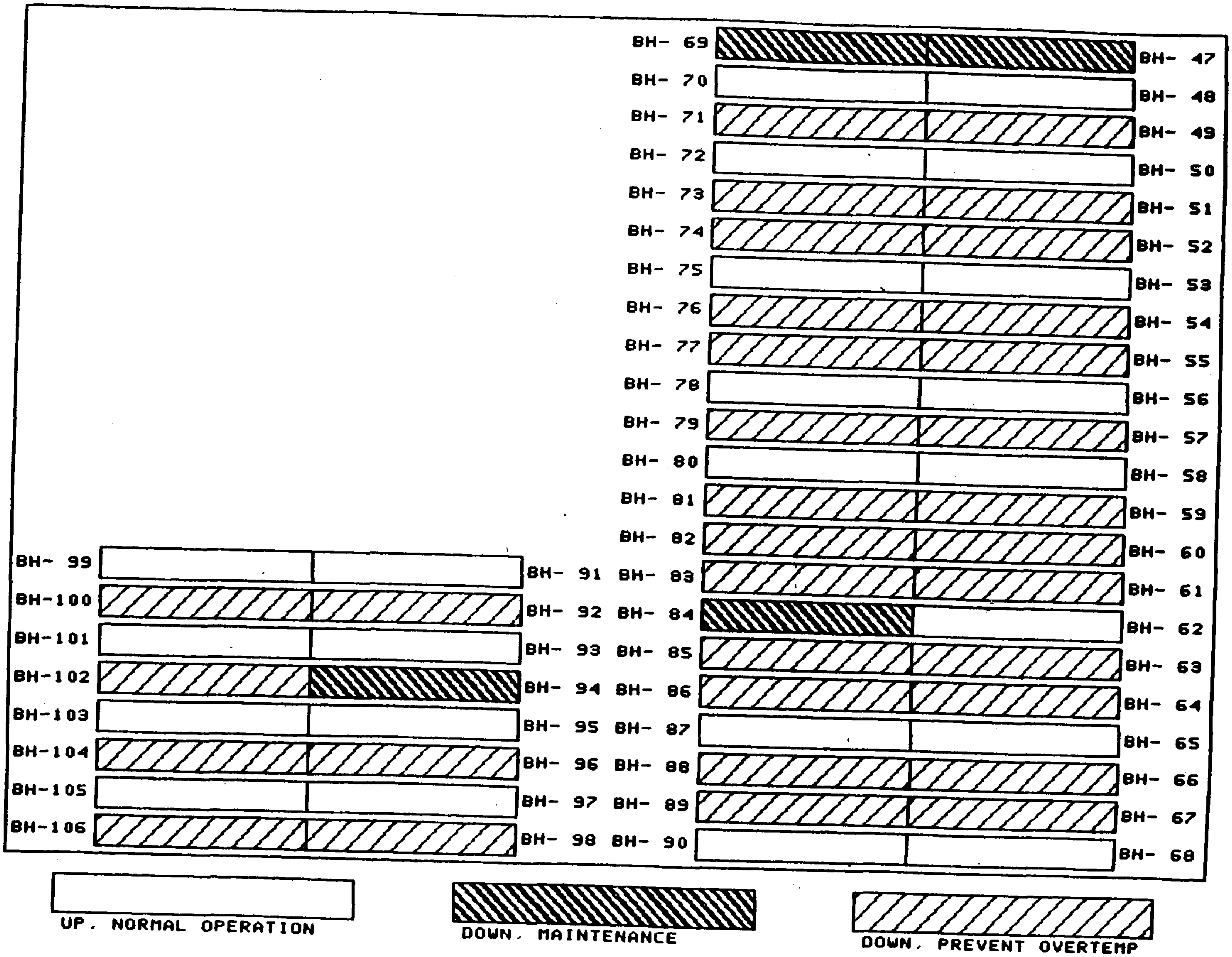
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
August 1983

Date	Active Area (ft^2)	Comments
8/1-8/9	17640	South Field: 13 drive rows up, no flow to down delta-T strings except string BH69/BH47
		North Field: 8 drive rows up, no flow to down delta-T strings
8/10-8/31	19320	South Field: 13 drive rows up, no flow to any down delta-T string.
		North Field: 8 drive rows up, no flow to down delta-T strings
8/1	--	Plant process heating system to operate only between 6:00 A.M. and 3:30 P.M., Monday-Friday. Solar system allowed to operate also on Sunday to preheat water for Monday.
8/15-8/19	--	Calibration of DAS sensors and modifications to software
8/19	--	Water in tracker head on Row BH58. Row does not properly focus
8/22	--	Most of the array passed sun during startup. Array was refocused at 12:45 PDT. Central controller sensitivity adjusted
8/23	--	Rows BH-50, -53, -87 passed sun. Rows were refocused at 12:45 PDT
8/29	--	Most of the array passed sun during startup. Array not refocused
8/31	--	Begin manually stowing collectors at 3:00 P.M. because control system flow switches oscillate during automatic shutdown (see Comments for 8/1)



TIME PERIOD: AUGUST 1-9

FIGURE 2



TIME PERIOD: AUGUST 10-31

FIGURE 3

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
February-August 1983

	O & M Activity	Hours	Cost: Labor $	Cost: Materials $	Cost: Total $	Total Cost to Date $
February	o Repair Row BH-92 o Manually refocusing collectors periodically because of startup sequence failure	18.0	433.37	-0-	433.37	433.37
March	o Maintenance of Row BH-47 hydraulics o Maintenance of Row BH-81 controls o Adjustments to system oepration due to overtemperature conditions	27.2	693.91	-0-	693.91	1127.28
April	o Maintenance of Row BH-94 hydraulics o Adjustments to system operation due to overtemperature conditions	12.0	275.59	-0-	275.59	1402.87
May	o Reinstall Row BH-81 controller o Reinstall BH-94 hydraulics o Maintenance of Row BH-67 hydraulics o Adjustments to system operation due to overtemperature conditions	34.8	793.24	260.00	1053.24	2456.11
June	o Repair Row BH-47, -67 hydraulics o Manually refocus field because of startup sequence failure	35.0	837.10	200.00	1037.10	3493.21
July	o Maintenance of Row BH-69 hydraulics o Adjustments to system operation to match output to load	10.0	246.31	-0-	246.31	3739.52
August	o Manually refocus rows that miss sun o Routine inspection o Deactivate Row BH-47/-69 o Activate Row BH-48/-70 o Repair DAS printer	20.0	529.27	-0-	529.27	4268.79

It is seen that the actual solar radiation values are 87% of the ones tabulated in the performance reports prior to this. The data presented in Monthy Reports 1-9 are being reviewed so that errata notices can be distributed.

During this site visit, the collector mirror reflectances were measured to help determine the mirror surface (FEK-244) degradation rate. The results of this inspection and a similar one conducted during April 5, 1983 are shown below.

Row	Average Specular Reflectance (%) 4/5/83	Average Specular Reflectance (%) 8/16/83	Degradation pct. pts per day
BH-48/-70	81.2	73.7	0.0564
BH-65/-87	80.9	59.8	0.1586
BH-91/-99	81.4	57.6	0.1789
BH-95/-103	80.6	56.6	0.1805
Average	--	--	0.1435

These measurements were taken with a Devices and Services Model 15R (Ser. No. 011) Specular Reflectometer loaned to SwRI by Sandia. The results shown above are based on an arbitrary selection of the test samples. No efforts were made to wash the collectors between these dates; however, they may have been rinsed by rain if the collectors were operating at the time a rain shower started. It should be noted that row BH-48/-70, which shows a markedly decreased degradation rate compared to the other test rows, is on the east end of the building. The east end of this CTCo building faces a residential section of San Leandro while the west end faces an industrial section and San Francisco Bay. It is thought that fewer air borne pollutants impinge on the east side of the collector field due to blockage of wind by the western most rows of the collector field.

IV. System Performance

A. Monthly Summary

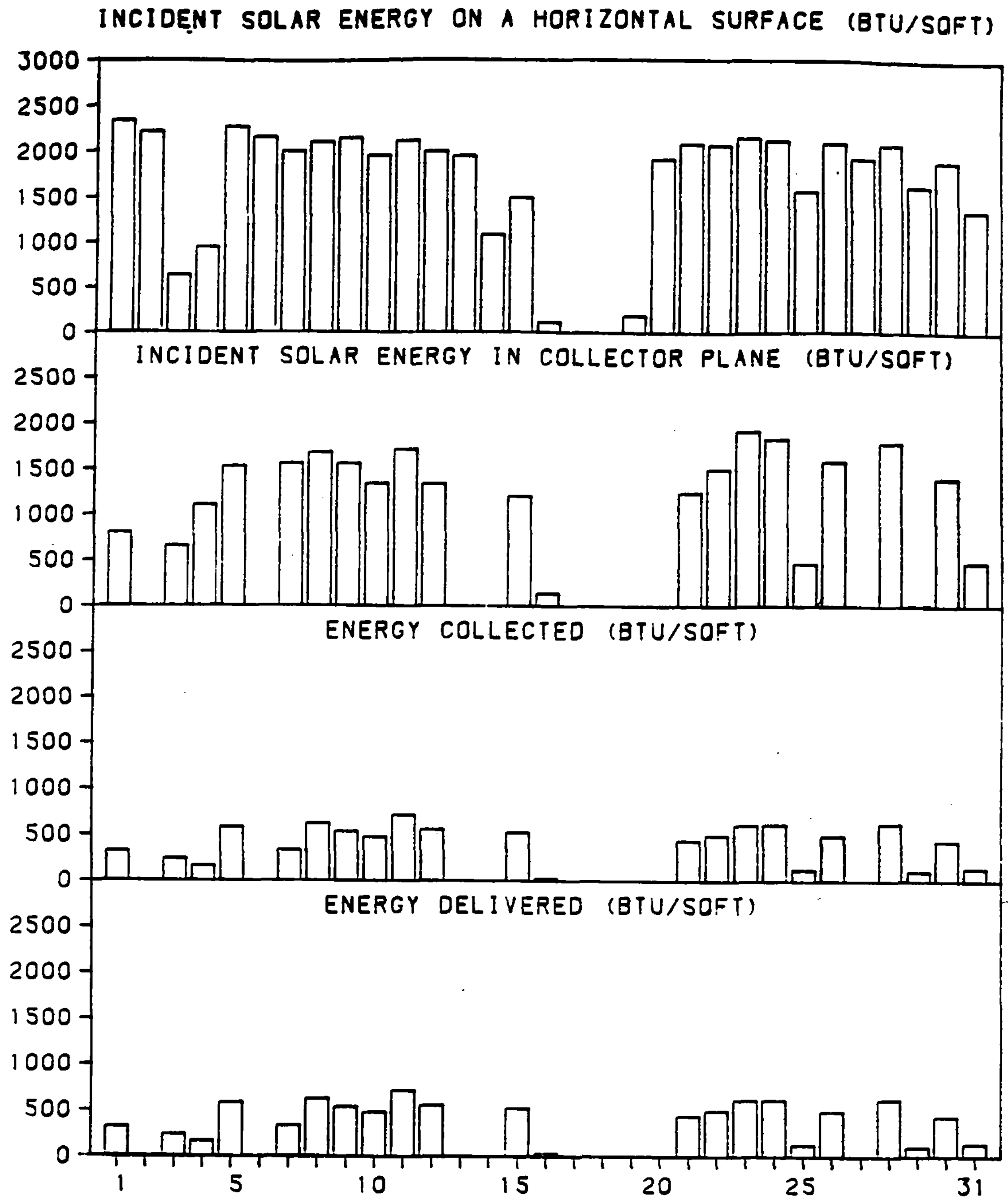
The collector array performance for August 1983 is summarizerd in Table III and Figure 4. It is seen that a different format for presenting the data is used this month. This change is to accommodate a request by CTCo that total energy delivery be reported rather than energy delivery normalized to active collector area. To provide a means of computing equipment performance, the array active area is tabulated for the respective dates.

It is seen that little or no data are reported for the period August 16-August 19, corresponding to the site visit described above. Also, the effects of the new plant operating procedures described above are seen in Table III. The system did not operate on August 6, August 13, August 20, and August 27 which are Saturdays. Finally, since most of the array missed focusing all day on August 29, no reliable performance can be reported for that day.

For the entire month, system efficiency was 34.4%

TABLE III. MONTHLY PERFORMANCE SUMMARY TABLE - 8/83

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
8/ 1	213	2337.7	810.3	17640.	5728.1	13.9	40.1	260.8
8/ 2	214	2216.6	0.0	17640.	0.0	0.0	0.0	11.5
8/ 3	215	639.1	661.5	17640.	4280.0	38.0	36.7	151.7
8/ 4	216	950.8	1108.3	17640.	2979.3	17.8	15.2	193.5
8/ 5	217	2280.4	1531.7	17640.	10390.4	25.8	38.5	331.2
8/ 6	218	2170.7	-0.7	17640.	0.0	0.0	0.0	15.7
8/ 7	219	2018.3	1563.1	17640.	5974.5	16.8	21.7	378.2
8/ 8	220	2122.3	1680.7	17640.	11087.3	29.6	37.4	368.3
8/ 9	221	2161.4	1564.6	17640.	9543.1	25.0	34.6	368.8
8/10	222	1968.4	1346.7	19320.	9301.4	24.5	35.7	315.7
8/11	223	2127.5	1718.8	19320.	13887.4	33.8	41.8	408.8
8/12	224	2011.8	1347.6	19320.	10860.6	27.9	41.7	335.3
8/13	225	1956.6	-0.2	19320.	0.0	0.0	0.0	17.1
8/14	226	1080.4	-0.2	19320.	0.0	0.0	0.0	14.9
8/15	227	1495.4	1209.7	19320.	10244.8	35.5	43.8	296.1
8/16	228	120.9	144.1	19320.	655.7	28.1	23.6	44.2
8/17	229	0.0	0.0	19320.	0.0	0.0	0.0	0.0
8/18	230	0.0	0.0	19320.	0.0	0.0	0.0	0.0
8/19	231	192.6	0.0	19320.	0.0	0.0	0.0	8.7
8/20	232	1919.6	0.7	19320.	0.0	0.0	0.0	18.4
8/21	233	2091.8	1251.7	19320.	8606.8	21.3	35.6	253.9
8/22	234	2078.2	1510.1	19320.	9679.8	24.1	33.2	469.6
8/23	235	2160.0	1923.8	19320.	11898.0	28.5	32.0	479.1
8/24	236	2132.2	1837.1	19320.	11954.5	29.0	33.7	453.4
8/25	237	1570.6	468.4	19320.	2486.9	8.2	27.5	195.0
8/26	238	2106.8	1587.1	19320.	9559.7	23.5	31.2	329.0
8/27	239	1931.3	0.0	19320.	0.0	0.0	0.0	18.7
8/28	240	2093.2	1795.5	19320.	12063.0	29.8	34.8	356.1
8/29	241	1626.1	11.7	19320.	2085.0	6.6	925.5	307.7
8/30	242	1899.8	1411.0	19320.	8456.7	23.0	31.0	393.7
8/31	243	1353.7	483.1	19320.	2742.7	10.5	29.4	214.6
TOTALS		50814.4	26966.3		174465.6	18.3	34.4	7009.4
AVG		1752.2	929.9		6016.1			241.7



MONTHLY PERFORMANCE GRAPH 8-83

FIGURE 4

B. Clear Day Performance

The hourly performance of the collector array on August 11 is summarized in Table IV and Figure 5. It is shown that the peak efficiency was 49.0% with an energy delivery rate of 1843 KBtu/hr while the all-day efficiency was 40.6% with an energy delivery of 13548 KBtu.

TABLE IV. CLEAR DAY PERFORMANCE TABLE - 8/11/83 (JULIAN DAY 223)

ARRAY ACTIVE AREA = 19320 SQ. FT.

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED KBTU/HR	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY KBTU/HR
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	55.0	4.4	38.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
8.	67.8	2.3	101.5	172.3	82.6	209.5	213.1	176.3	208.3	212.1	564.5	28.8	17.0	46.4
9.	71.8	2.0	160.8	178.9	83.2	218.3	228.5	185.3	217.5	230.2	1526.4	49.1	44.2	45.6
10.	73.4	3.0	210.9	186.2	83.7	221.7	233.1	186.2	220.9	234.9	1699.2	41.7	47.2	45.5
11.	73.9	4.7	249.1	194.7	83.9	222.6	235.1	186.8	222.0	237.2	1843.6	38.3	49.0	45.8
12.	74.1	5.9	283.3	206.0	83.9	224.1	236.9	186.5	223.3	238.7	1874.5	34.2	47.1	45.6
13.	77.5	9.4	296.0	236.8	83.8	227.8	240.9	186.2	227.0	243.0	1944.4	34.0	42.5	45.5
14.	76.7	10.6	269.0	261.6	83.7	229.4	242.9	185.9	228.6	245.5	2027.5	39.0	40.1	45.2
15.	77.7	10.1	222.4	222.7	83.6	237.8	248.5	185.9	236.5	250.1	1622.2	37.8	37.7	47.2
16.	78.9	10.2	158.8	66.7	60.5	239.0	242.1	134.0	238.4	242.1	445.3	14.5	34.5	37.1
17.	78.8	10.8	90.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
18.	77.2	9.3	42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
19.	70.9	8.8	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
20.	65.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
21.	63.5	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
22.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			2128.7	1725.9							13547.7	32.9	40.6	407.5
AVG	72.1	7.1	163.7	191.8	81.0	225.6	235.7	179.2	224.7	237.1	1505.3			27.2

CLEAR DAY PERFORMANCE GRAPH 8-11-83

ARRAY ACTIVE AREA = 19320. SQ. FT.

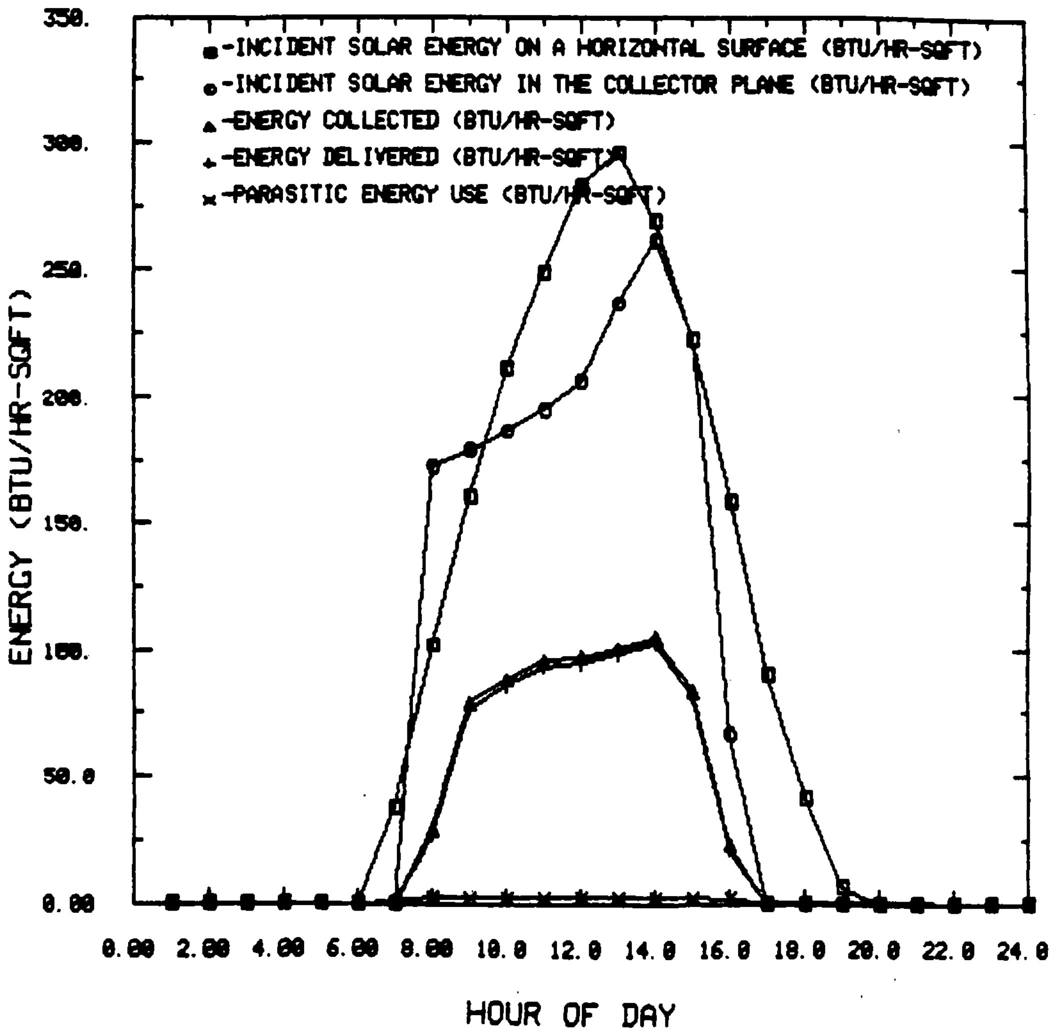


FIGURE 5

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
October 18, 1983
Monthly Progress Report No. 44
Reporting Period September 3, 1983
through September 30, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC03OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

This report documents the last month of one-year of operation. The cost and manpower plans for the second year will be included in next month's report.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The solar system and DAS operated smoothly during the month of September with only minor maintenance required. This activity is discussed in the accompanying monthly performance report.

Respectfully submitted,

Danny M. Deffenbaugh
Project Manager

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 11

REPORT PERIOD: September 1, 1983 - September 30, 1983

REPORT NO.: CTCo-11

DOE CONTRACT NO.: DE-FC03-79CS30309

SwRI PROJECT NO.: 06-5821

CONTRACT TITLE: A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.

CONTRACTOR: Southwest Research Institute
P. O. Drawer 28510
6220 Culebra Road
San Antonio, Texas 78284
Contact: D. Deffenbaugh, 512/684-5111, ext 2384

PROJECT SITE: Caterpillar Tractor Co.
1930 Davis Street
San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

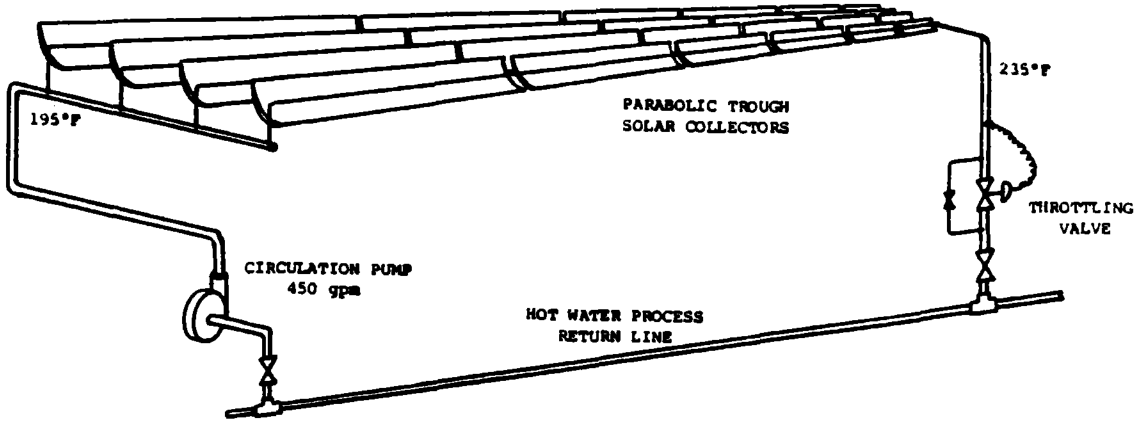


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system operation was not changed during the month of September from the conditions of the end of August. Minor maintenance was required in the collector field and on the Acurex datalogger. The PDP 11/23 DAS operated without problem throughout the month.

A summary of the solar system operation is presented in Table I, while the status of each of the rows is shown in Figures 2 and 3. It is seen that the hose on the outlet of row BH-49 was discovered leaking on September 28. This is one of the rows that have been stowed to decrease the system output so that solar system operation was not affected by performing the necessary maintenance.

The Techtran cassette recorder used in conjunction with the Acurex datalogger as a backup system to the PDP 11/23 DAS experienced problems during September. It was discovered on September 9 that the recorder was not recording data on tape. A replacement of this cassette recorder is being arranged for installation as soon as possible. The PDP 11/23 system, however, operated normally throughout the entire month so system performance can be reported.

The costs for operation and maintenance of the solar system are presented in Table II. It is seen that in the eight months for which these costs have been accounted the unit cost of O&M are approximately $0.15/year/ft^2 of collector areas. This amount includes all expenditures for O&M activities by CTCo personnel.

IV. System Performance

A. Monthly Summary

The performance of the CTCo solar system is summarized in Table III and Figure 4. It is seen that while the system was not operational on any Saturday (9/3, 9/10, 9/17, 9/24), it was functioning on two of the Sundays (9/11, 9/18) of the month to preheat the process heating system for Monday operations. The system delivered approximately 133.9*10^6 Btu during the month for a system efficiency of 29.8% based on the actual collector plane radiation. Peak daily efficiency was 37.0% on September 11.

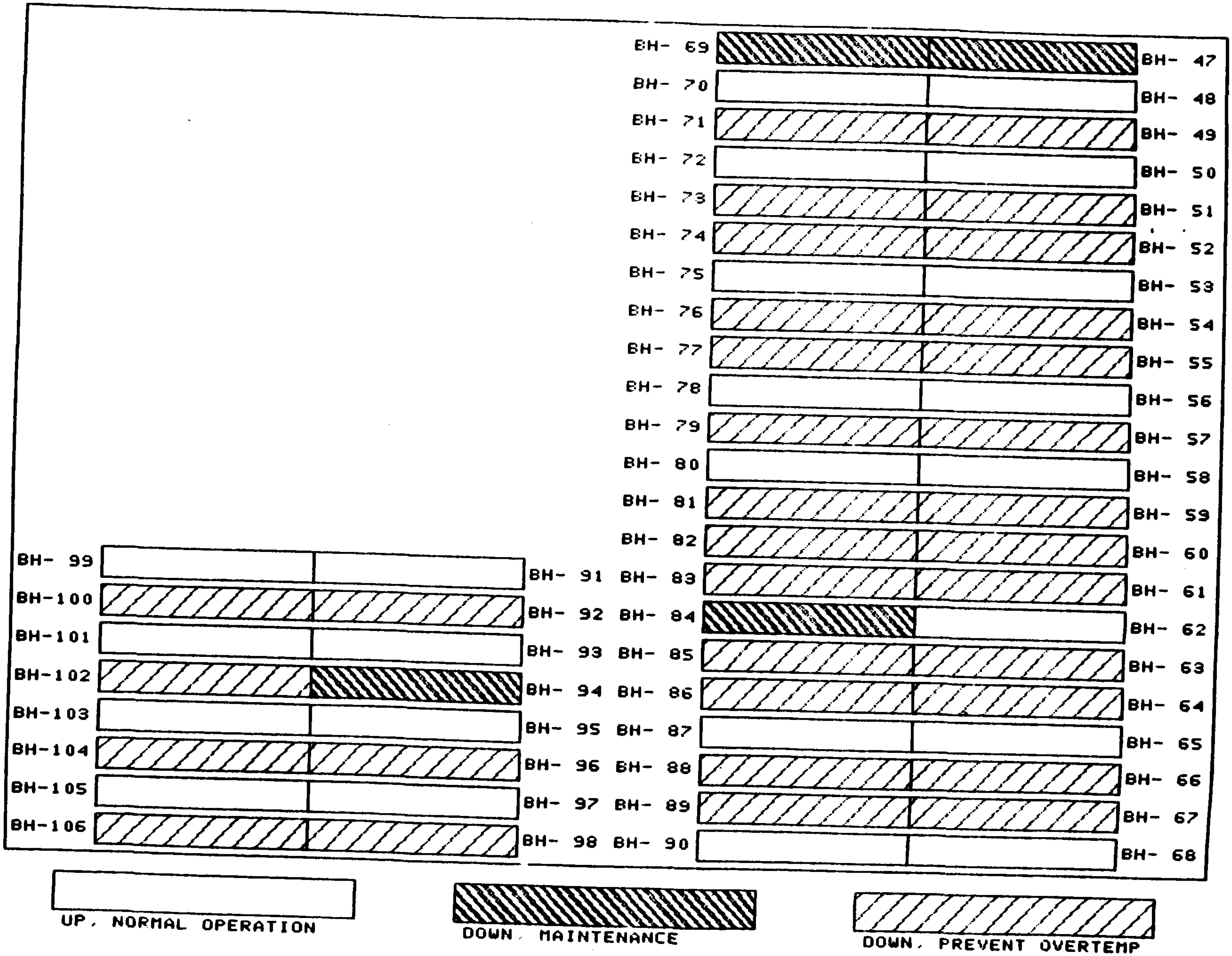
B. Clear Day Performance

The performance for a typical clear day is shown in Table IV and Figure 5 for September 11. It is seen that the system operated 8:00 a.m. and 6:00 p.m. (PST) and provided 13.5*10^6 Btu over the entire day.

It is also observed that the collector plane radiation drops to near zero while the system seems to remain operating. This is due to a late afternoon shading problem on the pyranometers. Plans are being made to move the collector plane pyranometers along with the tracker heads from the mirror rim to the center of the collector. This will elimiante any shading problem now seen on the leading edge of the collector mirror. This action will be taken on the next site visit by SwRI personnel.

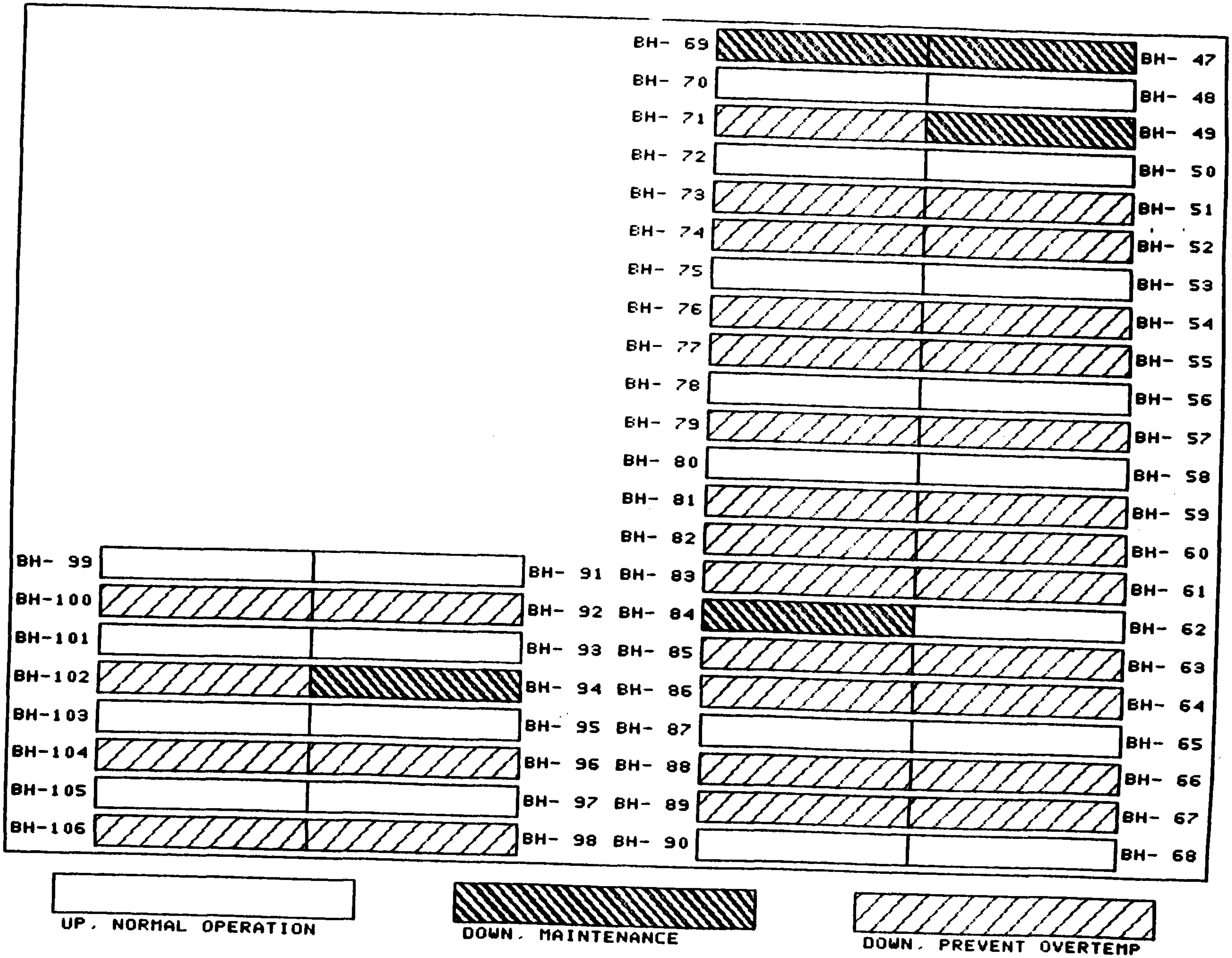
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
September 1983

Date	Active Area (ft^2)	Comments
9/1-9/30	19320	South Field: 13 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
9/9	-	Datalogger cassette record not operating properly.
9/28	-	Outlet hose on row BH-49 leaking. Hose removed for repair.



TIME PERIOD: SEPTEMBER 1-27

Figure 2



TIME PERIOD: SEPTEMBER 28-30

FIGURE 3

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
September 1983

		Cost			
O & M Activity	Hours	Labor $	Materials $	Total $	Total Cost 2/83 - 9/83 $
o Routine inspection and DAS disk changes	20	498.52	178.00	676.52	4945.31
o Remove hose from Row BH-49					
o Checkout datalogger cassette recorder					

TABLE III. MONTHLY PERFORMANCE SUMMARY TABLE - 9/83

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY: ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
9/ 1	244	2060.9	1597.6	19320.	9911.8	24.9	32.1	333.1
9/ 2	245	2021.1	1525.4	19320.	9916.3	25.4	33.6	324.5
9/ 3	246	2024.1	1.6	19320.	0.0	0.0	0.0	19.1
9/ 4	247	1998.9	0.2	19320.	0.0	0.0	0.0	20.9
9/ 5	248	1981.2	1916.3	19320.	13040.7	34.1	35.2	416.5
9/ 6	249	1795.3	1009.9	19320.	5558.9	16.0	28.5	231.6
9/ 7	250	1297.6	282.6	19320.	1473.9	5.9	27.0	97.2
9/ 8	251	1879.9	1017.8	19320.	6207.4	17.1	31.6	233.5
9/ 9	252	1954.7	1530.5	19320.	8930.1	23.6	30.2	324.8
9/10	253	1949.2	0.7	19320.	0.0	0.0	0.0	18.4
9/11	254	1971.6	1896.0	19320.	13553.9	35.6	37.0	456.4
9/12	255	2113.0	1429.1	19320.	8700.6	21.3	31.5	328.7
9/13	256	1874.2	1432.8	19320.	8499.1	23.5	30.7	317.2
9/14	257	1745.8	1132.4	19320.	5774.1	17.1	26.4	298.9
9/15	258	1806.2	1151.5	19320.	6115.0	17.5	27.5	282.2
9/16	259	1643.7	938.1	19320.	5118.4	16.1	28.2	225.5
9/17	260	1758.9	-0.1	19320.	0.0	0.0	0.0	17.6
9/18	261	1735.4	1244.8	19320.	8160.1	24.3	33.9	291.7
9/19	262	1698.8	1379.6	19320.	7469.5	22.8	28.0	317.7
9/20	263	1775.8	1513.6	19320.	8513.4	24.8	29.1	334.1
9/21	264	1234.1	225.8	19320.	792.8	3.3	18.2	144.4
9/22	265	1203.7	123.8	19320.	219.7	0.9	9.2	79.4
9/23	266	1580.0	865.7	19320.	2401.0	7.9	14.4	264.7
9/24	267	1659.5	-0.3	19320.	0.0	0.0	0.0	18.2
9/25	268	1295.0	-0.3	19320.	0.0	0.0	0.0	18.8
9/26	269	411.2	-0.2	19320.	0.0	0.0	0.0	21.2
9/27	270	1264.5	322.9	19320.	1270.3	5.2	20.4	112.8
9/28	271	1395.2	618.7	19320.	2216.6	8.2	18.5	182.7
9/29	272	662.1	-0.2	19320.	0.0	0.0	0.0	14.8
9/30	273	1106.4	126.0	19320.	99.0	0.5	4.1	128.7
TOTALS		48897.9	23282.4		133942.6	14.2	29.8	5875.2
AVG		1629.9	776.1		4464.8			195.8

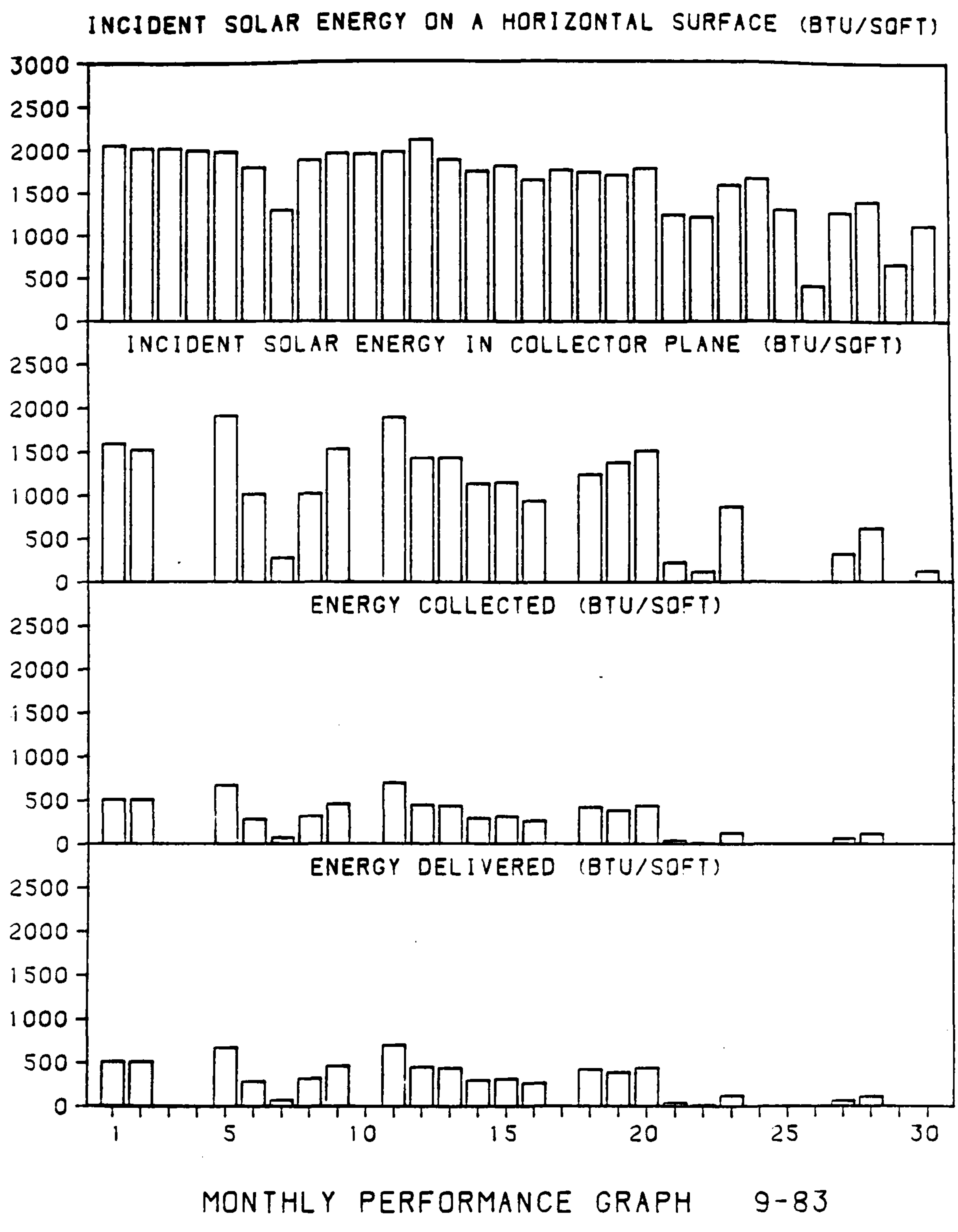

INCIDENT SOLAR ENERGY ON A HORIZONTAL SURFACE (BTU/SQFT)
3000
2500
2000
1500
1000
500
0
INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/SQFT)
2500
2000
1500
1000
500
0
ENERGY COLLECTED (BTU/SQFT)
2500
2000
1500
1000
500
0
ENERGY DELIVERED (BTU/SQFT)
2500
2000
1500
1000
500
0
1
5
10
15
20
25
30
MONTHLY PERFORMANCE GRAPH 9-83

FIGURE 4

TABLE IV. CLEAR DAY PERFORMANCE TABLE - 9/11/83 (Julian Day 254)

ARRAY ACTIVE AREA = 19320. SQ. FT.

HOUR	AMB TEMP F	WIND SPD MPH	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/HR-FT2	INCIDENT SOLAR ENERGY: IN THE COLLECTOR PLANE (2) BTU/HR-FT2	NORTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	NORTH FIELD: COLLECTOR ARRAY TEMP IN F	NORTH FIELD: COLLECTOR ARRAY TEMP OUT F	SOUTH FIELD: COLLECTOR ARRAY FLOW RATE GPM	SOUTH FIELD: COLLECTOR ARRAY TEMP IN F	SOUTH FIELD: COLLECTOR ARRAY TEMP OUT F	TOTAL SYSTEM: ENERGY COLLECTED KBTU/HR	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (1) %	TOTAL SYSTEM: COLLECTOR ARRAY EFF. BASED ON (2) %	TOTAL SYSTEM: PARASITIC ENERGY KBTU/HR
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	58.0	0.1	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
8.	76.0	-0.1	77.7	35.1	17.2	124.9	125.4	31.7	124.7	131.8	59.7	4.0	8.8	12.2
9.	79.7	1.3	137.9	202.8	83.0	148.5	156.3	150.9	147.8	158.4	1115.0	41.8	28.5	44.2
10.	78.3	3.4	191.7	207.0	83.6	154.6	164.2	163.6	154.8	167.6	1434.5	38.7	35.9	45.2
11.	79.5	3.3	231.5	214.9	83.7	161.1	170.3	170.1	161.0	173.0	1390.3	31.1	33.5	45.6
12.	84.1	4.3	254.7	227.8	83.7	169.1	179.0	174.7	168.9	181.7	1503.3	30.6	34.2	45.9
13.	88.4	6.5	262.1	246.0	83.3	179.7	190.7	178.3	179.4	193.0	1640.0	32.4	34.5	45.8
14.	92.5	7.6	247.0	256.4	82.9	189.1	201.3	182.8	188.8	203.7	1820.3	38.2	36.8	45.7
15.	95.3	8.7	243.4	262.6	82.8	198.3	211.0	184.7	197.8	213.6	1927.1	41.0	38.0	45.8
16.	94.0	9.9	179.1	245.3	83.0	206.5	219.0	185.2	205.9	220.6	1812.6	52.4	38.2	45.7
17.	91.7	10.5	99.9	0.1	81.3	206.5	211.2	180.3	206.5	213.8	835.6	43.3	*****	45.9
18.	87.0	7.3	30.2	1.7	44.3	197.7	196.8	96.7	197.9	197.2	-21.4	—	—	29.2
19.	79.8	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
20.	76.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
21.	74.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
22.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			1972.9	1899.7							13517.0	35.5	36.8	454.4
AVG	82.4	4.7	164.4	172.7	73.5	176.0	184.1	154.4	175.8	186.8	1228.8			30.3

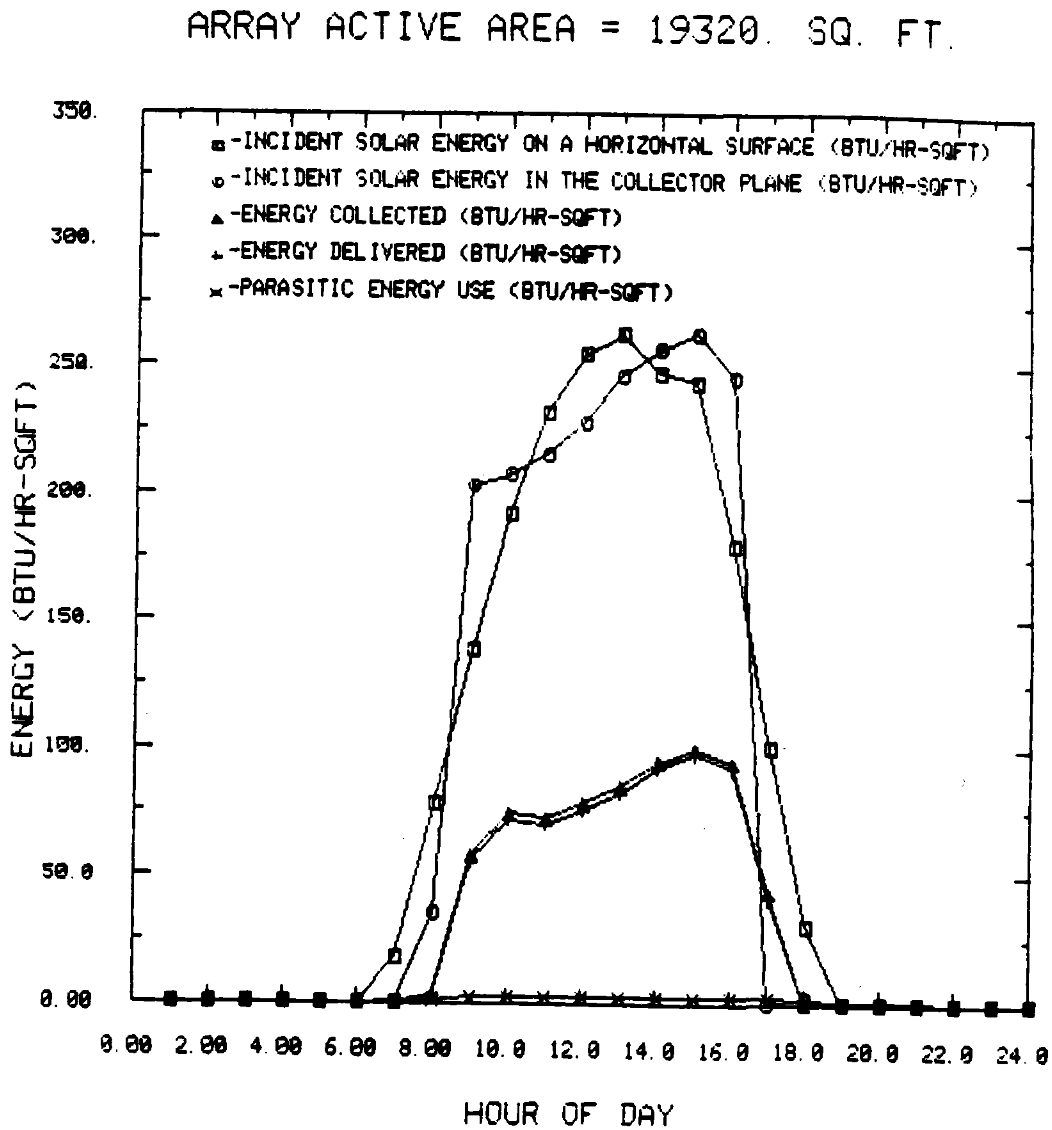


FIGURE 5. CLEAR DAY PERFORMANCE GRAPH - 9-11-83

SOUTHWEST RESEARCH INSTITUTE
POST OFFICE DRAWER 28510 • 6220 CULEBRA ROAD • SAN ANTONIO, TEXAS, USA 78284 • (512) 684-5111 • TELEX 76-7357

Department of Mechanical Sciences
November 15, 1983
Monthly Progress Report No. 45
Reporting Period October 1, 1983
through October 28, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC03OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The cost and manpower plans for the final year of operation are enclosed with this report.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The solar system and DAS operated smoothly during October. Additional portions of the collector array were activated due to the seasonal decrease in available radiation. The accompanying Performance Report summarizes this month's operation.

Respectfully submitted,

Steve Green

Steve T. Green
Research Engineer

APPROVED:

Danny M. Deffenbaugh
Project Manager

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 12

REPORT PERIOD:	October 1, 1983 - October 31, 1983
REPORT NO.:	CTCo-12
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

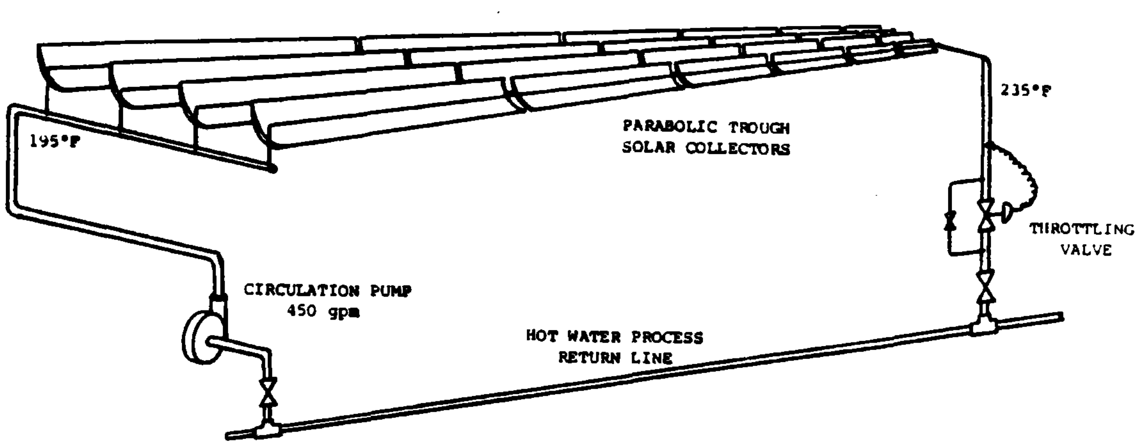


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation throughout the month of October. Several changes in the number of operating rows were made to accommodate seasonal changes in the solar system performance. The DAS operated smoothly during the entire month.

The operation of the solar system is summarized in Table I. It is seen that on 10/4 and 10/11 delta-T strings which had previously been deactivated were brought back into service. As the amount of solar radiation decreases, the active area of the collector array must be increased to maintain the collector array outlet temperature at an adequate level. This activity will be continued until all available delta-T strings are brought into service.

Figures 2-5 show the status of each of the 60 drive strings throughout the month of October. Figure 5 shows that at the end of October, 7 drive rows are down for maintenance. Table II shows the current status of each of these drive rows.

The maintenance activities for October are listed in Table III. It can be seen that replacement tracker heads (on order since June 1983) were received and immediately used.

IV. System Performance

A. Monthly Summary

The performance of the solar system is summarized in Table IV and Figure 6. It is seen that the solar system was allowed to operate on one of the Saturdays (10/23) and one of the Sundays (10/9) of the month. So, while system availability was 100% the utilization was only 74% (23 out of 31 days).

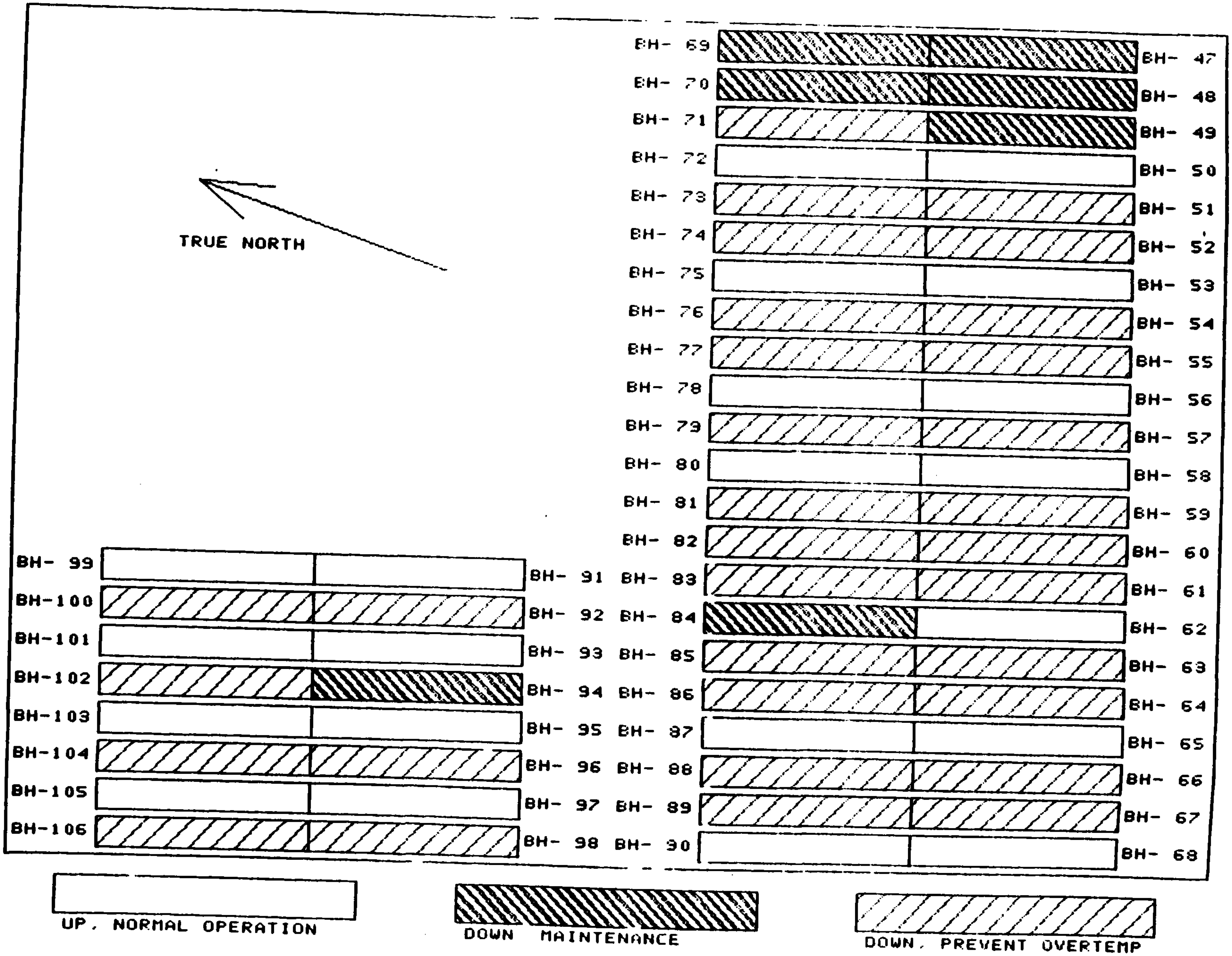
The horizontal radiation sensor was not operating properly on 10/31 so that no radiation data can be reported for that day. The total and average horizontal radiation and the respective array efficiency values were modified accordingly. The total monthly efficiency is 20% while the peak daily efficiency is seen to be 31.6%.

B. Clear Day Performance

The hourly performance for 10/24/83 is shown in Table V and Figure 7. The total energy delivery for this day was 9.37 $*10^6$ Btu at a day-long efficiency of 23.4%. Peak hourly efficiency was approximately 33%.

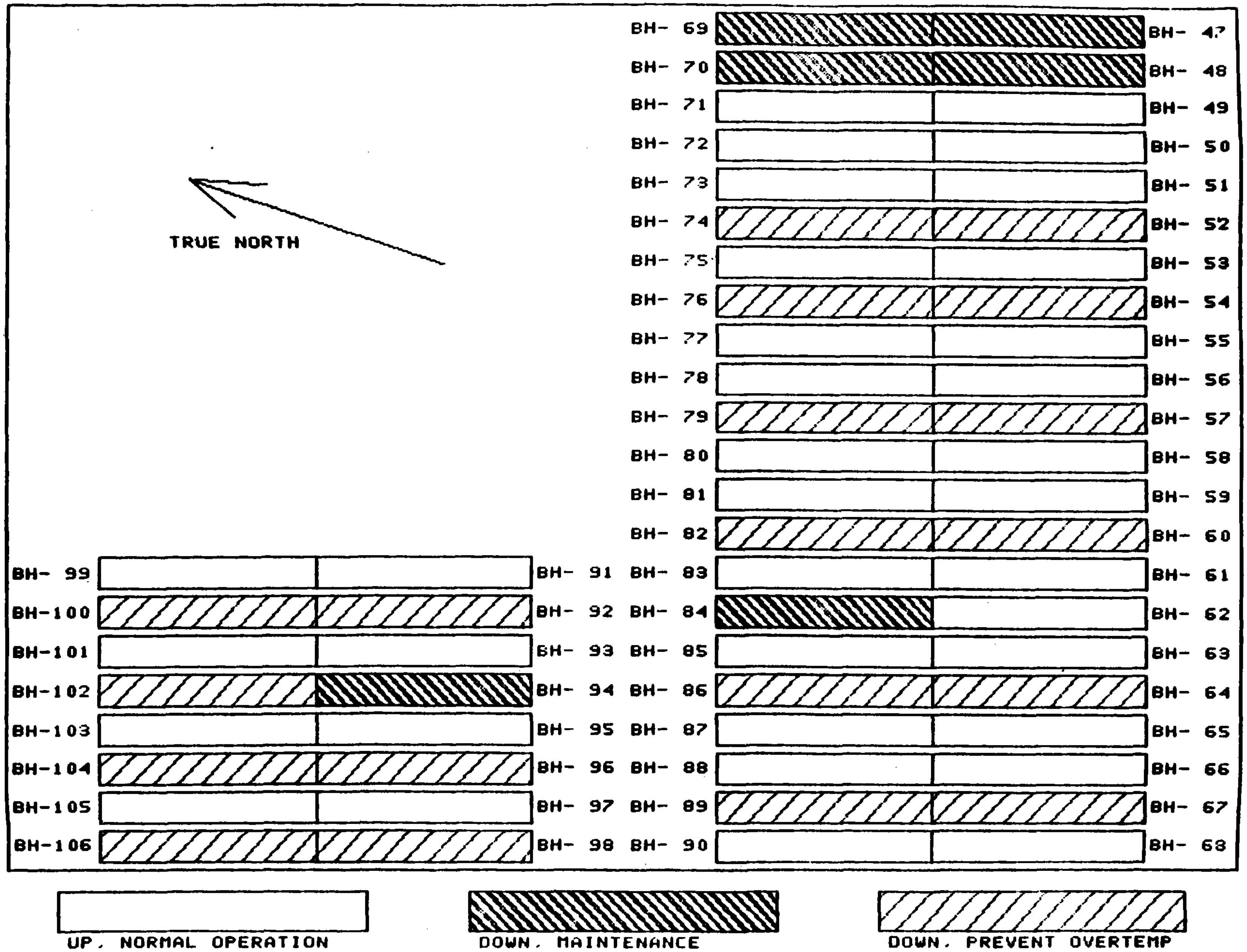
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
October 1983

Date	Active Area (ft^2)	Comments
10/1-10/3	19320	South Field: 13 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
10/4-10/10	29400	South Field: 27 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
10/11-10/26	39480	South Field: 39 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
10/27-10/31	38640	South Field: 38 drive rows up, no flow to down delta-T strings
		North Field: 8 drive rows up, no flow to down delta-T strings
10/27	--	Receiver tube glass on BH-49 broken. Row removed from service.



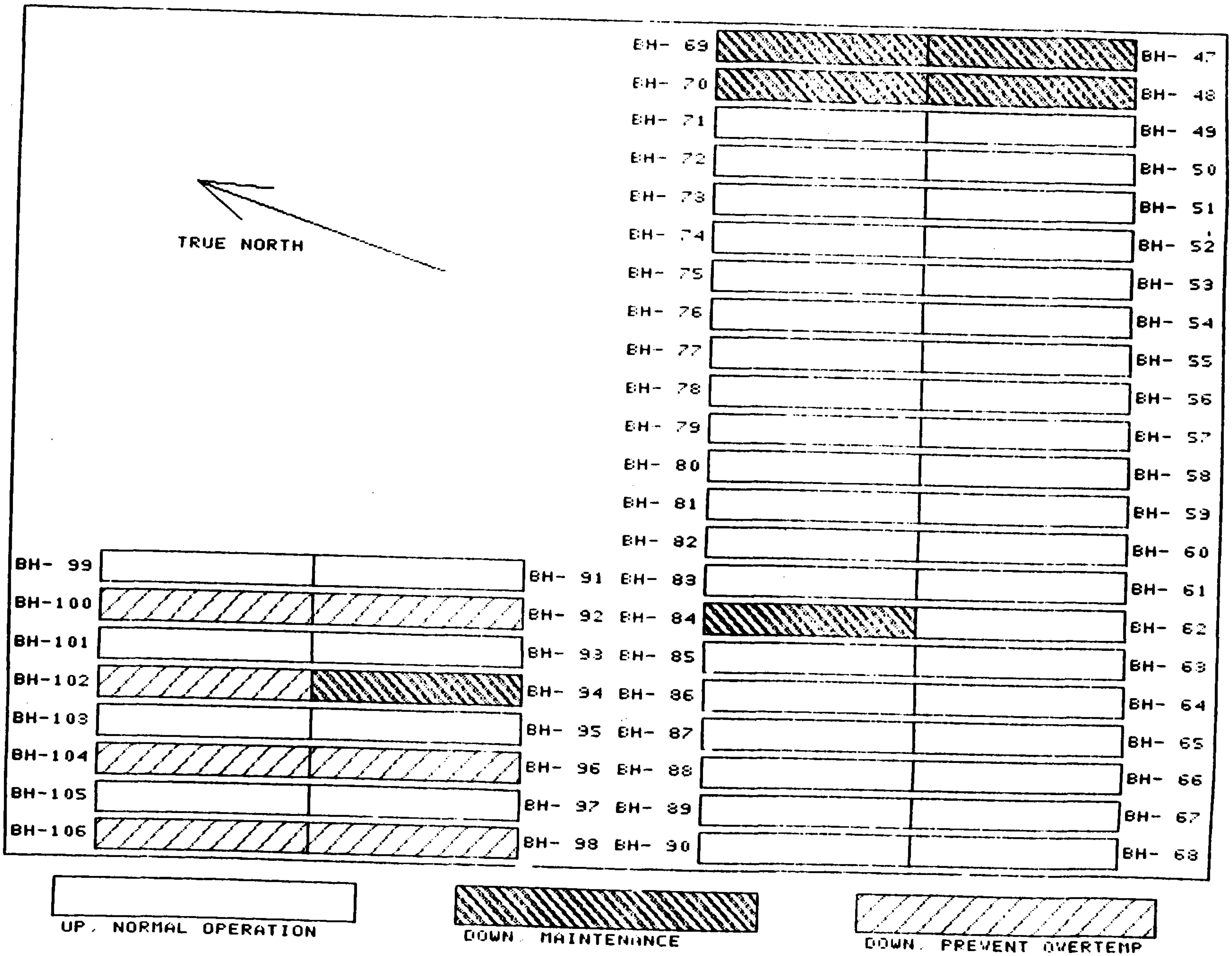
TIME PERIOD: OCTOBER 1-3

FIGURE 2



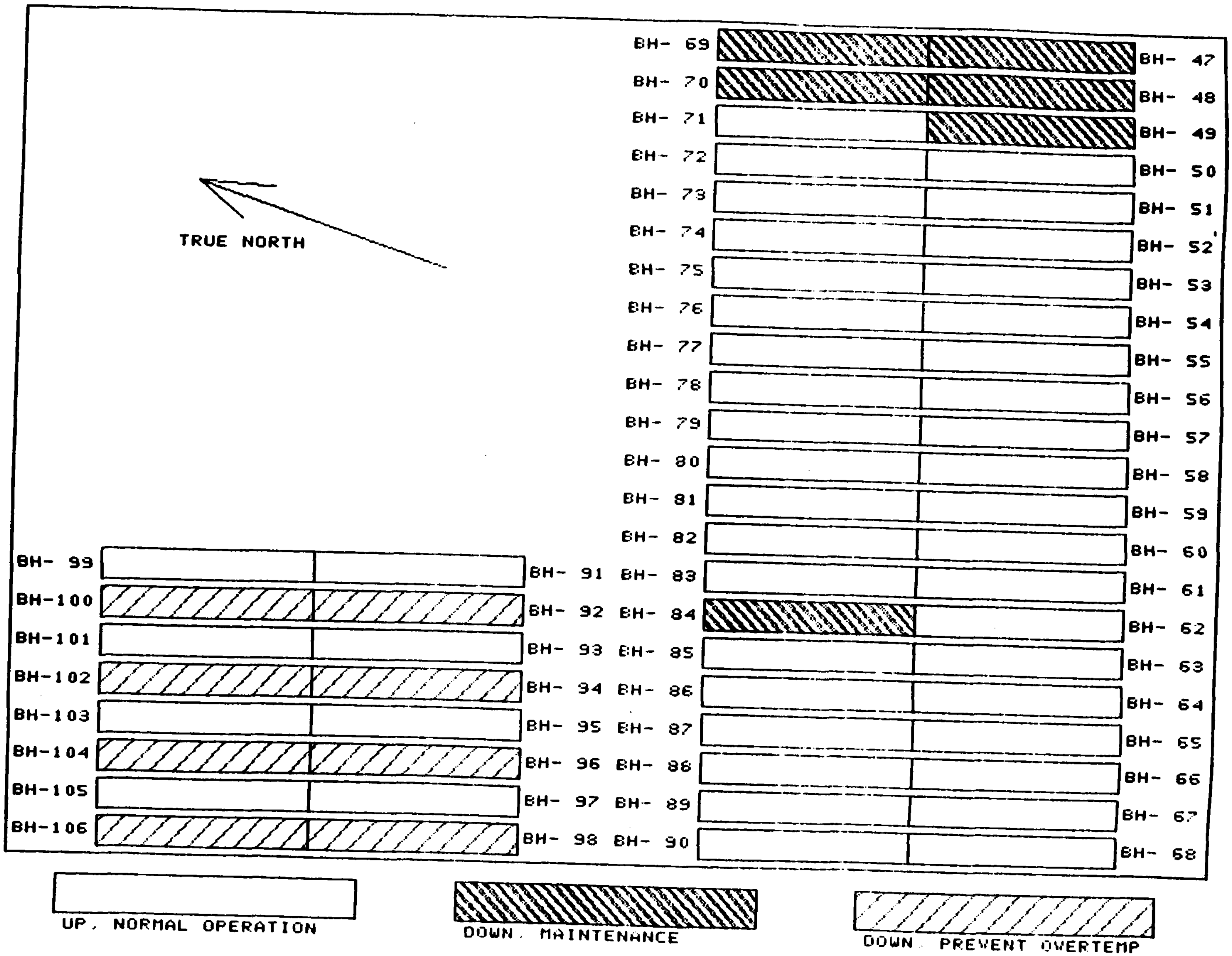
TIME PERIOD: OCTOBER 4-10

FIGURE 3.



