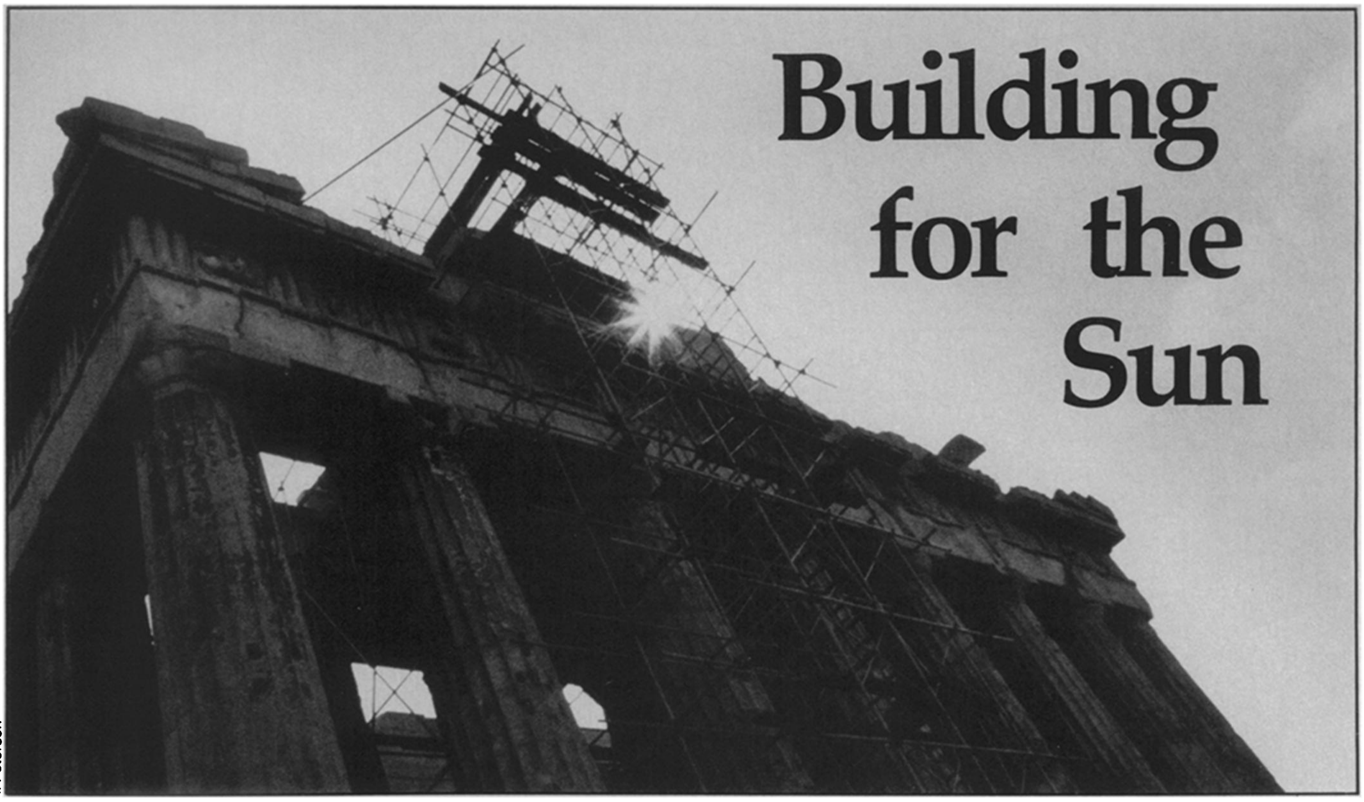


Building for the Sun

I. Peterson

By IVARS PETERSON

The Greek philosopher Socrates once remarked that the ideal house should be warm in winter and cool in summer. As long as 2,500 years ago, the ancient Greeks, working with little more than sun and wind, planned entire towns and designed individual homes that captured winter sunlight and snagged summer breezes. Centuries later, the Romans, in search of comfort throughout their empire, developed solar designs for different climates, introduced transparent window glass as heat traps and even enacted laws to protect access to sunlight.

The passive use of solar energy has a long history, and it's tempting to say there's nothing new under the sun. But, insists Leon Glicksman of the Massachusetts Institute of Technology, "Although we're dealing with the same old questions, we need to find new answers."

