LA-UR-83-1968

Conf-830929--4

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LA-UR--83-1968

DE83 015263

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SUBMITTED TO: American Solar Energy Society for publication in the Proceedings of the Eighth National Passive Solar Conference to be held September 7-9, 1983, in Glorieta, New Mexico.

ANALYSIS OF VALIDATION DATA SETS IN THE CLASS A PERFORMANCE EVALUATION PROGRAM*

by

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ABSTRACT

The primary objective of the DOE Passive Solar Class A Performance Evaluation Program is to collect, analyze, and archive detailed test data for the rigorous validation of analysis/design tools used for passive solar research and design. This paper presents results of the analysis and qualification of several one- and two-week data sets taken at three Class A test sites for the purpose of validating envelope and thermal-storage-energy-transfer processes in passive solar analysis/design tools. Analysis of the data sets consists of editing the measured data and comparing these data with simulated performance results using public-domain, passive solar analysis tools and a standard reporting format developed for the Class A program. Comparisons of the measured data with results using the DOE-2 computer program are presented.

1. INTRODUCTION

Under the DOE Passive Solar Class A Performance Evaluation Program, in progress since 1980, detailed hourly performance data are being collected, analyzed, and archived for the primary purpose of rigorous validation of analysis and design tools (both component models and complete tools) used for passive solar research and design. The Los Alamos National Laboratory, working closely with the Solar Energy Research Institute (SERI), is coordinating this effort.

The Class A program, originally outlined in a SERI report (1), has been developed and expanded as described in Ref. 2; SERI and the National Bureau of Standards (NBS) have been actively involved in the program since its beginning. Although the initial thrust involves test cells, small unoccupied test buildings, and a residence, the program is to be expanded later to include commercial buildings and other test facilities.

Validation of several public-domain, hour-by-hour computer programs is essential to instill confidence in the research community in their use for passive solar research and applications. Furthermore, because virtually all simplified design tools used by passive solar designers are based on correlations of results using the hour-by-hour programs, validation of these primary, reference programs is essential.

This paper presents results of the analysis and qualification of several one- and two-week data sets taken at three Class A test sites for the purpose of validating envelope and thermal-storage-energy-transfer processes in hour-by-hour passive solar analysis/design tools. Analysis of the data sets consists of checking, screening, and reformatting the data within the context of the validation methodology developed under the Class A program (3).

2. PROCEDURES FOR COLLECTION AND ANALYSIS OF TEST DATA

To check the usability and effectiveness of data sets and the empirical tests in the Class A validation methodology (3), we compared the measured data sets with simulated results using public-domain, passive solar analysis/design tools and a standard reporting format. To illustrate the data analysis procedures, we compared hourly space temperatures and auxiliary energy use with simulations using the DOE-2 building-energy-analysis computer program.

Data sets for full program validation have been collected at several Class A passive heating test facilities; the representative data sets discussed here were collected at the SERI Validation Test House in Golden, Colorado; at the NBS Passive Test Facility in Gaithersburg, Maryland; and at the Lo-Cal House in Champaign, Illinois.

*Work sponsored by the US Department of Energy, Office of Solar Heat Technologies, Passive and Hybrid Systems Division.

Upon receipt of raw data tapes from a given site, the data were checked for accuracy and completeness, missing data periods were deleted or the missing data were filled in using average values for adjacent hours, or were correlated with known variables. The data were edited using a specialized input preprocessor for the DOE-2 program; this placed the measured weather data and building-operating data in a DOE-2 readable format.

Drawings and specifications of the facility, together with conversations with the site operators, provided detailed building-construction data and dimensions. Measured thermophysical property data were obtained wherever possible.

With this information and the measured site-weather data, we prepared DOE-2 input that reflected the description of the building and its operation during the one- to two-week period for which performance data were measured. DOE-2 was then run, generally for a single-week, continuous period; measured hourly temperatures and/or auxiliary-heating energy were then compared with the simulated results. The measured and predicted results were then compared and analyzed on an hourly and total-run-period basis. Summary data plots and statistics were prepared in a standardized format developed for the Class A program.

