

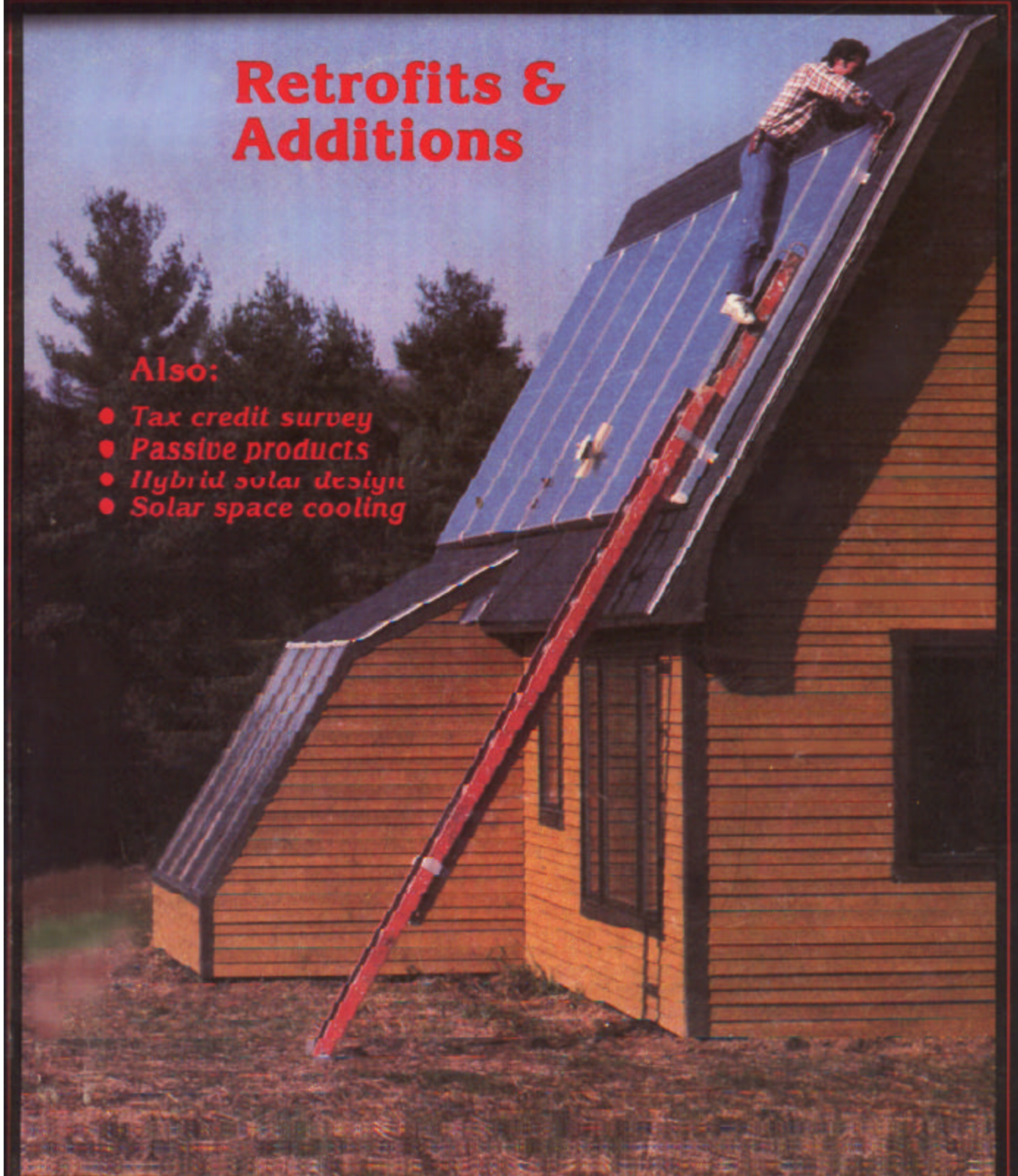
# S ● L A R

## ENGINEERING & CONTRACTING

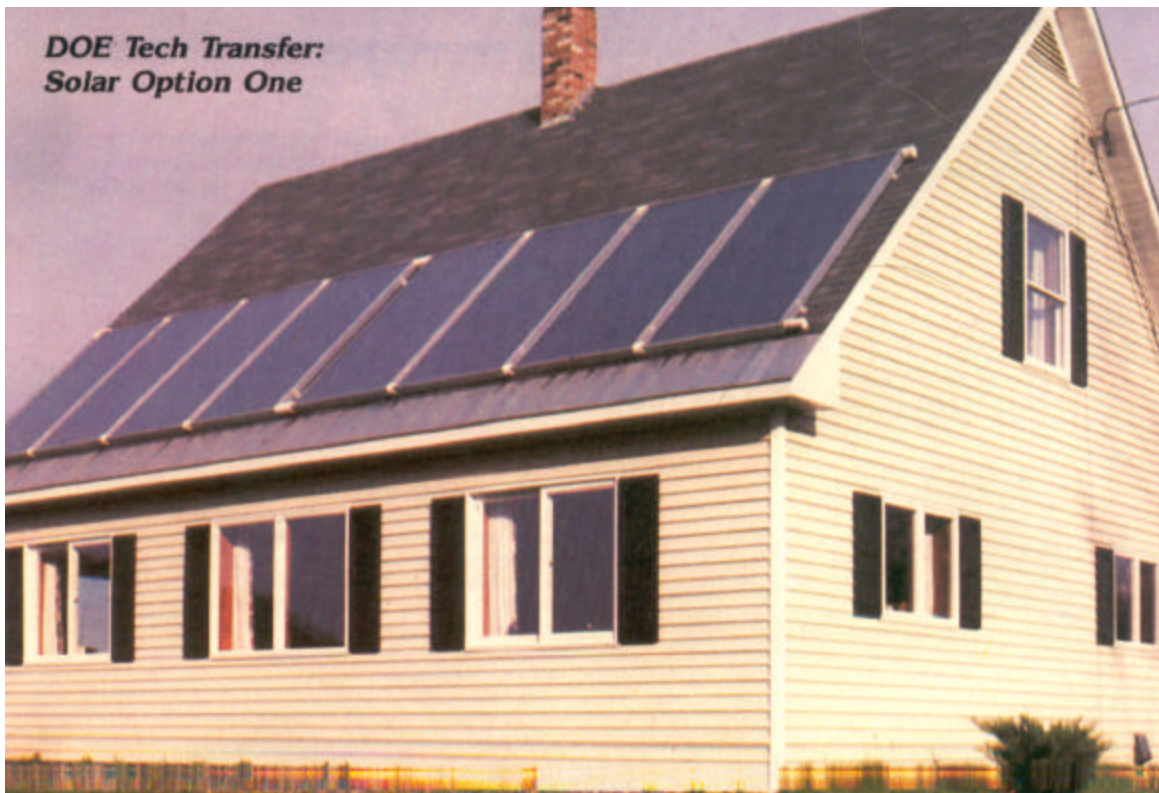
### Retrofits & Additions

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- *Hybrid solar design*
- *Solar space cooling*







## Hybrid solar system supplies radiant heat

By Wayne Johnson

Ever since active and passive products were divided into separate solar categories, hybrid concepts have fascinated system designers. If the particular advantages of active and passive technologies could be combined without also incorporating the usual disadvantages of each, the resulting system should be expected to show superior performance and cost-effectiveness.

A hybrid space-heating concept that incorporates active solar collection with thermal mass storage and distribution has been investigated by the national Bureau of Standards (NBS) and an academic subcontractor to the Department of Energy (DOE) - Dr. Jon G. McGowan and his assistant Brian P. McNiff of the University of Massachusetts department of Mechanical Engineering.

These federally funded studies found the hybrid design unique, technically valid, and not yet fully understood by the energy community.

According to a report submitted to DOE's Technical Support Division\* by Robert J. Starr whose The Solar Option One Co. developed the hybrid design, working models had been installed in several single-family homes in northeastern Vermont before Starr received any federal support.

Starr said these low-cost working models seemed to be working well, as evidenced by high collector efficiencies and low auxiliary energy use. Designed to achieve solar performances of about 50%, the models exhibited relatively stable temperatures and nonfluctuating inputs of auxiliary energy. This suggested that higher levels of solar performance were possible without diminishing returns.

(Solar performance, which refers to a system's ability to displace auxiliary energy, should not be confused with efficiency, which is a system's ability to deliver a percentage of the solar energy available.)

### **Radiant heating**

The solar option One (SOO) is a hydronic heating system that uses conventional liquid-type solar collectors to heat a radiant panel slab. Whenever solar energy is available, a heated glycol fluid is pumped from the collectors through the entire radiant slab. The heat is stored within both the slab and the compacted earth underneath and is released without controls by radiation and convection. A bypass valve allows the solar heat to be used for domestic hot water exclusively when space heating is not required.