TIME PERIOD: OCTOBER 11-26

FIGURE 4



TIME PERIOD: OCTOBER 27-31

FIGURE 5

TABLE II. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
October 31, 1983

Row	Date of Last Action	Comment
BH-47	6-13-83	Hydraulic oil pressure switch O-ring failure
BH-48	9-28-83	Outlet water hose leaking at fitting crimp
BH-49	10-27-83	Broken receiver tube glass
BH-69	7-3-83	Hydraulic oil hose leak
BH-70	9-28-83	See BH-48
BH-84	7-3-83	Hydraulic oil leak

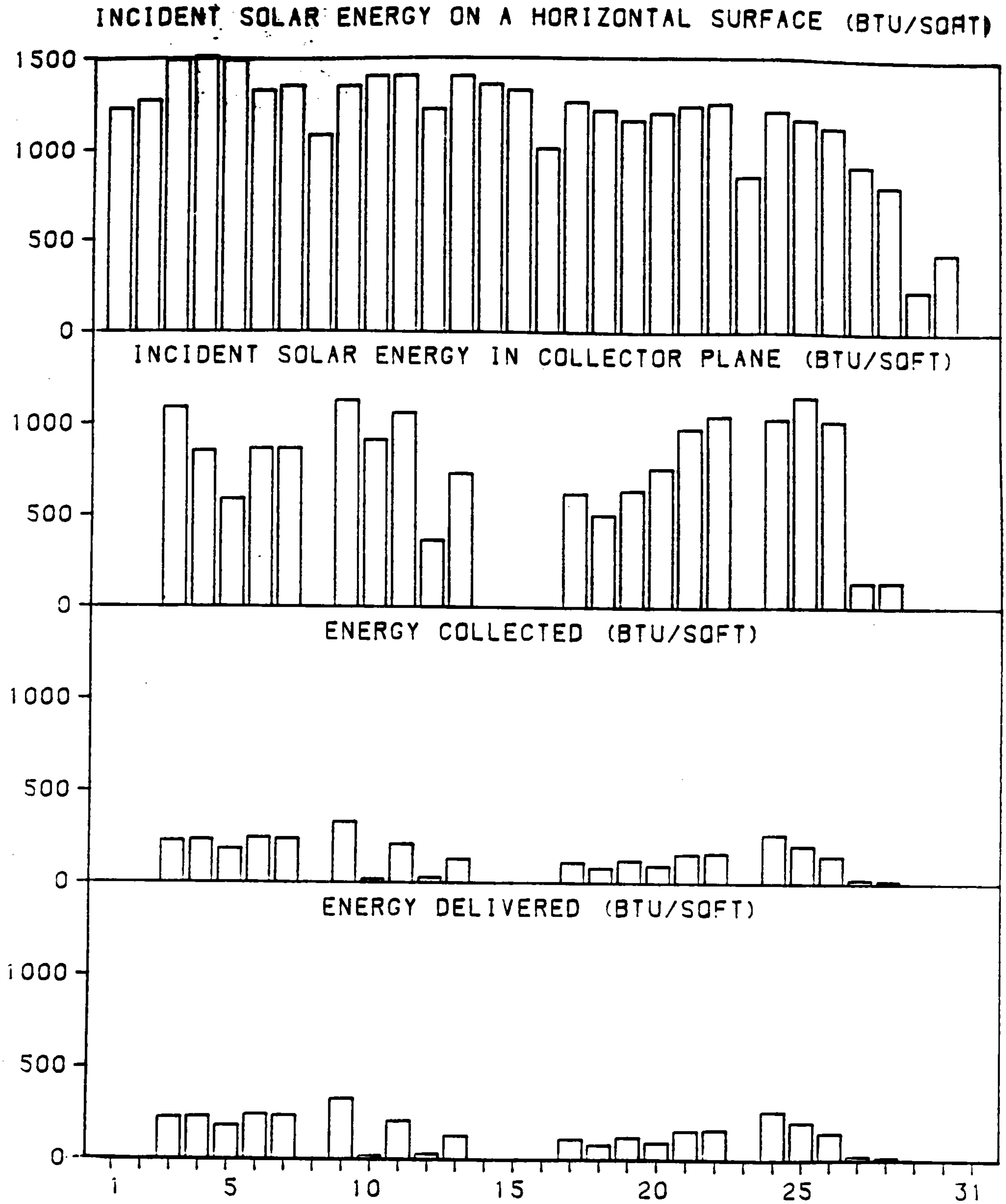
TABLE III. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
October 1983

O & M Activity	Hours	Cost Labor $	Cost Materials $	Cost Total $
o Routine inspection	7	217.58	-0-	217.58
o DAS disk change				
o Secure row BH-49 because of broken glass				
o Activate drives to increase array active area				
o Seal row BH-49 tracker head leak	1	31.09	-0-	31.09
o Replace leaking tracker head on Row BH-58	1	31.09	-0-	31.09
o Replace faulty tracker head on row BH-94	1	31.09	-0-	31.09
TOTAL	10	310.85	-0-	310.85

Total Cost for 2/83 - 10/83 = $5256.19

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 10/83

		INCIDENT SOLAR ENERGY						
DATE	JULIAN DAY	ON A HORIZ SURFACE (1) BTU/SQFT	ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
10/ 1	274	1232.2	-0.4	19320.	0.0	0.0	0.0	15.3
10/ 2	275	1277.3	0.0	19320.	0.0	0.0	0.0	16.2
10/ 3	276	1492.8	1087.2	19320.	4472.3	15.5	21.3	293.2
10/ 4	277	1512.5	852.1	29400.	6958.0	15.6	27.8	297.8
10/ 5	278	1492.8	591.2	29400.	5499.3	12.5	31.6	206.5
10/ 6	279	1336.6	864.5	29400.	7282.6	18.5	28.7	297.4
10/ 7	280	1361.1	863.8	29400.	7104.8	17.8	28.0	283.8
10/ 8	281	1088.8	0.0	29400.	0.0	0.0	0.0	24.6
10/ 9	282	1357.5	1126.1	29400.	9781.9	24.5	29.5	372.2
10/10	283	1409.1	912.4	29400.	686.3	1.7	2.6	286.8
10/11	284	1408.7	1058.9	39480.	8422.5	15.1	20.1	366.0
10/12	285	1228.4	365.5	39480.	1336.8	2.8	9.3	241.7
10/13	286	1405.7	730.6	39480.	5224.6	9.4	18.1	350.6
10/14	287	1359.4	0.0	39480.	0.0	0.0	0.0	36.6
10/15	288	1330.1	-0.1	39480.	0.0	0.0	0.0	36.0
10/16	289	1013.7	0.0	39480.	0.0	0.0	0.0	34.4
10/17	290	1265.9	622.5	39480.	4538.3	9.1	18.5	273.8
10/18	291	1220.0	503.3	39480.	3298.3	6.8	16.6	261.5
10/19	292	1164.5	635.8	39480.	4929.9	10.7	19.6	233.1
10/20	293	1207.6	755.3	39480.	3796.3	8.0	12.7	384.4
10/21	294	1243.7	975.5	39480.	6269.0	12.8	16.3	354.4
10/22	295	1257.2	1042.7	39480.	6511.4	13.1	15.8	381.9
10/23	296	859.2	-0.3	39480.	0.0	0.0	0.0	34.5
10/24	297	1217.3	1026.3	39480.	10518.3	21.9	26.0	372.5
10/25	298	1172.6	1148.5	39480.	8196.0	17.7	18.1	416.0
10/26	299	1131.3	1018.1	39480.	5957.6	13.3	14.8	421.2
10/27	300	922.0	139.1	38640.	952.8	2.7	17.7	145.4
10/28	301	811.1	139.8	38640.	688.0	2.2	12.7	159.8
10/29	302	237.6	-0.4	38640.	0.0	0.0	0.0	32.7
10/30	303	440.7	-0.2	38640.	0.0	0.0	0.0	32.6
10/31	304	———	-0.2	38640.	0.0	0.0	0.0	32.6
TOTALS		35457.6	16457.6		112425.1	9.2	20.0	6695.7
AVG		1181.9	530.9		3626.6			216.0



MONTHLY PERFORMANCE GRAPH 10-83

FIGURE 6

TABLE V. CLEAR DAY PERFORMANCE TABLE - 10/24/83 (Julian Day 297)

ARRAY ACTIVE AREA = 39480 SQ FT

			INCIDENT SOLAR ENERGY		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AMB TEMP F	WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/HR-FT2	IN THE COLLECTOR PLANE (2) BTU/HR-FT2	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	COLLECTOR ARRAY FLOW RATE GPM	COLLECTOR ARRAY TEMP IN F	COLLECTOR ARRAY TEMP OUT F	ENERGY COLLECTED KBTU/HR	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY KBTU/HR
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.	50.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.	59.3	4.1	36.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
9.	64.1	2.3	89.0	101.5	69.1	194.6	186.4	242.0	191.1	188.0	-476.3	-13.6	-11.9	51.4
10.	68.2	2.7	140.6	143.4	75.0	214.9	216.6	332.7	214.3	221.9	1287.0	23.2	22.7	56.1
11.	68.6	5.9	171.6	145.8	75.0	221.6	224.1	333.3	221.4	229.2	1347.3	19.9	23.4	55.9
12.	69.2	6.5	188.3	168.5	74.6	221.2	224.3	332.7	220.9	231.0	1727.8	23.2	26.0	55.8
13.	74.4	7.2	187.9	182.5	74.3	222.5	227.8	332.2	224.5	235.4	1937.6	26.1	26.9	55.5
14.	75.5	8.7	170.2	211.3	74.3	228.5	235.9	332.2	230.0	245.4	2715.7	40.4	32.6	55.2
15.	74.4	10.3	128.4	63.1	20.4	231.3	235.4	91.8	234.3	248.3	831.1	16.4	33.4	24.1
16.	72.4	9.8	77.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
17.	69.9	8.0	27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
18.	64.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
19.	62.2	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
20.	59.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
21.	58.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
22.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS			1218.2	1016.2							9370.2	19.5	23.4	370.7
AVG	66.1	5.3	121.8	145.2	66.1	219.2	221.5	285.3	219.5	228.5	1338.6			24.7

CLEAR DAY PERFORMANCE GRAPH 10-24-83

ARRAY ACTIVE AREA = 39480. SQ. FT.

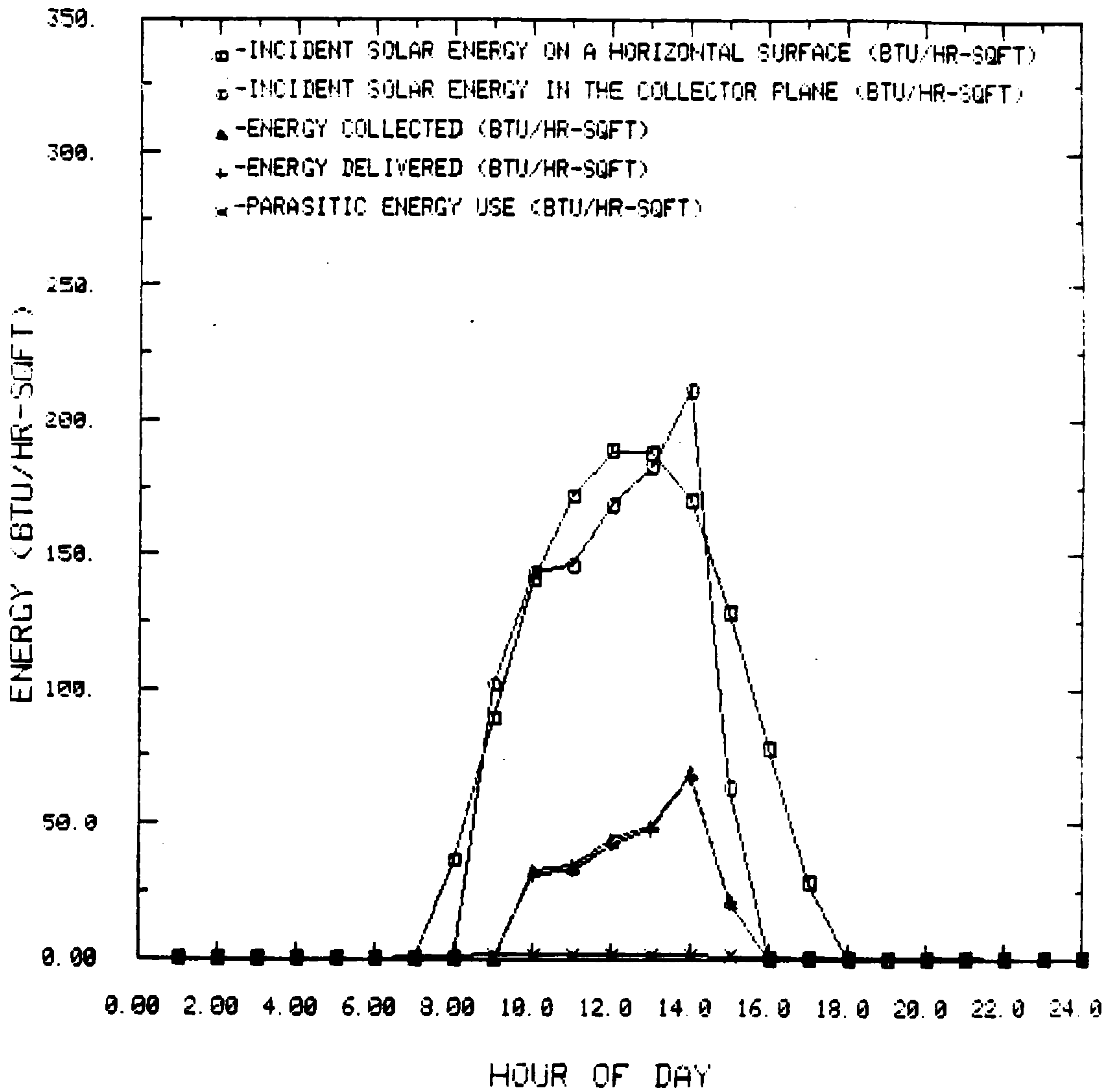


FIGURE 7

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
December 15, 1983
Monthly Progress Report No. 46
Reporting Period October 27, 1983
through November 25, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation cotinued this month with close attention paid to system maintenance.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The solar system's central controller microprocessor failed several times during the month. This problem, combined with several days of poor weather prevented the system from operating for approximately half of the month. Also, the DAS horizontal radiation sensor experienced problems. These are more fully discussed in the accompanying Performance Report.

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 13

REPORT PERIOD:	November 1, 1983 - November 30, 1983
REPORT NO.:	CTCo-13
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application: Preheat of process hot water for parts washing.

Site: 37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.

Process Schedule: Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.

Auxiliary Fuel: Natural gas.

Collectors: 50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).

Fluid Type, Flow: Treated water, North field - 330 gpm, South field - 120 gpm.

Design Energy Delivery: 14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.

Phase 1 Cost (Design): $143,045

Phase 2 Cost (Construction): $2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

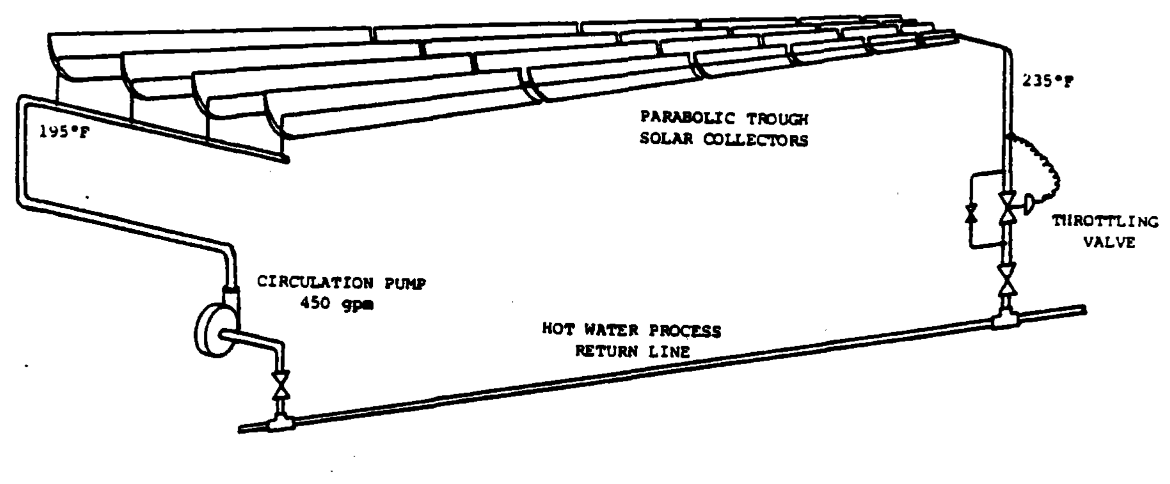


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation only from November 1 through November 13. Intermittent failure of the central controller prevented operation after that time. The DAS experienced problems with the horizontal radiation measurement.

The operation of the solar system is summarized in Table I. No changes were made in the number of rows available for operation; however, the central controller microprocessor failed sometime during the weekend of November 12-13. The microprocessor program was lost, so that apparently the central controller battery backup did not operate during a power failure. This failure went unnoticed for several days because of maintenance personnel changes. Also, after the system was placed back in operation, several more occurrences of this microprocessor failure were experienced. In each of these cases, the microprocessor had to be reprogrammed. The combination of equipment failures and poor weather prevented the system from operating between November 14 and November 30.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
November 1983

Date	Active Area (ft^2)	Comments	
11/1-11/30	38640	South Field:	38 drive rows up, no flow to down delta-T strings
		North Field:	8 drive rows up, no flow to down delta-T strings
11/14-11/30	--	Microprocessor failures prevent system operation	

The collector drive row status for the month of November is shown in Table II and Figure 2. It is seen that no changes were made in the drive row status in November.

The O & M activities are summarized in Table III. The only non-routine activity undertaken in November was the extensive maintenance on the central controller microprocessor.

IV. System Performance

Before presenting the performance summaries it should be noted that changes have been made in the format of the performance summary tables. This format change accompanies a minor change in the integration/averaging technique used in analyzing the data.

In the hourly performance table, the flow rate shown for each hour is the average flow rate for the entire hour. For example, a flow rate of 100 gpm for only 30 minutes of a given hour would be shown as an average flow of 50 gpm. This allows the reader to estimate the portion of the startup and shutdown hour for which the system actually operated. Conversely, the

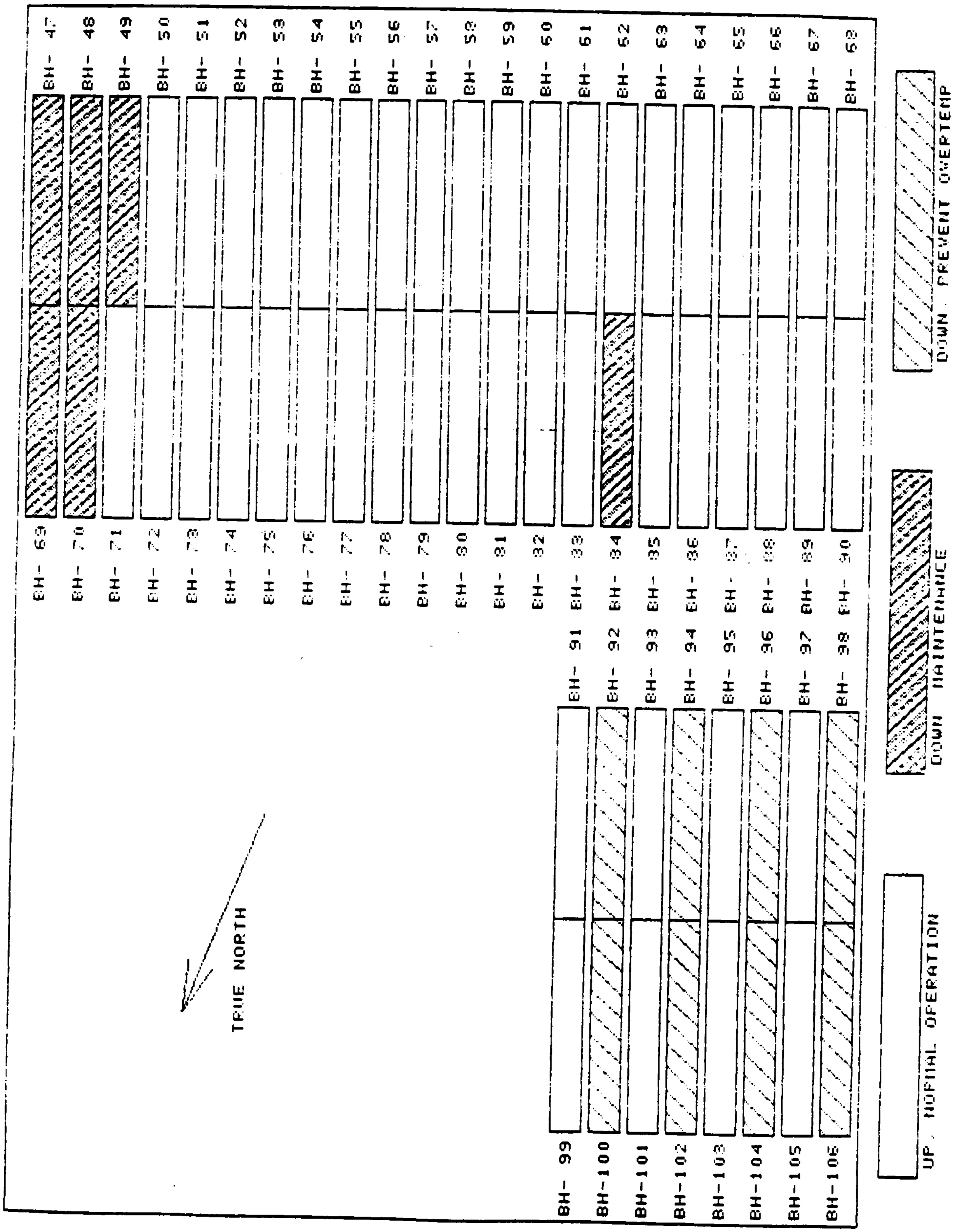
TABLE II. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
November 30, 1983

Row	Date of Last Action	Comment
BH-47	6-13-83	Hydraulic oil pressure switch O-ring failure
BH-48	9-28-83	Outlet water hose leaking at fitting crimp
BH-49	10-27-83	Broken receiver tube glass
BH-69	7-3-83	Hydraulic oil hose leak
BH-70	9-28-83	See BH-48
BH-84	7-3-83	Hydraulic oil leak

TABLE III. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
October 1983

		Cost		
O & M Activity	Hours	Labor $	Materials $	Total $
o Routine inspection	5	136.80	-0-	136.80
o DAS disk changes				
o Field walkthrough				
o Maintenance of central controller micro-processor	10	273.59	-0-	273.59
TOTAL	15	410.39	-0-	410.39

Total Cost for 2/83 - 11/83 = $5666.58



TIME PERIOD: NOVEMBER 1-30

FIGURE 2

average flow listed in the summary portion of the hourly performance table is the average flow rate only for the time in which the pump was operating.

Also, temperatures are now averaged only for the time in which the system is actually operating. These slight changes in flow and temperature data presentations more accurately portray the actual system operating conditions than had previously been done.

Finally, it will be noted that the decimal places have been dropped from all table entries except for the electrical energy consumption. This prohibits the assumption of a false accuracy when using the tabulated data.

A. Monthly Summary

The solar system performance for the month of November is summarized in Table IV and Figure 3. First of all it is seen that horizontal radiation cannot be presented for November 1-5. The pyranometer used for this measurement was giving erroneous readings during this time; however, the readings for the remainder of the month appear to be reasonable. Moisture contamination is thought to be the reason for this erratic behavior This will be investigated during the next site visit by SwRI personnel.

Second, the system was virtually unavailable for the period November 14-30. The availability during November was, therefore, only 43%. The system was utilized during November 1-13 whenever weather permitted so that system utilization was 43% as well.

Since no horizontal radiation can be reported for November 1-5, the monthly system efficiency based on horizontal radiation cannot be reported. Based on collector plane radiation, the total system efficiency is 19% with a daily peak value of 26%.

B. Clear Day Performance

System performance on November 11 is summarized on an hourly basis in Table V and Figure 4. The solar system delivered 6.8 $*10^6$ Btu on this day for an overall efficiency of 23%. The peak hourly efficiency was 39%.

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 11/83

MONTHLY PERFORMANCE SUMMARY TABLE - 11/83

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU	
11/ 1	305	———	22.	38640.	-668.	—	-79.	108.1	
11/ 2	306	———	814.	38640.	8243.	—	26.	464.4	POSSIBLE MISSING DATA
11/ 3	307	———	0.	38640.	0.	—	0.	28.2	
11/ 4	308	———	0.	38640.	0.	—	0.	28.0	
11/ 5	309	———	700.	38640.	3069.	—	11.	387.7	
11/ 6	310	1441.	196.	38640.	1922.	3.	25.	118.1	
11/ 7	311	475.	467.	38640.	2416.	13.	13.	266.5	
11/ 8	312	261.	0.	38640.	0.	0.	0.	24.9	POSSIBLE MISSING DATA
11/ 9	313	208.	0.	38640.	0.	0.	0.	24.0	
11/10	314	193.	0.	38640.	0.	0.	0.	24.2	
11/11	315	1668.	772.	38640.	6767.	10.	23.	395.9	
11/12	316	722.	0.	38640.	0.	0.	0.	26.7	
11/13	317	494.	0.	38640.	0.	0.	0.	27.1	
11/14	318	1020.	0.	38640.	0.	0.	0.	24.2	
11/15	319	990.	0.	38640.	0.	0.	0.	25.0	
11/16	320	374.	0.	38640.	0.	0.	0.	25.3	
11/17	321	421.	0.	38640.	0.	0.	0.	25.1	
11/18	322	988.	0.	38640.	0.	0.	0.	24.7	
11/19	323	467.	0.	38640.	0.	0.	0.	24.4	
11/20	324	694.	0.	38640.	0.	0.	0.	25.1	
11/21	325	1015.	0.	38640.	0.	0.	0.	23.9	
11/22	326	406.	0.	38640.	0.	0.	0.	24.5	
11/23	327	269.	0.	38640.	0.	0.	0.	24.7	
11/24	328	338.	0.	38640.	0.	0.	0.	28.0	
11/25	329	967.	0.	38640.	0.	0.	0.	26.8	
11/26	330	980.	0.	38640.	0.	0.	0.	23.7	
11/27	331	958.	0.	38640.	0.	0.	0.	24.9	
11/28	332	942.	0.	38640.	0.	0.	0.	24.2	
11/29	333	664.	0.	38640.	0.	0.	0.	24.1	
11/30	334	247.	0.	38640.	0.	0.	0.	24.5	
TOTALS		17203.	2971.		21748.	---	19.	2347.0	
AVG		688.	99.		725.			78.2	

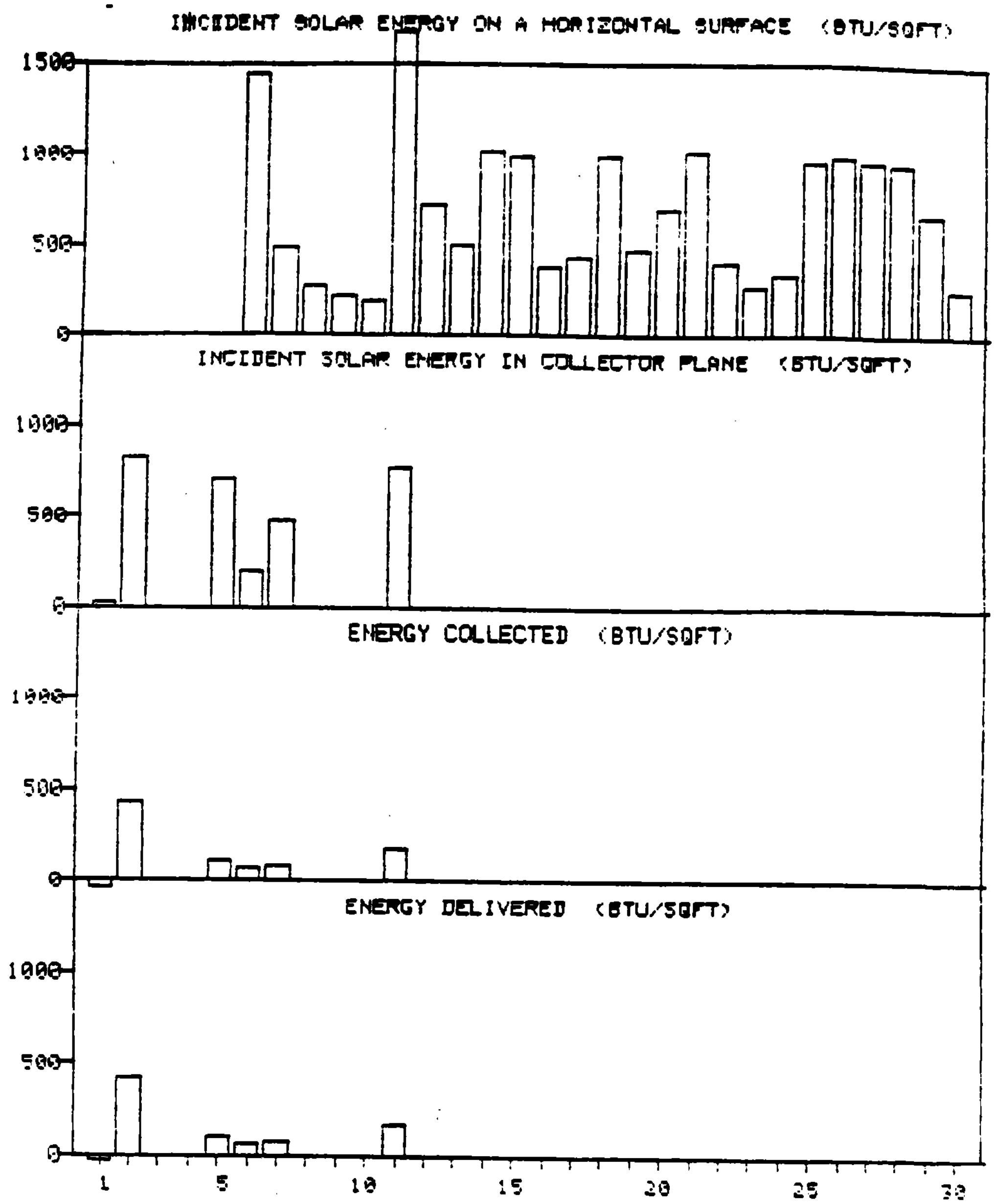


FIGURE 3. MONTHLY PERFORMANCE GRAPH 11-83

TABLE V. HOURLY PERFORMANCE TABLE - 11-11-83 (JULIAN DAY 315)

ARRAY ACTIVE AREA = 38640. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
			ON A HORIZ SURFACE (1)	IN THE COLLECTOR PLANE (2)	AVERAGE FLOW RATE OVER HOUR	AVERAGE OPERATING TEMPERATURE		AVERAGE FLOW RATE OVER HOUR	AVERAGE OPERATING TEMPERATURE		TOTAL ENERGY COLLECTED OVER HOUR	HOURLY COLLECTOR ARRAY EFF BASED ON (1)	HOURLY COLLECTOR ARRAY EFF BASED ON (2)	TOTAL ELEC ENERG USED OVER HOUR
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	BTU/SQFT	BTU/SQFT	GPM	IN F	OUT F	GPM	IN F	OUT F	KBTU	%	%	KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	54.	1.	21.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
8	56.	2.	44.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.3
9	61.	5.	91.	74.	74.	208.	199.	220.	205.	199.	-752.	***	***	46.6
10	61.	4.	126.	67.	90.	220.	219.	326.	220.	221.	119.	2.	5.	55.7
11	64.	3.	181.	120.	90.	224.	227.	327.	224.	229.	896.	13.	19.	56.4
12	64.	3.	180.	83.	75.	222.	225.	260.	221.	227.	723.	10.	23.	56.8
13	71.	3.	227.	164.	89.	223.	229.	324.	222.	234.	2089.	24.	33.	55.6
14	69.	4.	217.	190.	88.	227.	236.	323.	227.	242.	2827.	34.	39.	55.6
15	67.	4.	192.	76.	76.	228.	234.	277.	228.	233.	865.	12.	30.	54.1
16	65.	4.	143.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
17	63.	5.	87.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
18	59.	3.	52.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
19	57.	1.	42.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
20	55.	0.	36.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
21	53.	1.	31.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			1668.	772.							6767.	10.	23.	386.7
AVG	61.	3.	112.	117.	84.	222.	225.	296.	221.	227.	1028.			7.8

ARRAY ACTIVE AREA = 38640. SQ. FT.

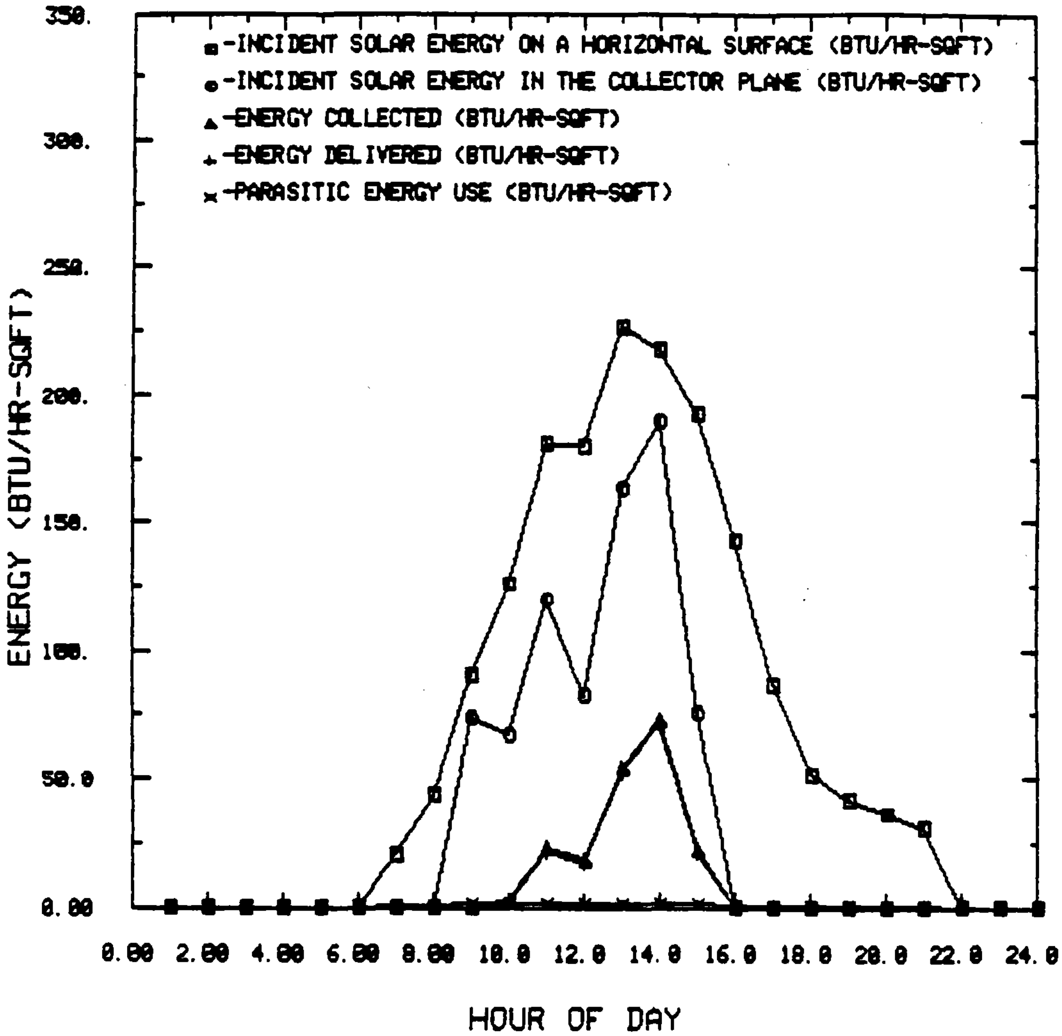


FIGURE 4. CLEAR DAY PERFORMANCE GRAPH 11-11-83

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
January 20, 1984
Monthly Progress Report No. 47
Reporting Period November 26, 1983
through December 23, 1983

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued this month.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The solar system was available for operation for the entire month, but bad weather prohibited extensive operation. A site visit by SwRI personnel is planned for January to perform DAS preventative maintenance and upgrade, and to review solar system operations.

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 14

REPORT PERIOD:	December 1, 1983 - December 31, 1983
REPORT NO.:	CTCo-14
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

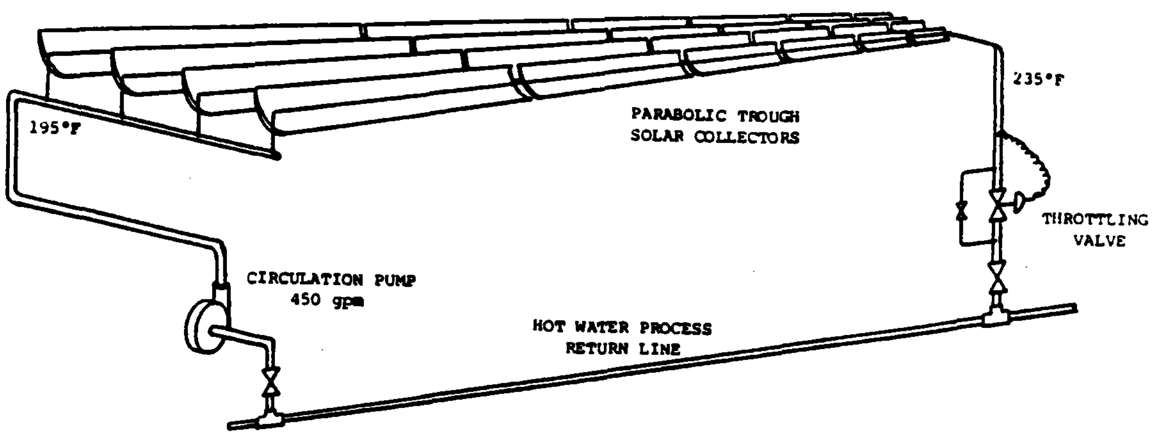


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation throughout the month of December, but bad weather prohibited extensive operation. The data acquisition system operated smoothly, with the exception of a pressure transmitter.

The operation of the solar system is summarized in Table I. All available rows were brought into service on December 5th. At this time, then, the plant can use any energy which the solar system can deliver without the danger of heating the system to high temperatures, as observed in the spring and summer months (see Monthly Report CTCo-5 and CTCo-6, March and April, 1983).

Maintenance activities for December are summarized in Table II. The only non-routine tasks performed were the installation of new hydraulic circuit components. Because of the plant maintenance priorities, the installed components could not be thoroughly checked out; so, drive rows BH-47 and BH-69 were left out of service. A summary of the out-of-service rows is given in Table III, which remains virtually unchanged from the report for November, CTCo-13. Figures 2 and 3 show the status of each of the drive rows in a plan view of the array.

While reviewing the data for December, a pressure transducer was discovered to be producing an erroneous signal. This has no effect on the acquisition of thermal performance data; however, the replacement of this transducer is scheduled for the next SwRI site visit.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
December 1983

Date	Active Area (ft^2)	Comments	
12/1-12/4	640	South Field:	38 drive rows up, no flow to down delta-T strings
		North Field:	8 drive rows up, no flow to down delta-T strings
12/5-12/31	47040	South Field:	38 drive rows up, no flow to down delta-T strings
		North Field:	All 16 drive rows operational

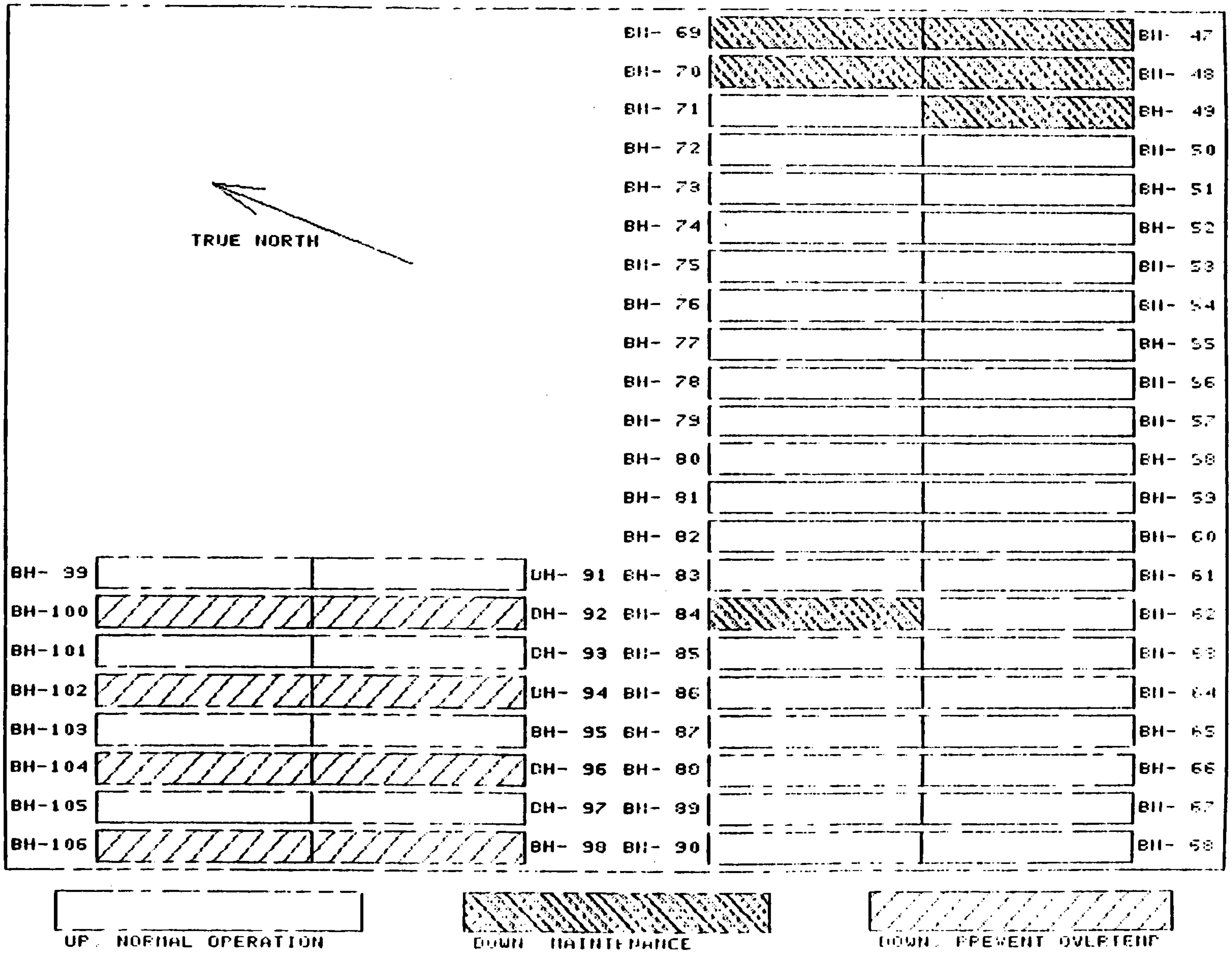
TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
December 1983

O & M Activity	Hours	Cost: Labor $	Cost: Materials $	Cost: Total $
o Routine inspection	10	310.85	-0-	310.85
o DAS disk changes				
o Field walkthrough				
o Hydraulic drive components installed	7.3	175.76	-0-	175.76
TOTAL	17.3	486.61	-0-	486.61

Total Cost for 2/83 - 12/83 = $6153.19

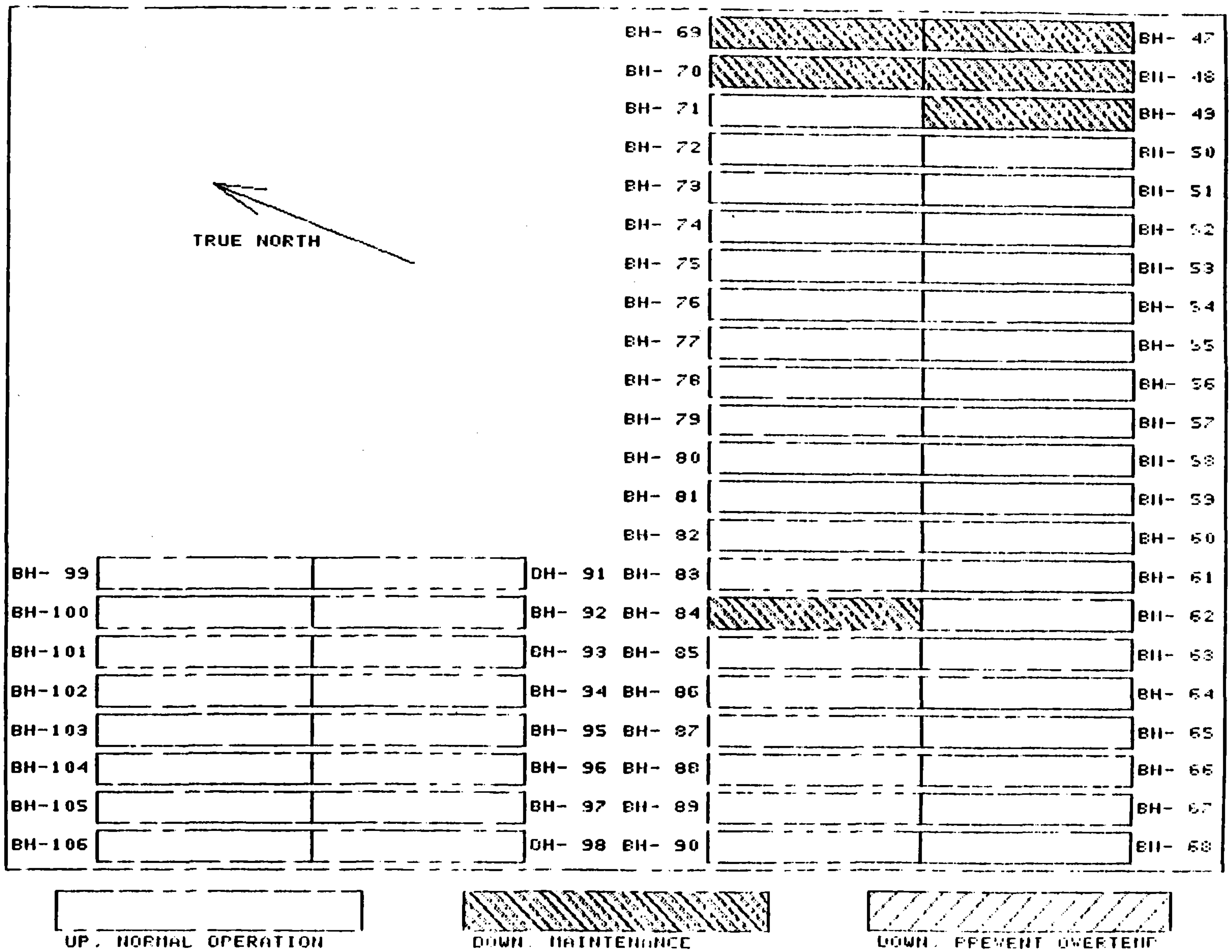
TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
December 31, 1983

Row	Date of Last Action	Comment
BH-47	12-83	Oil pressure switch repaired but not filled with oil
BH-48	9-28-83	Outlet water hose leaking at fitting crimp
BH-49	10-27-83	Broken receiver tube glass
BH-69	12-83	Oil hose replaced but not filled with oil
BH-70	9-28-83	See BH-48
BH-84	7-3-83	Hydraulic oil leak



TIME PERIOD: DECEMBER 1-4

FIGURE 2



TIME PERIOD: DECEMBER 5-21

FIGURE 3

IV. System Performance

A. Monthly Summary

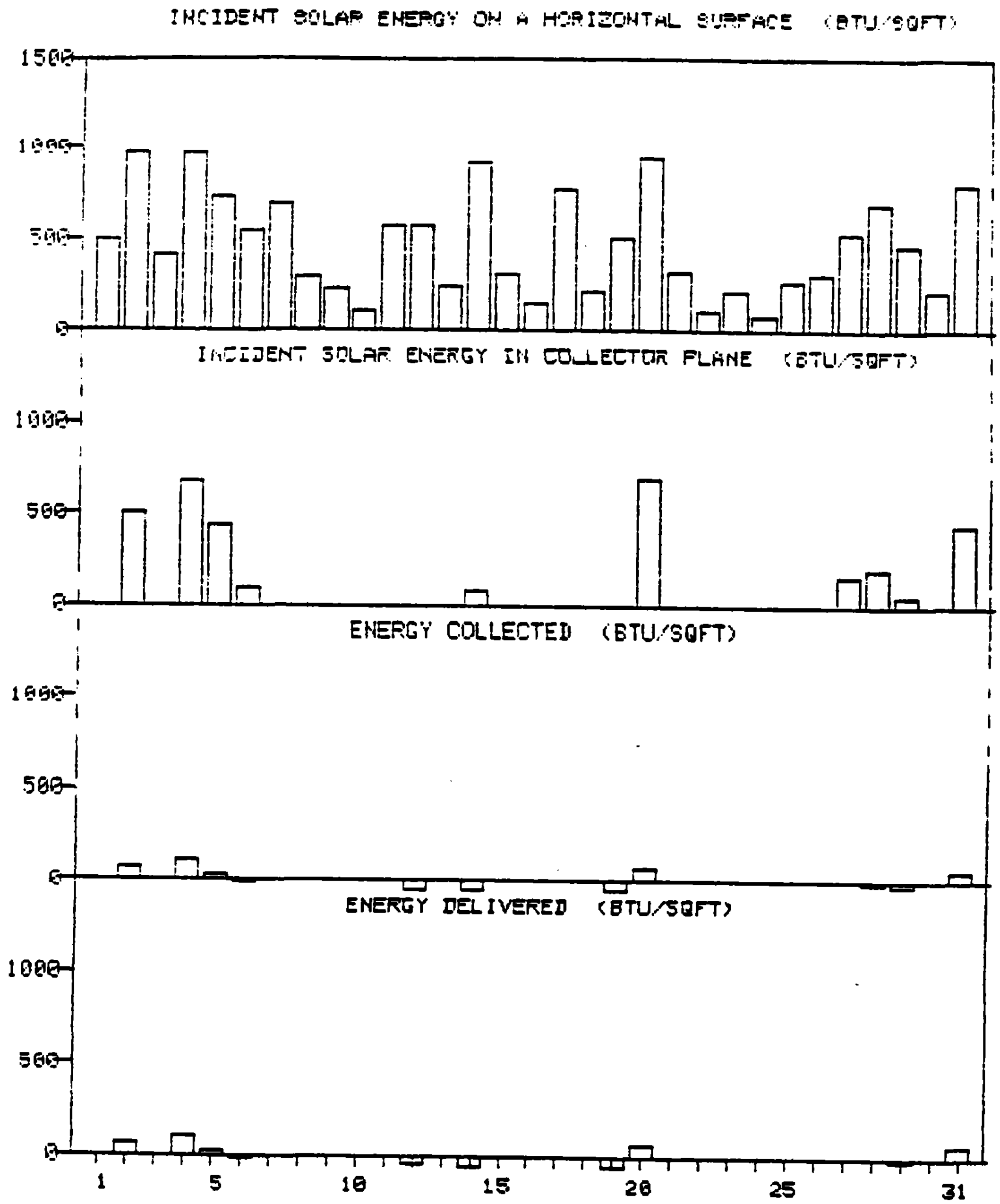
The solar system thermal performance for December, 1983 is summarized in Table IV and Figure 4. It is seen that very little solar radiation was available for most of the month. By reviewing Table IV it may be claimed that the radiation threshold for operation of the solar system appears to be approximately 700 Btu/ft2-day (horizontal). It is also seen that on several days substantial amounts of energy were lost. This is thought to be due to an inappropriate setting in the light sensor circuit in the central controller. If only the days for which there is positive energy delivered is considered the overall monthly efficiency is approximately 9.9% with a total energy delivery of 13.8 $*10^6$ Btu. So, perhaps if a more appropriate threshold in the central controller had been chosen, a significant increase in system performance could have been realized. this problem will be reviewed with CTCo personnel.

B. Clear Day Performance

The performance for Decembear 4. 1983 is summarized in Table V and Figure 5. The solar system delivered 4.1 $*10^6$ Btu on this day for an overall efficiency of 16%. The peak hourly efficiency was 32%.

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 12/83

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU	
12/ 1	335	499.	0.	38640.	0.	0.	0.	24.5	
12/ 2	336	968.	494.	38640.	2668.	7.	14.	337.7	
12/ 3	337	409.	0.	38640.	0.	0.	0.	30.5	
12/ 4	338	971.	677.	38640.	4140.	11.	16.	339.0	
12/ 5	339	739.	431.	47040.	1125.	3.	6.	316.1	POSSIBLE MISSING DATA
12/ 6	340	543.	84.	47040.	-679.	-3.	-17.	121.7	
12/ 7	341	691.	0.	47040.	0.	0.	0.	36.6	
12/ 8	342	300.	0.	47040.	0.	0.	0.	34.9	
12/ 9	343	230.	0.	47040.	0.	0.	0.	34.1	
12/10	344	101.	0.	47040.	0.	0.	0.	32.8	
12/11	345	577.	0.	47040.	0.	0.	0.	35.0	
12/12	346	571.	0.	47040.	-2464.	-9.	*****	94.0	
12/13	347	235.	0.	47040.	0.	0.	0.	33.6	
12/14	348	920.	76.	47040.	-2454.	-6.	-68.	321.9	
12/15	349	300.	0.	47040.	0.	0.	0.	29.2	
12/16	350	145.	0.	47040.	0.	0.	0	27.7	
12/17	351	771.	0.	47040.	0.	0.	0.	30.7	
12/18	352	214.	0.	47040.	0.	0.	0	28.6	
12/19	353	511.	-12.	47040.	-2668.	-11.	475.	144.0	
12/20	354	946.	683.	47040.	3221.	7.	10.	463.3	
12/21	355	320.	0.	47040.	0.	0.	0.	26.8	
12/22	356	101.	0.	47040.	0.	0.	0.	27.3	
12/23	357	210.	0.	47040.	0.	0.	0.	29.0	
12/24	358	78.	0.	47040.	0.	0.	0.	27.3	
12/25	359	265.	0.	47040.	0.	0.	0.	26.8	
12/26	360	311.	0.	47040.	0.	0.	0.	32.3	
12/27	361	536.	148.	47040.	20.	0.	0.	122.2	
12/28	362	697.	195.	47040.	-514.	-2.	-6.	289.0	
12/29	363	471.	40.	47040.	-1191.	-5.	-63.	91.7	
12/30	364	209.	0.	47040.	0.	0.	0.	29.0	
12/31	365	794.	438.	47040.	2626.	7.	13	268.9	
TOTALS		14634.	3254.		3830.	1.	3.	3486.1	
AVG		472.	105.		124.			112.5	



MONTHLY PERFORMANCE GRAPH 12-83

FIGURE 4

TABLE V. HOURLY PERFORMANCE TABLE - 12/4/83 (JULIAN DAY 338)

ARRAY ACTIVE AREA = 38640. SQ.FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	43.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.8
8	43.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
9	48.	0.	57.	50.	57.	156.	151.	108.	155.	151.	-479.	***	***	35.2
10	51.	2.	100.	83.	96.	167.	169.	225.	169.	171.	364.	9.	11.	52.9
11	53.	7.	140.	92.	97.	163.	164.	216.	165.	166.	247.	5.	7.	52.4
12	52.	10.	158.	124.	96.	163.	166.	226.	165.	170.	713.	12.	15.	52.4
13	58.	10.	162.	161.	94.	168.	173.	250.	170.	179.	1364.	22.	22.	53.4
14	58.	9.	145.	149.	92.	177.	184.	273.	179.	190.	1825.	33.	32.	54.0
15	57.	9.	109.	18.	23.	182.	188.	70.	184.	186.	127.	3.	18.	21.2
16	55.	10.	66.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
17	53.	6.	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
18	49.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
19	48.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
20	47.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
21	45.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			971.	677.							4140.	11.	16.	331.1
AVG	51.	6.	107.	114.	88.	167.	170.	216.	169.	173.	700.			6.7

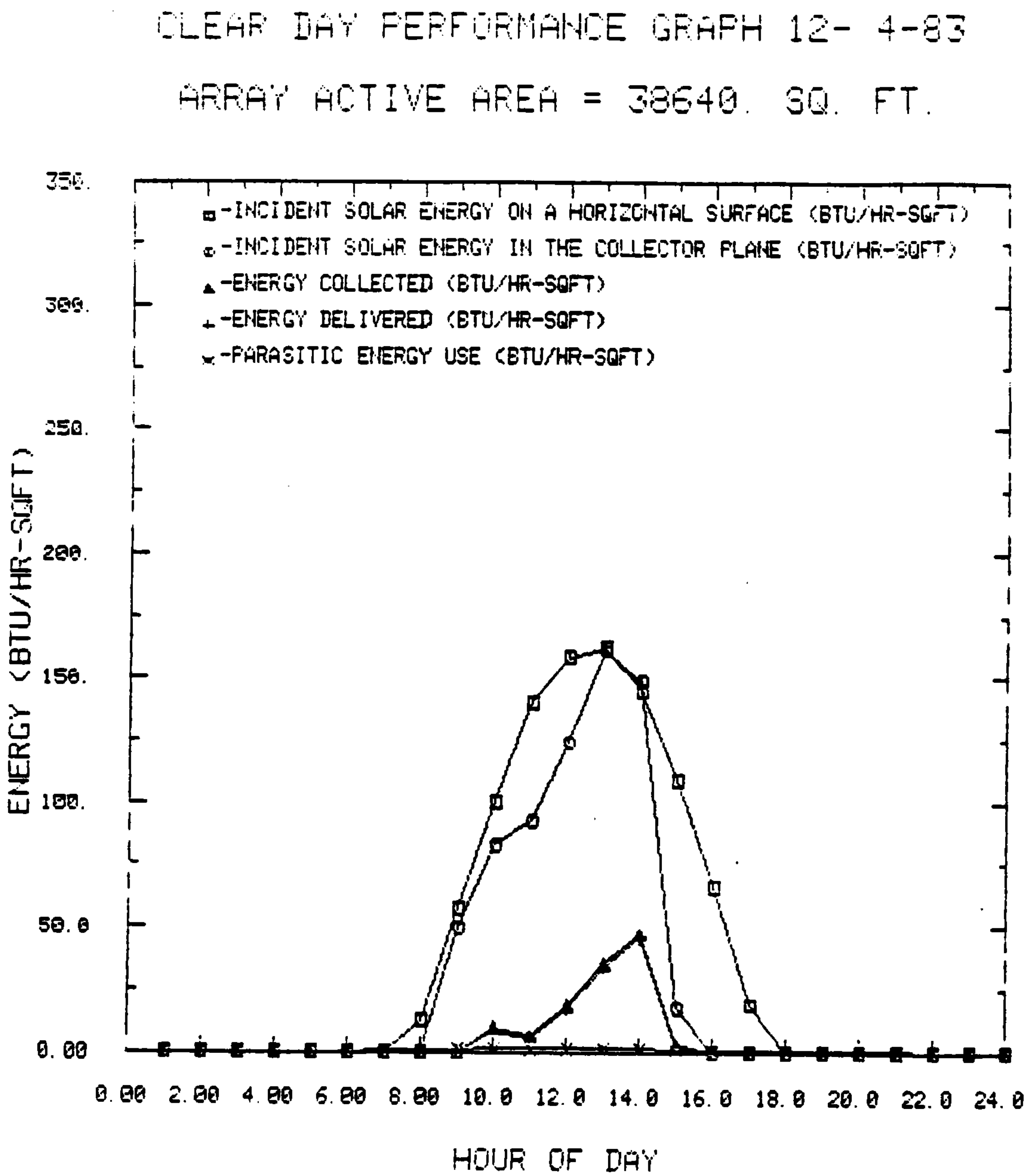

CLEAR DAY PERFORMANCE GRAPH 12- 4-83
ARRAY ACTIVE AREA = 38640. SQ. FT.
-INCIDENT SOLAR ENERGY ON A HORIZONTAL SURFACE (BTU/HR-SQFT)
-INCIDENT SOLAR ENERGY IN THE COLLECTOR PLANE (BTU/HR-SQFT)
-ENERGY COLLECTED (BTU/HR-SQFT)
-ENERGY DELIVERED (BTU/HR-SQFT)
-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 5

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Department of Mechanical Sciences
February 20, 1984
Monthly Progress Report No. 48
Reporting Period December 24, 1983
through January 20, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

SwRI made a visit to the site to perform maintenance on the solar system and to update the DAS software.

SUMMARY STATUS ASSESSMENT AND FORECAST:

SwRI and CTCo personnel were able to repair many of the disabled drive rows in the solar system. The problems were positively identified for those rows which could not be immediately repaired and brought back to service. These rows will be repaired as soon as spare parts are made available.

The mirrors of the north array were rinsed and the glass envelopes were washed so that the optical efficiency could be improved. The south field was left untouched so that a comparison between dirty and clean collectors could be performed.

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

These activities are discussed in detail in the accompanying Performance Report, CTCo-15.

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

MONTHLY REPORT NO. 15

REPORT PERIOD:	January 1, 1984 - January 31, 1984
REPORT NO.:	CTCo-15
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

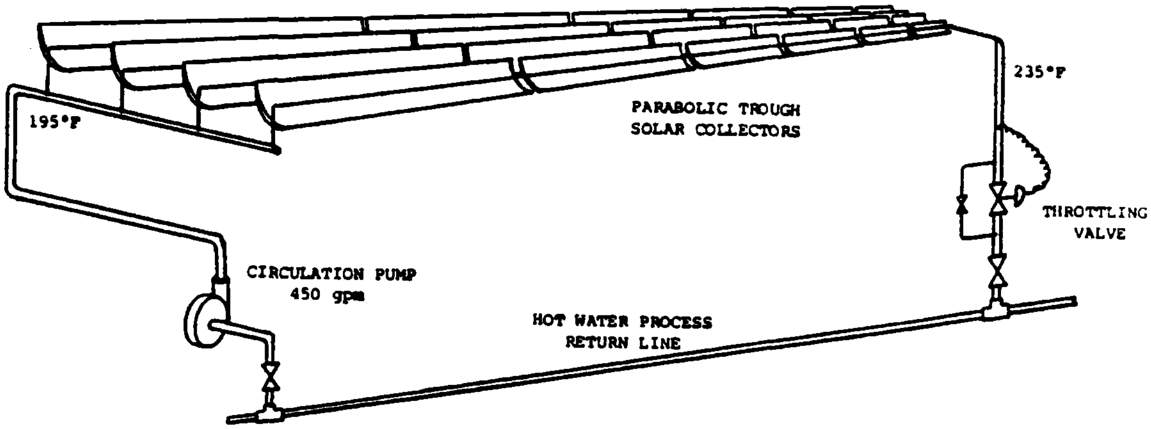


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The CTCo solar-system was available for operation during the month of January except for 1/10/84 and 1/11/84. The solar system and DAS were down these two days for maintenance during the SwRI site visit of 1/9/84-1/13/84.

The operation of the solar system is summarized in Table I. It is seen that after the maintenance tasks were performed during this site visit, there are only 4 of the 60 drive rows down because of drive pylon problems.

The maintenance activities performed during the past month are summarized in Table II. As a result of these maintenance activities, rows BH-47, -48, -69, and -70 were brought into service and the maintenance problems with rows BH-49, -59, -64, and -84 were clearly defined. The remaining maintenance problems are listed in Table III. The locations of the rows in question are shown in Figures 2 and 3.

During the site visit SwRI personnel also measured the reflectance of several mirror surfaces. These reflectance measurements are shown in Table IV along with measurements made on 8/16/83. If one considers the period 8/16/83-1/10/84 the average reflectance degradation over the 147 day period is 0.165%/day (neglect row BH-103; it falls out of the small band formed by the other 5 rows). The North Field was rinsed on 1/11/84; the subsequent reflectance measurements are shown in Table IV. The average reflectance of the rinsed collectors is approximately 85% of the value achieved by thoroughly cleaning the mirror surface.

IV. System Performance

A. Monthly Summary

The solar system thermal performance for the month of January is summarized in Table V and Figure 4. It is seen that the only weekend day the solar system delivered energy was 1/1, which happened to be the day of highest all-day efficiency. The day in which the system delivered the most energy, however, was 1/30.

It can be seen that the values shown for radiation in the horizontal plane are questionable for several days. This problem was first observed in November 1983, but had not been observed again until January 14, 1984. The problem did not manifest itself during the site visit, however, so the source could not be identified. A replacement pyranometer and transducer are being calibrated for shipment to CTCo for installation by plant personnel.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
January 1984

Date	Active Area (ft^2)	Comments
1/1-1/9	43680	South Field: 36 drive rows up, no flow to down delta-T strings.
		North Field: All 16 drive rows operational.
1/10-1/11	--	Solar system and DAS down for maintenance. North Field washed.
1/12-1/31	47040	South Field: 40 drive rows up.
		North Field: All 16 drive rows operational. Full flow to both fields.

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
January 1984

O & M Activity	Hours	Cost Labor $	Materials $	Total $
o Routine inspection	4	124.25	--	124.25
o DAS disk changes				
o Field walkthrough				
o Drive row troubleshoot and repair	10	250.00*	--	250.00
o Wash North Field	4	100.00*	160.00 (Subcontract)	260.00
o Replace BH-49 receiver tube	4	100.00*	--	100.00
o Replace BH-48 flex hose	4	100.00*	--	100.00
TOTAL	26	674.25	160.00	834.25

Total Cost for 2/83-1/84 = $6987.44

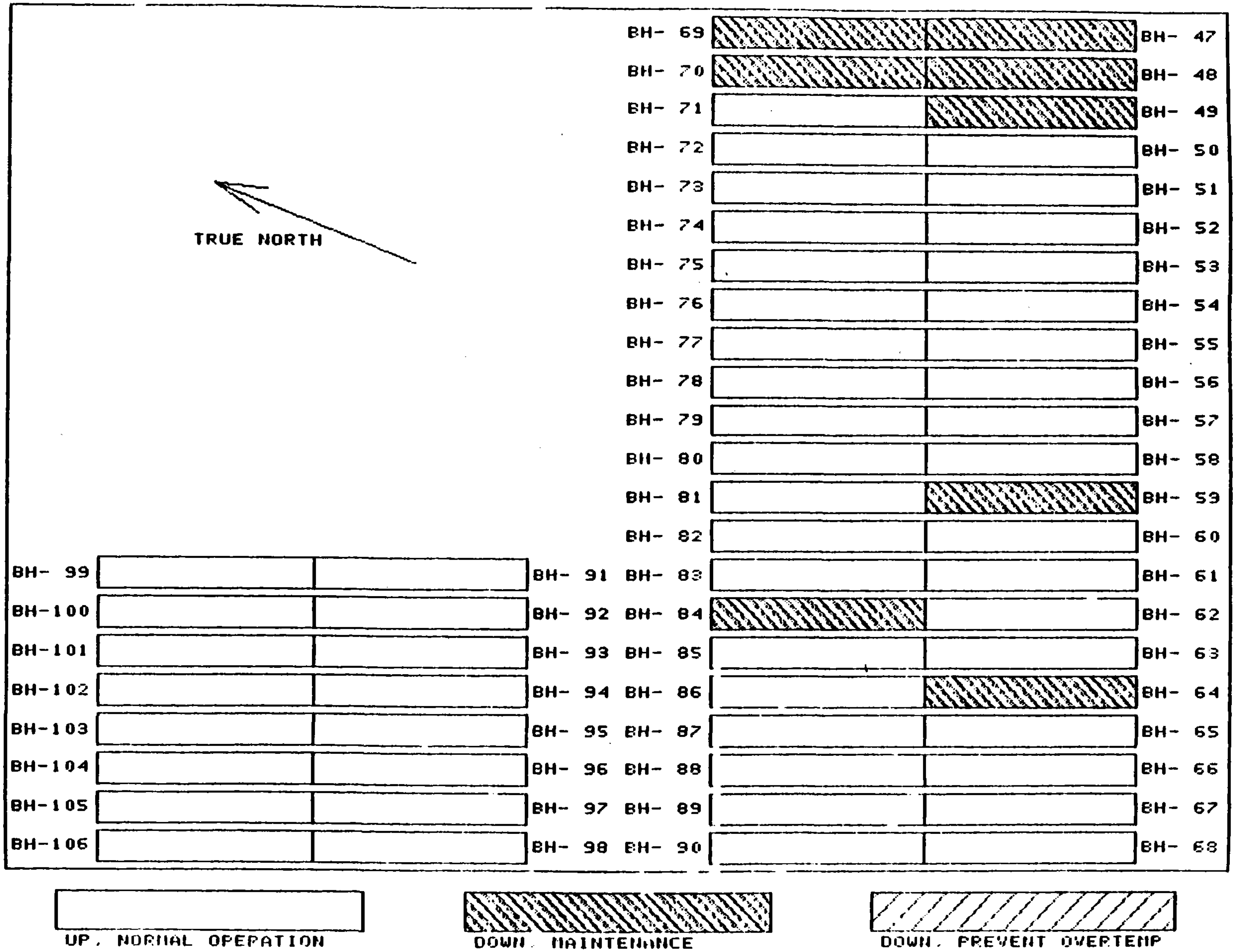
*These activities were performed by SwRI personnel. The costs were determined using the approximate CTCo average labor rate.

