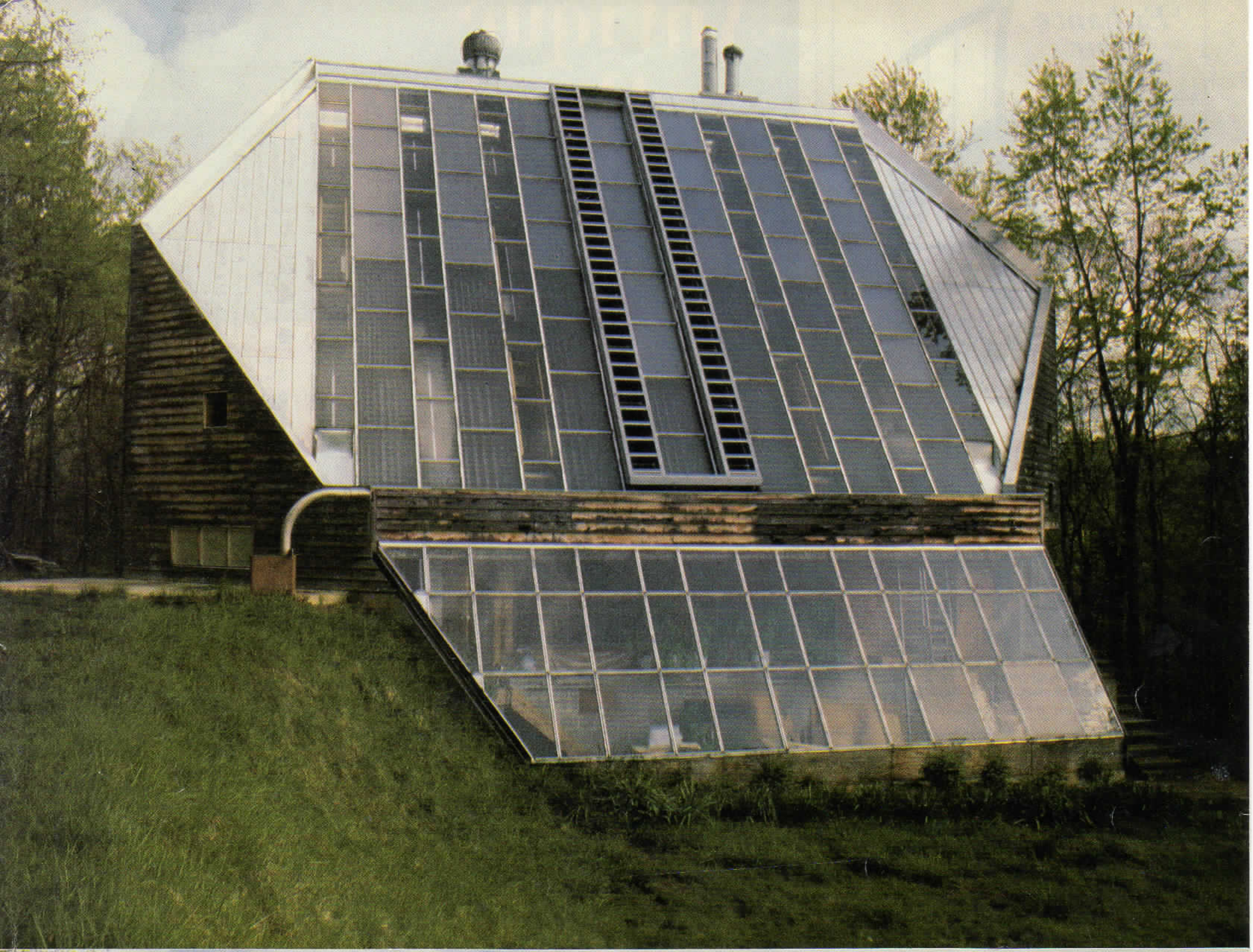

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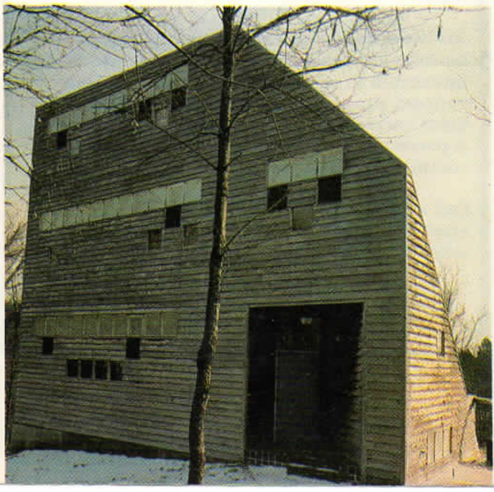
A Slice off the Cube