**Four 220-ft lengths of 0.75"-ID high-density polyethylene tubing are imbedded in the 5.5" thick slab-on-grade of the test house. Beneath the slab, 600-ft. of tubing runs through a 2-ft layer of gravel.**

Starr's report to DOE stated that the glycol heat transfer fluid is showing "good service life because of low operating temperatures and lack of exposure to air. Glycol solutions which have been in service for five years are still showing effective levels of corrosion inhibitors."

According to the report, the SOO design "raises a uniquely large thermal mass to relatively modest temperatures, unlike conventional systems which raise a small thermal mass to relatively high temperatures.

"A large thermal mass, integrated with the building's structure, provides prolonged solar storage, radiant comfort, and further lowered costs," the report stated.

the final technical report from MBS stated that radiant panel systems provide a comfortable indoor environment "by controlling surface temperatures and minimizing excessive air motion within the heated space. The occupant is not aware that the environment is being heated.

"When the temperature of room surfaces begin to deviate excessively from the ambient air temperature of the heated space, it becomes difficult for convective systems to counteract the resulting losses from the occupant's body," the NBS report stated.

According to Starr, the overall simplicity of the SOO design, which features few components and moving parts, creates greater consumer confidence. He said the design also lends itself to convenient packaging, which would make it available to building professionals in a form to which they are accustomed.

The storage/heat exchanger pipe in the slab is 0.75-in.-diameter polyethylene tubing manifolded to achieve reasonable pressure drops and appropriate flow through the system.

**"Solar energy is utilized at the lowest possible temperature, resulting in the highest possible collector efficiencies. This translates into fewer solar panels, lowered costs, and easier design integration into accepted building styles." - Robert Starr**

**Table 1**

	<b>Solar input To Collectors (Million Btu)</b>	<b>Output from Collectors (Million Btu)</b>	<b>Efficiency (%)</b>
<b>November</b>	<b>3.36</b>	<b>1.67</b>	<b>49.7</b>
<b>December</b>	<b>3.93</b>	<b>1.97</b>	<b>50.2</b>
<b>January</b>	<b>4.92</b>	<b>2.35</b>	<b>47.9</b>
<b>February</b>	<b>6.63</b>	<b>3.33</b>	<b>50.3</b>
<b>March</b>	<b>6.39</b>	<b>3.10</b>	<b>48.6</b>
<b>April</b>	<b>6.03</b>	<b>2.97</b>	<b>49.2</b>

The NBS report said polyethylene tubing "is superior to copper because it is lower in cost, can be installed without inaccessible joints, and has low friction losses, high resistance to corrosion, and a long service life. The pipe's low cost permits redundancy in design."

Starr said abusive testing of the heat exchanger tubing, including repeated dumping of collector fluid at 300° F-plus stagnation temperatures, produced no ill effects. However, prolonged exposure to very high fluid temperatures, caused by unlikely multiple and simultaneous subsystem failures, could cause a failure at the plastic-to-copper connection joint. But, because this connection between the collectors and storage is accessible, it can be repaired easily without damage to the pipe itself.

### **A residential test**

A test house was monitored to determine the SOO design's energy-based performance during the 1982-83 heating season. The test residence, located in Lyndonville, VT, where The Solar Option One Co. is headquartered, was subjected to the area's cold and cloudy winter climate.

The two-story home had 1,400 ft<sup>2</sup>, 5.5-in.-thick concrete floor slab. Both the slab and a 24-in.-deep packed gravel bed beneath it were insulated to R-11 with two inches of polystyrene material.

Although the frame house could not be considered "superinsulated," it was insulated to modern levels (R-42 in ceiling, R-24 in walls) and was constructed tightly for low air infiltration. The window area was concentrated on the southern side and almost eliminated on the north.

The monitoring equipment used in the test generated an internal heat gain of about 17,000 Btu/day, which Starr estimated to be roughly the equivalent of occupancy by two people.

As shown in Table 1, the test house stored approximately half of all the solar radiation available to the collectors during the winter. Starr credited low collector temperatures as the primary reason for this efficiency.

Starr said the test home efficiencies were "substantially higher" than those achieved by the Solar Energy Applications Laboratory of Colorado State University during 1978-79 in three houses tested for the Solar Energy Research Institute. He said this was especially significant because of the availability of more than twice as much solar radiation at the Colorado site than in the Vermont location.