3. ANALYSIS OF EXAMPLE DATA SETS

Examples of the data-analysis procedures are given below:

3.1 SERI Validation Test House: April 1982 Data

A data tape from the SERI Validation Test House, for the period April 17-26, 1982, has recently been analyzed. The SERI Validation Test House, an unoccupied single-story frame house of approximately 93.5 m^2 (1005 ft^2) in floor area, is well insulated and tightly constructed. It includes a crawl space and an attic, and has substantial south-facing glazing for direct gain. A layer of bricks has been placed on the living room and south bedroom floors to provide thermal storage mass. A multizone tracer-gas monitoring system was used to take hourly infiltration measurements. Hourly weather and solar radiation data were also taken at the site. A detailed description of the building and its instrumentation is given in Ref. 4.

The period chosen for analysis was April 20-26, 1982, during which the auxiliary heating was controlled to maintain a 24.4°C (76°F) setpoint. First, a four-zone simulation was performed using DOE-2 with tabulated design values (5) for thermophysical properties and operating characteristics, but using weather data measured at the site. This represents the characteristic precision of input data available to an analyst familiar with the building, but not having measured property and operating data.

Figure 1 shows the weather patterns and a comparison of measured and predicted temperatures for the kitchen. Note that the temperature comparison is not particularly good, with an rms difference for the 168 hours of 3.4°C (6.1°F). This is primarily because a typical, residential, internal-heat-gain rate for a family of 4 (0.88 kW or 18,000 Btu/person-day) was used in DOE-2, whereas the measured value was significantly lower. However, results for the south bedroom are better, with an rms difference of 1.1°C (2.0°F). Similar results are obtained for the auxiliary-heating energy for the kitchen. DOE-2 overpredicts the auxiliary heating required; the rms difference for all the 168 hours is 0.31 kW, but with a strong overprediction bias.

Figures 2 and 3 show similar results, except that measured input values for selected thermophysical properties (wall and ceiling insulation, exterior-surface absorptances, window conductances, and ground reflectances) and operating characteristics (infiltration, internal heat gains, thermostat set points, and ground temperatures beneath the building) were used in the simulation. The comparison is improved to an rms temperature difference of only 1.15°C (2.1°F), and an rms auxiliary-heating difference of 0.03 kW.

A statistical summary of the predicted vs measured data for the case where measured input values were used is shown in Table I. Root-mean-square, mean, and maximum differences are presented for hourly space-air temperatures and auxiliary-heating energy, for each of the four zones; these are aggregated for the building as a whole for the auxiliary-heating energy. These results indicate excellent agreement in the temperatures, with rms differences typically about 1°C (1.8°F), and maximum differences about 2-3°C (3.6-5.4°F). Auxiliary heating for the building is typically predicted to within 0.4 kW on an hourly basis. Peak heating loads for the full-run period are predicted to within 9%.

3.2 NBS Direct Gain Test Cell: October 1981 Data

A data tape has been processed for the October 20-26, 1981, period for the NBS Direct-Gain Test Cell. This single-zone 30.7 m^2 (330 ft^2) slab-on-grade test cell includes south-facing patio door units and a clerestory window for solar gain (6). Thermal mass is contained in the 10 cm (4 in.) thick floor slab and in a 20 cm (8 in.)-thick, solid core concrete block

