NREL/TP-471-20313 • UC Category: 1302 • DE96007879

A Performance Data Network for Solar Process Heat Systems

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*Prepared for ASME's Solar Engineering 1996,
March 31-April 3, 1996
San Antonio, Texas*

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1617 Cole Boulevard
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A national laboratory of the U.S. Department of Energy
Managed by the Midwest Research Institute
for the U.S. Department of Energy
Under Contract No. DE-AC36-83CH10093

Prepared under Task No. SI51.2020

March 1996

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A PERFORMANCE DATA NETWORK FOR SOLAR PROCESS HEAT SYSTEMS

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ABSTRACT

A solar process heat (SPH) data network has been developed to access remote-site performance data from operational solar heat systems. Each SPH system in the data network is outfitted with monitoring equipment and a datalogger. The datalogger is accessed via modem from the data network computer at the National Renewable Energy Laboratory (NREL). The dataloggers collect both ten-minute and hourly data and download it to the data network every 24-hours for archiving, processing, and plotting. The system data collected includes energy delivered (fluid temperatures and flow rates) and site meteorological conditions, such as solar insolation and ambient temperature.

The SPH performance data network was created for collecting performance data from SPH systems that are serving in industrial applications or from systems using technologies that show promise for industrial applications. The network will be used to identify areas of SPH technology needing further development, to correlate computer models with actual performance, and to improve the credibility of SPH technology. The SPH data network also provides a centralized bank of user-friendly performance data that will give prospective SPH users an indication of how actual systems perform.

There are currently three systems being monitored and archived under the SPH data network: two are parabolic trough systems and the third is a flat-plate system. The two trough systems both heat water for prisons; the hot water is used for personal hygiene, kitchen operations, and laundry. The flat plate system heats water for meat processing at a slaughter house. We plan to connect another parabolic trough system to the network during the first months of 1996. We continue to look for good examples of systems using other types of collector technologies and systems serving new applications (such as absorption chilling) to include in the SPH performance data network.

INTRODUCTION

Researchers from the US Department of Energy's Solar Industrial Program have created a solar process heat (SPH) performance data network that remotely downloads and archives data from selected solar heat systems. We began developing the network software in the fall of1994. Shortly after the initial software development, we connected the first SPH system to the data network. During 1995 software refinements were completed and two additional SPH systems were connected to the data network. This paper reports on data network software, the systems in the data network, and our future plans for the expansion of the data network.

DATA NETWORK OBJECTIVES AND USES

The SPH performance data network was created for collecting performance data from SPH systems that are serving in true industrial applications or from systems using technologies that show promise for higher temperature industrial applications. This information is needed to document areas in SPH that need further development, to correlate computer models to actual performance, and to improve the credibility of SPH technology. The SPH data network was designed to simplify and improve the accuracy and reliability of data collection.

The main purpose of the performance data network is to analyze how well specific SPH systems can meet industry's needs for high energy production and a high delivery temperature. By using performance data and measured property values, we can pinpoint the areas where the technology needs to improve and determine how the degradation of specific system components affects the behavior of the SPH system. Understanding the actual performance of these types of systems is essential to the credibility and advancement of SPH technology. The SPH data network provides a centralized bank of user-friendly performance data to present to prospective SPH technology users giving them an indication of how actual SPH systems perform.

The SPH data network can also be used to correlate performance models with a system's actual performance. Performance models are necessary tools that can help develop SPH system technology and to size projects. However, there are often large discrepancies between a SPH system's modeled and actual performance. The SPH data network collects current, reliable performance data to validate the models.

Many large-scale SPH systems are already being monitored by their owners or designers; however, the data is often difficult to use and sometimes inconsistent. The SPH data network uses a standard set of monitoring equipment, ensuring consistent data quality and providing identical data formats for all sites. This consistency allows for easy comparison of performance between different sites and minimizes problems caused by accommodating the idiosyncrasies of different data collection equipment and system configuration. Monitoring through the SPH data network also lends credibility to the collected data because the SI program has no interest in showing that one system performs better than another. The collected data is also not proprietary and is for public use.

COLLECTED DATA

For each system monitored, the data network collects the temperatures and flows required to determine the energy delivered by the system, the site insolation, and ambient temperature. When situations allow, we use a standardized set of data collection points, mounting techniques, and equipment. Table 1 lists the monitoring instruments we have chosen to be the standard equipment package for the data network. Our equipment decisions were based on accuracy, reliability, cost, and practicality. Table 1 also lists the manufacturer specified accuracies for the monitoring instruments. Instruments with comparable specifications and accuracy could be used in place of the ones listed.

