Solar Heat in Snow Country

In our **Back to the Future** offering for this issue, an active solar heating system designed by the late Harry Thomason provides two-thirds of the space heating for the Pinnacle Road U.S. Customs border station in Richford, Vermont, on the U.S.-Canadian border.

by Nick Pine

Nick Pine

The Richford Customs House is located on a windy hill on the Vermont-Canadian border, an area known for its frigid winters.

Buckminster Fuller said he was taught in school that bees can't fly, notwithstanding millions of counterexamples. For years, academic and government scientists believed that Harry Thomason's trickle collectors wouldn't work, even as they heated hundreds of houses.

Thomason trickled water between a dark metal roof and a single layer of glazing, and some of the water evaporated from the roof and condensed on the underside of the glazing. Many believed the resulting heat loss would make these "trickle collectors" so inefficient as to be useless. William A. Shurcliff questioned this belief and gave "reasons for believing H. E. Thomason's decision was a wise one" in his 1979 book **New Inventions in Low-Cost Solar Heating**. (See "Thermal Misunderstanding" by Frank de Winter, page 38.)

The Pinnacle Road U.S. Customs border station in Richford, Vermont, is located on a windy hill on the Vermont-Canadian border, where temperatures often fall below zero. Harry Thomason's trickle collectors have been providing two-thirds of the building's heat since 1984.

Nick Pine

This 704 square feet of Harry Thomason's trickle collectors have been providing two-thirds of the Richford Customs House's heat since 1984.

Thomason licensees Ronald G. Howitt and Robert E. Grenier of Woonsocket, Rhode Island (who installed dozens of Thomason systems—both now live in houses heated this way) were chosen to install the solar heating system in the Richford building in 1981. The project was part of a U.S. Department of Energy (DOE) "Solar in Federal Buildings" program to solar heat customs houses along the U.S.-Canadian border. As Howitt tells it, however, the installation was delayed for three years, because NASA scientists believed the Thomason system would not work.

From 1981 until 1984, scientists from NASA, Rockwell International and DOE studied the working system on Walter Karasak's house in Blackstone, Massachusetts, using 75 temperature sensors. They came away in disbelief, wondering if there were hidden heaters or other shenanigans. The Richford installation finally began in 1984, after a long battle with U.S. Customs. Engineer George P. Fors, PE, finally convinced them that it could work by pointing out that the earlier approved systems were failing, the simple system he sought for the Richford station had a track record of good performance since 1959 and the bid for the simple system was nearly $10,000 lower than the next lowest bid.

The installation was completed in the winter of 1984 with an acceptance test. Before the public dedication, government skeptics sent the installers home, turned off the backup heating system, opened the windows, let the building cool off to about 40°F, then closed the windows and watched as the Thomason system warmed it back up to 70°F over a few days. It appears that the skeptics were satisfied.

By 1984, most of the other 21 systems in the DOE program (trackers, evacuated collectors and so on) had failed. Richford is the only one working today. The original bid specifications required a "solar furnace" located some 75 feet away from the building and connected by pipes, but Thomason convinced Fors that locating the collectors and heat storage on and in the building was a better idea. Grenier and Howitt also increased the pitch of the roof that supports the 704 square feet of collectors to collect more heat in the winter.

Describing the Richford system in 1995, Port Director Amos Hamilton wrote Thomason saying: "'Truly remarkable' is an understatement; year after year your solar system has provided ample and reliable heat... like the Maytag repairmen, we have nothing to do because your system runs so well." Acting Chief Jim Alexander says "We were delighted that we could take off our coats in the winter!" The building (one of few owned by Customs rather than the General Services Administration) was constructed in 1975, and the original forced air heating system was very uncomfortable,

Nick Pine

The solar system uses simple, reliable hardware, such as these two Grundfos pumps installed in series that move water from two 700 gallon tanks in an insulated rock bin up to the roof ridgeline above the collector.

Nick Pine

Acting Chief Jim Alexander appreciates the solar heating system, because he and his staff can take their coats off inside the building.

