THE CAL POLY HOUSE DOCTOR LAB

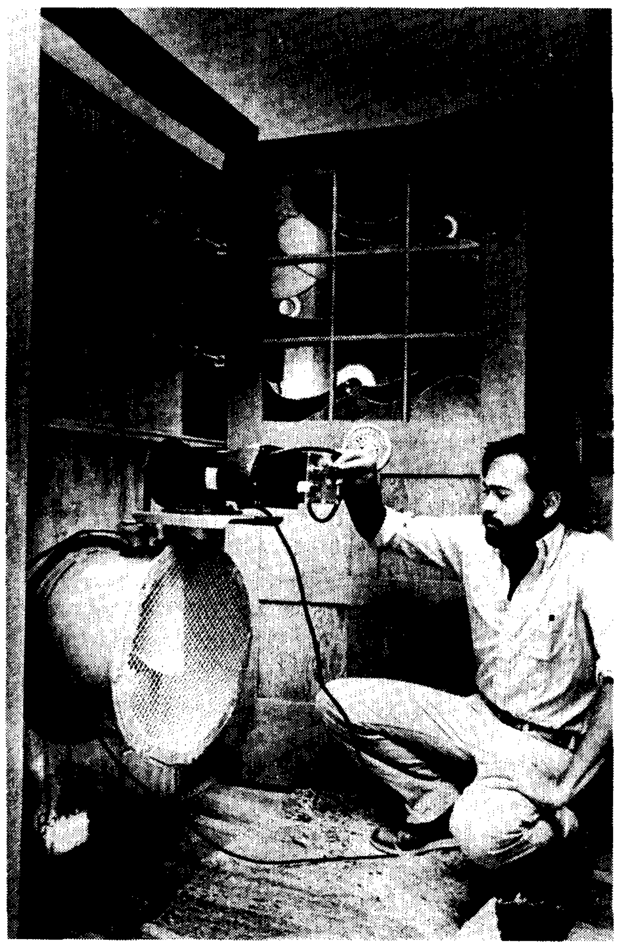
by
David Hafemeister

Not every university is an ivory tower. Cal Poly's "House Doctor Lab" is providing architects with the tools needed to design energy-efficient buildings.

California Polytechnic State University, in San Luis Obispo, California, has the nation's largest school of architecture with 1500 students. Because a typical architect will walk through literally thousands of buildings in her career, each can have a tremendous, multiplicative effect on the energy efficiency of the nation's buildings. As a response to the oil embargo of 1973-74, the physics department at Cal Poly created the "Cal Poly House Doctor Lab" in order to give architects both "hands-on" and theoretical training in energy conservation.

After surviving two quarters of engineering physics, the Cal Poly architects take a special course using our own text, *Physics for Modern Architecture*, and a lab manual. Because California is "earthquake" country, the laboratory addresses dynamic properties of buildings as well as energy use. In one laboratory session, the students bring in models of buildings that they have designed to be resilient to earthquakes. One loud speaker shakes the structures while another picks up the response of the shaken structure. The dynamic properties of the structure are measured with an oscilloscope (Fig. 1).

After the oil embargo of 1973-74, the text and laboratory were considerably broadened to address energy efficiency in buildings. During the quarter, the budding architects learn to estimate losses from buildings using linear circuit analogues, daily and hourly solar gains, and time constants of ther-



Student Jim Woolaway measures the leakage area of the Hafemeister house in San Luis Obispo with a blower door. Site visits were carried out as part of the "House Doctor Lab". (Photo by T. Hertz.)

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mal storage, and estimate the economic value of these losses using discounted future benefits.

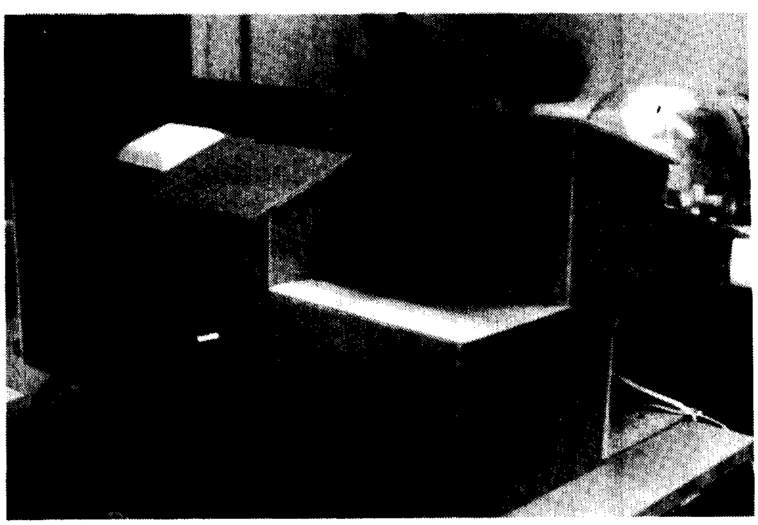
In the early years of the house doctor lab, we visited homes in the San Luis Obispo area to measure actual buildings. After the local newspaper wrote a story about our house doctor services, local citizens began calling up to sign up for a free diagnosis. But the transportation of 24 students, blower doors and various meters became too crowded, hectic, and cumbersome—for example, students standing next to dainty statues and walking through deep rugs with dirty shoes. We now perform measurements in a room in the physics department to avoid these problems and no longer offer free measurements of peoples' homes. Some of the measurements are as follows:

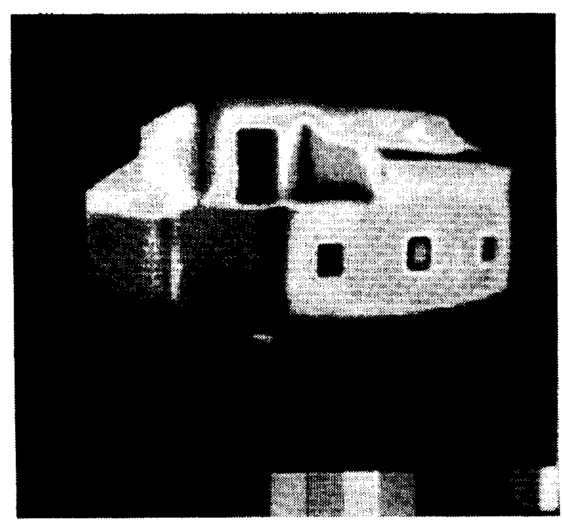
Blower Door: We pressurize the house with a blower door and use smokesticks for qualitative leakage measurements. To make sure the blower door gives accurate readings, the door was calibrated at the Lawrence Berkeley Laboratory (LBL). We added small amounts of extra leakage area to our test chamber by opening windows, and then using computer software to analyze the data. In order to measure the rotational speed of the fan, student Jim Woolaway built a circuit with chips and photodiodes to count the shadows of light created by the fan blades. In 1981 Woolaway improved the LBL blower door design by using quick-release mechanisms and by constructing the door out of two separable pieces.

Air-to-Air Heat Exchangers: A Mitsubishi unit has been modified with external baffles to separate the four air streams. Rough measurements of thermal efficiency are made with digital thermometers. Our measurements are consistent with the LBL measurements of about 75 percent heat recovery efficiency. The air-to-air heat exchangers are not really necessary for southern California conditions, but for a superinsulated house in Saskatchewan, they are essential.

Heat Flow Through Surfaces: An Abbeon Heatprobe thermometer is used to directly measure heat losses and gains through walls. In order to reduce the hourly variation in heat transfer during the day, we average measurements over 24 hour periods. The R-values of various materials have been determined by using a hot box built by Peter Govea. (Peter now works on energy conservation with the City of Palo Alto utility.) For windows, we have used window energy meters to measure both solar gains and heat losses.

Infrared Measurements: We use an AGA Thermovision 680 to measure infrared temperature differences of a few tenths of a degree. (This is a top-of-the-line IR camera that retails for $40,000.) Two students have constructed a model house in order to demonstrate the effects of different glazing, infiltration losses, insulation levels, and surface emissivities. By creating a heat pulse (hot, then cold) in a copper rod, one can estimate the thermal conductivity of the rod by observing the heat pulse traveling down the rod.





Left: **A model of a house constructed by students Jeff Kepple and Ted Trouard. The effects of various glazings, insulations, and materials (black chrome, etc.) are easily accessible to infrared measurements by the architecture students.** *Right:* **Note that the infrared image of the house has been reversed.**

Appliances and Lighting: We measure the energy efficiencies of microwave ovens and other appliances using a kilowatt-hour meter. We have also compared the efficacy (lumens/Watt) of incandescent bulbs and the more energy-efficient fluorescent lamps using photometers and kWH meters. We tested the GE Circline and the Philips SL-18 and found that these fluorescent lamps with solid-state ballasts were four times more efficient than the incandescents.

Solar Energy: The solar flux is measured as a function of the angle of the sun with respect to the zenith angle, and then compared to the exponential formulas that account for absorption in the air. Styrofoam and glass boxes are used to create greenhouse effects with a short time constant. Efficiencies of both passive and active (hot water and hot rocks) are measured. Student Alan Lyon constructed an active solar unit. (Alan now works for a solar firm in Berkeley, CA.)

Conclusions

The architecture students tell us that they prefer these kinds of applied measurements of buildings because of their career orientation. Hopefully, the budding young architects will enthusiastically apply the energy lessons from their "House Doctor Lab" to many buildings over their careers.

New Jersey Energy Studies Program

A state college in New Jersey is one of the few schools in the country that has an energy studies program offering hands-on experience with energy conservation equipment. The Energy Studies Certification Program at Stockton State College was established in 1983. It covers all aspects of building energy conservation, including heat loss, appliances, energy management, and mechanical systems in residential and commercial buildings. The courses give students majoring in other areas a firm background in the energy conservation field. "We make sure that our students get experience with the latest conservation technologies," says Lynn Stiles, a professor at Stockton State. "However, we place less emphasis on actually performing the retrofit and more on understanding the physical processes governing energy use in buildings."

The program received a boost in 1984 when the New Jersey Department of Higher Education gave it a grant to purchase conservation equipment, including two AGA infrared cameras (one with a color monitor), a blower door, an insulation blower, a Neotronics fuel-efficiency monitor, and a gas chromatograph for tracer gas analysis. Many of the students pursue research projects on campus buildings or nearby residences. In one recent project, for example, a group of students tightened up an old Victorian house to achieve energy savings without destroying the building's architectural integrity. For more information about the Stockton State program, contact: Lynn Stiles, Division of Natural and Mathematical Sciences, Stockton State College, Pomona, NJ 08240. Tel: (609) 652-1776.

References

[1] A. Buffa, D. Hafemeister, and R. Brown, *Physics for Modern Architecture*, Pladin House, Geneva, IL. The text and laboratory manual are available from the El Corale Bookstore, Cal Poly University, San Luis Obispo, CA 93407.

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