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
January 31, 1984

Row	Date of Last Action	Comment
BH-49	1/12/84	Tracker head leaks. Requires replacement.
BH-59	1/12/84	4-way valve leaks hydrualic fluid.
BH-64	1/12/84	460/120 VAC transformer bad.
BH-84	1/12/84	Hydraulic drive piston leaks.

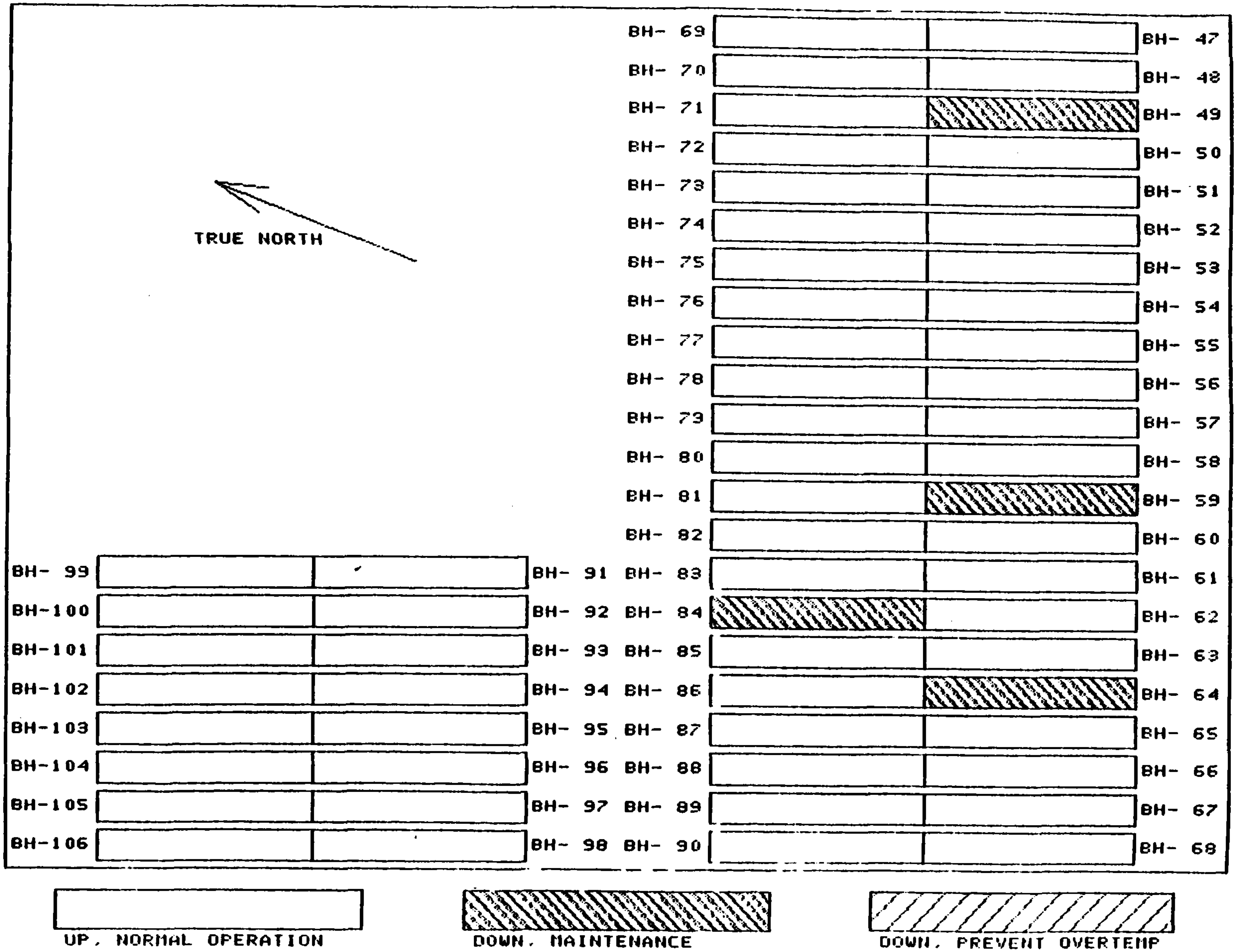
TABLE IV. MIRROR REFLECTANCE

Date	Comment	Average Row Reflectance (%)					
		BH-65	BH-87	BH-95	BH-103	BH-91	BH-99
8/16/83		58.5	61.0	57.1	56.1	57.7	57.4
1/10/84		33.9	36.5	33.5	39.8	32.6	33.6
1/11/84	North Field rinsed. Mirror reflectance at well washed spot = 83.2%	--	--	70.6	73.1	70.5	67.7



TIME PERIOD: JANUARY 1-12

FIGURE 2

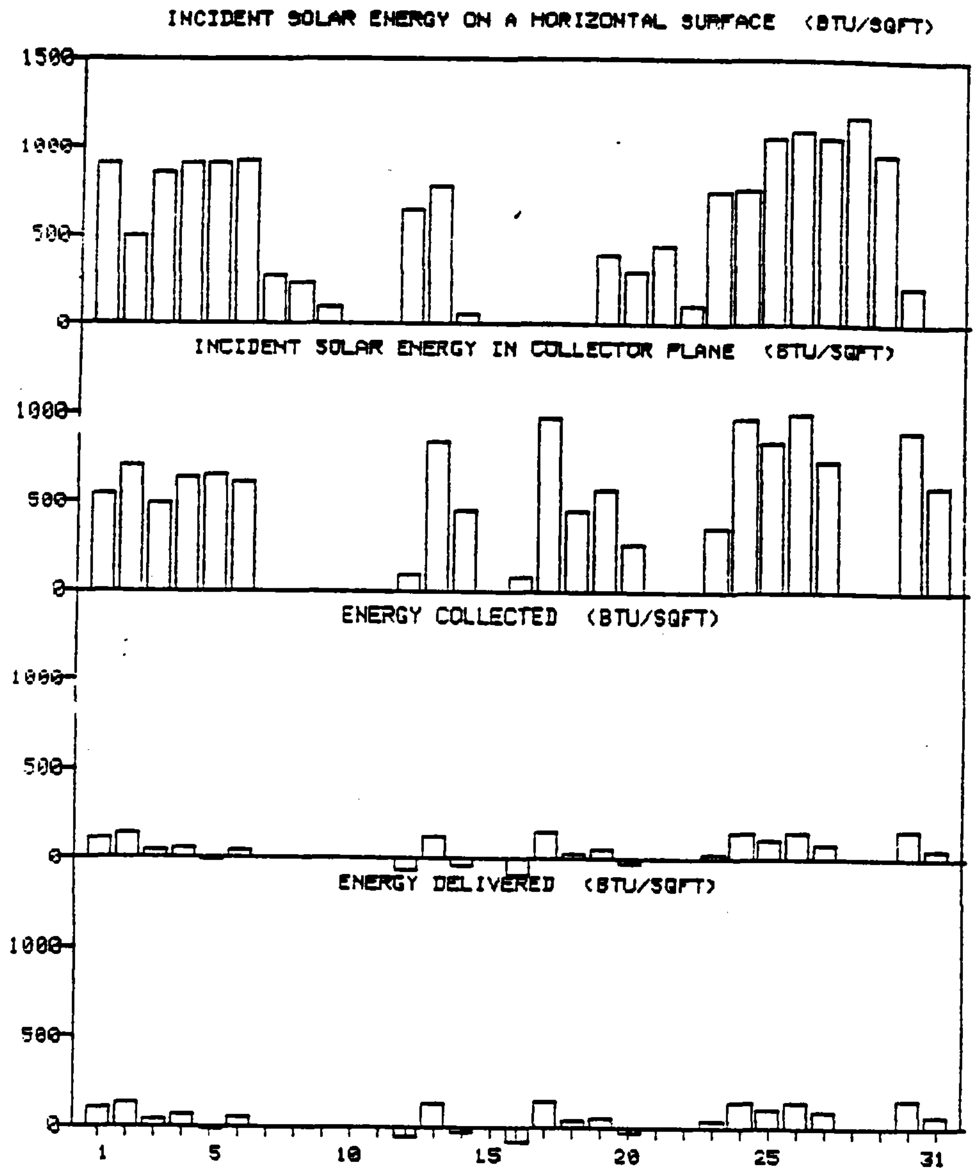


TIME PERIOD: JANUARY 13-31

FIGURE 3

TABLE V. MONTHLY PERFORMANCE SUMMARY TABLE - 1/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
1/ 1	1	908.	544.	43680.	4641.	12.	20.	297.4
1/ 2	2	494.	702.	43680.	5617.	26.	18.	446.4
1/ 3	3	847.	487.	43680.	1555.	4.	7.	422.2
1/ 4	4	910.	637.	43680.	2588.	7.	9.	453.6
1/ 5	5	912.	650.	43680.	-587.	-1.	-2.	467.7
1/ 6	6	914.	611.	43680.	1969.	5.	7.	458.7
1/ 7	7	269.	0.	43680.	0.	0.	0.	57.9
1/ 8	8	229.	0.	43680.	0.	0.	0.	59.8
1/ 9	9	90.	0.	43680.	0.	0.	0.	25.9
1/10	10		DAS DOWN FOR PREVENTATIVE MAINTENANCE					
1/11	11		DAS DOWN FOR PREVENTATIVE MAINTENANCE					
1/12	12	642.	83.	47040.	-2791.	-9.	-71.	328.0
1/13	13	779.	839.	47040.	5886.	16.	15.	537.1
1/14	14	50.	441.	47040.	-1580.	-68.	-8.	503.2
1/15	15	0.	0.	47040.	0.	0.	0.	57.5
1/16	16	0.	71.	47040.	-4164.	0.	-124.	376.1
1/17	17	2.	964.	47040.	6884.	7193.	15.	536.5
1/18	18	0.	442.	47040.	1411.	0.	7.	450.8
1/19	19	390.	565.	47040.	2245.	12.	8.	528.9
1/20	20	291.	254.	47040.	-1271.	-9.	-11.	333.5
1/21	21	442.	0.	47040.	0.	0.	0.	51.1
1/22	22	111.	0.	47040.	0.	0.	0.	57.4
1/23	23	742.	358.	47040.	1508.	4.	9.	405.5
1/24	24	766.	964.	47040.	6815.	19.	15.	571.7
1/25	25	1058.	837.	47040.	4866.	10.	12.	559.2
1/26	26	1094.	998.	47040.	6957.	14.	15.	603.1
1/27	27	1059.	724.	47040.	3961.	8.	12.	508.0
1/28	28	1175.	0.	47040.	0.	0.	0.	57.0
1/29	29	957.	0.	47040.	0.	0.	0.	63.4
1/30	30	214.	895.	47040.	7448.	74.	18.	565.4
1/31	31	0.	592.	47040.	2770.	0.	10.	432.5
TOTALS		15344.	12660.		56728.	8.	10.	10215.5
AVG		529.	437.		1956.			352.3



MONTHLY PERFORMANCE GRAPH 1-84

FIGURE 4

B. Clear Day Performance

The performance of the solar system is summarized for two clear days in Table VI and VII. This information is shown graphically in Figures 5 and 6. The effects of row-to-row shading and rinsing the North field will be discussed by using the data for these two days.

It can be seen that on both these days, the system remains operating well after the time at which the collector plane radiation decreases. This is due to the row-to-row shading.

Recall that at the CTCo site, the collector drive tracking sensor is mounted on the western edge of the collector mirror. This edge is the one which is first shaded by the row to the west in the afternoon. When this occurs, the collectors stop tracking, so that no more radiation is focused on the receiver tube. The central controller, on the other hand, is still focused on the sun and does not shut the field down even though no energy can be gathered. Thus, a substantial amount of energy is lost by convection from the receiver tubes.

Finally, the energy delivered by the solar system for these two days is decomposed into the separate portions delivered by the North and the South fields in Table VIII. This table clearly shows the obvious effect of mirror reflectance on the field performance. This difference between the two fields will continue to be monitored over the next few months to observe the degradation of the North field mirrors' reflectance values.

TABLE VI. HOURLY PERFORMANCE TABLE - 1/2/84 (JULIAN DAY 2)

ARRAY ACTIVE AREA = 43680 SQ. FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
			ON A HORIZ SURFACE (1)	IN THE COLLECTOR PLANE (2)	AVERAGE FLOW RATE OVER HOUR	AVERAGE OPERATING TEMPERATURE		AVERAGE FLOW RATE OVER HOUR	AVERAGE OPERATING TEMPERATURE		TOTAL ENERGY COLLECTED OVER HOUR	HOURLY COLLECTOR ARRAY EFF BASED ON (1)	HOURLY COLLECTOR ARRAY EFF BASED ON (2)	TOTAL ELEC ENERGY USED OVER HOUR
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	BTU/SQFT	BTU/SQFT	GPM	IN F	OUT F	GPM	IN F	OUT F	KBTU	%	%	KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	44.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.7
8	45.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
9	48.	1.	31.	28.	35.	124.	125.	57.	124.	124.	8.	1.	1.	24.0
10	52.	1.	86.	89.	106.	124.	126.	161.	125.	127.	265.	7.	7.	51.0
11	59.	1.	135.	96.	107.	124.	125.	163.	124.	125.	107.	2.	3.	51.3
12	57.	3.	117.	107.	111.	124.	129.	166.	124.	131.	805.	16.	17.	51.3
13	64.	3.	65.	137.	119.	129.	136.	168.	129.	142.	1464.	51.	24.	51.3
14	64.	7.	11.	160.	127.	140.	148.	172.	139.	158.	2165.	***	31.	52.1
15	63.	6.	4.	87.	128.	147.	152.	175.	147.	153.	798.	***	21.	52.0
16	61.	6.	39.	-17.	126.	147.	147.	175.	147.	147.	75.	4.	***	49.9
17	59.	5.	5.	15.	108.	142.	142.	151.	142.	141.	-69.	***	***	51.0
18	53.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
19	51.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
20	49.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
21	47.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			494.	702.							5617.	26.	18.	438.1
AVG	54.	3.	78.	85.	113.	134.	137.	161.	134.	140.	681.			8.8

TABLE VII. HOURLY PERFORMANCE TABLE - 1/24/84 (JULIAN DAY 24)
ARRAY ACTIVE AREA = 47040 SQ. FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL SYSTEM TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	45.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
8	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.4
9	55.	3.	43.	95.	114.	214.	212.	266.	213.	208.	0.	0.	0.	4.0
10	56.	2.	97.	114.	120.	221.	228.	329.	221.	223.	-822.	***	***	58.4
11	59.	4.	137.	122.	120.	223.	231.	329.	223.	225.	705.	15.	13.	60.4
12	60.	4.	137.	138.	120.	225.	235.	328.	226.	229.	699.	11.	12.	60.4
13	64.	5.	125.	164.	119.	228.	242.	327.	228.	235.	1053.	16.	16.	60.2
14	65.	4.	105.	181.	115.	231.	248.	327.	232.	241.	1782.	30.	23.	59.3
15	65.	4.	47.	159.	115.	232.	245.	326.	232.	239.	2436.	49.	29.	59.2
16	65.	2.	55.	-17.	118.	225.	226.	325.	225.	225.	1685.	76.	22.	57.7
17	63.	3.	20.	0.	118.	224.	221.	325.	224.	221.	0.	0.	0.	58.8
18	59.	0.	0.	7.	21.	224.	222.	58.	224.	221.	-615.	***	***	57.8
19	56.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-106.	0.	***	19.4
20	55.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.2
21	52.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.4
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.9
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			766.	964.							6815.	19.	15.	563.7
AVG	58.	2.	90.	105.	116.	225.	232.	315.	225.	227.	743.			11.3

CLEAR DAY PERFORMANCE GRAPH 1- 2-84

ARRAY ACTIVE AREA = 43680. SQ. FT.

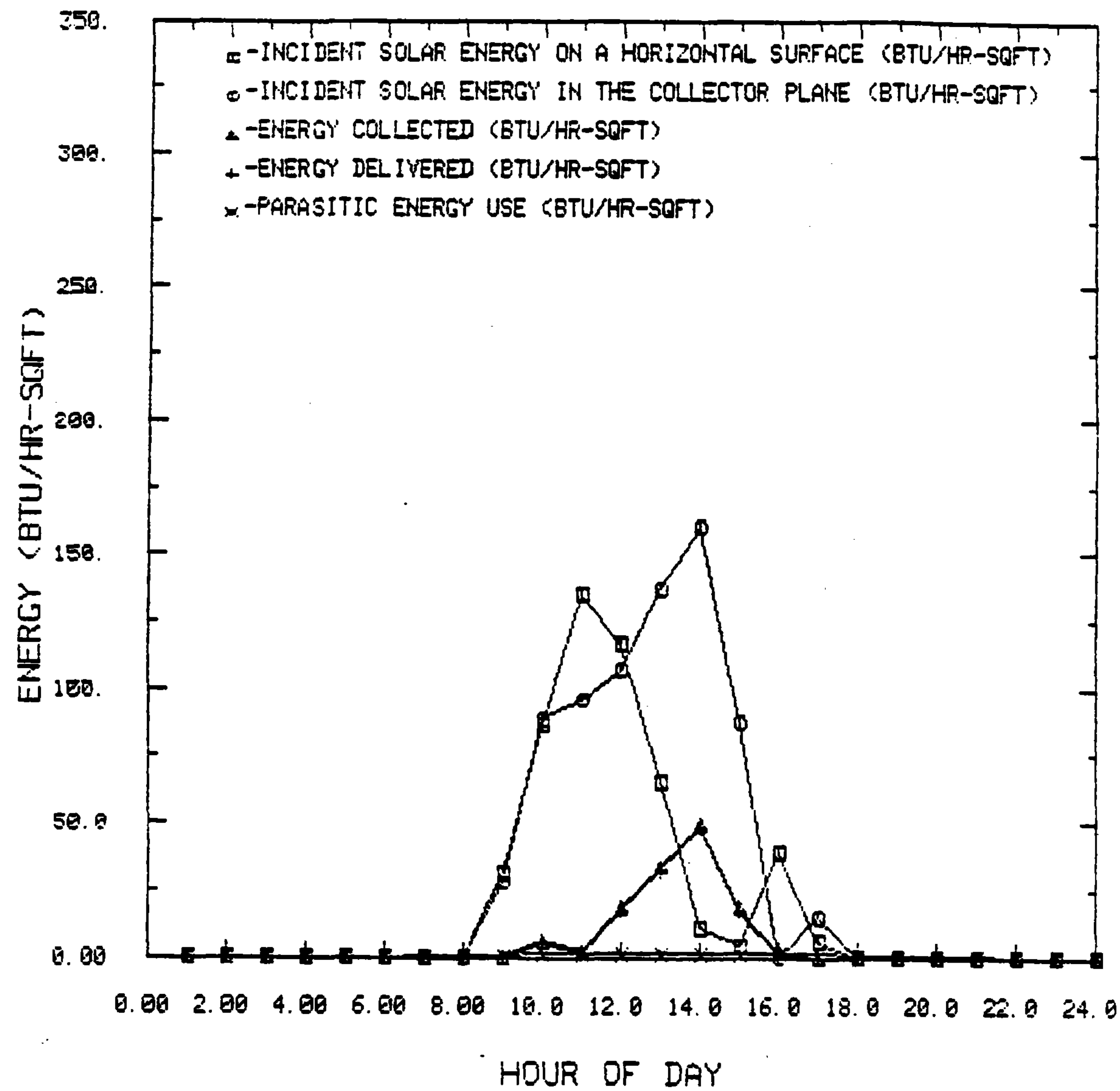


FIGURE 5

CLEAR DAY PERFORMANCE GRAPH 1-24-84

ARRAY ACTIVE AREA = 47040. SQ. FT.

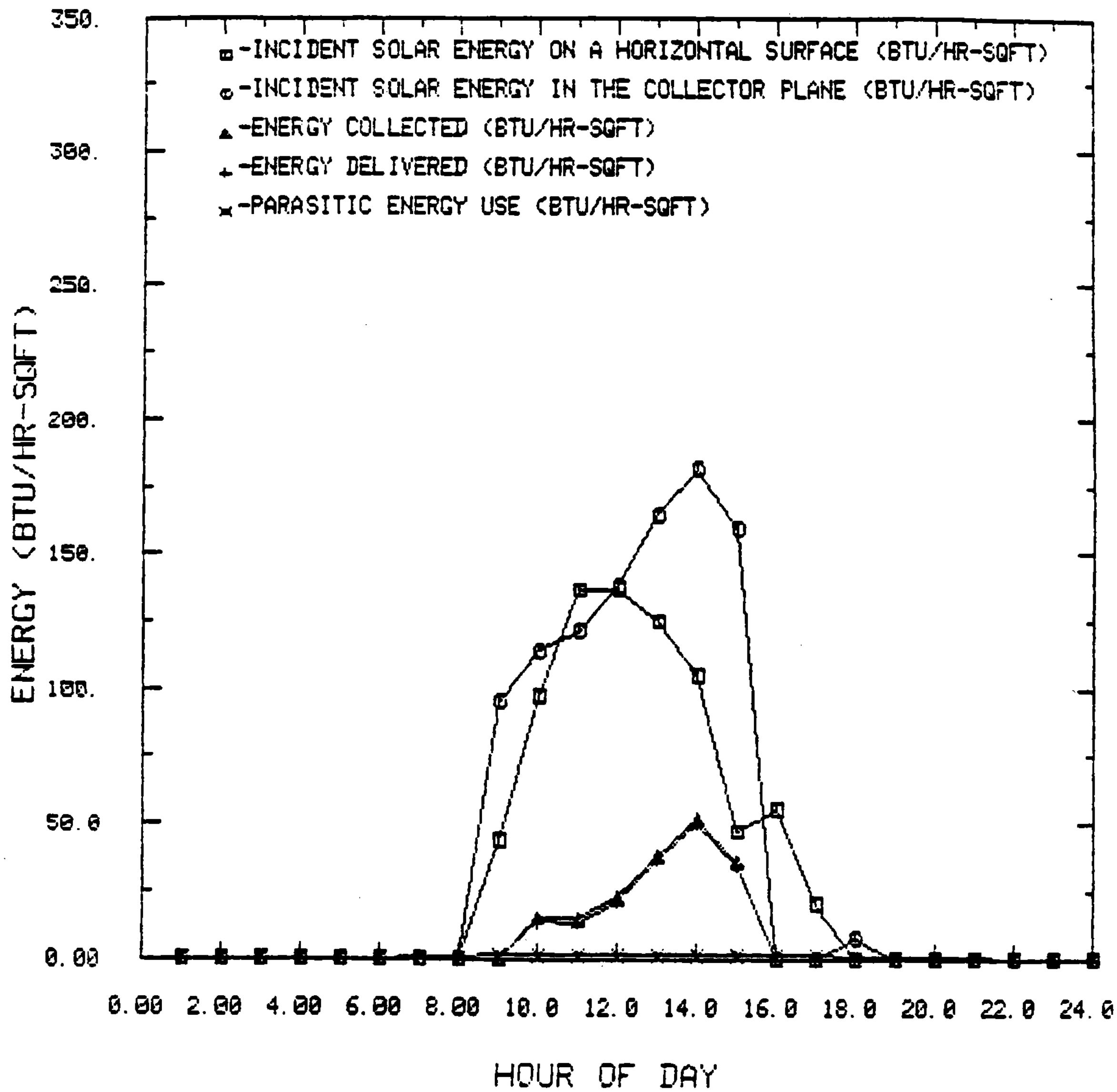


FIGURE 6

TABLE VIII

Solar Time	DATE: January 2, 1984 — Collector Plane Radiation Btu/hr-ft^2	North Field Output Btu/hr-ft^2	South Field Output Btu/hr-ft^2	DATE: January 24, 1984 — Collector Plane Radiation Btu/hr-ft^2	North Field Output Btu/hr-ft^2	South Field Output Btu/hr-ft^2
8	--	--	--	22	-21	-22
9	45	1	0	111	20	5
10	90	6	7	115	30	8
11	98	4	4	127	34	9
12	111	20	22	146	47	19
13	144	32	40	172	63	35
14	163	40	51	180	71	47
15	51	15	10	95	30	12
16	-18	4	2	-13	0	-6
17	18	-1	-3	9	-8	-12
Total	702	121	132	964	266	97

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
April 19, 1984
Monthly Progress Report No. 50
Reporting Period February 18, 1984
through April 16, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

The costs for periods 6 and 7 of this fiscal year are combined in this monthly report to bring the cost reporting period more up-to-date with the monthly reports. The monthly performance report for February 1984 (CTCo-16) is attached. The disk changing problems have been resolved, but the report for March 1984 will be sent under separate cover.

SUMMARY STATUS ASSESSMENT AND FORECAST:

It has been observed that three of the system flow meters are now defective. A site visit is being planned to inspect the solar system and the DAS to resolve this problem. The current status of the DAS will be described in the March Performance Report (CTCo-17).

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Enclosure

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Mr. Don Lucas, CTCo
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 16

REPORT PERIOD:	February 1, 1984 - Feburary 29, 1984
REPORT NO.:	CTCo-16
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14×10^9 Btu/yr, peak hourly 8.6×10^6 Btu/hr, peak daily - 78.6×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

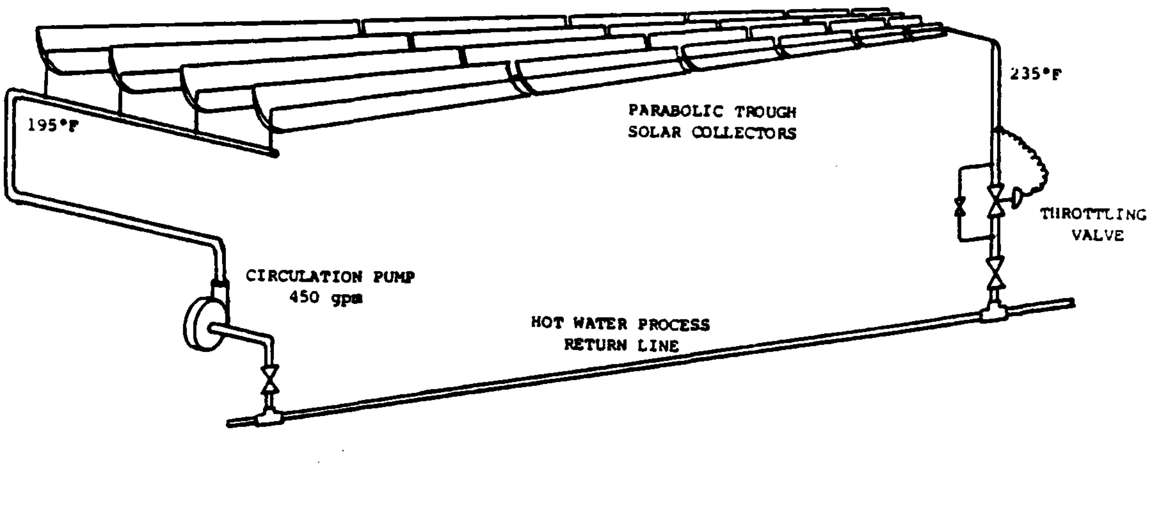


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The CTCo solar system was available for operation during the entire month of February. Some hardware problems, however, required that maintenance be performed on two of the collector drive mechanisms.

The operation of the solar system is summarized in Table I. It is seen that 6-8% of the field was down because of a malfunction or maintenance activity during this month. These maintenance activities are described in Table II and Table III. One drive row (BH-69) failed due to a control circuit malfunction for which no cause could be immediately determined. A seal on the hydraulic piston in Row BH-84 was replaced on 2/9 but failed again on 2/16. The status of each of the drive rows for various periods during February is shown in Figures 2, 3, and 4.

CTCo maintenance personnel reviewed the manufacturer's literature for several of the drive system components and concluded that the maximum operating pressure is 1000 psi. CTCo found, however, that the hydraulic pressure controls were set at approximately 1200. They have begun the task of resetting the pressure limit switches to 800 psi.

The field was rinsed during several rainstorms in February. The effect of this rinsing activity is discussed below in the performance section.

Finally, the DAS experienced problems on 2/29/84. The DAS was brought back into operation late that day, but most of the data were lost. The cause of the failure was undetermined.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
February 1984

Date	Active Area (ft^2)	Comments
2/1-2/15	47040	Four drive rows inoperative, full flow to entire collector array.
2/16-2/29	46200	Five drive rows inoperative, full flow to entire collector array.
2/29		Power failure caused data system to shut down.

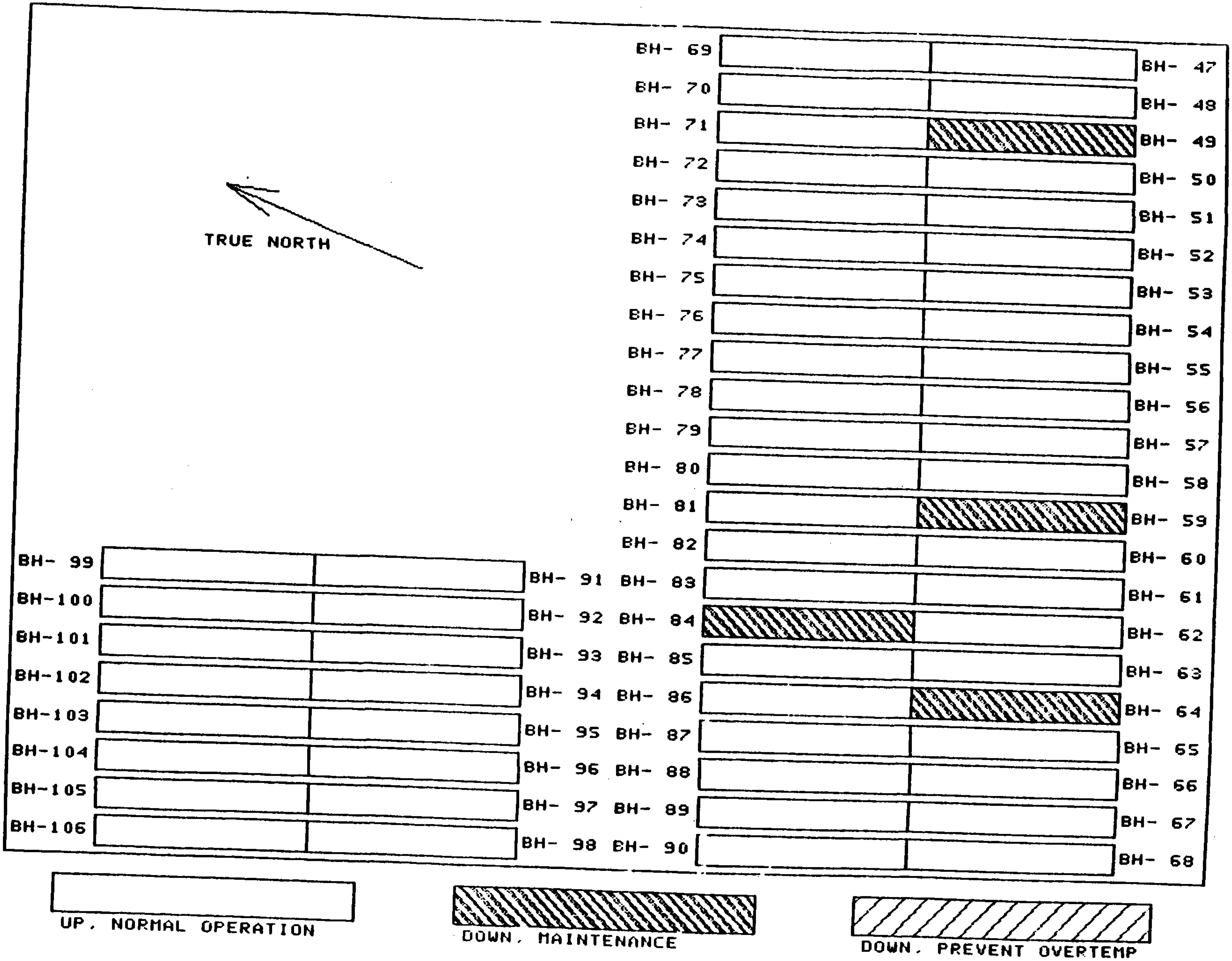
TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
February 1984

O & M Activity	Hours	Cost		
		Labor $	Materials $	Total $
o Routine inspection	10	291.29	-0-	291.29
o DAS disk changes				
o Field walkthrough				
o Rinsing collector field during rain	2	58.26	-0-	58.26
o Hydraulic drive system maintenance	8	233.03	-0-	233.03
o Control board trouble-shooting	2.5	72.82	-0-	72.82
TOTAL	22.5	655.40	-0-	655.40

Total estimated maintenance costs for 2/83 - 2/84 = $7642.84

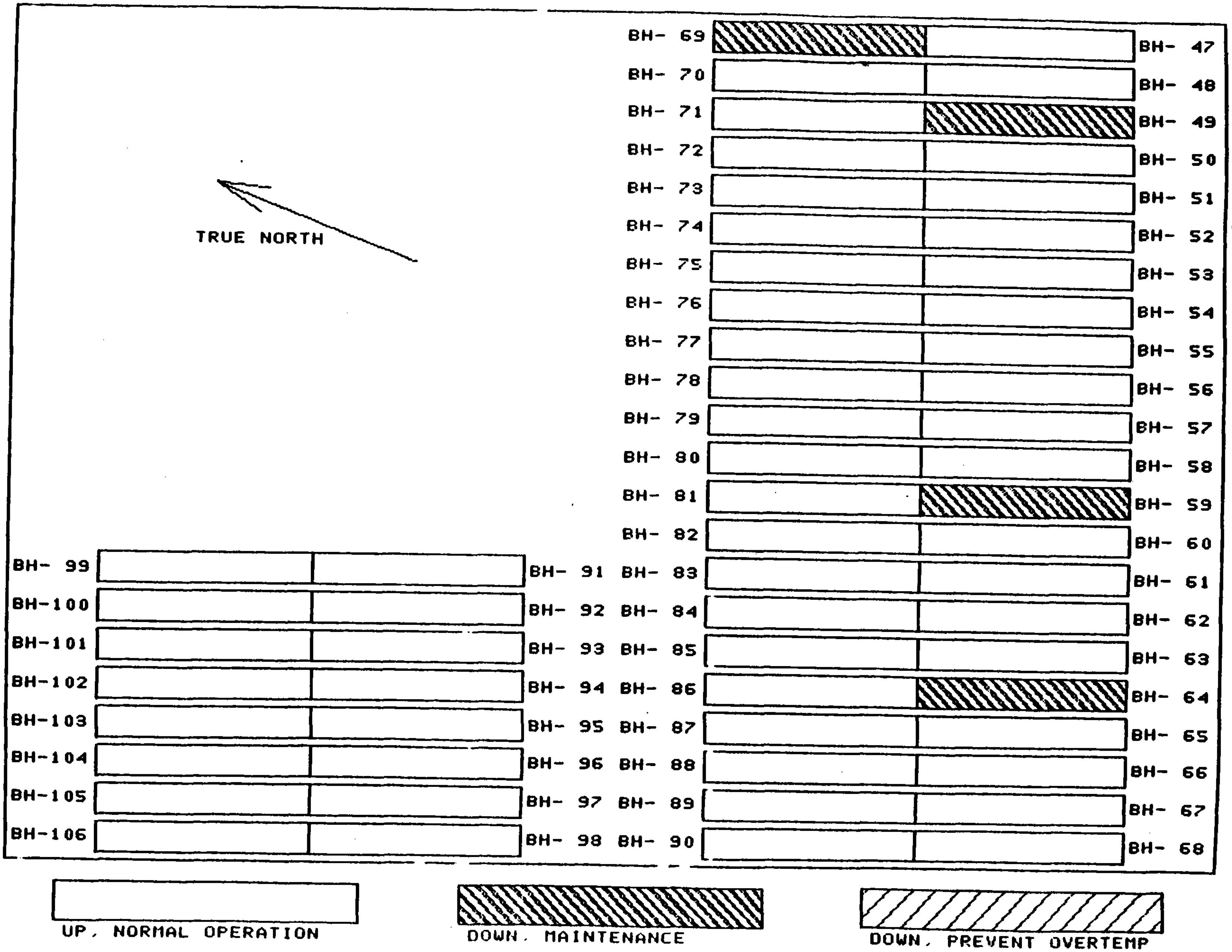
TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
January 31, 1984

Row	Date of Last Action	Comment
BH-49	1/12/84	Tracker head leaks. Requires replacement.
BH-59	1/12/84	4-way valve leaks hydrualic fluid.
BH-64	1/12/84	460/120 VAC transformer bad.
BH-69	2/9/84	Control board failure.
BH-84	2/16/84	Oil seal replaced on 2/9/84 developed leak on 2/16. Row back out-of-service.



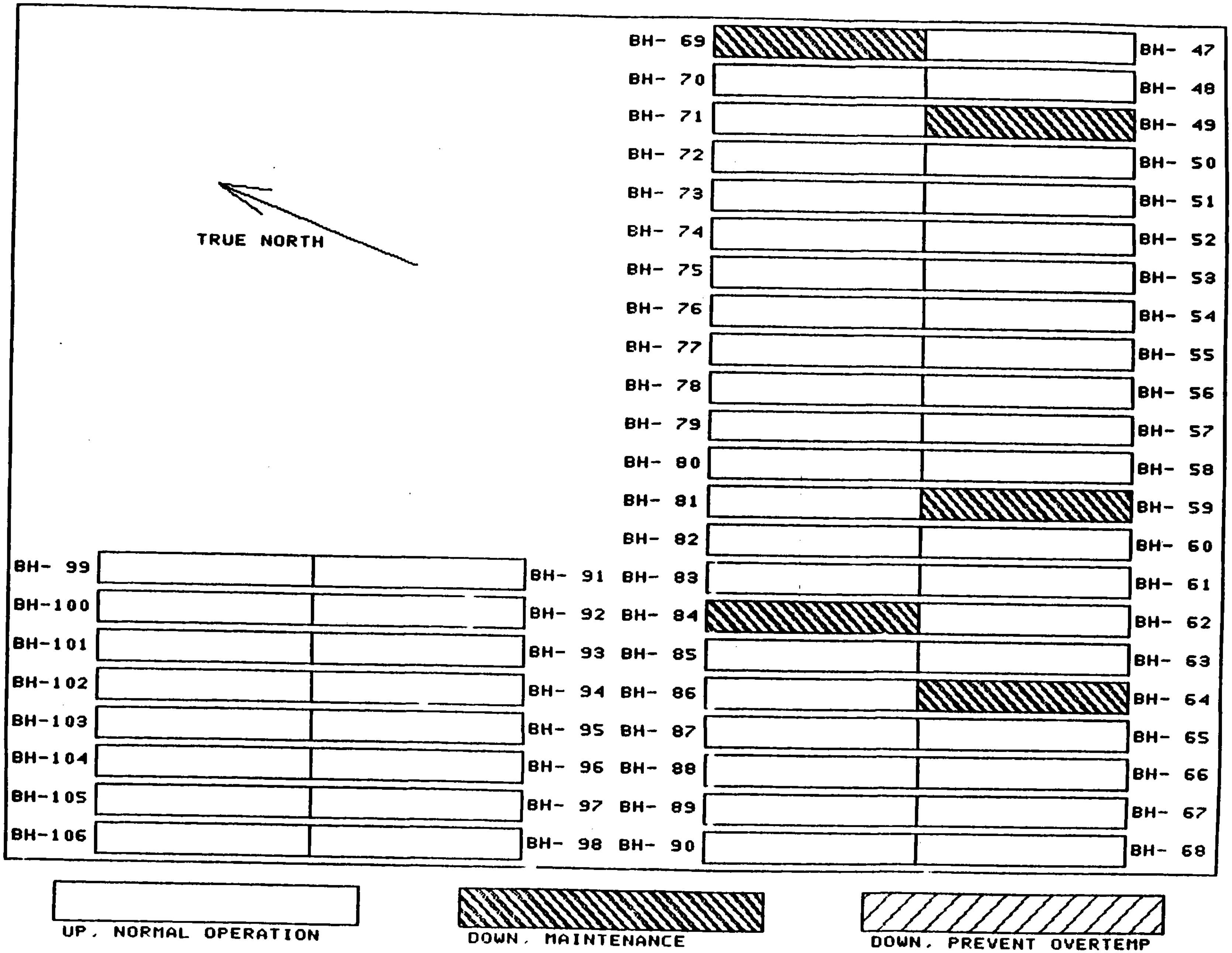
TIME PERIOD: FEBRUARY 1-8

FIGURE 2



TIME PERIOD: FEBRUARY 9-15

FIGURE 3



TIME PERIOD: FEBRUARY 16-29

FIGURE 4

IV. System Performance

A. Monthly Summary

The daily, overall performance of the solar system is summarized for February, 1984 in Table IV and Figure 5. First, it is seen that the field exhibited a 27% efficiency for the month of February with an energy delivery of 1.36 *10^8 Btu. The peak daily efficiency was 37% for days which exhibit reasonable operation. Efficiency values over this amount are attributed to cloudy days during which the tracking mechanism causes erroneous radiation measurements.

Also, the horizontal radiation data is still in error during February. The replacement transmitter for this sensor has not yet been received.

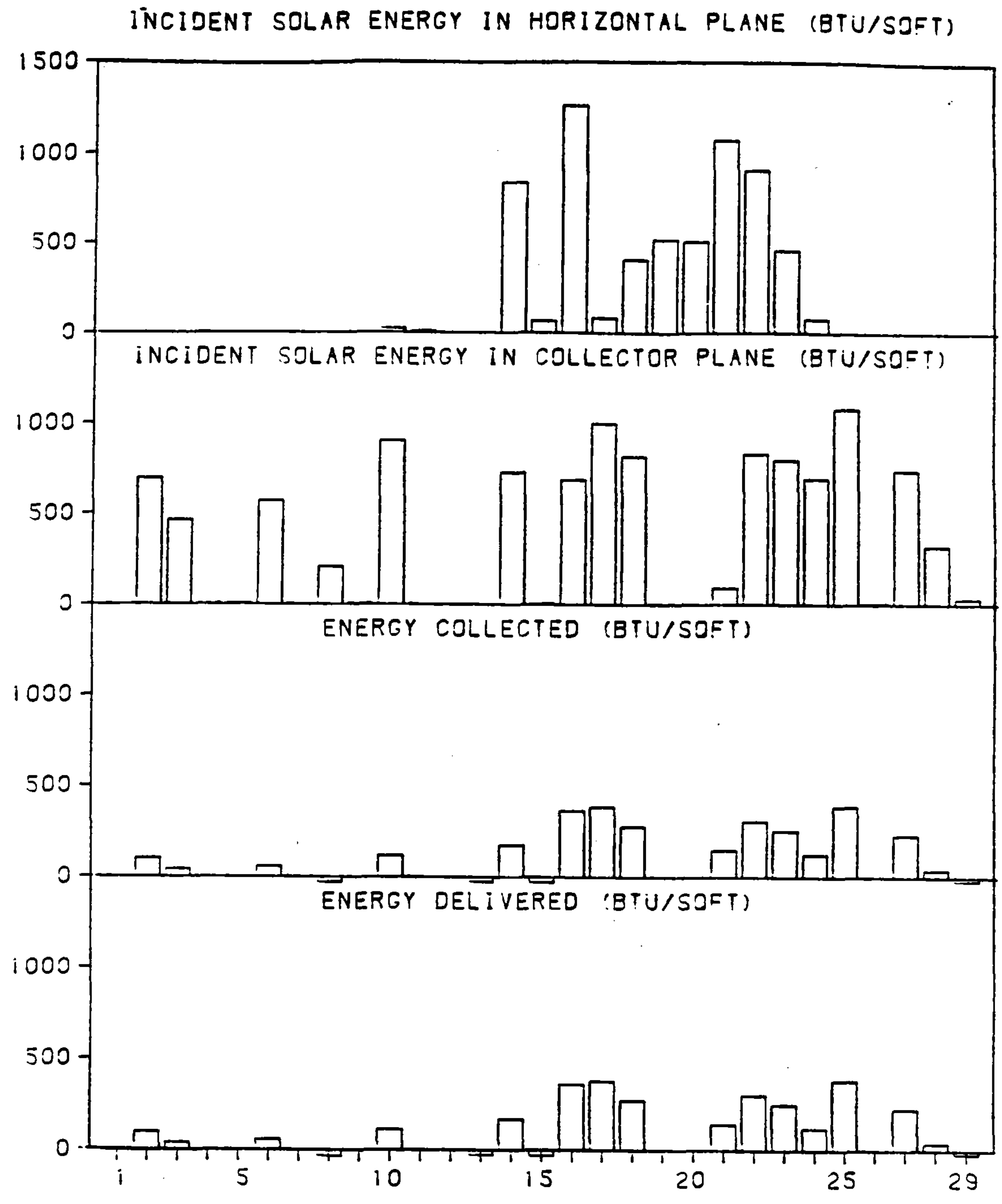
B. Clear Day Performance

The solar system performance on February 22, 1984 is summarized in Table V and Figure 6. The peak efficiency during this day was 47%. The total energy delivery was 14.3 *10^6 Btu during this day with 0.48 *10^6 Btu of electrical power consumed in the controls and motors. Parasitic energy consumption is, thus, 3.3% of the delivered energy.

The system energy delivery is separated into the portions delivered by the north and south field in Table VI. The data for the first two days is taken from the previous monthly report for January, CTCo-15. These data show the effect of washing the collectors during a rainstorm. The data for 1/2/84 were taken prior to a complete washing of the north field, while the data for 1/24/84 were taken a few days after completely washing the north field. The north field efficiency was much greater than the south field efficiency after being cleaned. The data for 2/22/84 were taken after the entire collector field was rinsed with rainfall. This was accomplished by manually rotating the collectors to a vertical position during a storm. The efficiencies of the north and south field are equivalent after being rain-washed and are much greater than the efficiencies for 1/2/84, the completely dirty case. The increase in efficiency is partially due to more favorable incidence angles, but it is clear that rainwashing can greatly improve collector performance.

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 2/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY: ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY: ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
2/ 1	32	0.	0.	47040.	0.	0.	0.	54.8
2/ 2	33	0.	696.	47040.	4870.	0.	15.	460.6
2/ 3	34	0.	466.	47040.	2059.	0.	9.	449.5
2/ 4	35	0.	0.	47040.	0.	0.	0.	61.3
2/ 5	36	0.	0.	47040.	0.	0.	0.	64.5
2/ 6	37	0.	572.	47040.	2799.	0.	10.	381.2
2/ 7	38	0.	0.	47040.	0.	0.	0.	55.0
2/ 8	39	0.	208.	47040.	-1544.	0.	-16.	287.1
2/ 9	40	0.	0.	47040.	0.	0.	0.	58.9
2/10	41	28.	907.	47040.	5633.	427.	13.	581.9
2/11	42	11.	0.	47040.	0.	0.	0.	55.3
2/12	43	0.	0.	47040.	0.	0.	0.	57.7
2/13	44	4.	2.	47040.	-1372.	-746.	*****	94.2
2/14	45	836.	730.	47040.	8354.	21.	24.	493.9
2/15	46	71.	1.	47040.	-1504.	-45.	*****	69.1
2/16	47	1262.	690.	46200.	16947.	29.	53.	463.1
2/17	48	87.	1002.	46200.	17860.	445.	39.	622.6
2/18	49	409.	821.	46200.	12945.	68.	34.	529.6
2/19	50	519.	0.	46200.	0.	0.	0.	58.3
2/20	51	508.	0.	46200.	0.	0.	0.	64.6
2/21	52	1074.	95.	46200.	6952.	14.	159.	571.2
2/22	53	904.	833.	46200.	14291.	34.	37.	490.2
2/23	54	458.	798.	46200.	11899.	56.	32.	425.0
2/24	55	81.	696.	46200.	5869.	156.	18.	487.5
2/25	56	0.	1084.	46200.	18028.	0.	36.	634.1
2/26	57	0.	0.	46200.	0.	0.	0.	59.1
2/27	58	0.	742.	46200.	10788.	0.	31.	510.0
2/28	59	0.	325.	46200.	1898.	0.	13.	367.8
2/29	60	0.	34.	46200.	-1026.	0.	-66.	66.1
TOTALS		6254.	10701.		135745.	47.	27.	8574.0
AVG		216.	369.		4681.			295.7



MONTHLY PERFORMANCE SUMMARY 2-84

FIGURE 5

TABLE V. HOURLY PERFORMANCE TABLE - 2/22/84 (JULIAN DAY 53)

ARRAY ACTIVE AREA = 46200 SQ. FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION: ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION: IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD: AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD: AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD: AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD: AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD: AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD: AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM: TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM: HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM: HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL SYSTEM: TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	42.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.3
8	45.	2.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.7
9	48.	4.	53.	34.	33.	201.	193.	59.	198.	185.	-591.	***	***	21.7
10	51.	3.	94.	148.	117.	210.	224.	314.	210.	222.	2647.	61.	39.	58.9
11	54.	4.	130.	159.	116.	216.	231.	320.	215.	228.	2828.	47.	39.	56.3
12	56.	4.	134.	164.	113.	220.	237.	317.	220.	234.	3262.	53.	43.	59.8
13	59.	4.	131.	144.	114.	221.	235.	315.	221.	234.	3027.	50.	46.	64.1
14	60.	6.	130.	130.	115.	220.	233.	317.	220.	233.	2851.	47.	47.	59.8
15	57.	7.	114.	57.	116.	215.	218.	319.	215.	219.	748.	14.	28.	56.5
16	56.	6.	81.	-2.	104.	211.	212.	266.	211.	211.	48.	1.	***	56.7
17	54.	8.	28.	0.	39.	208.	201.	81.	208.	198.	-528.	***	***	31.1
18	51.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.5
19	50.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.9
20	49.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.1
21	46.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.8
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			904.	833.							14291.	34.	37.	480.2
AVG	52.	4.	100.	111.	107.	215.	225.	289.	215.	224.	1904.			9.7

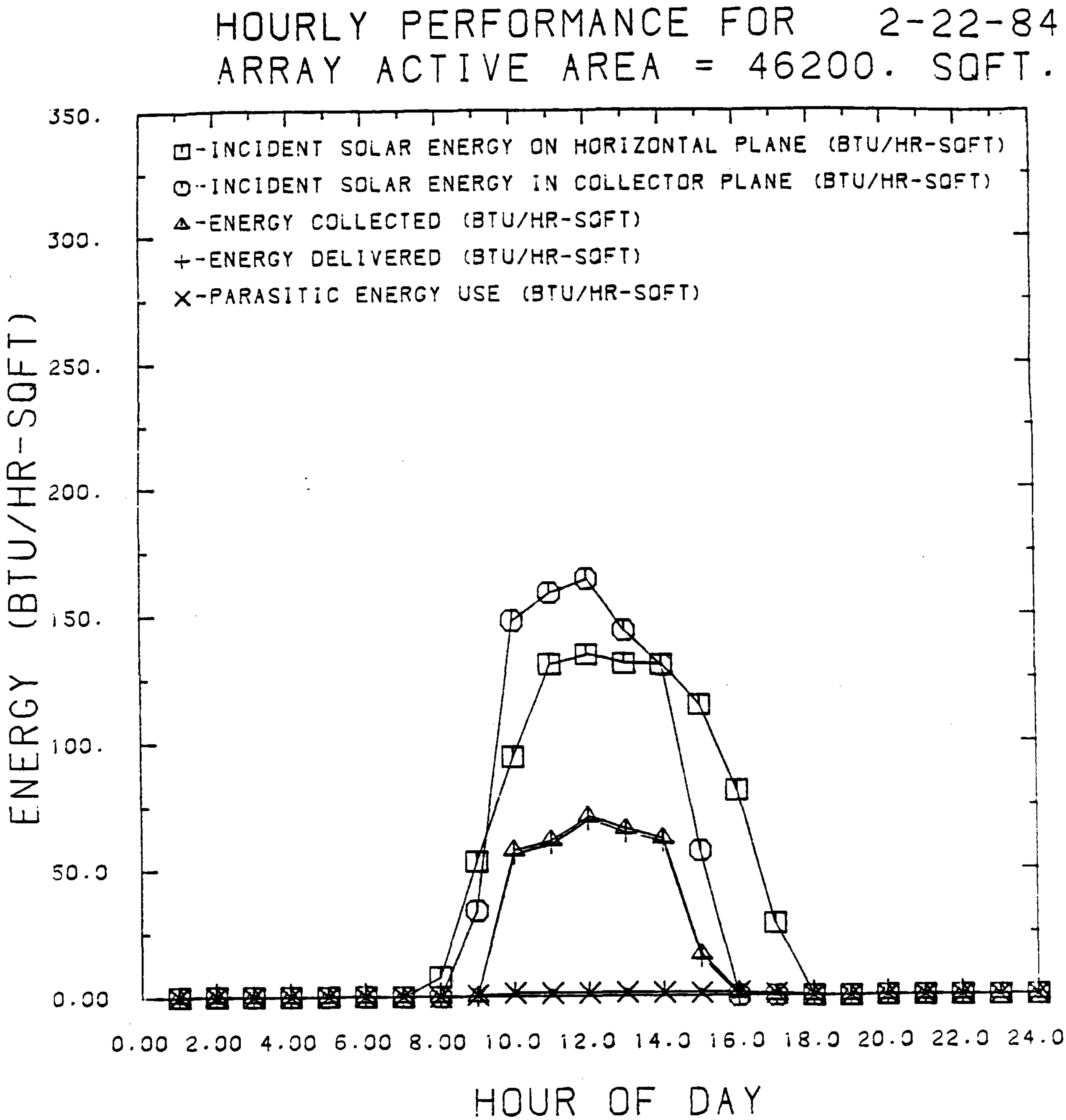

HOURLY PERFORMANCE FOR 2-22-84
ARRAY ACTIVE AREA = 46200. SQFT.
□-INCIDENT SOLAR ENERGY ON HORIZONTAL PLANE (BTU/HR-SQFT)
○-INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/HR-SQFT)
△-ENERGY COLLECTED (BTU/HR-SQFT)
+-ENERGY DELIVERED (BTU/HR-SQFT)
X-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 6

TABLE VI

	DATE								
	January 2, 1984			January 24, 1984			February 22, 1984		
Solar Time	Collector Plane Radiation Btu/hr-ft^2	North Field Output Btu/hr-ft^2	South Field Output Btu/hr-ft^2	Collector Plane Radiation Btu/hr-ft^2	North Field Output Btu/hr-ft^2	South Field Output Btu/hr-ft^2	Collector Plane Radiation Btu/hr-ft^2	North Field Output Btu/hr-ft^2	South Field Output Btu/hr-ft^2
8	—	—	—	22	-21	-22	0	0	0
9	45	1	0	111	20	5	88	7	7
10	90	6	7	115	30	8	151	61	51
11	98	4	4	127	34	9	165	65	58
12	111	20	22	146	47	19	159	64	66
13	144	32	40	172	63	35	133	52	59
14	163	40	51	180	71	47	112	44	46
15	51	15	10	95	30	12	30	6	6
16	-18	4	2	-13	0	-6	-4	2	0
17	18	-1	-3	9	-8	-12	0	-11	-10
Total	702	121 (17%)	132 (19%)	964	266 (28%)	97 (10%)	833	288 (35%)	282 (34%)

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
May 20, 1984
Monthly Progress Report No. 51
Reporting Period April 14, 1984
through May 11, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued during April much the same as in March. There was significant maintenance activity during March and April which is described in the accompanying Monthly Performance Reports. A site visit by SwRI personnel is planned for early June to review system status and perform DAS maintenance.

SUMMARY STATUS ASSESSMENT AND FORECAST:

CTCo personnel will not disable portions of the collector field this spring and summer to match their load. Instead, solar system daily energy output will be maximized by allowing the system outlet temperature to

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

exceed thermostat settings, thereby forcing oscillatory operation of the collectors. The effects of this scenario are briefly described in the attached Performance Reports, CTCo-17, and CTCo-18.

Respectfully submitted,

Steve T. Green
Research Engineer

APPROVED:

Danny M. Deffenbaugh
Project Manager

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

MONTHLY REPORT NO. 17

REPORT PERIOD:	March 1, 1984 - March 31, 1984
REPORT NO.:	CTCo-17
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

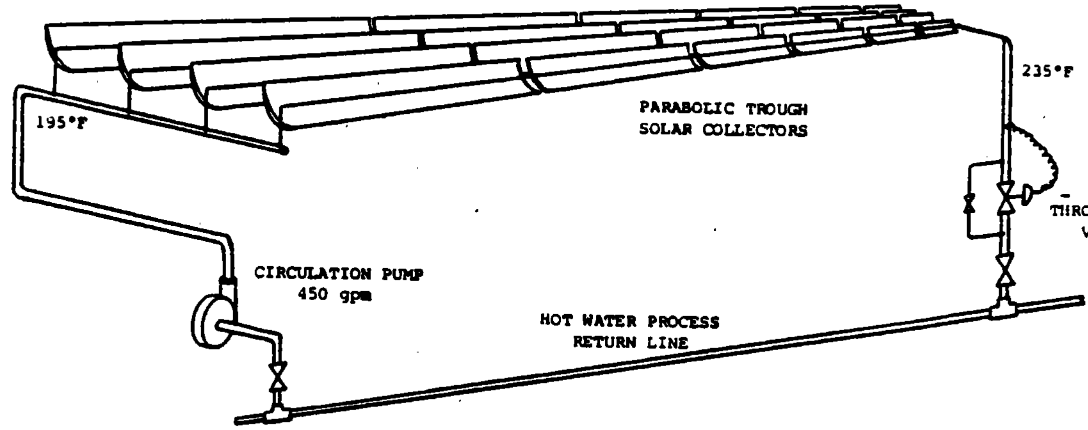


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The CTCo solar system was available for operation during the entire month of March, 1984. The DAS experienced some minor problems so that three entire days of data were lost and two partial days of data were lost.

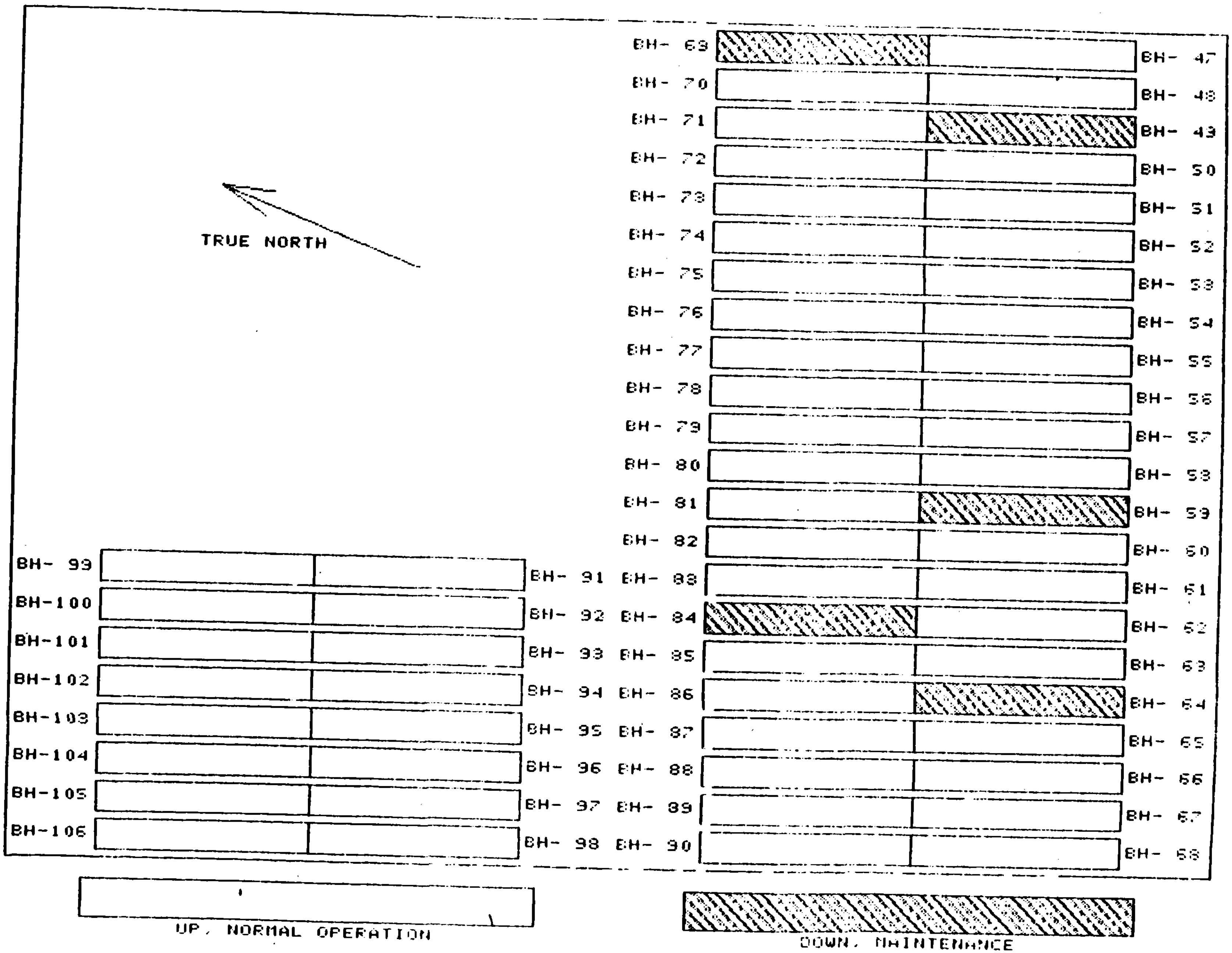
During this summer, CTCo personnel plan to keep as many rows operating as possible which is a departure from the operating philosophy during the spring and summer of 1983. Last year, drive rows were deactivated as the performance of the collectors increased because of more favorable solar angles. This was necessary to match the collector system energy output to the decreased plant process heat load.

This spring and summer, however, no rows will be deactivated. This will cause the collector system outlet temperature to increase beyond the desired limit. Limit switches will then close and cause the collector array to unfocus until the process fluid temperature decreases below the set point. The net effect of this unfocusing will be to decrease the hourly and daily efficiency of the collector hardware, since the focusing/unfocusing frequency is on the order of 10 minutes. The reason for allowing the array to focus/unfocus is so that energy output is maximized over the entire day within the limits imposed by thermostat set points.

The operation of the solar system during March is summarized in Table I and Figures 2 through Figure 6, while the maintenance activities are listed in Table II and Table III. It is seen that a substantial maintenance activity was performed during March.

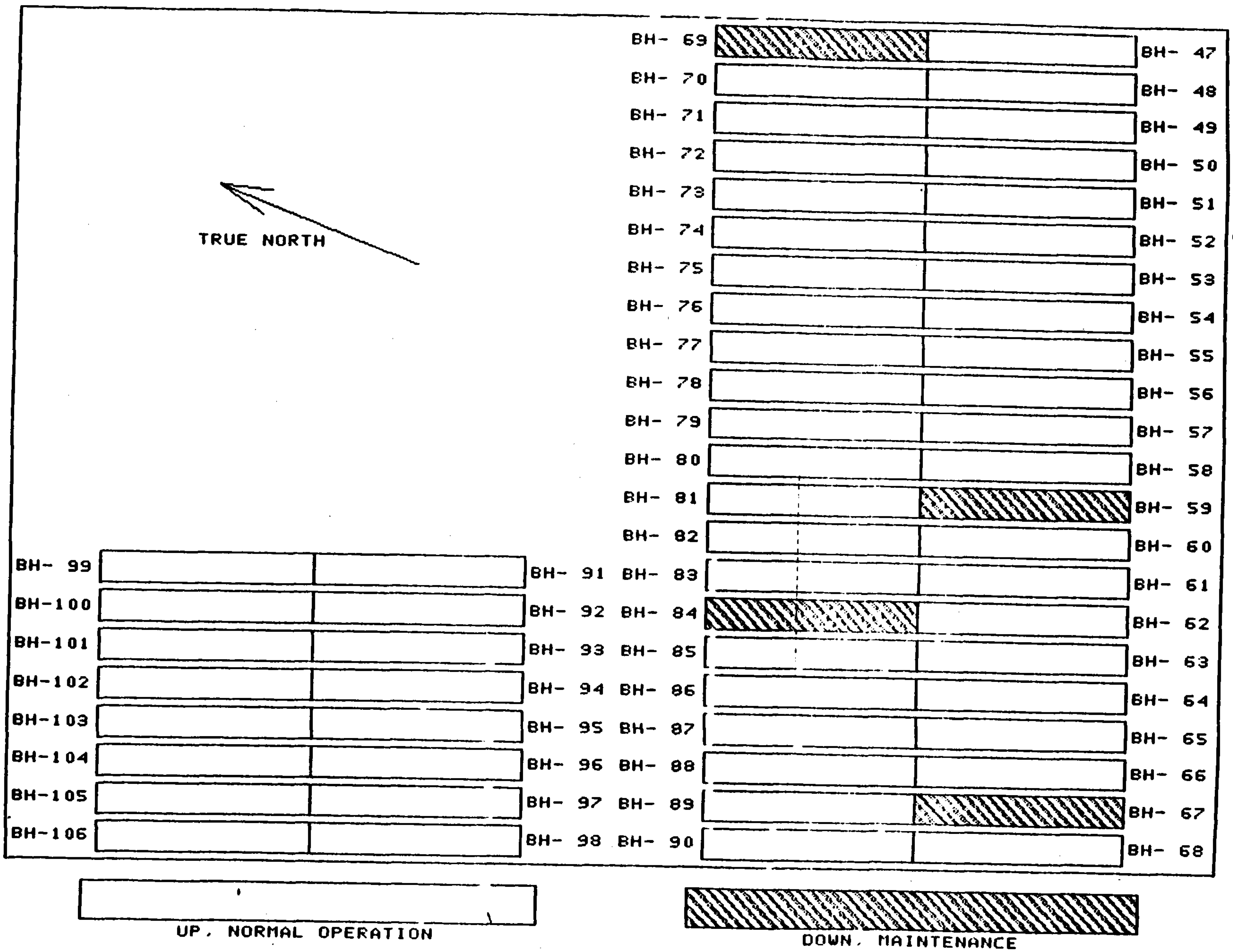
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
March 1984

Date	Active Area (ft^2)	Comments
3/1-3/5	46200	Five drive rows inoperative. Full flow to array.
3/6	47040	Four drive rows inoperative. Full flow to array.
3/7	48720	Two drive rows inoperative. Full flow to array.
3/8	47880	Three drive rows inoperative. Full flow to array.
3/9-3/31	46200	Five drive rows inoperative. Full flow to array.
3/4	--	Power failure caused DAS to shut down.
3/20-3/21	--	DAS failure; cause unknown.



