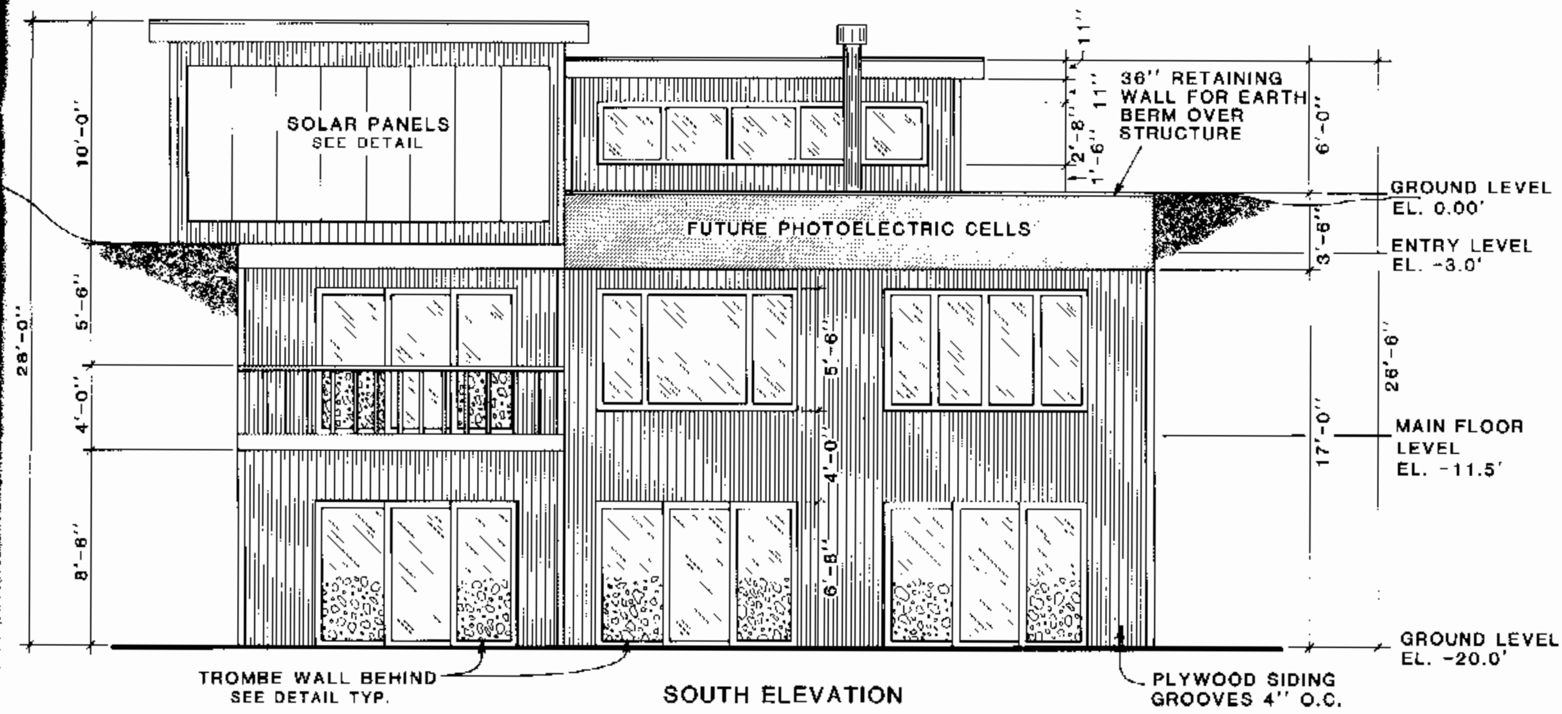
A SOLAR HOUSE FOR SOUTHEASTERN ALASKA

by Brian A. Emerich



SOUTH ELEVATION

Our entry in the State of Alaska's energy-efficient home design competition had two goals: first, to produce an energy-efficient house that could be built successfully in most of the populated areas of coastal Alaska, and second, to develop appropriate technology that would be effective throughout Alaska. All the alternative energy methods proposed for this house had been used in similar forms in some of our previous works; each of these projects had achieved energy efficiencies as high as, or higher than, we had predicted. Thus we were confident that this design would reduce energy consumed for purposes other than cooking by about 75 percent compared to a standard house on a similar site.

