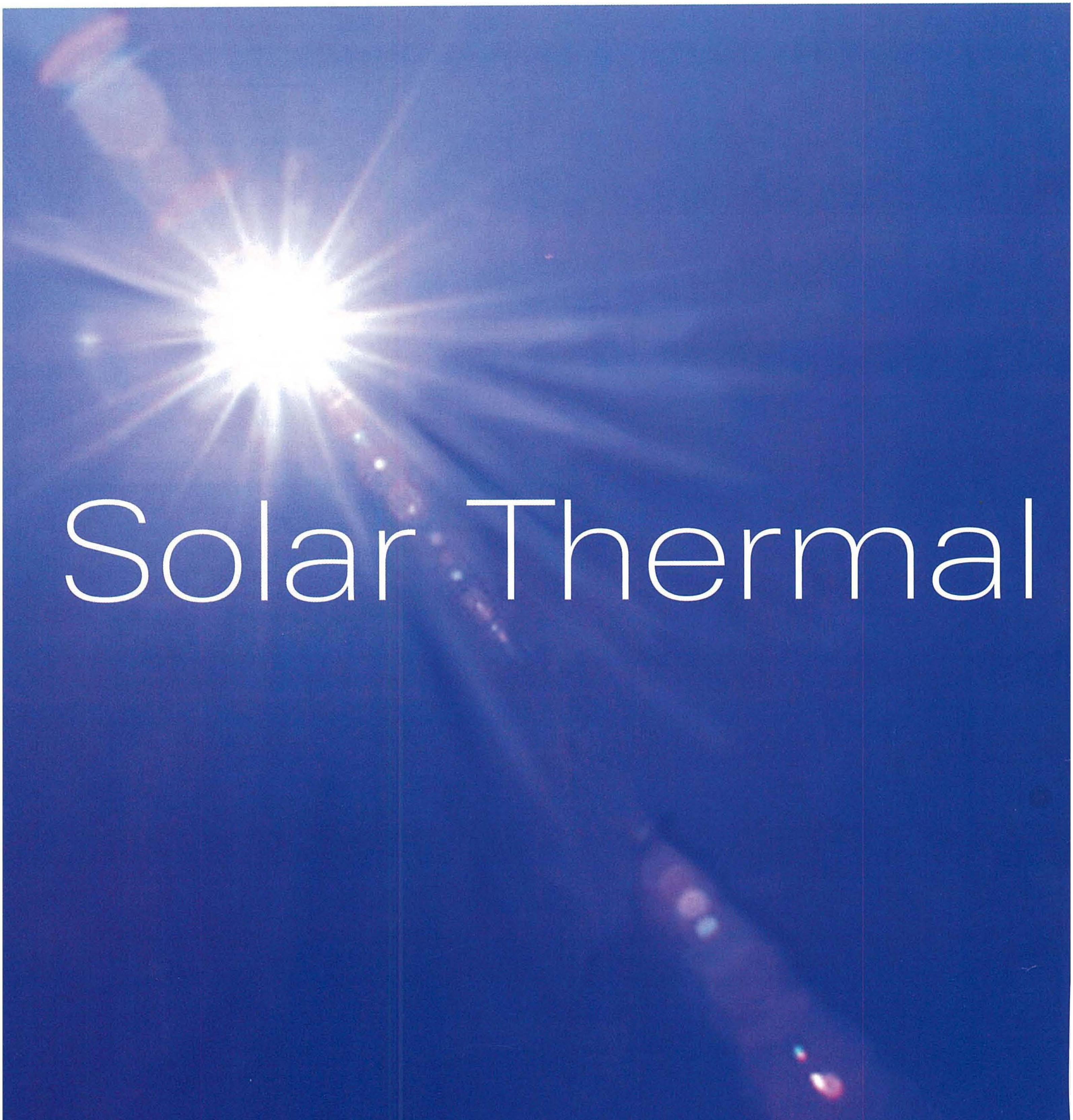
Solar Thermal

System Design

Part 1: Solar Thermal Applications and Modern Solar Collectors

BY W. HOLLIS FITCH III

In this three-part series, we will look at commercial solar thermal systems, lessons learned since the 1970s, and state-of-the-art technologies. This first part includes information on applications for solar thermal systems and compares modern collector design and performance. Part 2 will address freezing and stagnation conditions, and Part 3 will discuss system design and best practices as applied to solar thermal systems.

INTRODUCTION TO SOLAR ENERGY

Using the sun to make hot water is nothing new. Romans placed clay pipes in the sun to warm bath water, and we all have felt how hot water can get when a garden hose is left in the sun. Over the years, engineers have been drawn toward improving this process-seeking to eke as much heat as possible from a solar collector.