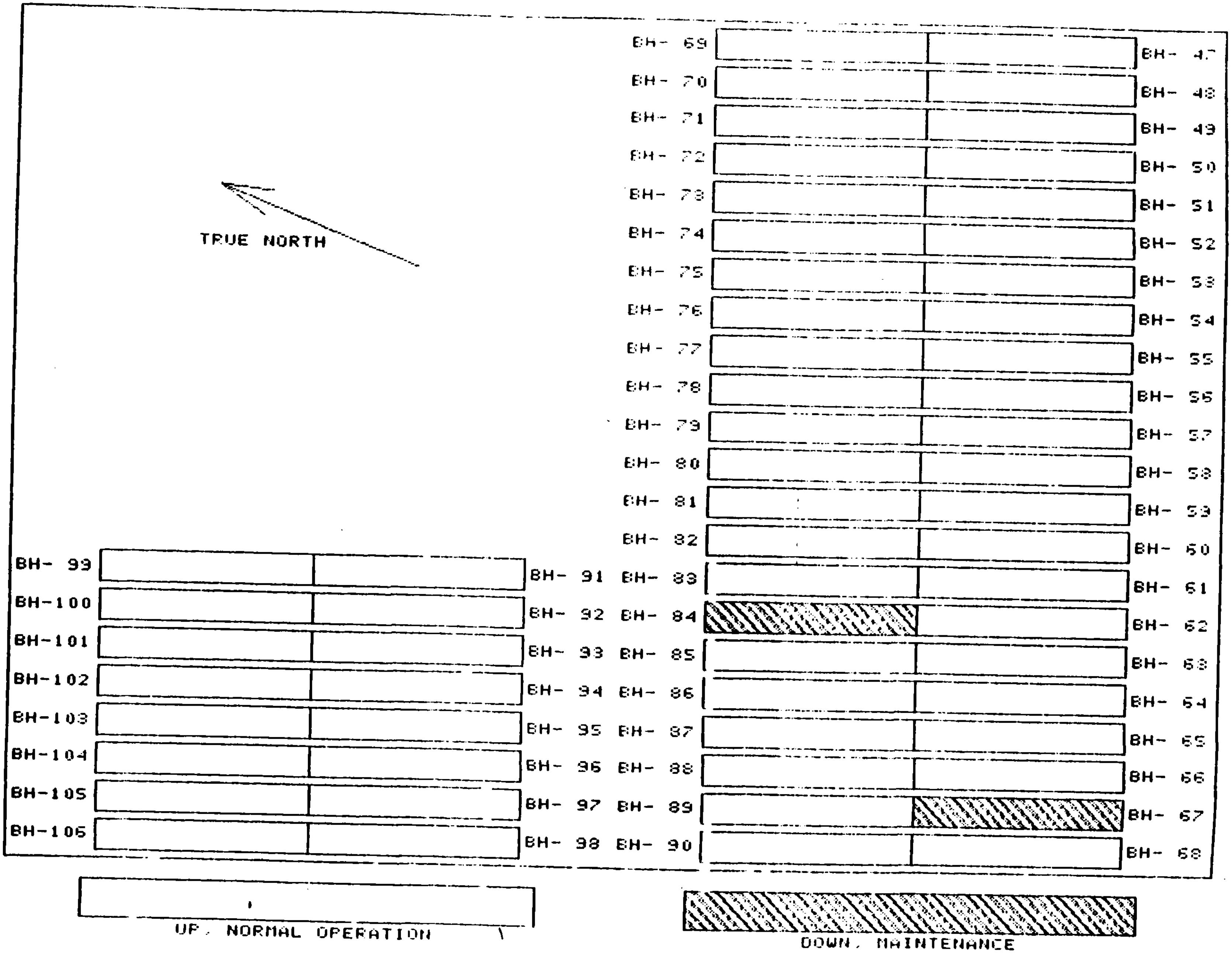
TIME PERIOD: MARCH 1-5

FIGURE 2



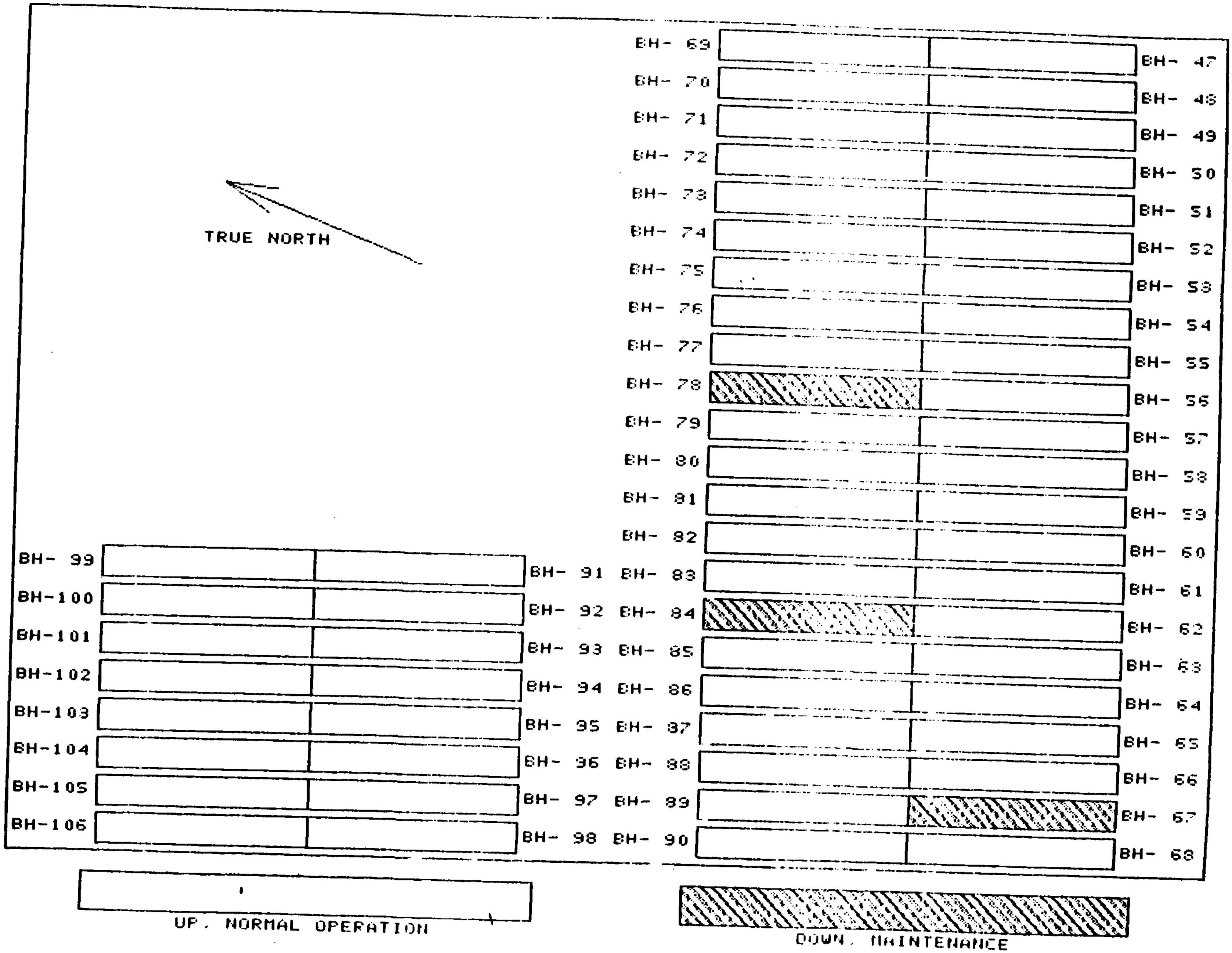
TIME PERIOD: MARCH 6

FIGURE 3



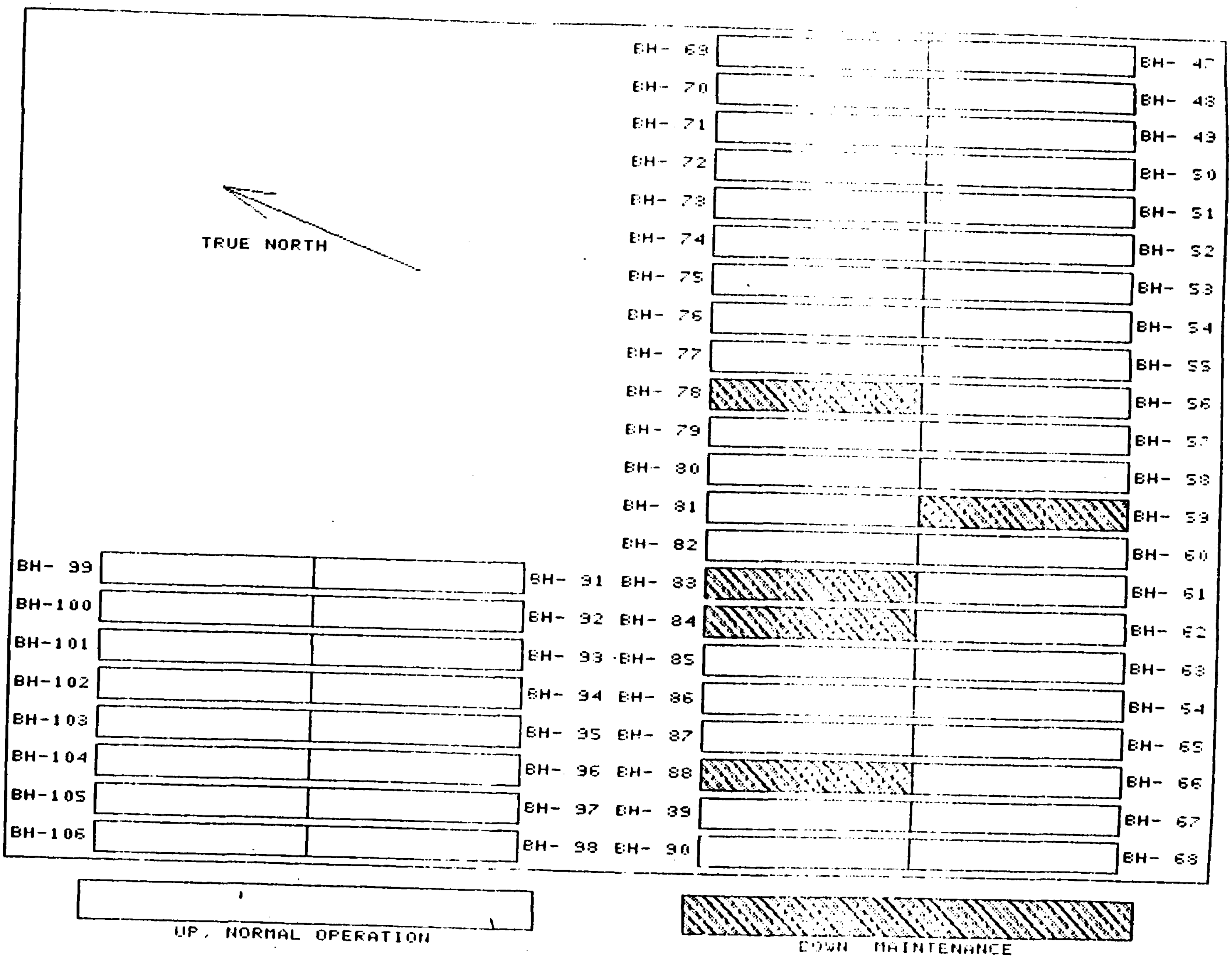
TIME PERIOD: MARCH 7

FIGURE 4



TIME PERIOD: MARCH 8

FIGURE 5



TIME PERIOD: MARCH 9-31

FIGURE 6

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
March 1984

O & M Activity	Hours	Cost Labor $	Cost Materials $	Cost Total $
o Routine inspection	10	253.82	-0-	253.82
o Repair pyranometer transmitter	4	101.53	-0-	101.53
o Electrical trouble-shooting and repairs - Replace BH-64 transformer - Replace BH-49 tracker - Replace BH-69 transformer - BH-88 Temp switch failure	38	964.55	-0-	964.55
o Hydraulics trouble-shooting and repairs - Replace BH-59 4-way valve seals - BH-78 pump seal failure - BH-83 oil leak - BH-59 seal leak - Reset BH-67 pressure switch	38	964.55	-0-	964.55
TOTAL	90	2284.46		2284.46

Total estimated maintenance cost for 2/83 - 3/84 = $9927.30

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
March 31, 1984

Row	Date of Last Action	Comment
BH-59	3/9/84	Hydraulic oil leak.
BH-78	3/8/84	Hydraulic pump seal failure.
BH-83	3/9/84	Hydraulic oil leak.
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.

IV. System Performance

A. Monthly Summary

The daily performance for the month of March, 1984 is summarized in Table IV and Figure 7. The efficiency of the collector array was 22% for the month with a peak daily efficiency of 39%. The low overall efficiency is the result of the unfocusing described above.

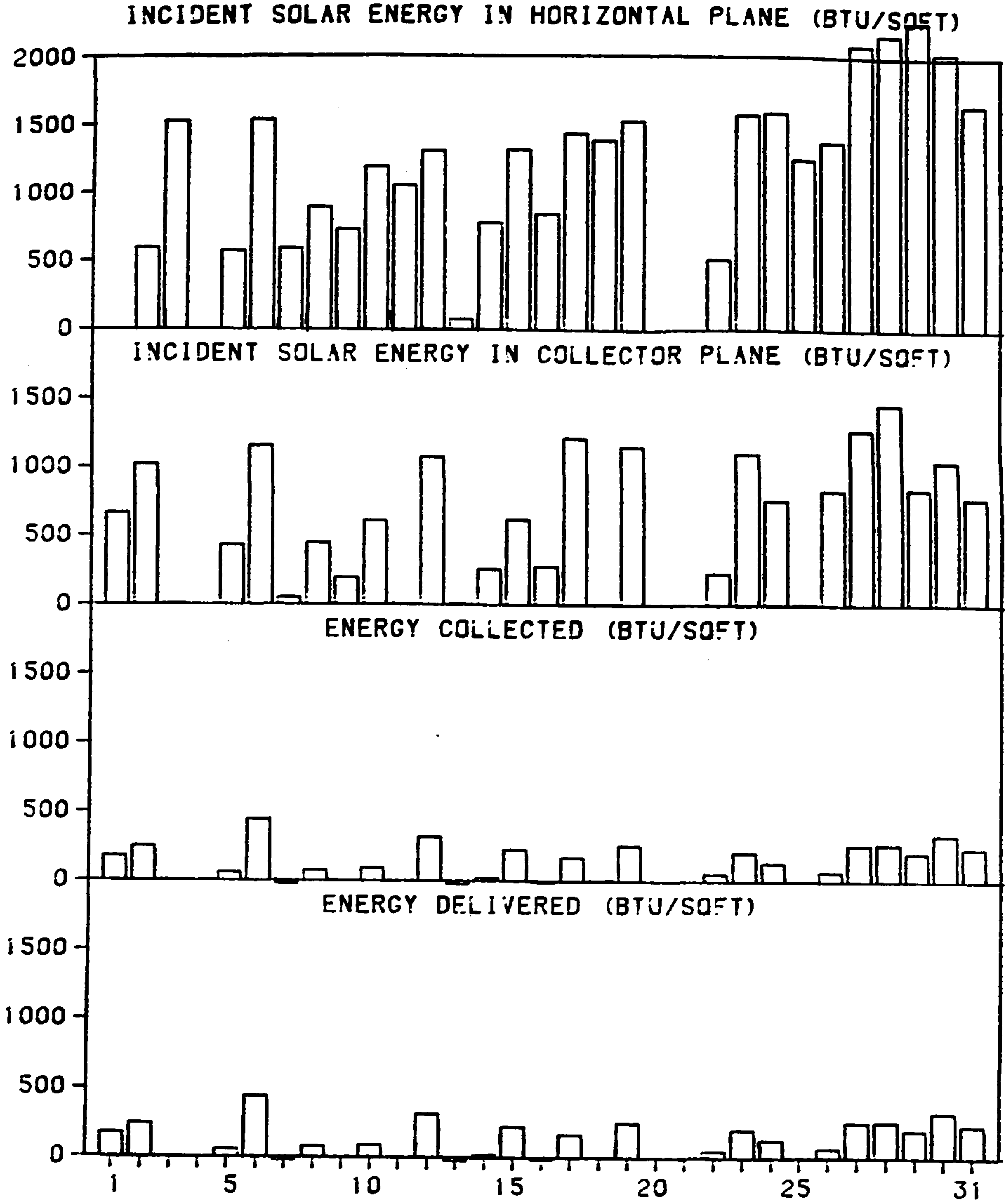
B. Clear Day Performance

The solar system performance on March 6, 1984 is summarized in Table V and Figure 8. There was very little unfocusing of the array on this day so these results are fairly representative of the performance of the equipment under steady conditions. The peak efficiency was 58% at 1600 with an overall daily efficiency of 39%.

TABLE IV

MONTHLY PERFORMANCE SUMMARY TABLE - 3/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF BASED ON (2) %	PARASITIC ENERGY USED KBTU
3/ 1	61	0.	663.	46200.	8132.	0.	27	494.4
3/ 2	62	592.	1019.	46200.	11408.	42.	24	607.3
3/ 3	63	1527.	0.	46200.	0.	0.	0.	51.0
3/ 4	64			DAS DOWN				
3/ 5	65	576.	430.	46200.	2743.	10.	14.	282.6
3/ 6	66	1538.	1153.	47040.	21005.	29.	39.	569.2
3/ 7	67	596.	48.	48720.	-1229.	-4.	-52	188.2
3/ 8	68	898.	446.	47880.	3702.	9.	17.	338.8
3/ 9	69	733.	194.	46200.	-187.	-1.	-2.	193.8
3/10	70	1196.	607.	46200.	4274.	8.	15.	422.2
3/11	71	1059.	0.	46200.	0.	0.	0.	39.6
3/12	72	1312.	1071.	46200.	14736.	24.	30.	475.7
3/13	73	80.	1.	46200.	-1227.	-33.	*****	40.9
3/14	74	781.	257.	46200.	1032.	3.	9.	250.4
3/15	75	1317.	617.	46200.	10398.	17.	36.	550.2
3/16	76	844.	275.	46200.	-728.	-2.	-6.	316.4
3/17	77	1437.	1210.	46200.	7805.	12.	14.	639.2
3/18	78	1388.	0.	46200.	0.	0.	0.	41.4
3/19	79	1530.	1149.	46200.	11817.	17.	22.	685.6
3/20	80			DAS DOWN				
3/21	81			DAS DOWN				
3/22	82	515.	226.	46200.	2330.	10.	22.	283.0
3/23	83	1576.	1099.	46200.	9473.	13.	19.	530.6
3/24	84	1596.	759.	46200.	6059.	8.	17.	516.0
3/25	85	1258.	0.	46200.	0.	0.	0.	43.5
3/26	86	1384.	831.	46200.	3193.	5.	8.	458.4
3/27	87	2087.	1270.	46200.	12003.	12.	20.	728.8
3/28	88	2162.	1460.	46200.	12284.	12.	18.	711.0
3/29	89	2261.	841.	46200.	9292.	9.	24.	536.4
3/30	90	2033.	1047.	46200.	15349.	16.	32.	581.7
3/31	91	1651.	772.	46200.	10910.	14.	31.	510.1
TOTALS		33929.	17443.		174572.	11.	22.	11086.1
AVG		1212.	623.		6235.			395.9



MONTHLY PERFORMANCE SUMMARY 3-84

FIGURE 7

TABLE V.

HOURLY PERFORMANCE TABLE - 3/ 6/84(JULIAN DAY 66)
ARRAY ACTIVE AREA = 47040. SQ.FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL SYSTEM TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
8	52.	0.	14.	64.	92.	201.	196.	197.	200.	193.	-345.	***	***	36.3
9	59.	1.	77.	119.	118.	209.	217.	309.	209.	217.	1668.	46.	30.	56.1
10	63.	1.	136.	125.	117.	212.	223.	314.	212.	221.	1955.	31.	33.	56.7
11	64.	3.	202.	149.	115.	216.	230.	319.	216.	227.	2535.	27.	36.	56.4
12	61.	5.	227.	138.	115.	218.	230.	317.	218.	229.	2485.	23.	38.	56.6
13	66.	3.	235.	146.	113.	221.	235.	312.	221.	233.	2960.	27.	43.	55.8
14	67.	7.	237.	191.	110.	224.	244.	305.	224.	244.	4584.	41.	51.	55.4
15	67.	9.	212.	165.	110.	230.	246.	304.	230.	246.	3661.	37.	47.	56.4
16	65.	8.	129.	65.	111.	235.	243.	309.	234.	241.	1716.	28.	57.	59.2
17	64.	9.	69.	-8.	115.	229.	228.	317.	229.	228.	-151.	-5.	38.	55.5
18	59.	7.	0.	0.	16.	223.	221.	44.	223.	221.	-62.	***	***	15.7
19	57.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.4
20	55.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.6
21	54.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.4
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			1538.	1153.							21005.	29.	39.	569.2
AVG	60.	5.	162.	118.	111.	220.	230.	301.	220.	229.	2154.			11.4

HOURLY PERFORMANCE FOR 3/6/84
ARRAY ACTIVE AREA = 47040 SQ FT

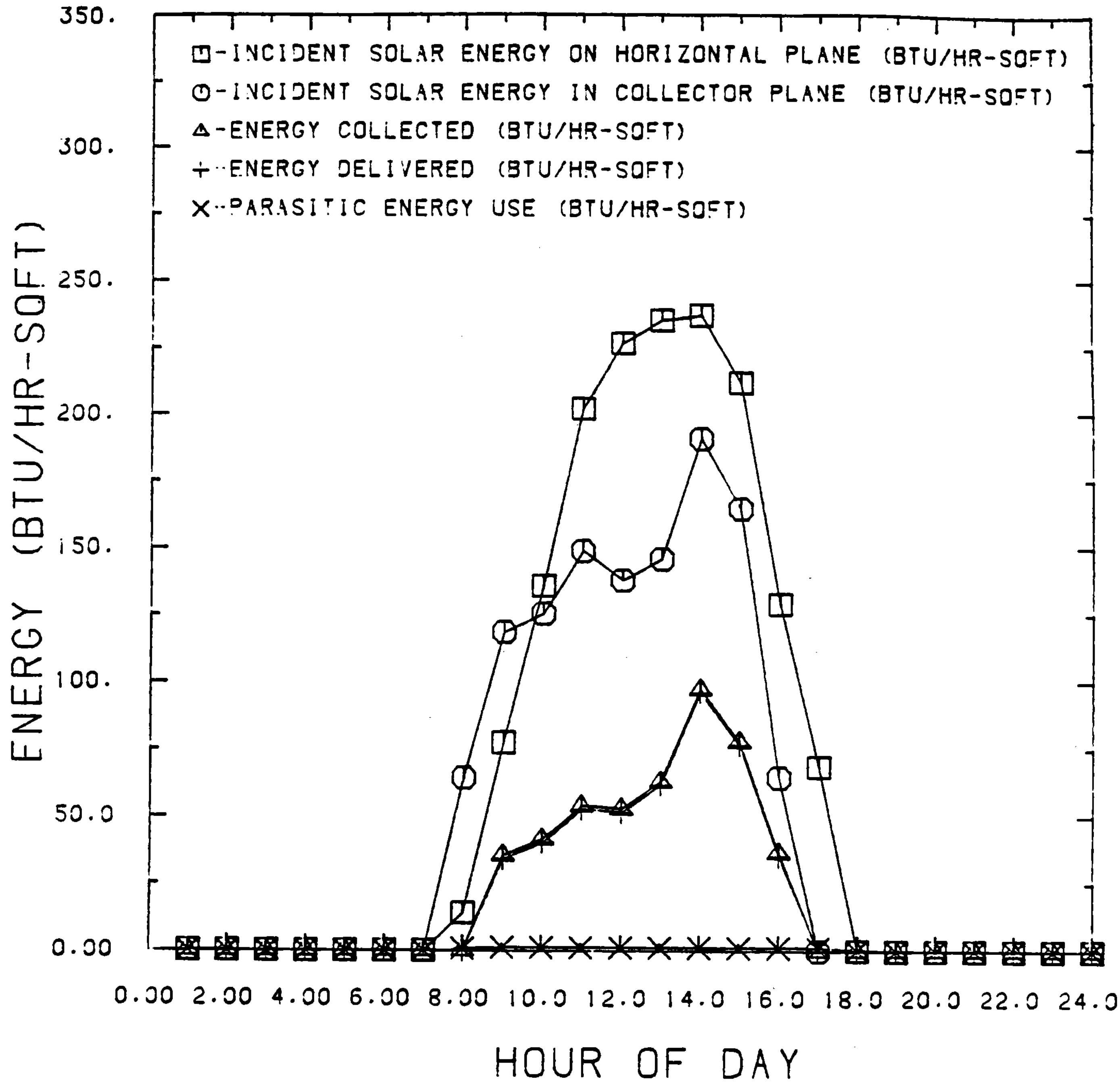


FIGURE 8

MONTHLY REPORT NO. 18

REPORT PERIOD:	April 1, 1984 - April 30, 1984
REPORT NO.:	CTCo-18
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

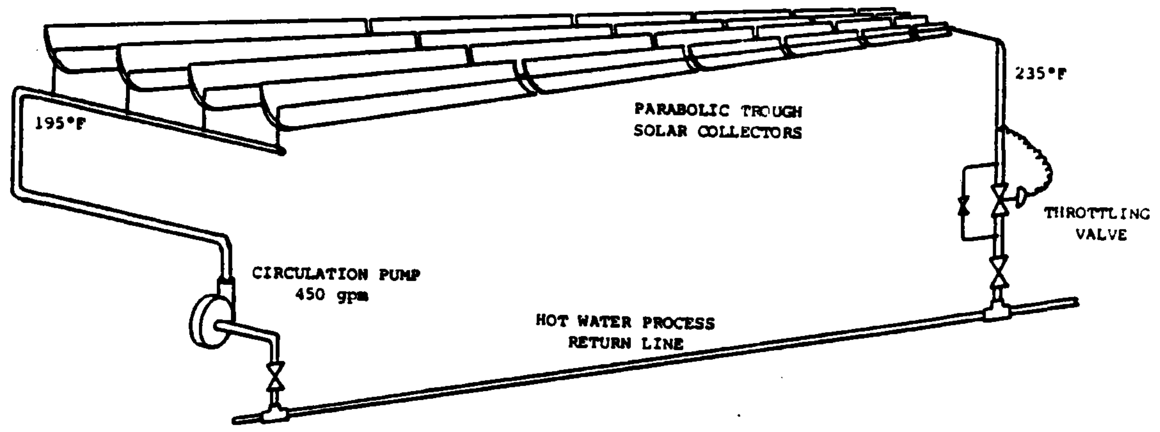


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation during the entire month of April 1984. During this month, several drive rows experienced problems which are described below.

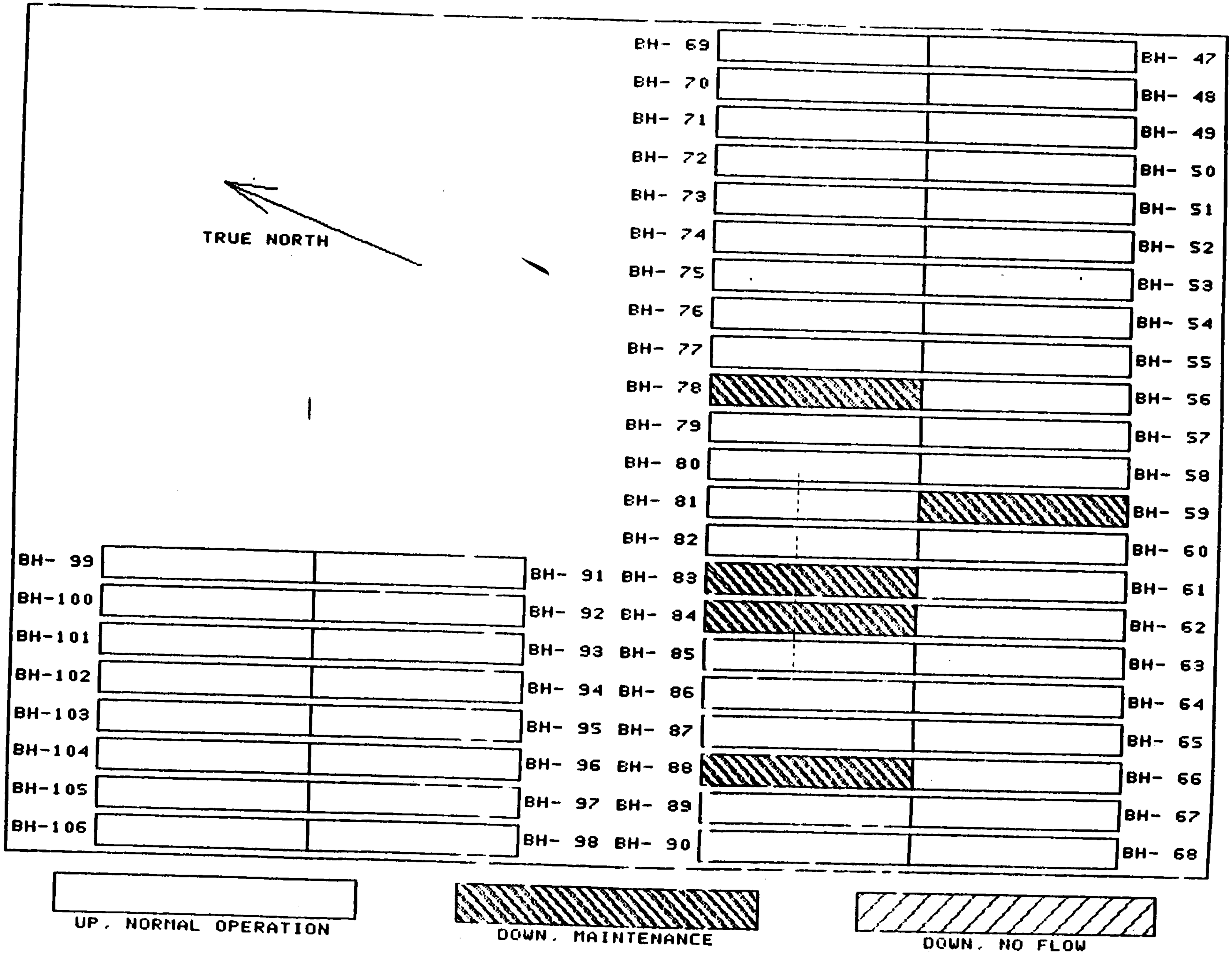
The operation of the solar system for April, 1984 is summarized in Table I, while the status of each of the drive rows is shown in Figure 2 through Figure 5. Obviously, now that the system is operating more, some problems are occurring which will require maintenance to be performed.

The O & M activities are summarized in Table II and Table III. It is seen that the majority of the failures are related to the hydraulic oil system. Several seals have failed, which CTCo personnel believes is due to the high pressures being maintained. As these seals are replaced, they are decreasing the pressure limit setting on the switch to prevent seal blowouts.

The transformer that supplies power to the DAS failed on April 18, 1984. This transformer was replaced the next day so, only two days worth of data were lost.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
April 1984

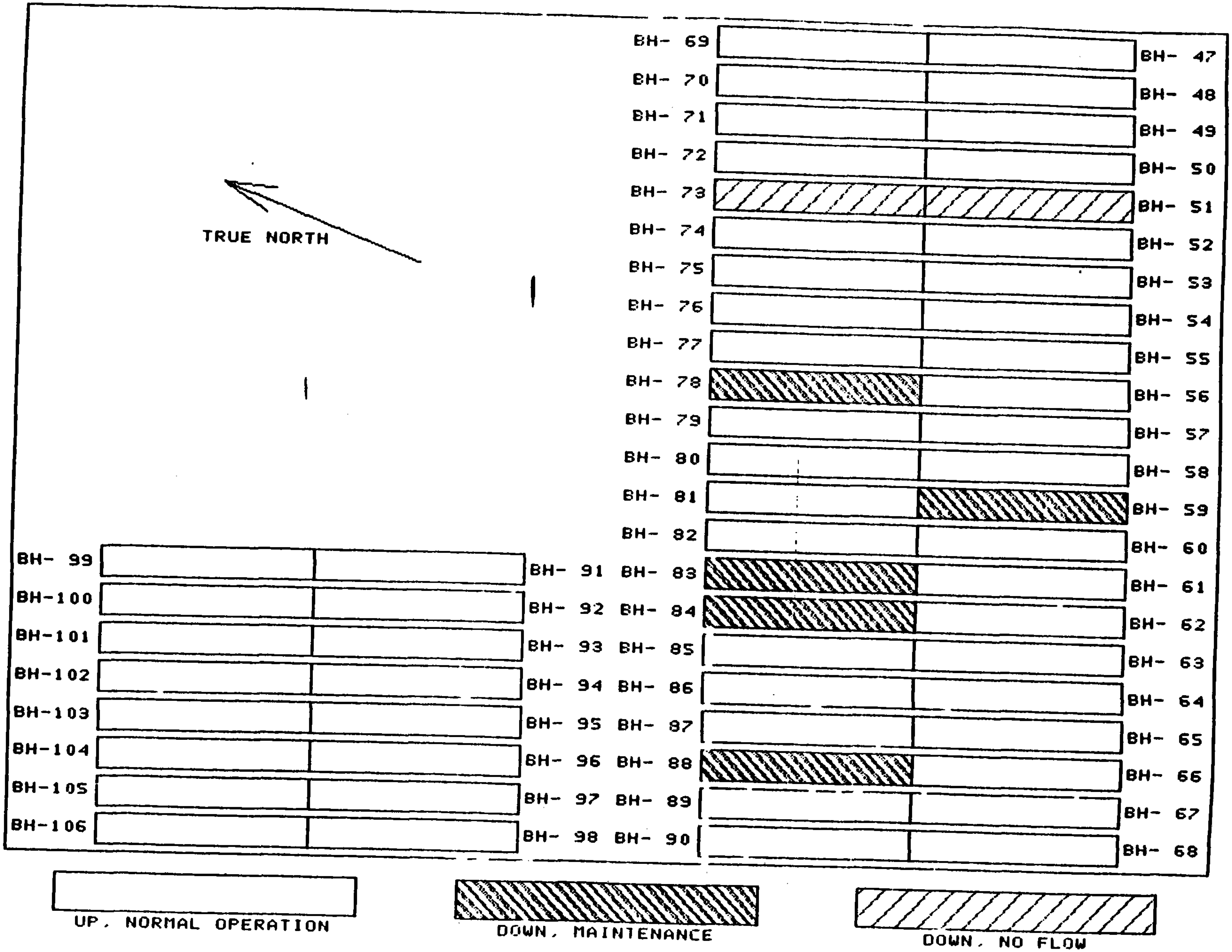
Date	Active Area (ft^2)	Comments
4/1-4/23	46200	Five drive rows inoperative. Full flow to array.
4/24	45360	Seven drive rows inoperative. No flow to delta-T string BH-73/-51.
4/25	43680	Nine drive rows inoperatie. No flow to delta-T string BH-75/51
4/26-4/30	42840	Ten drive rows inoperative. No flow to delta-T string BH-75/51.
4/18	--	Replace DAS 480/120 V transformer.



TIME PERIOD: APRIL 1-23

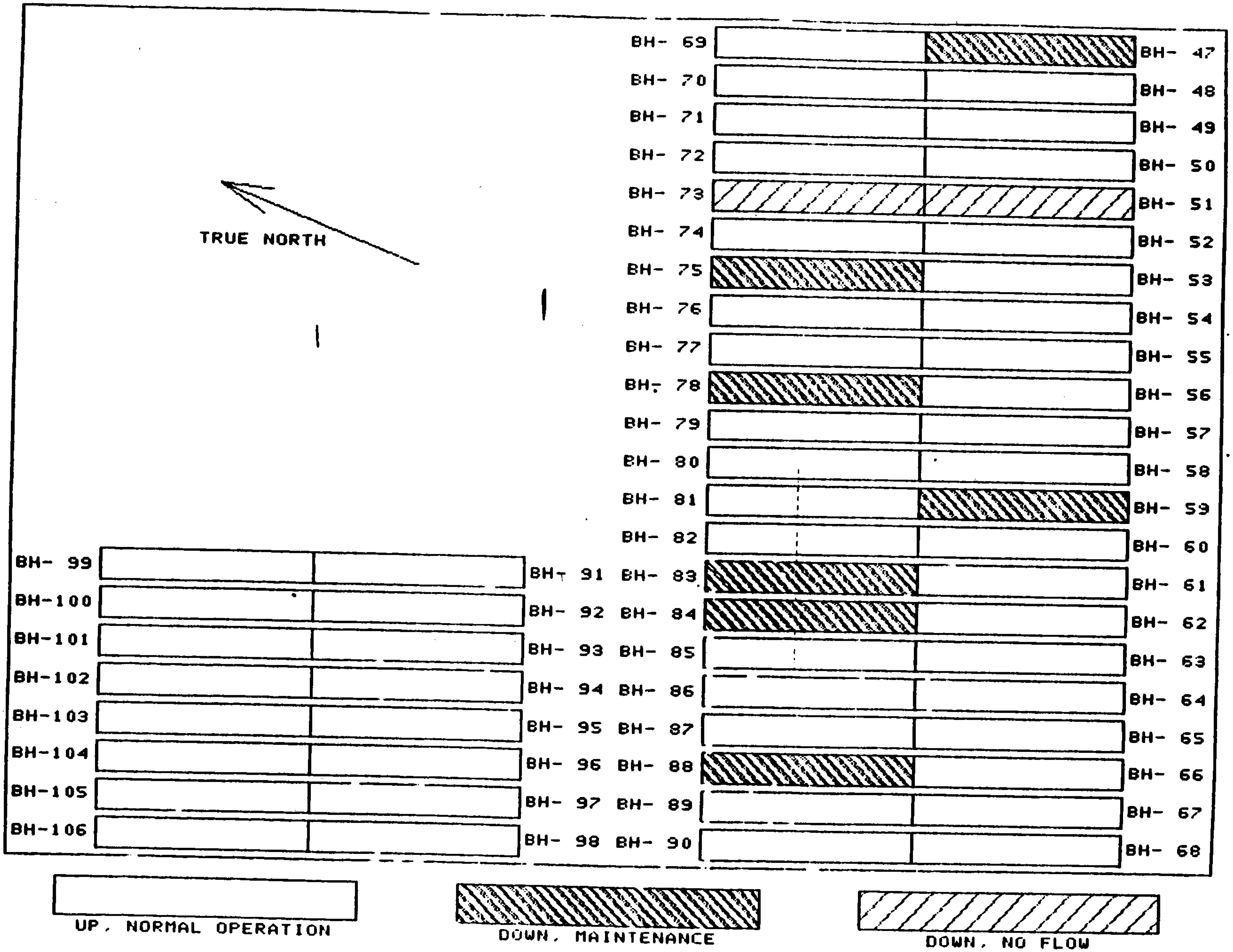
FIGURE 2

C-220



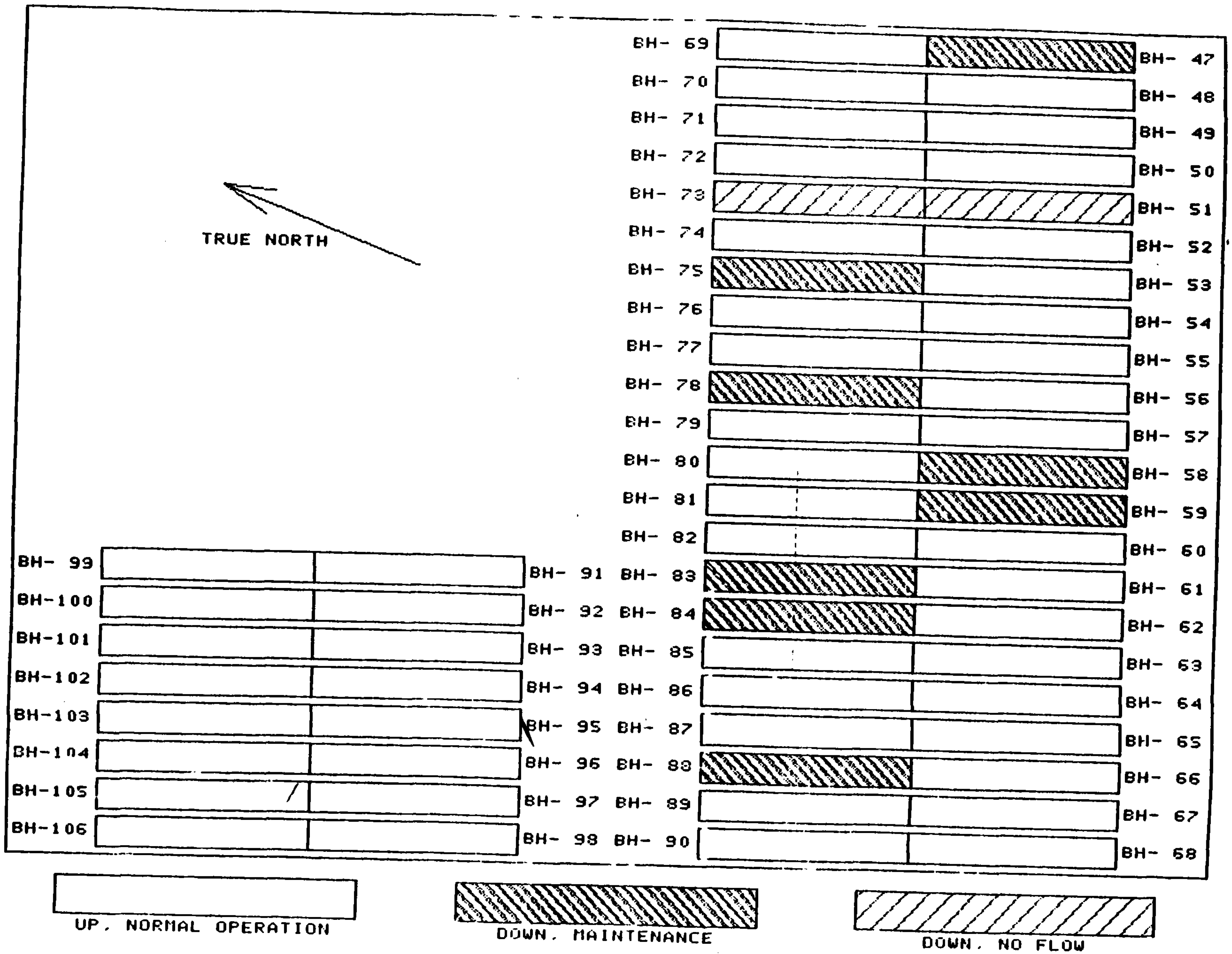
TIME PERIOD: APRIL 24

FIGURE 3



TIME PERIOD: APRIL 25

FIGURE 4



TIME PERIOD: APRIL 26-30

FIGURE 5

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
March 1984

O & M Activity	Hours	Cost Labor $	Cost Materials $	Cost Total $
o Routine inspection	5.3	154.31	-0-	154.31
o Repair DAS 480/120 V transformer	1	29.12	-0-	29.12
o Secure and isolate delta-T string BH-51/-73; water leaks	1	29.12	-0-	29.12
o Secure new B-47; glass breakage	1	29.12	-0-	29.12
o Secure BH-78; hydraulic pump seal leak	1	29.12	-0-	29.12
o Secure BH-73; hydraulic seal leak	1	29.12	-0-	29.12
o Secure BH-58; tracking problem	1	29.12	-0-	29.12
TOTAL	11.3	329.03	-0-	329.03

Total estimated maintenance cost for 2/83 - 4/84 = $10256.33

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
April 30, 1984

Row	Date of Last Action	Comment
BH-47	4/25/84	Broken glass.
BH-51	4/24/84	Water leak at outlet connection; row isolated
BH-58	4/26/84	Row not tracking.
BH-59	3/9/84	Hydraulic oil leak.
BH-73	4/24/84	See BH-51.
BH-75	4/25/84	Hydraulic pump seal failure.
BH-78	3/8/84	Hydraulic pump seal failure.
BH-83	3/9/84	Hydraulic oil leak.
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.

IV. System Performance

A. Monthly Summary

The CTCo solar system performance for April 1984 is summarized in Table IV and Figure 6. It is seen that the system provided 2.0 $*10^5$ Btu during April at an average efficiency of 29%. The peak daily efficiency is seen to be approximately 53%.

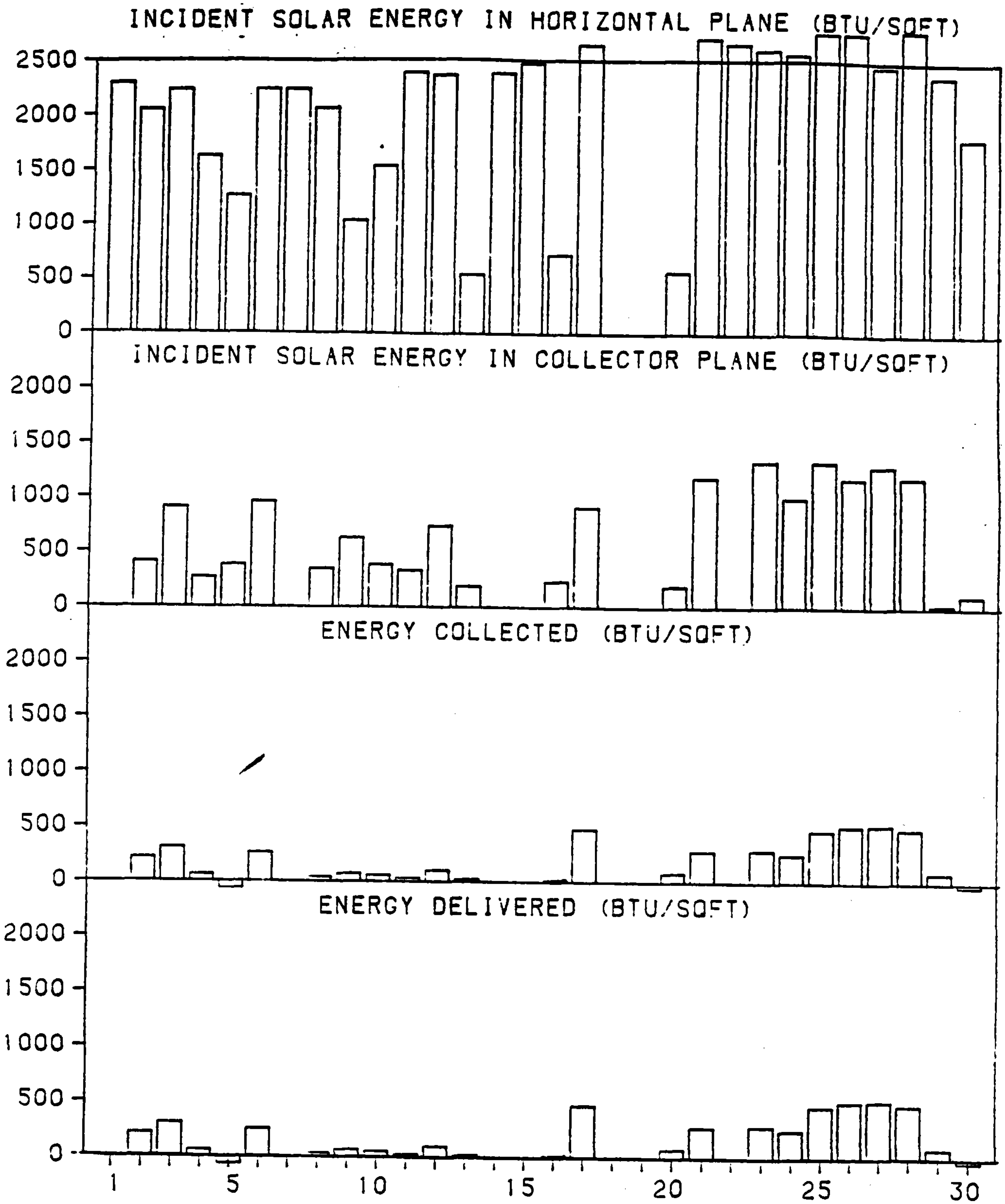
B. Clear Day Performance

The performance for April 28, 1984 is summarized in Table V and Figure 7. The system operated from just after 7:00 to just after 17:00 on this day. The solar system delivered 20.2 $*10^3$ Btu at an average efficiency of 41%. The peak hourly efficiency was 47%.

TABLE IV

MONTHLY PERFORMANCE SUMMARY TABLE - 4/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
4/ 1	92	2296.	0.	46200.	0.	0.	0.	48.2
4/ 2	93	2057.	408.	46200.	9922.	10.	53.	545.9
4/ 3	94	2236.	907.	46200.	14216.	14.	34.	634.4
4/ 4	95	1630.	269.	46200.	2836.	4.	23.	304.4
4/ 5	96	1265.	383.	46200.	-3097.	-5.	-17	394.2
4/ 6	97	2237.	960.	46200.	12008.	12.	27.	652.0
4/ 7	98	2239.	0.	46200.	0.	0.	0	45.9
4/ 8	99	2068.	349.	46200.	1835.	2.	11.	375.9
4/ 9	100	1033.	631.	46200.	3287.	7.	11.	308.9
4/10	101	1538.	386.	46200.	2691.	4.	15	296.2
4/11	102	2384.	334.	46200.	1485.	1.	10.	313.0
4/12	103	2360.	739.	46200.	4776.	4.	14.	668.6
4/13	104	541.	192.	46200.	1116.	4.	13	253.2
4/14	105	2381.	0.	46200.	0.	0.	0	52.5
4/15	106	2475.	0.	46200.	0.	0.	0	51.1
4/16	107	722.	233.	46200.	1073.	3.	10	161.9
4/17	108	2645.	914.	46200.	22177.	18.	52.	745.3
4/18	109			DAS DOWN				
4/19	110			DAS DOWN				
4/20	111	568.	190.	46200.	3797.	14.	43.	101.0
4/21	112	2701.	1185.	46200.	13108.	11.	24.	740.9
4/22	113	2654.	0.	46200.	0.	0.	0.	38.4
4/23	114	2600.	1333.	46200.	13593.	11.	22.	728.1
4/24	115	2564.	998.	44520.	11360.	10.	26.	603.0
4/25	116	2757.	1331.	42840.	20304.	17.	36.	598.2
4/26	117	2758.	1180.	42000.	21657.	19.	44.	677.1
4/27	118	2463.	1291.	42000.	22041.	21.	41.	664.8
4/28	119	2788.	1186.	42000.	20432.	17.	41.	698.6
4/29	120	2379.	23.	42000.	3794.	4.	389.	388.5
4/30	121	1804.	107.	42000.	-1472.	-2.	-33.	204.2
TOTALS		58144.	15528.		202937.	8.	29.	11294.5
AVG		2077.	555.		7248.			403.4



MONTHLY PERFORMANCE SUMMARY 4-84

FIGURE 6

TABLE V.

HOURLY PERFORMANCE TABLE - 4/28/84(JULIAN DAY 119)
ARRAY ACTIVE AREA = 42000. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	53.	4.	51.	117.	101.	213.	213.	223.	211.	211.	-203.	-9.	-4.	46.2
8	61.	3.	132.	178.	113.	226.	241.	287.	226.	240.	2767.	50.	37.	56.5
9	63.	4.	213.	116.	110.	231.	243.	283.	231.	242.	2049.	23.	42.	62.5
10	63.	5.	282.	131.	112.	229.	243.	292.	229.	241.	2323.	20.	42.	63.2
11	64.	6.	332.	112.	113.	232.	244.	291.	231.	243.	2087.	15.	44.	63.6
12	65.	8.	361.	104.	113.	233.	244.	290.	232.	243.	2047.	14.	47.	63.4
13	65.	10.	365.	106.	113.	233.	244.	289.	232.	243.	2074.	14.	47.	64.1
14	64.	11.	347.	108.	113.	232.	244.	288.	232.	243.	2034.	14.	45.	63.8
15	64.	10.	297.	104.	113.	234.	245.	287.	233.	244.	2003.	16.	46.	64.3
16	63.	9.	209.	95.	113.	236.	245.	289.	235.	244.	1702.	19.	43.	64.8
17	60.	9.	133.	18.	115.	231.	239.	297.	231.	238.	1456.	26.	***	57.4
18	60.	7.	60.	-3.	33.	226.	228.	86.	226.	228.	94.	4.	***	22.0
19	53.	9.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
20	50.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
21	50.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
22	49.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			2788.	1186.							20432.	17.	41.	698.6
AVG	60.	7.	231.	107.	110.	230.	241.	280.	230.	240.	1843.			13.7

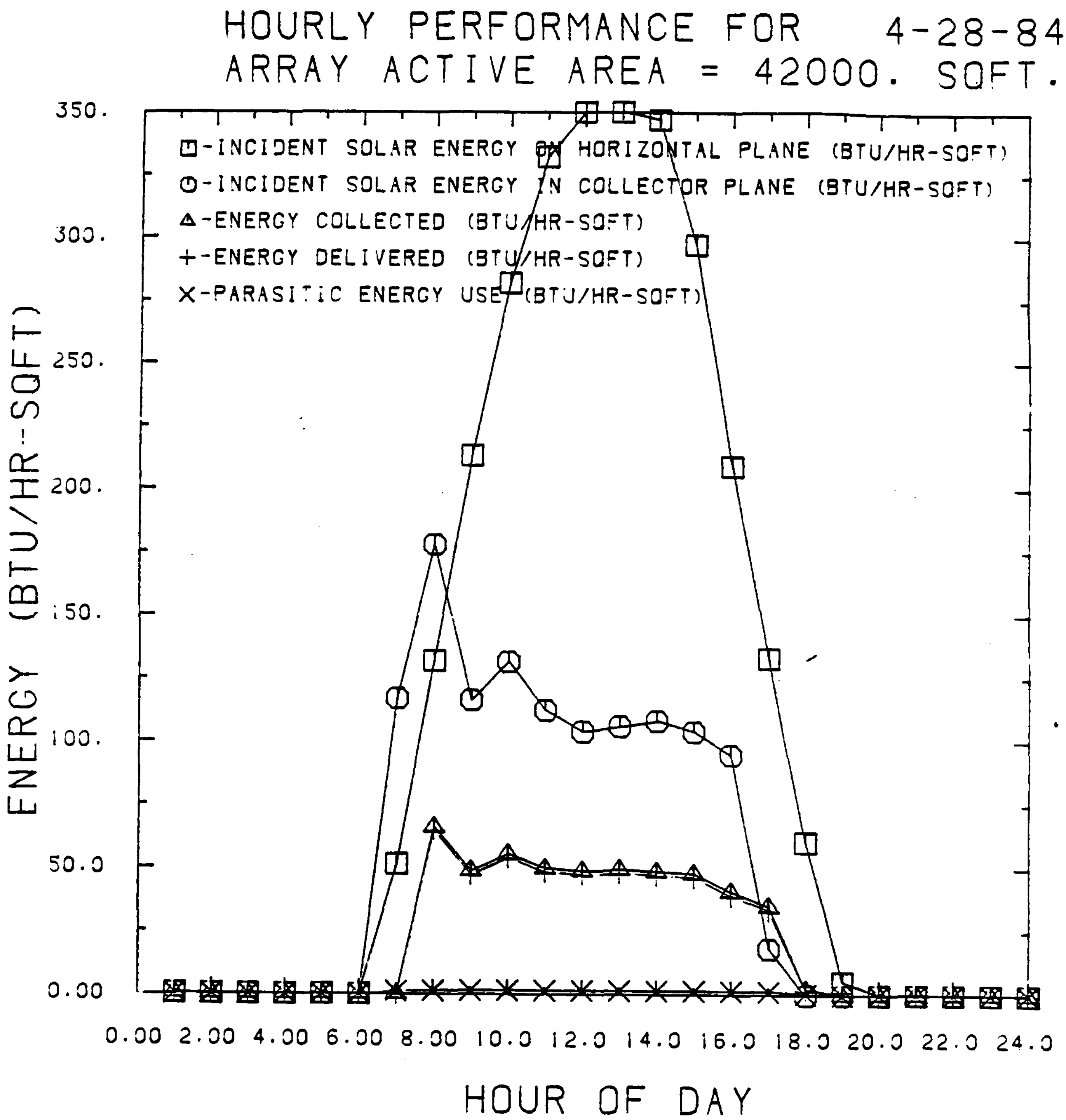

HOURLY PERFORMANCE FOR 4-28-84
ARRAY ACTIVE AREA = 42000. SQFT.
□-INCIDENT SOLAR ENERGY ON HORIZONTAL PLANE (BTU/HR-SQFT)
O-INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/HR-SQFT)
Δ-ENERGY COLLECTED (BTU/HR-SQFT)
+-ENERGY DELIVERED (BTU/HR-SQFT)
X-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 7

The effects of the collector's focus/unfocus action is seen in the graphs of Figure 8. First it is seen in Figure 8(a) that as the collector oscillates, the radiation in the plane of the collectors changes. The reason for the oscillation is seen in Figure 8(d). As the outlet temperature exceeds approximately 250°F, a thermostat signals the central controller to unfocus the collectors. When the temperature decreases to less than the thermostat setting the collectors refocus, and begin the cycle anew. The oscillating energy output of the field is as shown in Figure 8(b).

These oscillations prevent the solar system from producing as much energy as it possibly can, but the computed efficiency of the array remains high because the radiation energy input is oscillating along with the thermal energy output.

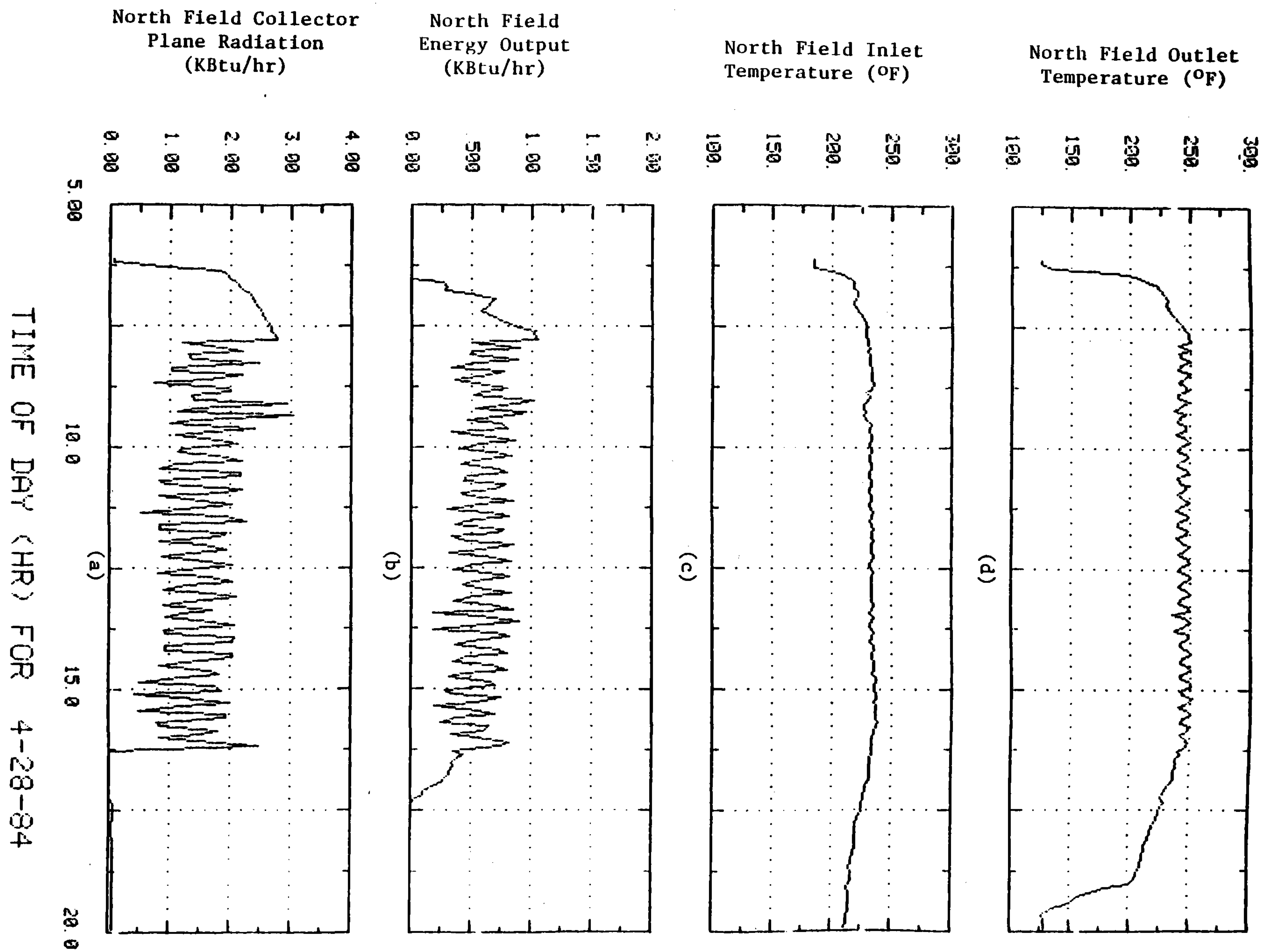

North Field Collector Plane Radiation (KBtu/hr)
North Field Energy Output (KBtu/hr)
North Field Inlet Temperature (°F)
North Field Outlet Temperature (°F)
0.00
1.00
2.00
3.00
4.00
0.00
500
1.00
1.50
2.00
100.
150.
200.
250.
300.
5.00
10.0
15.0
20.0
(a)
(b)
(c)
(d)
TIME OF DAY (HR) FOR 4-28-84

FIGURE 8

SOUTHWEST RESEARCH INSTITUTE

POST OFFICE DRAWER 28510 • 6220 CULEBRA ROAD • SAN ANTONIO, TEXAS, USA 78284 • (512) 684-5111•TELEX 76-7357

Department of Mechanical Sciences
June 15, 1984
Monthly Progress Report No. 52
Reporting Period May 12, 1984
through June 8, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC030CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued during May exactly as in April. There was some maintenance activity during May, but it was limited to troubleshooting.

A site visit was made during the period June 4-8 which will be described in the June Monthly Report.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Current operation will continue. Any necessary maintenance activities are limited by parts delivery and personnel scheduling.

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

APPROVED:

Danny M. Deffenbaugh
Project Manager

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 19

REPORT PERIOD:	May 1, 1984 - May 31, 1984
REPORT NO.:	CTCo-19
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application: -	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

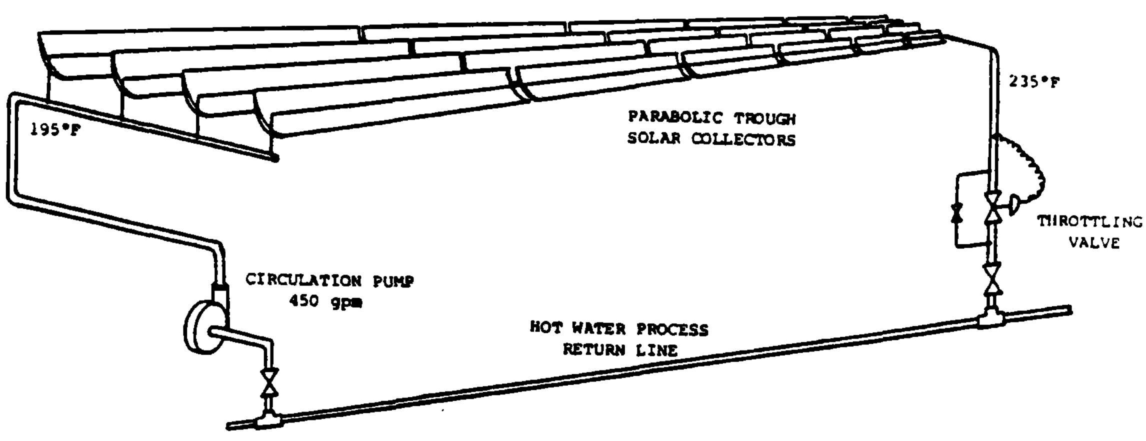


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation during the entire month of May 1984. The DAS experienced some minor problems, however.

The operation of the Caterpillar Solar System for May 1984 is summarized in Table I, with the status of each of the drive rows depicted in Figure 2. No change in the status of the system was made during May. As seen in Table II, there was some maintenance activity during May, but it was limited to troubleshooting. Since the solar system can currently provide more energy than the plant needs, drive row maintenance is not of high priority.

The DAS printer experienced problems on 5/11 which caused the DAS to fail during 5/11-5/13. The local DEC personnel were called out for maintenance so the system was returned to service on 5/14. An unexplained failure caused a DAS crash on 5/31 with intermittent activity through June 6, 1984.