SITE

The home was planned for a lot at 20 mile North Glacier Highway outside Juneau. The site is steeply sloping, a situation typical for most of coastal Alaska south of the Bering Sea. Juneau's climate is maritime, with a normal January temperature of 25°F and a July normal of 55°F. Periods of severe cold are generally brief and are caused by strong northwest winds funneling through mountain passes. These "Taku" winds sometimes gust through the channels to the northwest and southeast, and are occasionally strong enough to cause considerable damage. From February to June, monthly precipitation averages about three inches of water-equivalent. Beginning in July, precipitation steadily increases, peaking in October with a monthly average above seven inches. From November through January precipitation declines again.

Temperature and precipitation vary greatly within a very small area; such microclimates are again typical of Alaska's rugged coastal areas. The weather station at the airport, located on relatively low, flat terrain in the path of air draining from the Mendenhall Glacier, averages about ten days a year with minimum temperatures below zero. The city of Juneau is built on steep slopes and averages only one day a year with subzero readings. Juneau's maximum yearly precipitation is almost twice that recorded at the airport, even though the rain gauges are only eight miles

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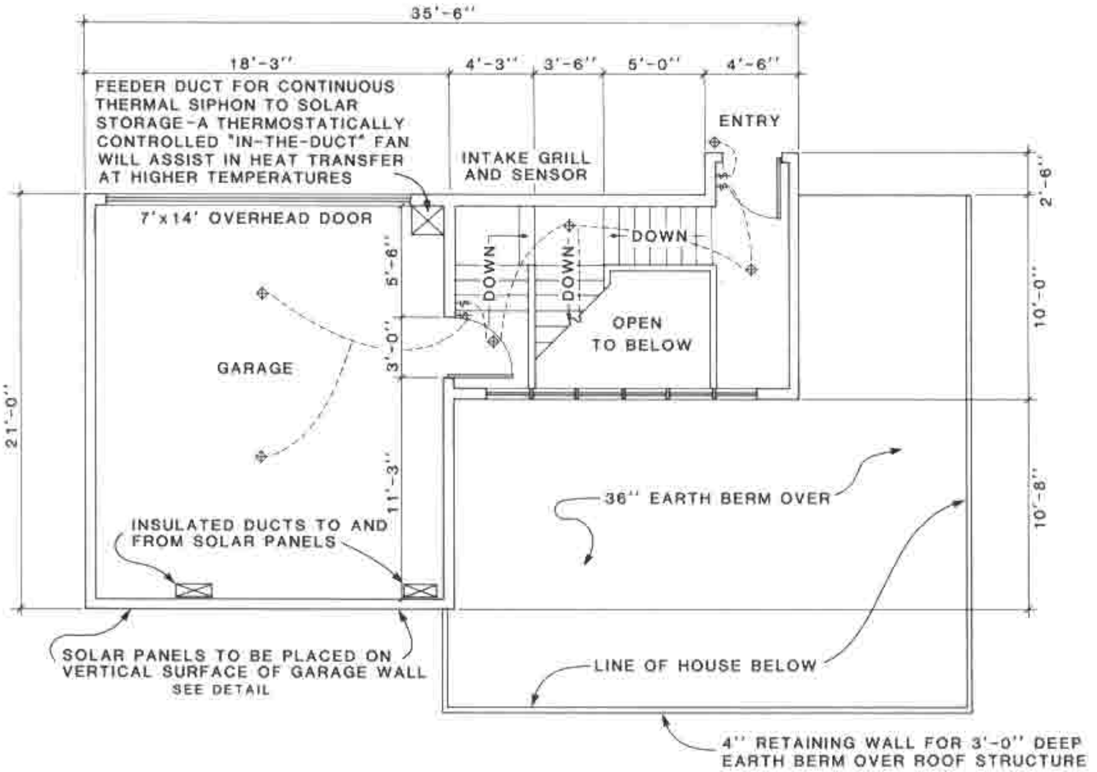
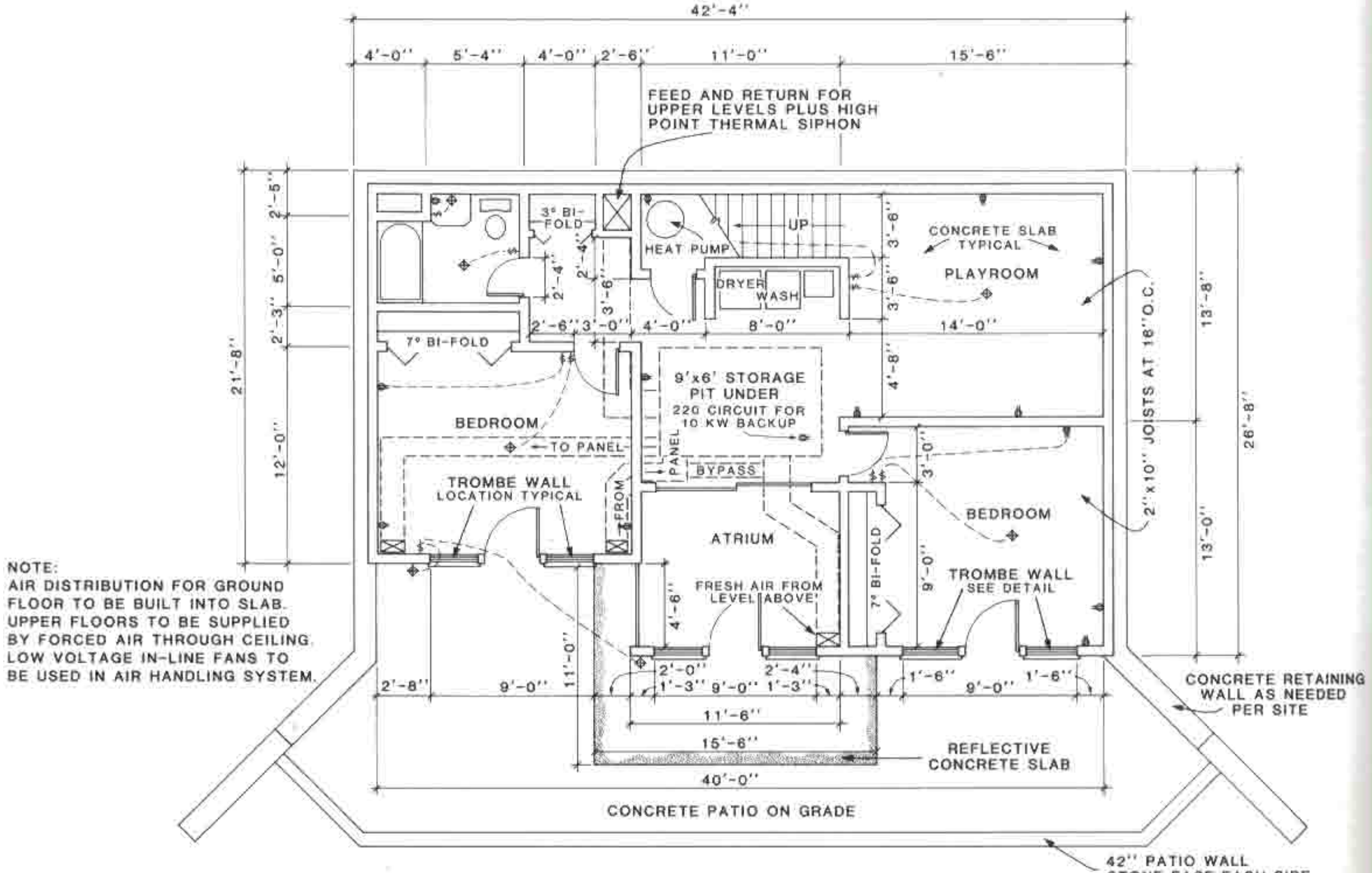
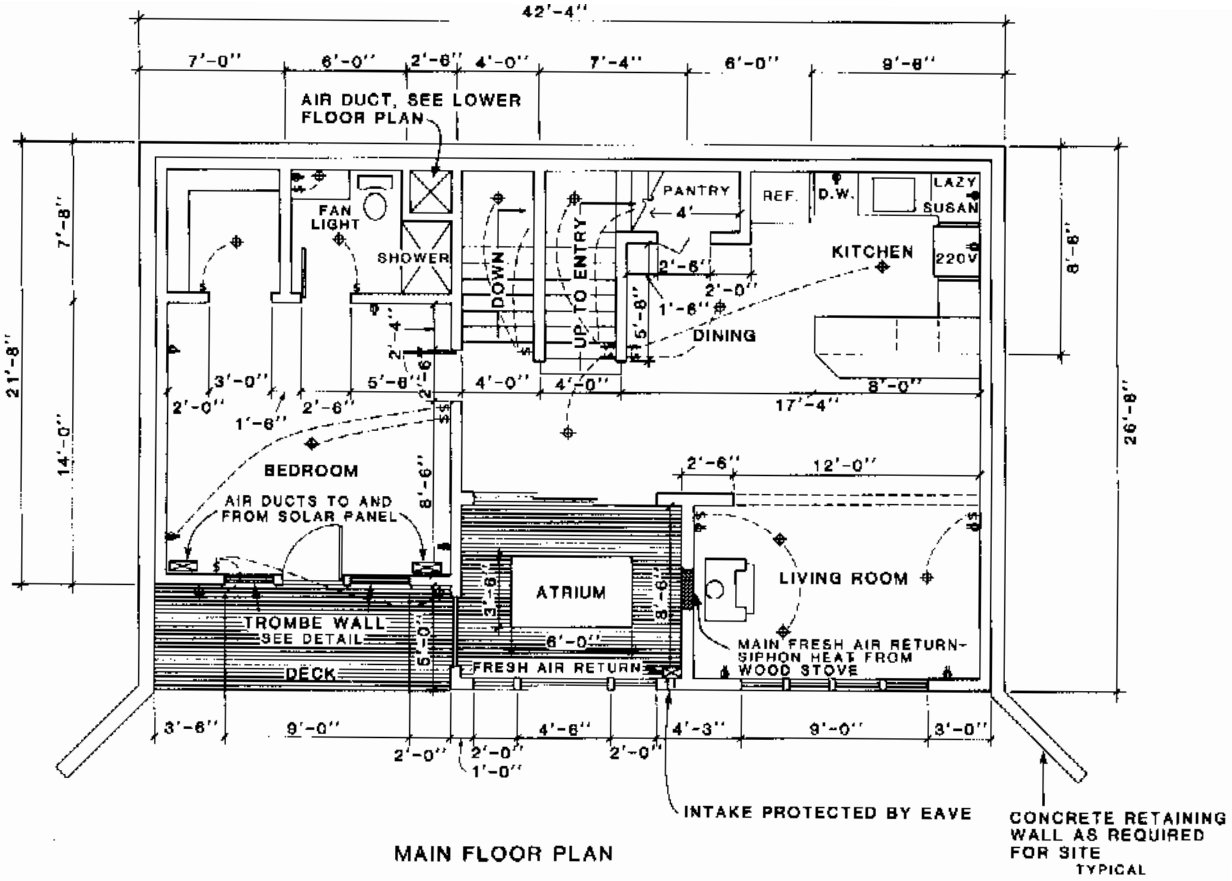


