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TITLE: ON-LINE PERFORMANCE CALCULATIONS FOR THE LOS ALAMOS NATIONAL SECURITY AND RESOURCES STUDY CENTER

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ON-LINE PERFORMANCE CALCULATIONS FOR THE LOS ALAMOS NATIONAL SECURITY AND RESOURCES STUDY CENTER

by

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ABSTRACT

The National Security and Resources Study Center at Los Alamos, New Mexico, has been heavily instrumented to permit monitoring of the performance of the solar heating and cooling system. The monitoring system includes a computer, which provides the capab'lity for doing real-time engineering calculations. This capability permits data compression and allows the researcher to interact with the system and to see immediately the results of changing the system parameters.

I. INTRODUCTION

The solar heating and cooling system of the National Security and Resources Study Center (NSRSC) at Los Alamos, New Mexico, incorporates a number of energy conserving features and represents the use of a solar energy system integrated into the design of a modern commercial building.

Studies of the NSRSC system include a performance evaluation of the solar heating and cooling system and overall optimization of the energy system. Cooling experiments include a comparative study of absorption refrigeration versus a solar Rankine cycle cooling unit. Several different modes of operation of the system are available, and the control system has numerous set points and parameters, which may be varied to optimize system performance. About 160 measurements are made in the system to analyze the performance.

In order to conduct the necessary experiments on the energy system effectively, a computer-based data acquisition system was required. The additional computational power offered by a computer over more conventional data acquisition systems allows the researcher to interact with the system and to see immediately the results of changing the system parameters in a comprehensible format. Changes in the operating mode of the system and the occurrence of other significant events can be detected by the computer and the effect of these changes can be summarized. The researcher is able, with minimum effort, to add or modify engineering calculations using the basic data from the system, to display the results, and to save the results in a summary form. By performing the calculations necessary to determine system component energy balances in real time, the amount of data that must be stored is reduced considerably, and the need to do additional post-processing of data to determine system performance is totally eliminated.

II. SYSTEM DESCRIPTION

A description of the building energy system and a detailed view of the installed instrumentation is given in another paper by M. A. Trump.[1]

The computer system consists of a PDP-11/34* central processor with 32K words of core memory, a 5 M byte fixed disk, a 2.5 m byte removable disk pack, a system console, a CRT terminal with limited graphics capability, and a process I/O subsystem. A communications interface is also available to permit access to the computer from remote terminals.

The operating system software for this computer is RSX-11M,* a real-time, multi-user, multi-task system. This system provides for the building, scheduling, and running of the real-time programs (tasks). A number of utilities are provided to perform program text editing, file management, and high-level language processing. All programs are written in FORTRAN IV, and the system provides FORTRAN callable subprograms to service the I/O subsystem.

Because of the limited size of the computer, only one task may be in memory at any time. The user may assign priorities to the various tasks and the system allows competing tasks to run on the basis of their relative priorities. A task may also be assigned the attribute of "checkpointability," which will allow the system to remove that task to run a time-critical task and then to restore the checkpointed task so that it may run to completion. The system utilities are checkpointable, allowing program development to be accomplished concurrently with and without interfering with the running of the real-time tasks.

III. SYSTEM FUNCTIONS

The system basically provides for data acquisition, data conversion, energy calculations, interrupt processing, energy summaries, data storage, and data display.

A. Data Acquisition

The data acquisition task runs every 15 seconds at the highest task priority and may not be checkpointed by another task. All of the channels are sampled at this interval and converted to engineering units. The components of the data acquisition task are:

1. The I/O subsystem driver
2. Resistance probe conversions
3. Thermocouple conversions
4. Turbine flowmeter conversions and pressure differentials
5. Weather station (temperature, wind, and pyranometer) conversions
6. Watt transducer conversions
7. Propeller anemometer conversions
8. Dew probe conversions

The converted values are stored in a permanently core-resident common data area, which provides the link for communication among the various tasks.

At the conclusion of a complete data scan, a task that performs the energy calculations is activated by the data acquisition task.