Delivered Energy

The most important data collected at each site are the readings used to calculate the energy delivered by the solar heat system. This is the parameter that reveals how well the SPH system is performing relative to its design predicted performance, and it can be used to determine the real cost of delivered solar energy.

The real-time delivered energy is calculated by a datalogger using the load-side flow rate and temperature increase across the heat exchanger. We use a thermopile for the load-side temperature-difference measurement. The advantage of this type of measurement over other methods, such as RTDs or thermistors, is that the thermopile by definition measures a temperature *difference*; if the reference temperature drifts for some reason, the temperature difference is still measured accurately.

Our goal is to use a completely standardized monitoring equipment package for all data network systems, but because the first systems in the data network were existing systems, this was not possible. When instrumenting an existing system, it is not always practical to install the complete equipment package or install the equipment in the most desirable way. For example, it is best to measure fluid temperatures using thermal wells inserted in the pipes. However, installing thermal wells involves shutting down the system and cutting the pipes. When faced with this situation, we have instead attached the eight junctions on each end of the thermopile around the surface of the pipes and used thermally conductive grease between the sensors and the pipe surface. We then wrapped several inches of insulation around the junctions and pipe. The error introduced by this mounting technique is examined below.

It can also be impractical to use the flow meter in the standardized monitoring equipment package (Table 1). The three systems currently in the SPH data network were already being monitored prior to being incorporated in the network. We elected to use the previously installed flow meters for the data network flow measurements. Although this de-standardized the monitoring equipment package for all three systems, the specified accuracies for the previously installed flow meters exceeded the accuracy specification for the flow meter in Table 1.

The first SPH system to be included in the network - a trough system at the Adams County jail in Colorado - has a turbine flow meter (model no. FTB 6115) with a manufacturer's (Omega Engineering, Inc.) accuracy specification of 1.5% of reading. We

Table 1. Instruments in Standard Monitoring Package

Description	Measurement	Manufacturer	Model / Cat. #	Accuracy
Datalogger	data acquisition	Campbell Scientific, Inc.	CR10	0.1% of reading
Paddle-wheel flow sensor	load-side flow rate	Omega Engineering, Inc.	FP-3-1500-2	0.2 fps
Type T thermocouple	absolute temperature	Omega Engineering, Inc.	TT-T-22S	0.2 °C
Type T 8-junction thermopile	temperature difference	MEP	NA	0.025 K
Reference thermistor	thermocouple reference temperature	Campbell Scientific, Inc.	10TCRT	0.2 °C
Pyranometer	global horizontal insolation	Licor, Inc.	LI200SZ	3% FSR
Plate-type radiation shield	radiation shield for outdoor temperature sensor	Campbell Scientific, Inc.	41004	N/A
Current-sensing solid-state relay	solar pump on/off status	Veris, Inc.	H908	N/A

mounted the thermopile for the network temperature difference measurements at this site on the outside of a 0.15 m steel pipe using the previously described method.

We were interested in knowing the uncertainty associated with the data network energy delivery measurements to ensure the integrity of the collected data. Because the three systems currently in the data network have slightly different temperature sensor mountings and different types of flow meters, the energy measurements for each system have a slightly different uncertainty. In this document, we calculate the bias uncertainty (based on manufacturers' equipment specifications) for the SPH system at the Adams County jail.

We calculated the uncertainty in the energy delivered measurement based on a typical hourly measurement at the Adams county facility. The two parameters from the energy delivered equation ($Q = mc_p(T_2 - T_1)$) we considered as affecting the bias error propagation were the mass flow rate and the temperature difference. The flow rate errors taken into account in the calculation were associated with the specified accuracy of the flow meter and the datalogger. The temperature errors accounted for the calculation were associated with the specified accuracies for the thermopile and datalogger and mounting the thermopile on the outside of the pipe.

The absolute temperature measurement will have a bias error caused by the temperature difference between the surface of pipes and the fluid, but as long as the flow is turbulent, the bias in the temperature difference measurement is acceptably small. For a conservative estimate of the error introduced by surface-mounted temperature sensors, consider the following worst-case, but still realistic, scenario. These conditions include a steel pipe (low conductivity) with sensors attached to the outside surface of the pipe and insulated with 10 centimeters (4 inches) of fiberglass. Table 2 gives the specific assumptions we have made for such a scenario.