Allthrough the 1900s, solar collector design and manufacturing focused on improving and standardizing the basic flat box. Technology evolved from wooden boxes with enclosed copper pipes to extruded aluminum casings, high-performance glass, and exotic TiNOX coatings on high-tech absorber plates. More recently, advances have been made in evacuated tube collectors, which show great promise in performance and durability.

In addition to improvements in manufacturing, the Solar Rating and Certification Corporation (SRCC) emerged as the leading third-party organization responsible for testing and certifying the construction and performance of solar thermal collectors. The almost universal adoption of the SRCC label in the United States provides a standard to measure against and has greatly helped the solar thermal industry by weeding out shoddy products that otherwise would make it to the market.

Despite this long history and a body of knowledge based on decades oftesting and installation best practices, solar thermal systems have remained on the fringes, many times misunderstood, misapplied, and regrettably unappreciated.

Figure 1 Evacuated tube array on the roof of a jail

THAT IS ALL CHANGING

Solar thermal now is recognized as the low-hanging fruit in the renewable energy arena. More than 80 percent of the sun's energy can be converted to heat by collectors as opposed to about 15 percent conversion to electricity by photovoltaic panels. Solar thermal is the only practical way to make commercial hot water from sunlight: It has built-in energy storage by the use of tanks and requires little roof space to make a significant impact on a facility's heating needs.

Advances in technology are sparking healthy competition and improving the industry as a whole. All of this has raised public awareness and is prompting a new generation of engineers to learn more about the proper design and installation of solar thermal systems.

SOLAR THERMAL APPLICATIONS

Usually we think of solar thermal in conjunction with domestic hot water systems. However, many other appropriate uses should be considered. These include:

- Domestic hot water systems for hotels, apartments, jails (see Figure 1), hospitals, dormitories, and cafeterias
- Industrial hot water systems for parts washing, process heat, steam makeup water, and condensate reheat
- Domestic or heating water for agricultural and food preparation, dairies, and bottling plants
- HVAC applications, air-conditioning reheat, dehumidification, space heating, other heating hot water, and absorption chillers
- Commercial swimming pools and therapy pools

When implementing a system, consideration should be given to the total facility demand, the use profile, and the temperature of the water, since these three factors can greatly impact performance. The ideal candidate for a solar thermal system would present a high British thermal unit (Btu) demand year-round and would use very low water temperatures.

Facilities with low demand are not good candidates for solar. For example, an office building with only lavatories simply does not use enough hot water to justify the installation of a solar thermal system.

Intermittent demand also presents complications to the designer since a solar array cannot be turned off. If there are periods of low or no demand, then storage tank temperatures will quickly rise, and any additional heat must be rejected to other consumers or to the atmosphere via air or water coolers, which is expensive.

An example of intermittent use is a high school, which uses less hot water in the summertime than during the rest of the year, so the designer will have to implement a waste heat strategy. This need not imply a loss of energy-instead of simply rejecting heat to the atmosphere, perhaps the energy could be sent to a pool or used to help control humidity in the building.

Hospitals, jails, process heating, and dairies present excellent opportunities for solar thermal. Such applications have a large daily demand for domestic or heating hot water, and downtime periods typically don't occur. In many cases, there are better opportunities to utilize solar thermal on heating hot water systems than in domestic hot water systems, and these applications should be considered during the design phase.

All solar collectors perform better with low entering water temperatures. It is not practical, in most cases, to consider solar heating on systems with higher than 180°F water. On the other hand, some of the highest achievable performance targets can be reached in swimming pool heating, since the water temperatures are relatively low.

FLAT PLATE COLLECTOR DESIGN

As mentioned, flat plate collectors (see Figure 2) have seen a laudable increase in performance and construction during the past 30 years. A number of high-quality flat panel collectors are now available that utilize rugged construction materials and the best glass possible to promote the highest light transmission and insulation levels.

In a flat panel collector, water enters the bottom header, flows through the capillaries, and exits the top header. Sunlight enters the glass-enclosed box and heats a large copper absorber plate, which is fused to the capillaries and headers, thereby warming the water (see Figure 3).

EVACUATED TUBE COLLECTORS

When it was realized that the single biggest problem with flat plate collectors is the loss of heat through the glass cover, engineers were challenged to come up with a solution that would allow the energy from sunlight to be absorbed by the working fluid, yet have a higher R value than a plate glass-covered collector. Evacuated tube collectors (see Figure 4) do just that. In this technology, the absorber plate is contained inside a sealed glass tube from which all air is evacuated. Sunlight can enter the tube and strike the absorber plate, but since there is no air, there can be no convective or conductive losses, leading to very high R values. In addition to the vacuum insulation, most evacuated tube collectors use a heat pipe to transfer the absorbed heat to the working fluid.