A Kentucky architect alters a simple shape to design an integrated system aimed at optimum solar performance

by Tim Snyder



When Richard Levine started to design his house in 1974, interest in solar components was on the rise. Spurred on by the energy crisis, entrepreneurial manufacturers were cranking out a new generation of active and passive-solar equipment. The emphasis was on developing new products to meet a need; sound procedures for testing and evaluation weren't yet available.

Most of these early designs were add-on units, and there wasn't much information on system sizing or long-term performance. Levine, a professor of architecture at the University of Kentucky, wanted to build an integrated solar house whose structure and form would be directly linked to the sun-catching systems that would heat and cool it. And he wanted its design to be straightforward enough so that he and his wife, Anne Frye, could do much of the building themselves.

Levine wasn't satisfied with the manufactured solar collectors that were available at the time, so he decided to start from scratch and come up with his own system. By foregoing commercial hardware in favor of site-built collectors, he was forced to develop the system more carefully, without making assumptions about performance or appearance.

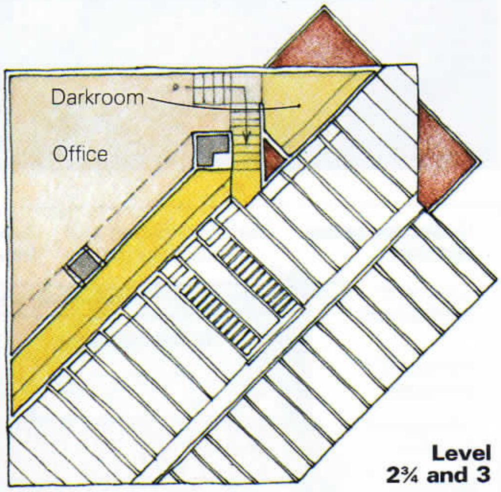
Since he and his wife moved into the house late in 1977, Levine's system has performed well. It's based on a bank of collectors that can heat the house passively during sunny days and actively at other times, through a rock-storage bed in the basement. The system incorporates a series of dampers and thermostats that are linked to a small computer, enabling the various components to react automatically to a variety of conditions. Levine can also evaluate the house and fine-tune its system to respond better to the weather and to temperatures inside the house.

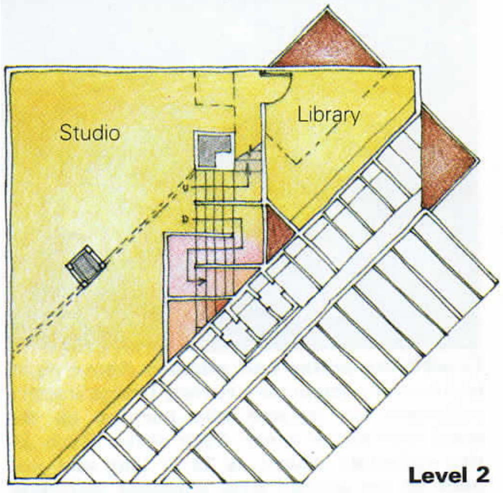
Slicing the cube—What looks to be an intricate shape is actually a very simple one. Levine began with a 40-ft. cube, a conventional shape with a volume-to-surface area ratio that would keep heat loss to a minimum. He oriented the cube with one corner facing due north, then symmetrically sliced through its top face at an angle close to 55°, halving the form. The slice yielded a large, hexagonal surface area for the solar collectors, which faced the sun at close to the optimum angle for Lexington's latitude.