For a circular duct with fully developed laminar flow and a constant wall temperature, the Nusselt number is assumed equal to 3.66 (1). For flow just fast enough to be in the turbulent regime (Re = 2300), using the Petukhov-Popov equation, the Nusselt number for fluid #1 calculates to be 16.43, and 33.70 for fluid #2 (2, 3).

Figure 1 shows a thermal resistance diagram of the pipe-and-sensor configuration. The thermal resistance diagram leads to the following equation for T_{sensor}, which compares the difference between T_{sensor} and the actual fluid temperature:

$$T_{sensor} = T_{fluid} + \frac{(T_{air} - T_{fluid}) * (R_{fluid} + R_{pipe})}{(R_{fluid} + R_{pipe} + R_{insul} + R_{air})} \qquad (1)$$

where

$$R_{fluid} = \frac{1}{2\pi r_1 L h_{fluid}}, \quad R_{pipe} = \frac{1}{\dfrac{\ln(r_2/r_1)}{2\pi k_{pipe} L}},$$

$$R_{insul} = \frac{1}{\dfrac{\ln(r_3/r_2)}{2\pi k_{insul} L}}, \quad R_{air} = \frac{1}{2\pi r_3 L h_{air}}$$

The resistance values for Eqn. 1 are listed in Table 3.

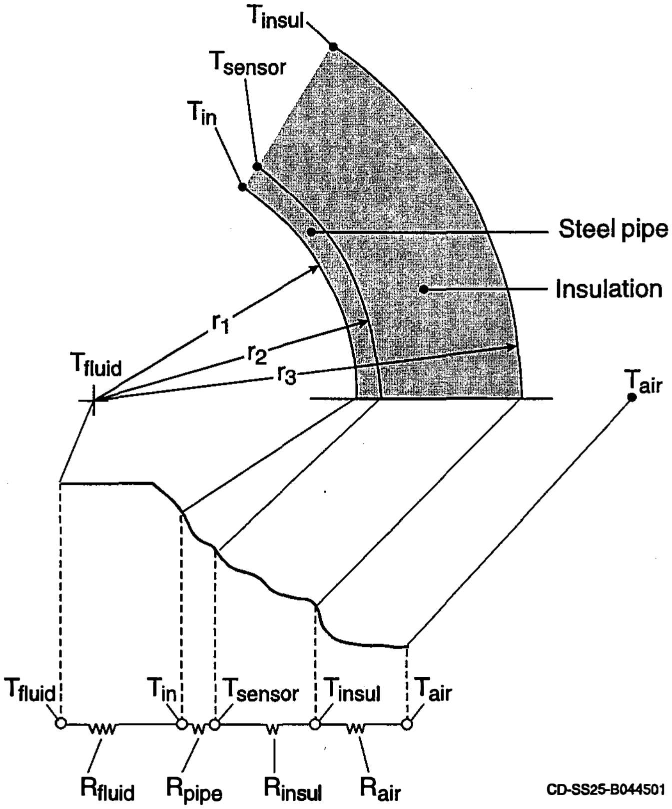


Figure 1. Thermal Resistance Diagram of Pipe Equipped with Sensors

Calculating Eqn. 1 for each of the two fluids yields the following results:

	Laminar	Turbulent
T_{sensor}, fluid #1,°C	0.907	0.210
T_{sensor}, fluid #2,°C	97.0	99.7
($T_{sensor\_2} - T_{sensor\_1}$),°C	96.1	99.5
($T_{fluid\_2} - T_{fluid\_1}$),°C	100.0	100.0
Bias Error,°C	3.9	0.5

Table 2. Conditions Assumed for Temperature Difference Calculations

	Temperature (°C)	Conductivity (W/mK)	Thickness (m)
Fluid #1	0.0	0.558	0.15 (diam.)
Fluid #2	100.0	0.682	0.15 (diam.)
Pipe	NA	54.0	0.005
Insulation	NA	0.04	0.1
Air	20.0	0.026	NA

Table 3. Resistance Values for the Fluid and Surrounding Pipe, Insulation, and Air

	Resistance (m^2K/W)	Symbol
Fluid #1	0.0347 (turbulent) 0.156 (laminar)	R_{fluid}
Fluid #2	0.0138 (turbulent) 0.127 (laminar)	R_{fluid}
Pipe	1.90×10^{-4}	R_{pipe}
Insulation	3.23	R_{insul}
Air	0.0589	R_{air}

