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Final Report

NCSU SOLAR ENERGY AND CONSERVATION HOUSE

Prepared for

APPROPRIATE ENERGY TECHNOLOGY
Small Grants Program
Southeastern Region
U.S. Department of Energy

October 1981

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MECHANICAL & AEROSPACE ENGINEERING
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NORTH CAROLINA

DISCLAIMER

NCSU SOLAR ENERGY AND CONSERVATION HOUSE

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2. SUMMARY

A passive solar energy house has been built adjacent to the NCSU McKimmon Continuing Education Center. The house contains a two-story embedded sunspace, two Trombe walls, active solar hot water heating, thermal storage in a rock filled ceiling/floor, and numerous research treatments, and energy conservation features. (See attached photo brochure; Appendix 1). The house is completely decorated and furnished in an attractive manner and the exterior architecture is traditional and has broad consumer appeal. It is also thoroughly instrumented to monitor performance. The house is open to the public on weekends and numerous people come to visit on their own initiative and others take advantage of the close proximity to McKimmon while there attending conferences. The house will influence and motivate large numbers of people to consider solar and energy conservation facets in their homes and will provide data to substantiate performance to prospective home buyers and meaningful data on design and construction for builders.

3. BODY OF REPORT

Project Objective: to build a research, demonstration, and education solar and energy conservation house adjacent to the NCSU McKimmon Continuing Education Center. This House would be open to the public each weekday and on selected weekends.

Project Schedule: was quite explicit and concise. It simply said -- we will complete the house in September in time to be used as a focal point for North Carolina Home Week (Sept. 21-27) and to "kickoff" the statewide Parade of Passive Solar Homes sponsored jointly by North Carolina State University and the N.C. Home Builders Association. Enclosed is the Performance Schedule (Appendix 2) which is a summary of the field work and schedule of activities which culminated in meeting our objective on time.

Approach Used

a) We organized a steering committee consisting of five representatives from each of three sectors (university, state government, private industry); the three principal investigators, a consulting architect, and the house builder. This committee helped to make decisions regarding the overall design philosophy during the planning phase and to review the house design while in progress.

b) We solicited and received some price reductions and donations of materials, equipment, and labor from various sources in exchange for public credit for doing so. This assistance was

b) (continued)

received in large part because of a close affiliation with the N.C. Home Builders Association and the respect that NCSU School of Engineering has in the State.

c) The project "staff" (some worked voluntarily) was comprised of the following:

i) principal investigator who coordinated all phases of design, guided work on details, and documented the above in writing.

ii) principal investigator at the job site overseeing the installation of instrumentation and supplying labor on non-traditional details of construction.

iii) principal investigator who was responsible for traditional construction and coordination with builder.

iv) highly motivated and capable graduate students, supervised by principal investigators, to work in the field.

v) three faculty members from Agricultural Extension and Home Economics at NCSU to select and coordinate interior design and furnishings.

d) The services of an easy going builder who will tolerate the vicissitudes of university faculty working in, around, and with subcontractors to install instrumentation and insure that the house is energy conservative and built as required for research purposes.

Results

a) Demonstration objective has been accomplished. The Solar House is open to the public on weekdays from 9:30 a.m. to 3:30 p.m., and on selected weekends (for State Fair, NCSU home football games, large attendance at the McKimmon Center, etc.) and has a full time hostess to guide visitors and answer questions. The house has a telephone number (919) 737-3799 and mailing address: NCSU Solar House, Box 50297, Raleigh, NC 27650. To date, over 2,000 persons have visited the facility and a register is kept for people to sign. Public response is overwhelmingly enthusiastic -- see enclosed publicity (Appendix 3).

b) Education objective has been accomplished. Participants at short courses and continuing education programs at the McKimmon Center visit the house while on coffee breaks and at lunchtime. The Solar House is scheduled to be used by some programs as a formal part of their agenda (25th Annual Warm Air Heating and Air Conditioning Short Course on Feb. 22-25, 1982, etc.). The Solar House has been used by various groups: the N.C. Solar Energy Association and the N.C. Home Economics Association for their annual statewide fall meeting.

c) Research objective is on schedule. Complete instrumentation was installed during house construction. See atachment for listing of research capability (Appendix 4). Work is underway

c) (continued)

to obtain a data acquisition system and computer. Data collection and analysis of the solar and energy conservation systems within the house is scheduled to begin in September 1982. This analysis will yield valuable information on the performance of solar systems in North Carolina and the Southeast (i.e. in humid climate with equal heating/cooling loads).

4. CONCLUSIONS

The project has been highly successful. The Solar House was finished on time as scheduled and was dedicated by Governor Jim Hunt to initiate the statewide Parade of Passive Solar Homes. See attached photographs with annotations (Appendix 5). Public interest in the House is diverse and far reaching as is reflected in the geographical spread of visitors.