B. Energy Calculations

This task uses the converted data to perform the energy flow calculations on the solar heating and cooling system components. Primarily,

*Digital Equipment Corporation, Maynard, MA these calculations consist of mass flow rate times specific heat times temperature differential calculations, and include mass flow rate calculations based on pressure differentials, fluid density and temperature, and corrections to specific heats and functions of temperature. The instantaneous energy flows as well as average values over the sampling interval are stored in the common data area. The task also integrates these values to provide a total energy figure for each subsystem.

The contents of the common data block are backed up on the fixed disk every 5 minutes. This allows the system to be stopped for maintenance and restarted without losing integrated energy information. This feature also protects against loss of data in the event of a system "crash."

C. Interrupt Processing

A task is linked to the interrupt module in the I/O subsystem, which is activated upon the occurrence of any interrupt. The total electrical power is tallied in the common data block using interrupts from the main watt hour meter, and system operating mode changes are stored for examination by other tasks to determine which components should be analyzed.

D. Energy Summaries

A summary of all of the instantaneous heat flows, and integrated energies, weather data, and system temperatures and flow rates, is written on the fixed disk automatically every one-half hour from 6 a.m. to 6 p.m., and every hour otherwise. Additional summaries are written in response to any operating mode change.

At the end of the day (midnight), all of these data are copied to the removable disk for permanent storage. One month's worth of data typically uses about two-thirds of a disk pack's capacity. At this time all of the energy integrals are reset for the next day and the periodic summaries are printed on the system terminal. An additional file is then created that contains integrated energy values for the entire day as well as other pertinent information such as maximum and minimum storage and ambient temperatures. The condensed daily summary is also printed during the night. The daily summaries are saved for subsequent examination and display.

III. DATA DISPLAY AND RESULTS

Figure 1 is a typical print out from the periodic summaries taken during the day. In addition to being recorded on disk automatically, this information may also be displayed or printed on any terminal at any time in response to an operator request. This particular record was written at 1 p.m. on March 4, 1978. All energies and heat flows are in BTUs per square foot of collector area. Temperatures are in degrees Fahrenheit, and electrical powers in killowatts. A few of the significant variables shown in this table are:

1. Instantaneous collector insolation (QSUN35)
2. Integrated collector insolation for the day (ESUN35)
3. Storage tank vertical temperature stations (T1-1, 2, 3, and 4)
4. Solar collector output (COLL, SUPPLY)
5. Solar collector flow rate (COLL,FLOW) in gallons per minute

6. Domestic hot water energy consumption (DHW, SUPPLY)
7. Pump instantaneous electrical power (PUMP KW)
8. Pump integrated energy consumption (PUMP E) in BTU/ft^2

A similar summary is made for the air system.

Figure 2 is the condensed daily summry for the solar heating system only. The values are the integrated energies in BTU/ft^2/day for

QH - horizontal insolation
Q35 - collector incident
QCOLL - collector output
H1 - collector heat exchanger output
T1IN - storage tank input
T1OUT - storage tank output
H23 - auxiliary heat exchanger output
RHHW - total reheat energy
RHHWS - solar portion of reheat energy
DHW - domestic hot water
DD - degree-days of heating

Figures 3 and 4 show the computer generated daily summaries and monthly running totals for the system through March 6, 1978. Total monthly summaries are also kept on a seasonal basis (heating or cooling) to determine overall system performance, per cent solar, for example, for a full heating or cooling season. These tables to date are shown in Fig. 5.

Daily summary data may be viewed in bar graph form on the CRT terminal. An example of this is shown in Fig. 6. The hard copy feature of the CRT terminal is not of sufficiently high quality for reports, so data are also transmitted over the dial-up port to an HP 9830* system at another site for the purpose of making better quality plots. (An example of this type of plot is shown in Fig. 7.) The CRT, however, has proved extremely valuable for "snapshots" of current data.