If the flow is laminar, the error in temperature difference measurement is 3.9%, which is unacceptably high. For turbulent flow, however, the error is an acceptably low 0.5%. Fortunately, for this application it is rare to encounter laminar flow in the load-side piping; if the flow rate is that low for a short period, the energy delivery rate is proportionally low, and thus the effect of the error is small on the total delivered energy over the day. To put the laminar flow rate into perspective, flow through our example pipe at the laminar-turbulent transition Reynolds number of 2300 translates to a velocity in the pipe of only 0.45 cm/sec. Actual fluid velocities inside pipes tend to be much larger than this, and in fact our experience with measuring the flow rates in the three monitored systems in the database corroborate this assertion. Thus, 0.5% of reading can serve as a maximum bias error bound for mounting the thermopile on the outside of the pipe.

The error sources we accounted for in the total bias error calculation in the energy delivered measurement are listed in Table 4.

The associated error propagated through the energy delivered measurement was calculated by performing a Taylor's series expansion (4) of the energy delivered equation for each of the error sources listed in Table 4:

$$Bias = \pm\sqrt{\left(\frac{\partial Q}{\partial m}\left(\sum B_m\right)\right)^2 + \left(\frac{\partial Q}{\partial (T_2 - T_1)}\left(\sum B_{T_2-T_1}\right)\right)^2} \qquad (2)$$

$$= \pm\sqrt{\left(c_p (T_2 - T_1)\left(\sum B_m\right)\right)^2 + \left(c_p m\left(\sum B_{T_2-T_1}\right)\right)^2}$$

To calculate a "typical" bias error for an hourly measurement at the Adams County facility, we chose the flow and temperature difference measurements corresponding to 2 p.m. on July 11, 1995 and plugged them into Eqn. 2. The numbers from the data network that we used in the calculation are listed below in Table 5.

The energy delivered for the hour calculates to 142.6 kWh and, using Eqn. 2 with the listed flow rate and temperature difference bias errors, the bias error calculates to ±2.3 kWh, or ±1.6%.

Table 4. Values of Error Sources Accounted for in Error Calculation

	Error Source	Value
Fluid Mass Flow Rate Errors	turbine flow meter manufacturer's specified accuracy	1.5% of reading
	datalogger manufacturer's specified accuracy	0.1% of reading
Temperature Difference Errors	thermopile manufacturer's specified accuracy	0.025 °C
	mounting temperature sensors on outside of pipe (turbulent flow)	0.5% of reading
	datalogger manufacturer's specified accuracy	0.1% of reading

Table 5. Values of Energy Delivery Parameters Obtained from the SPH Performance Data Network for July 11, 1995

Parameter	Value
mass flow rate, m (kg/hr)	3028
temp. difference, T_2-T_1 (°C)	41.08
specific heat of water, c_p (J/kgK)	4178

Solar Insolation Measurements

The only solar radiation measurement that is routinely collected by the data network is the site's global horizontal insolation. We measure this parameter with a silicon cell pyranometer. The high cost and maintenance requirements of pyrheliometers and more elaborate pyranometers has precluded adding directly measured beam and diffuse insolation as data network standards.

For an imaging collector array, the global horizontal can be converted to its beam and diffuse components using accepted engineering algorithms. Perez et al (5) have shown that the beam and diffuse components of solar radiation can be estimated from hourly measured global horizontal, using their model, with a mean bias error of 6 W/m^2 and an root-mean-square error of 71 W/m^2. Statistics on daily totals are expected to be quite a bit better, but studies have not yet confirmed these statistics. The model is a modification to the DISC model developed by Maxwell at Solar Energy Research Institute (SERI) in 1987 (6). The primary difference between this new model and all older models is that each estimate of the present hour's value of direct normal fraction is based not only on the present hour's measurement of global horizontal, but also the past hour's measurement and the next hour's measurement. This gives a measurement of the change in clearness index over a three-hour period, and the direct normal component is correlated not only with the present hour's global horizontal measurement, but with the change in clearness index surrounding the present hour. This approach helps the model to distinguish between "white sky," or smooth, diffuse conditions, and "puffy cloud," or high-deviation conditions.

