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CONF-780432--2

TITLE: DATA ACQUISITION AND MONITORING SYSTEM FOR LOS ALAMOS NATIONAL SECURITY AND RESOURCES STUDY CENTER

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SUBMITTED TO: Conference on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems
April 3 and 4, 1978
Shoreham-Americana Hotel
Washington, D. C.

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Form No. 836
St. No. 2629
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UNITED STATES
ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

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DATA ACQUISITION AND MONITORING SYSTEM FOR LOS ALAMOS NATIONAL SECURITY AND RESOURCES STUDY CENTER

by

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ABSTRACT

The National Security and Resources Study Center, a modern, three level building containing 5574 m^2 of temperature controlled space and an integral solar energy heating and cooling system is in operation at Los Alamos, New Mexico. This report describes the instrumentation system used to measure the energy production (solar energy system) and consumption (HVAC system) in all the building operating modes. Included are descriptions of the sensors (temperature, mass flow, power, etc.) and the data acquisition system.

I. INTRODUCTION

The National Security and Resources Study Center (NSRSC), located at Los Alamos, New Mexico, has been heavily instrumented as part of a research program into the use of solar energy for the heating and cooling of large commercial and public buildings. The Study Center is a three level building containing approximately 5574 m^2 of temperature controlled space. The solar energy system, designed to supply up to 96 percent of the building's heat and 76 percent of its cooling requirements, is an integral part of the building. Other energy saving features include extensive use of insulation, heat recovery from the ventilation exhaust, and the use of both evaporative and mechanical cooling. The energy storage system is designed so that it may be split between hot, pressurized water and chilled, low pressure water during the cooling season.

For the purpose of instrumentation, the Study Center may be considered as three interconnected systems. These are the solar energy system, the heating, ventilating, and air conditioning (HVAC) system, and the control system. In the following sections of this report, the instrumentation of each will be described in detail.

II. INSTRUMENTATION

A. Solar Energy System

Figure 1 is the simplified mechanical schematic of the system. Instrument locations are marked by type (i.e., Temp, Flow, Power, etc.). This instrumentation is the minimum required to yield energy balances for the basic system components. Thus the energy input from the solar collector to the primary heat exchanger, H1, is determined by temperature measurements at its inlet and outlet, and a mass flow measurement in the collector coolant loop. The other system components are instrumented in a similar manner.

With the exception of the solar collector manifold temperatures, all temperature measurements are made with 100 ohm platinum resistance probes (RTDs). With the RTD probes in LASL designed bridge completion networks, temperatures are read with a resolution of 0.025°C to an accuracy of 0.12°C. The collector manifold temperatures are measured with copper-constantan (Type T) thermocouple probes referenced to 65.5°C. Resolution and accuracy are 0.1 and 0.25°C.

Flow measurements are made by turbine flowmeters (TFMs) and equal area pressure-drop (Annubar*) probes. The TFMs are used on 1/2 in., 1 1/4 in., and 3 in. diameter pipes while the Annubar probes are used on the 4 in. and 6 in. diameter lines. The TFMs and the Annubar probes are typically 1 percent devices. Each TFM is provided with a pulse rate to dc converter, which transmits a 4 to 20 mA signal to the data acquisition system. The Annubar differential pressure signals are translated by means of individual differential pressure transducers, which send 4 to 20 mA signals to the data acquisition system.

Auxiliary energy is supplied to the building in the form of steam at 862×10^3 Pa. When this auxiliary energy is required for heating or cooling, the pressure is reduced to 172×10^3 Pa and it is allowed to flow through two small heat exchangers and the condensate is returned to the central power plant. For the purpose of energy determination, steam pressure and temperature, and the condensate flow and temperature are measured. The pressure and flow measurements produce 4 to 20 mA signals.

The electrical power consumed by the major pumps in the solar energy system is measured by three-phase watt transducers whose 4 to 20 mA outputs are sent to the data acquisition system. The watt transducers are 480 volt delta connected and each reads the current in two legs of the three phase line. Accuracy is better than 1 percent.

Weather data in the form of ambient temperature, wind speed, and wind direction is gathered from a small weather station located on the roof. In addition, the solar flux is measured in both the horizontal and collector planes by two pyranometers designed for this purpose.

The solar energy system instrumentation occupies 68 analog channels in the data acquisition system and permits the determination of energy balances, efficiencies, and overall system performance.