The confluence of organizational factors, which made this project possible, were highly favorable. The principal investigators are registered professional engineers with practical backgrounds who work and teach academically at a state insitution (NCSU). NCSU enjoys a statewide reputation as a leading engineering and technical school. NCSU is located in the capital of North Carolina (Raleigh) and has working relationships with State Government (the Energy Division), N.C. Home Builders Association, and regional electric utility company (Carolina Power and Light Co.). Lastly, land was procured adjacent to the McKimmon Continuing Education Center for use as the building site.

5. RECOMMENDATIONS

(i) The essential solar and energy conservation elements incorporated in the NCSU Solar House should be considered for implementation by the building industry.
Basis: Preliminary evaluations indicate that the house performs very well thermally.

(ii) Great care should be exercised during construction to properly implement those elements with which the construction industry has little familiarity.

Basis: Construction errors can render the best designs inoperative, and often result in large cost overruns.

(iii) A project of this magnitude (a house for research, demonstration, and education) should be undertaken only if the factors listed under Approach Used are present and/or a large funding source is available.

APPENDIX 2 - PERFORMANCE SCHEDULE

SUMMARY OF
DAILY FIELD WORK
NCSU SOLAR HOUSE

May 1981

6 Excavate/Level site with bulldozer.
8 Dig/Pour Footings.
13 Lay out Foundations. Work on Earth Tubes.
14 Masons Begin Foundation Walls (North & West)
15 Complete Foundation Walls.
18 Waterproofed Foundation Walls.
19 Masons Begin Trombe Walls (TW). Installed two sets of Thermocouples (T/C) in brick TW.
21 Worked on brick TW. Installed T/C in brick TW.
22 Worked on block TW. Installed T/C in block TW.
25 Worked on block TW. Installed T/C in block TW.
26 Masons Begin exterior Retaining Walls.
27 Masons Begin sunspace Interface Walls.
28 Worked on sunspace Interface Walls. Fill block TW with concrete.
29 Worked on sunspace Interface Walls. Install T/C.

June

1 Complete Sunspace Interface Walls (to first level).
3 Plumbers Stub in Basement.
4 Worked on Earthtubes.
5 Installed Foundation Drain.
8 Placed gravel for concrete floor.
9 Installed T/C, Conduit, Insulation for Sunspace Floor.
10 Poured Concrete Floor.
11 Hauled more gravel for foundation drain.
15 Unsuccessful attempt to clean interface walls.
17 Begin installation of Exterior North Wall Research Treatments (T/Cs, conduit, insulation, etc.)
10 tons rock delivered for filling spandeck.
18 Off Loaded Spandeck. Begin Filling Spandeck with rocks.
Complete Installation of North Wall T/C.
19 Filling Spandeck with rocks.
20 Complete Filling of Spandeck.
21 Marked off location of spandeck on walls. Laid out bearing pad (#90 felt) for spandeck.
22 Placed spandeck with crane. Backfilled North & West walls.
23 Dug and Poured Footings for front and side porches.
24 Installed vent holes in spandeck for duct/manifold.
25 Masons Laid brick & block foundations for front and side porch.
26 Pour concrete side porch. Professional, high pressure cleaning of sunspace Interface Walls.
29 Sealed North ends of spandeck cavities.
30 Begin Framing.

July

1 Frame lower level.
2 Frame lower level.
3 Frame floor joists. Pull masonry and North Wall T/C's to Data Acquisiton. Room.
6 Frame floor joists. Pull masonry and North Wall T/C's to Data Acquisition, Room.
7 Frame upper level. Caulk under all sole plates.
8 Frame ceiling joists.
9 Frame rafters.
10 Frame rafters and roof.
13 Hang sheathing.
14 Install siding. Put duct tape on all blue board sheathing.
15 Install siding. Install T/C for East Wall Research Treatments.
16 Install siding.
17 Install siding.
20 Install siding. Install spandeck ductwork manifold.
21 Complete siding. Complete ductwork. Plumbing Roughed In.
22 Begin Rough Wiring. Carpenters box around manifold.
23 Rough Wiring. Complete framing for chimney.
24 Rough Wiring.
25 Complete Rough Wiring.
27 Start Roof Shingles. Install room T/C's.
28 Complete Roof Shingles.
29 Insulate walls and ceiling.
30 Hang Sheetrock.
31 Start sheetrock finish. Masons Start 2nd level of interface wall.

August

1 Brickwork on Interface Wall.
3 Complete Interface Wall and Chimney. Grading.
4 Grading. Sheetrock finishing.
5 Exterior stained. Sheetrock sprayed.
6 Subfloor laid.
7 Tile men roughed in lath.
8 Professional brick cleaning of interface wall. Spandeck sprayed.
10 Interior finish and trim.
11 Interior finish and trim. Decking.
12 Interior finish and trim. Decking. Tile, Dug septic field and earth tube.
13 Interior finish and trim. Decking. Tile. Sewer line dug.
14 Interior finish and trim. Septic field heat exchanger installed.
15 Tilemen. Septic field heat exchanger installed.
17 Interior finish and trim. Grading. Sprinkler system installed
18 Interior finish and trim. Grading. T/C's installed in septic heat exchanger.
19 Interior finish and trim.
20 Plumbing completed for septic field heat exchanger.
21 Septic field filled.
22 Paint.
24 Brick paving of patio and walkways.
25 Brick paving of patio and walkways.
26 Brick paving of patio and walkways. Install light fixtures.
27 Brick paving of patio and walkways. Set solar panels.
28 Brick paving of patio and walkways. Final rough grade.
31 Underground service installed.