UPPER FLOOR PLAN - ENTRY



LOWER FLOOR PLAN



MAIN FLOOR PLAN

apart. We could safely assume, therefore, that we would be dealing with a cool but not bitter climate, heavy precipitation, and possibly severe winds. With all the rain and clouds, one could well ask if solar still works. In a word, yes.

DESIGN

The house is basically an earth-sheltered home, buried on three sides and partially over the roof but with the south face exposed to take advantage of available sunlight. The steepness of the particular site permits burying a full two-story house without the need for berming, but the same design would be used on more gentle slopes if berms were used; the techniques could also be adapted to a one-story structure. (Partially buried houses are, of course, not suitable for permafrost terrain, but permafrost is not a problem in Southeastern.)

The layout is similar to that of a conventional three-bedroom contemporary home, with a combined country kitchen/dining/living room, playroom (likely to be quite useful for a family living in a wet climate), two bathrooms, and an attached garage. There are also some specialized spaces to serve the energy-efficient aspects of the design: an atrium, arctic entry, and space for thermal storage. All areas of the house are interconnected by an air circulating system tapping the various solar heat sources and the air-to-air heat exchanger.

The earth sheltering mitigates any possible wind problems and enhances energy efficiency, but does make waterproofing an even more important concern than it would be for a building on grade in this location. To prevent seepage problems, we specified an underground sheathing of Volclay™ panels, which are made of sodium bentonite. The bentonite swells when wet, forming a gel-like mastic that seals out water and is self-healing if damaged. The dry bentonite is used to fill the center flutes of 4' x 4' corrugated kraft-paper panels. The paper makes the material easy to handle and apply but is biodegradable. After the paper decomposes, it leaves behind a layer of impermeable mastic clinging to the walls and slab.

ENERGY ASPECTS

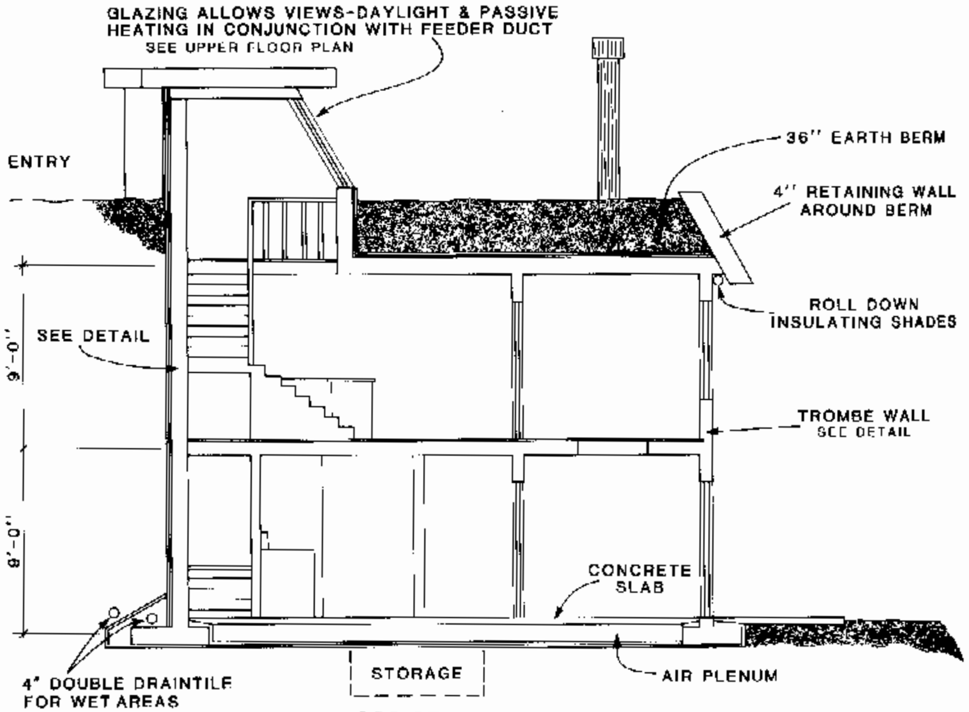
Energy-efficient *design* includes conservation of energy consumption, conservative use of materials, practical and effective building practices, and the use of renewable resources. The actual performance of the house, that is, energy-efficient *use*, becomes a product of both design and the inhabitants' practices. An architect can provide permanent built-in features, such as insulation, and dynamic features, like window shutters and openable vents; the key to the success of the latter is to make these features easy to operate and compatible with the residents' lifestyle.