B. Heating, Ventilating, and Air Conditioning Systems

Figure 2 is a simplified HVAC system schematic in which typical instrumentation locations are shown. Two types of air temperature measurements are made. Copper-constantan (Type T) thermocouples are used in all air supply and return ducts as well as in the fan discharges. The accuracy of these measurements is within ± 0.5°C with a resolution of 0.1°C. The reference system is shared with the solar energy system instrumentation. When air temperature measurements must be made in ducts of large cross-sections, an averaging temperature probe is used. These applications include the air washers, cooling coils, and a heat recovery unit. The probe consists of a 1000 ohm Balco resistance thermometer with an active length of 6.6 m, which is suspended across the duct so that it may respond to the average air temperature. Excitation and read-out of the probe is accomplished through a conventional bridge network. The accuracy and resolution of the measurement is similar to the thermocouple measurement described above.

Air flow measurements within the supply and return ducts are made by precision propeller anemometers pre-calibrated to provide an output of 1 volt at an air speed of 180 m/s. As a means of checking the in-place calibration of the anemometers, each is provided with a Duct Air Monitor Device (DAMD)* permanently mounted in the duct up stream of the anemometer. Each DAMD consists of a honeycomb air straightner section followed by an array of static and total pressure sensors interconnected in an averaging configuration. The output lines (static and total pressure) from each DAMD are routed to a central jack panel where the differential pressure across a selected DAMD may be measured by means of 0 to 1 torr differential capacitance manometer. The electrical output (0-10 volts) of this instrument is connected to one channel of the data acquisition system so that on-line calibration of the propeller anemometers may be made during system operation.

Dew point temperature measurements are made in the return air ducts and at selected locations in the air handling equipment. The device used is a DewProbe,** an electrically heated, self-regulating, lithium chloride dew point hygrometer. The DewProbe temperature is sensed by a 500 ohm nickle resistance thermometer. A conventional bridge network is used for excitation and read-out of the resistance thermometer. The actual dew point temperature is related to the measured temperature by a nearly linear function. This conversion is done in the data reduction program.

Air flow in the HVAC system is controlled by variable position dampers, which respond to pneumatic outputs from the control system. The relative positions (0 to 100 percent) of 14 of these dampers are measured by potentiometers coupled to the actuator shafts. The potentiometers coupled to the actuator shafts. The potentiometers are excited with 5 volts dc and the voltage at the arm of each potentiometer is read by the data acquisition system as a measure of the damper position.

Electrical power to the two supply and two return fans is measured by three phase delta connected watt transducers, which provide 4 to 20 mA signals to the data acquisition system. In a similar manner, the building lighting loads are measured by 7 additional watt transducers. The total electrical load of the building is measured by a cam-driven contact installed in the main kWh meter. This contact, which provides one transition per kWh, is used to generate interrupts in the data acquisition program; these interrupts are counted to provide a measurement of the electrical energy consumed in the building.

C. Control System

The controls for the solar energy system and the HVAC system are based on conventional pneumatic proportional control systems. The solar energy system has two heating modes (normal and auxiliary) and three cooling modes (normal, auxiliary, and night-time evaporative). Operation of the system in any one of these modes results in the closure of a contact associated with a pressure to electric transducer. The contact closures are wired to a digital interrupt module in the

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*Air Monitor Corp., Santa Rosa, CA

**Honeywell, Minneapolis, MN

data acquisition system, which senses the state of the control system, and then makes any necessary changes in the data acquisition and display tasks.

III. DATA ACQUISITION

A. Requirements

Early in the project it was realized that the complexity of the system and the number of measurements needed to characterize it made it imperative that some form of on-line data reduction and display of system behavior be provided. A simple data-logging scheme would result in the generation of large quantities of data, which would be useless until further processed. Therefore, specifications were written for a minicomputer based data acquisition system with the capability for simultaneous data acquisition, reduction, display, and program development. The specifications also provided for system expansion, both in the number of data acquisition channels and in the capability for analog and digital outputs, since a projected expansion of the research program will require development and implementation of programs for energy management and control of the building energy systems.

B. Configuration

The system selected, and ultimately delivered, consists of a PDP-11/34* central processor with 32K of parity core memory, 7.5 megabytes of mass storage (disk pack), a console terminal, a CRT terminal with both alphameric and graphics capability, and a fully integrated local process I/O subsystem. A communications interface and auto-answer modem are also included to permit access from remote terminals. The local process I/O is presently configured with two A/D converters connected to 160 analog channels and a single 16 channel digital interrupt module. All but 5 analog and 6 digital channels are presently in use.

The system software, RSX-11M,* is a real-time, multi-user, multitask operating system. All program development is done in FORTRAN IV. The system permits task scheduling as a function of time and specific events; this permits the system to operate around the clock with a minimum of operator intervention.