Unlike a flat panel collector, water in an evacuated tube collector flows only through the header, absorbing heat from the heat pipe in each evacuated tube as it passes (see Figure 5). The heat pipe technology and the high R value presented by the evacuated tube mean greater performance characteristics over a broad range of temperatures.

Figure 2 Flat panel array

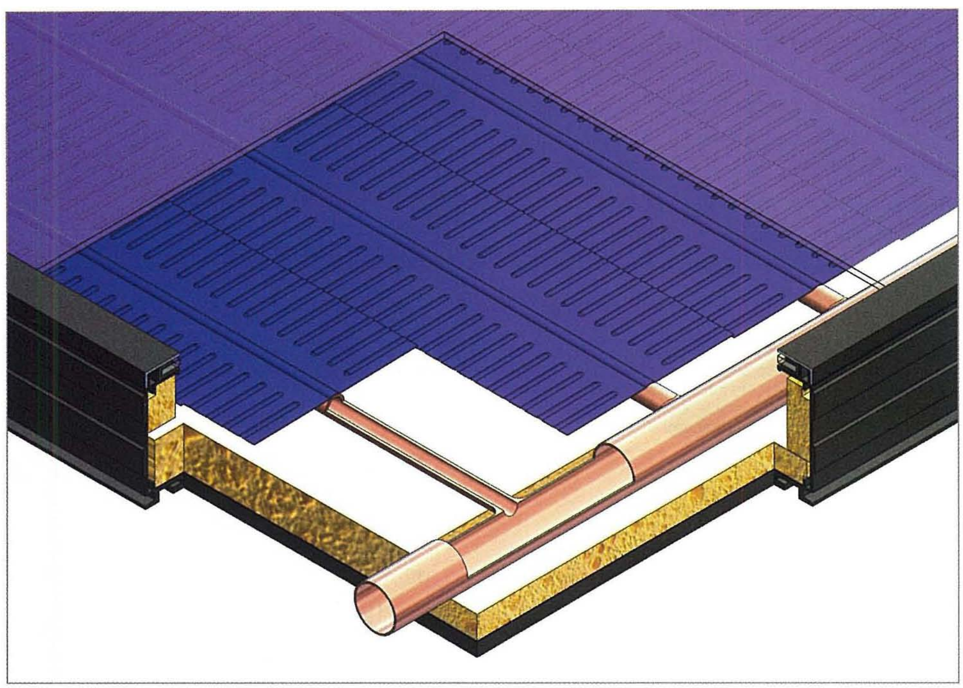

Figure 3 Flat panel construction

Evacuated tube collectors present three major improvements over the flat panel collector technology of the past:

1. They can operate efficiently at much higher water temperatures.
2. Their performance is more constant year-round (see Figure 6).
3. They present far less risk of freezing.

While it may appear that these three factors are minor improvements in performance to be expected of any technology over time, this is not the case. These changes allow the solar thermal engineer much more flexibility in the design and specification of a system than was previously possible.

LOOKING TO THE FUTURE

As solar thermal moves into mainstream use, the industry must look forward to increased training of plumbing and mechanical engineers, as well as the use of innovative design techniques and software, especially in colleges and universities. Also, regulating bodies must implement a broader certification standard that addresses the advances in technology, is in line with the more stringent European standards, and adds a new certification for the structural interface between collectors and roofs. Finally, simplified field installation procedures need to be developed to ensure robust, long-lasting installations. **PSD**

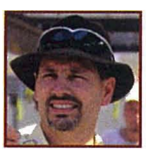

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Figure 4 Evacuated tube collector array

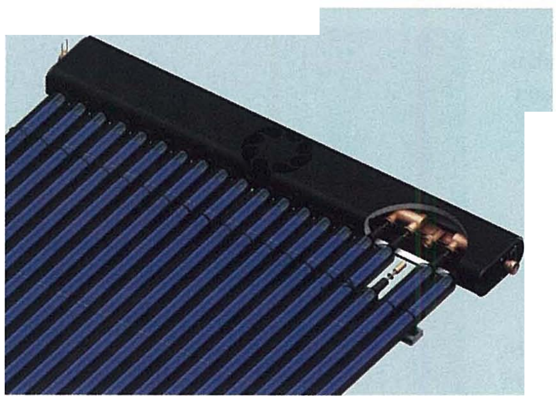

Figure 5 Evacuated tube construction

Figure 6 Evacuated tube performance versus flat plate