Energy Use

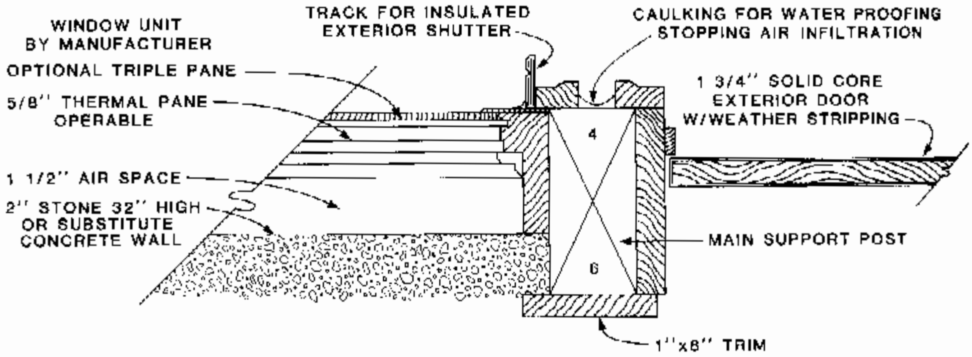
A house built mostly underground is surrounded by a medium of great thermal stability. The earth has a continual (although usually low) flux of heat from its interior, provides insulation and potential solar heat storage, and prevents unwanted infiltration of cold air.

Windows on the south side of the home provide natural lighting. Exterior rollup shutters for the windows can be lowered to reduce heat loss through the glazing when no solar gain is possible.

The building is designed to be efficiently (rather than heavily) insulated with a large thermal mass.



CROSS SECTION



PLAN VIEW TROMBE WALL DETAIL
N.T.S.

Materials/Practice

The basic concrete structure is insulated with rigid foam and covered with earth. We intended to use foams — not containing formaldehyde — suitable for below-ground application with R-values up to 7.2 per inch. The interior is to be of concrete, wallboard and plaster. Unquestionably this house will cost more to build than would a standard home. It requires extensive excavation and concrete work, neither of which is inexpensive (see concluding section). However, the materials and techniques are for the most part standard. The particular demands of this design are modifications of standard details and should require no specialized labor. Furthermore, materials and systems selected would require low maintenance. Although initial costs are higher, life cycle costs are lower than with conventional construction and heating techniques. In our previous energy-efficient structures, we have found that the initially higher cost has had a payback period as short as four years.

