The Solar Hot-Water System

The solar hot-water system was designed to preheat the cold water supplied to the oil-fired domestic water-heating system. Under a contract from Alpha Energy, Thermo Dynamics Ltd. of Dartmouth, Nova Scotia, designed and installed the system described in Table 1. Figure 1 shows a schematic of the system.

The solar collector array consists of one hundred 2.3-m^2 flat-plate collectors, rack-mounted in two rows of 50 collectors. The rows were mounted on Unistrut® galvanized steel channels and have a gross area of 228 m^2. The collectors were set at a 45° angle and installed on the building's roof, facing due south.

The white structure at the right of the panels is the rooftop mechanical room (see photo opposite). Its proximity allows for short piping runs for the glycol-filled heat-transfer piping between the collectors and the mechanical equipment. This piping, which is 41 mm in diameter and has 13 mm of elastomeric insulation, is less than 100 metres long overall.

The glycol circulator, the counterflow heat exchanger, the domestic water circulator and the ten 455-litre glass-lined hot-water storage tanks were added to the domestic hot-water system. Combined with the 1700-litre main tank and the 1360-litre replacement tanks, the complex has a total storage capacity of 7600 litres of hot water.

Table 1
Solar Technical Design Information – Quinpool Towers, Halifax, Nova Scotia

Application: Preheat Domestic Hot Water

Collector Information

Type	Flat plate, metal absorber
Number	100
Size	Total gross area: 228 m^2
Mounting location	Rooftop
Slope	45°
Azimuth	0° east of south

Storage Information

Type	Water
Volume	4.5 m^3 (4550 litres)
Location	Rooftop mechanical room
Loss coefficient	10.8 watts/°C
Antifreeze	Glycol

Piping Information

Length	100 m
Diameter	41 mm
Insulation	13-mm wall – elastomeric

Hot-Water Data

Consumption	19 000 m^3/year
Total load	3730 GJ/year

Solar Contribution

Solar energy delivered	630 GJ/year
Solar fraction	17 percent
Displaced energy (with a boiler efficiency of 65 percent)	970 GJ/year
Displaced fuel oil	25 000 litres

Actual Capital Cost of System (1987 dollars)

Design and testing	$2,000
Solar equipment material	$63,500
Solar installation labour	$14,500
Building modifications	$4,000
Miscellaneous and overhead	$9,000
Total	$93,000
Monitoring	$1,700

Actual Operating and Maintenance Costs (1987 dollars) $300/year

Energy savings (fuel oil)	$8,350/year approximately
Price of oil	$0.33/litre
Simple payback – with incentive	5.8 years
Simple payback – with no incentive	11.5 years
GHG emissions factor	2.9 kg per litre
Annual displacement of carbon dioxide	72 700 kg

COLLECTORS ON TOP OF THE ROOF, MECANICAL ROOM LOCATED TO THE RIGHT.

The data used for the solar heating system's design reveal that the total annual hot-water consumption for the apartment complex was thought to be 19 000 cubic metres per year, with a corresponding total energy load of 3730 gigajoules (GJ) per year. The predicted fraction for solar power was 17 percent; thus, the solar heating system was expected to deliver 630 GJ annually. With the boiler operating at a seasonal efficiency of 65 percent, 970 GJ (25 000 litres) of oil would be saved each year, displacing 72 700 kg of carbon dioxide emissions per year.