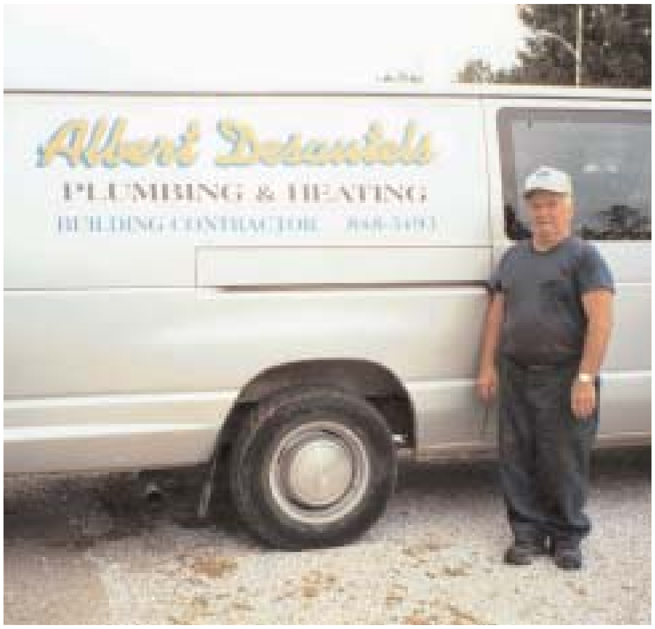
and subjected the occupants to wide temperature swings.

The solar system uses simple, reliable hardware, such as the two Grundfos pumps installed in series that move water from two 700 gallon tanks in an insulated rock bin up to the roof ridgeline above the collector. The water trickles back down into the tanks in this drainback system. Air forced through the bin of stones, which increase the effective heat transfer surface of the tank and provide additional thermal mass, actually heats the building. A new building might have a polycarbonate instead of a glass collector cover, which might lower the cost, and an efficient hydronic floor instead of the bin of stones, which might raise the COP significantly. An oil-fired water heater provides backup heat as needed via a water-air heat exchanger in the upper airpath leaving the tank.

Albert Desautels is the Maytag repairman in Richford. He recalls fixing a small leak in an outside gutter "maybe 4 or 5 years ago." The Richford system has performed well for 18 years with almost no maintenance, although it needs a little now. On a recent visit, we noted a clogged air filter and an apparent control malfunction. But overall, this system is a remarkable success story. ☼

Nick Pine of Pine Associates, Ltd., 821 Collegeville Road, Collegeville, Pennsylvania 19426, (610) 489-1475, FAX (610) 831-9533, e-mail: nick@ece.vill.edu, is an electrical engineer by training and a registered U.S. Patent Agent with a longtime interest in sailing and low-cost solar house heating.

◆ ◆ ◆ ◆



Nick Pine

Albert Desautels, the Maytag repairman in Richford, recalls fixing a small leak in an outside gutter "maybe 4 or 5 years ago." The Richford system has performed well for 18 years with almost no maintenance.

◆ ◆ ◆ ◆

A Thermal Misunderstanding

by Frank de Winter

I think a revisit of the Thomason houses is a great idea. Many of the solar energy old guard made fun of the Thomason collectors, claiming that the water condensation on the collector glazing would cause great heat losses. What they did not realize is that they were working with collector forced convection heat transfer coefficients (from the glazing to the outside ambient) that were about four times higher than the actual ones. This was because the flat plate collector field was, until quite recently, based on the forced convection heat transfer coefficients of A. Jurges in 1924. This is the basic reference found in McAdams and later throughout the flat plate collector literature, in the 1942 Hottel and Woertz classic paper and in solar energy textbooks right through the 1970s into the 1980s.

The Jurges numbers were based on a vertical, sharp-edged 50 cm by 50 cm plate, heated to 100°C, and then subjected to the wind. Collectors are never that small, they never have sharp edges, they are never vertical and they never have outside surfaces at 100°C.

I felt the Jurges numbers were quite inappropriate, and when I wrote my Copper Development Association "do-it-yourself" booklet on solar swimming pool heating in the 1970s, I ignored Jurges altogether. Instead, I calculated forced convection heat transfer coefficients using the boundary layer theory calculations from the Schlichting book. My results were half as high as the Jurges values. According to the recent literature reported by Noam Lior, the values for full size collectors that do not have sharp edges, are not vertical and are not at 100°C are lower by still another factor of two—four times lower than the Jurges values.