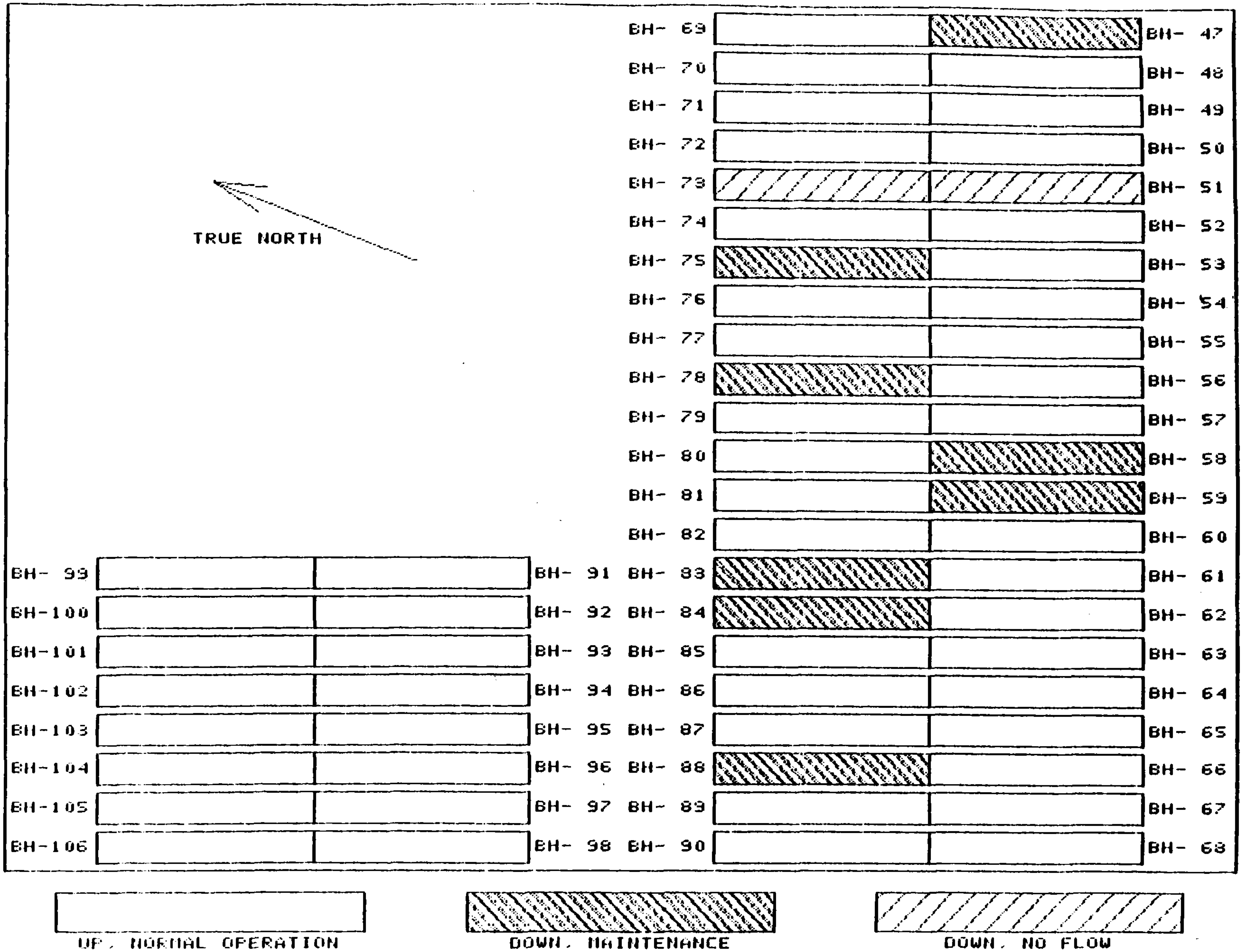
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
May 1984

Date	Active Area (ft^2)	Comments
5/1/-5/31	42000	Eleven drive rows inoperative. No flow to delta-T string BH-75/51
5/11-5/13	-	DAS printer failure caused system crash
5/31	-	DAS down

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
May 1984

		Cost		
O & M Activity	Hours	Labor $	Materials $	Total $
o Routine inspection	8	203.98	-0-	203.98
o Troubleshoot hydraulic problems	20	509.98	-0-	509.98
o Troubleshoot control problems	20	509.98	-0-	509.98
TOTAL	48	1223.94	-0-	1223.94

Total estimated maintenance cost for 2/83 - 5/84 = $11480.27



TIME PERIOD: MAY 1-31

FIGURE 2

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
May 31, 1984

Row	Date of Last Action	Comment
BH-47	6/7/84	Broken glass, high temperature switch failure.
BH-58	4/26/84	Row not tracking.
BH-59	3/9/84	Hydraulic oil leak.
BH-73	4/24/84	See BH-51.
BH-75	4/25/84	Hydraulic pump seal failure.
BH-78	3/8/84	Hydraulic pump seal failure.
BH-83	3/9/84	Hydraulic oil leak.
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.

IV. System Performance

A. Monthly Summary

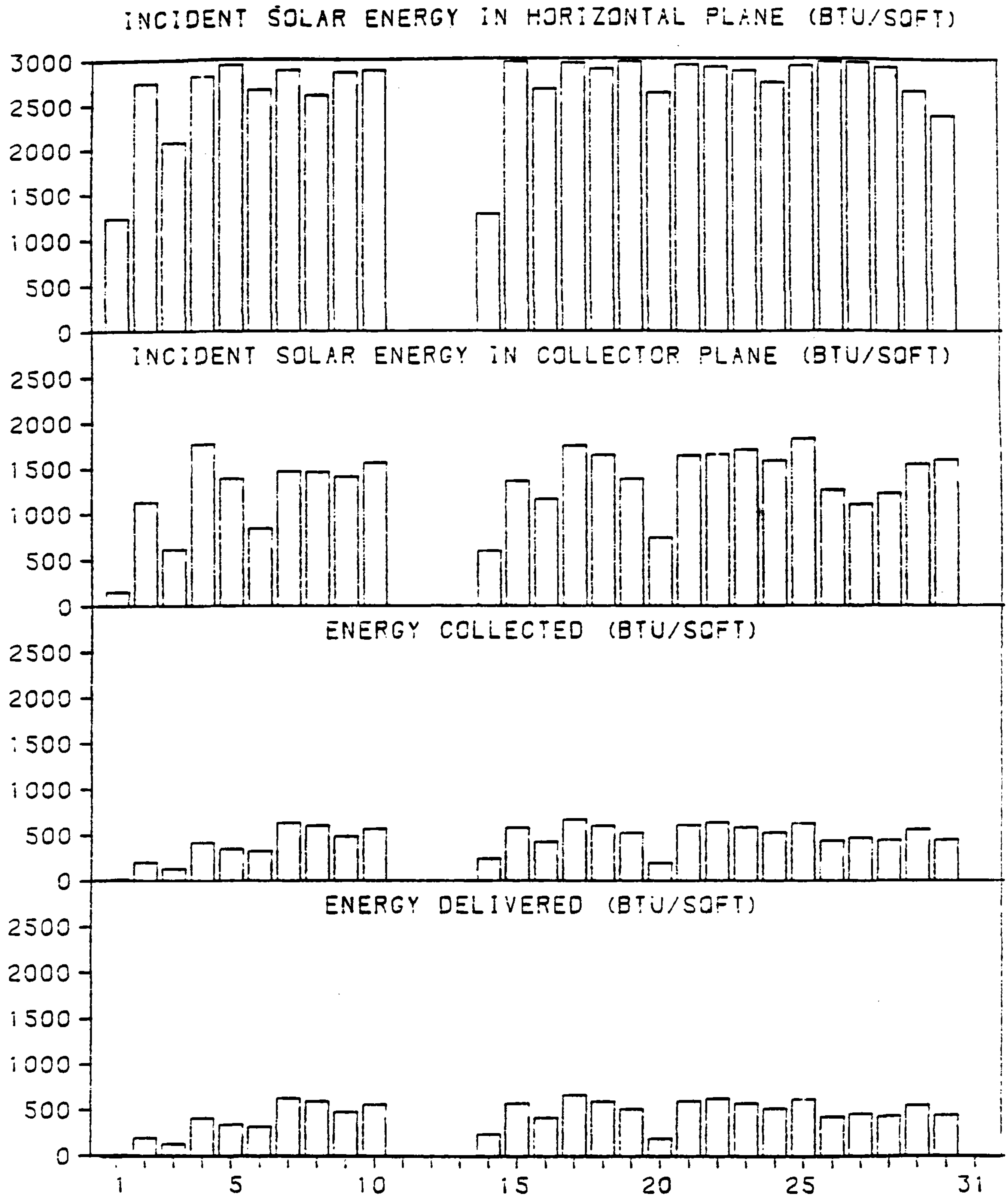
The CTCo solar system performance for May 1984 is summarized in Table IV and Figure 3. It is seen that approximately 524 $*10^6$ Btu were delivered during May at an average efficiency of 35%. Peak daily efficiency was 43%.

B. Clear Day Performance

The daily performance for May 23, 1984 is summarized in Table V and Figure 4. The peak hourly efficiency was 41% near solar noon with respect to the collector orientation. Approximately 25 $*10^6$ Btu were delivered for an all day efficiency of 35%

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 5/84

		INCIDENT SOLAR ENERGY						
DATE	JULIAN DAY	ON A HORIZ SURFACE (1) BTU/SQFT	ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
5/ 1	122	1239.	160.	42000.	887.	2.	13.	115.4
5/ 2	123	2745.	1134.	42000.	8610.	7.	18.	636.0
5/ 3	124	2093.	620.	42000.	5801.	7.	22.	387.0
5/ 4	125	2818.	1770.	42000.	17835.	15.	24.	710.7
5/ 5	126	2944.	1398.	42000.	14940.	12.	25.	754.6
5/ 6	127	2670.	854.	42000.	13841.	12.	39.	701.3
5/ 7	128	2882.	1478.	42000.	26954.	22.	43.	754.2
5/ 8	129	2606.	1467.	42000.	25650.	23.	42.	744.5
5/ 9	130	2861.	1416.	42000.	20663.	17.	35.	749.0
5/10	131	2883.	1570.	42000.	24200.	20.	37.	760.0
5/11	132			DAS FAILURE				
5/12	133			DAS FAILURE				
5/13	134			DAS FAILURE				
5/14	135	1291.	609.	42000.	10399.	19.	41.	350.7
5/15	136	2969.	1370.	42000.	24657.	20.	43.	774.2
5/16	137	2669.	1172.	42000.	18145.	16.	37.	588.0
5/17	138	2954.	1755.	42000.	28362.	23.	38.	755.7
5/18	139	2887.	1650.	42000.	25582.	21.	37.	750.3
5/19	140	2966.	1393.	42000.	22240.	18.	38.	780.9
5/20	141	2626.	751.	42000.	8418.	8.	27.	476.5
5/21	142	2932.	1645.	42000.	25813.	21.	37.	749.8
5/22	143	2907.	1660.	42000.	27004.	22.	39.	795.6
5/23	144	2867.	1708.	42000.	24764.	21.	35.	759.0
5/24	145	2741.	1587.	42000.	22436.	19.	34.	665.6
5/25	146	2924.	1827.	42000.	26652.	22.	35.	793.0
5/26	147	2965.	1269.	42000.	18674.	15.	35.	723.6
5/27	148	2960.	1109.	42000.	19886.	16.	43.	742.1
5/28	149	2912.	1231.	42000.	18847.	15.	36.	714.0
5/29	150	2651.	1550.	42000.	23696.	21.	36.	611.6
5/30	151	2376.	1593.	42000.	19029.	19.	28.	513.9
5/31	152			DAS FAILURE				
TOTALS		72340.	35746.		523985.	17.	35.	17857.1
AVG		2679.	1324.		19407.			661.4



MONTHLY PERFORMANCE SUMMARY 5-84

FIGURE 3

TABLE V.

HOURLY PERFORMANCE TABLE - 5/23/84(JULIAN DAY 144)
ARRAY ACTIVE AREA = 42000. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	54.	4.	8.	3.	9.	185.	146.	15.	185.	133.	-509.	***	***	7.4
8	59.	4.	65.	126.	107.	207.	208.	238.	206.	207.	324.	12.	6.	55.0
9	66.	2.	145.	168.	117.	222.	234.	289.	221.	234.	2475.	41.	35.	55.0
10	67.	5.	228.	180.	114.	226.	241.	282.	225.	241.	3003.	31.	40.	55.1
11	68.	5.	259.	114.	117.	223.	232.	292.	223.	232.	1709.	16.	36.	56.4
12	68.	7.	337.	167.	114.	227.	242.	283.	227.	242.	2814.	20.	40.	61.9
13	66.	10.	360.	171.	114.	227.	242.	284.	227.	242.	2923.	19.	41.	61.0
14	66.	10.	369.	160.	115.	227.	240.	286.	226.	241.	2720.	18.	41.	62.6
15	66.	11.	351.	162.	116.	227.	240.	287.	226.	241.	2755.	19.	41.	62.9
16	66.	10.	305.	152.	115.	228.	240.	287.	227.	241.	2567.	20.	40.	63.3
17	66.	11.	225.	154.	115.	230.	241.	287.	229.	242.	2386.	25.	37.	63.2
18	63.	12.	137.	153.	115.	231.	241.	289.	231.	240.	1861.	32.	29.	60.6
19	61.	9.	68.	2.	118.	224.	224.	300.	224.	224.	38.	1.	37.	55.7
20	58.	9.	10.	-5.	64.	218.	215.	163.	217.	215.	-301.	***	***	36.6
21	55.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.2
22	53.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			2867.	1708.							24764.	21.	35.	759.0
AVG	63.	8.	229.	136.	111.	225.	234.	276.	224.	235.	1968.			14.9

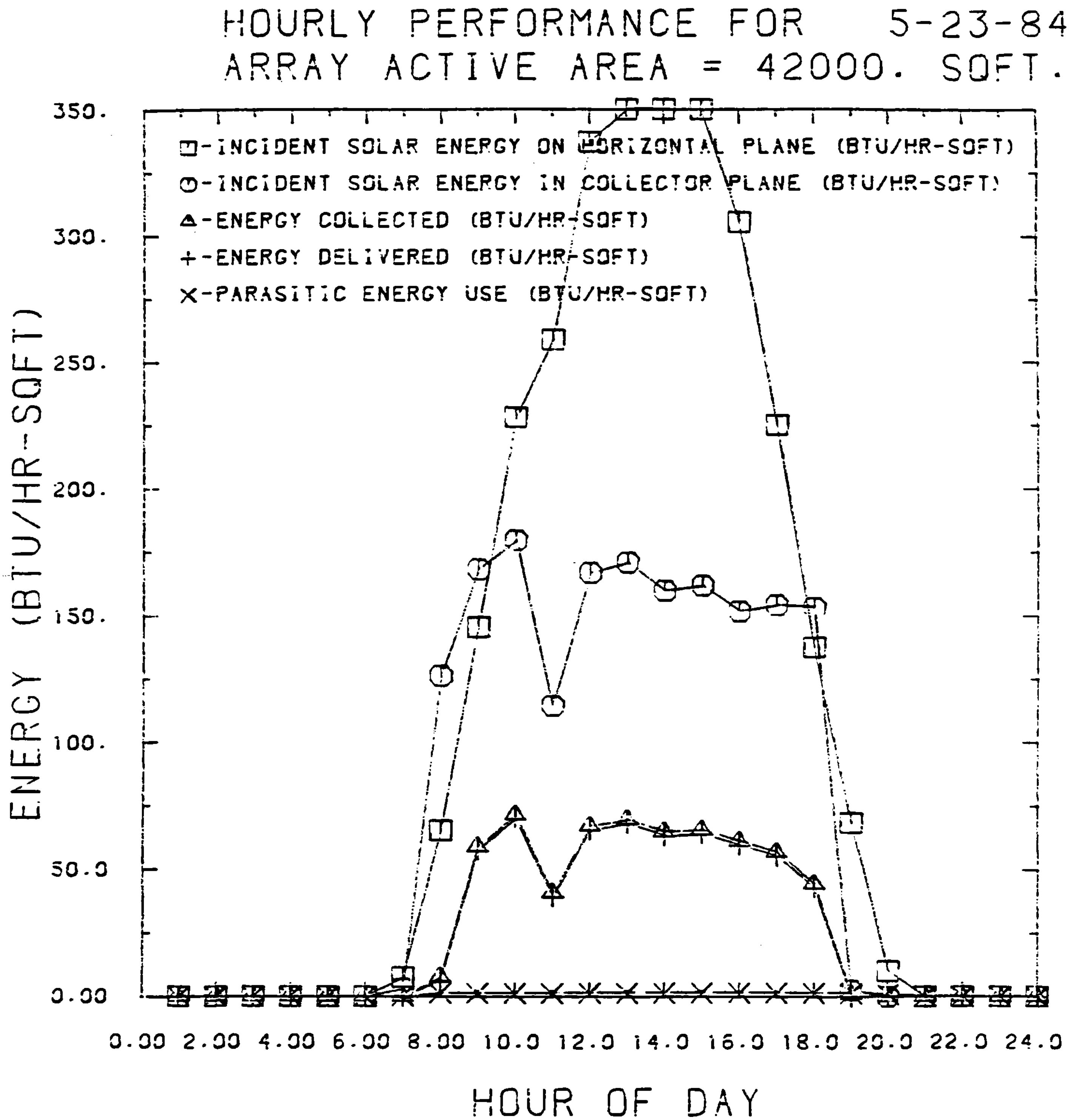

HOURLY PERFORMANCE FOR 5-23-84
ARRAY ACTIVE AREA = 42000. SQFT.
□-INCIDENT SOLAR ENERGY ON HORIZONTAL PLANE (BTU/HR-SQFT)
○-INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/HR-SQFT)
△-ENERGY COLLECTED (BTU/HR-SQFT)
+-ENERGY DELIVERED (BTU/HR-SQFT)
×-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE IV

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
July 20, 1984
Monthly Progress Report No. 53
Reporting Period June 9, 1984
through July 6, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC03OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to September 30, 1984

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

A site visit was made by SwRI personnel during the week of June 4, 1984. The activities performed are described in the accompanying Monthly Performance Report.

Replacement parts have been ordered so CTCo personnel can reactivate a number of rows.

SUMMARY STATUS ASSESSMENT AND FORECAST:

A contract extension has been negotiated to allow SwRI to continue taking performance data until December 1984.

Respectfully submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 20

REPORT PERIOD:	June 1, 1984 - June 30, 1984
REPORT NO.:	CTCo-20
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

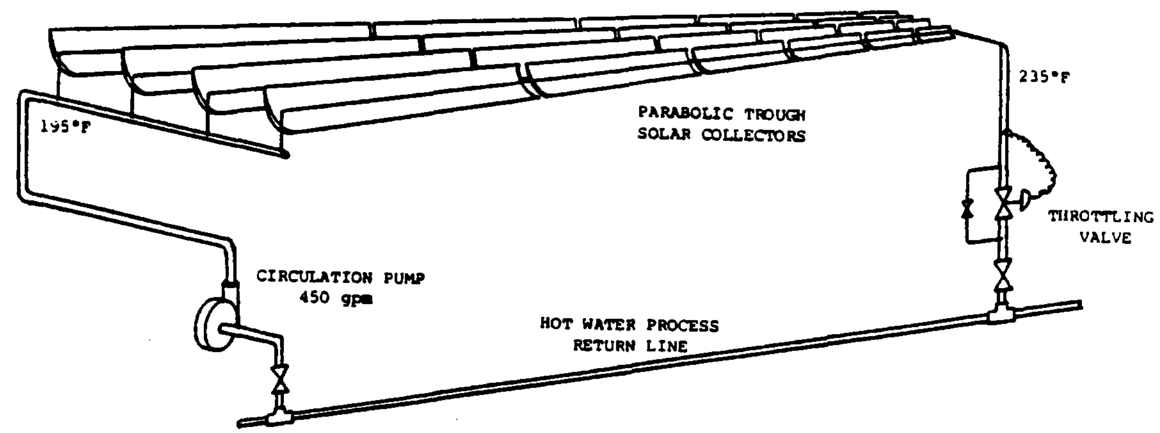


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation during the entire month of June, 1984. Some intermittent operation in the period 6/4-6/8 occurred during an SwRI site inspection visit. The DAS experienced some minor problems again during June, the cause of which were undetermined.

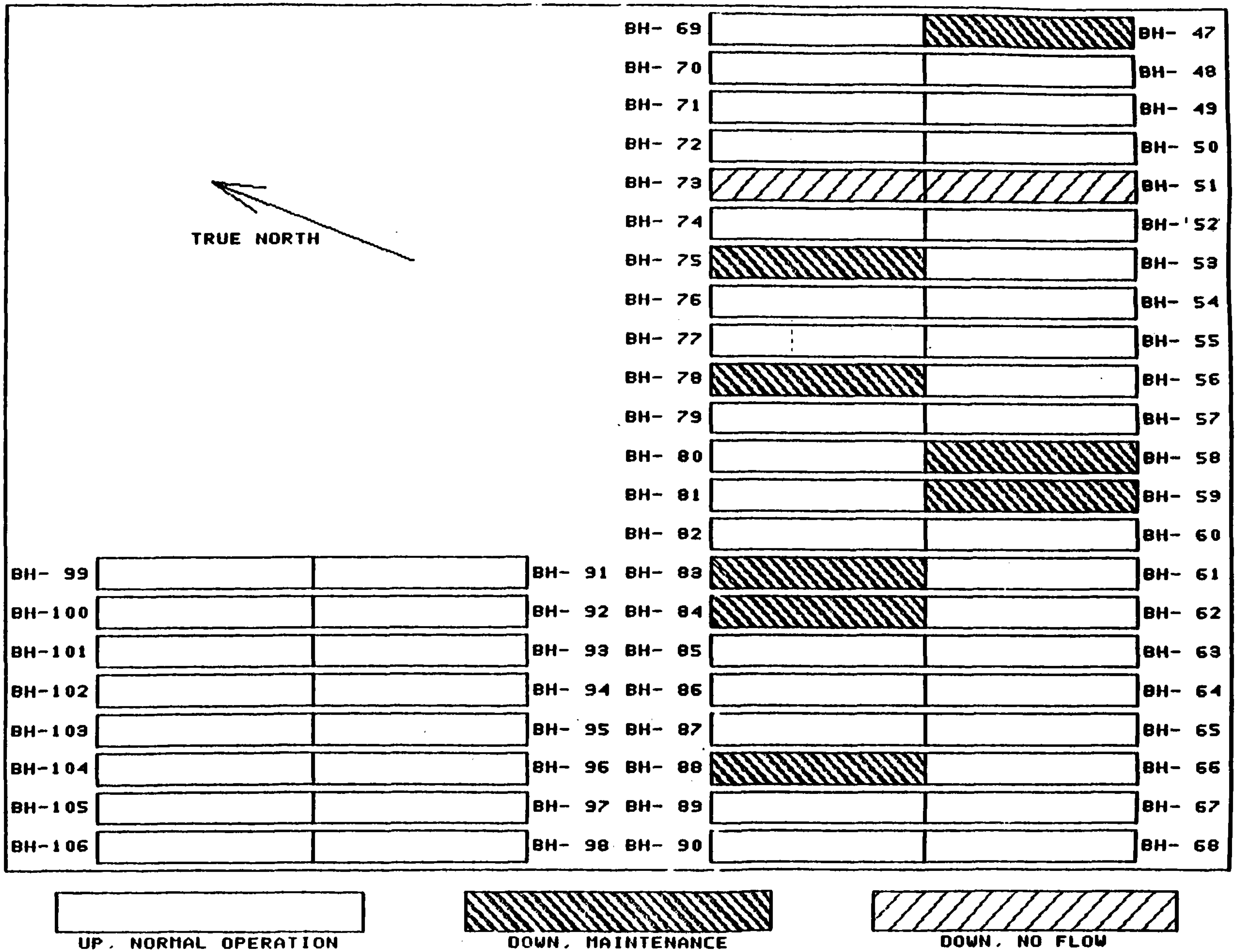
The operation of the Caterpillar Solar System is summarized in Table I, with the status of each of the drive rows depicted in Figure 2 and Figure 3. It is seen in these figures that approximately 20% of the drive rows continue to be inoperative at any given time. This figure is high; however, since the collector array still produces more energy than can be used, drive row maintenance is not a high priority.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
June 1984

Date	Active Area (ft^2)	Comments
6/1-6/5	42000	Eleven drive rows inoperative. No flow to delta-T string BH-73/51
6/6-6/30	42840	Nine drive rows inoperative
6/1-6/3	-	DAS down
6/4-6/6	-	Intermittent operation during SwRI site visit
6/12-6/13	-	DAS down - cause unknown
6/6	-	North field washed

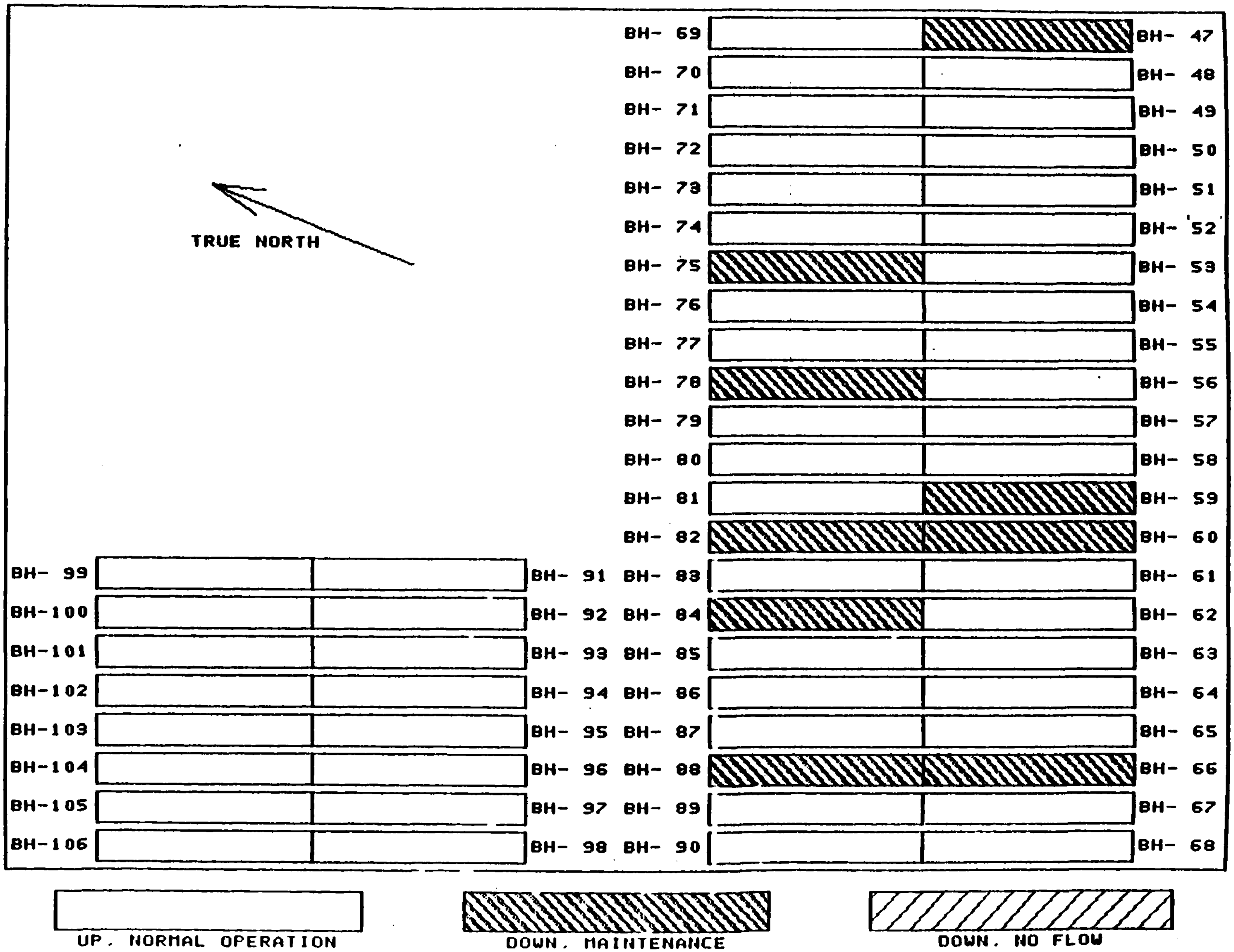
Along with routine troubleshooting of electrical and hydraulic problems, SwRI personnel encountered an interesting maintenance problem during the site visit. The "O"-ring seals between several receiver tube sections on row BH-73/51 failed and the row was shutdown on 4/24/83. Prior to the shutdown, however, the water which leaked onto the collector surface caused extensive delamination of the FEK film. This is attributed to the water treatment chemicals in the plant process water. While this type of failure is probably rare, the subsequent replacement of several sections of FEK will be a costly and time-consuming operation.

A summary of maintenance costs and out-of-service rows is found in Table II and Table III.



TIME PERIOD: JUNE 1-5

FIGURE 2



TIME PERIOD: JUNE 6-30

FIGURE 3

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
June 1984

O & M Activity	Hours	Cost Labor $	Cost Materials $	Cost Total $
o Routine inspection	16	497.36	-0-	497.36
o Wash north field	-	320.00 Subcontract	-0-	320.00
o Troubleshoot problem rows (by SwRI personnel	16	400.00*	-0-	400.00
TOTAL	32	1217.36	-0-	1217.36

Total estimated maintenance cost for 2/83 - 6/84 = $12697.63

*This cost figure determined with estimated average hourly rate for CTCo maintenance activities.

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
June 30, 1984

Row	Date of Last Action	Comment
BH-47	6/7/84	Broken glass, high temperature switch failure.
BH-59	3/9/84	Hydraulic oil leak.
BH-60	6/7/84	Hydraulic oil leak.
BH-66	6/7/84	Hydraulic cylinder leak.
BH-75	6/7/84	Hydraulic pump seal inspection.
BH-78	3/8/84	Hydraulic pump seal failure.
BH-82	6/7/84	High temperature switch failure.
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.

IV. System Performance

A. Monthly Summary

The daily performance for June, 1984 is summarized in Table IV and Figure 4. It can be seen that approximately 424 $*10^6$ Btu of parasitic energy were used for an overall efficiency of 34%.

B. Clear Day Performance

The hourly performance for June 21, 1984 is summarized in Table V and Figure 5. The average efficiency for this day was 39% with a peak of 47%. There were 25.4 $*10^6$ Btu collected by the system.

This performance is somewhat less than it would have been under steady state operation. The transient nature of the field operation caused by overdriving the plant process heating system is seen in Figure 6. It is seen in Figure 6d that as the array outlet temperature increases to undesirable limits, the collectors are unfocused as evidenced by the graphs of total and diffuse radiation in the collector plane, Figure 6(a) and (b). The collectors remain unfocused until the outlet temperature decreases to a safe level. This temperature oscillation is seen to be approximately ±20°F centered at 250°F for this single row.

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 6/84

MONTHLY PERFORMANCE SUMMARY TABLE - 6/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
6/ 1	153	DATA ACQUISITION SYSTEM DOWN						
6/ 2	154	DATA ACQUISITION SYSTEM DOWN						
6/ 3	155	DATA ACQUISITION SYSTEM DOWN						
6/ 4	156	200.	0.	42000.	0.	0.	0.	37.9
6/ 5	157	1583.	71.	42000.	1991.	3.	67.	382.2
6/ 6	158	251.	1.	42840.	-891.	-8.	*****	29.2
6/ 7	159	2628.	1403.	42840.	26883.	24.	45.	754.0
6/ 8	160	2608.	1605.	42840.	26954.	24.	39.	773.3
6/ 9	161	2650.	1409.	42840.	23780.	21.	39.	792.7
6/10	162	2695.	1455.	42840.	21671.	19.	35.	704.7
6/11	163	5.	10.	42840.	-342.	-175.	-84.	4.3
6/12	164	DATA ACQUISITION SYSTEM DOWN						
6/13	165	DATA ACQUISITION SYSTEM DOWN						
6/14	166	1232.	745.	42840.	12082.	23.	38.	373.3
6/15	167	2427.	1460.	42840.	20163.	19.	32.	603.7
6/16	168	2443.	1237.	42840.	19541.	19.	37.	643.0
6/17	169	2570.	1338.	42840.	20423.	19.	36.	694.2
6/18	170	2519.	1570.	42840.	23713.	22.	35.	725.4
6/19	171	660.	0.	42840.	0.	0.	0.	30.7
6/20	172	2464.	1600.	42840.	19785.	19.	29.	595.7
6/21	173	2595.	1522.	42840.	25401.	23.	39.	751.7
6/22	174	2581.	1844.	42840.	27926.	25.	35.	749.6
6/23	175	2617.	1028.	42840.	14737.	13.	33.	612.0
6/24	176	2488.	1170.	42840.	17905.	17.	36.	539.7
6/25	177	2363.	1386.	42840.	19158.	19.	32.	578.8
6/26	178	2580.	1485.	42840.	21969.	20.	35.	651.2
6/27	179	2516.	1699.	42840.	25944.	24.	36.	743.4
6/28	180	2178.	1202.	42840.	10439.	11.	20.	500.0
6/29	181	2596.	1706.	42840.	20525.	18.	28.	734.8
6/30	182	2560.	1380.	42840.	23859.	22.	40.	772.3
TOTALS		52008.	28322.		423618.	19.	35.	13777.8
AVG		2080.	1133.		16945.			551.1

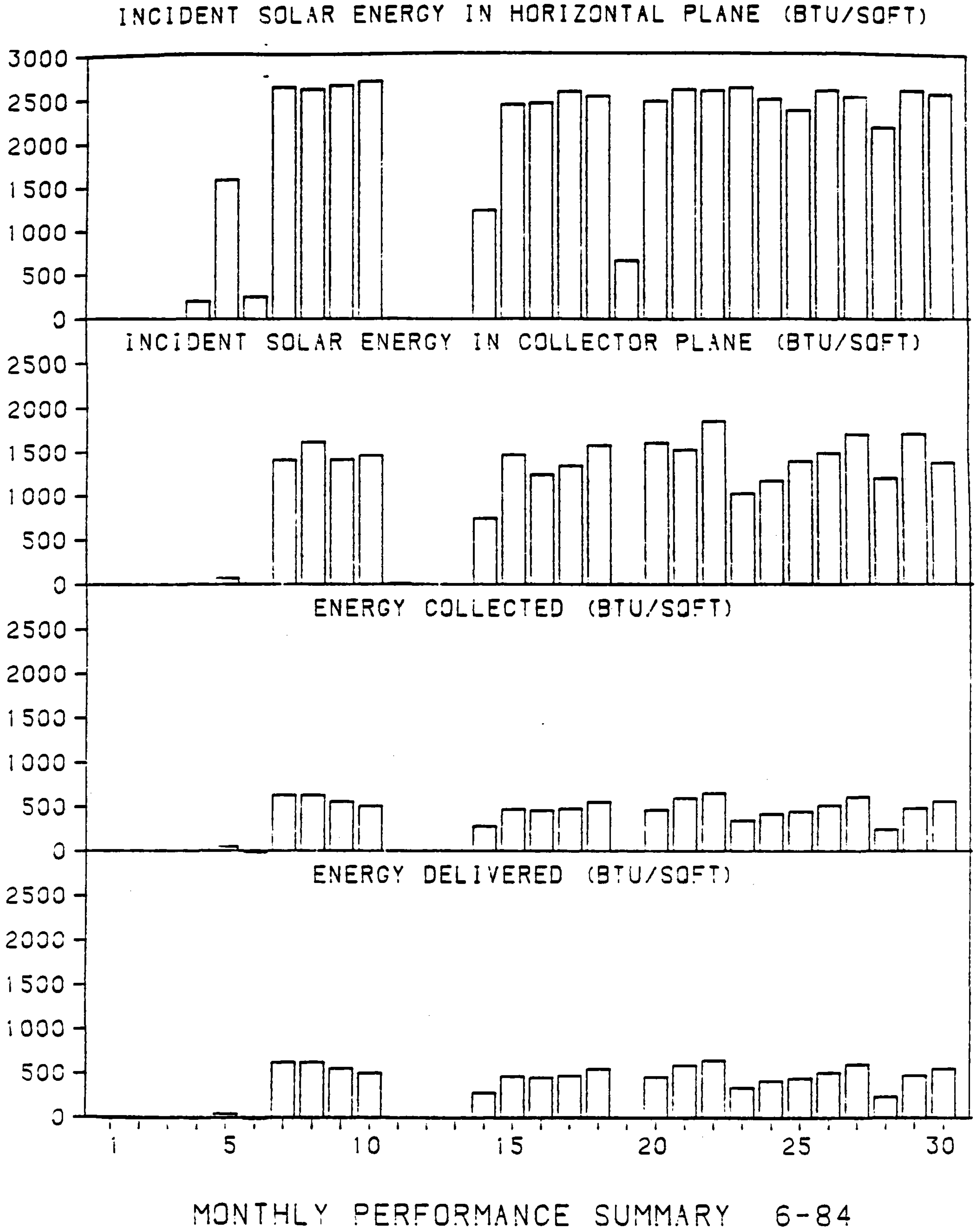

INCIDENT SOLAR ENERGY IN HORIZONTAL PLANE (BTU/SQFT)
INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/SQFT)
ENERGY COLLECTED (BTU/SQFT)
ENERGY DELIVERED (BTU/SQFT)
3000
2500
2000
1500
1000
500
0
1
5
10
15
20
25
30
MONTHLY PERFORMANCE SUMMARY 6-84

FIGURE 4

TABLE V.

HOURLY PERFORMANCE TABLE - 6/21/84(JULIAN DAY 173)
ARRAY ACTIVE AREA = 42840. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	59.	3.	67.	161.	115.	210.	215.	269.	209.	213.	881.	31.	13.	49.7
8	62.	3.	134.	188.	102.	225.	242.	278.	225.	239.	2674.	47.	33.	56.0
9	66.	3.	194.	165.	95.	227.	247.	280.	226.	241.	2917.	35.	41.	58.9
10	66.	5.	246.	160.	96.	228.	247.	280.	227.	242.	2764.	26.	40.	59.8
11	68.	6.	286.	141.	97.	227.	246.	282.	226.	240.	2595.	21.	43.	60.6
12	71.	7.	310.	114.	97.	230.	247.	279.	229.	241.	2311.	17.	47.	60.9
13	73.	9.	315.	126.	98.	229.	246.	279.	228.	241.	2419.	18.	45.	61.3
14	73.	11.	302.	130.	98.	229.	246.	279.	229.	241.	2318.	18.	42.	60.4
15	74.	10.	273.	108.	97.	232.	248.	276.	232.	243.	2062.	18.	44.	61.5
16	73.	11.	220.	130.	100.	231.	245.	278.	230.	241.	2088.	22.	37.	62.7
17	73.	11.	145.	132.	101.	231.	245.	279.	231.	241.	1899.	31.	34.	61.9
18	72.	8.	75.	-26.	110.	226.	230.	284.	226.	230.	682.	21.	***	54.6
19	67.	6.	28.	-8.	68.	216.	215.	178.	216.	215.	-209.	***	60.	38.7
20	61.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
21	58.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.6
22	56.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			2595.	1522.							25401.	23.	39.	751.7
AVG	68.	7.	204.	122.	99.	227.	241.	274.	226.	237.	2032.			14.9

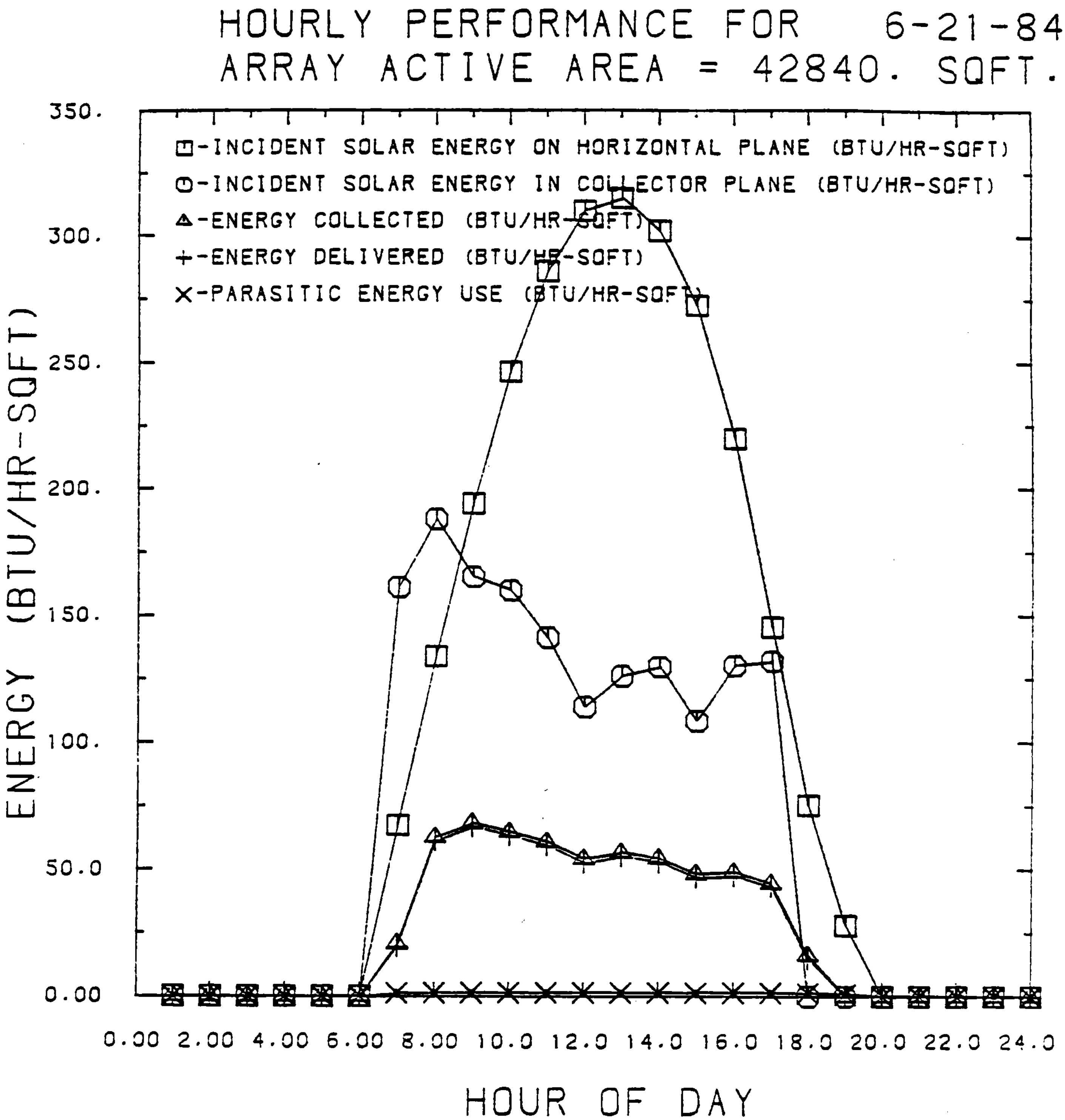

HOURLY PERFORMANCE FOR 6-21-84
ARRAY ACTIVE AREA = 42840. SQFT.
□-INCIDENT SOLAR ENERGY ON HORIZONTAL PLANE (BTU/HR-SQFT)
○-INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/HR-SQFT)
△-ENERGY COLLECTED (BTU/HR-SQFT)
+-ENERGY DELIVERED (BTU/HR-SQFT)
×-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

FIGURE 5

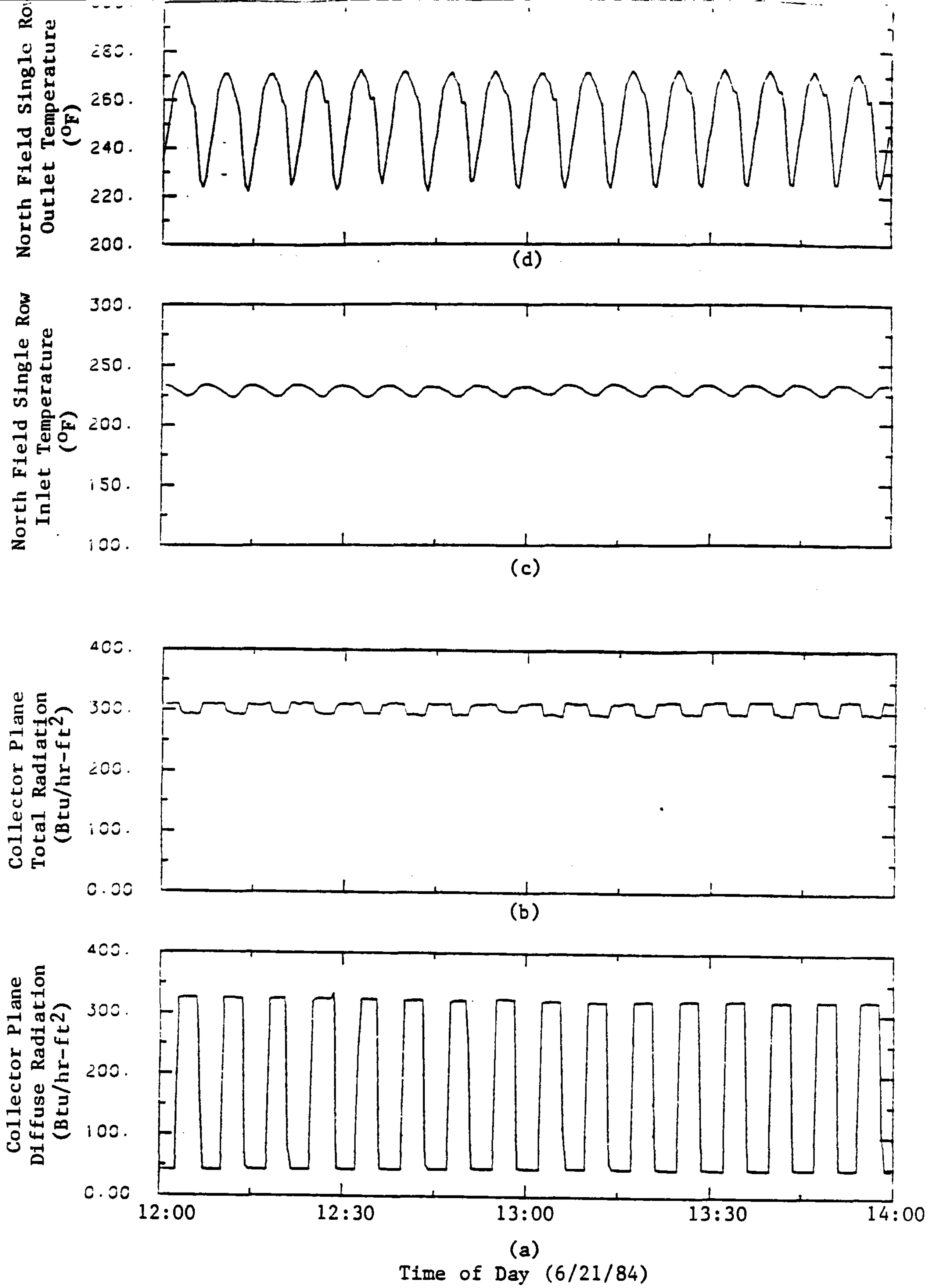


FIGURE 6. COLLECTOR SYSTEM TRANSIENT OPERATION

SOUTHWEST RESEARCH INSTITUTE

POST OFFICE DRAWER 28510 • 6220 CULEBRA ROAD • SAN ANTONIO, TEXAS, USA 78284 • (512) 684-5111 • TELEX 76-7357

Department of Mechanical Sciences
August 20, 1984
Monthly Progress Report No. 54
Reporting Period July 7, 1984
through August 3, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC04OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September12, 1979 to March 31, 1985

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Normal operation continued during July with no major problems.

A new Cost Plan is enclosed which reflects the extension of the completion date. System performance will be monitored until 12/31/84. A project final report will be prepared and submitted for review at that time. It is anticipated that the review process will be complete by 3/31/85.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Operation will continue as planned until 12/31/84. The accompanying Monthly Performance Report describes the system performance for July 1984.

Respectively submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 21

REPORT PERIOD: June 1, 1984 - June 30, 1984

REPORT NO.: CTCo-20

DOE CONTRACT NO.: DE-FC03-79CS30309

SwRI PROJECT NO.: 06-5821

CONTRACT TITLE: A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.

CONTRACTOR: Southwest Research Institute
P. O. Drawer 28510
6220 Culebra Road
San Antonio, Texas 78284
Contact: D. Deffenbaugh, 512/684-5111, ext 2384

PROJECT SITE: Caterpillar Tractor Co.
1930 Davis Street
San Leandro, California

II. Project Description

Application: -	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	14 x 10^9 Btu/yr, peak hourly 8.6 x 10^6 Btu/hr, peak daily - 78.6 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

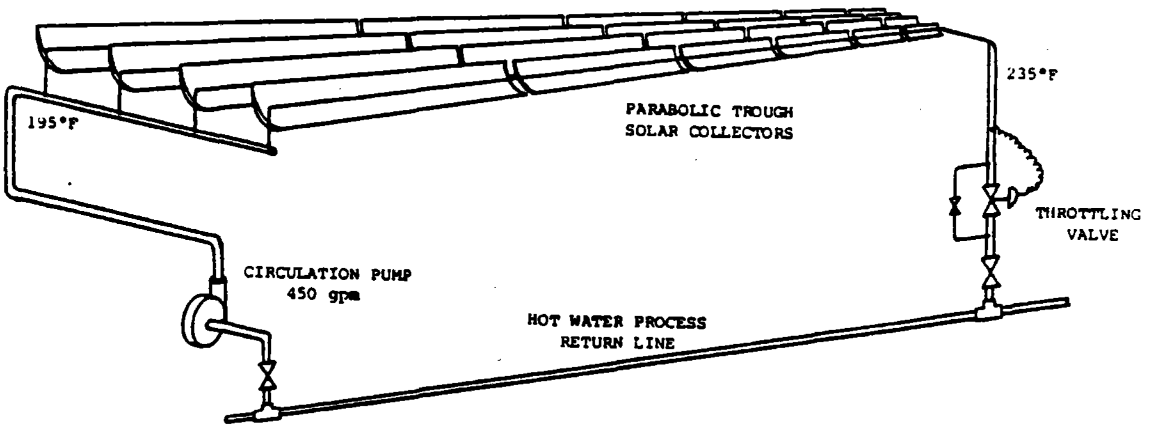


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available for operation during the entire month of July, 1984. The DAS was operational during this entire period, as well.

The operation of the Caterpillar Solar System is summarized in Table I, with the status of each of the drive rows being depicted in Figure 2. It can be seen that the status of the system remained unchanged during July.

There was no significant repair activity during July, so that the status of the inoperative rows is unchanged as seen in Table III.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
July 1984

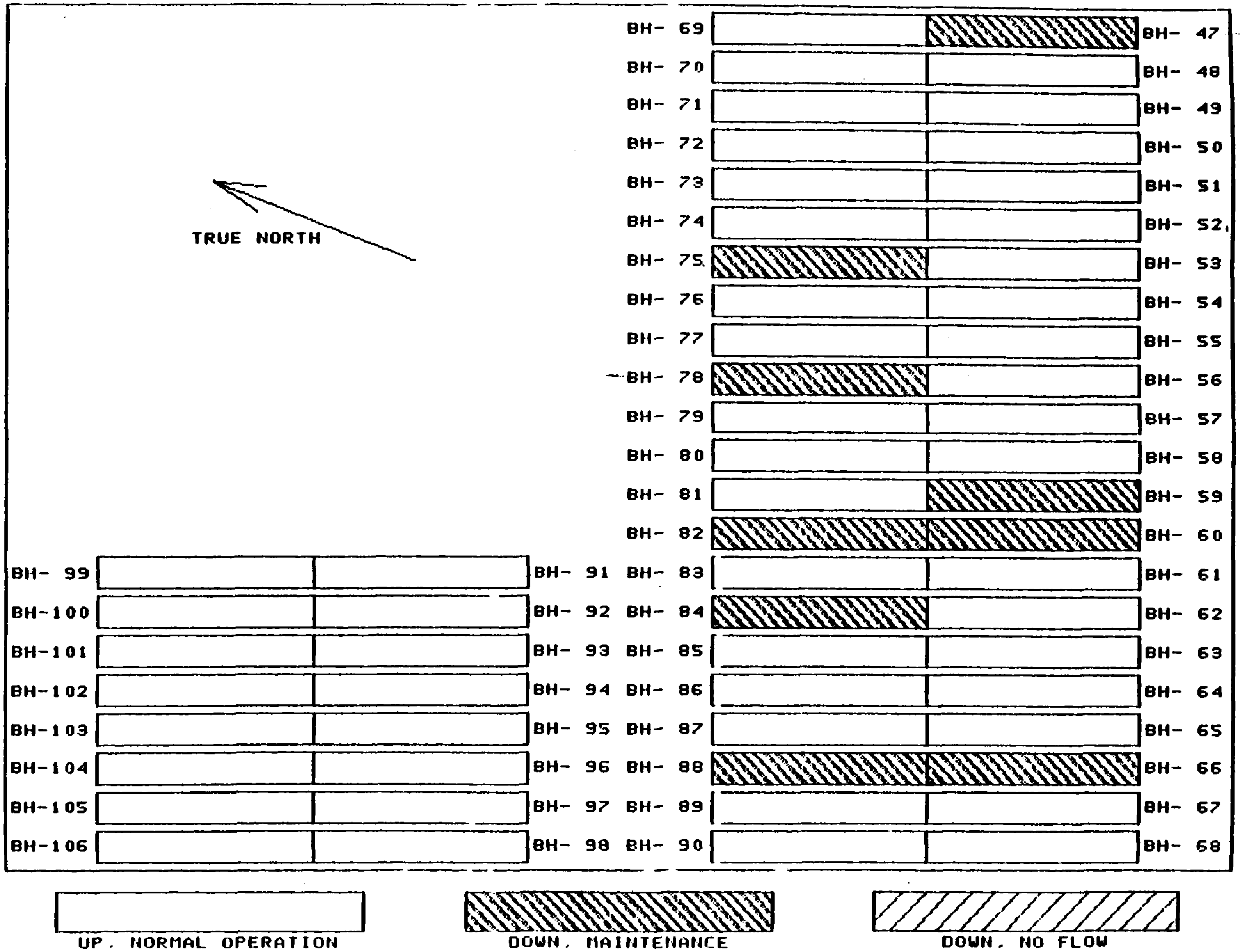
Date	Active Area (ft^2)	Comments
7/1-7/31	42840	Nine drive rows inoperative

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
July 1984

O & M Activity	Hours	Cost: Labor $	Cost: Materials $	Cost: Total $
o Routine inspection	16	412.03	-0-	412.03
o Wash north field	-	320.00 Subcontract	-0-	320.00
o Electrical and hydraulic maintenance	24	680.04	-0-	680.04

Total estimated maintenance cost for 2/83 - 7/84 = $14047.70

*This cost figure determined with estimated average hourly rate for CTCo maintenance activities.



TIME PERIOD: JULY 1-31

FIGURE 2

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
July 31, 1984

Row	Date of Last Action	Comment
BH-47	6/7/84	Broken glass, high temperature switch failure.
BH-59	3/9/84	Hydraulic oil leak.
BH-60	6/7/84	Hydraulic oil leak.
BH-66	6/7/84	Hydraulic cylinder leak.
BH-75	6/7/84	Hydraulic pump seal inspection.
BH-78	3/8/84	Hydraulic pump seal failure.
BH-82	6/7/84	High temperature switch failure.
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.

IV. System Performance

A. Monthly Summary

The system performance for July is summarized in Table IV and Figure 3. It is seen that the collectors delivered approximately 442.1 $*10^6$Btu at an overall efficiency of 32%. Electrical power consumption was 18.1 $*10^6$ btu, or 4.1% of the energy collected.

It is seen that on 7/18 a substantial amount of energy was collected but the collector plane radiation was not measured properly. This is probably because the row instrumented with pyranometers was not focused properly on that day. Also, on 7/23 the system pumps were activated but the system had a net loss of energy because the field was probably not activated that day. The causes of these two anomalies are being investigated.

Despite these two questionable days, the system operated quite well in July.

B. Daily Summary

The system performance is summarized for the typical clear day, July 9, in Table V and Figure 4. The system had a peak hourly operating efficiency of 42% and an overall efficiency of 33% for that day. There were 26.6 $*10^6$ Btu collected on this day.

TABLE IV

MONTHLY PERFORMANCE SUMMARY TABLE - 7/84

		INCIDENT SOLAR ENERGY						
DATE	JULIAN DAY	ON A HORIZ SURFACE (1) BTU/SQFT	ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
7/ 1	183	2520.	1114.	42840.	20665.	19.	43.	715.5
7/ 2	184	2399.	1427.	42840.	23558.	23.	39.	759.9
7/ 3	185	2410.	1573.	42840.	24841.	24.	37.	738.5
7/ 4	186	2455.	1228.	42840.	18823.	18.	36.	728.6
7/ 5	187	1912.	964.	42840.	13469.	16.	33.	377.7
7/ 6	188	2334.	1445.	42840.	18677.	19.	30.	631.5
7/ 7	189	2551.	1559.	42840.	22150.	20.	33.	714.4
7/ 8	190	2558.	1371.	42840.	19898.	18.	34.	622.5
7/ 9	191	2580.	1891.	42840.	26600.	24.	33.	755.3
7/10	192	2528.	1845.	42840.	26531.	24.	34.	761.8
7/11	193	2513.	174.	42840.	481.	0.	6.	98.3
7/12	194	2416.	1838.	42840.	25008.	24.	32.	754.2
7/13	195	2368.	1692.	42840.	24724.	24.	34.	749.9
7/14	196	1648.	660.	42840.	6087.	9.	22.	459.5
7/15	197	2354.	1183.	42840.	17159.	17.	34.	686.4
7/16	198	2256.	1378.	42840.	15455.	16.	26.	669.7
7/17	199	2282.	796.	42840.	12315.	13.	36.	659.1
7/18	200	2337.	-69.	42840.	13756.	14.	—	646.7
7/19	201	2302.	1076.	42840.	16402.	17.	36.	682.6
7/20	202	2077.	664.	42840.	10527.	12.	37.	527.9
7/21	203	1931.	-52.	42840.	-181.	0.	8.	346.3
7/22	204	1484.	0.	42840.	0.	0.	0.	37.0
7/23	205	1517.	78.	42840.	-2417.	-4.	—	301.8
7/24	206	2122.	1038.	42840.	3253.	4.	7.	467.6
7/25	207	2449.	1370.	42840.	17688.	17.	30.	779.0
7/26	208	2430.	1229.	42840.	17156.	16.	33.	779.6
7/27	209	2414.	1032.	42840.	13597.	13.	31.	655.0
7/28	210	1912.	521.	42840.	3326.	4.	15.	393.8
7/29	211	2274.	789.	42840.	8672.	9.	26.	513.8
7/30	212	2103.	1262.	42840.	13243.	15.	24.	579.2
7/31	213	2061.	1496.	42840.	10629.	12.	17.	504.3
TOTALS		69497.	32571.		442092.	15.	32.	18097.3
AVG		2242.	1051.		14261.			583.8

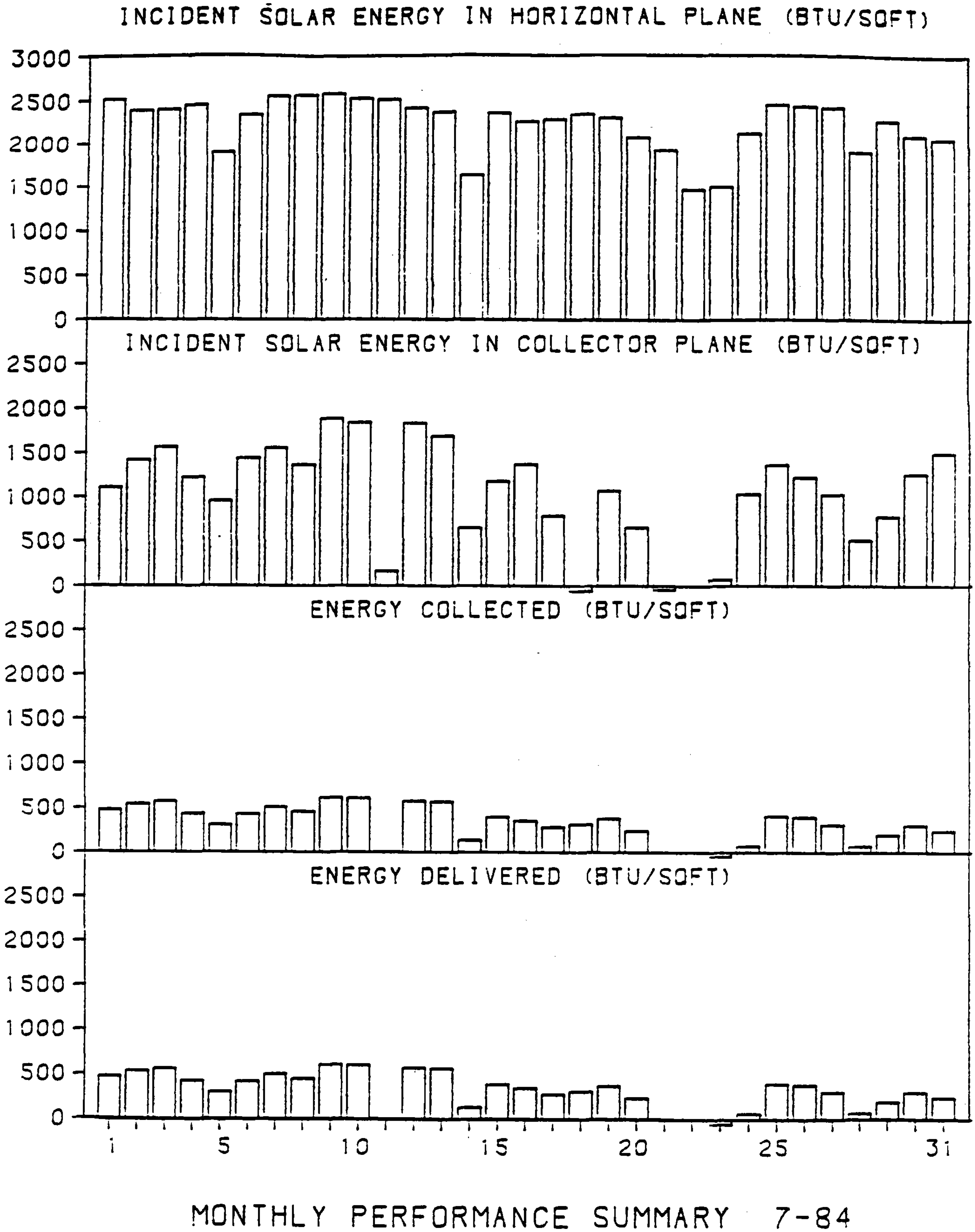

INCIDENT SOLAR ENERGY IN HORIZONTAL PLANE (BTU/SQFT)
3000
2500
2000
1500
1000
500
0
INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/SQFT)
2500
2000
1500
1000
500
0
ENERGY COLLECTED (BTU/SQFT)
2500
2000
1500
1000
500
0
ENERGY DELIVERED (BTU/SQFT)
2500
2000
1500
1000
500
0
1
5
10
15
20
25
31
MONTHLY PERFORMANCE SUMMARY 7-84

FIGURE 3

TABLE V

HOURLY PERFORMANCE TABLE - 7/ 9/84(JULIAN DAY 191)
ARRAY ACTIVE AREA = 42840. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	58.	4.	62.	143.	115.	208.	207.	259.	206.	202.	-184.	-7.	-3.	49.8
8	63.	4.	124.	198.	113.	217.	231.	293.	217.	229.	2423.	46.	29.	54.4
9	65.	4.	189.	238.	107.	224.	245.	281.	223.	241.	3553.	44.	35.	53.7
10	68.	5.	244.	185.	106.	229.	247.	282.	228.	243.	2903.	28.	37.	58.7
11	68.	5.	285.	155.	107.	228.	244.	284.	228.	241.	2495.	20.	38.	61.2
12	71.	6.	310.	150.	108.	228.	243.	285.	227.	240.	2532.	19.	39.	62.7
13	71.	8.	322.	150.	108.	228.	243.	284.	227.	241.	2677.	19.	42.	62.4
14	70.	9.	314.	187.	107.	225.	243.	284.	225.	241.	3050.	23.	38.	60.9
15	70.	10.	280.	144.	107.	229.	243.	283.	228.	241.	2535.	21.	41.	62.6
16	71.	9.	224.	126.	108.	231.	243.	283.	230.	241.	1989.	21.	37.	63.0
17	69.	11.	137.	166.	107.	231.	244.	285.	230.	241.	2143.	37.	30.	61.0
18	66.	9.	65.	58.	111.	228.	233.	292.	228.	231.	746.	27.	30.	55.4
19	63.	7.	25.	-9.	79.	218.	216.	206.	218.	216.	-263.	***	67.	43.7
20	58.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.0
21	56.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.9
22	55.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			2580.	1891.							26600.	24.	33.	755.3
AVG	66.	7.	202.	150.	107.	225.	238.	279.	224.	235.	2114.			14.8

HOURLY PERFORMANCE FOR 7-9-84

ARRAY ACTIVE AREA = 42840 SQ. FT.

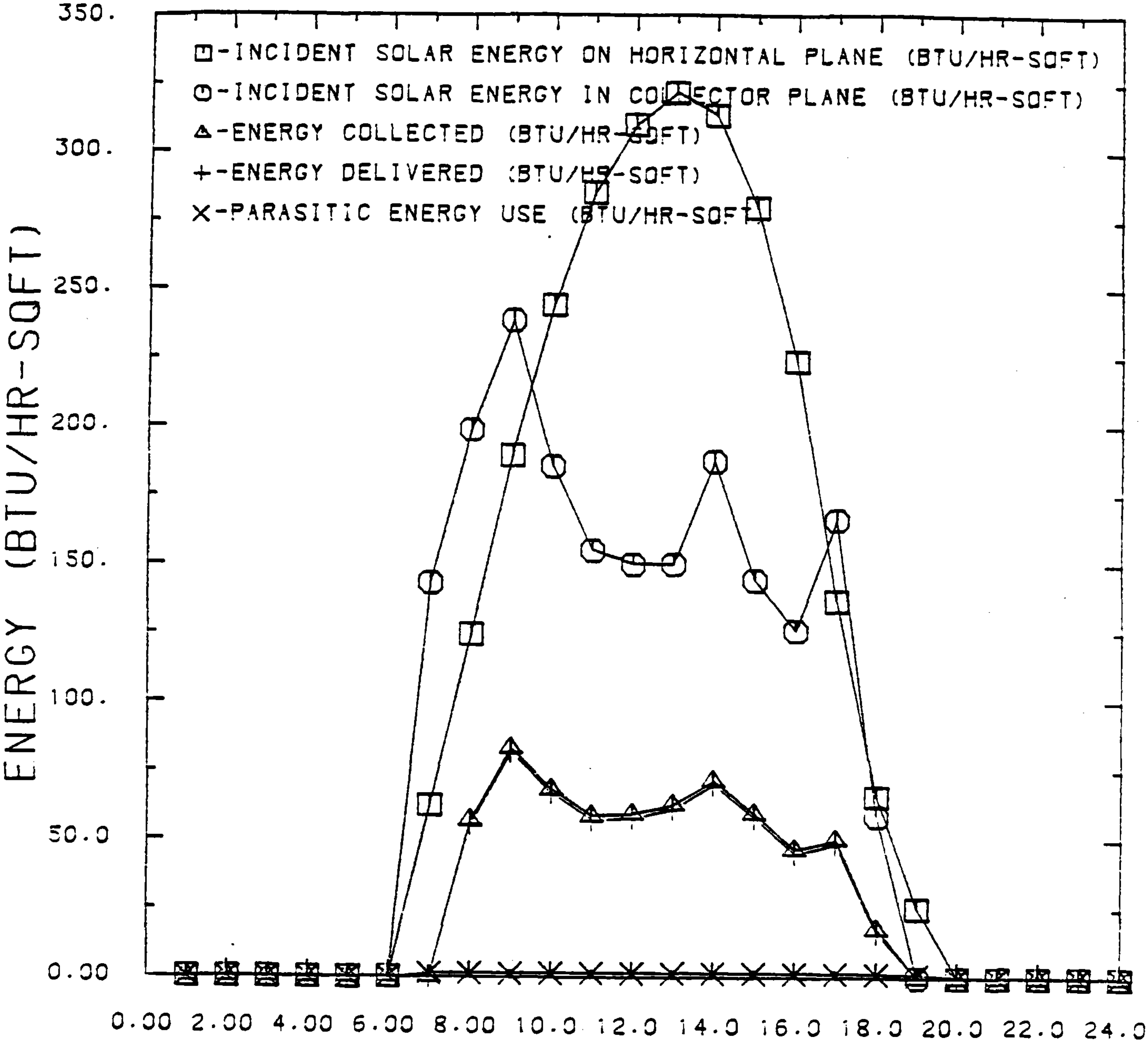


FIGURE 4. HOUR OF DAY

SOUTHWEST RESEARCH INSTITUTE
POST OFFICE DRAWER 28510 • 6220 CULEBRA ROAD • SAN ANTONIO, TEXAS, USA 78284 • (512) 684-5111 • TELEX 76-7357

Department of Mechanical Sciences
September 20, 1984
Monthly Progress Report No. 55
Reporting Period August 4, 1984
through August 31, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC04OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to March 31, 1985

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Normal operation continued until August 16 when a system failure occurred. Several receiver tubes were damaged, some glass tubes were broken and the pump check valves failed. The system was returned to automatic operation on August 31. This failure is described in detail in the accompanying Monthly Performance Report.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Twenty drive rows are down for maintenance. Parts have been ordered to repair the damage which occurred on August 16, 1984.