IV. CONCLUSIONS

The computer-based data acquisition and processing system at the NSRSC has proved to be an effective tool for analyzing system performance, particularly from the standpoint of presenting system operating data in real time in a comprehensible format. This feature is virtually a necessity when system optimization studies are being conducted. The system has also proved to be highly reliable with very little downtime or loss of data.

ACKNOWLEDGMENTS

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REFERENCES

1. M. A. Trump, Data Acquisition and Monitoring System for Los Alamos National Security and Resources Study Center, to be presented at the "Conference on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems," Washington, D.C., April 1978.

*Hewlett Packard, Palo Alto, CA

DATE	TIME	MODE	MODE LAST	DT
3/ 4/78	13: 0: 0	1	1	0.25

TA	WSPEED	WDIR	QSUNH	QSUN35	ESUNH	ESUN35
40.5	1.8	-0.2	261.5	329.6	1008.2	1416.5

T1-1	T1-2	T1-3	T1-4	T2-1	H23S
135.2	137.4	137.7	137.5	72.6	259.2

	COLL	H1	T1IN	T1OUT	H23	RH	DHW
SUPPLY	167.3	142.8	142.6	140.3	106.7	139.8	139.7
RETURN	156.9	135.1	134.9	128.8	102.1	128.4	138.7
FLOW	460.2	309.0	309.0	59.8	0.0	59.8	15.7
HEAT	152.4	153.9	152.9	44.5	0.0	44.1	1.0
HEATAV	110.3	109.0	107.7	42.1	0.0	42.7	0.9
ENERGY1	567.1	572.1	564.9	156.8	200.4	354.7	5.2
ENERGY2	220.1	335.2	0.0	0.0	0.0	161.4	0.0

HTM	166.3	166.9	165.3	165.9	165.5	166.5	166.1	165.7	166.7	164.7

PUMP KW	9.56	1.12	1.17	0.00	0.00	0.00	0.00	
PUMP E	20.0	2.4	7.1	0.0	0.0	0.0	0.0	
LITE KW	48.66	0.42	0.42	0.00	0.00	11.09	19.37	0.40
LITE E	280.23	2.27	2.27	0.06	0.00	64.01	103.96	14.67
FAN KW	10.96	12.19	5.00	2.23				
FAN E	34.84	38.50	15.85	7.03				

HTRC	PFA	IFA	TFA
28.70	19.35	39.28	58.63
144.53	115.13	220.05	335.18

Fig. 1. Periodic energy summary.

DATE 3/ 6/78

QH	Q35	QCOLL	H1	T1IN	T1OUT	H23	RHHW	RHHWS	DHW
1316	1623	564.	574.	570.	346.	209	574.	369.	12.3

TA MAX/MIN/DD 48/28/27.

Fig. 2. Daily summary, solar system.

NATIONAL SECURITY AND RESOURCES STUDY CENTER

HEATING RESULTS FOR 3/78

SOLAR DATA

DAY	SUN HORZ	SUN .35	COLL OUT	HTEX IN	TANK OUT	DOM HW	AUX STM	TOT HEAT	PUMP 1+2	TSMAX F	TSMIN F
1	333	296	0	0	17	5	476	498	0	98	97
2	1456	1602	570	582	284	11	262	557	29	132	96
3	886	838	113	117	179	7	402	588	12	115	105
4	1528	1998	782	788	448	9	200	657	32	148	104
5	739	772	156	166	403	2	79	484	16	126	99
6	1316	1623	564	574	346	12	209	567	24	131	98
TOT	6258	7209	2185	2227	1677	46	1628	3351	113	125	100

UNITS: BTU/FT2/DAY

Fig. 3. Solar system daily summary table.

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HEATING RESULTS FOR 3/78

BUILDING DATA

DAY	HOT WATER	TOT ELECT	TOT LITE	FANS S+R	PUMP 3+4	TOT HEAT	HTRC UNIT	FRESH AIR	TAMAX F	TAMIN F	DD F*D
1	516	1099	660	161	12	1349	369	1057	44	35	25
2	556	1099	657	162	12	1387	290	1110	46	31	25
3	596	961	649	160	13	1418	401	1237	33	16	40
4	664	605	343	165	12	1184	210	860	44	27	29
5	518	597	350	164	13	1045	198	775	47	33	24
6	573	1012	664	160	12	1409	192	930	47	28	26
TOT	3423	5373	3323	972	74	7792	1660	5969	44	28	169

UNITS: BTU/FT2/DAY

Fig. 4. Building daily energy summary.

