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INSTRUMENTATION OF THE NEW MEXICO DEPARTMENT
OF AGRICULTURE SOLAR HEATED AND COOLED BUILDING

Progress Report, September—November 1975

R. L. San Martin

June 1976

Work Performed Under Contract No. E(29-2)-3652

Department of Mechanical Engineering
New Mexico State University
Las Cruces, New Mexico

MASTER

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Solar Energy

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INSTRUMENTATION OF THE NEW MEXICO
DEPARTMENT OF AGRICULTURE
SOLAR HEATED AND COOLED BUILDING

Progress Report for the
Period September-November 1975

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PREPARED FOR
ENERGY RESEARCH AND DEVELOPMENT
ADMINISTRATION
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UNDER CONTRACT NO. E(29-2)-3652

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I. ABSTRACT

This is the first quarterly progress report on Contract No. E(29-2)-3652, awarded to New Mexico State University, Engineering Experiment Station, to study the instrumentation of the New Mexico Department of Agriculture Solar Heated and Cooled Building. Work on this contract was initiated on September 1, 1975.

This first of its kind solar heated and cooled building is being instrumented to evaluate its performance, and also to allow a comparison of solar system's actual performance versus predicted performance. A computer controlled data acquisition system, with appropriate sensors, is being developed to collect and process all performance evaluation data.

Data collection system design was initiated along with the acquisition of some of the system components and data sensors. Collection of detailed information on each of the solar system components was also initiated.

During the next reporting period the data collection system design will be finalized, along with the specification of the remaining data sensors and corresponding transducers. Building of the data system interface components will be initiated.

II. NARRATIVE

Notification was received from the ERDA Division of Solar Energy that the proposed project had been accepted as the basis for the negotiation of a contract. Immediate contact was made with the ERDA Albuquerque Operations Office. Work began on September 2, 1975 and official notification of acceptance was received from ERDA/ALO during October of 1975.

Initial work on this project had been supported by the New Mexico Energy Research and Development Program. This work began in September 1974. The ERDA support will allow the project to proceed towards its goals.

On November 5, 1975 the principal investigator met in Washington, D. C. with Mr. Gene Doering, project Program Manager, and briefed him on the progress of the current program and the accomplishments during the previous year. The program plan was reviewed and Mr. Doering's comments were incorporated into revisions of the plan.

A. Research Objectives

This project provides for the Instrumentation of New Mexico Department of Agriculture Solar Heated and Cooled Building. The specific research objectives are: (1) to evaluate the performance versus predicted performance and solar system operating cost versus conventional fuel system operating costs, (2) to promote the consideration, acceptance and utilization of solar energy as an economical substitute for conventional fuels in future construction, and (3) to participate in the first University office and laboratory building in the nation to use solar energy for both heating and cooling. The major effort will be the procurement, construction, installation, calibration and testing of the diagnostic instrumentation, as well as preparation of test plans, test procedures and computer software.

B. Summary of the Progress

The building solar system was first tried on September 9, 1975 and initially checked out. The building was occupied in the middle of October 1975 and officially dedicated on October 22, 1975 at solar noon. The solar system has remained in continuous operation. Preliminary indications are that the system is operating very nearly as anticipated.

The data collection system design is more than two thirds complete and approximately one half of the data sensors and transducers have been specified and ordered. Data sensor locations have been specified and most sensing wells have been installed in the system piping. The collection of detailed information on each of the solar system components is over half completed.

The system is currently being fine-tuned (minor problems are being corrected). The air distribution system is being rebalanced along with a few of the liquid flow loops. Approximately ten percent of a particular exterior collector piping (soldered) connection have been found to leak. Initial analysis indicates this is a workmanship problem and these are being resoldered.

C. Report of the Progress: Instrumentation System

The instrumentation system for the New Mexico Department of Agriculture (NMDA) solar heated and cooled building is designed to provide maximum flexibility for the acquisition, processing and analysis of solar system performance data. It is a computer-based system that will enable the solar researcher to perform real-time or historical system analysis with no interference to the computer's full time commitment of logging, processing and storage of performance data.