Energy Sources

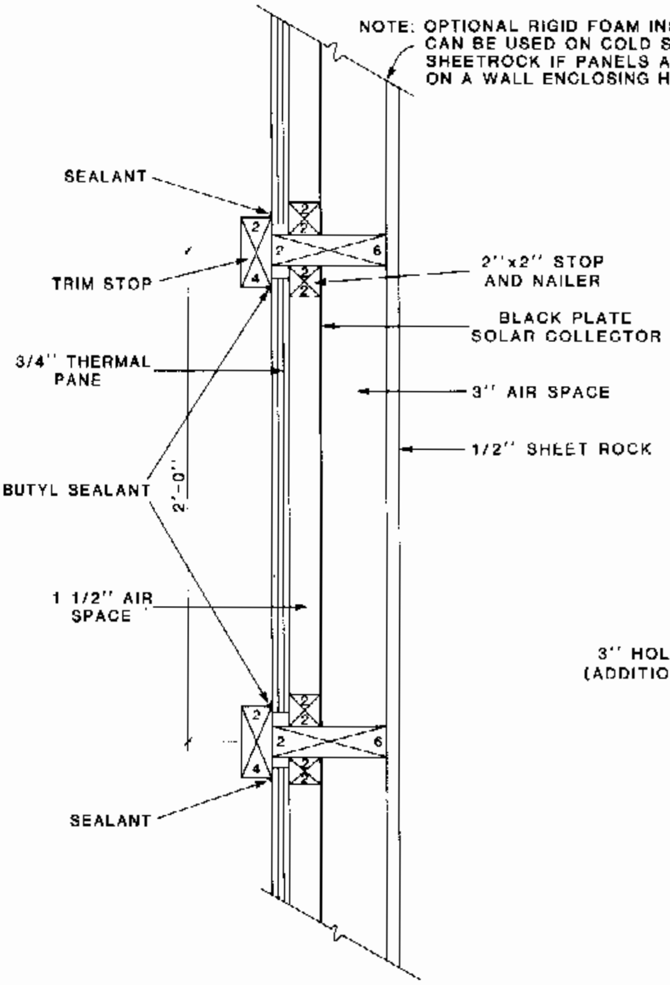
This is essentially a solar-heated house. Juneau lies at approximately 58°N, which means that the most desirable angle for solar collection would be 73° (58 + 15). We chose to use vertical collectors because the 90° angle is far more economical to build and maintain but loses only 3% in efficiency. The south wall is a combination of glass, solar panels, and a built-in greenhouse. The home's windows act as passive solar collectors; part of the glazing covers a Trombe wall, which collects heat when the sun is shining and releases it as the house cools down at night. The solar collector panels represent a refinement of our earlier designs. Now connected to a heat pump for preheating domestic hot water in this house, they no longer need an antifreeze closed loop, which simplifies installation and reduces maintenance. (We estimated that this part of the system could save up to 50% of the typical water heating costs.)

Water from the solar collectors may also be shunted to thermal storage. Storing heat is an important attribute of the overall design; the house itself is sufficiently massive to serve as the first line for storage. However, we have also incorporated a specific thermal storage area stocked with phase-change material—Thermol 81 Energy Rods™ which have a melting point of 81°F. Hot air from the house and the woodstove is also passed into the thermal storage.