NATIONAL SECURITY AND RESOURCES STUDY CENTER

HEATING RESULTS FOR 77/78

SOLAR DATA

MON	SUN HORZ	SUN 35	COLL OUT	HTEX IN	TANK OUT	DOM HW	AUX STM	TOT HEAT	PUMP 1+2	TSMAX F	TSMIN F
11	30833	48217	16902	19425	14476	0	1966	16442	0	133	108
12	28187	46472	15528	16360	13453	275	4909	18637	309	134	111
1	28840	43648	14413	14874	11997	394	7382	19773	683	130	105
2	33762	44895	14047	14188	11786	358	5335	17479	674	138	109
TOT	121622	183232	60890	64847	51712	1027	19592	72331	1666	143	113

BUILDING DATA

MON	HOT WATER	TOT ELECT	TOT LITE	FANS S+R	PUMP 3+4	TOT HEAT	HTRC UNIT	FRESH AIR	TAMAX F	TAMIN F	DD F*D
11	14952	0	0	0	0	14952	0	0	47	31	634
12	18249	11574	8233	[illegible]704	87	29273	0	0	45	28	859
1	19361	29183	17149	521[illegible]	[illegible]91	42120	1404	3474	39	23	1018
2	17211	27286	16095	4683	346	38335	6096	17313	41	24	880
TOT	69773	68043	41477	12606	82[illegible]	124[illegible]80	7500	20787	43	24	3391

UNITS: BTU/FT2/MON

Fig. 5. Seasonal tables.