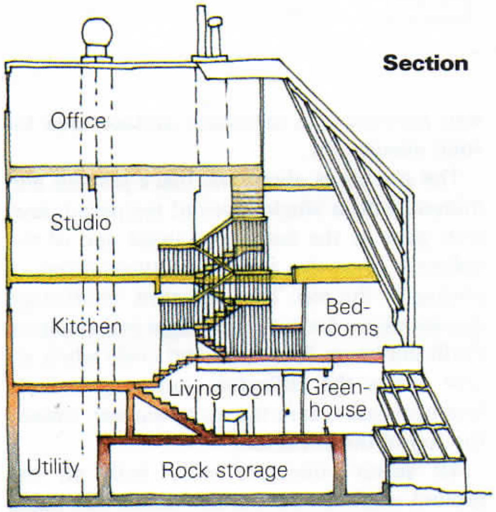
The square north corner and the angled south face of the sliced cube gave Levine some unique design opportunities in terms of interior space. He found that the south face generated low, triangular interior spaces, while the north side of the house wanted higher ceilings and rectangular rooms. These different geometries meet at the center of the house, and are linked to one another by the stairway. This open framework of landings, stringers and treads is a strong focal point, integrating interior forms with the solar shape and orientation of the house.

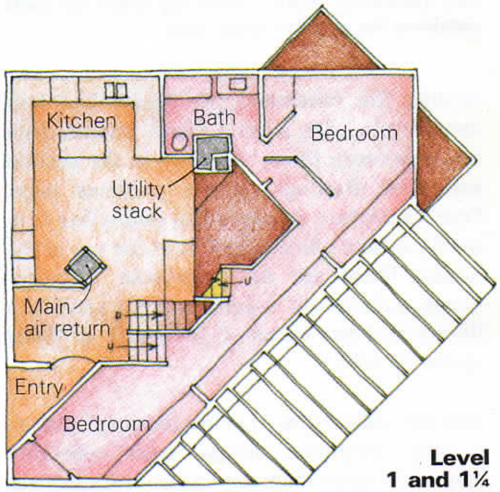
The complex interior led Levine to build a framing model at ½-in. = 1-ft. scale before construction began (photo top right). Not in-

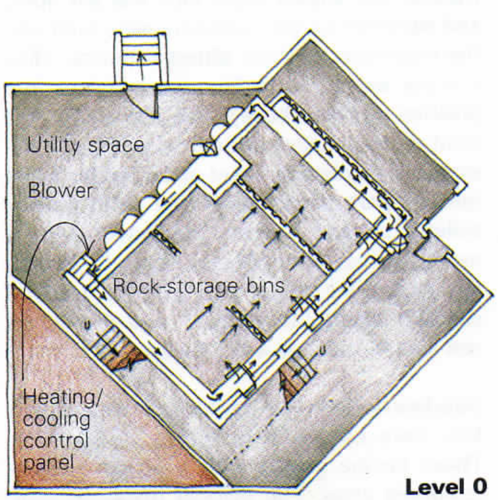
Solar front, square back. **A south-facing, 55° slice through the otherwise cubic structure holds a bank of solar collectors above greenhouse glazing (facing page, top). Triangular sections of the south face are roofed with standing-seam aluminum, and the twin-runged metal ladder can be rolled across the collector bank without blocking it, for glazing inspection and repair. The north sides of the house (facing page, bottom) contain three different window types, all designed to fit between 2x6 studs set on 2-ft. centers. Windows for viewing are clear. Windows for diffuse interior lighting are glazed with translucent fiberglass. Ventilation windows are covered with slide-down insulating panels. Levine put together a framing model, right, to help determine construction details before actually beginning to build. Interior space allocation is shown in the section and plan-view drawings below.**