Major components of the instrumentation system are shown in Figure 1. An important feature of the system is the interconnection of the computer and remote stations with a bi-directional digital bus. The digital bus is a single conductor-pair that eliminates a common requirement for long, multi-conductor cable runs for the transmission of low level analog signals between the primary sensors and the data acquisition system. Remote stations can be located several hundred feet from the computer and each is simply connected to an extension of the single pair bus.

Remote stations are typically located in areas where sensor populations are greatest. Each remote station is designed to accept up to 40, 9 to 5 volt differential analog inputs. These inputs are time multiplexed, converted from their analog form to 12-bit digital words and transmitted serially to the computer. Each input in a remote station is addressed and controlled separately by the computer, thus providing maximum versatility throughout the system for the assignment of sampling rates and sequences. The 12-bit output provides a resolution of 1.25 mv for a 0 to 5 volt (5.12 volt actual) input.

The heart of the instrumentation system is the mini-computer and its peripherals including a typewriter terminal, disk storage (two), clock and a digital plotter. The software is a high performance, real-time operating system and includes various programs required for subsequent program development. Higher level programming languages such as FORTRAN are being considered for addition to the operating system.

Present Status

Implementation of the instrumentation system as shown in Figure 1 is proceeding and most major hardware items are either on order or already

received. A prototype remote station and computer/bus interface unit have been constructed and tested to the extent possible without the computer. The computer and typewriter have been received and are awaiting initial check-out by factory representatives. After check-out, a period of operator familiarization will be required before testing can begin with prototype remote stations (two) and the computer/bus interface unit. The portable display unit shown in Figure 1 will be tested as part of a remote station.

Project Schedule (See Figure 2)

Work remaining to ready the instrumentation system for installation in the NMDA Building includes laboratory testing of prototype remote stations and interface unit with the computer, construction and testing of operational remote stations (3), construction and testing of interface unit and portable readout, software development, error budget development, and full system tests in the laboratory. This final test involves all hardware shown in Figure 1 with the exception of the sensors and a modem. Sensor signals will be simulated and the modem will not become a part of the system until after installation in the NMDA Building.

Simultaneously with the laboratory system tests, sensors will be calibrated (if required) and installed in the NMDA Building. Interconnecting cables will be pulled in conduits previously installed during building construction. Final installation and testing of the instrumentation system in the NMDA Building according to the schedule in Figure 2 will complete a major portion of the project. Data logging will then commence on a full-time basis with solar system analysis proceeding as software is developed and implemented.

MONTHS FROM START OF PROJECT

Figure 2. Work Plan

Instrumentation System Characteristics

General

System Type	Computer-based with digital bus interconnecting computer with remote stations.
Location:	Solar Heated and Cooled New Mexico Department of Agriculture Building.
Measured Parameters:	Insolation, temperature, flow, barometric pressure, relative humidity, power, pH, wind speed, wind direction.
Accuracy:	(See Remote Station)
System Timing:	Computer Generated

Major Hardware

Remote Station

Number Required:	Three
Location:	NMDA Building; one on roof and two in equipment room.
Purpose:	Time division multiplexing and digital conversion of multiple analog inputs.
Components:	Analogic MP6912 Data-Acquisition Module (1) Analogic MP6932 Multiplexer Expander (2) Control logic and power supplies.
Input:	40 true differential 0 to 5 volt channels.
Control:	Computer control of scan rates and scan sequence via digital bus.