Perez has developed two forms of the model: the first of which requires only a measurement of global horizontal, and the second also requires measurement of the dewpoint temperature. Other inputs to the model can all be calculated using accepted algorithms for solar geometry as a function of location and time of year. The second version of the model is only slightly more accurate than the first. A disadvantage of the Perez models is that, because they require knowledge of the conditions one hour ahead of the desired beam/diffuse estimate, they cannot be used in real-time; the model is by definition a post-processing technique.

We have not yet incorporated the Perez model into the SPH data network. We plan to do this within the next 18 months. At that time we will test its accuracy with regard to the data network insolation measurements.

Other Data Network Measurements and Reliability

The site's outdoor dry-bulb temperature is a standard data network measurement. The air temperature is measured using a shielded thermocouple mounted in a shaded area.

If the SPH system's collector-side measurements are also desired, we include solar-loop temperatures, the heat collected, and pump-on time in the data network.

Looking over the network's data collection from the Adams County SPH system from November 1994 through November 1995,

Table 6. Recommended Calibration Schedule and Approach

Sensor	Calibration Interval	Action Required	Location
Flow Meter	1 year	replace moving parts	NREL
Pyranometer	1 year	calibrate against standard	NREL
Thermocouples	3 years	ice-bath check	on site
Pump-On Sensors	3years	remote checkusing on-sitehelp	NREL

shows that the network's reliability has gotten better over time. During the first two months, the network did not collect data properly on 18 days. For the rest of the year, however, the network only lost data on four days at this site. Now that the glitches are worked out of the network software, we expect to be able to keep the number of days the network loses data below ten for each site.

The instruments in the field are calibrated in accordance with NREL calibration guidelines. Table 6 gives the recommended intervals and methods for calibration. To minimize data acquisition downtime, a calibrated flow meter will be sent to the site and exchanged for the currently installed meter, which will then be sent back to NREL for calibration.

INSTALLATION OF MONITORING EQUIPMENT

For a given site, the data network monitoring equipment is generally installed by two people during a two-day site visit. The first day is spent installing the monitoring equipment and checking the calibration of the temperature sensors. The second day is spent correcting any installation problems realized during the night and collecting descriptions of the solar collectors (such as manufacturer, orientation, tilt, and system area), pump specifications, working fluid composition (i.e. glycol/water concentration), and piping specifications. The system-description information is put on standardized data sheets in the system notebook that is kept at NREL with the data network computer.

Before our researchers make the site visit, they have extensive interactions with the people responsible for installing and maintaining the system. If the system is already installed and is being retrofitted with monitoring equipment (this is the case for the three systems currently in the data network), we work with the system owners to find the best and least disruptive way to outfit the system with our monitoring equipment. If the system is still in the design stages (the next system to be incorporated into the data network), we work with the system designers to make sure the proper plumbing fixtures are part of the system design.

DATA NETWORK CAPABILITIES AND FEATURES

The SPH data network software was developed using an industry-standard data base program, Microsoft FoxPro Relational Database Management System for Windows. All data is collected automatically each night via modem. The dataloggers can store up to seven days' worth of data, so if the data network computer is down for a few days, data is not lost.

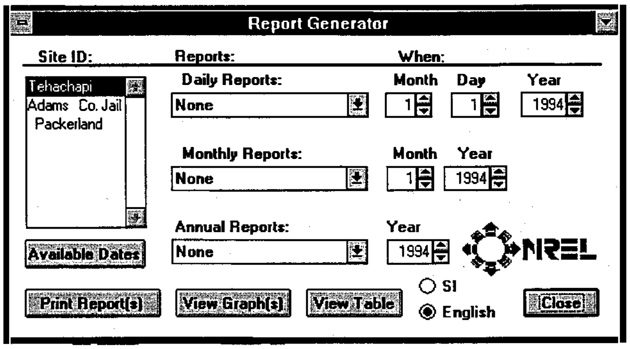
The data network computer program provides three basic services:

- Automatic daily collection (via modem) of both hourly and ten-minute data from all sites
- Data archiving
- Simple graphical or text summaries of hourly, daily, and monthly data.

The summaries can be printed or viewed on the screen. In general, the data can be used for comparing performance between systems, between predicted and measured performance, and for tracking system performance degradation over time. Archived ten-minute data can be used for more detailed studies, including computer simulation validation studies. The archived raw data is in a standard format for all systems, simplifying the comparison and manipulation of data from several systems.