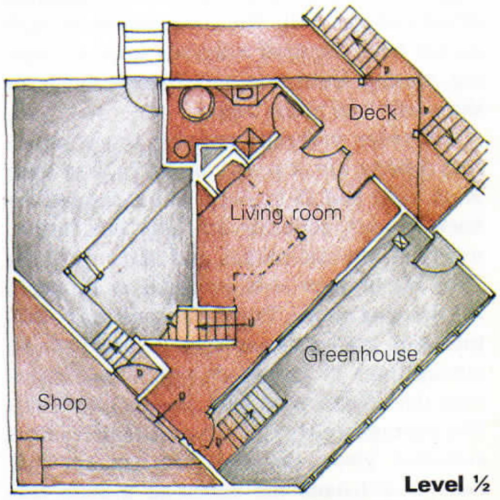




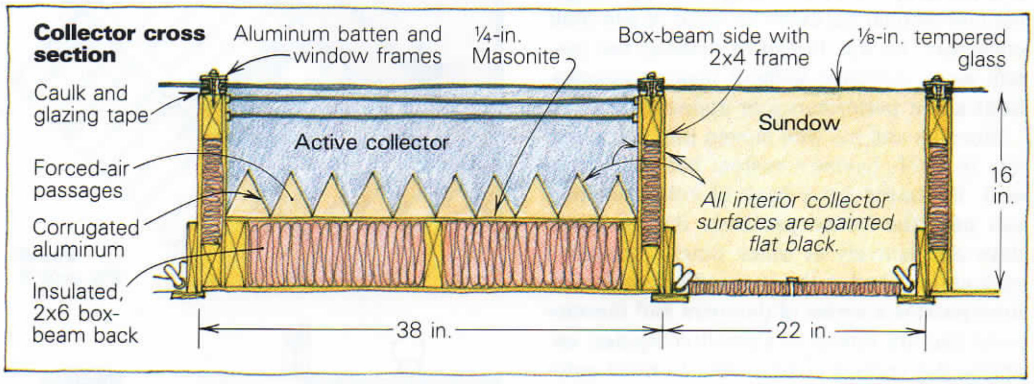








Combining active and passive. **Above right, protected by temporary covers, Levine's active collectors are hoisted into position on the south face of the house. Each of the seven active collectors, above, is 32 ft. long and was built on the ground from standard materials. Levine glazed the space between active collectors (drawing, right), creating what he calls sundows for passive-solar gain.**



cluding the basement, the house has four main levels, with several small, intermediate levels between them, as shown in the section and plan drawings on the previous page. Frye's sculpture studio is just below her husband's design office, which is at the top of the house. There are two bedrooms, a greenhouse, a darkroom, a living room, a kitchen, a library and two baths—3,700 sq. ft. of living space, all told.

Hot-air collectors—Levine reasoned that in a truly integrated design, solar collectors should do more than just absorb the sun's energy. So he designed his collectors to function structurally as well. The solar panels he built on site from standard materials serve as framing, glazing, insulation and interior finish for the south face of the house.

The seven vertically oriented active collectors (photo, top of p. 26) are each 32 ft. long, 38 in. wide and 16 in. deep. The sides and the back of each collector are long box beams, with 2x4 internal frames and skins of either ¼-in. Masonite or ¼-in. plywood, as shown in the drawing above. They're air-heating collectors, with forced-air passages located beneath corrugations of tempered, 4-mil sheet aluminum that Levine bent on a sheet-metal brake. The corrugations run the whole length of the collector, giving the aluminum enough stiffness to withstand the forced-air system, and also providing an increased surface area for solar absorption.

The glazing is above the black-painted aluminum, with a single layer of tempered, low-iron glass at the bottom or input end of the collector, then two and finally three layers of glazing at the top. This patented, multi-stage design allows for maximum light transmission (with minimum insulation and cost) when air first enters the collector, and progressively less heat loss where the air is warmer, toward the top of the collector.