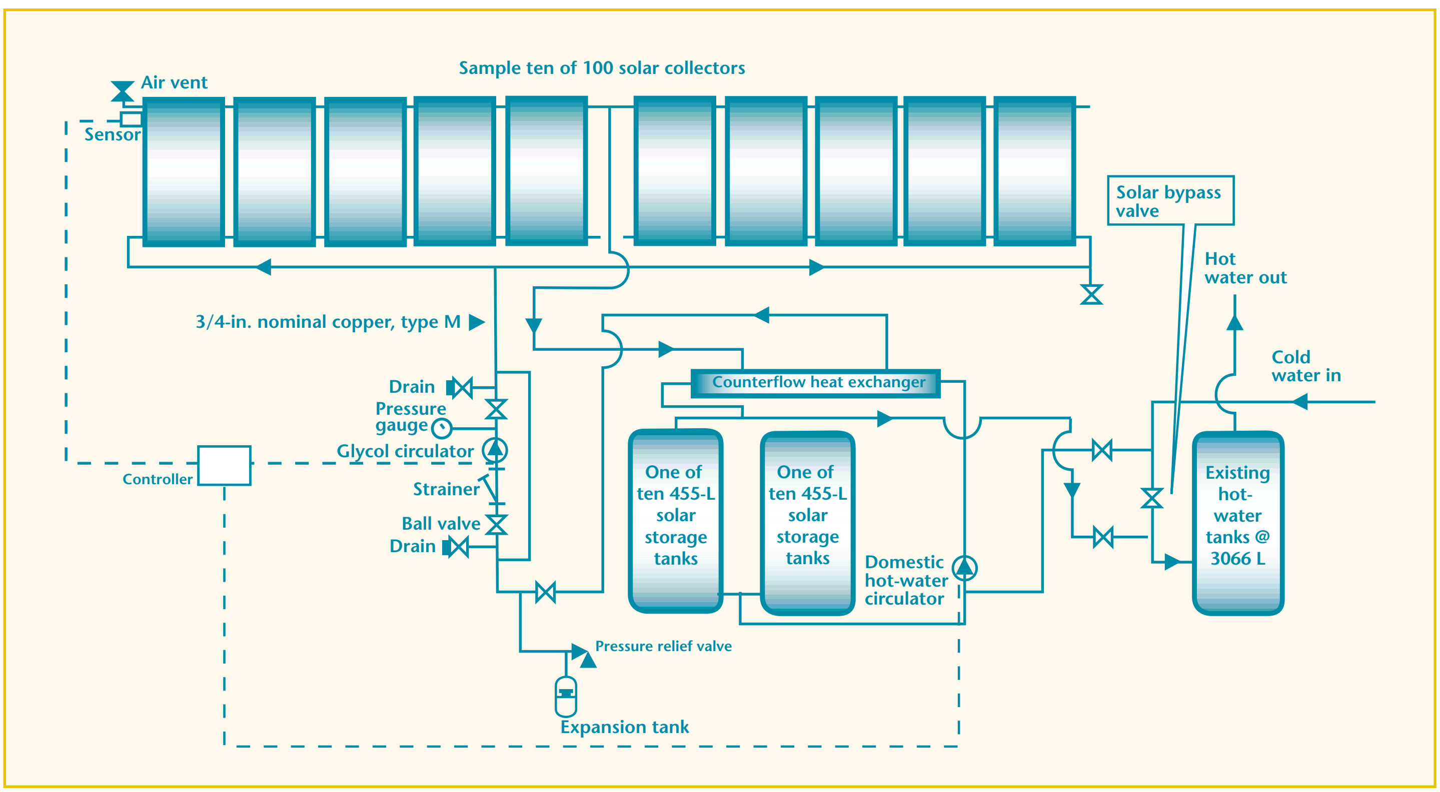
Project costs are detailed in Table 1. The solar heating system was designed and installed for a total cost of $94,700, including $1,700 for monitoring equipment (1987 dollars). With the 50-percent rebate from the Government of Canada, the total cost to Quinpool Towers was $47,350. The system's capital, operating and maintenance costs are described in Table 1. Using the price of oil in 1987, the simple payback with no incentive was 11.5 years; with the rebate, this was reduced to 5.8 years.