Local Display:	LED, floating decimal, four digits plus sign. Display is part of Portable Display Unit. <u>Any</u> channel in system may be selected for display when display unit is connected to a remote station. Parameter is displayed in engineering units.
Scan Rate:	36 Data Point Samples Per Sec (Typ.)
Output (to digital bus):	32-bit serial (12 bits of data, 20 bits for control and identification)
Resolution:	12-bit (1.25 mv)
Accuracy:	± 1.4 mv ($\pm 0.015\%$ F. S. $\pm 1/2$ LSB)
Computer:	Manufacture - Digital Equipment Corp. (DEC). Type - PDP-11T10
Includes:	<ol style="list-style-type: none"> 1. PDP-11/10 Center Processor 2. 16K words of core memory 3. Line Frequency Clock 4. Power Fail/Restart 5. LA36 DEC Writer II - 30 Characters/sec, Hard copy console Terminal 6. Asynchronous serial interface for LA36 7. Two (2) RK05 DEC pack moving - head disk drives - 1.2 M word capacity per drive 8. RK11D Controller/Interface for RK05 Disk Drives - expandable to a total of eight (8) individual disk drives. 9. Bootstrap loader

10. Expansion spaces for adding one system unit and two small peripheral controllers, mounting hardware and cables.

Additional Hardware:

1. M1719 - Unibus interface foundation module (used in bus interface unit)
2. W966 - wire wrapping module (used in bus interface unit)
3. RK05K-11 - monodisk diskcartridges (additional units for RK05 disk drives)
4. XY-11 - plotter control for a XY incremental digital plotter.
5. DP-1 - digital plotter manufactured by Houston Instruments.

Software:

1. RT-11: high performance real-time operating system includes a text editor, macro assembler, linker, on-line debugging technique, peripheral interchange program, and utility programs.
2. Fortran IV/RT-11: this higher level language is being considered as an addition to the software.

Storage Capacity:

73 days per disk pack (estimated)

D. Report of the Progress: Sensors

Table 1 lists the parameters that will be measured in order to determine the performance of the solar heating and cooling system in the NMDA Building. Sensor quantities are also listed although some variability is expected as the program develops.

With the exception of a pH meter(s), watt or watt-hour transducers and differential pressure transducers for the flow meters, all sensors have been ordered and received.

Information relative to each sensor type is presented in the following sections.

TABLE I

Measurement List

<u>Parameter</u>	<u>No. of Sensors</u>
Solar Radiation	3
Temperature	46
Pressure	3
Mass Flow Rates	18
Liquid pH	1 or 2
Electrical Energy	8
Wind Speed and Direction	1 for each
Relative Humidity	2

Solar Radiation

Solar radiation input to the NMDA system will be measured with two pyranometers and one pyr heliometer. The pyranometers are 180° Eppley Model 8-48's and the pyr heliometer is an Eppley Model NIP on a tracking pedestal. One 8-48 will measure total radiation, direct plus diffuse, on a horizontal surface and the other 8-48 will be inclined at the fixed collector angle of 30° to measure total radiation. The NIP will measure direct beam radiation.

Outputs of the three instruments will be recorded simultaneously by the data acquisition system in the NMDA Building and by strip chart recorders with integrators. Integration of the sampled data will be performed by the

computer. The sampling rate for all radiometers has tentatively been established at one sample every 6 seconds. This rate was selected on the basis of work by D. J. Norris (1).

The Eppley Model 8-48 Pyranometer has been reported to have cosine errors in excess of the values quoted by the manufacturer. A study of these errors is presently being conducted at this laboratory and results will be reported at a later date.

Temperature Transducers

National Semiconductor Corporation Type LX5700H solid state temperature transducers are used for all temperature measurements in the system. These devices are useful over a -55°C to $+125^{\circ}\text{C}$ temperature range and produce a high level linear output of $10\text{ mv}/^{\circ}\text{K}$ ($10\text{ mv}/^{\circ}\text{C}$) directly calibrated in $^{\circ}\text{K}$. 100°C will, for example, produce an output of 3.73 volts.

Each device, with extension leads attached, will be encapsulated with Emerson & Cummings 2850KT Filled Epoxy into a cylindrical probe measuring one fourth inch diameter by one inch long. After encapsulation, a two point calibration at 0°C and 100°C will produce units with an absolute accuracy of $\pm 0.5^{\circ}\text{C}$. The long term stability is 0.2°C .