September

1 Landscaping.
2 Landscaping. Painting. Plumbing for solar collectors.
3 Install shutters. Plumbing for solar collectors.
8 Glass. Brick paving.
9 Trim. Carpet. Brick paving.
10 Furniture. Brick paving.
11 Smooth grading. Interior decoration.
12 Interior decoration.
14 Landscaping. Interior decoration. Cleaning.
15 Landscaping. Interior decoration. Cleaning.
16 Landscaping. Interior decoration. Cleaning.
17 House dedication.

APPENDIX 4

NCSU SOLAR HOUSE

Research Opportunities

and
their relationship to

Electric Utility Operation

Research
Opportunities
Issues/Questions

Active Solar Domestic Hot Water Heating System

flow rates, heat exchangers, control strategy, solar contribution

Building Materials/Techniques

(i) Six different insulation treatments on bermed wall

(ii) Six different insulation treatments on east wall (above grade)

(iii) Operable exterior insulating shutters on north windows

(iv) (2x4) versus (2x6) construction

(v) Extensive caulking and weatherstripping to reduce infiltration

Passive Solar Systems for Space Heating

(i) Optimum thickness of mass floors

(ii) Insulation under slab

(iii) Optimum thickness of
- Trombe walls
- interface walls

(iv) Summer performance of mass walls
- a/c liability?
- insulation?

(v) Trombe wall vents

(vi) Mass wall building material
- block vs. brick

Spandeck Thermal Storage System

(i) solar contribution

(ii) operating characteristics
- -flow requirements
- -pressure drop
- -noise
- -temperature gradients
- -control strategies

(iii) installation guidelines
- -fan selection
- -fan support
- -span-deck support
- -rock loading
- -cost analysis

Septic Field Heat Exchanger Coupled to Water-to-Air Heat Pump

(i) effectiveness - COP

(ii) HX flow rates

(iii) HX sizing

(iv) winter versus summer operation

Others

(i) ventilation fan - for summer cooling

(ii) natural circulation - sunspace to living space

(iii) earthtubes

(iv) infiltration rates

(v) temperature stratification
- -in room
- -floor to floor

(vi) affect of sunspace temp. variation on SHF

(vii) determine overall SHF

APPENDIX 5

PHOTOGRAPHS OF NCSU SOLAR HOUSE

Photograph 1 OPENING CEREMONIES AT HOUSE DEDICATION

Governor of North Carolina, James B. Hunt cutting the ribbon to signify the official opening of the NCSU Solar House on September 17, 1981. The facility is and will be open to the public for visitation on weekdays from 9:30 a.m. to 3:30 p.m. A hostess is on duty in the house during this time to answer questions and guide people as appropriate. To date about 1600 persons have visited the facility and signed the register.

Other people in the ceremony are (from left-to-right)
Dr. William L. Turner, Vice Chancellor for Extension and Public Service, NCSU

Dr. Nash N. Winstead, Acting Chancellor, NCSU

Governor James B. Hunt

Durwood Stephenson, President, North Carolina Home Builders Association

Dr. Larry K. Monteith, Dean, School of Engineering, NCSU

Photograph 2 FRONT VIEW (NORTH SIDE)

Note small amount of glazing area and the operable insulating shutters. These shutters are completely weatherstripped with V-shaped spring bronze and are tight fitting.

House is completely landscaped and has walkways, ramps, and access for the handicapped in conformance with North Carolina Building Codes.

Some additional features are cedar siding and the first use of "chaparral style" fiberglas shingles which were donated by the Owens Corning Co.

Photograph 3 BACK VIEW (SOUTH SIDE)

Main Visible Features

*Revere active solar collectors are used for a two-tank domestic hot water system. Collectors do not drain down and consequently they use an antifreeze as a heat transfer fluid.

*Two story sunspace with lower vented windows. Balcony and railing inside the sunspace can be seen by looking closely. Outside the sunspace is a patio with a removable overhang that is used for summertime shading.

*The two Trombe walls are symmetrically placed on either side of the sunspace. Each Trombe wall is 12 inches thick and both have removable overhang (like the lower portion of the sunspace). The Trombe wall on the left is constructed of block (filled with concrete) while the one on the right is obviously brick (three rows wide and filled with mortar).

Photograph 4 ANOTHER BACK VIEW

This shows some of the people present at the initial house opening on the dedication day which also corresponded to the start of the N.C. Home Builders Association, "Parade of Homes".

Photograph 5 INTERIOR VIEW IN LIVING ROOM

These are the three persons, (specialists in housing and interior design from the NCSU Agricultural Extension Service) who participated in choosing the interior furnishings and appliances for the house.

From left-to-right are:

Dr. Glenna M. Herman
Dr. Linda F. McCutcheon
Wilma S. Hammett