SYSTEM OPERATION

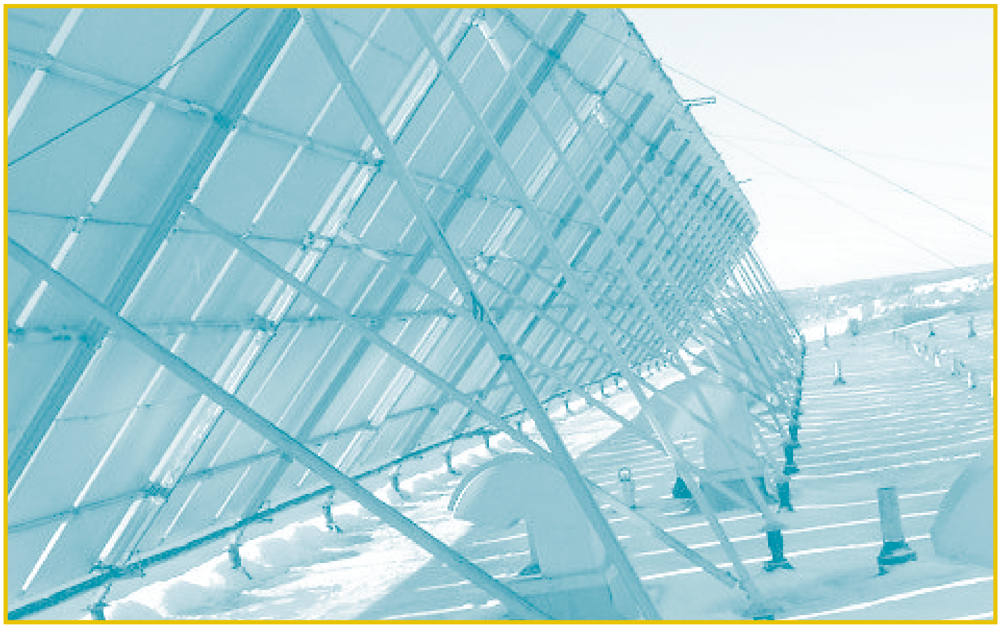
Figure 1 shows an overview of the original design for the solar hot-water system. On the right side of the schematic, one can see how the solar heating system is connected to the existing hot-water tanks and system. The solar heating system's bypass valve was closed in order to allow the cold supply water to circulate through the solar tanks.

A temperature sensor within the glycol at the solar collector senses the temperature within the solar panels. Another sensor in the solar water tanks measures the water's temperature. When the temperature differential between the two sensors is greater than 5°C, the glycol circulator is activated and circulates the heated

FIGURE 1 – THE QUINPOOL TOWERS – ORIGINAL SCHEMATIC DIAGRAM



glycol through the collector array and to the counterflow heat exchanger. At the same time, the solar tank water circulator begins to operate and raises the temperature of the solar tanks. When the temperature differential between the solar array and the solar tank is less than 2°C, the circulation section of the solar heating system shuts down.



Solar array on roof. Note special boots anchoring frame to roof.

Mr. Devison, the building's manager, modified the system to replace the manual solar bypass shut-off valve with an automatic one. When combined with a temperature sensor, the cold water can to go directly to the existing hot-water tanks and oil boiler system until the temperature in the solar tanks reaches 50°C. At this temperature, the bypass valve closes, and the solar heating system becomes part of the domestic hot-water system. Thus, when the solar water tanks reach a temperature of 50°C, the solar heating system supplies the hot domestic water and continues to supply it until the water in the solar heating system drops below the 50°C threshold. This modification reduces the contribution of the solar heating system because it tends to raise the average temperature at which the solar collectors begin to operate. However, the higher average delivery temperature from the solar heating system will likely result in less on-off cycling of the oil-fired boiler, thereby increasing its service life and reducing its maintenance costs.

Operating and Maintenance Experience

According to Mr. Devison, the system has had very few operating and maintenance problems over the years. During its installation, however, a leaking storage tank damaged an apartment below.

During windstorms, the gravel laid over the asphalt membrane on the original roof cracked some of the glass on the solar panels. Solar collectors often have tempered glass to avoid such damage. In addition, Mr. Devison was not satisfied with the sealing method used to attach the solar array to the roof. These problems were solved when the roof was replaced during routine maintenance. A modified roofing material was used that did not require a gravel sunscreen. The building contractor also installed special boots around the panel frame anchors to improve the water seal at these joints (see picture above). Mr. Devison recommends that a roofing contractor be involved in the initial installation to ensure proper roof sealing.