Installation in the New Mexico Department of Agriculture Building will in most cases involve installation of the sensors in existing temperature wells. Wells will then be filled with a light oil or other thermally conductive material such as Wakefield 120 to provide good heat transfer between the sensor and the well.

Details of the temperature probe are given in Figure 3. Temperature sensor locations are indicated in Figure 4 as T_1 through T_{46} .

Flowmetering

The mass flow rate through all system components that input, exchange, or remove energy for the system will be monitored. Included are the following:

- (1) Components that input energy to system
 - (a) solar collectors
 - (b) stand-by gas fired boiler

Figure 3. Temperature Probe

Figure 4. Temperature and Flow Sensor Locations

- (2) Components that exchange energy
 - (a) liquid to liquid heat exchangers (2) - for the transfer of energy in solar loops to storage
 - (b) liquid to air heat exchangers (2) - for the transfer of energy to or from building air
 - (c) absorption units (2)
- (3) Components that remove energy
 - (a) cooling tower
 - (b) domestic hot water supply

The flow sensors to be used are Annubar Types 73 and 71.

Type 73 - standard insert sensor for pipes 1.5"-16". Unit mounts through single 1/2" weld collar.

Type 71 - nipple type element for pipes 1/2"-2.5". Unit is installed in nipple for insertion into pipe.

Manufacturer's claim for accuracy for this type of sensor is $\pm 0.55\%$ to $\pm 1.55\%$ actual (instantaneous) flow for sizes 1/2" to 24" pipe diameter.

The manufacturer further details four methods of sizing the operating range of the sensor with various regimes of accuracy. A copy of these methods is given in reference (3) and it is specified that method "C" (precise theoretical) will be used.

Location of Flow Sensors

The location of the sensors is detailed below and Figure 4 gives quick reference to system placement. Sensors are indicated as $F_1, F_2, \dots, F_{18}$.

F_1 - installed on inlet side of solar loop pump #20, measures flow through tube side of heat exchanger #18.

F_2 - installed on inlet side of solar loop pump #19, measures flow through tube side of heat exchanger #17.

The sum of flows measured by F_1 and F_2 is the total flow through collectors on roof.

F_3 - installed on inlet to shell side of heat exchanger #18.

F_4 - installed on inlet to shell side of heat exchanger #17.

The sum of flows measured by F_3 & F_4 is the total flow of hot water supply through storage tank circulating pumps.

- F₅ - installed on outlet of hot water supply line to York absorbtion unit.
- F₆ - installed on outlet of chilled water supply from York unit.
- F₇ - installed on inlet of the condenser water supply line to York unit.
(cooling tower line)

The sensors F₅, F₆ & F₇ measure the flow of all fluids through the York absorbtion unit.

- F₈ - installed on inlet of hot water supply to Arkla Servel Absorbtion unit.
 - F₉ - installed on outlet side of chilled water supply from Arkla Servel unit.
 - F₁₀ - installed on inlet of condenser water supply to Arkla Servel unit.
- The sensors F₈, F₉ and F₁₀ measure the flow of all fluids through the Arkla Servel unit.

- F₁₁ - installed on inlet to building air heating coil.
- F₁₂ - installed on inlet of building air cooling coil.
- F₁₃ - to be installed on inlet of stand-by boiler.
- F₁₄ - to be installed on outlet of domestic hot water supply heat exchanger located in tank #2.
- F₁₅ - to be installed on inlet side of one unit (4 collectors in series) of fixed position Sunsource collectors.
- F₁₆ - to be installed on inlet of one unit (2 collectors in series) of variable angle Sunsource collectors.
- F₁₇ - to be installed on inlet of one unit of Northrup concentrating collectors.
- F₁₈ - to be installed on outlet of cooling tower.

Fifteen of the Annubar flowmeters were installed during construction of the building. The remaining three (F₁₅, 16 and 17) are required in the collector circuits and will be installed at a future date.