Glicksman and his colleagues have just started a project that may turn out to be one of these innovative solutions. Their system — a "fluidized bed" solar collector — is a new technique for concentrating solar energy. The scheme involves bubbling air through a wall cavity filled with small, light particles such as Perlite beads or hollow glass spheres. As the particles swirl and bump in the gently flowing stream, they transfer heat from the sun-warmed wall to air inside the pipes of a heat exchanger also installed in the wall cavity. Because a pump is used only to agitate the particles, it need not be as powerful as one used to drive solar-heated air throughout a house.

The system also provides a bonus: controllable insulation. At night, turning off the pump lets the particles settle to form an insulating layer that fills 80 percent of the wall cavity.

"No one has ever looked at low-density, fluidized beds before," says Glicksman, who was one of several researchers presenting new findings on solar buildings at a recent conference sponsored by the Department of Energy (DOE) in Washington, D.C. "This is one innovative solution that may work."

Research on passive solar technologies continues despite recent upheavals and policy shifts at DOE, says the agency's David Pellish, and despite the grumbling of builders who complain that solar technologies are too expensive, unreliable and impractical. "It takes a long time for an innovative idea to be accepted and to go into widespread use throughout the country," he says.

DOE estimates that the United States has about 85 million buildings, ranging from single-family dwellings to large office complexes. Although total energy consumption has gone down during the last 10 years, these structures guzzle more energy now than they did a decade ago. One reason, says Pellish, is that "we are not demolishing old buildings as quickly as we are putting up new [energy-efficient] ones." Technologies are needed that would allow the existing inventory of structures to be upgraded easily.

One approach taken by DOE researchers is to look upon a building as a vast solar-collecting "membrane" that separates the inside from the outside environment. "You control the use of solar energy by controlling that membrane," says Pellish. This means using new materials and new designs to take advantage of sunlight that falls naturally on a building's roof and walls.

One simple way to do this is to use wallpapers or paints that, as needed, reflect or absorb infrared light. Researchers at Honeywell, Inc., in Minneapolis, for example, are investigating vanadium dioxide, a "thermochromic" material. At 68°C, this compound switches from one crystal form to another, changing the material's ability to reflect infrared light. Interior walls covered with paint pigments containing this material would absorb heat below a certain critical temperature and reflect infrared light at higher temperatures.

Gordon V. Jorgenson and his colleagues at Honeywell are now looking for ways to lower vanadium dioxide's transition temperature to a more useful level. One possible approach, they believe, is to dope polycrystalline vanadium dioxide films with traces of tungsten or molybdenum.

Having interior walls that reflect heat would by itself save energy, says Donald A. Neeper of the Los Alamos National Laboratory in Los Alamos, N.M. Walls coated with an infrared-reflecting wallpaper would bounce heat from any radiant heat source back into a room. "Just by changing your wallpaper, you could get a 5°F drop in indoor temperature," says Neeper, and still be just as comfortable while saving energy.

Letting the sun shine in is an old idea now wrapped in new technologies

Equally intriguing is the idea of a "living" wall that responds to temperature fluctuations by absorbing or emitting heat. One way to achieve this is to incorporate "phase-change" materials in plaster or gypsum walls. Phase-change substances, depending on the material, absorb large amounts of energy when melting, losing water (dehydrating) or changing their crystal structure. The reverse process — for instance, freezing or the addition of water — releases that energy.

Ival O. Salyer and his group at the University of Dayton (Ohio) Research Institute are on their way to identifying a suitable phase-change material for this application. Their most promising candidates are the crystalline alkyl hydrocarbons — long chains of singly bonded carbon atoms. These paraffin waxes are inexpensive and readily available as by-products of petroleum refining. Different waxes can be blended to shift melting and freezing points to a useful range for particular applications. Moreover, when added to cement or plaster, they waterproof those materials.

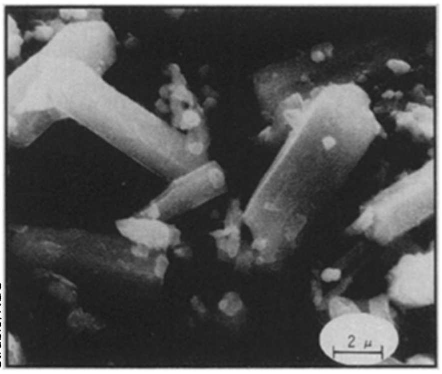
Salyer's group is now studying ways of reducing the flammability of crystalline alkyl hydrocarbons and incorporating them in building materials. He is already looking toward using similar additives to improve the heat-storing properties of carpets, floor tiles and even fabrics.