C. Capabilities

Each A/D converter is capable of sampling analog channels at the rate of 200/s. By using the two converters in parallel, an effective sampling rate of 400/s is achieved. The full scale range of each analog channel is programmable between ±10 mv and ±10 volts in a 1, 2, 5 sequence with 12 bit resolution. The gain programming and channel selection are accomplished by FORTRAN subroutine calls to the process I/O. At present, the system samples all the channels once every 15 s and converts the readings to appropriate engineering units (°F, gal/min, etc.) and stores these values in a common block accesible to other programs. A second program, running at the same interval, then calculates the energy balances appropriate to the building's operating mode (heating, cooling, etc.) and updates a disk file with the current and

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*Digital Equipment Corp., Maynard, MA

integrated values for these balances. Every one-half hour during the day (hourly at night) a summary of these balances is printed on the system console and also written in a disk file. In addition, mode changes sensed by the digital interrupt module will force summaries to be printed. Once a day, at midnight, a disk file, located on the removable disk pack, is updated with the day's summaries and all integrations are reset to zero. This disk pack holds up to one month's summary data and serves as long term archival storage. During the day additional summaries and information regarding the individual channels may be requested without interrupting the system operation.

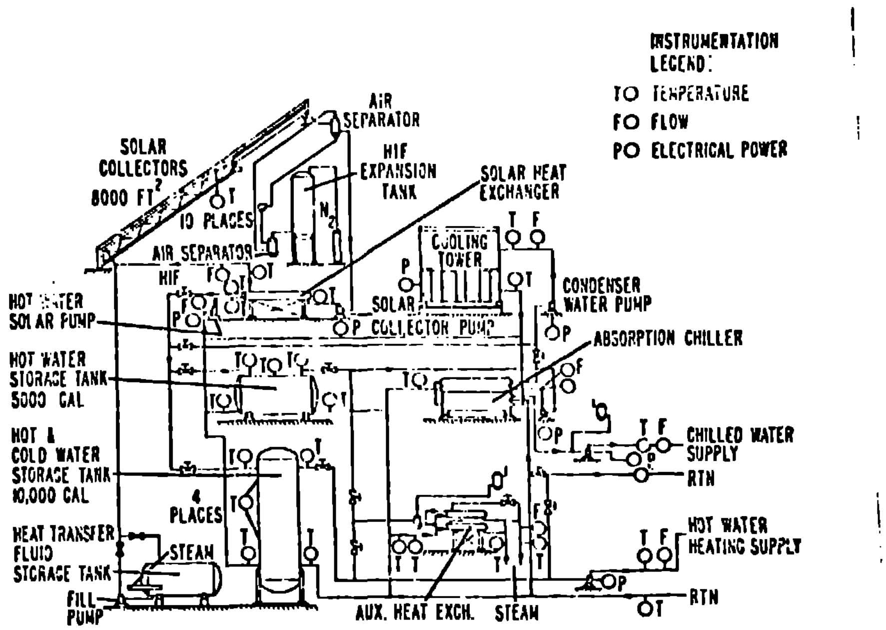

Fig. 1. Simplified mechanical schematic.

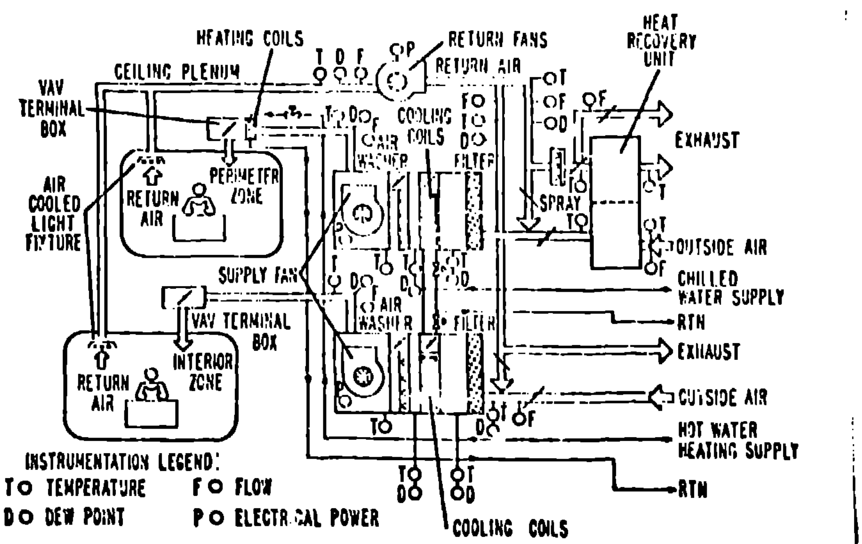

Fig. 2. Simplified HVAC schematic.