Differential pressure transducers have not been selected for use with the Annubars. Evaluation units will be supplied by several manufacturers for testing in the laboratory.

Liquid pH

The pH of the antifreeze-water solution in the collector loops must be maintained at a neutral level to prevent corrosion. The present measurement technique involves draining fluid, measuring the pH and adding inhibitors as required. The requirement for a continuous in-line monitor will be determined after more experience is gained with the manual technique. If the change rates are determined to be relatively high, a continuous monitor may be warranted.

Electrical Energy

Energy consumption by electrical equipment associated with the operation of the solar heating and cooling system will be measured and accounted for in deriving the system's overall energy balance. Major electrical loads in the NMDA system are motors driving pumps, fans and compressors. Solar and nonsolar related loads are controlled from a single motor control center located in the building's equipment room. Solar related loads will be measured collectively by first measuring the total energy input to the motor control center. From this total the relatively few nonsolar loads will be individually measured and subtracted. The ratio of solar to nonsolar loads is three to one, making the above approach economical by minimizing the total number of transducers required.

Current transformers have been installed in the motor control center to provide the step-down required for operation of available transducers. The selection of transducers will depend upon finalization of the technique for interfacing the transducers to the data acquisition system and upon evaluation of the accuracy requirement.

Meteorological

The meteorological parameters of wind speed, wind direction, relative humidity, barometric pressure, rainfall and ambient air temperature contribute to the performance of the solar heating and cooling system and will be monitored and recorded. Instruments have been purchased and will be installed on site as work progresses. Instrument characteristics are listed below.

Wind Speed:

Manufacturer: Texas Electronics, Inc.
Model: 2011A
Range: 0 to 100 MPH
Accuracy: +1%
Output: 0 to 5 VDC

Wind Direction:

Manufacturer: Texas Electronics, Inc.
Model: 2010
Range: 0° to 360°
Accuracy: +0.5%
Output: 0 to 5 VDC

Relative Humidity:

Manufacturer: Texas Electronics, Inc.
Model: TH-2013-2
Range: 0 to 100% R. H.
Accuracy: $\pm 2\%$ R. H. from 20% to 90% R. H.
Output: 0 to 5 VDC

Barometric Pressure:

Manufacturer: National Semiconductor Corp.
Model: LX3700 AIM
Range: 25 to 50 Inches Hg
Accuracy: $\pm 0.75\%$ of span
Output: 2.5 to 5.0 volts

Ambient Temperature:

Manufacturer: National Semiconductor Corp.
Model: LX5700H
Range: 55°C to 125°C
Accuracy: $\pm 0.5^{\circ}\text{C}$
Output: 10 mv/ $^{\circ}\text{K}$ (10 mv/ $^{\circ}\text{C}$)

Rainfall:

Manufacturer: Texas Electronics Corp.
Model: 525
Type: Tipping Bucket
Resolution: 0.01 inches water

Miscellaneous

1. Each of two collector loops in the NMDA Building is pressurized by nitrogen to about 20 psig. Pressure transducers will be installed on each loop to provide for continuous monitoring by the data acquisition system.
2. Natural gas consumption by the gas fired auxiliary boiler will be determined by logging the boiler operating time and multiplying by the fixed gas consumption rate.

E. Report of the Progress: Solar System Evaluation

The emphasis here has been to first have a viable, operating, trouble free solar system before the detailed testing and modeling begins. The first difficulty was with the central system. A couple of sensors had been incorrectly located and had to be moved to give accurate representative readings. The temperature limits (i.e., temperature difference) for the operation of the solar collector loop was expanded to 12°F (temperature difference between storage and collector plate).

The northeast corner of the building experienced cold (55-65°F) morning temperatures and this was traced to an air distribution problem which resulted from greatly accelerated infiltration in that region caused by an unanticipated 1200 cfm evening exhaust hood load. By judicious use of the building exhaust system this was reduced to 1200 cfm and the infiltration problem was solved.