Another promising group of phase-change materials is the polyhydric alcohols. These solid alcohols release or absorb energy when they shift from one solid form to another. Using a recently patented process, researchers at the Solar Energy Research Institute (SERI) in Golden, Colo., have fabricated concrete, gypsum and wood products that incorporate a large amount of polyhydric alcohols.

These novel composite materials can be sawed, nailed or painted and, in the case of concrete, poured on-site or precast. Traditional construction practices and labor skills can still be used, but the resulting structures store more heat than their conventional counterparts.

SERI's David K. Benson and Craig Christensen suggest that it may be possible to design polyhydric alcohol mixtures that can be triggered to release their stored energy not at the transition temperature but at some lower temperature. Allowing this "supercooling" would ensure that the heat would be released only when it's needed. Such control, they say, would greatly increase the usefulness of storing heat in a building's walls for later use.

A new name on the thermal energy storage block is ettringite, a crystalline material that forms during the hydration of Portland cement. It's prepared by mixing aluminum sulfate and calcium hydroxide. In this case, the addition of water causes the release of heat while dehydration absorbs heat.



Struble/NBS

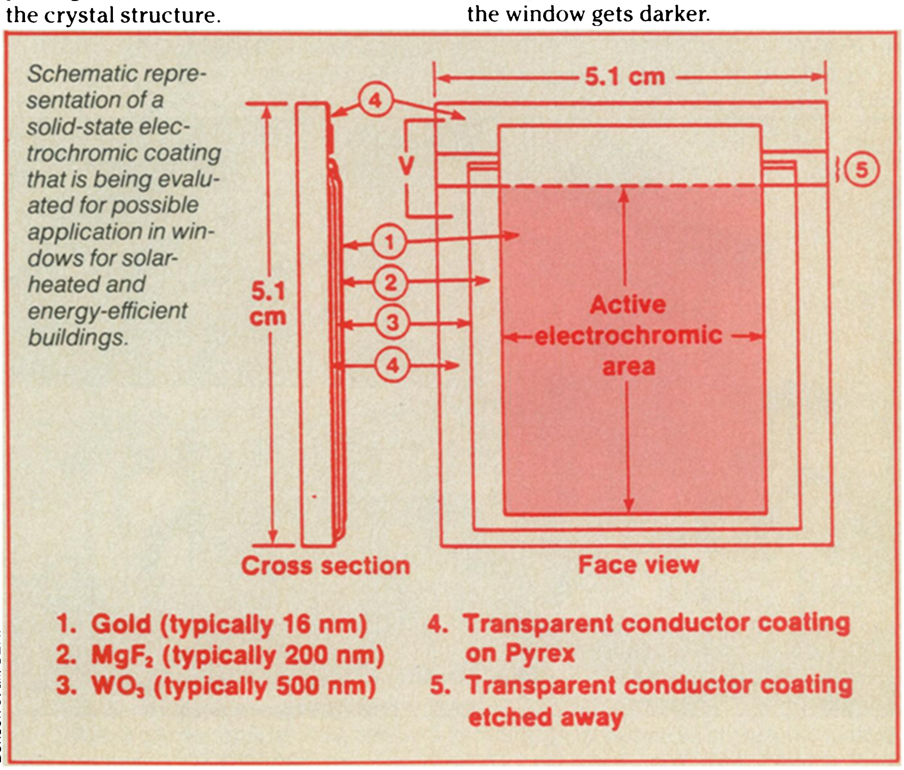
Micrograph of ettringite.

Because the material is inorganic, nonflammable and nontoxic, Leslie J. Struble and Paul Brown of the National Bureau of Standards in Gaithersburg, Md., think ettringite may have some advantages over organic substances being considered for solar energy storage. What's needed is a way of lowering the material's dehydration temperature, perhaps by replacing some aluminum ions with iron in the crystal structure.

Windows, too, can be reworked so that they insulate better or transmit only particular wavelengths of light. At the Lawrence Berkeley (Calif.) Laboratory, researchers have been studying ways of manufacturing highly insulating "aerogels" (transparent silica materials that are about 95 percent air by volume) for use in north-facing windows (SN: 2/25/84, p. 125). Their new production method lowers the temperature and shortens the time that it takes to produce aerogel sheets. However, the material is still somewhat fragile and absorbs enough visible light to appear bluish.