**"Plumbers seem to work well with the Solar Option One. They know the advantages of radiant heat and they know the mechanics of hydronic systems." - Robert Starr**

The hybrid system in the test house provided a solar space-heating fraction exceeding 90%. The backup heating system delivered a total of only 1.8 million Btu during the entire heating season.

Electrical energy consumed by the pump and controller at the SOO test house was 5.3% of the total solar energy collected. This figure would have been lower without the additional flow resistance of the monitoring equipment made it necessary to select a pump with twice the output of a pump that ordinarily would have been sufficient.

Although the SOO design can be integrated easily into the construction of a new home, it also is possible to retrofit an existing dwelling, Starr said. To do that, he recommended laying 0.5-in.-dia polyethylene tubing (instead of 0.75 in. dia) on the existing slab and then pouring a new slab on top. For maximum efficiency, it also would be advisable to insulate the perimeter of the slab.

New or retrofit installations are not difficult, according to Starr, but some contractors appear to be more comfortable with the design.

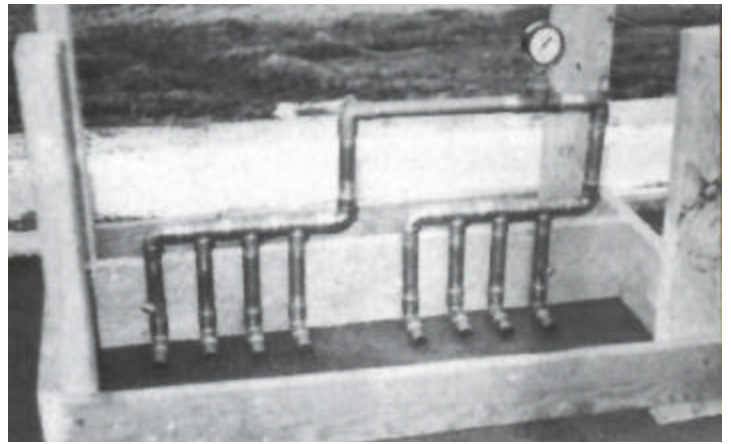
"Plumbers seem to work well with the Solar Option One," Starr said. "They know the advantages of radiant heat and they know the mechanics of hydronic systems.

Starr said he realizes that some radiant heating designs still have poor reputations because of past operational or performance problems.

"The use of copper tubing caused many problems," he said. "Corrosion inevitably develops, which impedes and sometimes stops the flow of fluid. Another problem in the past has been tubing that was not manifolded. With one continuous loop, a single break or obstruction can stop the flow completely. Of course, this is almost impossible to repair because the tubing is buried in the slab. With our design, a flow stoppage in one section of the pipe is less serious, causing a decrease in efficiency of only a few percent."

Starr said problems with excessive temperature swings and over heated floors also have dissuaded some from using radiant systems.

"If the system is not sized properly or the building is not tightly constructed and properly insulated, the tube heat exchanger may release heat too rapidly, creating a hot foot' for anyone walking on the floor. A wide temperature difference between the room air and heat exchanger is neither comfortable nor efficient. We have found this temperature differential to be five degrees or less with the Solar Option One," he said.



**Manifolding the solar-heated fluid into four storage/heat exchanger loops allows better flow and prevents a single break in the tubing from disabling the entire system.**

### **Other applications**

In his report to DOE, Starr identified five main corollary applications that are possible with the SOO design. These are described briefly below.

**Radiant cooling with cold water supply**—Cold supply water passes through the slab on the way to the fixtures. Heat is extracted from the building in the process.

**Radian panel heating with draindown solar and cold water supply cooling**— During the heating season, solar-heated potable water is circulated through the slab while supply water goes directly to the fixtures. When cooling is required, supply water draws heat from the structure. This application eliminates the glycol loop and thus offers improved performance. It can be used in areas where freeze protection is less important.

**Indirect radiant heating using solar, off-peak electricity, or solid fuels**—This method could be used when a full basement is available or when a second story is present in a home with slab-on-grade construction. Heat from the first story (or basement) helps warm the second story (or first floor). The structure needs to be well-insulated.

**Radiant nighttime cooling with unglazed collectors**— During the day, solar energy is collected and used for a purpose other than space heating. At night, the structure is cooled by radiating heat to the night sky through the collectors.

**Solar radian panel heating with phase change materials**—Solar panels charge a phase change material located within interior partitions or floor joists. Heat transfer from storage is accomplished by radiant and convection. 3

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