Respectively submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 22

REPORT PERIOD:	August 1, 1984 - August 31, 1984
REPORT NO.:	CTCo-22
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9×10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6×10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking, parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 Δ T strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	11.6×10^9 Btu/yr, peak hourly 8.2×10^6 Btu/hr, peak daily - 74.1×10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235 , 450 gpm. The water is heated from 195 F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235 F.

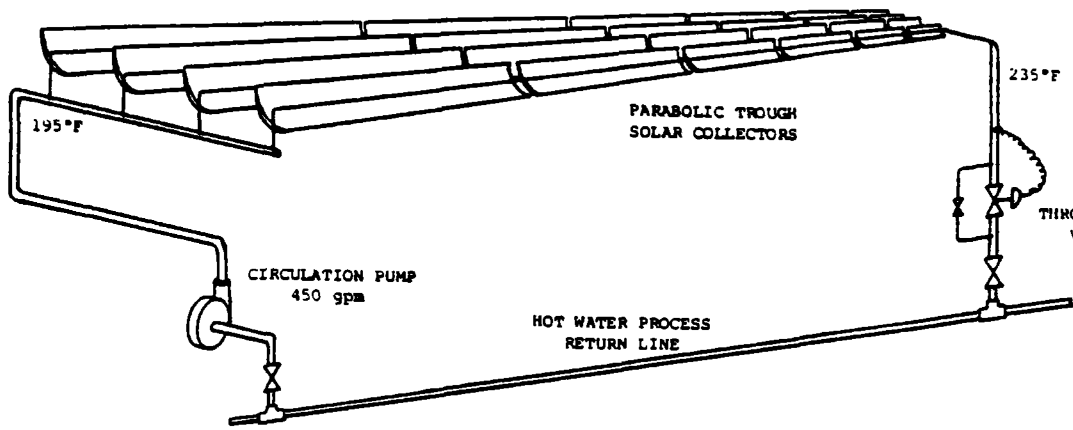


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The CTCo solar system experienced a system failure on August 16, 1984. The system was available for operation from the 1st through the 15th, but operation was intermittent from the 16th to the 30th. The field was again available for automatic operation on August 31, 1984. The data acquisition system was functional during the entire month.

The operation of the CTCo solar system for the month of August 1984 is summarized in Table I. On 8/2 row BH-47 and on 8/9 row BH-78 were brought back into service. On August 16 the system experienced a failure. A review of the data collected on that day reveals the following sequence of events.

Time (PST)	Events
1233	Power to the pump is lost; flow rate drops significantly collectors remain focused.
1235	Temperature at field outlet begins increasing from ~250F
1237	Temperature at field inlet begins increasing from ~230 F
1240	Temperature at field outlet reaches steady value of ~290 F
1241	Temperature at field inlet reaches steady value of 285 F
1250	Pump is reactivated; collectors are stowed
1252	Power to the pump is turned off, but is activated every ten minutes for two minute periods for the remainder of the day; collectors are never reactivated

The ten minute cycle of activation for the pump is a noraml procedure for the system.

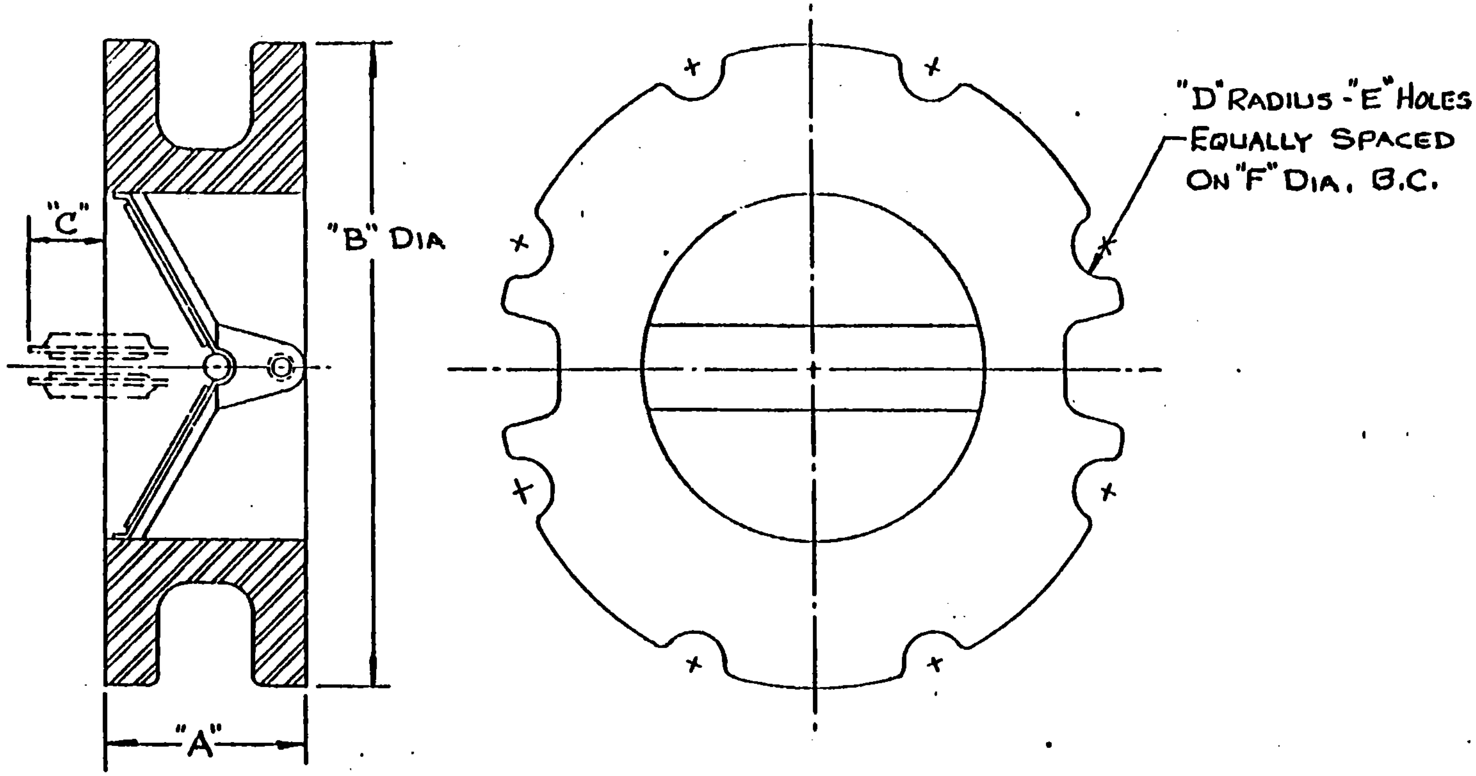
TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
August 1984

Date	Active Area (ft^2)	Comments
8/1	42840	Nine drive rows inoperative
8/2-8/9	43680	Eight drive rows inoperative
8/9-8/15	44520	Seven drive rows inoperative
8/16-8/30	~33600	Various drive rows inoperative. Intermittent operation due to system failure.
8/31	33600	Twenty drive rows inoperative. System available for automatic operation.

As a result of these events the solar system experienced some damage. First, the ends of several glass tubes were chipped and broken. Second, some receiver tubes were also forced to bend and impact the glass, thereby breaking glass near the middle of its span. Also, several receiver tube flange clamps were stretched so that the seals between receiver tubes failed. Some of the silicone "O"-rings between receiver tube sections hardened and the receiver tubes became discolored which are evidences of exceeding material temperature limits. Finally, several days afterward, it was discovered that the pump discharge check valves had failed.

The specific cause for this sequence of events is not known; however, it appears that power was lost to the central controller and the collector drive rows. This caused the pump to stop but the collectors remained focused until the sun traveled far enough away from the trough focal line. When power was again available, the pump started and the system temperature switches forced the system to shutdown. Other failure scenarios are plausible but require simultaneous failures of various safety switches in the system; so they will not be discussed here.

Figure 2 shows a schematic of the check valve. It is seen that the Hypalon seal also acts as a hinge for the steel backing members. CTCo personnel have inspected the valve and found that the Hypalon member failed. The quoted temperature limit for this valve is 300,F, so the failure is probably a combination of mechanical and thermal action. The reduced flow caused some localized overheating of receiver tubes, resulting in black chrome discoloration and possibly more thermal expansion in the form of tube flexure than the system was designed to accommodate. This thermal expansion is responsible for some of the glass breakage and the receiver tube clamp failures. The spring section opposite the bolt on the clamp, shown in Figure 3, was stretched so that an adequate seal could not be maintained.



VALVE SIZE	A	B	C	D	E	F	VALVE SIZE	A	B	C	D	E	F
2"	1 3/8"	4 3/4"	1/2"	3/8"	4"	4 3/4"	18"	9 3/8"	22 3/4"	4 1/4"	5/8"	16"	22 3/4"
2 1/2	1 5/8	5 1/2	9/16	3/8	4	5 1/2	20	10 3/8	25	4 3/4	5/8	20	25
3	1 7/8	6	11/16	3/8	4	6	24	12 3/8	29 1/2	5 3/4	11/16	20	29 1/2
4	2 3/8	7 1/2	7/8	3/8	8	7 1/2	30	15 3/8	36	7 3/4	11/16	28	36
5	2 7/8	8 1/2	1 1/8	7/16	8	8 1/2	36	18 3/8	42 3/4	8 1/2	13/16	32	42 3/4
6	3 3/8	9 1/2	1 1/2	7/16	8	9 1/2	42	21 3/8	49 1/2		13/16	36	49 1/2
8	4 3/8	11 3/4	2 1/4	7/16	8	11 3/4	48	24 3/8	56		13/16	44	56
10	5 3/8	14 1/4	2 1/2	1/2	12	14 1/4	54	27 3/8	62 3/4		15/16	44	62 3/4
12	6 3/8	17	3	1/2	12	17	60	30 3/8	69 1/4		15/16	52	69 1/4
14	7 3/8	18 3/4	3 1/4	9/16	12	18 3/4	66	33 3/8	76		15/16	52	76
16	8 3/8	21 1/4	3 3/4	9/16	16	21 1/4	72	36 3/8	82 1/2		15/16	[illegible]	82 1/2

Modified for High Temperature Water Service
- Cast Iron Body
- Cadmium Plated Steel Internals
- Hypalon Sealing Member

TECHNO CORP.
ERIE, PA.

INSTALLATION DWG. ~ SHORT FORM TECHNOCHECK VALVE

DWN BY	SCALE	DWG NO.
PAD	~	5118
DATE FEB 3, 1969		

FIGURE 2.

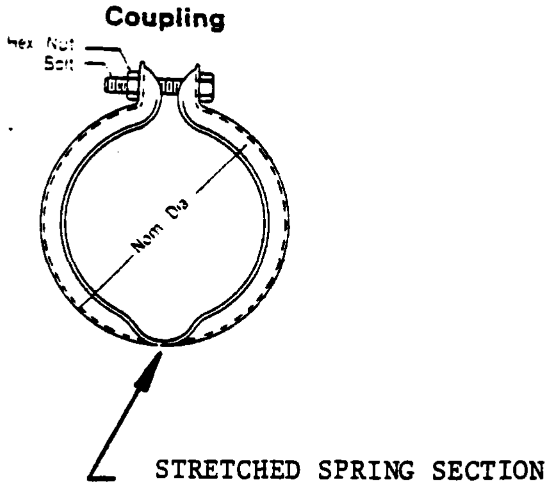


FIGURE 3. RECEIVER TUBE FLANGE CLAMP
(From Aeroquip Marman Catalog 864)

The chipped glass on the ends of the receiver tubes could have been caused by one of two phenomena. Because of the low flow conditions, there may have been some local boiling in the receiver tubes. This boiling causes violent movement of piping which could have caused the glass tubes to impact the end of the receiver tube stand assembly. Another explanation could be that the failed check valve initiated a water hammer which shook the receiver tubes. This, however, would have been difficult for a centrifugal pump in an open system unless the failed check valve members somehow suddenly restricted the flow downstream from the pump.

CTCo personnel have installed another check valve of all bronze construction, so the system is functioning. They are awaiting delivery of a second check valve to again allow a parallel backup pump. They have had to remove and adjust the stretched receiver tube clamps to provide an adequate seal, and will monitor them to determine if replacements are warranted. A number of glass sections have been ordered for replacement.

Presently, there are a total of 20 drive rows down for maintenance. Seven of these were previously down, so that 13 drive rows were affected by the check valve failure. The maintenance activities for the month of August are summarized in Table II while the maintenance status of the out-of-service rows is listed in Table III. Receiver glass sections and related hardware have been ordered so that repairs can be made as quickly as possible. The status of each of the drive rows is shown in Figures 4-7 for each day in August 1984.

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
August 1984

		Cost		
O & M Activity	Hours	Labor $	Materials $	Total $
o Routine inspection	16	382.50	-0-	382.50
o Repair broken glass on row BH-47	4	95.62	-0-	96.62
o Repair hydraulic leaks on rows BH-54, -78, -105	16	382.50	-0-	382.50
o Repair failed check valve and related activities	142	3394.55	-0-	3394.55
TOTAL	178	4255.14	-0-	4255.14

Total estimated maintenance costs for 2/83 -8/84 = 18302.84

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
August 31, 1984

Row	Date of Last Action	Comment
BH-51	8/16/84	Receiver tube seal failure*
BH-55	8/16/84	Broken receiver tube glass*
BH-60	6/7/84	Hydraulic oil leak
BH-66	6/7/84	Hydraulic oil leak
BH-69	8/16/84	Broken receiver tube glass*
BH-71	8/16/84	Receiver tube seal failure*
BH-73	8/16/84	Receiver tube seal failure*
BH-75	6/7/84	Hydraulic oil leak
BH-77	8/16/84	Broken receiver tube glass*
BH-78	8/16/84	Broken receiver tube glass*
BH-82	6/7/84	High temperature switch failure.
BH-83	8/16/84	Broken receiver tube glass*
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-88	3/9/84	High temperature switch failure.
BH-92	8/16/84	Receiver tube seal failure*
BH-101	8/16/84	Broken receiver tube glass*
BH-103	8/16/84	Broken receiver tube glass*
BH-104	8/16/84	Broken receiver tube glass*
BH-105	8/15/84	Broken receiver tube glass*

*Result of system failure described above.

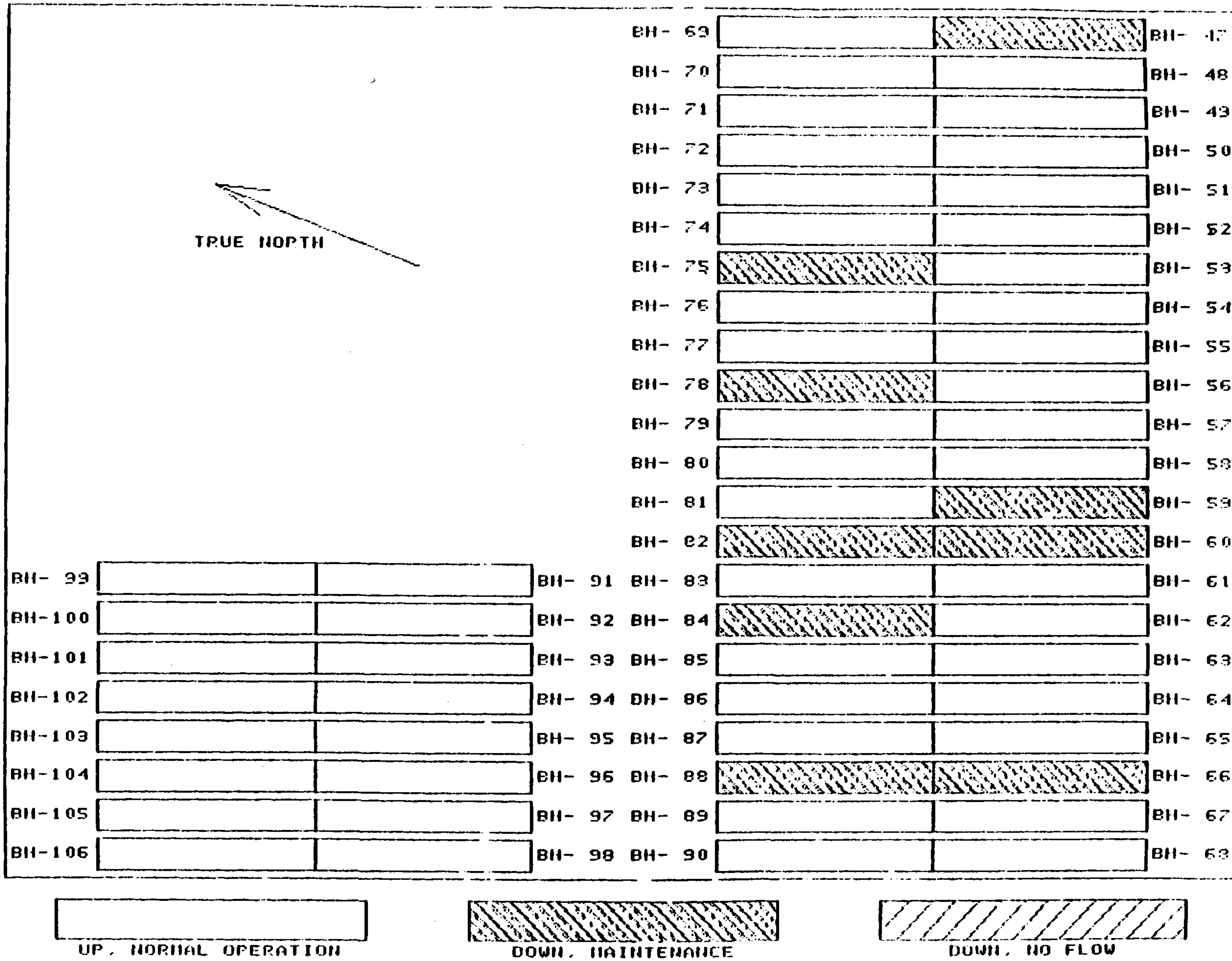
IV. System Performance

A. Monthly Summary

The performance for each day of August is summarized in Table IV and Figure 8. It is seen that before the failure on August 16 the system operated at approximately the same performance level as in July 1984. The field was able to supply $240.2*10^6$ Btu during the month for an overall efficiency of 22%. Because the operation is intermittent, however, during August 16-30, the values shown for collector plane radiation for those days is suspect.

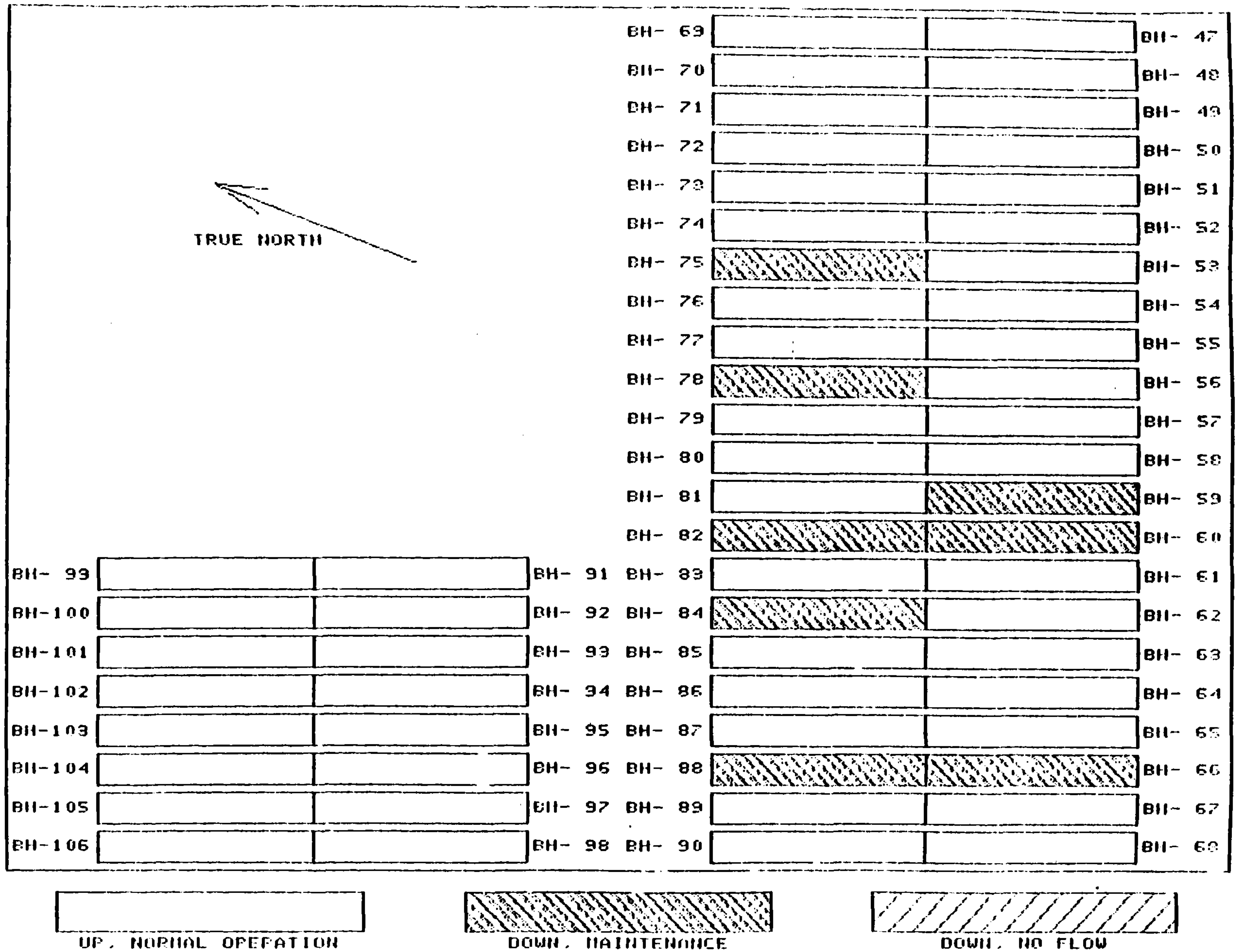
B. Daily Summary

The performance for each hour of operation for August 8, 1984 is summarized in Table V and Figure 9. The net energy delivery of the solar system was $23.8*10^6$ Btu for that day at an overall efficiency of 32%. The maximum hourly efficiency was 40% at 1500 hours.



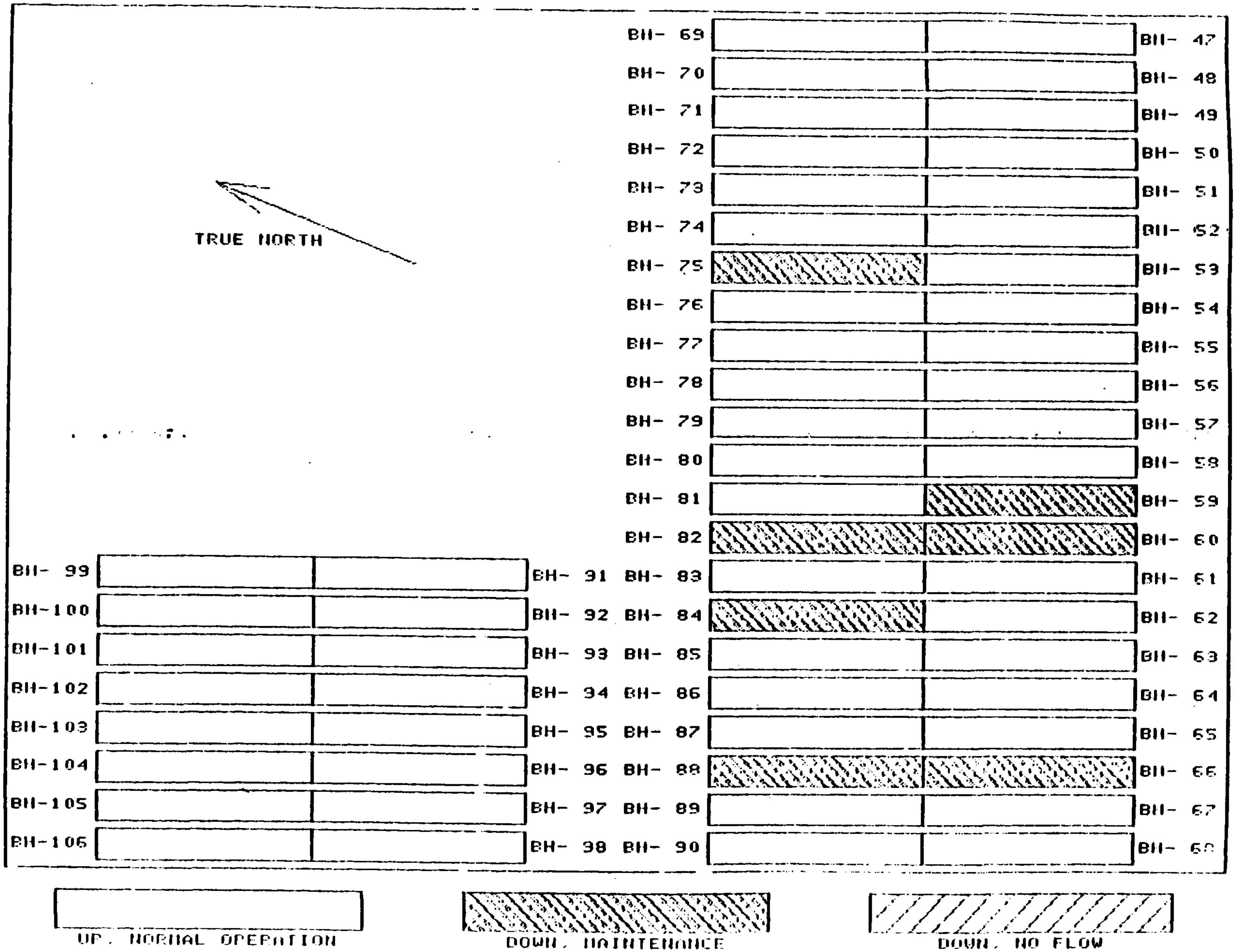
TIME PERIOD: AUGUST 1

FIGURE 4.



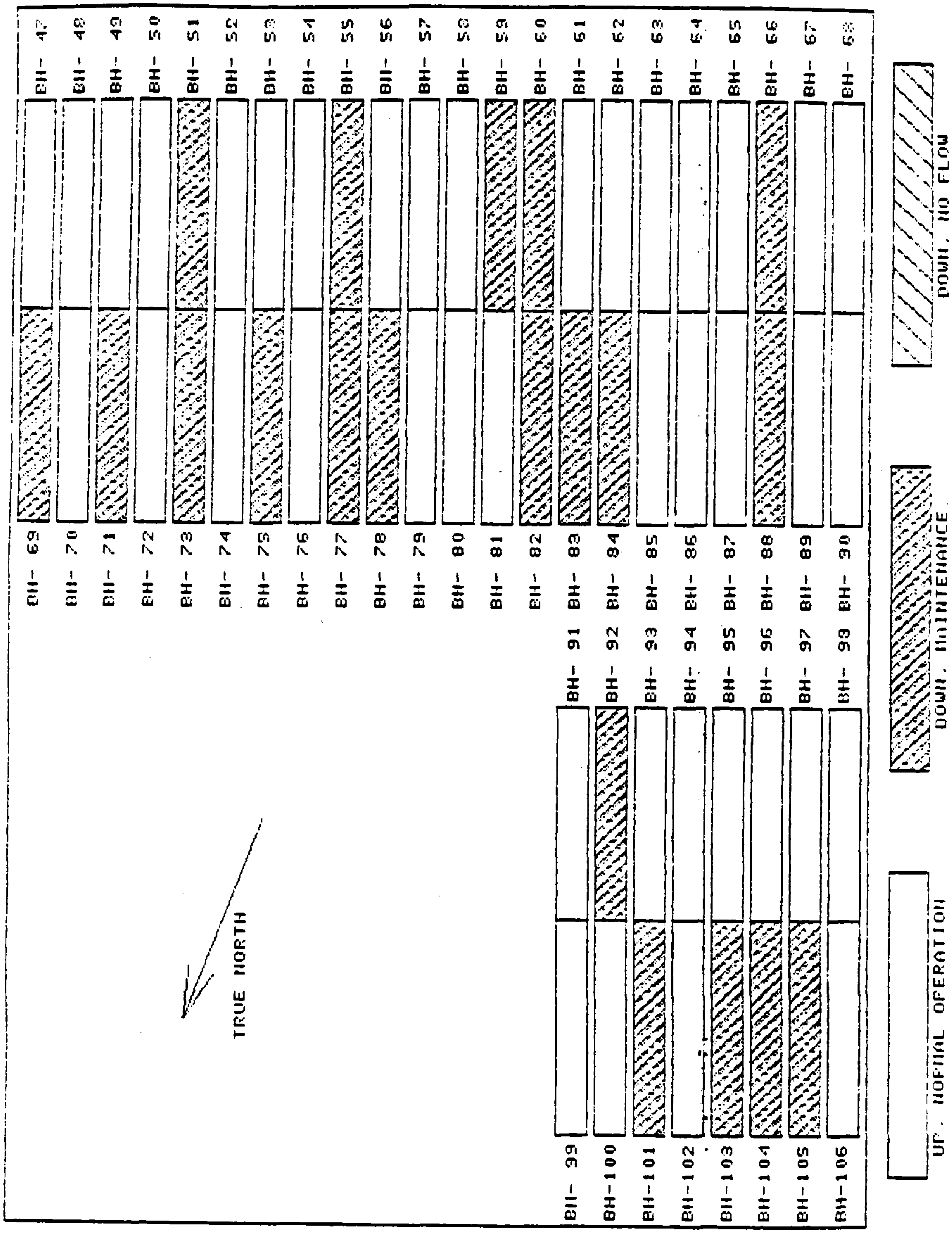
TIME PERIOD: AUGUST 2-8

FIGURE 5.



TIME PERIOD: AUGUST 9-15

FIGURE 6



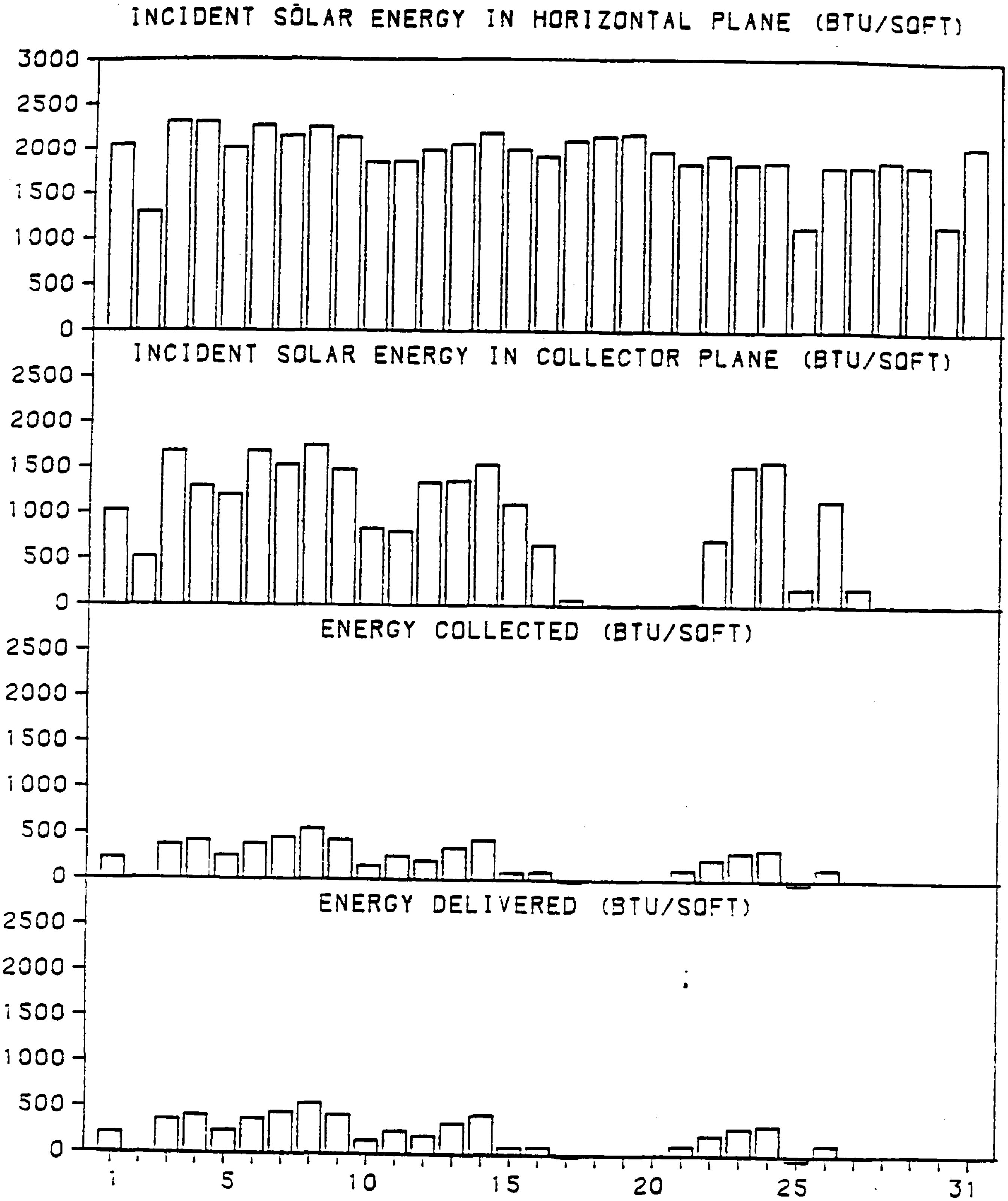
TIME PERIOD: AUGUST 16-31

FIGURE 7

TABLE IV.

MONTHLY PERFORMANCE SUMMARY TABLE - 8/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
8/ 1	214	2059.	1032.	42840.	9734.	11.	22.	515.7
8/ 2	215	1306.	521.	43680.	57.	0.	0.	225.1
8/ 3	216	2318.	1685.	43680.	16506.	16.	22.	702.1
8/ 4	217	2310.	1299.	43680.	18401.	18.	32.	734.1
8/ 5	218	2028.	1208.	43680.	11237.	13.	21.	357.5
8/ 6	219	2269.	1688.	43680.	17013.	17.	23.	719.6
8/ 7	220	2155.	1537.	43680.	20116.	21.	30.	767.9
8/ 8	221	2256.	1747.	43680.	24532.	25.	32.	769.6
8/ 9	222	2147.	1486.	44520.	19431.	20.	29.	585.7
8/10	223	1869.	843.	44520.	6903.	8.	18.	557.8
8/11	224	1880.	809.	44520.	11518.	14.	32.	535.6
8/12	225	2004.	1349.	44520.	9315.	10.	16.	493.9
8/13	226	2069.	1364.	44520.	15482.	17.	25.	627.5
8/14	227	2190.	1542.	44520.	19396.	20.	28.	740.2
8/15	228	2005.	1109.	44520.	3779.	4.	8.	537.3
8/16	229	1931.	666.	33600.	3027.	5.	14.	297.2
8/17	230	2104.	70.	33600.	-939.	***	***	124.4
8/18	231	2160.	0.	33600.	0.	0.	0.	49.8
8/19	232	2177.	0.	33600.	0.	0.	0.	50.8
8/20	233	1985.	0.	33600.	0.	0.	0.	11.4
8/21	234	1854.	19.	33600.	3729.	6.	***	296.7
8/22	235	1950.	726.	33600.	7642.	12.	31.	506.0
8/23	236	1854.	1534.	33600.	10203.	16.	20.	443.4
8/24	237	1874.	1582.	33600.	11291.	18.	21.	433.9
8/25	238	1151.	194.	33600.	-1714.	***	***	225.7
8/26	239	1818.	1151.	33600.	4130.	7.	11.	392.8
8/27	240	1824.	197.	33600.	-591.	***	***	96.8
8/28	241	1889.	0.	33600.	0.	0.	0.	27.5
8/29	242	1844.	0.	33600.	0.	0.	0.	24.1
8/30	243	1186.	0.	33600.	0.	0.	0.	22.3
8/31	244	2059.	0.	33600.	0.	0.	0.	26.8
TOTALS		60525.	25361.		240199.	9.	23.	11899.3
AVG		1952.	818.		7748.			383.8



MONTHLY PERFORMANCE SUMMARY 8-84

FIGURE 8.

TABLE V.

HOURLY PERFORMANCE TABLE - 8/ 8/84(JULIAN DAY 221)
ARRAY ACTIVE AREA = 43680. SQ.FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL SYSTEM TOTAL ELEC ENER USED OVER HOU KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	65.	6.	40.	112.	95.	208.	206.	212.	207.	203.	-602.	***	***	4[illegible].4
8	71.	4.	103.	191.	109.	217.	229.	279.	216.	226.	1977.	44.	24.	5[illegible].[illegible]
9	77.	3.	161.	210.	107.	222.	241.	278.	221.	236.	2900.	41.	32.	5[illegible].1
10	80.	4.	215.	224.	104.	223.	245.	277.	222.	239.	3251.	35.	33.	5[illegible].2
11	82.	5.	251.	214.	101.	226.	250.	276.	226.	242.	3276.	30.	35.	5[illegible].2
12	83.	7.	286.	176.	104.	227.	246.	276.	226.	241.	2821.	23.	37.	6[illegible].5
13	86.	8.	293.	167.	105.	226.	244.	276.	225.	240.	2837.	22.	39.	6[illegible].0
14	88.	8.	280.	163.	104.	227.	244.	276.	226.	240.	2669.	22.	37.	6[illegible].2
15	86.	9.	248.	129.	105.	228.	243.	274.	228.	240.	2249.	21.	40.	6[illegible].5
16	86.	10.	193.	111.	105.	231.	243.	273.	230.	240.	1852.	22.	38.	6[illegible].6
17	84.	8.	118.	77.	106.	228.	238.	276.	228.	236.	1543.	30.	46.	60.5
18	78.	8.	58.	-23.	109.	218.	219.	278.	218.	218.	52.	2.	***	5[illegible].1
19	72.	7.	10.	-6.	68.	213.	210.	174.	212.	210.	-291.	***	***	4[illegible].[illegible]
20	65.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	[illegible].3
21	60.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.6
22	59.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			2256.	1747.							24532.	25.	32.	76[illegible].6
AVG	78.	7.	184.	141.	103.	223.	237.	267.	223.	233.	1976.			1[illegible].1

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
October 19, 1984
Monthly Progress Report No. 56
Reporting Period September 1, 1984
through September 28, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC04OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to March 31, 1985

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued through the month of September. Maintenance activities were performed relating to the problems encountered last month; however, the active area of the field remained unchanged.

SUMMARY STATUS ASSESSMENT AND FORECAST:

Plans have been initiated to bring this job to a close and to leave the solar system in as good status as possible when the plant minimizes operations in January, 1985.

Respectively submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 23

REPORT PERIOD:	September 1, 1984 - September 30, 1984
REPORT NO.:	CTCo-23
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	11.6 x 10^9 Btu/yr, peak hourly 8.2 x 10^6 Btu/hr, peak daily - 74.1 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235°, 450 gpm. The water is heated from 195° F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235°F.

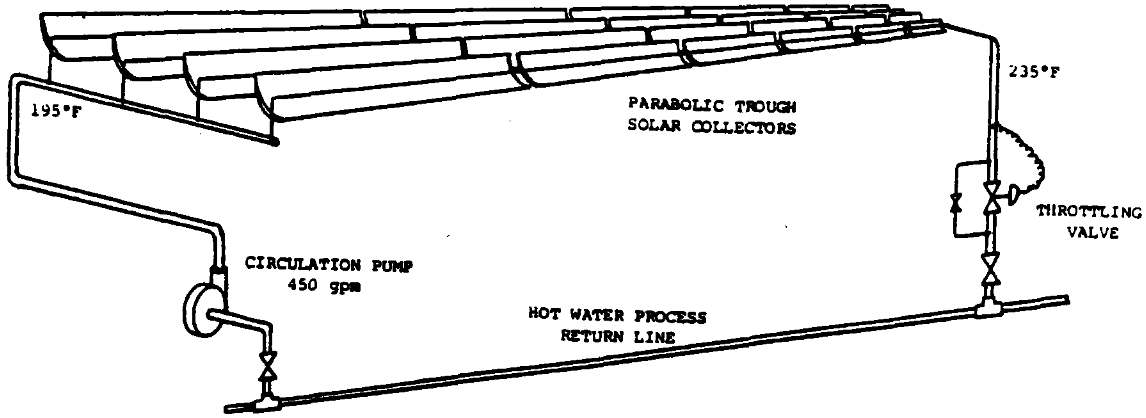


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available during the month of September, but the disk used to store data taken by the data acquisition system has errors so that one day's worth cannot be recovered and two other days have missing points. A summary of the system operation is found in Table I. for the system.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
September 1984

Date	Active Area (ft^2)	Comments
9/1 - 9/30	33600	Twenty drive rows inoperative
9/19,9/21,9/22	-	Computer disk error

While the amount of the system available for operation did not vary during the month, there was significant maintenance activity. Table II and III provide a summary of maintenance costs and activity for the month of September. As the CTCo personnel were repairing problems associated with the system failure of 8/16/84, other problems became apparent. There has been a noticeable increase in occurrences of hydraulic oil leaks. Figure 2 shows the status of each of the drive rows on September 30, 1984.

TABLE II. CATERPILLAR SOLAR SYSTEM MAINTENANCE SUMMARY
September 1984

		Cost		
O & M Activity	Hours	Labor $	Materials $	Total $
o Routine inspection	16	383.18	-0-	383.18
o Piping, electrical, and hydraulic maintenance related to system failure on 8/16	217	5196.88	235.00	5431.88
TOTAL	233	5580.06	235.00	5815.06

Total estimated maintenance costs for 2/83 -9/84 = 24117.20

TABLE III. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
September 30, 1984

Row	Date of Last Action	Comment
BH-55	8/16/84	Water leak on row BH-77
BH-60	6/5/84	Hydraulic oil leak
BH-65	8/16/84	Water leak at outlet flex hose
BH-66	8/16/84	Hydraulic oil leak, water leak at outlet flex hose
BH-68	9/84	Hydraulic oil pump won't start
BH-71	9/84	Hydraulic 4-way valve won't shift
BH-77	8/16/84	Broken receiver tube glass
BH-78	9/84	Hydraulic oil leak
BH-82	9/84	Stuck in stow position
BH-83	9/84	Hydraulic oil leak
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-87	9/84	Stuck in stow position
BH-88	8/16/84	Water leak on row BH-66
BH-90	9/84	Hydraulic oil leak
BH-91	9/84	Control board failure
BH-92	8/16/84	Water leak at outlet flex hose
BH-100	8/16/84	Water leak on row BH-92
BH-102	8/16/84	Broken receiver tube glass
BH-103	8/16/84	Broken receiver tube glass
BH-106	9/84	Hydraulic oil leak

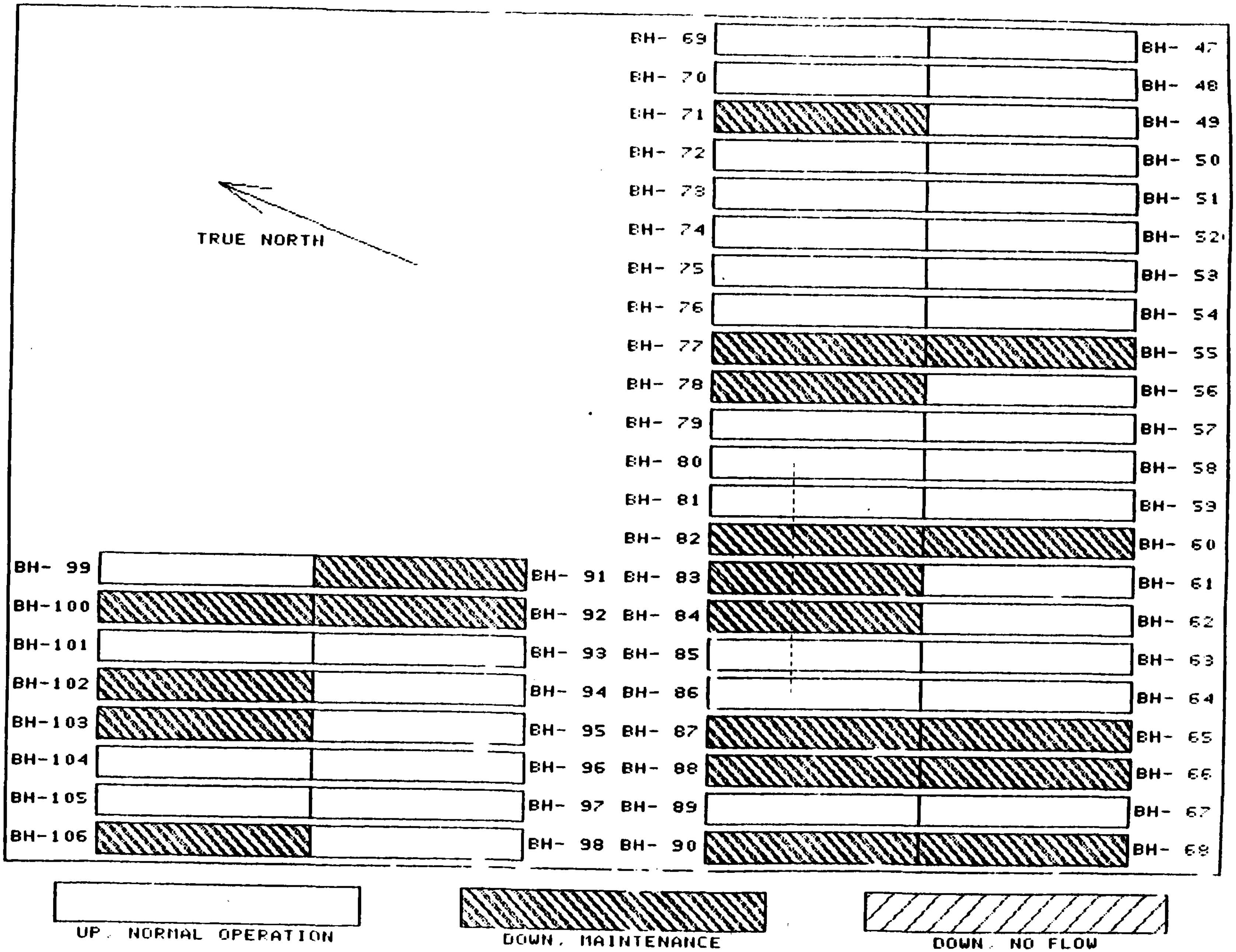
IV. System Performance

A. Monthly Summary

The system performance for September is summarized in Table IV and Figure 3. It is seen that the system delivered 250.3 * 10^6 Btu at an average efficiency of 24%. There were, however, three days for which no data can be recovered because of a disk failure.

B. Daily Summary

The CTCo system performance for September 4, 1984 is summarized in Table V and Figure 4. The peak hourly efficiency for this day was 30% while the daily total efficiency was 24%. The system delivered 17.0 * 10^6 Btu while parasitic energy consumption was 3.8% of the delivered energy.

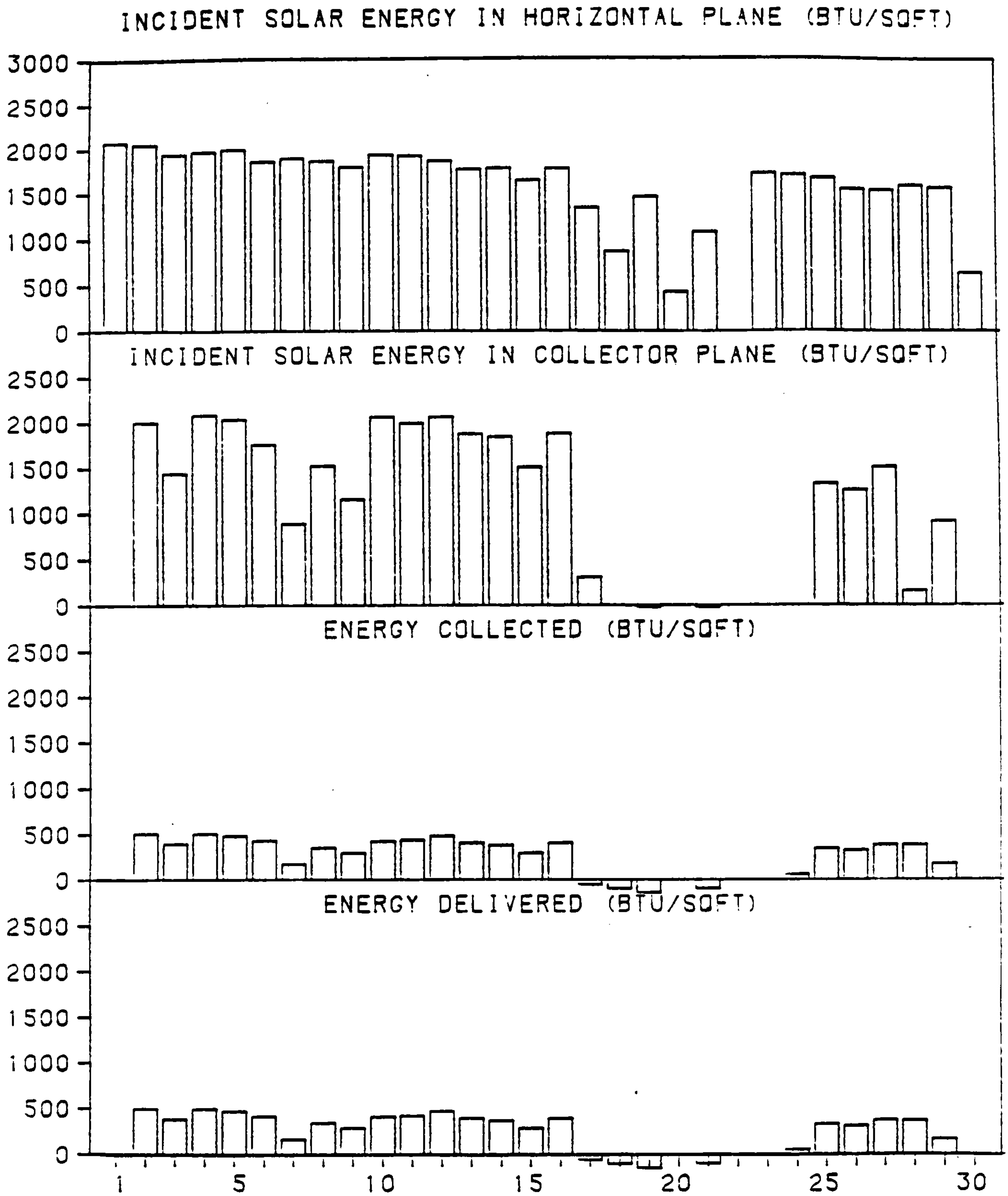


TIME PERIOD: SEPTEMBER 30

FIGURE 2

TABLE IV. MONTHLY PERFORMANCE SUMMARY TABLE - 9/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
9/ 1	245	2079.	0.	33600.	0.	0.	0.	32.5
9/ 2	246	2063.	2002.	33600.	16996.	25.	25.	593.8
9/ 3	247	1950.	1446.	33600.	13246.	20.	27.	365.6
9/ 4	248	1983.	2085.	33600.	17027.	26.	24.	651.6
9/ 5	249	2009.	2037.	33600.	16268.	24.	24.	651.0
9/ 6	250	1873.	1760.	33600.	14403.	23.	24.	579.8
9/ 7	251	1908.	892.	33600.	5783.	9.	19.	291.2
9/ 8	252	1874.	1527.	33600.	11849.	19.	23.	510.8
9/ 9	253	1806.	1158.	33600.	9907.	16.	25.	381.3
9/10	254	1947.	2064.	33600.	14201.	22.	20.	634.5
9/11	255	1935.	1995.	33600.	14627.	23.	22.	623.5
9/12	256	1878.	2063.	33600.	16275.	26.	23.	635.1
9/13	257	1783.	1877.	33600.	13680.	23.	22.	629.4
9/14	258	1793.	1847.	33600.	12732.	21.	21.	617.6
9/15	259	1661.	1513.	33600.	9945.	18.	20.	479.6
9/16	260	1790.	1881.	33600.	13641.	23.	22.	523.8
9/17	261	1359.	309.	33600.	-1997.	***	***	420.7
9/18	262	879.	-6.	33600.	-3436.	***	***	180.3
9/19	263	1481.	-33.	33600.	-4908.	***	***	479.3
9/20	264	434.	0.	33600.	0.	0.	0.	19.0
9/21	265	1099.	-33.	33600.	-3301.	***	***	314.5
9/22	266	DISK ERROR - NO DATA						
9/23	267	1736.	0.	33600.	0.	0.	0.	17.9
9/24	268	1717.	-3.	33600.	1997.	3.	***	179.2
9/25	269	1684.	1328.	33600.	11441.	20.	26.	491.6
9/26	270	1563.	1258.	33600.	10726.	20.	25.	625.0
9/27	271	1553.	1513.	33600.	12785.	24.	25.	623.0
9/28	272	1604.	158.	33600.	12714.	24.	***	631.8
9/29	273	1583.	917.	33600.	5818.	11.	19.	339.2
9/30	274	642.	0.	33600.	0.	0.	0.	11.3
TOTALS		47665.	31555.		242418.	15.	23.	12533.8
AVG		1644.	1088.		8359.			432.2



MONTHLY PERFORMANCE SUMMARY 9-84

FIGURE 3

TABLE V. HOURLY PERFORMANCE TABLE - 9/4/84 (JULIAN DAY 248)
ARRAY ACTIVE AREA = 33600 SQ. FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	63.	1.	21.	70.	45.	200.	194.	152.	198.	191.	-743.	***	***	31.2
8	72.	1.	80.	171.	74.	210.	216.	314.	210.	216.	1092.	40.	19.	53.3
9	78.	1.	137.	183.	74.	217.	223.	319.	216.	224.	1499.	33.	24.	53.7
10	79.	3.	193.	191.	74.	220.	227.	313.	219.	229.	1809.	28.	28.	53.7
11	78.	5.	239.	205.	74.	217.	224.	319.	216.	227.	1827.	23.	27.	53.5
12	80.	6.	262.	215.	74.	220.	228.	320.	220.	231.	1971.	22.	27.	53.5
13	86.	7.	267.	227.	74.	221.	229.	319.	220.	233.	2306.	26.	30.	53.6
14	87.	9.	253.	241.	74.	220.	228.	319.	220.	234.	2446.	29.	30.	54.6
15	84.	10.	217.	244.	74.	229.	236.	318.	228.	242.	2342.	32.	29.	53.7
16	80.	10.	167.	228.	73.	233.	240.	318.	233.	245.	2092.	37.	27.	55.2
17	80.	8.	104.	89.	73.	232.	236.	318.	232.	236.	763.	22.	26.	54.0
18	74.	8.	43.	6.	74.	221.	220.	314.	221.	219.	-243.	***	***	53.3
19	68.	6.	0.	16.	27.	215.	213.	112.	214.	212.	-134.	***	***	24.4
20	64.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
21	62.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.0
22	62.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			1983.	2085.							17027.	26.	24.	651.6
AVG	76.	5.	170.	175.	71.	221.	226.	304.	220.	228.	1429.			12.8

HOURLY PERFORMANCE FOR 9-4-84

ARRAY ACTIVE AREA = 33600 SQ. FT.

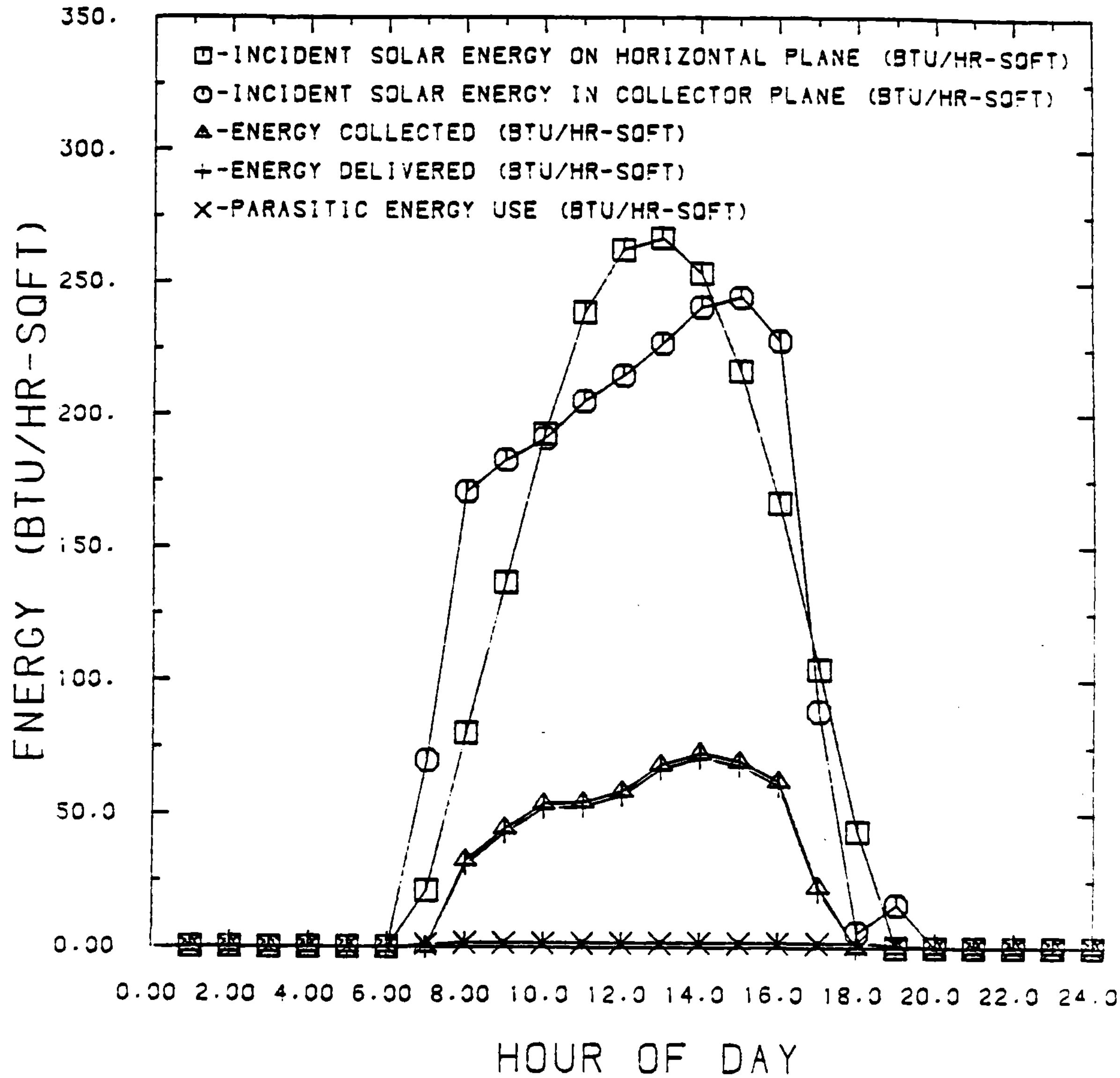


FIGURE 4

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
November 20, 1984
Monthly Progress Report No. 56
Reporting Period September 29, 1984
through October 26, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC040CS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to March 31, 1985

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued through the month of October. The status of the system is unchanged from September; however the computer DAS failed from 10/9 to 10/30. The on-site datalogger was used to gather the data during this period, so no data were lost.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The system will continue to operate as long as energy is needed by the plant.

Respectively submitted,

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 24

REPORT PERIOD:	October 1, 1984 - October 31, 1984
REPORT NO.:	CTCo-24
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	11.6 x 10^9 Btu/yr, peak hourly 8.2 x 10^6 Btu/hr, peak daily - 74.1 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235°, 450 gpm. The water is heated from 195° F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235°F.

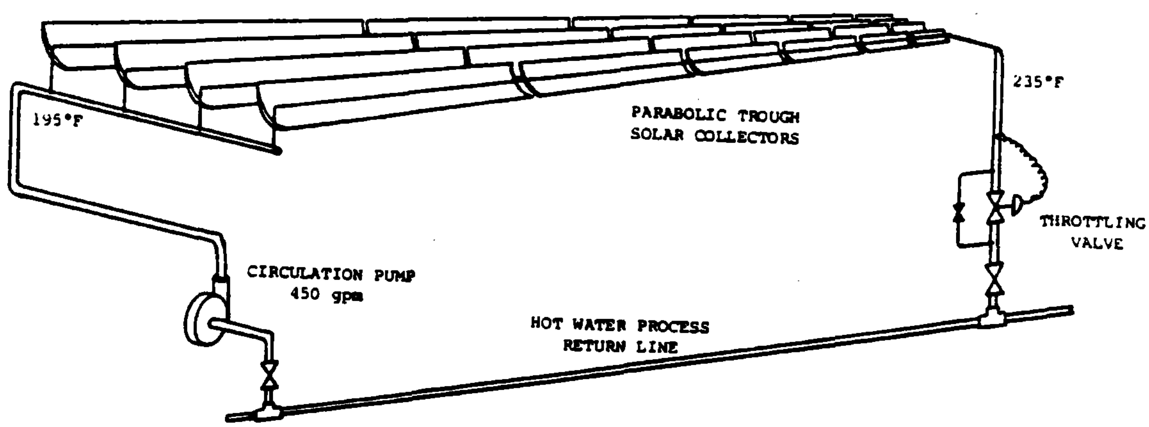


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available during the month of October, but the PDP 11/23 experienced problems. Data were not collected by the 11/23 between 10/9 and 10/30, but the Acurex datalogger was used to gather performance data for this period.

A summary of the system operation is found in Table I. There was virtually no change in the status of the solar system during October. This is a result of maintenance activity in the remainder of the plant. The status of each of the drive rows is the same as in September, as seen in Figure 2 and Table II. Since the plant is closing early next spring, there will be little activity on the solar system. So, CTCo will no longer be providing O&M cost accounting in the same detail as in the past. Any additional costs will be reported as estimates in the next two (final) monthly performance reports.

The cause of the computer failure is unknown; however, CTCo personnel have gotten the system running again. The Acurex datalogger will continue to serve as a backup until the PDP 11/23 is seen to be stable again.

IV. System Performance

A. Monthly Summary

The system performance for October, 1984 is summarized in Table III and Figure 3. The dates for which each portion of the DAS are responsible are indicated in Table III. It is seen that $154.0 * 10^6$ Btu were delivered to the plant in October at a long term efficiency of 20%.

B. Daily Summary

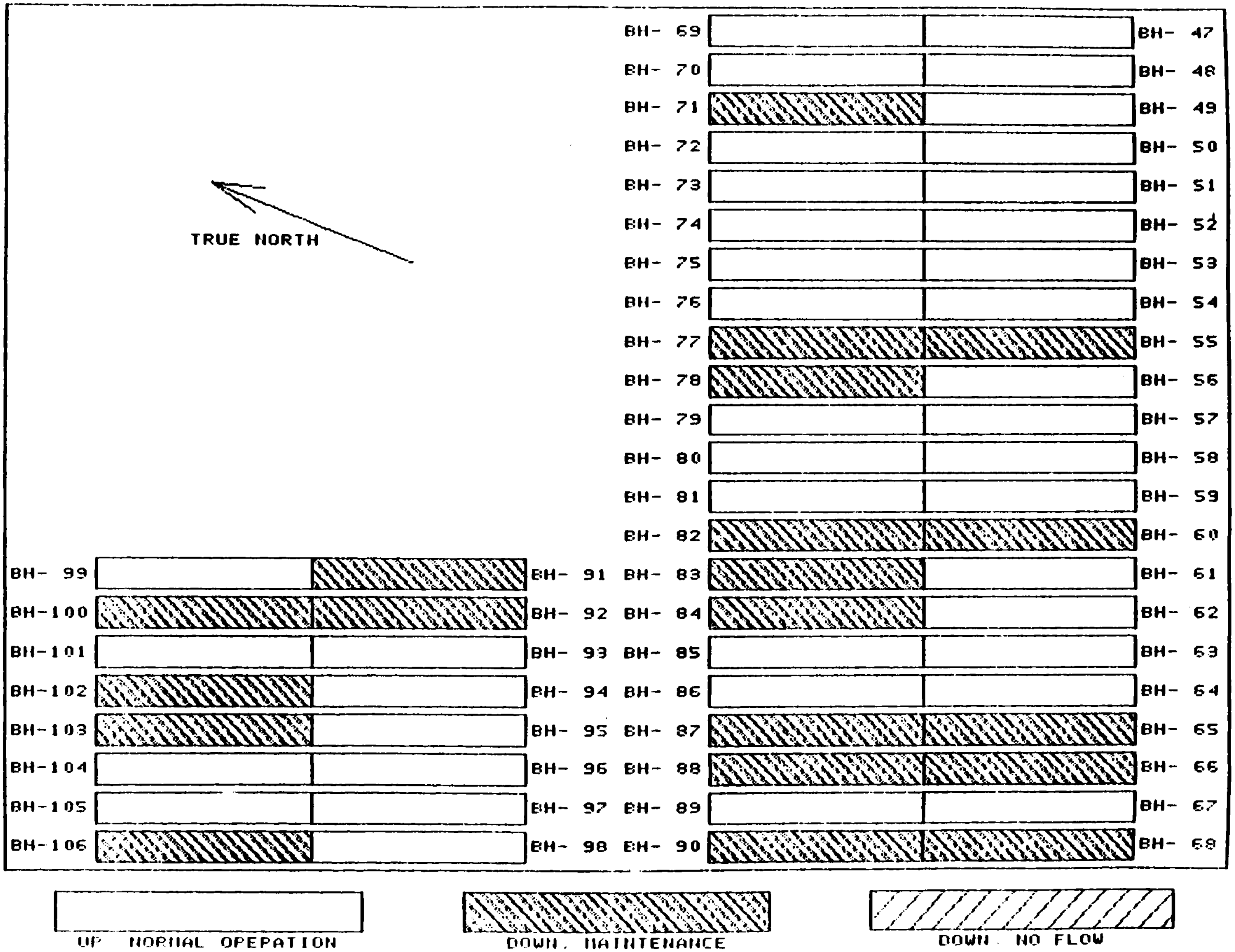
The CTCo solar system performance for October 7, 1984 is summarized in Table IV and Figure 4. The peak hourly efficiency was 34% on this day. The average efficiency was 27% while delivering a total of $11.5 * 10^6$ Btu during this day.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
October 1984

Date	Active Area (ft^2)	Comments
10/1 - 10/31	33600	Twenty drive rows inoperative
10/9 - 10/30	-	PDP 11/23 down. Acurex datalogger gathering data.