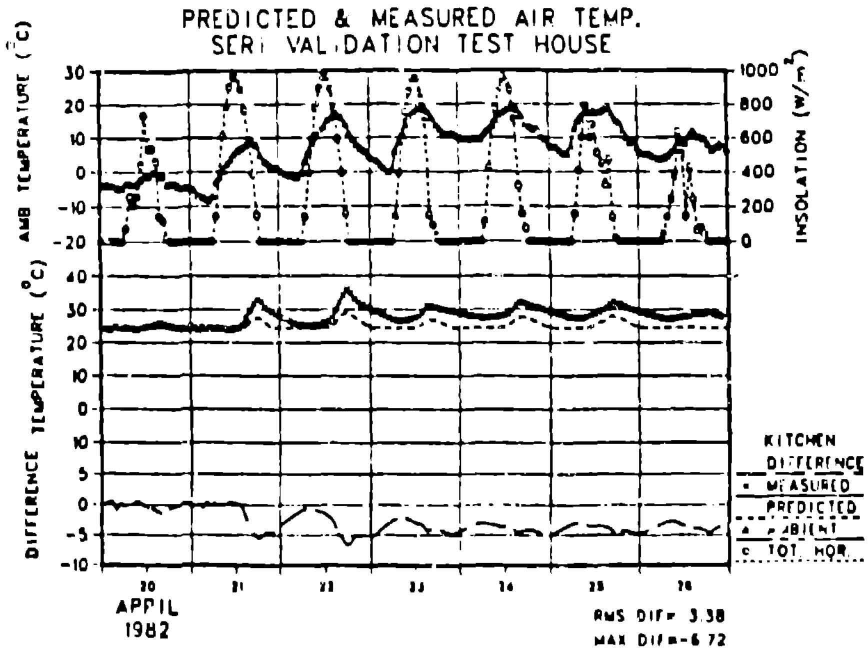

Fig. 1. Predicted vs measured space-air temperatures for the SERI Validation Test House--base case with tabulated input values.

thermal storage mass on the north wall. During the unoccupied October 1981 test period, the cell was operated in a floating temperature mode with no night insulation on the apertures.

DOE-2 input for the test cell was prepared using detailed drawings and specification, and measured properties for the concrete slab and concrete-block wall, and tabulated properties (5) for all other materials. Measured values of solar absorptances of exterior and interior surface materials, as well as infiltration and internal heat gains (measured on an hour-by-hour basis), were used for the DOE-2 input.

A comparison between measured space temperatures in the test cell and those predicted by DOE-2 is shown in Fig. 4. Note that the difference between predicted and measured temperatures is small except for the cloudy days of October 21-22 where DOE-2 overpredicts the space temperature. This difference is quantified by the 2.1°C (1.8°F) rms difference noted for the 168 h test period. The consistent bias we noted toward overprediction is likely a result of the fairly crude earth-contact heat transfer model in DOE-2 that does not properly account for the effective storage mass in the floor slab. Careful analysis also revealed that the low intensity solar radiation measurements were not reliable.

3.2 Lo-Cal House: January-February 1982 Data

A data tape for an unoccupied 6-day period during late January and early February 1982 at the Lo-Cal House has also been analyzed. These data are from the 158-m² (1700-ft²), single-family residence when the space temperature was controlled by thermostats on electric resistance heaters placed in several rooms of the house (7). The sun-tempered house uses moderate south glazing for direct gain, but contains no extra thermal mass.

The house was modeled as a single zone using the DOE-2 computer program with measured infiltration and internal gains, but with tabulated material properties. A comparison between measured space-air temperatures and those predicted by DOE-2, is shown in Fig. 5. For this case agreement is good, with an rms difference of 0.9°C (1.6°F).

4. CONCLUSIONS

Through our analysis of Class A data sets to date, we have concluded the following:

(1) Archivable data sets are available from

  a. SERI Validation Test House: April 1982,

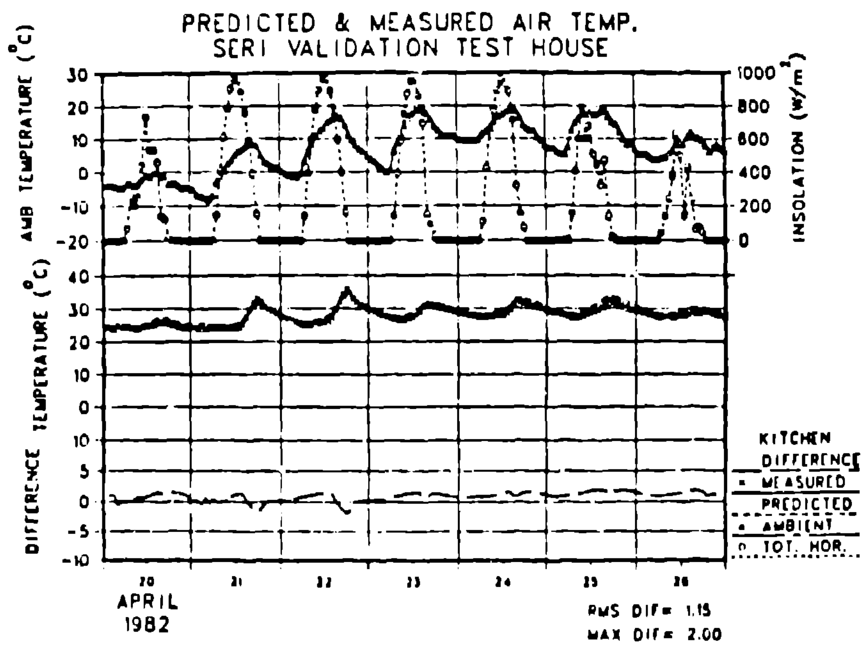

Fig. 2. Predicted vs measured space-air temperatures for the SERI Validation Test House--measured input values.

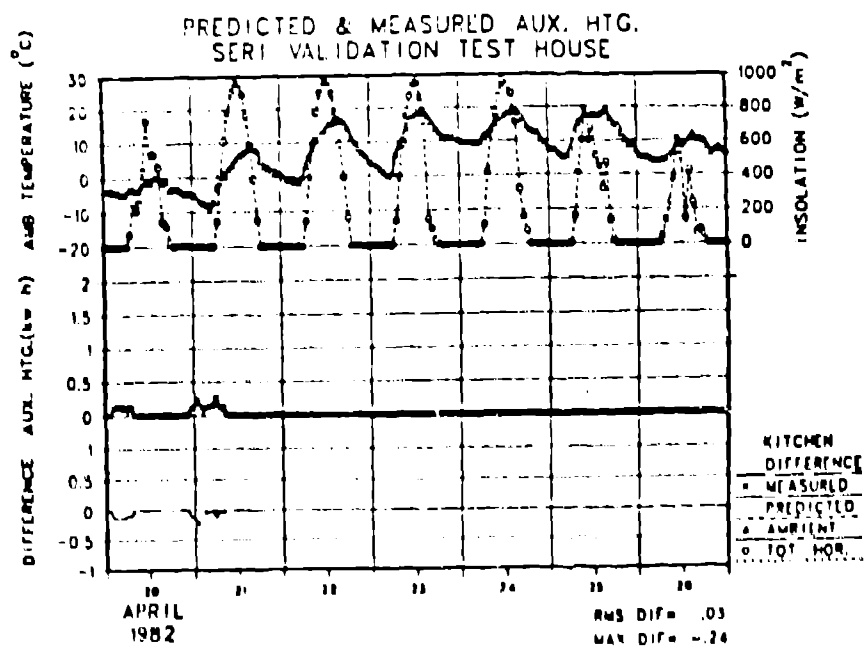

Fig. 3. Predicted vs measured auxiliary-heating energy for the SERI Validation Test House--measured input values.

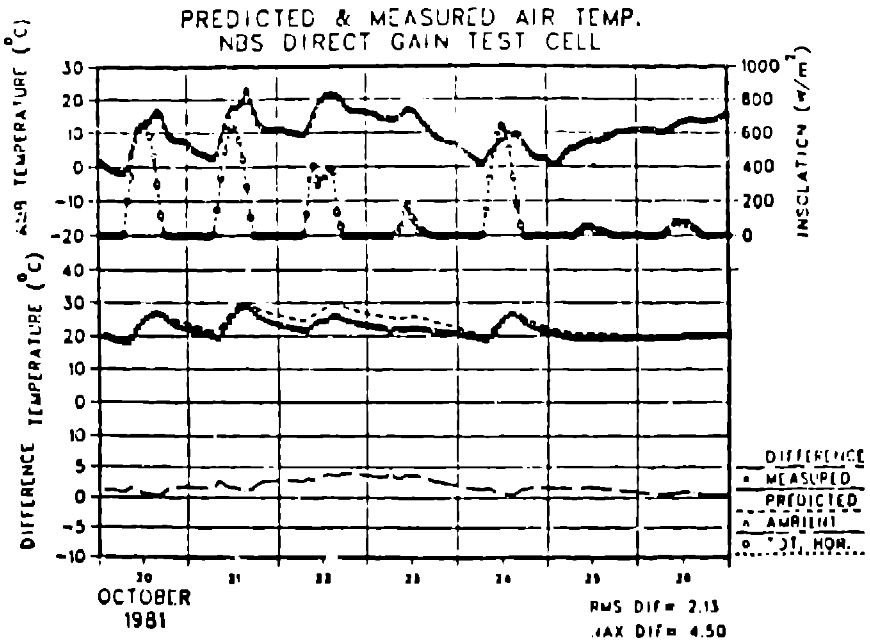

Fig. 4. Predicted vs measured space-air temperature for the NBS Direct-Gain Test Cell--measured input values.