The first data network screen offers the user two selections: "Edit Site" or "Reports." The Edit Site screen is used to add a new site to the data network or add or modify site-specific data to the description of a presently loaded site. The "Reports" screen, an example of which is shown in Figure 2, is used to view the data graphically or in text format, and to print the data to hard copy if desired.

Raw data can be viewed using the "View Table" button. Processed data (graphed or printed) can be presented in either SI or English units. The hourly data available (to be viewed or graphed) from the Reports screen include delivered energy, global horizontal insolation, outdoor dry-bulb temperature, and fluid temperatures. As an example, a data network graph of hourly energy delivered from the SPH system at the Adams County jail for July 11, 1995 is shown in Figure 3.



Report Generator

Site ID: Tehachapi, Adams Co. Jail, Packerland

Reports:

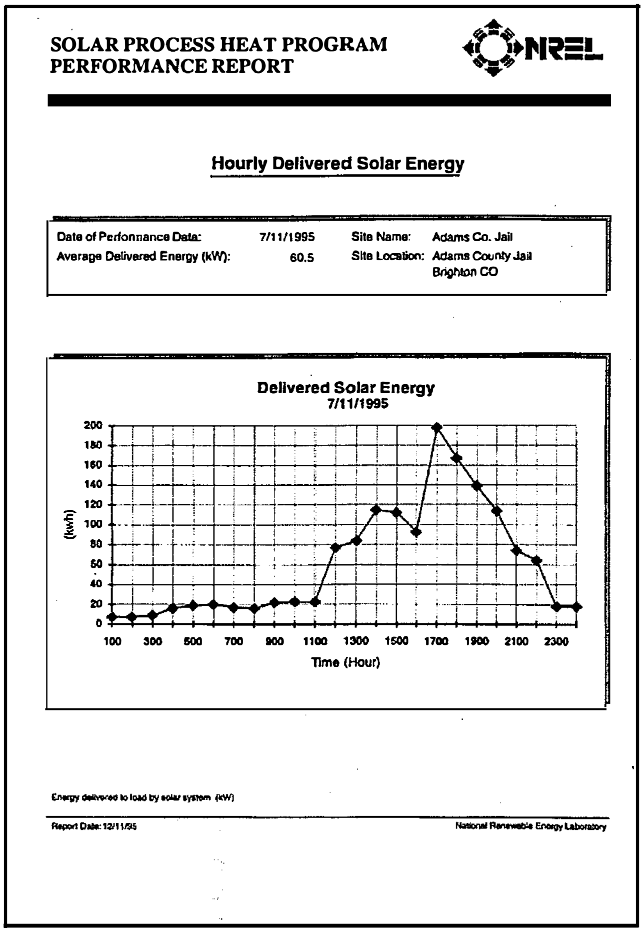
Daily Reports: None — When: Month 1, Day 1, Year 1994