To date, the solar heating system continues to operate well. Since its installation, there has been no need for routine servicing of the equipment. The glycol antifreeze has never been replaced except to top it up because of the occasional leak. Minor leaks were repaired promptly. Mr. Devison says that he quickly grasped the principles of heat recovery and has added to the system's total hot-water storage capability by using waste heat recovery to complement the solar and oil-fired hot-water sources.

Mr. Devison also found that the total hot-water storage of 7600 litres allowed him to shut down the oil-fired hot-water boiler for a significant portion of the day during the summer and use only solar heat to meet the building's domestic hot-water needs.

To enhance the impact of the solar heating system, Mr. Devison replaced all shower heads in the building with ones that have a low-flow rate of 9.5 litres per minute.

Table 2
Annual Solar Heating System Performance

	Design	Actual (2000–2001)
Daily domestic hot-water load	68 litres/person 765 occupants	134 litres/apartment 232 apartments
Total hot-water consumption	19 000 m^3	11 350 m^3
Total energy load	3730 GJ	2900GJ
Solar energy delivered	630 GJ	495 GJ
Solar fraction	17 percent	17 percent
Displaced fuel oil	25 000 litres	19 700 litres
Savings	$8,370 (at approximately $0.33/litre)	$9,840 (at approximately $0.50/litre)
Displaced carbon dioxide emissions	72 700 kg	57 100 kg

Observed System Performance

Although detailed yearly records of the building's oil consumption were not available, information from the following sources was used to estimate actual performance (summarized in Table 2):

- an energy audit in 1985 by the Province of Nova Scotia that provided a pre-solar installation base case;
- the original proposal for the solar water-heating system;
- actual data on the system's first year of operation; and
- current annual oil consumption for the building.

The original design anticipated significantly higher water use (67 percent) than was later found to be the case. As a result of this and other factors, the quantity of solar energy delivered to the load was 79 percent of that originally expected. On the other hand, recent oil price increases have meant that current annual savings exceed those predicted in the original proposal.

Owner Satisfaction

Building manager Derek Devison is extremely satisfied with the solar water-heating system. In his opinion, the system has provided excellent value for money. "Solar water heating is an important part of providing a cost-effective operation at Quinpool Towers Apartment Building," he says. When asked about maintenance of the system, he states that "The solar system has proven to be a very low maintenance part of the mechanical system at the complex." He adds, "During the summer months, the usage pattern of the tenants does not allow me to optimize the use of my solar capacity." Mr. Devison feels that there is still an opportunity to increase the contribution of solar power by increasing the additional storage capacity.

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Visit the Web site of Natural Resources Canada's Canadian Renewable Energy Network at http://www.canren.gc.ca.

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Case Study

Water Heating System for Apartment Building – Quinpool Towers, Halifax, Nova Scotia

The Building

Quinpool Towers (Quingate), owned by Quinhall Investments Ltd., is a 232-unit apartment building constructed in 1978 as part of the Quinpool Centre Complex in Halifax, Nova Scotia. The building, which houses approximately 500 occupants, is of poured concrete construction, has 10 storeys and has a flat concrete slab roof. The exterior of the building is metal clad.

The building has one-, two- and three-bedroom apartments and two bachelor suites. The space-heating distribution system is baseboard hot water. Service hot water is delivered through a circulating hot-water piping system supplied from hot-water storage and boilers in the mechanical room on the building's roof.

Choosing Solar Heating

In 1986, Alpha Energy approached Derek Devison, Quinpool Towers' building manager, to consider the installation of a solar heating system for the building. Mr. Devison and the building's owners were attracted to the solar option for the following reasons:

- Commercial oil prices in 1987 were fairly high ($0.33 per litre).
- Some of the building's hot-water storage tanks needed to be replaced.
- Alpha Energy offered a unique leasing arrangement that tied the lease payments to the price of oil.
- The Government of Canada offered a 50-percent rebate of the capital cost of the solar hot-water system.

A system designed to preheat service hot water for the building was installed in 1987.