Approximately ten percent of the joints (U-joints) where one collector is stacked on top of another began leaking during the first week of operation. Consideration was given to whether this was a design, materials or workmanship problem. After resoldering the leaking joints and experiencing negligible other leaks, it was concluded that this was most likely a workmanship problem.

The major solar system problem is that the collector loop valves do not seal tightly in the reverse flow direction. Therefore in the evening, with the storage tanks full of hot water, the system dumps (loses) energy by reverse thermosyphon action. These valves will be replaced in the near future. Some of the collector glazings appear to have been partially spray painted and might have to be cleaned.

As a severe system test, the auxiliary boiler (natural gas) was manually turned off on November 19, 1975. The solar system has been handling one hundred percent of the heating load with no measurable variations in the interior temperature of the building.

The experimental row (540 ft.²) of ten to one concentrating tracking collectors (Northrups) was put into operation during November. Small problems are being handled with the control system and leaks have been experienced in the rotating seals recommended by the supplier. Flexible hose connections have been recommended as replacements.

Detailed descriptions are being obtained for each component and subsystem. These will aid in the subsequent modeling and system performance interpretation.

F. Problems Encountered

No problems are currently anticipated with computer system or the acquiring and calibrating of the data monitoring sensors and transducers.

Some of the temperature sensing wells were incorrectly positioned during the building construction and they will have to be moved. Two flow measuring sensors were incorrectly installed and they will also have to be reinstalled. A probe and support must yet be designed to allow for the measurement of the interior temperature in the storage tanks.

G. Activities to Disseminate Project Results

Over one dozen talks were given in New Mexico by the members of this project during the reporting period. These were to technical and honorary societies, and to service and fellowship organizations. Numerous mail inquiries (over 100) have been answered with information on this project.

The principal investigator was invited and made presentations to the state energy offices of New Mexico, Oklahoma, Louisiana and Arkansas. In addition, this study was part of the material used by the author in the keynote address at the "Solar Energy in Louisiana Conference," in Baton Rouge on October 16, 1975.

Two students will be writing graduate thesis on this project. This should increase the amount of documentation which will result from the study.

Hundreds of visitors have toured the facilities (from throughout the nation and including several visitors from abroad), in addition to the more than two thousand during the dedication weekend. The official dedication was held in conjunction with a New Mexico State University sponsored on National Developments in Solar Heating and Cooling - A Progress Report. This was held on the campus in Las Cruces, New Mexico on October 21-22, 1975 (attendance was about 400). This was followed by the second annual meeting of the New Mexico Solar Energy Association on October 23-24, 1975. This meeting was also hosted on the university campus in Las Cruces (attendance was approximately 200). This was also the university football homecoming weekend. Talks on the building, its solar system and the instrumentation system were presented at each meeting.

The solar system on this building was used as one of the examples thoroughly discussed at two week long solar short courses on solar heating and cooling applications. These were short courses for engineers, architects and builders, and were held in Albuquerque and Las Cruces, New Mexico.

It is anticipated that several technical papers will be offered to appropriate national meetings in the future.

It is very difficult to accurately report on the creation of any new industry as a result of a project such as this one, because this type of demonstration creates much enthusiasm which surfaces at different times.

A more direct example is Southwest Sheet Metal of El Paso, Texas (43 miles south of Las Cruces, New Mexico). This company expanded its operation to include the manufacture of solar collectors, as a direct result of this heating and cooling demonstration, and is now a major supplier and manufacturer of flat plate solar collectors.

III. References

1. Norris, D. J., "Calibration of Pyranometers", Solar Energy Journal, Vol. 14, No. 2, January 1973.
2. "Annubar Certification" from Pittsburgh Testing Laboratory, Ellison Instrument Division, Dieterich Standard Corporation, Ellison Technical Manual, May 3, 1968.
3. "Annubar Flow Calculation Equations", Ellison Instrument Division, Dieterich Standard Corporation, Ellison Technical Manual.

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