Monthly Reports: None — Month 1, Year 1994

Annual Reports: None — Year 1994

○ SI
● English

Figure 2. "Reports" Screen



SOLAR PROCESS HEAT PROGRAM
PERFORMANCE REPORT

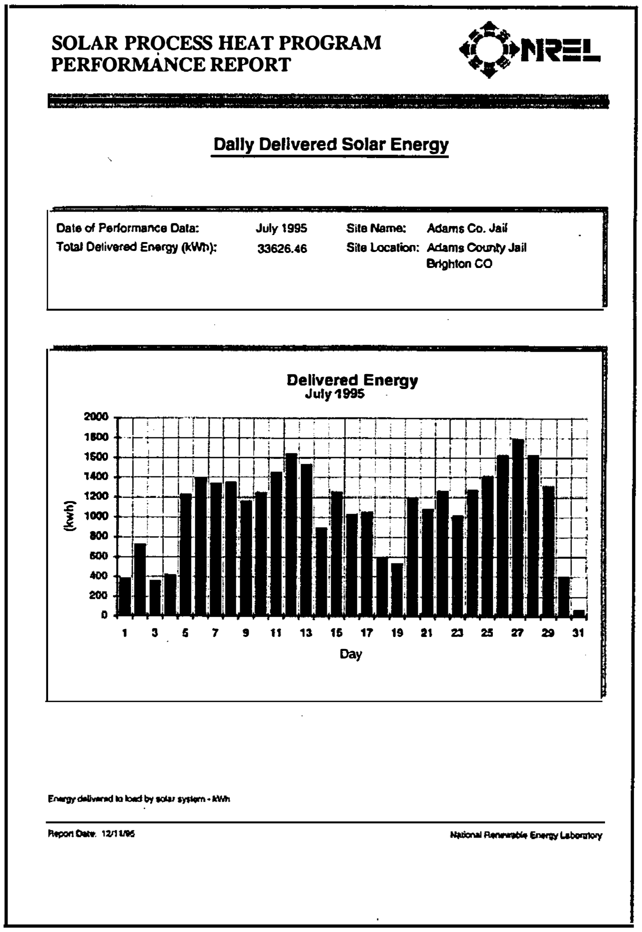
Hourly Delivered Solar Energy

Date of Performance Data: 7/11/1995
Average Delivered Energy (kW): 60.5
Site Name: Adams Co. Jail
Site Location: Adams County Jail
Brighton CO

Energy delivered to load by solar system (kW)

Report Date: 12/11/95
National Renewable Energy Laboratory

Figure 3. Example of Hourly Energy Delivered Report



SOLAR PROCESS HEAT PROGRAM
PERFORMANCE REPORT

Daily Delivered Solar Energy

Date of Performance Data: July 1995
Total Delivered Energy (kWh): 33626.46
Site Name: Adams Co. Jail
Site Location: Adams County Jail
Brighton CO

Energy delivered to load by solar system - kWh

Report Date: 12/11/95
National Renewable Energy Laboratory

Figure 4. Example of Daily Energy Delivered Report

Data available as daily totals are delivered energy and global horizontal insolation. An example of a graph of daily totals of delivered energy for July 1995 at the Adams County jail site in Colorado is shown in Figure 4.

For monthly totals, a text report showing monthly total delivered energy, monthly total global horizontal insolation, and monthly average outdoor dry-bulb temperature (during operation) can be viewed or printed. The annual totals and averages for the requested year are given at the top of the report. The 1995 report for Adams County is shown in Figure 5. This report was generated on December 5, 1995, so it does not include complete totals for the month of December.

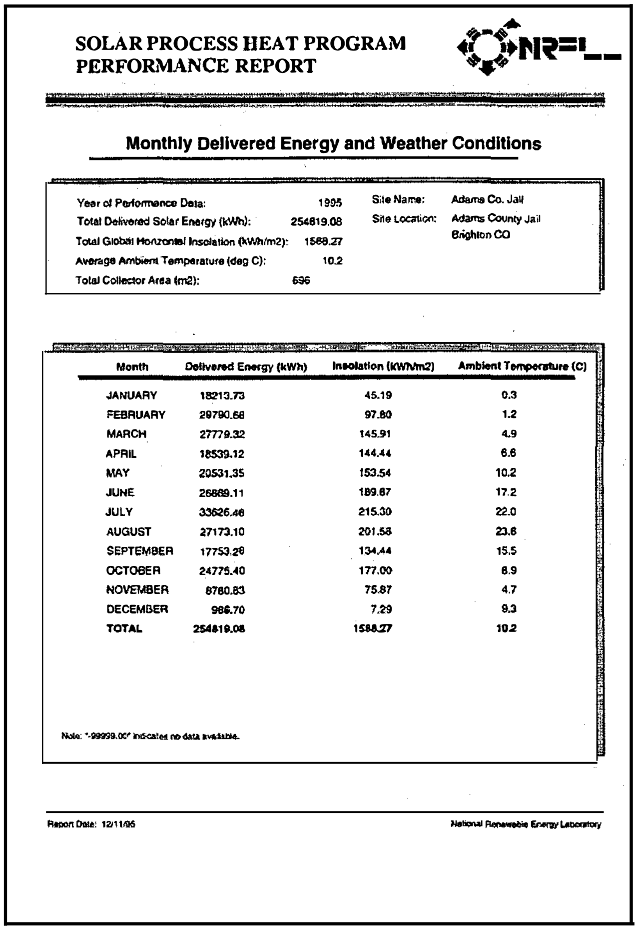
CURRENTLY MONITORED SYSTEMS

To date, three solar thermal systems are being monitored and archived under the data network program. Two are parabolic trough systems, and the third is a flat-plate system. Each has its unique characteristics, which are summarized below.

Adams County Jail, Brighton, Colorado. This 890 m^2 (9600 ft^2) parabolic trough system, built by Industrial Solar Technology (IST) in 1986, preheats domestic hot water for the jail. It was chosen not only as an example of an older system that is still working well, but also because it is near NREL, and thus could be used as a test case for our monitoring equipment installation procedures. Because of the pump house's remote location, it was impractical to have a telephone line for data transfer installed. A cellular phone has been successfully transferring the data since the monitoring equipment was installed in September of 1994.