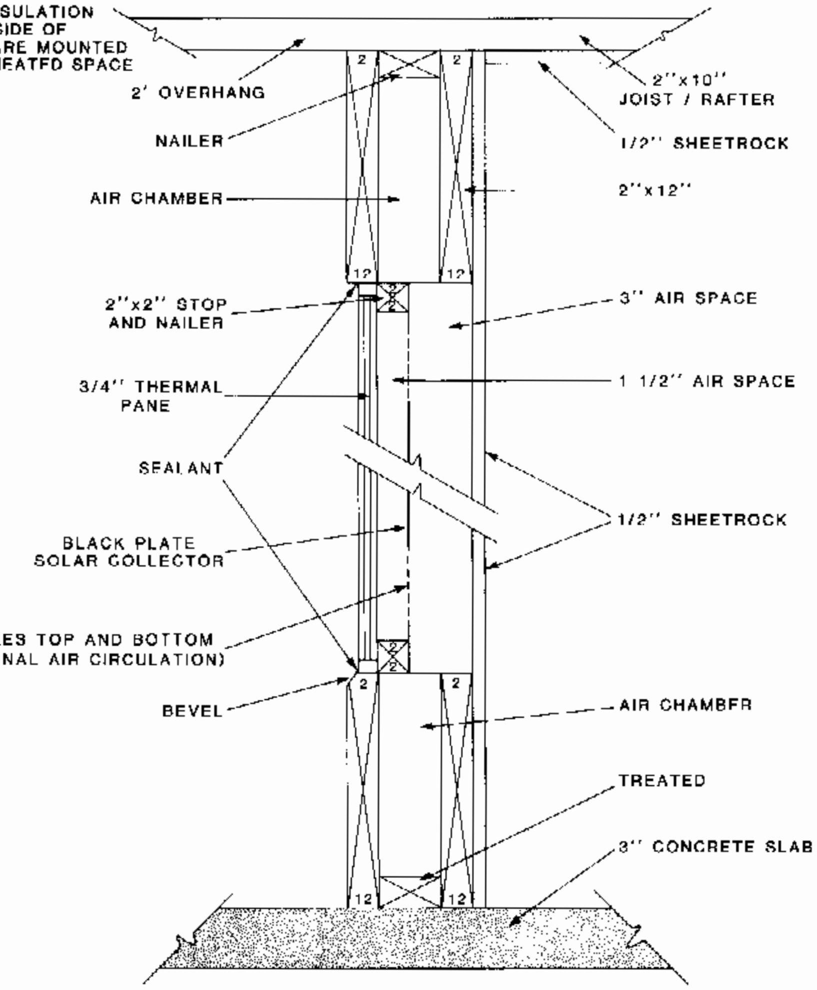
Because this home was designed for the "Urban" portion of the competition and would have access to reliable city utilities, we would incorporate a set of electronic controls into the heating system. A C-120 microprocessor monitors all sensors and controls total operation of the solar system. When there is a temperature difference of 20°F or greater between the solar collector and the bottom of storage, the C-120 engages output #1, which then turns on the fan and energizes the 24-volt transformer. The transformer in turn operates the damper motor to open the dampers, allowing the hot air to flow from the collector through the thermal storage and back to the collector. Whenever the temperature difference declines to less than 20°F, this system will shut down. A temperature-monitoring sensor is connected onto the discharge side of the water coil in the thermal storage; another, in the top of the storage box, can signal the system to shut down whenever the box reaches a high temperature of 179°F. A separate system, based on a C-130, is connected to the woodstove. Whenever the woodstove reaches a temperature of 110°F, the system opens dampers allowing the house return-air system to take the warm air from the room in which the stove is operating and send this warmed air through the storage box and then to rest of the house.

COST

Our calculations produced an estimate of an 8.6% construction cost increase for



SOLAR PANELS – PLAN SECTION



SOLAR PANELS – VERTICAL SECTION

this home over a conventional house of the same size. In Juneau (late 1981), a typical 2000 square foot house would have cost about $125,000 to build, so one constructed to our specifications would have cost $137,625.

Exactly what annual savings in energy expenditures that additional $12,625 would buy the homeowner is difficult to pin down. Table 1 gives our estimates, which we believe are conservative. For example, the total window area in this house is approximately the same, or less than, that in a conventional home of identical size—but here all the glass faces south, so the windows may gain as much heat by day as they lose by night. If the homeowner uses the insulated shutters consistently, the heat gain-loss balance would improve further. It is also difficult to calculate heat loss through the walls. Should one use the low outside air temperature of -10°F or the earth's temperature at the wall of 50°F? Clearly neither is completely accurate. Infiltration, which plays a large part in most conventional heat loss calculations, is not much of a factor here, nor is heat loss because of wind.

Taking the estimates in Table 1 as reasonable, and assuming an inflation factor of 7% per year on energy costs, the homeowner would pay back his higher construction expense out of energy savings in under seven years. We therefore believe that this project is feasible for long-term financing.

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TABLE 1

Annual Energy Costs

	Conventional House	Earth-Sheltered Solar House	Savings
Lights	$ 410	(-15%) $ 349	$ 61
Hot Water	$ 112	(-33%) $ 75	$ 37
Heating	$2200	(-60%) $ 880	$1320
Total	$2722	$1304	$1418

Assumptions: Both houses of 2000 ft^2 area located in Juneau; 9500 degree days; conventional home has 4'' of fiberglass insulation in the walls, 6'' in the ceilings; electric lights and hot water heater, oil-fired furnace; electricity @ 4.5¢/kWh, oil @ $1.10/gal. The percentage reductions are based on the performance of past projects.