Because many thought the outside forced convection heat losses were so high, they automatically concluded that the Thomason collectors were hopeless. Their reasoning went that the inside insulation effect of the "stagnant air" mechanism was reduced greatly because of the evaporation-condensation mechanism. They thought the Thomason collectors would automatically "short-circuit" out most of the solar energy, yielding a pathetically low collection efficiency.

Steve Baer of Zomeworks initially pointed this out to me. I had never thought of it, but it instantly made sense. It is in this context that a careful and well-documented technical review of the Thomason equipment can be really valuable. ✲

Frank de Winter is with Francis de Winter & Associates, 3085 Carriker Lane, Bay D, Soquel, California 95073, (831) 425-1211 (Office), (831) 462-6246 (Shop), FAX (707) 221-1859, e-mail: fdw@ecotopia.com.

Richford Customs House Project Details

by Drew Gillett

Background

What started as a simple request for information from a client interested in building an active solar space heated home in Vermont mushroomed into two visits to the U.S.-Canadian border—one by auto and one by air—to the site of an interesting design pioneered by Dr. Harry Thomason in 1959 and installed at a number of sites by builders in the 1970s and 1980s.

Description

This design, commonly called a trickle collector, incorporates a collector cross section of single or double glazing (single in this case), a simple corrugated aluminum roof painted black and conventional back and side insulation. Water to be heated is pumped to the peak of the collector and distributed through a manifold to be trickled down the face of the corrugated absorber and then collected in a gutter and returned to a storage tank. An integral part of the Thomason Solaris design is that the storage tank is imbedded in a box of rocks, through which air is blown to distribute the heat to the building as needed. A backup system (in this case an oil-fired water heater) is used to add heat to the air through a water-to-air heat exchanger in the distribution duct.

In some installations (although not in the Richford system) a hot water coil is placed in the tank to provide domestic hot water. Some installations also run the system in summer for cooling—not required on the northern border of Vermont, but useful where Dr. Thomason lived in Maryland.

The system uses inexpensive simple materials combined in a clever way to obtain heating, cooling and hot water from the sun. It is low-cost, large area and well-integrated into the building. On the down side, there have been concerns about corrosion from the open water in the system, higher pumping costs than closed loop systems (because the water must be pumped to the top of the collector for each circuit) and possibly lower efficiency due to evaporation and condensation on the glass. (See "Thermal Misunderstanding" by Frank de Winter, this page.)

The Richford system has 88 panes of glass approximately 2 feet by 4 feet arranged 11 wide by 8 high covering most of the south roof for a collector area of about 700 square feet. Note the glass does not need to be particularly well sealed, because there is a durable corrugated metal roof below it. The system also includes two 700 gallon stainless steel storage tanks in a room in the NW corner of the building, two collector pumps installed in series, a differential controller to turn the system on and off and several Btu and kWh meters for manual data collection. Some kind soul had dutifully recorded data occasionally thru 1994 and left the data sheet in place.

Cost and Initial Performance

R.L. Grenier Associates of Woonsocket, Rhode Island, installed the system in 1984. I have no current information on costs—Dr. Thomason estimated $3-4 per square foot of collector in 1970 dollars for the entire system including backup, distribution and labor. My best estimate is that a system today would run $20-$40 per square foot depending on materials and labor costs and location.

After the initial installation, a winter 1988 article on the project (which pointed out that 11 of 12 differently designed active systems had already failed) noted that this project had resulted in a reduction of fuel oil usage from an average of 855 gallons per year in prior years to 298 gallons in 85-86 and 263 gallons in 86-87 or a savings of about 550 to 600 gallons per year. Recent data from Jim Alexander, Acting Chief of the facility, shows continued low usage for the site, especially compared to a similar but slightly larger non-solar facility nearby—Morse's Line.