Tehachapi Federal Prison, Tehachapi, California. This 2,680 m^2 (28,800 ft^2) parabolic trough system, built by IST in 1990, provides additional heat to a central water heating loop located inside the prison's boiler room. The energy is used for domestic hot water as well as higher-temperature applications such as dish washing and space heating. Being newer, the Tehachapi system includes improvements compared to the system at Adams County Jail. Monitoring of the Tehachapi system had been performed for several years under a contract with Sandia National Laboratories. In November 1994, NREL took over the monitoring.

Packerland Packing, Co., Green Bay, Wisconsin. This flat-plate system, touted by its owners as the largest flat-plate system in the world, was built first in 1982, and had 29,700 m^2 (320,000 ft^2) of collector area. Due to poor system design and upkeep, it did not work properly until it was rebuilt from 1984 to 1988 by Public Energy Systems of Green Bay, WI. The rebuilt system is 15,600


SOLAR PROCESS HEAT PROGRAM
PERFORMANCE REPORT

Monthly Delivered Energy and Weather Conditions

Year of Performance Data:	1995	Site Name:	Adams Co. Jail
Total Delivered Solar Energy (kWh):	254819.08	Site Location:	Adams County Jail Brighton CO
Total Global Horizontal Insolation (kWh/m2):	1588.27		
Average Ambient Temperature (deg C):	10.2		
Total Collector Area (m2):	696		

Month	Delivered Energy (kWh)	Insolation (kWh/m2)	Ambient Temperature (C)
JANUARY	18213.73	45.19	0.3
FEBRUARY	29790.68	97.80	1.2
MARCH	27779.32	145.91	4.9
APRIL	18539.12	144.44	6.6
MAY	20531.35	153.54	10.2
JUNE	26889.11	189.67	17.2
JULY	33626.46	215.30	22.0
AUGUST	27173.10	201.58	23.6
SEPTEMBER	17753.28	134.44	15.5
OCTOBER	24775.40	177.00	8.9
NOVEMBER	8760.83	75.87	4.7
DECEMBER	986.70	7.29	9.3
TOTAL	254819.08	1588.27	10.2

Note: "-99999.00" indicates no data available.

Report Date: 12/11/95

National Renewable Energy Laboratory

Figure 5. Example of Monthly Energy Delivered Report

m² (168,000 ft²) and uses a 1,250 m³ (330,000 gallon) variable-volume storage tank. The energy is used by the Packerland meat processing plant at various delivery temperatures for cleaning applications during the meat-packing process. This system is a good example of a well-maintained industrial-sized flat-plate system. Data network monitoring equipment was installed in August 1995.

FUTURE PLANS AND CONCLUSIONS

A few software improvements are expected to be implemented in FY1996. The first will be a utility for archiving down-times for the various systems. If a particular system is shut down for a week for repairs, this should be part of the data stored, and the days of down-time noted in reports of delivered energy. Otherwise the system can appear to have performed badly over a certain time interval, with no clear explanation.

A second software improvement will be the calculation of daily total direct normal insolation for each site from measured global horizontal, according to the Perez model. This parameter is important for concentrating collectors such as parabolic troughs because only beam radiation is actually collected. Simply looking at the global horizontal insolation gives only a rough idea of the insolation available to a concentrating collector.

Several systems are expected to be added to the data network. One parabolic trough system at the Jefferson County, Colorado jail is expected to be built in the fall and winter of 1995 by IST, and we have already begun preliminary specifications for monitoring this system. The collectors are unique in that they will employ new reflective coatings and a new absorber design.

We are searching for good examples of other types of systems to add to the data network, including those using compound-parabolic collectors (CPC) and evacuated-tube collectors, especially in higher temperature applications. Also of interest are collector fields similar to those already monitored but used to supply different types of loads, such as absorption chillers.

Ultimately, the purpose of the data network is to assist in understanding and advancing SPH technology. What we've achieved so far is a major step in reaching this goal, but the network will be of value only if the collected data is actually used in analysis of systems, technology development, and eventually in marketing applications. It is important that the Solar Industrial Program work together with the solar industry to begin using the data network to its fullest potential. The flexibility of the SPH data network makes it adaptable to future needs as identified by the solar thermal industry and researchers.

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