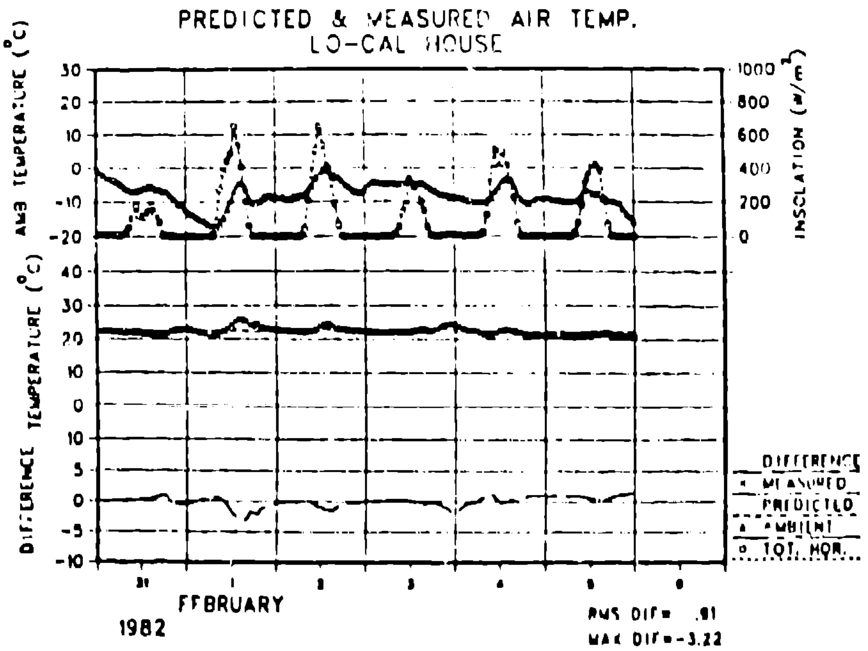

Fig. 5. Predicted vs measured space-air temperature for the Lo-Cal House--measured input values.

TABLE I

SUMMARY STATISTICS FOR PREDICTED/MEASURED COMPARISON
FOR SERI VALIDATION TEST HOUSE
(APRIL 1982 DATA WITH MEASURED INPUT VALUES)

Zone	Hourly Temperature Difference (°C)			Hourly Auxiliary-Heating Difference (kW)			Peak Heating-Load Difference (%)
	rms	mean*	max	rms	mean*	max	
Kitchen	1.15	1.03	2.00	.03	.01	-.24	-42
Living/Dining Room	1.01	.72	3.17	.17	.12	-.51	-9
South Bedroom	.79	.53	2.61	.11	.08	-.29	-2
North Bedroom	1.23	.94	3.22	.20	.14	-.73	-12
Building				0.43	0.32	-1.28	-9

*Mean absolute difference.

b. NBS Direct-Gain Test Cell: October 1981,

c. Lo-Cal House: January-February 1982.

Several other Class A data sets have been taken but have not yet been analyzed.

(2) A standard Class A reporting format for predicted vs measured hourly space-air temperature data, and for hourly and total-run-period, auxiliary-heating energy data, has been developed. This reporting format is highly useful for quantifying predicted vs measured comparisons and for facilitating comparisons among different sites.

(3) The predicted vs measured comparisons shown in this paper provide a preliminary validation of the envelope and thermal-storage-energy-transfer processes in the DOE-2 building-energy-analysis computer program. For a well-controlled test building, rms temperature differences of about 1°C (1.8°F) can be expected over a 1-week run period.

5. ACKNOWLEDGEMENTS

The expert assistance of G. S. Lazarus in running the DOE-2 computer program and preparing the output plots is gratefully acknowledged.

6. REFERENCES

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