Table 1

OIL USAGE (gallons)	FY 00	FY 01	FY02
	Warm	Normal	Warm
Pinnacle (solar)	527	294	~500
Morse's Line (non-solar)	1309	1510	N/A

Electricity Usage

A review of the power meter data provides some interesting insights into performance. The system included four kWh meters and four Btu meters—one for the solar pumps, one for the blower, one for the backup circulator and one for "other."

Table 2

	Annual kWh Use	
	Pre 1994	**Post 1994**
Solar pumps 2 x 225 watts	948.9	743.6
Blower 1/2 hp 800 watts	2842.6	1098
Backup circulator 1/6 hp 200 watts	340.1	573.6
Other	1847	1247

Drew Gillett

Nick Pine (left) and Drew Gillett are off on their excellent adventure to visit the Thomason solar system at the Richford Custom House.

It's somewhat difficult to be sure of the following, because no measured data was taken on the loads connected to the kWh meters and the wattages are approximate. However, the solar pumps seem to be operating fewer hours per year lately (perhaps because of the sensor problem noted below) and the backup circulator is operating more hours. One thing it does show is that the approximately 800 kWh consumed per year in electricity bring in about 550 therms or the equivalent of 550 gallons of oil (as delivered by the backup system) resulting in a COP of over 22. It also shows that air distribution systems are relative energy hogs, and that an effort to reduce the flow resistance and horsepower of the blower would be in order.

Btu Meter Information

The Btu meters of interest were on the solar collection circuit and the backup oil heating delivery circuit.

Table 3

100,000 Btu (therms) delivered annually for 18 years
(this data derived from simply taking the total Btu indicated on the recording Btu meters and dividing by the 18 years)

Collection	556
Oil backup delivered	114

The solar energy collected compares reasonably with the oft-repeated 1 gallon of fuel oil delivered for each square foot of collector each year for a good active space heating system. An average system might be more like 3/4 gallon, and a solar domestic hot water system (which is useful year round) might be as much as 1-1/2 gallon per square foot per year.

The oil heat energy delivered indicates that the backup is fairly inefficient (as oil-fired water heaters are because of low demand, infrequent use as a backup, high standby losses, high delivery temperatures and high inlet air temperatures at the backup heat exchangers). The oil-fired water heater is probably delivering less than 50 percent of the heating energy in the oil to the air system. Note, however, that some of the losses do go usefully into the mechanical room.

Drew Gillett

The heat exchanger was as clean as a new one after over 18 years of use.

Update

This fall, the oil backup water heater fortuitously failed, triggering a "no heat" call that resulted in an effort to completely check out and overhaul the pumps, controls etc. of the system. Maintenance and repairs included replacing a failed sensor, repairing a small leak (harmless because it's outdoors, but fixed anyway) in the gutter and the usual cleaning of filters and strainers. It's interesting to note that all the glass is intact, the paint appears in very good condition, the pumps worked—even the exterior pipe insulation is in good shape. Of particular interest was the cleanliness of the backup water-to-air heat exchanger (see photo).

Conclusion

Site-built integrated active solar space heating systems do function in Vermont (where it is cold and cloudy) and some even have a nearly two decade record of reasonably trouble-free, cost-effective performance. This system has been in service to our country guarding its borders and keeping our customs officers warm using solar energy for over 18 years. If more of our buildings reduced their fossil fuel use by two-thirds, perhaps we wouldn't have to double the number of guards. ☼

Drew Gillett, Professional Engineer and an MIT graduate twice, is a long time ASES member, 2000-hour instrument pilot and father of twin daughters who may actually save the world. He can be reached at 33 Holbrook Road, Bedford, New Hampshire 03110, (603) 668-7336.

◆ ◆ ◆ ◆

A Solar Pioneer

Dr. Harry E. Thomason was a graduate of Catawba College in Salisbury, North Carolina (Bachelor of Arts degree in physics), and the Georgetown University School of Law (J.D.). Dr. Thomason was a determined man. After five coronary bypasses in August 1996 and the death of his wife Hattie in September, he wrote in January "I am recovering, slowly, and I am now working about 80 hours per week." Before his death in April of 1998, he had received 36 patents and 4 registered trademarks related to solar energy.

Dr. Harry Thomason looks down the grooves of his trickle-flow collector.