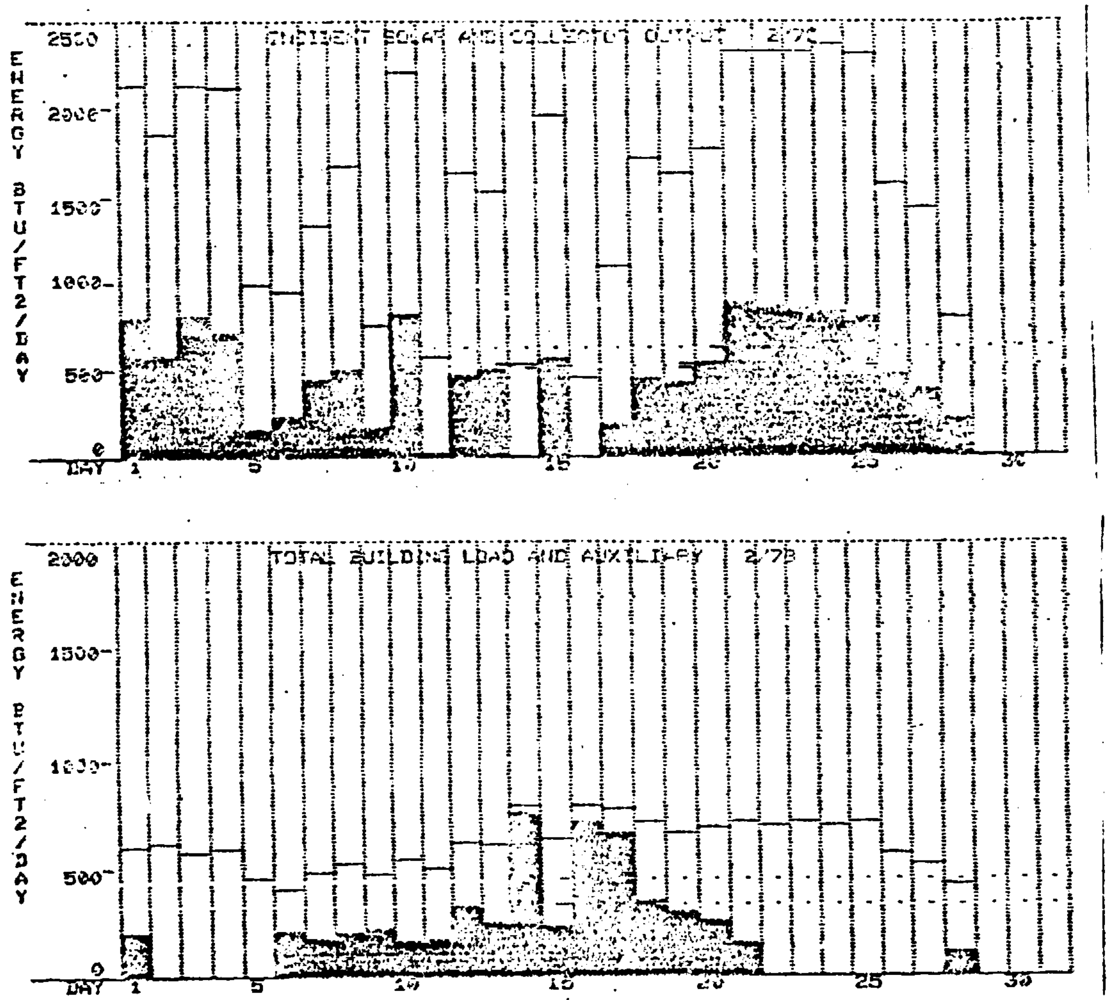

Fig. 6. Computer-generated energy summary bar graphs.

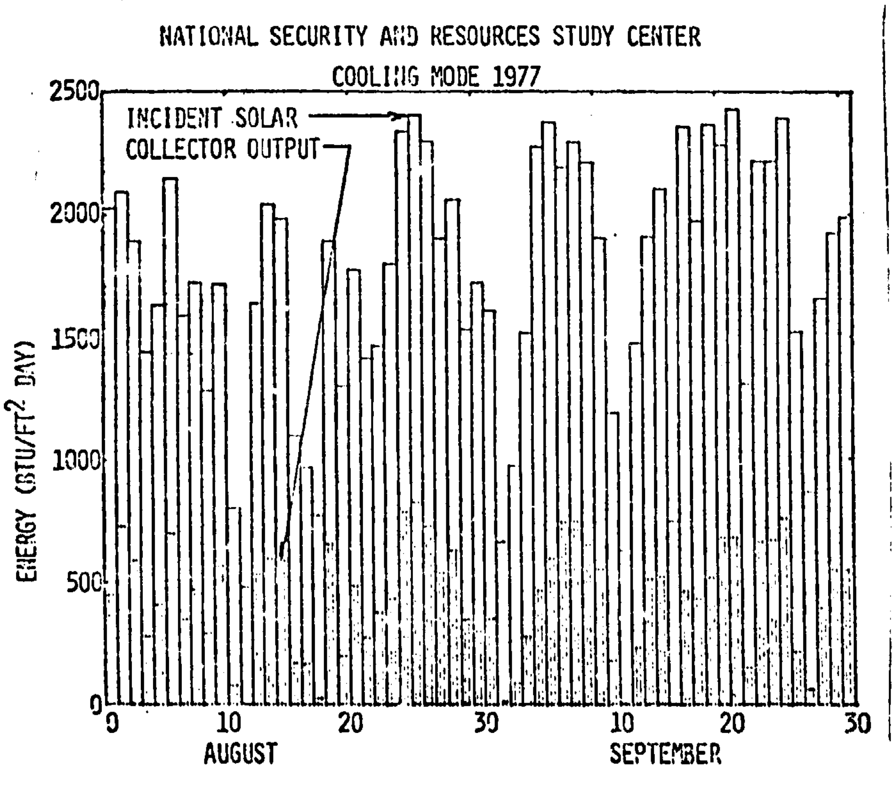

Fig. 7. HP 9830 bar graph.