Some types of special glazings that reduce heat loss through windows are already commercially available. One type consists of infrared-reflecting polymer films suspended and sealed within the gas-filled space between two glass sheets. Such windows could be made more highly insulating if a vacuum replaced the gap-filling gas. SERI researchers are studying the use of lasers to seal such evacuated window glazings. One problem is finding a reflective film that can withstand the high processing temperatures.

"Smart" windows, which react to sunlight by changing their properties, represent a more ambitious approach. This type of window is essentially a multilayered, transparent, thin-film battery affixed to a glass or plastic base. When a current flows through the active "electrochromic" layer, the window gets darker.



Schematic representation of a solid-state electrochromic coating that is being evaluated for possible application in windows for solar-heated and energy-efficient buildings.

Benson et al./SERI

These windows could be manually or automatically adjusted to reduce daylight heating needs and glare or to provide nighttime insulation and privacy, says R. David Rauh of EIC Laboratories in Norwood, Mass. EIC researchers are preparing to construct the stack of glass-mounted thin films needed for a functioning window. "We don't have one quite yet," says Rauh, "but we're on our way there."

Simpler versions of electrochromic, switchable films for various applications are likely to be on the market soon. Japan's Nikon, for example, has produced a fast, electrochromic shutter that survives more than 50,000 cycles, while Asahi Glass has a window glazing that electronically alters its ability to absorb light. SERI researchers last year demonstrated that relatively large sheets of a multilayered, electrochromic coating on glass could be produced. But although these panes had many of the right properties for solar applications, the outermost gold layer still wasn't transparent enough.

Smoke trails (horizontal lines) aid researchers in identifying airflow patterns in solar buildings. These patterns help building designers to place features like skylights and doors so that solar systems function properly.

Balcomb/LANL

High-tech inventions like switchable windows and fluidized-bed walls are only part of the solar picture. Some energy-saving answers are as simple as installing skylights or opening doors.

In many houses that have skylights, a sunspace or an atrium, air currents carry heat to more remote rooms. Although the use of natural convection in this way is probably as old as the days of cave dwellings, researchers are just beginning to understand in detail how the design of buildings affects airflow. Their aim is to develop a mathematical model that will help building designers decide, for example, where to put skylights or what size doors to use.

To validate the model, J. Douglas Balcomb of the Los Alamos National Laboratory has been leading "hit and run monitoring" invasions of various solar homes to collect airflow and temperature data. Many solar-based systems, he says, don't work as well as they should because of design or execution flaws. Yet the basic concepts are very simple. "You don't need an operating manual for a house," says Balcomb.

Interest in "daylighting" to reduce energy costs is also growing. As much as 50 percent of an office building's energy consumption goes into electric lighting and the added cooling needed to remove waste heat from the lighting fixtures.

Synergetics, Inc., of Raleigh, N.C., for example, has come up with a "variable-area, light-reflecting assembly," an elaborate name for a roller-mounted reflective film that projects sunlight into a building to provide low-glare daylight as a substitute for electric light. Changing the film's area and angle keeps it in tune with the amount of sunlight present and needed. With strategically placed interior mirrors, sunlight can probe the darkest corners of a home or an office building to provide cheap, natural lighting.

Another way to redirect sunlight is to use special laser-produced holograms that diffract light. A strip of this material across the top of a window could send sunlight, which might otherwise fall on the floor near the window, to a ceiling or some other surface that diffusely reflects light. Richard Ian of the Advanced Environmental Research Group of Cambridge, Mass., says such holograms could be designed to track the sun over a wide range of angles without having to be moved.

One futuristic, underground structure — the University of Minnesota's two-year-old Civil and Mineral Engineering Building in Minneapolis — already has a sophisticated system that beams sunlight into the building's interior. Twin tracking mirrors on the roof capture sunlight and direct it downward to a hallway 110 feet below. There, the sunlight is squeezed into special "light pipes" that, like leaky optical fibers, illuminate hallways and distant labs.

The building's trappings are high-tech, but the idea is as old as ancient Egypt. Centuries ago near Luxor, Egyptian artists used reflected light to illuminate underground chambers — to get smokeless lighting by which to decorate tombs. □

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Tom Foley/U. of Minn.

Exterior view of the University of Minnesota's Civil and Mineral Engineering Building. Inset shows a "light pipe" illuminating a hallway.