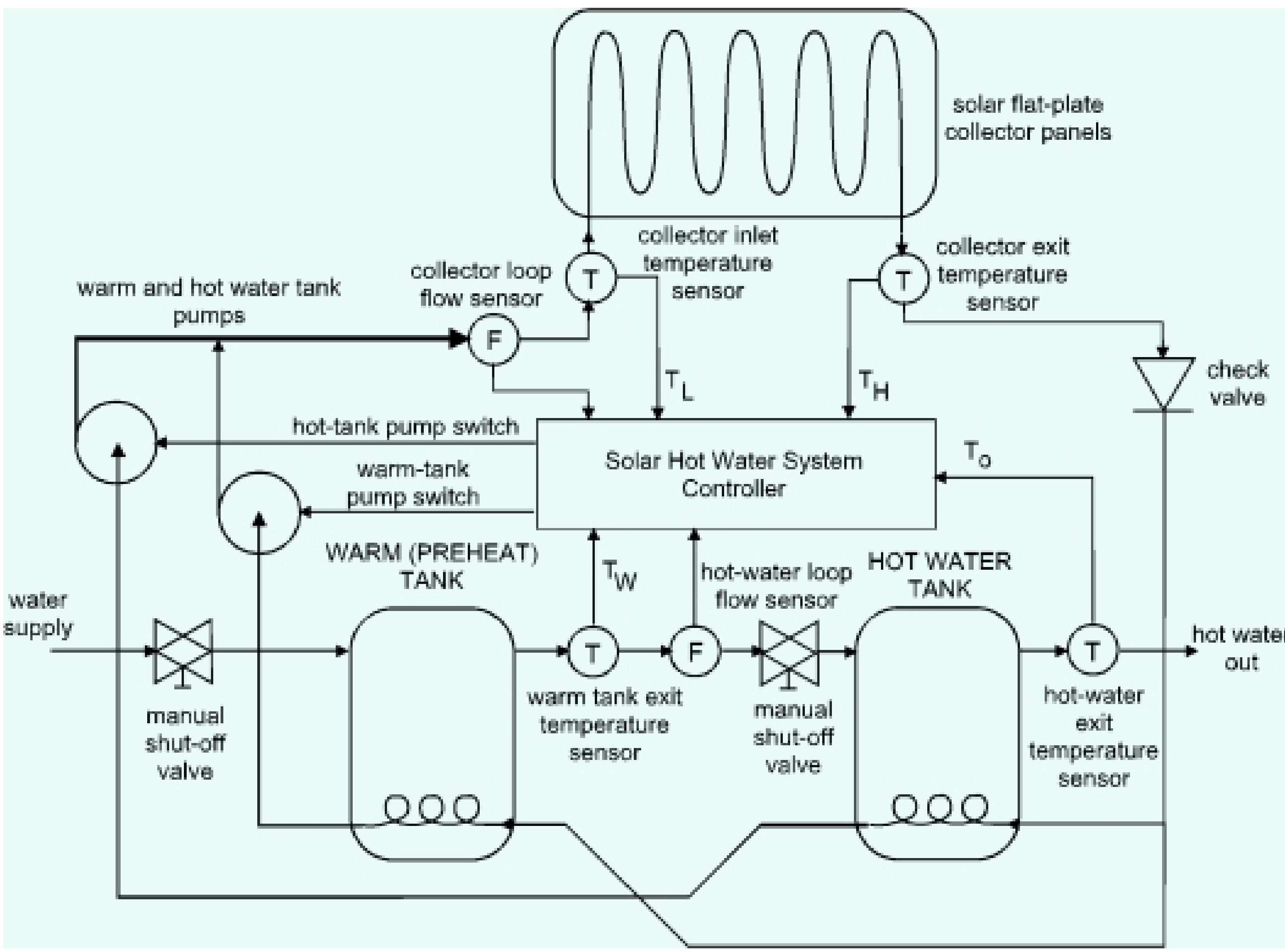
Solar Hot Water Controller Design, Part 1
by Dennis L. Feucht

The energy source for domestic or commercial water heating is usually gas or electricity. As the present sources of energy (gas, oil, coal, hydro) become less feasible (whether for natural-resource, ecological, or geopolitical reasons), alternative energy engineering emerges. This series of articles on solar water heating will present the considerations for solar hot water system (SHWS) controller design. Engineering design calculations for the complete system are presented. A full-scale version can be designed from these equations and implemented as a useful system, or a scaled-down version can be built as an introductory experience in engineering a working solar-energy system. The difference is largely the size of tanks and collector panels.

High-End SHWS Design

This design uses two tanks, as shown in the system diagram.



The system has two fluid loops: The solar collector loop that delivers heat to the water, and the larger water "loop" from water supply to the load (sinks, showers, swimming pool, hot tub, etc.) The *preheat* or *warm* tank captures additional solar energy that otherwise would be wasted - or worse yet, would overheat the solar collectors. When the main or *hot* tank, which is temperature-regulated, reaches the desired (set-point) temperature, the collector-loop fluid is diverted to the preheat tank by selecting which tank pump will be run. Water entering the hot tank from the warm tank thus requires less heating to achieve the desired temperature.

Besides the controller the components in this system are: The two water tanks, tank heat exchangers (which can be attachments to existing commercial tanks), solar collectors, collector pump, controller, check valves, manual valves, safety-vent valve (on hot-water tank), piping, joints and plumbing accessories. The tanks are the common household 35 to 50 gallon (150 to 200 liter) hot-water tanks that usually have a vent valve, but also include a means of heating (gas or electric). An existing hot-water tank could be used and the system could function as a hybrid (solar-gas or solar-electric) without modification, by setting the local tank control temperature slightly below the SHWS controller set-point temperature. Then non-solar heating will not occur unless solar heating is insufficient.

Solar Collectors

The solar collectors are flat-plate collectors. A typical house might use one to three 3 m^2 panels plumbed in series. These panels sell typically for under $500 each but have been found in the surplus market for $200 each. They can also be built using plate glass, copper tubing, plywood (for the frame), black anodized backing sheet, and insulation. A vacuum-insulated space for the tubing and backing is state-of-the-art but costly and more difficult to build. Three-meter panels can be carried and installed by two people of couch-potato build.

If the panels are mounted most simply - at a fixed angle relative to the earth - then if they are tilted so that sunlight is normal to their plane surfaces at noon, the traversal of the sun will sweep out an incident angle that, on average over the day, will result in a sine average, or $2/\pi$ times the noon-time peak energy, to the collectors. For minimum sun in winter of 8 hours/day, 8 hours of sunlight will be effectively (8 hours)$\cdot(2/\pi) \cong 5$ hours of equivalent normal incident radiation. Solar radiation power flux is 1 kW/m^2. On average over the sunlit day, this is 636 W/m^2.

Consequently, the effective solar heating rate is:

$$dQ/dt = (8h \div 24h)*(2 \div pi)*(1\ kW/m^2) \cong (0.333)(0.636)(1\ kW/m^2) = 212\ W/m^2$$

To Be Continued