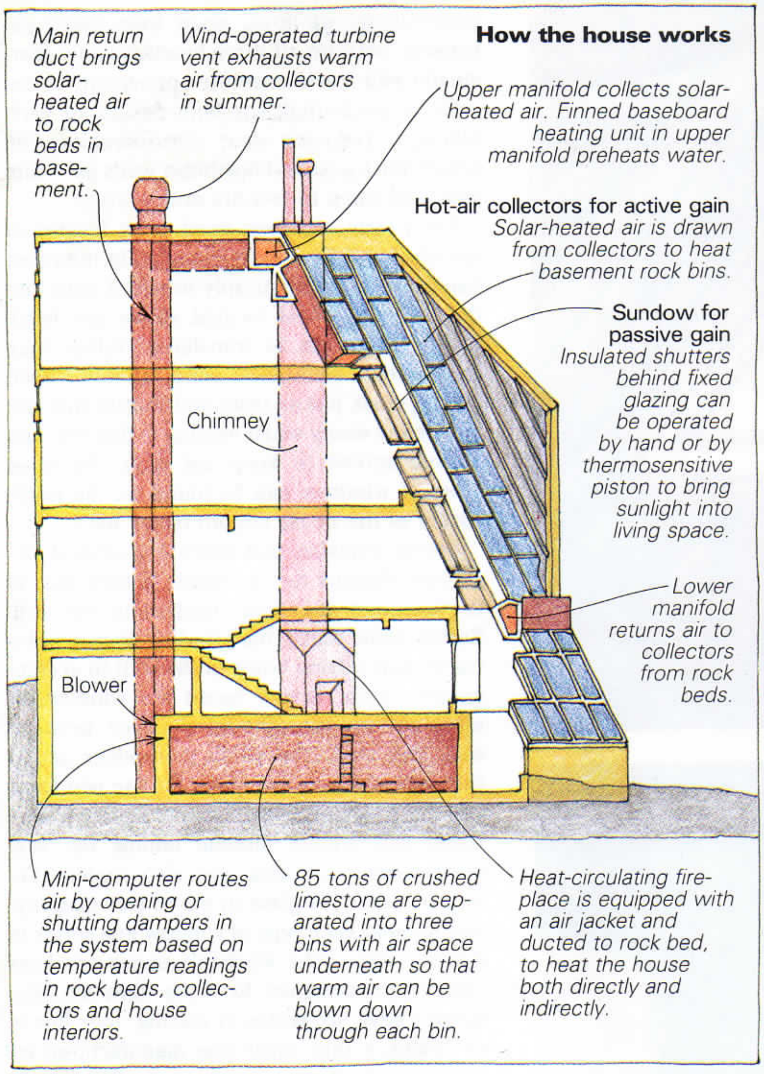
All seven collectors were built on the ground while the rest of the house was being framed. The angled south face was left open, and supports for the collectors were built into the framework at three different points. Then a crane was hired to lift each collector into position (photo above), and the south face went up in a matter of hours. Levine also designed a galvanized sheet-metal ladder as an integral part of the south face. With locking rollers top and bottom, the ladder can be moved across the collector bank, to inspect the glazing. Its treads provide twin bands of shading during the summer, and the ladder can also be used as a fire escape.

Sundows—Between the long, narrow collectors were equally long spaces 22 in. wide. These Levine glazed with a single pane of tempered glass. The pivoted insulated shutters installed flush with the back of the collectors open and close in response to a temperature-activated piston. As soon as the sun warms the opening, which is painted black like the inside of the active collectors, pistons push the shutters open, bringing narrow bands of light to all levels of the house. When the sun goes in, the shutters close automatically, insulating the living space. The shutters can also be operated by hand. Levine calls these heat-activated window collectors *sundows,* and points out that in his design they're achieved at low cost simply by glazing the space between the active collectors. The effective integration of active and passive systems, Levine feels, is a difficult but important step in solar design.

How the house works—Levine's solar heating system has three basic parts: collectors, rock storage and duct distribution. These subsystems work together through a minicomputer that monitors temperatures in the collectors, in the rock-storage bins, and in the house. The computer also operates the ¾-hp, three-speed blower and a series of dampers that route the air through the system.

The solar collectors are linked to the system at top and bottom with manifolds. The warmest solar-heated air rises naturally to the upper manifold, while the lower manifold channels cooler interior air back to the collec-

How the house works



Rock storage. **Eighty-five tons of mass in three separate rock bins can be heated individually or together by the forced-air system (drawing, left). Above, the vented mesh, shown here being covered by a load of crushed limestone, allows air to travel down through one rock bin and up through the next for maximum heat transfer.**

tors. On sunny winter days, the air is allowed to accumulate in the collectors and upper manifold until its temperature exceeds that of the rock-storage bins in the basement. Once the air gets hotter than the rocks, the blower turns on automatically, pulling the air down through a return duct and forcing it through the rock bins, where it gives up its heat.

The #2 crushed limestone rocks that store sun-generated heat are contained in three contiguous bins, each with its own damper control. This makes it possible to bypass one or two of the rock bins, should the air from the collectors be warm enough to heat only one bin rather than two or three. Levine built the concrete-block compartments for the rocks on the basement slab at the same time the block foundation was being built. Then he laid down a double, overlapping grid of heavy 2-in. by 4-in. wire mesh over block spacers, leaving an 8-in. airspace beneath the rock that was loaded on top of it (photo above). The open block cores in the partition walls between bins are used as vertical air passages in combination with the horizontal airways under the rock. Thus warm air is blown down through the rock bed, up through the vertical partition, and then down through the neighboring rock bed, giving up heat to the stones before returning to the lower manifold to be reheated in the collectors. When the house thermostat calls for heat, the computer routes house air through the rocks and then returns the warmed air to the living space through a conventional duct-distribution system.

The stone in the rock beds weighs close to 85 tons—enough mass to store heat for a week, should the skies cloud over. During the heating season, rock temperature hovers around 120°F, with highs of 140°F not uncommon on sunny days.