TABLE II. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
October 30, 1984

Row	Date of Last Action	Comment
BH-55	8/16/84	Water leak on row BH-77
BH-60	6/5/84	Hydraulic oil leak
BH-65	8/16/84	Water leak at outlet flex hose
BH-66	8/16/84	Hydraulic oil leak, water leak at outlet flex hose
BH-68	9/84	Hydraulic oil pump won't start
BH-71	9/84	Hydraulic 4-way valve won't shift
BH-77	8/16/84	Broken receiver tube glass
BH-78	9/84	Hydraulic oil leak
BH-82	9/84	Stuck in stow position
BH-83	9/84	Hydraulic oil leak
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-87	9/84	Stuck in stow position
BH-88	8/16/84	Water leak on row BH-66
BH-90	9/84	Hydraulic oil leak
BH-91	9/84	Control board failure
BH-92	8/16/84	Water leak at outlet flex hose
BH-100	8/16/84	Water leak on row BH-92
BH-102	8/16/84	Broken receiver tube glass
BH-103	8/16/84	Broken receiver tube glass
BH-106	9/84	Hydraulic oil leak



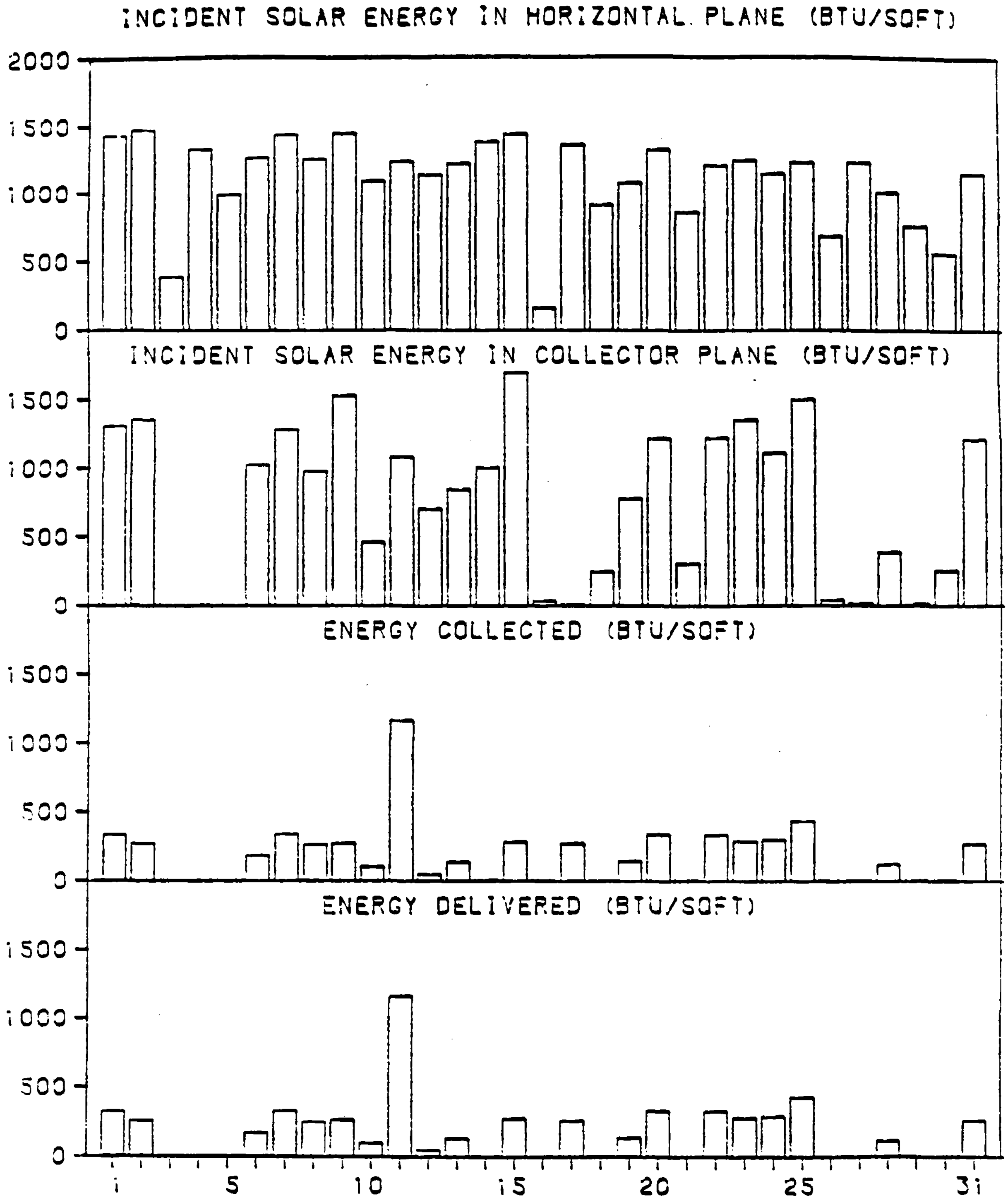
TIME PERIOD: OCTOBER 1-31

FIGURE 2

TABLE III

MONTHLY PERFORMANCE SUMMARY TABLE - 10/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU	
10/ 1	275	1428.	1304.	33600.	11185.	23.	26.	542.2	PDP 11/23 (10/1–10/8)
10/ 2	276	1471.	1350.	33600.	9041.	18.	20.	542.7	
10/ 3	277	387.	0.	33600.	0.	0.	0.	23.8	
10/ 4	278	1330.	-124.	33600.	-4438.	***	***	455.6	
10/ 5	279	995.	-78.	33600.	-2257.	***	86.	368.8	
10/ 6	280	1264.	1024.	33600.	6181.	15.	18.	464.2	
10/ 7	281	1430.	1281.	33600.	11479.	24.	27.	430.5	
10/ 8	282	1248.	978.	33600.	8874.	21.	27.	329.4	
10/ 9	283	1451	1528.	33600.	9358.	19.	18.	533.9	Acurex datalogger (10/9–10/30)
10/10	284	1098	464.	33600.	3603.	10.	23.	320.8	
10/11	285	1241.	1081.	33600.	10428.	25.	29.	391.8	
10/12	286	1145.	705.	33600.	1831.	5.	8.	332.9	
10/13	287	1226.	848.	33600.	4787.	12.	17.	401.7	
10/14	288	1387.	1007.	33600.	242.	1.	1.	320.7	
10/15	289	1441.	1698.	33600.	9677.	20.	17.	532.7	
10/16	290	167.	39.	33600.	-838.	***	***	16.8	
10/17	291	1362.	-4.	33600.	9218.	20.	***	522.6	
10/18	292	923.	249.	33600.	-909.	***	***	331.6	
10/19	293	1083	779.	33600.	4919.	14.	19.	346.8	
10/20	294	1327.	1216.	33600.	11492.	26.	28.	418.6	
10/21	295	870.	308.	33600.	-1209.	***	***	223.5	
10/22	296	1213.	1223.	33600.	11402.	28.	28.	495.7	
10/23	297	1248.	1353.	33600.	9815.	23.	22.	529.5	
10/24	298	1147.	1109.	33600.	10200.	26.	27.	453.4	
10/25	299	1229.	1499.	33600.	14796.	36.	29.	528.8	
10/26	300	692.	43.	33600.	-3270.	***	***	17.4	
10/27	301	1231.	20.	33600.	-3719.	***	***	17.6	
10/28	302	1015.	388.	33600.	4074.	12.	31.	160.0	
10/29	303	768.	13.	33600.	5.	0.	1.	21.8	
10/30	304	565.	256.	33600.	-621.	***	***	175.9	
10/31	305	1125.	1147.	33600.	8680.	23.	23.	504.4	PDP 11/23
TOTALS		34507.	22704.		154026.	13.	20.	10750.1	
AVG		1113.	732.		4969.			347.0	



MONTHLY PERFORMANCE SUMMARY 10-84

FIGURE 3

TABLE IV

HOURLY PERFORMANCE TABLE - 10/ 7/84(JULIAN DAY 281)
ARRAY ACTIVE AREA = 33600. SQ FT.

HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	HOURLY RADIATION: ON A HORIZ SURFACE (1) BTU/SQFT	HOURLY RADIATION: IN THE COLLECTOR PLANE (2) BTU/SQFT	NORTH FIELD: AVERAGE FLOW RATE OVER HOUR GPM	NORTH FIELD: AVERAGE OPERATING TEMPERATURE IN F	NORTH FIELD: AVERAGE OPERATING TEMPERATURE OUT F	SOUTH FIELD: AVERAGE FLOW RATE OVER HOUR GPM	SOUTH FIELD: AVERAGE OPERATING TEMPERATURE IN F	SOUTH FIELD: AVERAGE OPERATING TEMPERATURE OUT F	TOTAL SYSTEM: TOTAL ENERGY COLLECTED OVER HOUR KBTU	TOTAL SYSTEM: HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	TOTAL SYSTEM: HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL SYSTEM: TOTAL ELEC ENERGY USED OVER HOUR KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	58	0	3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.0
8	68.	0.	51.	39.	32.	162.	162.	61.	160.	161.	-118.	***	***	20.1
9	71.	1.	105.	149.	138.	194.	200.	268.	193.	196.	888.	25.	18.	54.2
10	71.	3.	152.	146.	132.	197.	207.	296.	197.	203.	1486.	29.	30.	53.7
11	72.	4.	191	154.	135.	201.	210.	296.	200.	205.	1367.	21.	26.	55.5
12	72.	5.	211.	177.	113.	207.	218.	288.	206.	213.	1589.	22.	27.	54.1
13	80.	5.	214.	195.	108.	215.	230.	275.	214.	223.	1925.	27.	29.	52.5
14	80.	7.	195.	195.	94.	226.	243.	272.	225.	236.	2202.	34.	34.	51.4
15	80.	8.	156.	168.	83.	233.	249.	253.	232.	242.	1811.	35.	32.	54.2
16	79.	9.	104.	58.	23.	230.	243.	70.	229.	235.	329.	9.	17.	19.2
17	73.	10.	47.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.7
18	66.	9.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
19	64.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
20	61.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.3
21	59.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.1
22	57.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			1430.	1281.							11479.	24.	27.	430.5
AVG	70.	5.	141.	169.	108.	209.	221.	262.	208.	215.	1514.			8.5

HOURLY PERFORMANCE FOR 10-7-84

ARRAY ACTIVE AREA = 33600 SQ. FT.

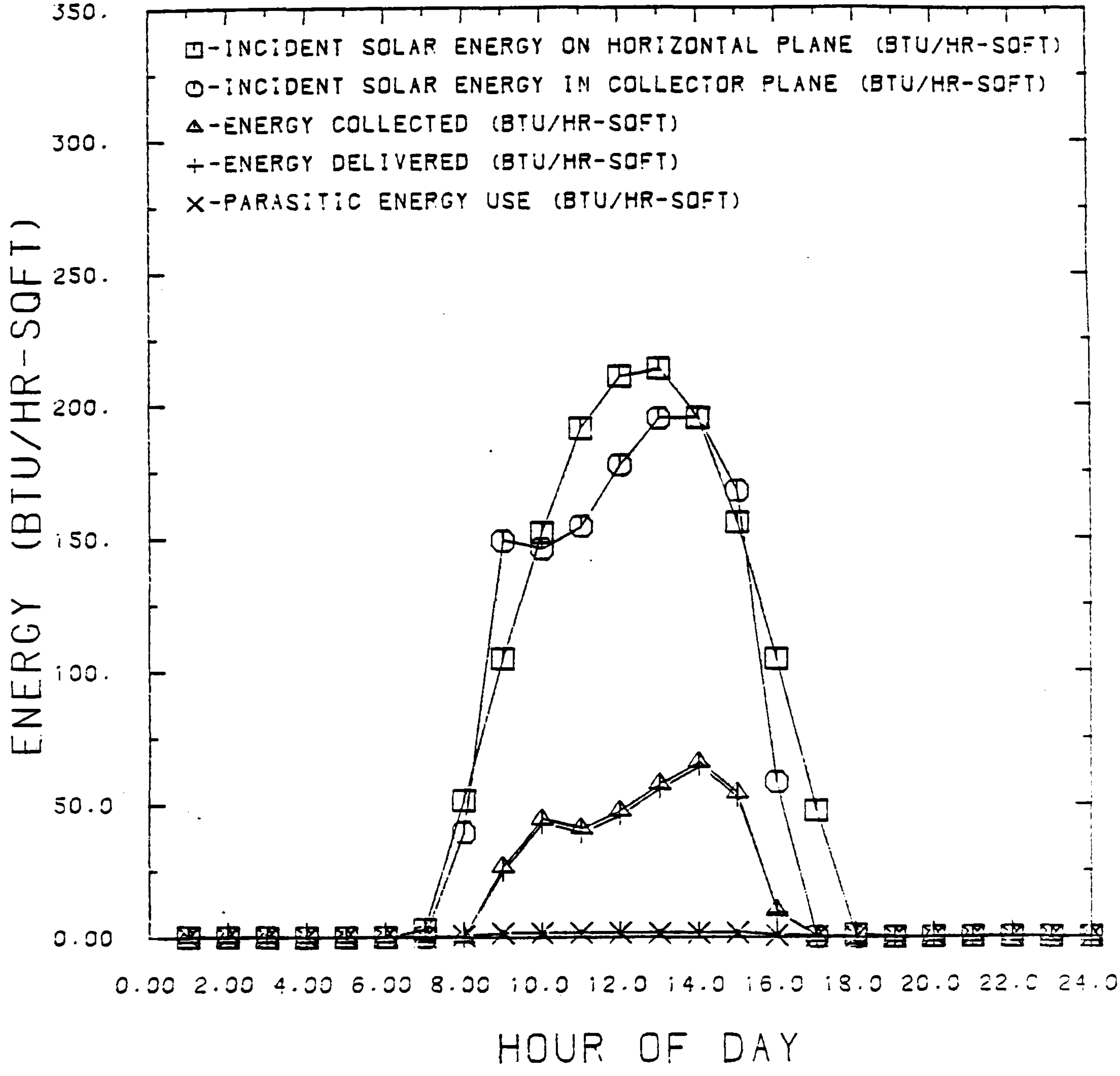


FIGURE 4

SOUTHWEST RESEARCH INSTITUTE

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Department of Mechanical Sciences
December 20, 1984
Monthly Progress Report No. 58
Reporting Period October 27, 1984
through November 23, 1984

CONTRACT TITLE AND NUMBER:

A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co. Phase III, DOE Contract No. DE-FC04OCS30309, SwRI Project No. 06-5821

CONTRACTOR:

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas

CONTRACT PERIOD: September 12, 1979 to March 31, 1985

CONTRACT OBJECTIVE CHANGE: None

TECHNICAL APPROACH CHANGE: None

CONTRACT TASKS:

Operation continued through the month of November.

SUMMARY STATUS ASSESSMENT AND FORECAST:

The PDP 11/23 was removed from the plant as part of the plant shutdown process. Many of the plant personnel concerned with the solar system will be leaving on December 21st so that performance cannot be reported any longer. The enclosed Monthly Performance Report will be the last such report. The Final Report for Phase III, Operation and Evaluation, is being prepared for submittal for review.

Respectfully submitted,

Steve Green

Steve T. Green
Research Engineer

STG:dle
Encl.

cc: Dr. R. L. Bass, SwRI
Ms. C. L. duMenil, SwRI
Appropriate DOE Personnel
Solar IPH Technical Advisors

APPROVED:

Danny M. Deffenbaugh

Danny M. Deffenbaugh
Project Manager

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

MONTHLY REPORT NO. 25

REPORT PERIOD:	November 1, 1984 - November 30, 1984
REPORT NO.:	CTCo-25
DOE CONTRACT NO.:	DE-FC03-79CS30309
SwRI PROJECT NO.:	06-5821
CONTRACT TITLE:	A Large-Scale Solar Industrial Process Heat System for Caterpillar Tractor Co.
CONTRACTOR:	Southwest Research Institute P. O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284 Contact: D. Deffenbaugh, 512/684-5111, ext 2384
PROJECT SITE:	Caterpillar Tractor Co. 1930 Davis Street San Leandro, California

II. Project Description

Application:	Preheat of process hot water for parts washing.
Site:	37° 44' N. Latitude, 122° 15' W. Longitude, Elevation = 108'.
Process Schedule:	Peak energy requirement is 9 x 10^6 Btu/hr of hot water at 235°F. The solar system will deliver a maximum of 8.6 x 10^6 Btu/hr.
Auxiliary Fuel:	Natural gas.
Collectors:	50400 ft^2 of Solar Kinetics tracking parabolic line focus, T-700 collectors. Roof mounted, horizontal on N-S axis, 30 ΔT strings @ 240 ft per string. 60 drive strings (2 per row). (North Field, 13440 ft^2; South field, 36960 ft^2).
Fluid Type, Flow:	Treated water, North field - 330 gpm, South field - 120 gpm.
Design Energy Delivery:	11.6 x 10^9 Btu/yr, peak hourly 8.2 x 10^6 Btu/hr, peak daily - 74.1 x 10^6 Btu/day.
Phase 1 Cost (Design):	$143,045
Phase 2 Cost (Construction):	$2,827,680

The tracking parabolic trough collectors are designed to produce hot water at 235°, 450 gpm. The water is heated from 195° F before entering the "boilers" to relieve some of the boiler load. Total plant requirement is an average of 836 gpm at 235°F.

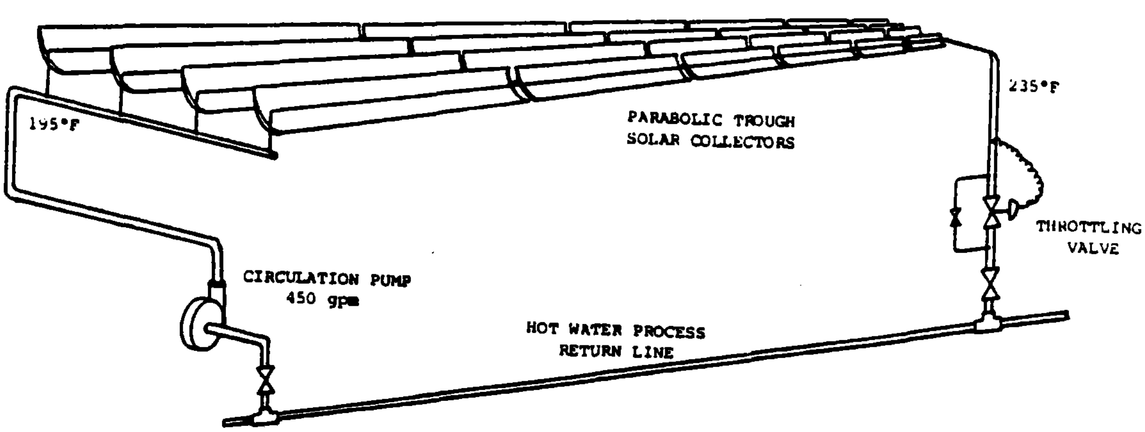


FIGURE 1. SYSTEM SCHEMATIC

III. Operating Experience

The solar system was available during the entire month of November. The PDP 11/23 computer was removed from the plant as part of the on-going plant shutdown process; however, the Acurex datalogger was able to gather data for all but the last day of the month.

A summary of the system operation is found in Table I. There was no change in the status of the system during November; so, the status of each of the out-of-service drive rows is unchanged from October, as seen in Table II and Figure 2.

The Techtran tape drive did not record data on 11/30. The cause of this failure is unknown, and since the system will see no operation for most of December, repair is unwarranted.

IV. System Performance

A. Monthly Summary

The performance for November is summarized in Table III and Figure 3. While there were some days of useful operation, the system did not perform well during this month. The peak daily efficiency was 29%, but the monthly efficiency was only 5%. This is because (1) weather conditions were marginal during November, and (2) CTCo personnel are not able to closely monitor the activity of the system because of the shutdown process.

B. Daily Summary

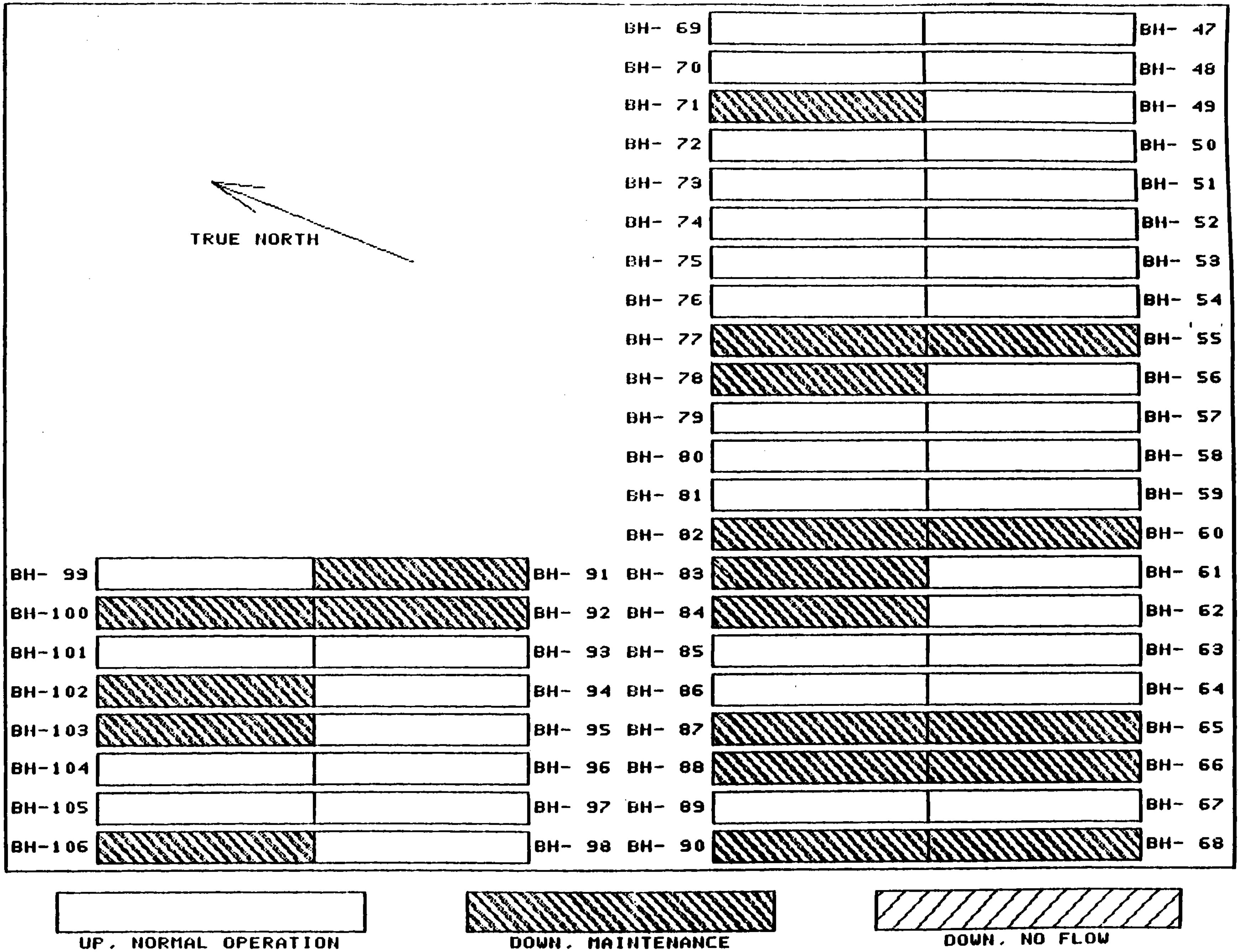
The CTCo solar system performance for November 4, 1984 is summarized in Table IV and Figure 4. It is seen that the overall daily efficiency was 29% with a peak hourly efficiency of 43%. It is also seen that the North Field flow rate is high for the first two hours of operation. The maximum expected flow in the North Field is 120 gpm; so, the data from this flowmeter are questionable. A review of other days' data reveal the same questionable behavior, which places some doubt in the data for the entire month.

TABLE I. CATERPILLAR SOLAR SYSTEM OPERATION
November 1984

Date	Active Area (ft^2)	Comments
11/1 - 11/30	33600	Twenty drive rows inoperative
11/31	-	Tape deck failure - no data

TABLE II. SUMMARY OF OUT-OF-SERVICE DRIVE ROWS
November 30, 1984

Row	Date of Last Action	Comment
BH-55	8/16/84	Water leak on row BH-77
BH-60	6/5/84	Hydraulic oil leak
BH-65	8/16/84	Water leak at outlet flex hose
BH-66	8/16/84	Hydraulic oil leak, water leak at outlet flex hose
BH-68	9/84	Hydraulic oil pump won't start
BH-71	9/84	Hydraulic 4-way valve won't shift
BH-77	8/16/84	Broken receiver tube glass
BH-78	9/84	Hydraulic oil leak
BH-82	9/84	Stuck in stow position
BH-83	9/84	Hydraulic oil leak
BH-84	2/16/84	Hydraulic cylinder seal failure.
BH-87	9/84	Stuck in stow position
BH-88	8/16/84	Water leak on row BH-66
BH-90	9/84	Hydraulic oil leak
BH-91	9/84	Control board failure
BH-92	8/16/84	Water leak at outlet flex hose
BH-100	8/16/84	Water leak on row BH-92
BH-102	8/16/84	Broken receiver tube glass
BH-103	8/16/84	Broken receiver tube glass
BH-106	9/84	Hydraulic oil leak



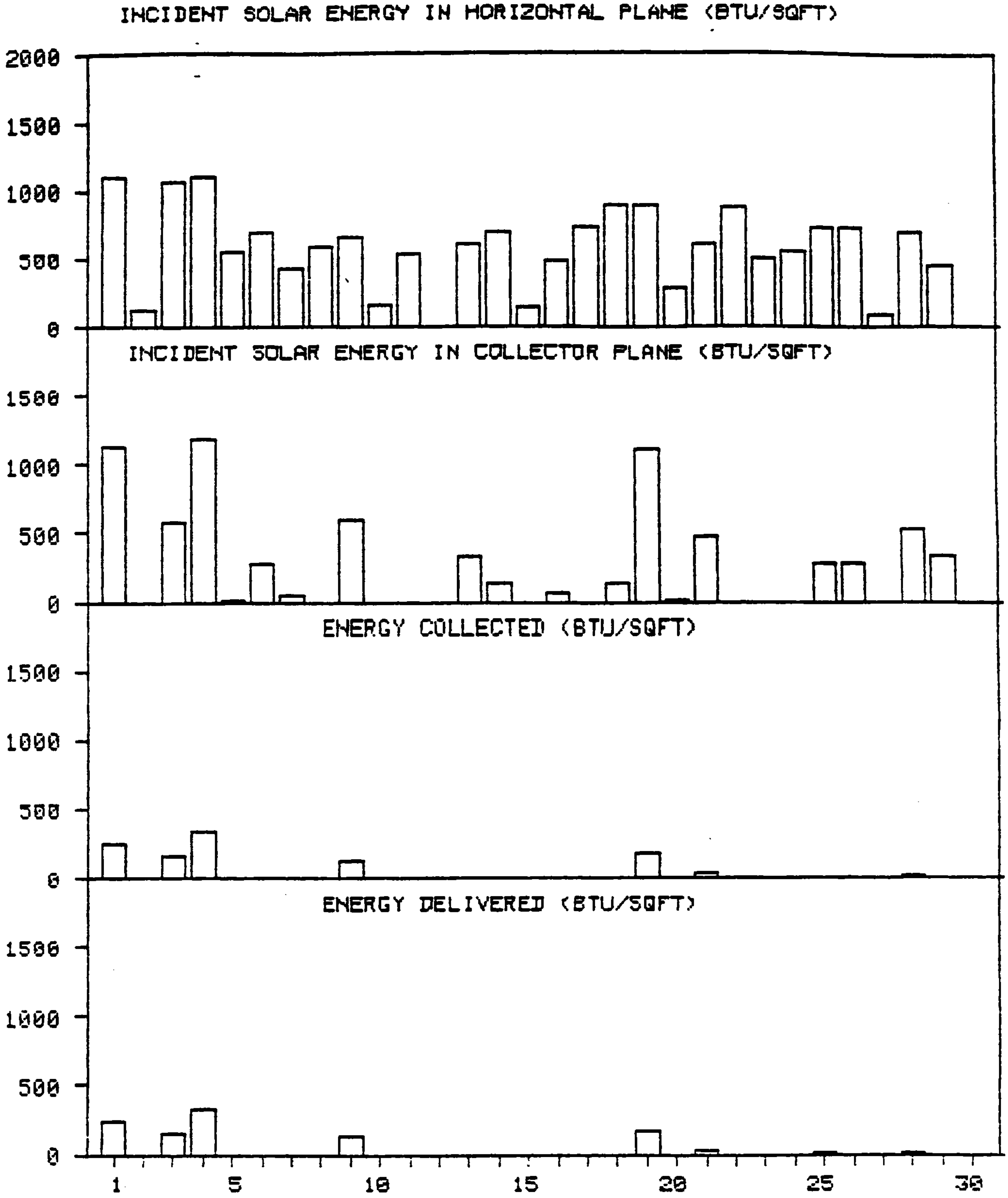
TIME PERIOD: NOVEMBER 1-30

FIGURE 2

TABLE III

MONTHLY PERFORMANCE SUMMARY TABLE - 11/84

DATE	JULIAN DAY	INCIDENT SOLAR ENERGY ON A HORIZ SURFACE (1) BTU/SQFT	INCIDENT SOLAR ENERGY ON THE COLLECTOR PLANE (2) BTU/SQFT	ARRAY ACTIVE AREA SQFT	ENERGY COLLECTED KBTU	COLLECTOR ARRAY EFF. BASED ON (1) %	COLLECTOR ARRAY EFF. BASED ON (2) %	PARASITIC ENERGY USED KBTU
11/ 1	306	1097.	1122.	33600.	8474.	23.	22.	483.8
11/ 2	307	122.	0.	33600.	0.	0.	0.	16.8
11/ 3	308	1060.	574.	33600.	5156.	14.	27.	265.1
11/ 4	309	1109.	1178.	33600.	11346.	30.	29.	419.0
11/ 5	310	550.	15.	33600.	-3777.	***	***	78.8
11/ 6	311	690.	282.	33600.	-369.	***	***	264.8
11/ 7	312	433.	40.	33600.	-1333.	***	***	104.6
11/ 8	313	589.	0.	33600.	0.	0.	0.	19.7
11/ 9	314	660.	592.	33600.	4417.	20.	22.	326.6
11/10	315	157.	0.	33600.	0.	0.	0.	23.2
11/11	316	537.	0.	33600.	0.	0.	0.	23.0
11/12	317	0.	0.	33600.	0.	0.	0.	20.8
11/13	318	601.	321.	33600.	-3962.	***	***	353.2
11/14	319	685.	142.	33600.	-5922.	***	***	272.3
11/15	320	141.	0.	33600.	0.	0.	0.	25.2
11/16	321	485.	68.	33600.	-1683.	***	***	100.6
11/17	322	732.	0.	33600.	0.	0.	0.	25.5
11/18	323	889.	137.	33600.	-251.	***	***	157.7
11/19	324	883.	1120.	33600.	5677.	19.	15.	479.4
11/20	325	285.	8.	33600.	-1207.	***	***	86.5
11/21	326	598.	477.	33600.	1095.	5.	7.	262.7
11/22	327	867.	0.	33600.	0.	0.	0.	28.3
11/23	328	489.	0.	33600.	0.	0.	0.	24.8
11/24	329	546.	0.	33600.	0.	0.	0.	25.4
11/25	330	721.	277.	33600.	47.	0.	1.	145.8
11/26	331	721.	273.	33600.	-3555.	***	***	306.6
11/27	332	86.	0.	33600.	0.	0.	0.	19.9
11/28	333	693.	526.	33600.	412.	2.	2.	277.5
11/29	334	439.	335.	33600.	-1627.	***	***	258.5
11/30	335	--------------NO DATA AVAILABLE--------------						
TOTALS		16865.	7489.		12938.	2.	5.	4896.1
AVG		582.	258.		446.			168.8



MONTHLY PERFORMANCE SUMMARY 11-84

FIGURE 3

TABLE IV.

HOURLY PERFORMANCE TABLE - 11/ 4/84(JULIAN DAY 309)
ARRAY ACTIVE AREA = 33600. SQ.FT.

			HOURLY RADIATION		NORTH FIELD			SOUTH FIELD			TOTAL SYSTEM			
HOUR	AVG AMB TEMP F	AVG WIND SPD MPH	ON A HORIZ SURFACE (1) BTU/SQFT	IN THE COLLECTOR PLANE (2) BTU/SQFT	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	AVERAGE FLOW RATE OVER HOUR GPM	AVERAGE OPERATING TEMPERATURE IN F	AVERAGE OPERATING TEMPERATURE OUT F	TOTAL ENERGY COLLECTED OVER HOUR KBTU	HOURLY COLLECTOR ARRAY EFF BASED ON (1) %	HOURLY COLLECTOR ARRAY EFF BASED ON (2) %	TOTAL ELEC ENE USED OVER HO KBTU
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
8	54.	3.	16.	19.	169.	0.	0.	36.	0.	0.	-402.	***	***	3.3
9	58.	2.	57.	88.	236.	160.	162.	165.	160.	182.	238.	13.	8.	10.7
10	61.	3.	106.	139.	128.	181.	187.	263.	181.	187.	1195.	33.	26.	15.4
11	63.	6.	148.	147.	107.	183.	189.	270.	183.	189.	1147.	23.	23.	15.5
12	64.	7.	172.	159.	97.	186.	193.	278.	186.	193.	1366.	24.	26.	15.6
13	67.	7.	179.	171.	119.	192.	201.	289.	192.	201.	1939.	32.	34.	15.6
14	70.	6.	168.	174.	127.	200.	211.	296.	200.	212.	2520.	45.	43.	15.6
15	70.	6.	136.	154.	107.	210.	221.	298.	210.	220.	2127.	46.	41.	15.6
16	70.	6.	92.	97.	72.	214.	224.	208.	214.	219.	995.	32.	30.	11.5
17	68.	4.	35.	29.	23.	0.	0.	59.	0.	0.	222.	19.	23.	4.1
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0
TOTALS			1109.	1178.							11346.	30.	29.	1[illegible]2.8
AVG	65.	5.	123.	131.	129.	191.	198.	233.	191.	200.	1261.			12.3

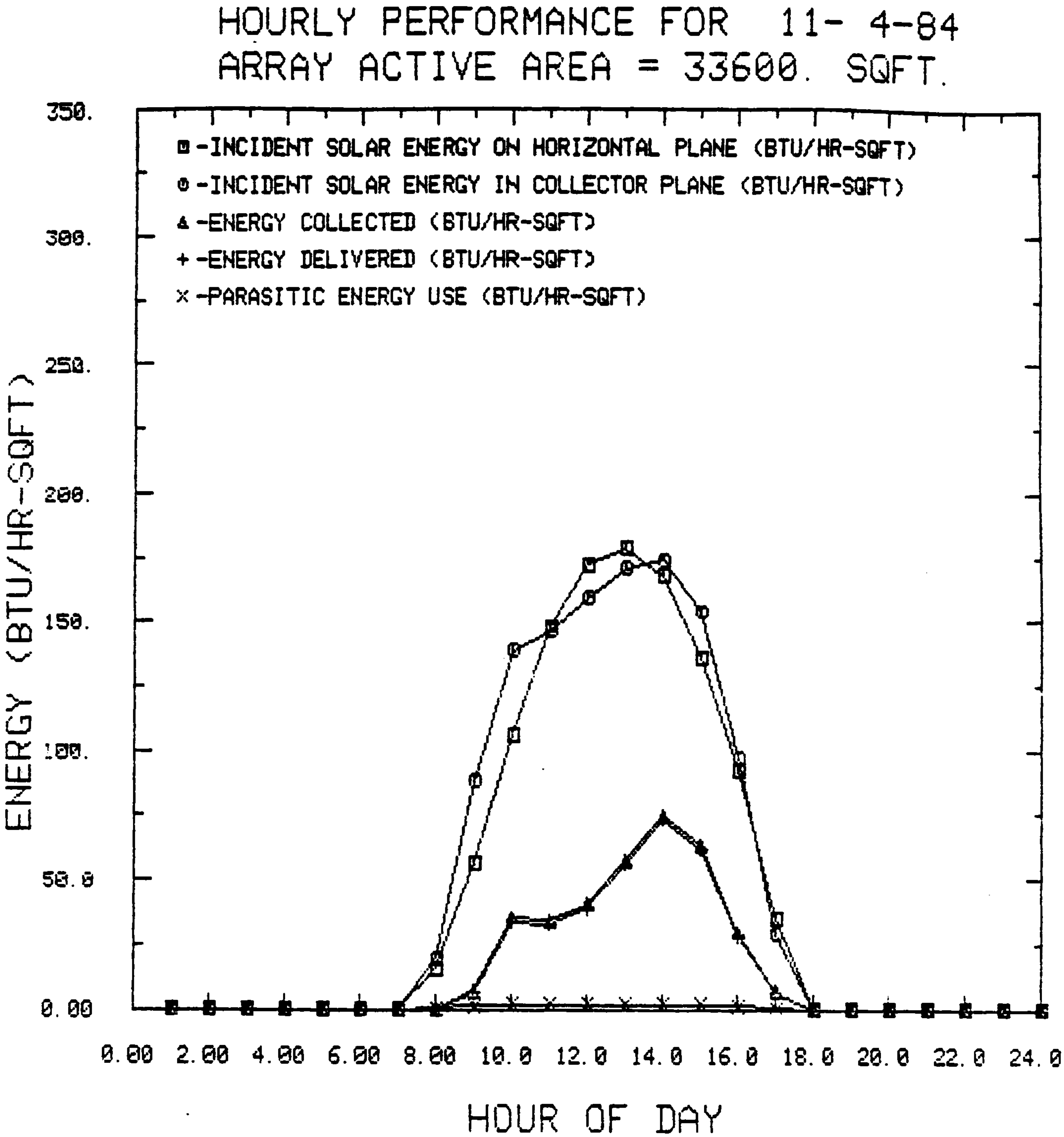

HOURLY PERFORMANCE FOR 11- 4-84
ARRAY ACTIVE AREA = 33600. SQFT.
□-INCIDENT SOLAR ENERGY ON HORIZONTAL PLANE (BTU/HR-SQFT)
⊙-INCIDENT SOLAR ENERGY IN COLLECTOR PLANE (BTU/HR-SQFT)
△-ENERGY COLLECTED (BTU/HR-SQFT)
+-ENERGY DELIVERED (BTU/HR-SQFT)
×-PARASITIC ENERGY USE (BTU/HR-SQFT)
ENERGY (BTU/HR-SQFT)
350.
300.
250.
200.
150.
100.
50.0
0.00
0.00 2.00 4.00 6.00 8.00 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
HOUR OF DAY

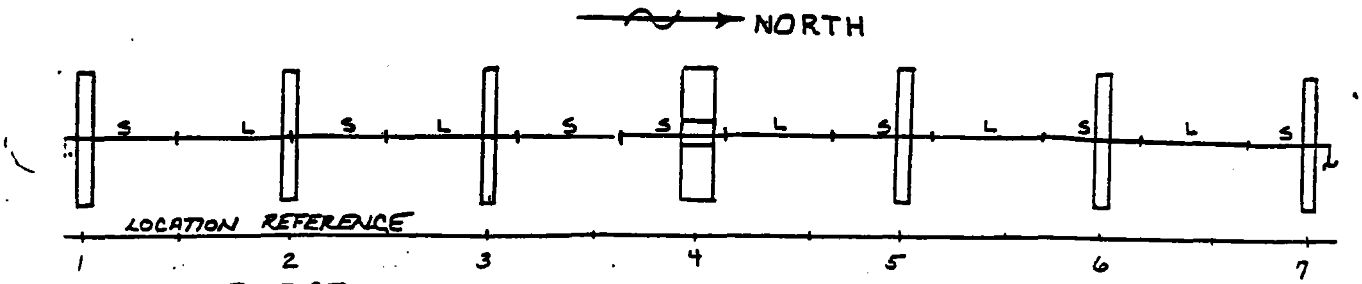
FIGURE 4

APPENDIX D

COLLECTOR DRIVE ROW MAINTENANCE RECORDS

Caterpillar Tractor Company plant engineering personnel maintain detailed records on all the equipment in their plants. The equipment in the solar system were incorporated into this system soon after construction was complete.

This appendix contains the maintenance log sheets for each of the 60 drive rows in the system. Each sheet describes the problems encountered with each of the drive rows and explains the maintenance activity to solve the problem. The dates of all activities are recorded so that downtime may be determined. As in the case of the Monthly Performance Reports, Appendix C, these log sheets form an important account of the operation and maintenance of a popular form of industrial grade solar equipment.



CODE REFERENCE

01 - TUBE BROKEN - SHORT (S)
02 - - LONG (L)
03 - TUBE DEFECT - SHORT
04 - - LONG
05 - SUPPORT BRACKET BROKEN
06 - MIRROR DAMAGE - SEVERE
07 - - MINOR
08 - INTERFERENCE - GIVE CLEARANCES

11 - TRACKING PROBLEM
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

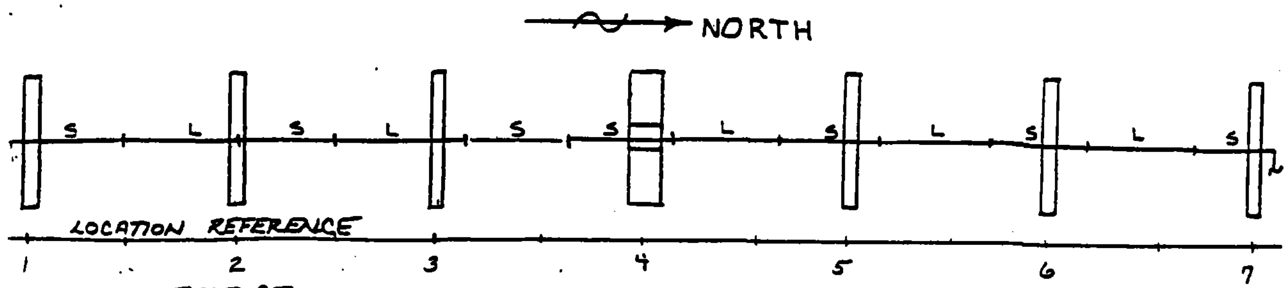
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 47

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	INSTALL COLLARS	R			11-6-82	SKT
13	4-7-83		PUMP START/STOP PRES. SWITCH HAS FAILED. ROW LEFT DOWN	D		✓	6-8-83	TSL
21	6-13-83		PRESURE SWITCH O-RING SEALS BLEW OUT	D		✓	1-12-84	DBL
01	4-25-84	1	GLASS TUBE BROKEN	-		✓	8-2-84	DBL

11-6-82



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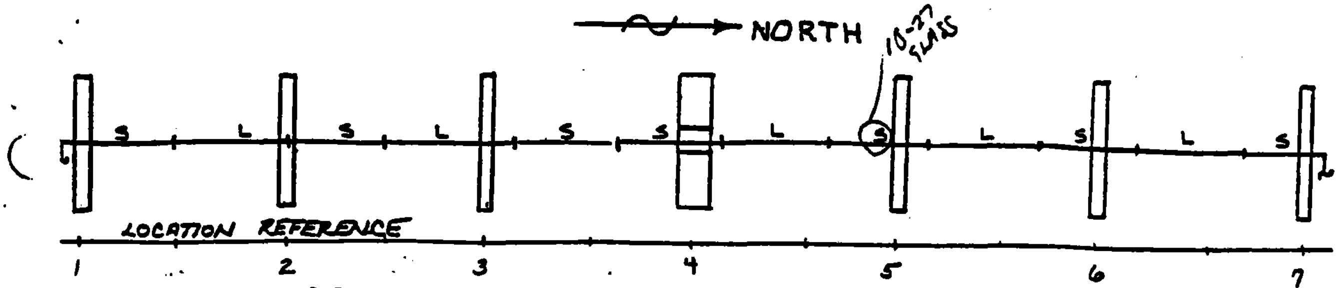
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 48

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	INSTALL COLLARS R	✓		11-6-82	SKI
22	9-28-83	1	WATER HOSE LEAKING AT CRIMP TO 90° BEND D		✓	1-13-84	SwRI



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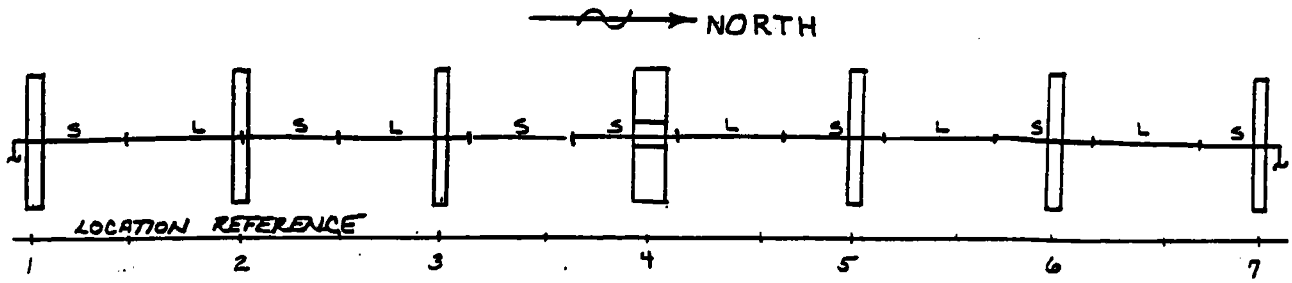
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 49

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R D			11-6-84	JK.
01	10-27-83	5	SHORT PIECE OF GLASS BROKE OFF THE END OF THE TUBE				
11	10-27-83	4	CONDENSATION IN TRACKER HEAD - RECAULKED HEAD D	✓		10-27-83	DBL
11	1-12-84	4	" " " D		✓	3-6-84	DBL



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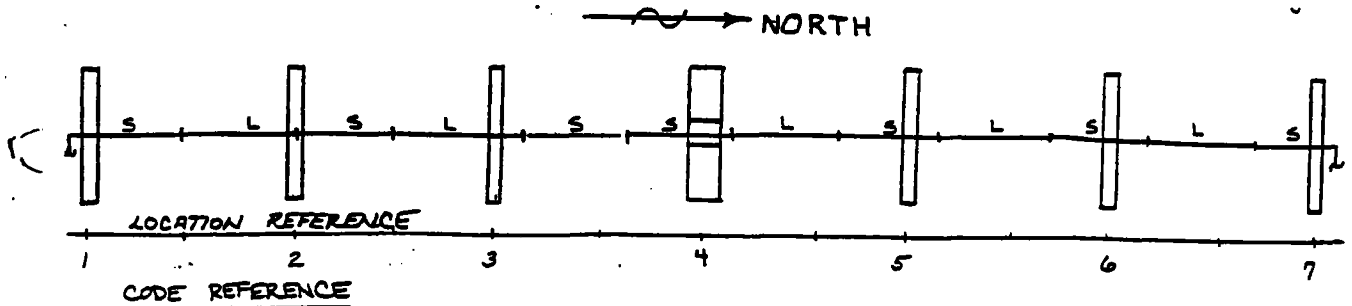
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 50

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SKI



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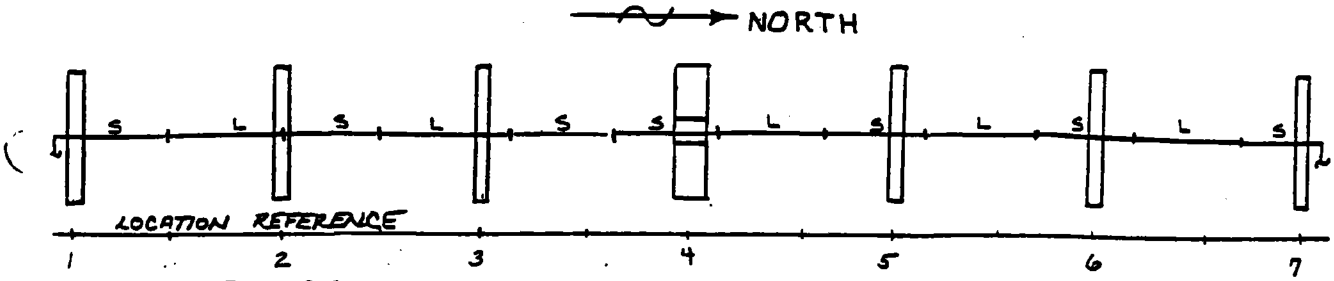
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-51

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SKI
22	~~4-24-84~~	2,3	HOT WATER LEAK AT "O" RINGS		✓	6-7-82	DBL
22	8-6-84	—	" " " " " "		✓	9-84	DBL



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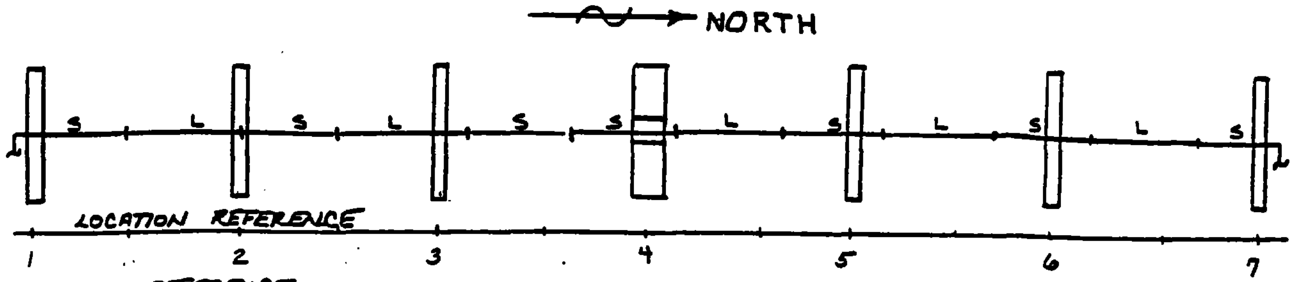
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 52

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SK[illegible]



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12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

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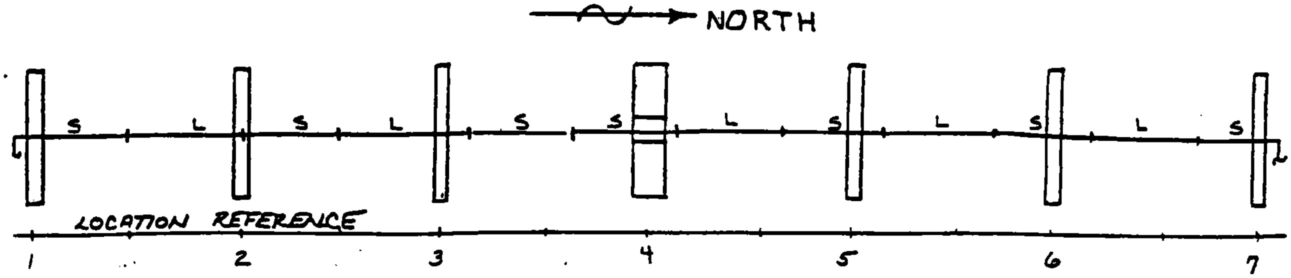
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 53

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-21-82	5.9	3/16" D	✓		11-6-82	SK
		1,2,6,7	COLLARS R			11-6-82	SK



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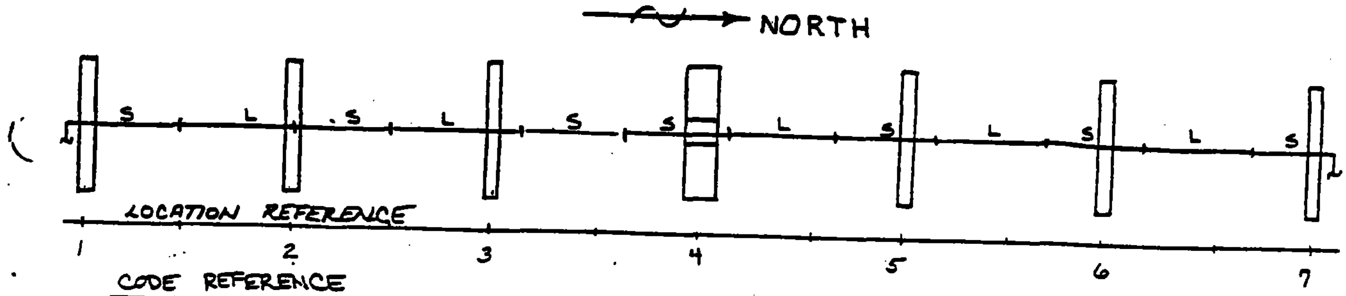
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-54

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08 ✓	9-21-82 ✓	5.9 7 1,2,6,7	-1/4" D -1/8" COLLARS R	✓ ✓		11-6-82	SK
21	8-8-84	4	O" RING UNDER 4-WAY VALVE SPLIT - LEAKING		✓	8-8-84	DBL



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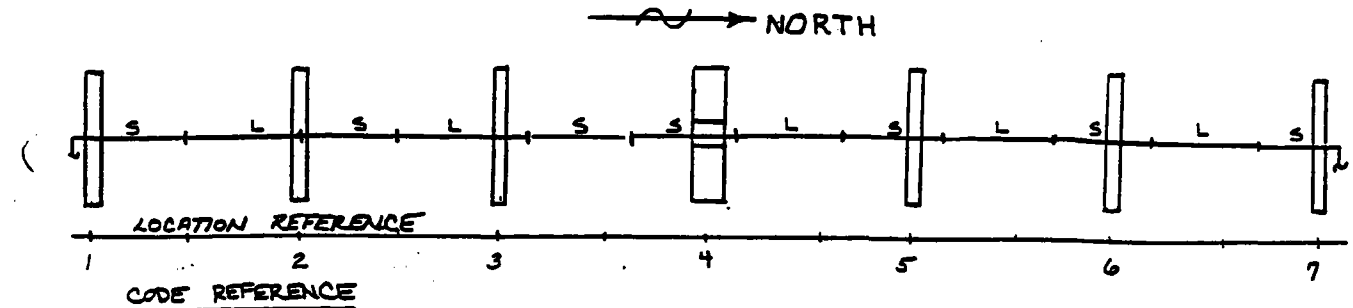
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-55

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
02	9-21	4					
05	✓	✓	D		✓		
		1,3,6,7	COLLARS		✓		
30	8-16-84	—	SHUTDOWN FOR WATER LEAKIN ROW 77 R D			11-6-82	SK



CODE REFERENCE

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04 - - LONG
05 - SUPPORT BRACKET BROKEN
06 - MIRROR DAMAGE - SEVERE
07 - - MINOR
08 - INTERFERENCE - GIVE CLEARANCES

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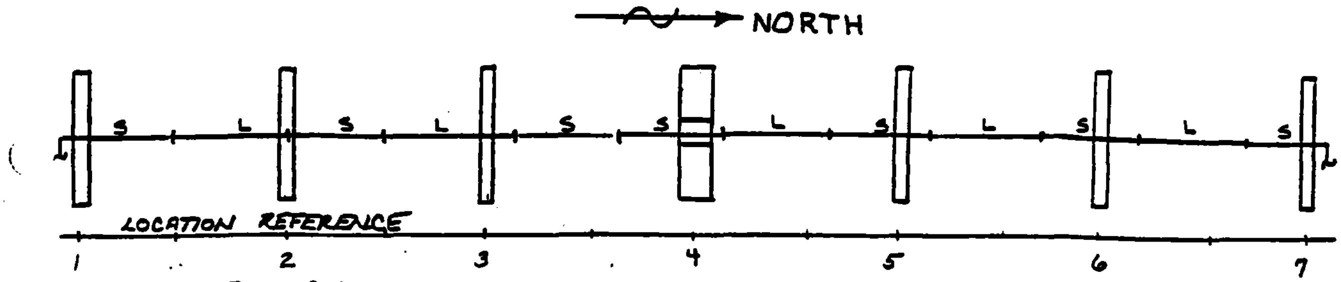
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 56

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SK



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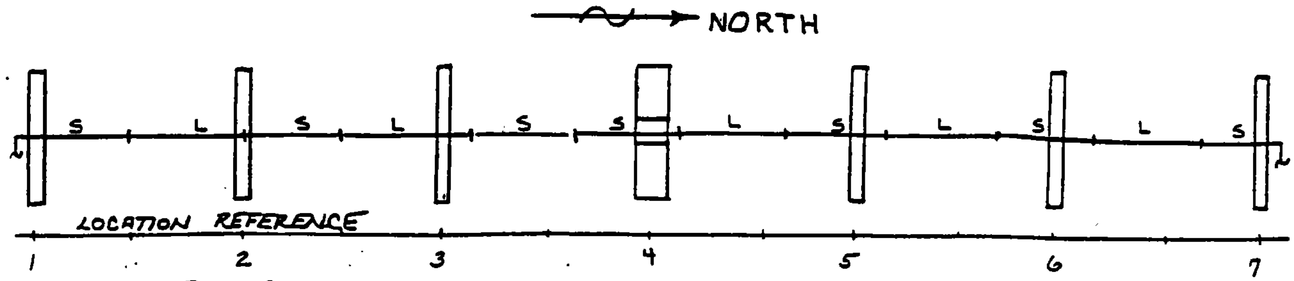
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 57

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SK



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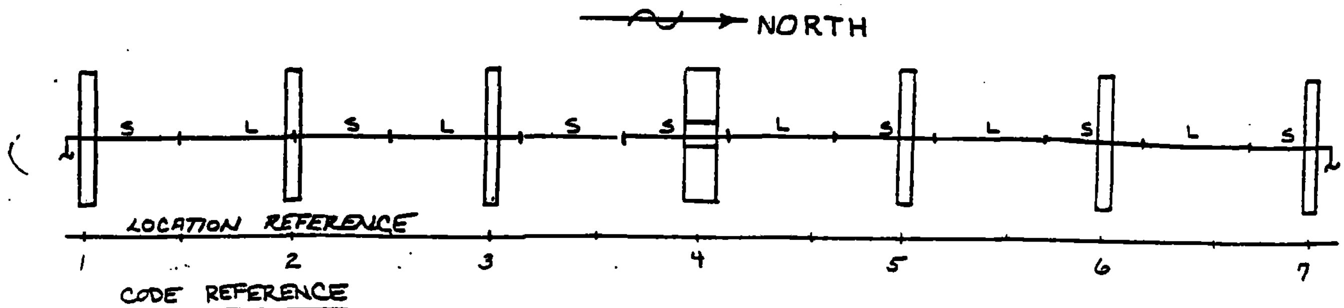
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 58

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
08	9-21-82	1	1/8"	D	✓		11-6-82	SK
		1,2,6,7	COLLARS	R				
11	8-19-83		CONDENSATION IN TRACKER HEAD IS CAUSING FOCUSING PROBLEMS DUE TO MOISTURE	R		✓	10-27-83	DB
11	4-26-84	4	FAILED TO TRACK THE SUN	R	✓		6-7-84	DB



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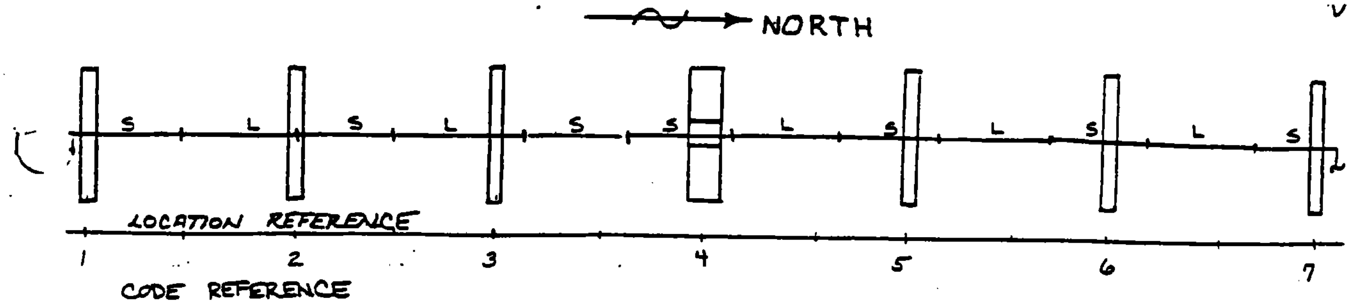
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 59

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
23 21	11-6 1-12-84	1,2,6,7 4 4	COLLARS R 4-WAY VALVE LEAKS AT BASE, "O" RINGS O		• ✓	3-7-84	SK DB
21	3-9-84	4	HYDRAULIC OIL LEAK REPLACED "O" RING UNDER 4-WAY	✓		8-7-84	DB



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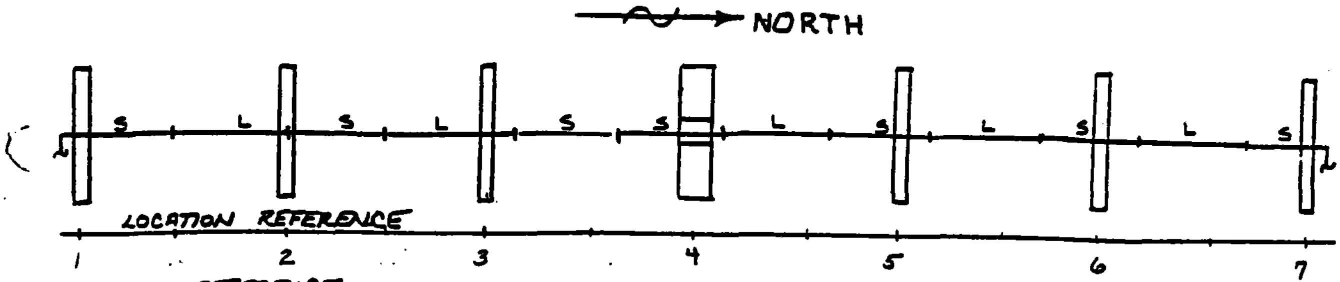
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 60

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
01	9-28-82	3.7	[illegible]		✓	11-6-82	SKI
		1,2,6,7	COLLARS R			-	-
21	6-5-84	4	HYDRAULIC OIL LEAK D				



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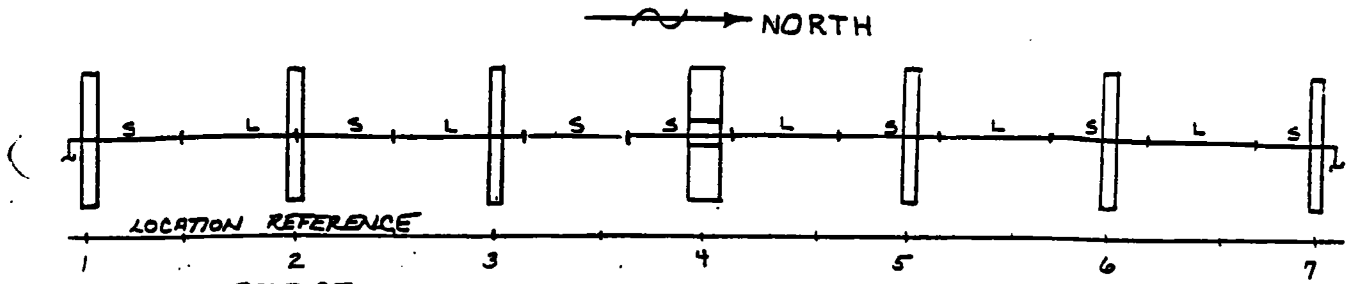
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 61

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
05	9-21	4	D		✓		
08	✓	7	-1/16"	✓			
		4,5,6,7	COLLARS R			11-6-82	SK



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13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

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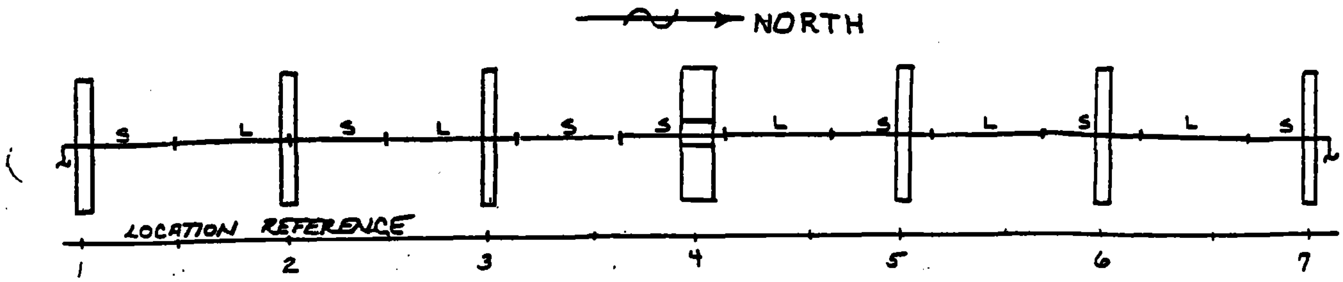
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-62

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-21	1	1/4" D	✓			
07	9-29	1 to 4	9 panels deformed Som		✓	11-2-82	SK
		1,2,6,7	COLLARS R			11-6-82	SK



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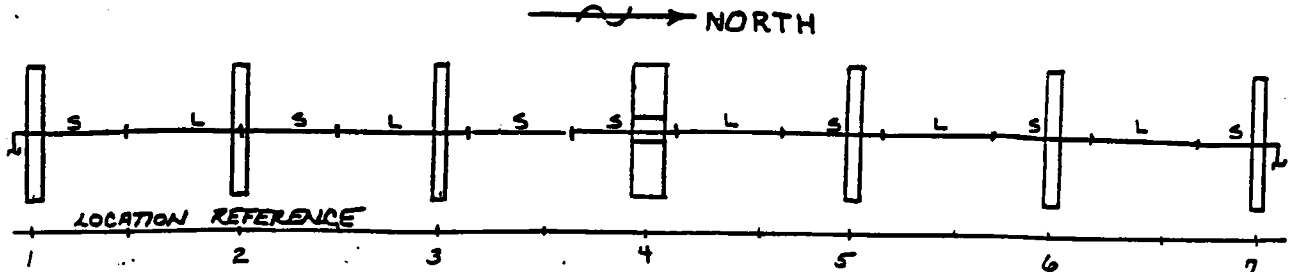
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 63

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-21	1 1,2,6,7	-1/4" COLLARS D R	✓		11-6-92	SK



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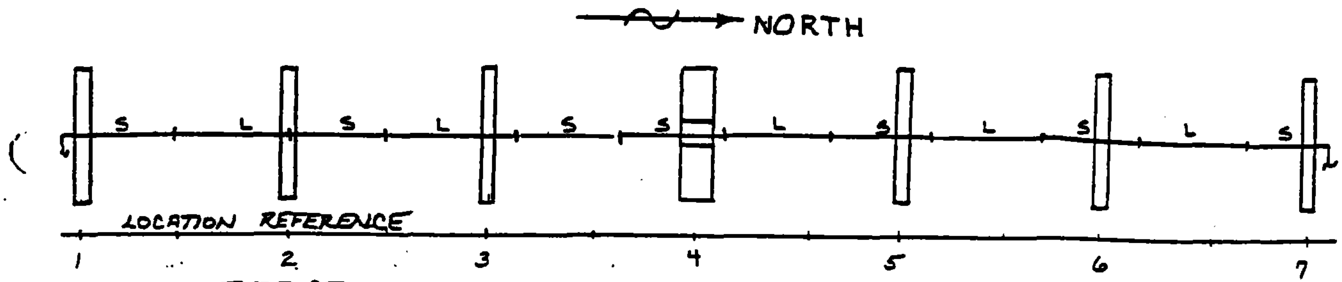
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 64

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-21	1	~1/4" D	✓			
✓	✓	2.1	Ø" HITS - DO NOT OPERATE	✓			
		1,3,4,7	COLLARS R			11-6-82	SK1
12	1-12-84	4	480V TO 120V TRANIFORMER IS BAD D		✓	3-6-84	DBL



V

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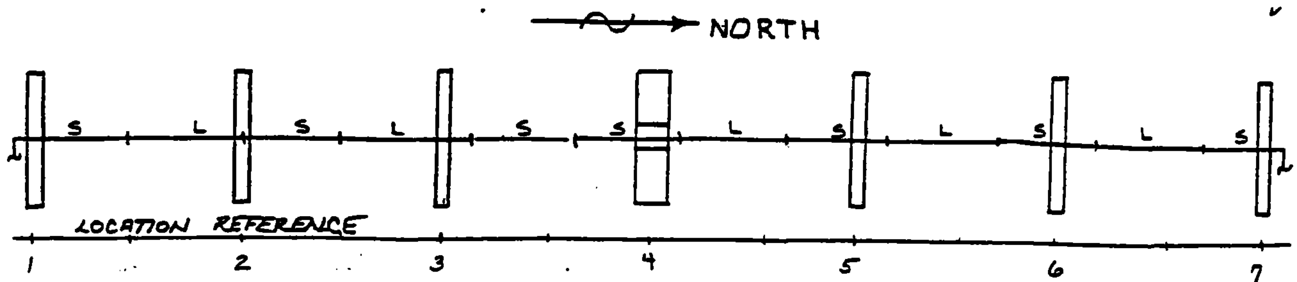
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-65

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SKI
22	9-84	1	VALUE CLOSED FOR WATER LEAK D				
	all month						



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14 - CIRCUIT BOARD PROBLEM

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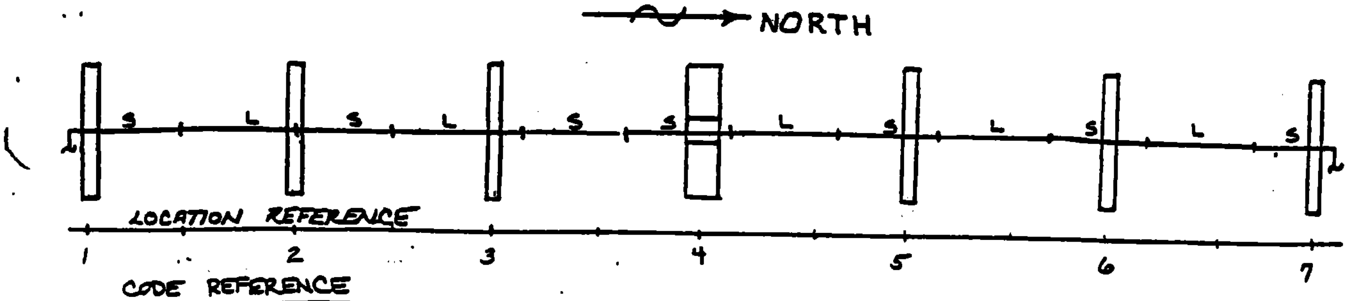
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-66

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-21	1	~3/8" D	✓			
		1,2,6,7	COLLARS R			11-6-82	SK1
21	6-5-84	4	HYDRAULIC OIL LEAK D				
22	9-84	1	ISOLATION VALVE OR "O" RING LEAKS D				

all North



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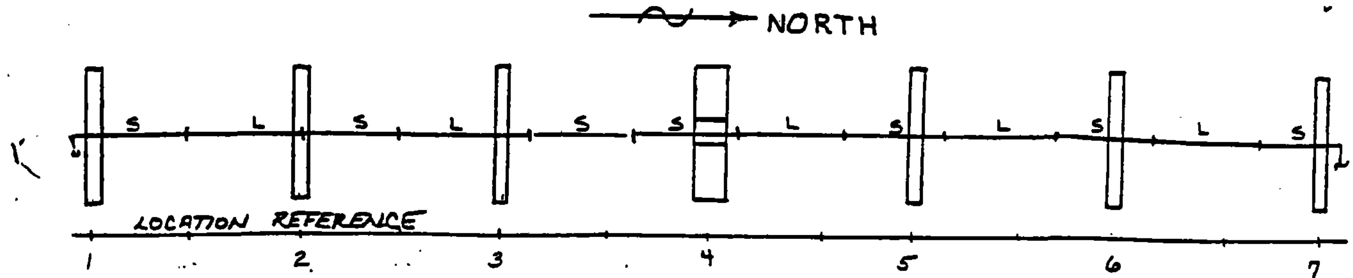
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 67

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
21	10-19-82	04	4 WAY VALVE	D		✓	11-2-82	
		1,2,6,7	COLLARS	R			11-6-82	SKI
13	1-31-83		WEST LIMIT SWITCH OR CIRCUIT BOARD FAILURE	R	✓		2-1-83	RS
13	5-?-83		PUMP START/STOP PRESSURE SWITCH FAILED	RW		✓	6-8-83	DBL
13	3-6-84	4	PUMP DOES NOT STOP AT 1000 PSI	D	✓		3-84	DBL

11-2-82



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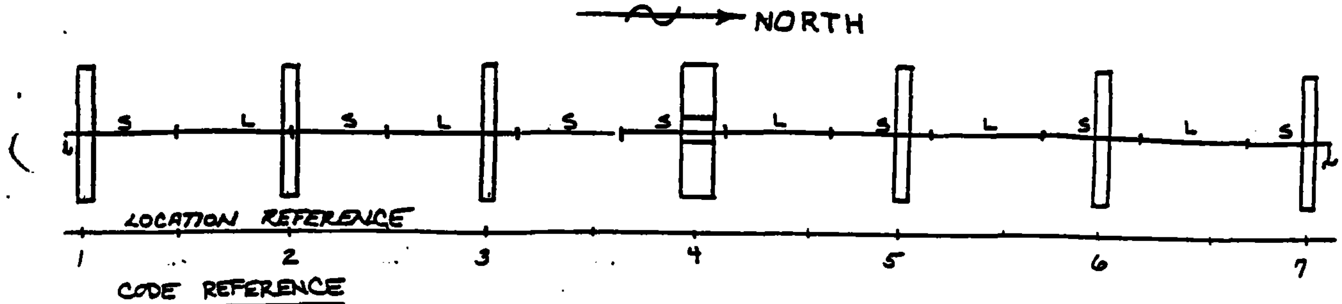
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-68

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
11	9-21	-	TRACKING IS O.K. D			11-2-82	SK1
13	✓	-	BAD SWITCH		✓		
		1,2,6,7	COLLARS (R)			11-6-82	SK1
14	9-84	4	PUMP WONT START D				

all north ?