The only backup heating is provided by the living-room fireplace. It is equipped with an air-heating jacket that Levine modified and ducted to the rock bins, so the fireplace can heat the house in two ways.

If the winter sun is shining, there's usually enough passive gain through the sundows and greenhouse to heat the house during the day. Then at night the active system takes over, and the sun-warmed rocks heat the house.

The sun also heats water. By soldering several lengths of standard finned-baseboard water-heater elements together, Levine created a heat exchanger that is plumbed directly to the cold-water supply line. It's located in the upper manifold, above the collectors. The solar-heated air drawn through the manifold by the blower preheats the water before it is pumped down to a conventional, glass-lined tank with an electric heating element.

In summer, the rock mass helps cool the house. Air from the collectors is exhausted by a turbine ventilator in the rooftop above the top manifold, so it never reaches the rocks. And the blower can pull cool air through a ground duct (installed 6 ft. below grade outside the foundation) to keep the rock-bed temperature down. Warm interior air can be drawn through the house return-air duct directly to the rock beds for cooling. But Levine hasn't had to use the system in this mode yet because the house's insulation and vent windows perform better than he expected. Levine and Frye have found that opening some of the vent windows at night and closing them during the day maintains comfortable interior temperatures during hot weather.

Below the collectors, glazing for a greenhouse extends nearly to ground level. Levine doesn't count on this single-glazed space to provide whole-house heat. Its function is to maintain an exchange of oxygen and carbon dioxide with a variety of plants, and to humidify the dry winter air.

The north corner—The 40-ft. height of the northwest and northeast sides of the house called for a strong frame. Levine decided to use 2x6 studs on 2-ft. centers. This would provide sufficient rigidity, and the 5½-in. deep wall cavity would allow for extra insulation.

Levine's approach to window design and location in the north-facing walls was to reexamine the functions windows are supposed to perform—light, view and ventilation. Most

conventional windows, apart from being expensive, perform all three functions only marginally well. Levine saw the opportunity to develop a specialized, site-built design for each function, reducing cost considerably. The broad northwest and northeast walls gave him plenty of room to test his design ideas.

For a view, windows need to be located at eye level and have clear glazing. On the other hand, windows meant only to admit light into the house are best located above eye level. Their glazing can be translucent rather than transparent. Ventilation windows don't need glazing at all, just an insulated shutter that can be opened easily when venting is desired, and a fixed screen to keep out bugs. All three types of windows can be found on the north corner of the house (photo below left).

Levine explains that there are several important reasons for the small, square size of the windows and their location in the wall. Rather than sizing his window frames arbitrarily and cutting holes in the wall to accommodate them, Levine based the window dimensions on the 22½-in. distance between each 2x6 stud. The studs themselves act as the vertical frame members for the windows, and 2x6 blocking completes the square frame. Using this square module unifies the vast north-corner wall area, and also enabled Levine to order his glass in cut-to-size quantity, and to build each type of window in a series of familiar steps. The kitchen's upper windows (which are designed to bring light into the house) have six layers of glazing: four layers of Tedlar, a thin, clear film manufactured by DuPont, are supported on a pair of very light subframes positioned between inner and outer layers of Kalwall translucent fiberglass.

View windows are double glazed, and additional insulation is achieved by a slide-down shutter built into the frame. By grouping the view windows in bands at eye level, Levine gained the effect of a large picture window without its expense or framing complications. Vent windows have slide-down insulated shutters that cover screened openings.

The interior finish was kept simple. Levine used locally sawn, kiln-dried white oak to build the stairways and all the casing and cabinetwork. Interior walls are gypboard. The stairs (photo above left) were built last. They tie the many levels of the house together and relate the square back of the structure to its slanted front. Thin oak balusters, open treads and a suspended landing make the staircase light, but rigid and strong. ☐

On the angled south side of the house, vertical bands of glazing between the active-solar collectors, above left, bring light and warmth to the upper levels. The plywood backs of the active collectors are the finished wall surface. Beneath the collectors, stepped seating hides storage bins with hinged covers. The stairway was built last of all, with the same white oak that was used for casing and cabinetwork throughout the house. Stair angles from one landing to the next relate the square back of the house to its sloping front. In the kitchen, left, bands of modular windows bring in light, a view and fresh air.