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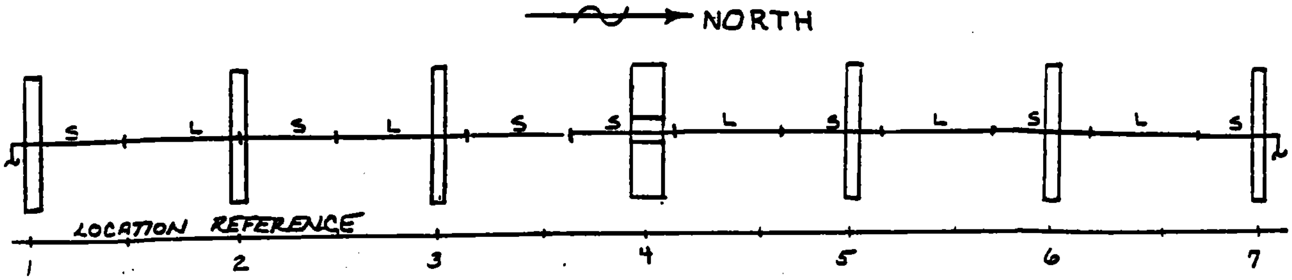
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-69

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
03	9-22	2.5 4,2,4,7	CRACKED & CHIPPED COLLARS (R)		✓	11-6-82	SK1
03	6-6-83	2	SPALLED OR CHIPPED - LEFT OPERATIONAL				
21	7-3-83		HYD. OIL HOSE LEAK LOST ALL HYD. FLUID ON ROOF (D)			1-12-84	DBL
12	2-9-84	4	LOST CONTROL POWER DOWN FACING WEST. CAUSE OF TROUBLE WAS 480V/120V TRANSFORMER (O)		✓	3-7-84	DBL
01	8-16-84	-	BROKEN GLASS D		✓	9-1-84	



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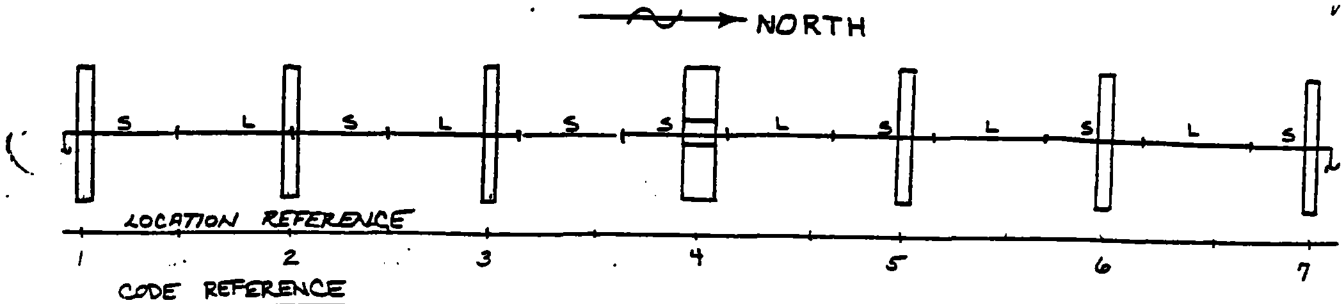
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 70

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
11	11-18-82	1,2,6,7 –	REPLACE BY-PASS COIL COLLARS (R) WILL NOT TRACK PAST 90° - CHECK LIMIT SWITCH SETTINGS (R)			11-6-82	SK
22	9-28-83	—	DOWN DUE TO LEAK IN ROW BH-43		✓	1-13-84	



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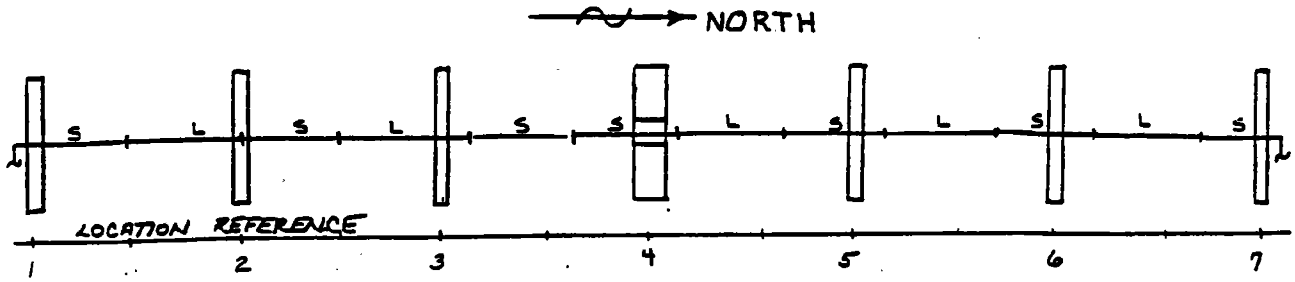
30 - OTHER - EXPLAIN

ROW BH - 71

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
21	9-22	4	SEVERE - ROOF DAMAGE - PRESSURE SWITCH & BULKHEAD FITTING D		✓	11-2-82	SKI
30	"	5	BROKEN MTNG. ARM WASHER		✓		
03	✓	3.3	? - SPIDER WEB - O.K.				
01		1.0	BROKEN END REQUIRES REPLACEMENT R		✓		
25	11-6-82	4.0	ATF LOW R				
		4,2,6,7	COLLARS (R)			11-6-82	SKI
30	9-84	4	WONT SHIFT 4-WAY VALVE D				

all month ?



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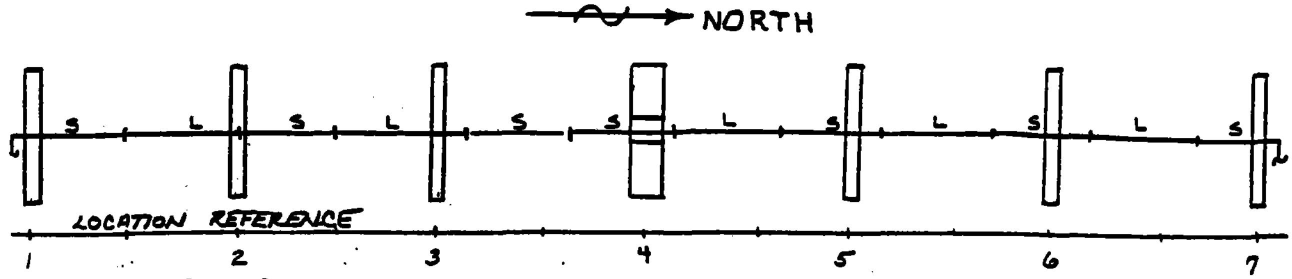
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 72

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
30	9-22	7	SHAFT END TO BEARING ~ 1/4"				
✓	✓	1-7	ALL PYLONS COCKED SOUTH TO AVOID INTERFERENCE CENTER PYLON MAYBE TOO FAR SOUTH.				
30	10-13-82	2.0	TWISTED PYLON				
		1,2,6,7	COLLARS (R)	✓		11-6-82	SK



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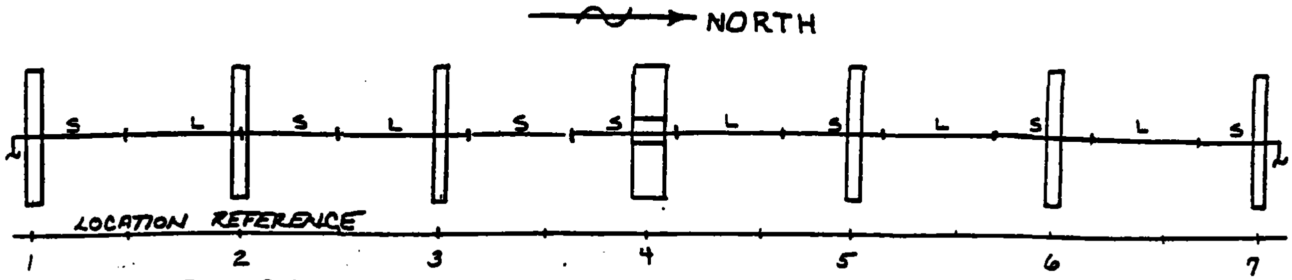
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 73

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
—	9-22	—	3/4" MIN. CLEARANCE - REACTIVATED				
21	10-18-82	04	MINOR TIGHTEN PLUG ON TANK	✓			
		1,4,6,7	COLLARS (R)			11-6-82	SK
22	4-24-84	-	DOWN DUE TO LEAKS IN ROW BH-51	✓	✓	6-7-84	S.R.I
22	8-16-84	-	WATER LEAK AT "O" RINGS		✓	9-1-84	



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06 - MIRROR DAMAGE - SEVERE
07 - - MINOR
08 - INTERFERENCE - GIVE CLEARANCES

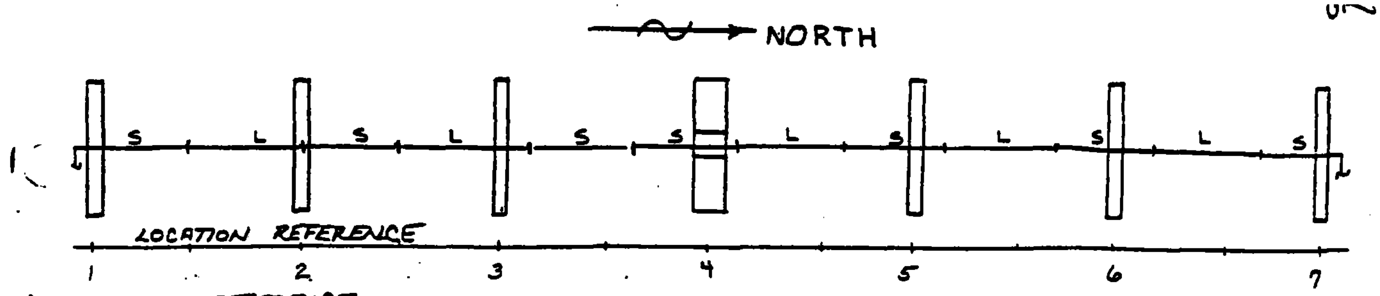
11 - TRACKING PROBLEM
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 74

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
30	9-22	— 1,2,6,7	ELECTRICALLY DEAD - BY PASS COIL SHORTED COLLARS D (R)	—	✓	11-6-82	SK



CODE REFERENCE

01 - TUBE BROKEN - SHORT (S)
02 - - LONG (L)
03 - TUBE DEFECT - SHORT
04 - - LONG
05 - SUPPORT BRACKET BROKEN
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07 - - MINOR
08 - INTERFERENCE - GIVE CLEARANCES

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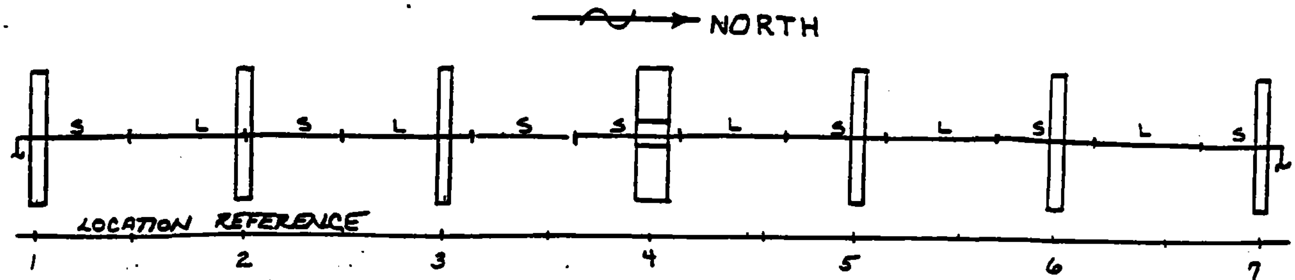
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 75

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-22	7	~1/2" D				
		1,2,6,7	COLLARS (P)			11-6-82	SK1
-	11-11-82		BLOWN 6/10 A FUSE - REPLACED W/ 1 A FNA-1 (R)		✓	11-11-82	[illegible]
21	4-25-84	4	HYDRAULIC SEAL LEAK D		R	8-84	DBL



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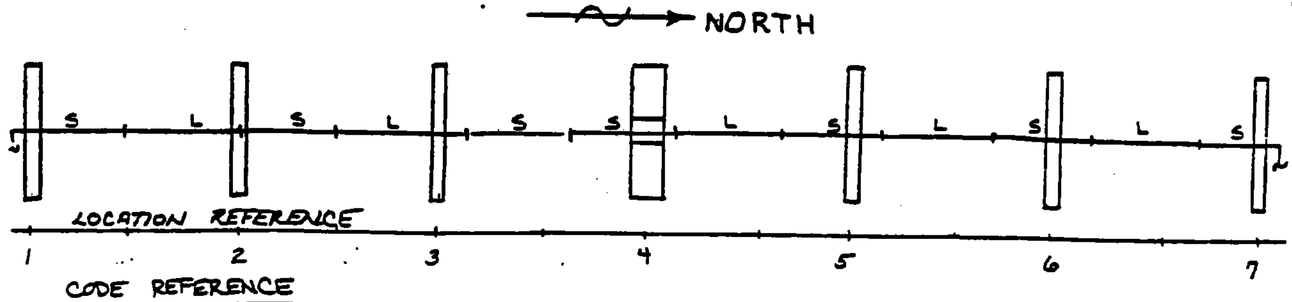
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 76

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
13	4-7-83	1,2,6,7	COLUMNS R EAST LIMIT SWITCH IS OUT OF ADJUSTMENT ROW LEFT UP	YES		11-6-82 4-14-83	SK DB

V



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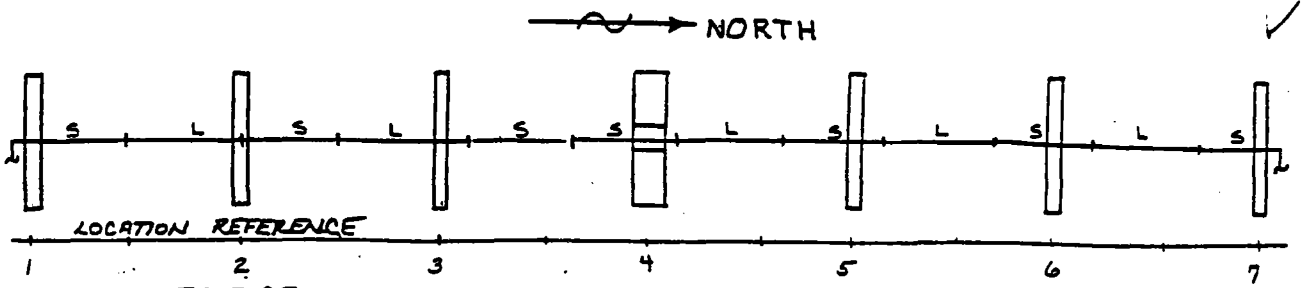
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 77

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS	R			11-6-92	SK1
22	9-84	1.5	"O" RING AT BRACKET LEAKS (8-16)	(D)				
02	9-84	6.5	GLASS BROKEN (8-16)	(D)				
	all North							



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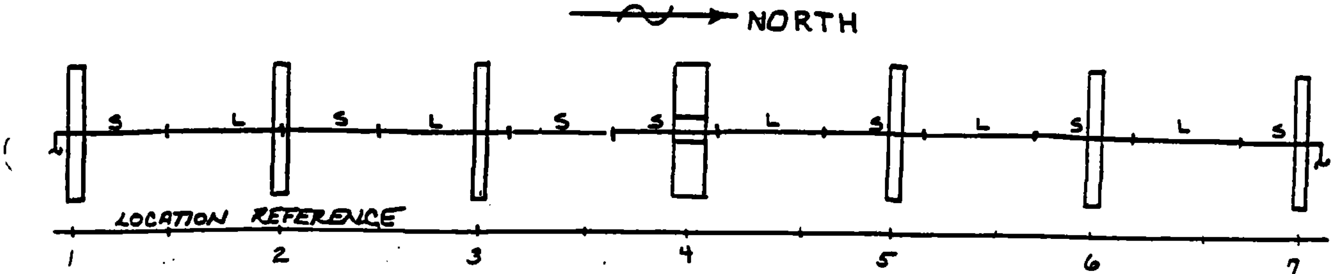
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 78

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
02 05 21	9-22 – 10-18-82	4.1 4 04	D MINOR - NONE FOUND	✓ ✓			
 21 21	 3-8-84 9-84	1,2,(,7 4 4	COLLARS R ~~PUMP SEAL FAILED~~ "O" RING BTWEEN PUMP BODY & BLOCK FAILED • MOTOR COUPLING (SHAFT) RUSTED OUT D NEW HYDRAULIC LEAK		 ✓	11-6-82 8-9-84	SK1 DBL
						all Month?	



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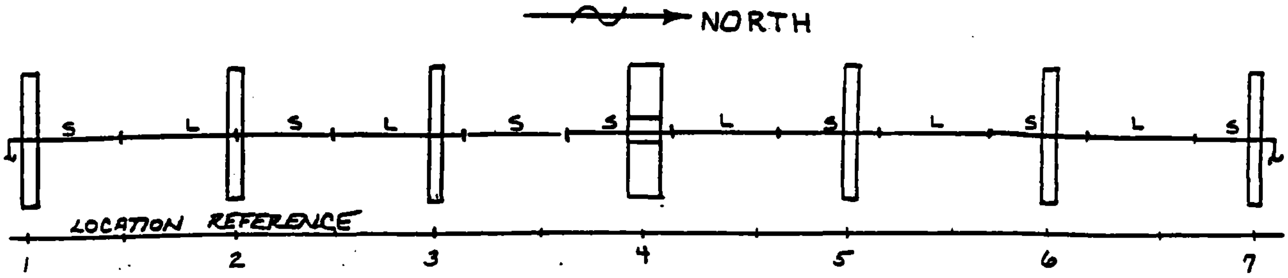
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 79

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,3,6,7	COLLARS R	✓		11-6-82	SK



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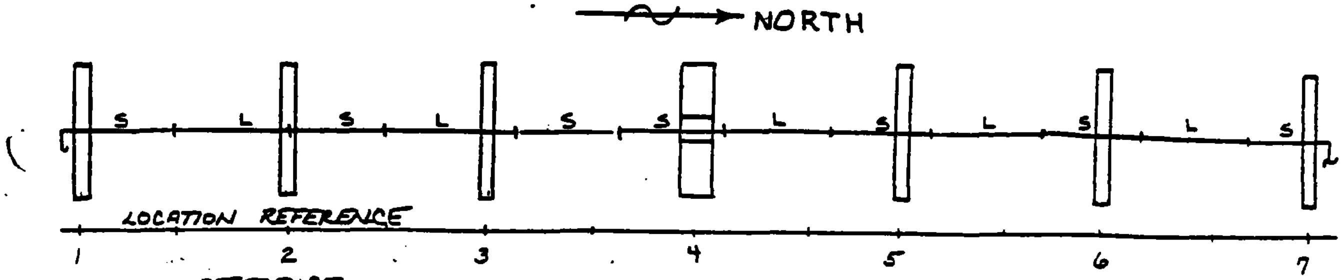
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-80

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
05	9-22	4 1,2,6,7	NO TUBE DAMAGE D COLLARS R		✓		



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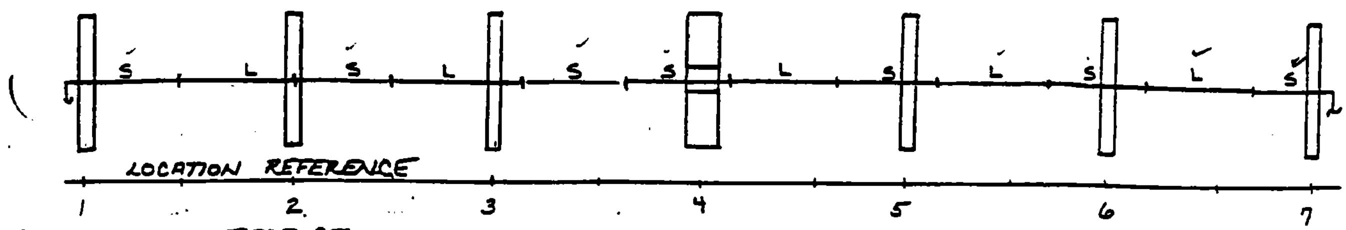
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 81

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
07	9-22	4.9	LEFT AS IS				
08	✓	7	-5/8" MIN. - REACTIVATED				
03	✓	1.5	CRACKED		✓		
21	✓	4	MINOR - TIGHTEN PLUG COLLARS	✓		11-6-82	SKI
14	4-7-83	1,2,6,7	24V TRANSFORMER APPEARS DEFECTIVE - ROW DOWN	✓		5-10-83	DBL
03	6-6-83	1	SPALLED OR CHIPPED GLASS - LEFT OPERATIONAL				

→ NORTH



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23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

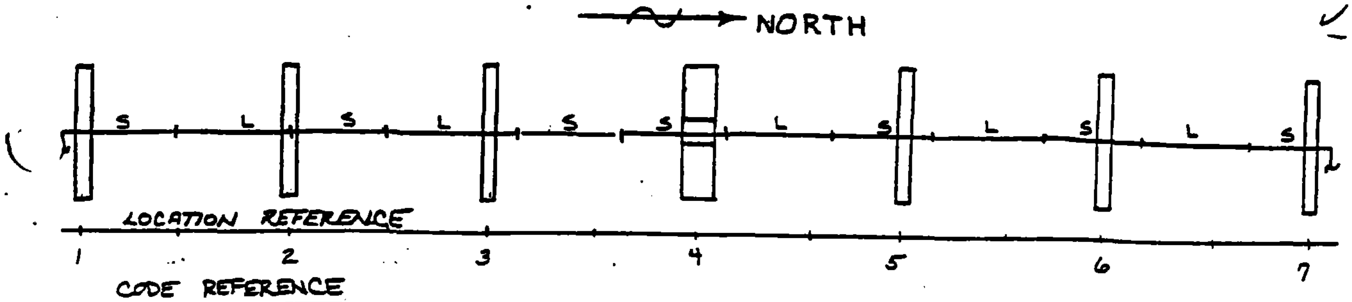
30 - OTHER - EXPLAIN

ROW BH-82

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
01	9-22	6.9		D		✓	11-4	SKI
03	–	5.9	OVERHEATING DEFORMATION & DISCOLOR			✓		
04	✓	5.2	– – –			✓		
03	✓	4.9	– – ✓		–			
04	–	4.1	– – ✓		–			
03	–	3.9	– – –			✓		
03	–	3.1	– ✓ ✓			✓		
04	–	2.9	✓ ✓ ✓		–			
03	–	2.1	✓ ✓ ✓			✓		
04	–	1.9	✓ ✓ ✓		–			
03	–	1.1	– ✓ ✓ CRACKED			✓		
		6.5	BROKEN IN INSTALLATION OF CLAMPS	R		✓		
		1,2,6,7	COLLARS	R			11-6-82	SKI
13	6-7-84	4	WONT UNSTOW, TEMP SWITCH FAILURE	D				

dll month?

11-5-82 R



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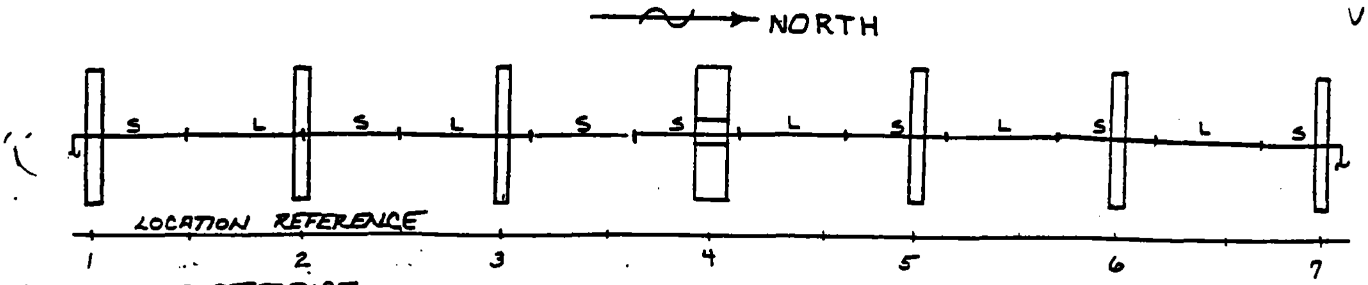
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 83

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
08	9-24	5.9	~1/2"	D				
"	"	2.9	~1/2"					
		1,2,6,7	COLLARS	R			11-6-82	SK
21	3-9-84	4	HYDRAULIC LEAK		✓		6-7-84	DBL
21	7-84	4	" "	D				

all Month?



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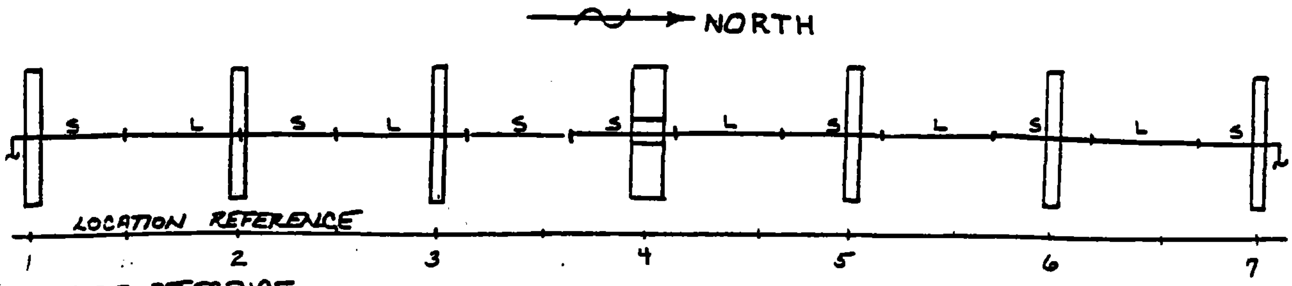
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-84

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
21	9-24	—	TIGHTENED FLEX HOSE	✓			
02	11-2-82	1,5	BROKEN END - UNDER CLAMP.		✓	11-2-82	SKI
		1,2,6,7	COLLARS (R)			11-6-82	SKI
21	7-3-83	4	HYDRAULIC OIL LEAK LOST MOST OF THE OIL	(R)		2-9-84	DBL
21	2-9-84	4	HYDRAULIC OIL LEAK AT LOWER CYLINDER ROD SEAL D				



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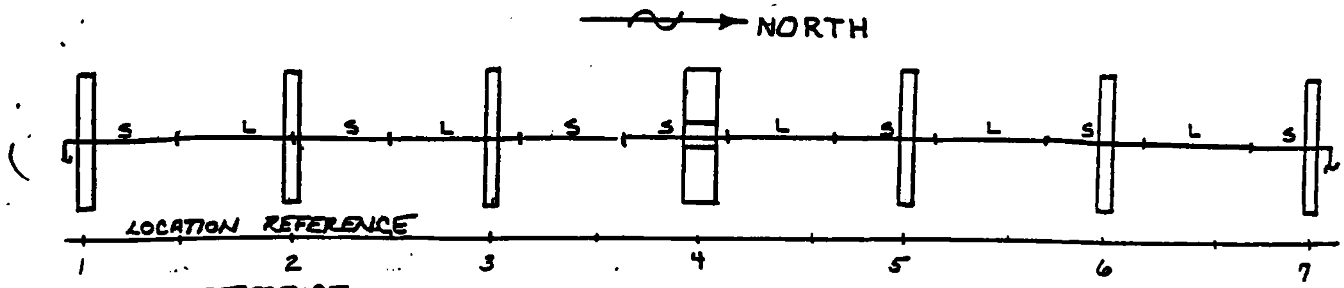
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 85

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
21	9-24	-	TIGHTEN PLUG D				
08	″	5,1	1/8"				
24	″	4	DOES NOT CUT-OFF -. O.K.				
		1,2,6,7	COLLAR R			11-6-92	SK



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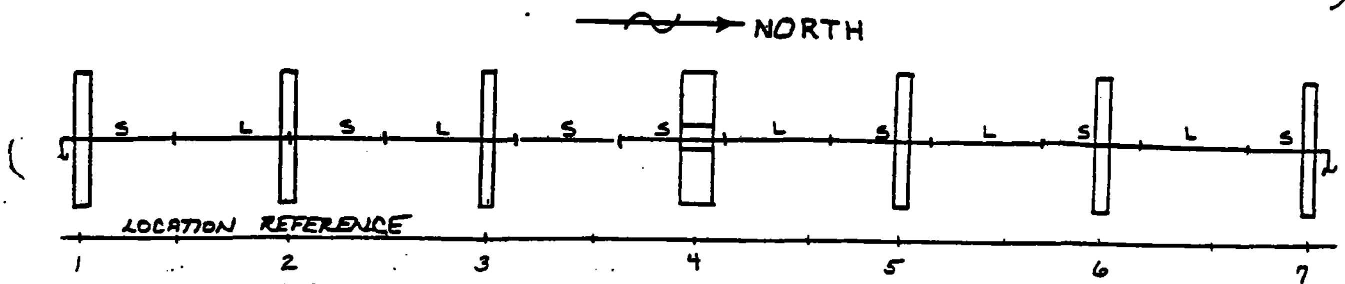
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-86

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
~~13~~	~~3-9-8?~~	1,3,6,7 ~~4~~	COLLARS R ~~HIGH TEMP SWITCH FAILED~~ ERROR ~~D~~	✓		11-6-82	SKI



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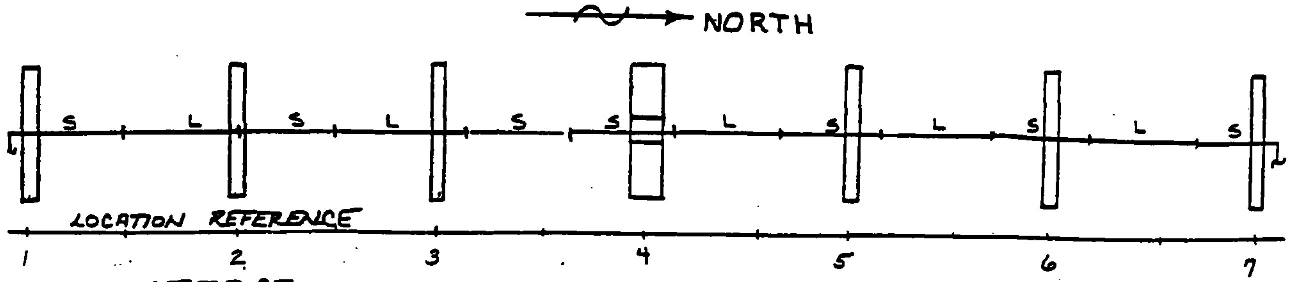
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 87

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
23	9-24	4	SLOW TRACKING - BURNED OUT MOTOR RELAY ON BOARD		✓		
			REPLACED O/L RELAY ON STARTER		✓		
23							
30	9-84	1,2,6,7	CALLARS WONT TRACK FROM STOW R D			11-6-82	SK1

All Month?



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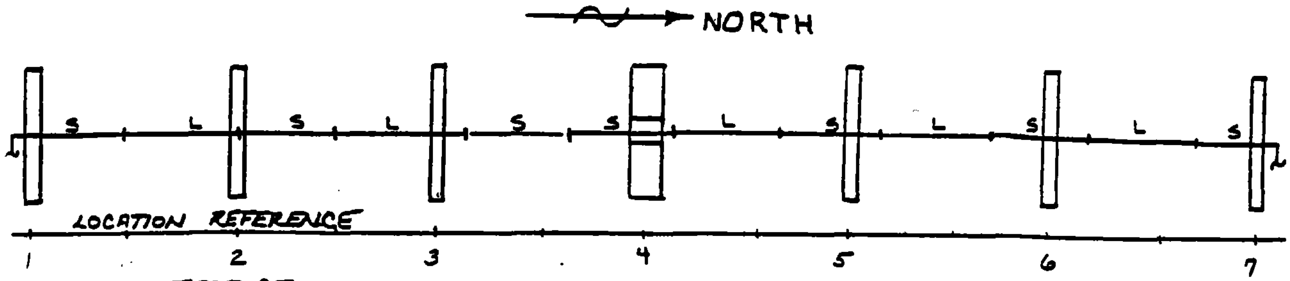
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 88

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SKI
13	3-9-84	4	HIGH TEMP. SWITCH FAILED D				
22	9-84	7	DOWN AND VALVE SHUT FOR ROW BH 66 O				
			all month				



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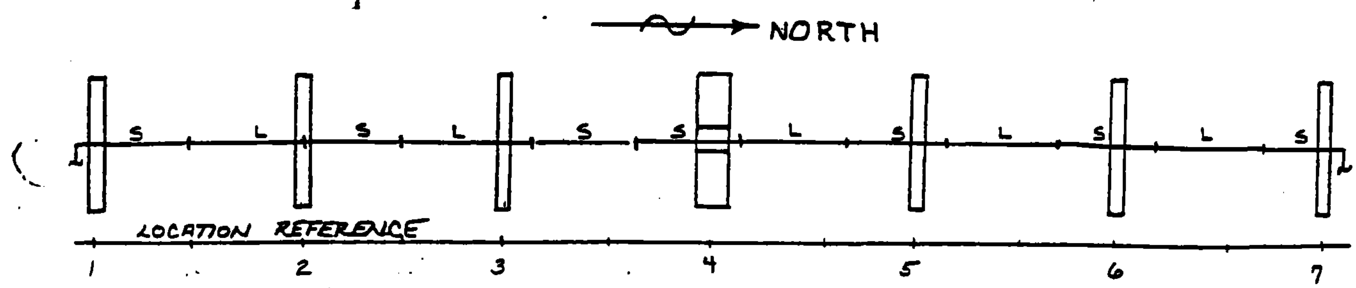
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-89

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
		1,2,6,7	COLLARS R			11-6-82	SK



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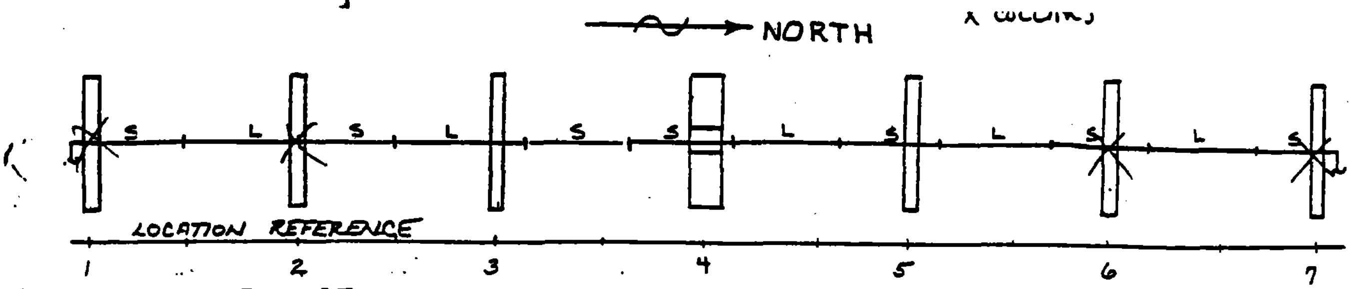
30 - OTHER - EXPLAIN

ROW BH - 90

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-24	5.1	~1/4" D				
✓	✓	2.1	~1/4"				
✓	✓	1	~1/4"				
	9-29		Very Slow Moving SBM - ADJ. TRACK SPEED	✓			
		1,2,6,7	COLLARS (R)			11-6-82	SKJ
21	9-~~84~~	4	HYDRAULIC LEAK D				

all month



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24 - PUMP PROBLEM
25 - LOW HYD. FLUID

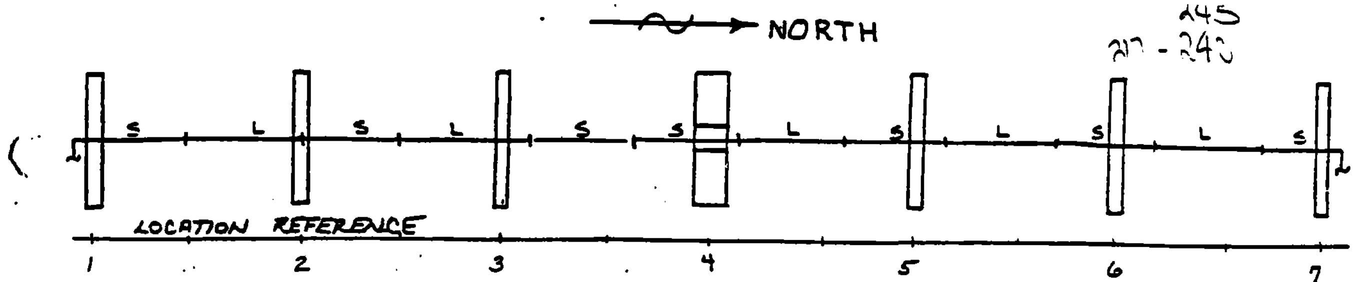
30 - OTHER - EXPLAIN

ROW BH - 91

CODE	DATE	LOCATION	DOWN REMARKS		REPAIR	REPLACE	DATE	INITIALS
01	9-22	3.5	DUE TO BROKEN BRACKET SPOT WELD	D	✓	✓	10-19-82	SKI
05	"	4.0			✓	–	✓	✓
08	"	1-9	½"					
		7.0	INSTALL COLLAR				10-21-82	(R)
		6.0	INSTALL COLLAR				✓	(R)
		5.0	ADJUST SOUTH, 7/8 @ 5.1 ; 1" @ 4.9		✓		✓	(R)
		2.0	ADJUST SOUTH INSTALL COLLAR		✓		✓	(R)
		1.0	INSTALL COLLAR	(R)	✓		✓	(R)
14	9-84	04	BOARD IS BAD	D			all mon	

10-21-82

245
217 - 240



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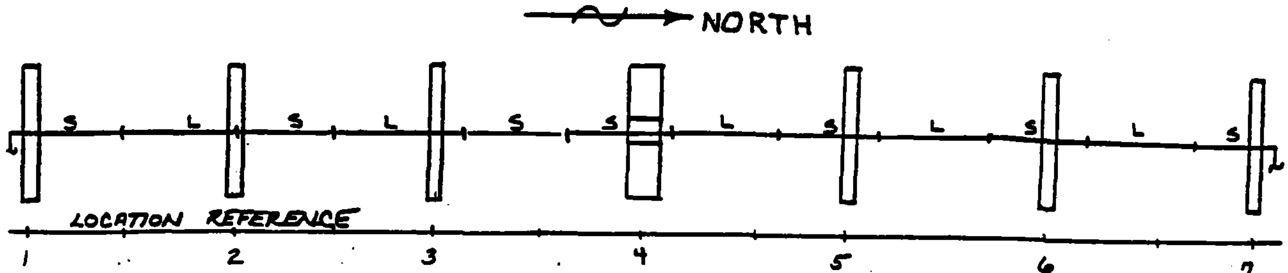
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 92

CODE	DATE	LOCATION	RUNNING REMARKS		REPAIR	REPLACE	DATE	INITIALS
	9-22		CLEANED WITH A SPONGE & SQUEEGE					
		1,2,4,7	COLLARS	(R)			11-6-82	SK
12	1-28-83	04	BLOWN FUSE ON CONTROL TRANS. ROW DOWN	D				
	3-7-83	04	SHORTED BY-PASS SOLENOID COIL REPLACED. ROW UP	R		X	3-7-83	DBL
11	9-84	04	TRACKER HEAD WONT WORK	D				
21	9-84	04	HYDRAULIC BY PASS VALVE IS MISSING	D				
22	9-84	01	ORING AT NOSE TO PIPE JOINT LEAKS	D				
			all month					



CODE REFERENCE

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07 - - MINOR
08 - INTERFERENCE - GIVE CLEARANCES

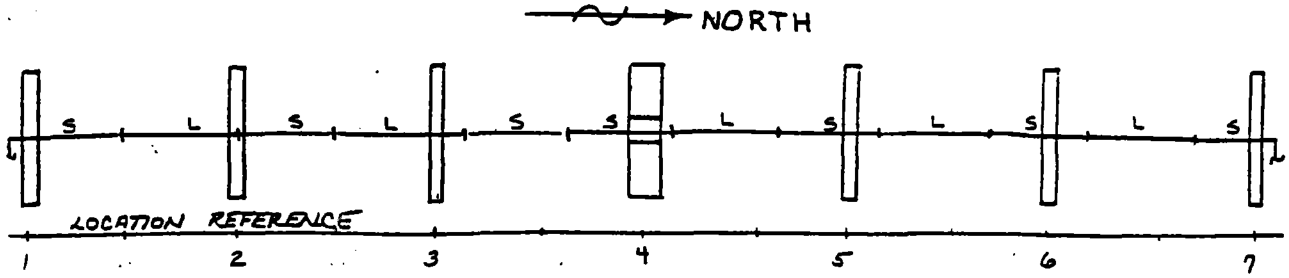
11 - TRACKING PROBLEM
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 93

CODE	DATE	LOCATION	RUNNING REMARKS	REPAIR	REPLACE	DATE	INITIALS
	9-22	1,2,6,7	RUNNING - COLLARS R			11-6-82	SICI



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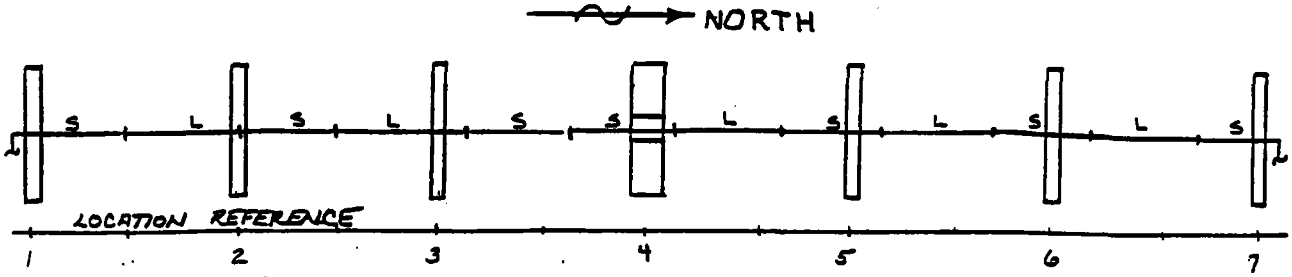
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 94

CODE	DATE	LOCATION	RUNNING REMARKS	REPAIR	REPLACE	DATE	INITIALS
1	9-22-82	1,3,6,7	RUNNING COLLARS R			11-6-82	JK
21	4-14-83		DOWN DUE TO OIL LEAK R	✓		5-10-83	DBL
11	5-10-83		DOWN DUE TO TRACKER HEAD FAILURE		✓	10-27-83	DBL



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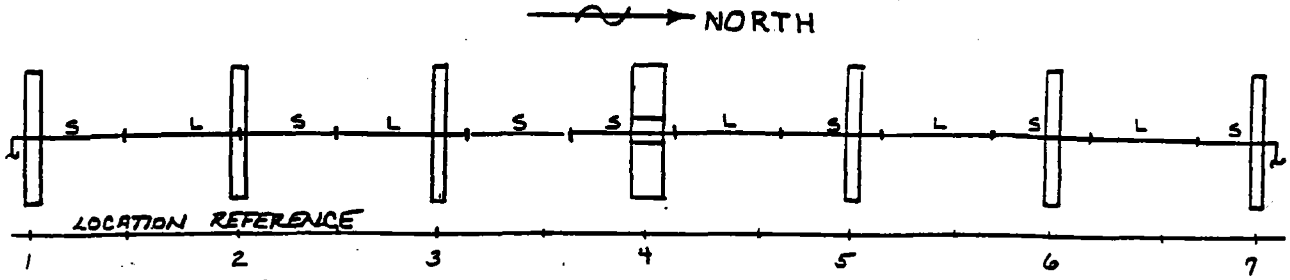
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 95

CODE	DATE	LOCATION	DOWN REMARKS	REPAIR	REPLACE	DATE	INITIALS
08 08 08 08	9-23 " " "	5.1 6.1 1.1 2.1	½", DRIVE PYLON SE[illegible] TO LE[illegible] S[illegible] D 9[illegible]" 5[illegible]" 5/8"				
08	"	3.1 1,3,6,7	3/8" COLLARS R			11-6-82	SKJ



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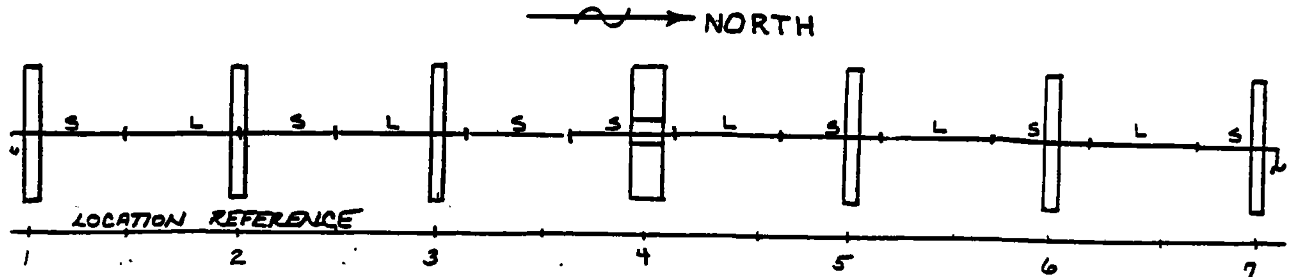
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 96

CODE	DATE	LOCATION	DOWN REMARKS	REPAIR	REPLACE	DATE	INITIALS
30	9-22	6.9 1,2,6,7	3/8" COLLARS D (R)			11-6-82	SKJ



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13 - SWITCH DEFECT
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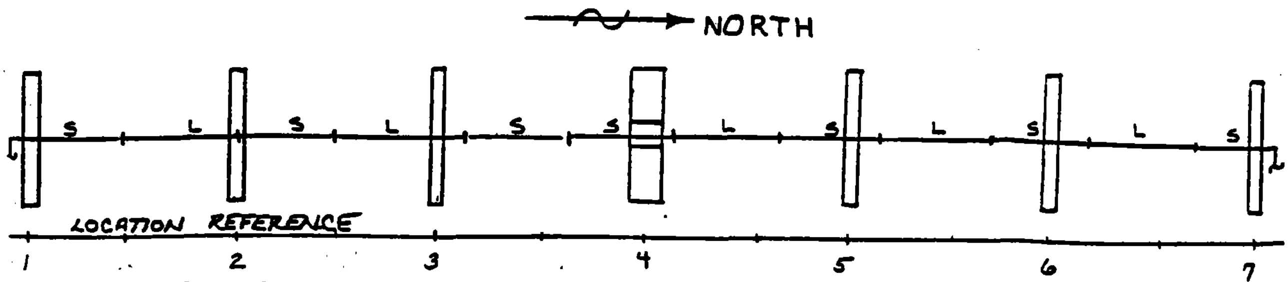
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-97

CODE	DATE	LOCATION	RUNNING REMARKS	D	REPAIR	REPLACE	DATE	INITIALS
	7-22 10-15		VALVED OFF - TUBE OUT @ 105	R		✓	10-19	SKI
		1,2,6,7	COLLARS	R			11-6-92	SK



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13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

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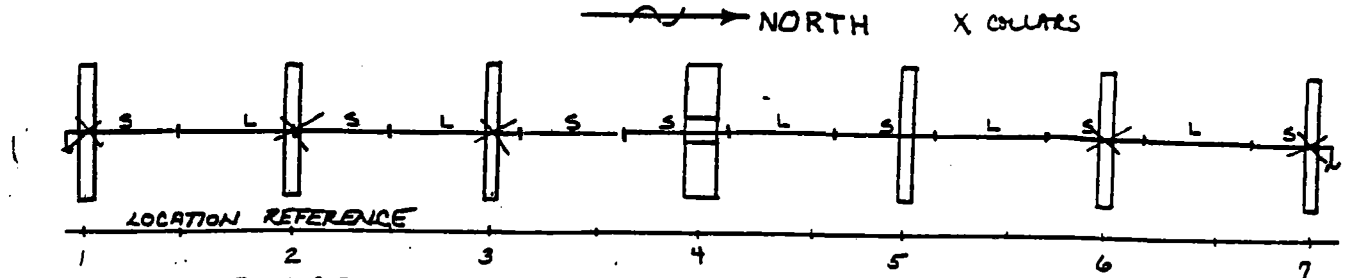
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 98

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
21	7-22	4	MINOR - INSPECTED BY SKI 10-19 FOUND NO LEAKS D	✓			
08	"	6.9	3/3", 5.9 [illegible]				
08	"	2.9	5/8" -				
-		6&7	COLLARS R			11-6-82	SKI



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13 - SWITCH DEFECT
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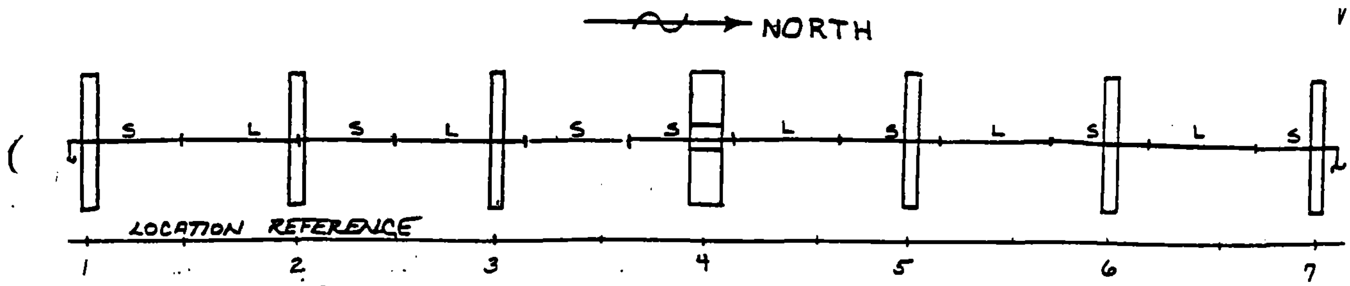
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-99

CODE	DATE	LOCATION	DOWN REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-22-92	2.9	7/16" DOWN - 10/21 ADJUSTED TO NORTH/INSTALL COLLAR D	✓		10-21	[illegible]
02	9-22-92	6.9	1/2" - ADJUST TO SOUTH & INSTALL COLLARS	✓		✓	[illegible]
—	10-15		VALVED OFF/TUBE @ 91 - TURNED ON 10-15 D	✓		10-19	SK
		7.0	INSTALL COLLAR, ADJUST TO NORTH	✓		10-21	[illegible]
-		1.0	INSTALL COLLARS	✓		10-21-92	[illegible]
		2.0	✓ ✓ BRNG CENTERED/NO INTERFERENCE w/ COLLAR, PYLON ADJUSTED TO SOUTH. (R)	✓		✓	[illegible]

10-21-92



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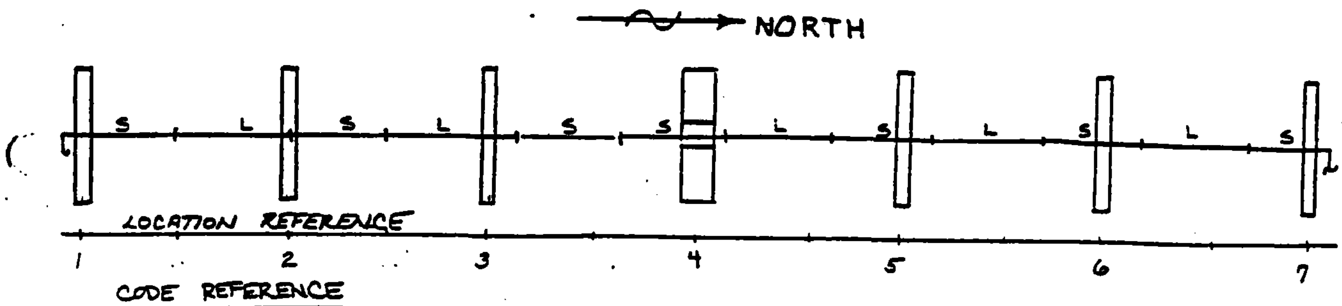
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 100

CODE	DATE	LOCATION	RUNNING REMARKS		REPAIR	REPLACE	DATE	INITIALS
	9-22	2,4,7	RUNNING - CLEANED WITH SPONGE [illegible] COLLARS	(R)			11-6-82	SKJ
30	9-84	7	VALVED OFF DUE TO LEAK ON BH92	D				
			all Month					



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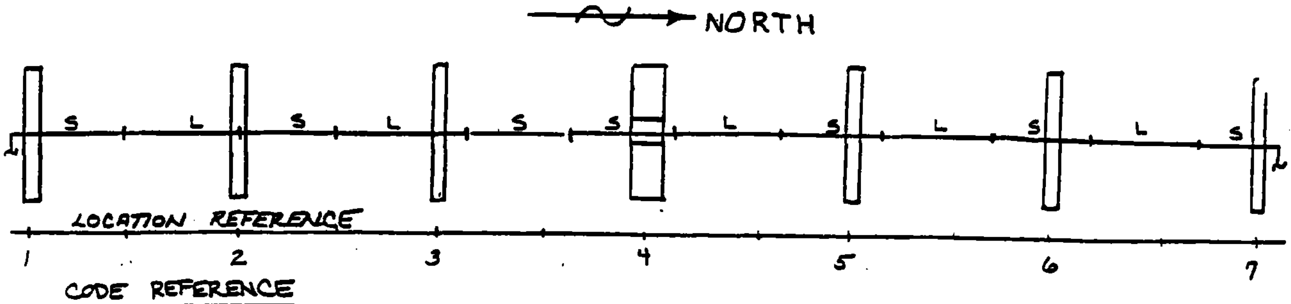
12 - ELECTRICAL SHORT
13 - SWITCH DEFECT
14 - CIRCUIT BOARD PROBLEM

21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 101

CODE	DATE	LOCATION	RUNNING REMARKS	REPAIR	REPLACE	DATE	INITIALS
08	9-22	4.9	BOLTS ARE BACKED OUT INSTALLATION PROBLEM [illegible]	✓		11-2-82	SKI
		1,2,6,7	COLLARS R			11-6-92	SKI



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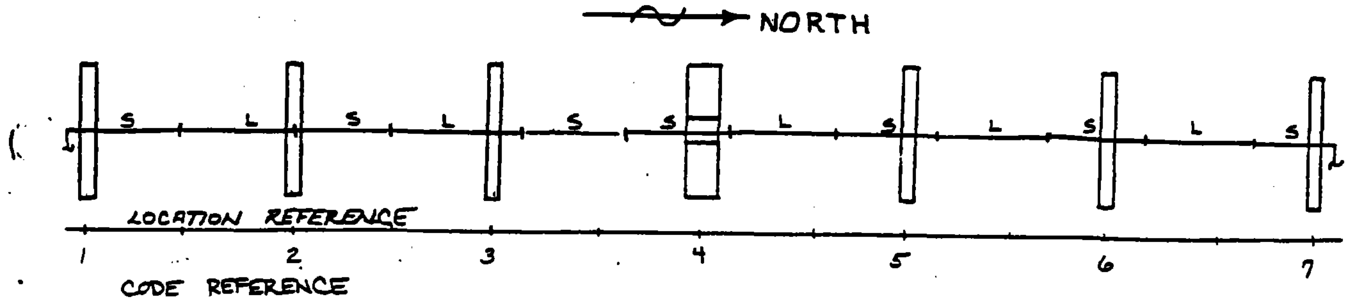
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH-102

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
[illegible]	[illegible]	[illegible]	[illegible]	-		11-2-82	SK
		1,2,6,7	COLLARS R	✓		11-6-82	SK
02	9-84	4,5	BROKEN GLASS ON TUBE (18-16) D				



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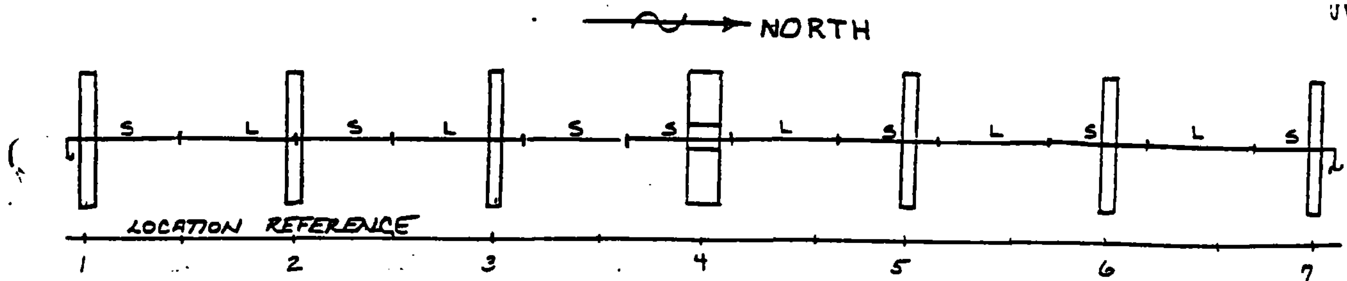
21 - HYDRAULIC LEAK
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 103

CODE	DATE	LOCATION	RUNNING REMARKS	REPAIR	REPLACE	DATE	INITIALS
	9-22	1,2,1,7	RUNNING COLLARS				
01	9-84	7	BROKEN TUBEGLASS (E-16) R D			11-6-92	SK
			all north				



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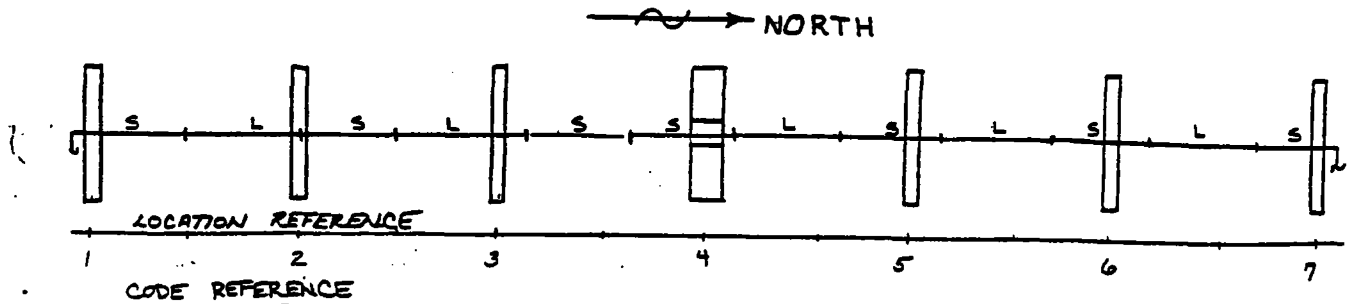
22 - WATER LEAK
23 - ACCUMULATOR LOW
24 - PUMP PROBLEM
25 - LOW HYD. FLUID

30 - OTHER - EXPLAIN

ROW BH - 104

CODE	DATE	LOCATION	RUNNING REMARKS	REPAIR	REPLACE	DATE	INITIALS
21 08	9-22 "	4 2.1	MINOR - NOT FOUND BY SKI - 10-15-82 - FLEX HOSE @ 9/16 DRIVE CYLINDER LEAKING		✓	11-2-82	SKI
02	9-84	1,2,6,7 3	COLLARS (R) BROKEN TUBE 8-16 STILL RUNNING R	✓		11-6-82	SKI
01	9-84	7	" " " " " R				
			all Month.				

11-2-82



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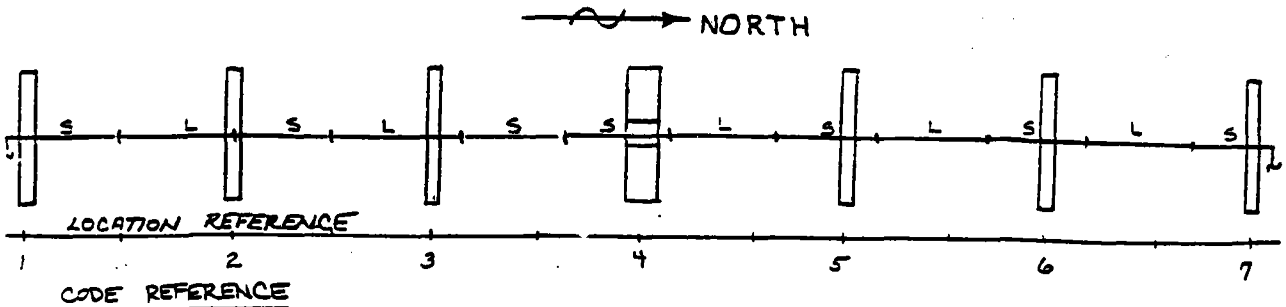
30 - OTHER - EXPLAIN

ROW BH - 105

CODE	DATE	LOCATION	REMARKS		REPAIR	REPLACE	DATE	INITIALS
02	9-22	1.8	DUE TO 7/16 CLEARANCE PROBLEM AT LOCATION	D		✓		
06	"	1.0 TO 3.9	MEASURED COLD @ 0930.			✓	11-2-82	SKI
30	10-19	1.0	BEARING CAP OFF		✓			
			REPLACE MIRROR SKINS			✓		
	10-26		FOCUS PROBLEM / ENTIRE TUBE LENGTH — NOT REPAIRABLE			—		SKI
08	11-2	1.0	7/16 CLEARANCE	D				
		1,2,6,7	COLLARS	R			11-6-82	SKI
21	3-8-84	7	"O" RING BLEW OUT UNDER 4-WAY VALVE. ALSO PUMP SEAL LEAKED. REPLACED BOTH			✓	3-8-84	DBL



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30 - OTHER - EXPLAIN

ROW BH - 106

CODE	DATE	LOCATION	REMARKS	REPAIR	REPLACE	DATE	INITIALS
30	7-72		CON[illegible] HAS BEEN PULLED FOR [illegible] POTENTIAL [illegible] SHOULD BE CHECKED [illegible]				
			REPLACE CPTx - RAN FOR 2-3 DAYS - CLEARANCE PROBLEMS		✓	11-2-82	SKI
		1,4,6,7	COLLARS D R			11-6-82	SKI
21	9-84	4	HYDRAULIC LEAK D				