Solar Industry

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Flat Plate Versus Evacuated Tube: Which Performs Better?

Studies have shown that the performance of both flat plates and evacuated tubes will vary depending upon weather conditions.

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Between 1976 and 1986, the thermal solar industry in U.S. developed into a thriving vital industry, as Fortune 500 companies spent hundreds of thousands of dollars in product development and testing. Many parties currently interested in solar thermal installations, however, unintentionally ignore the experiences and knowledge gained in the past.

Thus, the following article should serve as an educational guide for architects, engineers, installers and buyers in this industry.

Data in this article are based on two studies by northern California utility Pacific Gas & Electric Co.'s (PG&E) department of electrical research (report 005.41-80.1 and report 005-82.5). The studies, which both incorporated ASHRAE 93-77 testing methods, used the following equipment and materials: GE Model TC 100 10-tube evacuated tubes, Owens-Illinois Sunpak 20-tube collectors, FAFCO swimming pool collectors with single-fiber glass glazing, Sanyo STC 10-tube collectors and Lordan LSC flat-plate collectors. The tests took place in San Ramon, Calif.

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To review, solar thermal energy is based on some very elementary principles that can be easily understood with the following three axioms:

First, the amount of solar energy that falls on a square foot of our planet is a constant. It does not improve by using a batch collector, concentrator, evacuated tube or flat plate.

Fuel for a thermal solar system is solar energy if the number of Btus available is a constant in your area. When one is collecting energy, the only way to increase effectiveness is to increase the collection area. Starting with 1.25 square feet of collector per gallon of storage, you can advance to 2.2 square feet per gallon and beyond, based on solar exposure and collector angle ambient temperatures, for a domestic hot water system.

Finally, the engine of a system is the collector. We must use the most efficient method we can to absorb and transport solar for reuse. The core of the engine is the absorber area, which is the area that faces the sun and retains the heat for transport to use. Sizing of a collector array is based on annual contribution of a collector, not on maximum performance.

In other words, sizing is based not on what the collector can deliver under the best conditions (i.e., during the summer), but on the collector's year-round output, including when the sun is at a lower angle at certain times during the year.

Test procedures

In the late 1970s, PG&E began its monitoring and testing program for domestic hot water and collector efficiency. Some of the reports are available and are very relevant to today's upsurge in solar thermal energy practices.

The specific reports reviewed in this discussion pertain to three types of evacuated tubes contrasted with two types of flat plates.

As mentioned, all tests were performed in accordance with ASHRAE standard 93-77. The test measured performance of the collectors under similar conditions by measuring the collectors' productivity in capturing heat in the transport medium. Elements measured included ambient temperature, the plane of the collector, wind velocity and the physical properties of the collector. The goal was to determine the thermal efficiency of the collectors under an accepted standardized test.

To properly understand the collectors and other items used in PG&E's tests, we must start by reviewing their exact physical characteristics. First, the pool collector was composed of polymer plastic. This collector was a flat plate with a single Tedlar glazing to retain temperature and protect the absorber area from wind.

The second flat plate was a standard parallel-flow, vertical fin and tube, bi-metal absorber plate with single-glazed, low-iron glass and a steel case collector.

The first evacuated tube studied was a double-glazed glass tube with vacuum between glass for insulation. The absorber was a copper tube with an aluminum fin and selective surface on the absorber that used flow-through configuration. (Because no heat exchanger was needed at the collector, this unit performed better than a typical single-port tube.)

The other evacuated tube in the tests used an evacuated double glazing, with the inner tube interior acting as a selective surface absorber, with a U-configured copper tube touching absorber used to collect heat. The third evacuated glass tube unit was configured in a serpentine-type manifolding of copper pipe with a reflective surface behind each tube.

All of the collectors were tested on thermal performance, efficiency and operation at different incident angles. According to some test results, very little heat escaped from the evacuated tubes once it entered through both glazing layers of the double-glazed units, making collectors with this glazing significantly less sensitive to ambient temperatures and wind than others.

In contrast, two single-glazed collectors posted inferior test results under certain conditions. When the collectors were placed at different tilt angles, the flat-plate units were not affected up to a 40-degree incidental angle. Performance of the evacuated tubes was more sensitive to their angle of exposure due to reflectivity off the glazing.

Obviously, collectors used today have improved somewhat since these early tests, but the shape and glazing techniques have not been substantially altered. A flat-plate collector still has the same shape, and the evacuated tube is still a double-glazed curved unit.

Therefore, if the test were performed today, one would arrive at the same performance conclusions. The results of PG&E's early test can be considered quite current, as it is the features of the units that determined the outcome of these tests.

Climate considerations

The PG&E researchers found that under summer-like conditions, all of the collectors were able to satisfy the requirements of a domestic hot water system. However, the optimum annual contribution for domestic hot water was found with the flat-plate collector.

In general, in a tropical or mild climate, the single-glazed plastic panel could be used to heat domestic hot water, but the ambient temperatures need to be high for water temperature to be useful. Its best application is for temperature ranges that are close to those of hot tub and swimming pool use.

The flat-plate collectors performed best at moderate temperatures, such as an 80 degree F change from ambient temperatures, and when providing hot water temperatures to about 145 degrees F. The flat plate can be used for higher temperatures, but its best general performance is found in lower-temperature domestic hot water applications.

The evacuated tube collectors, in contrast, performed well under severe ambient temperatures. The insulative qualities of the unit excelled when the useful temperatures represented more than a 100 degree F temperature difference between outside air and the desired temperature.

These collectors work best when the angle of the sun is at an optimum angle to the absorber area, and their performance drops off with lesser incidental angles. The evacuated tubes are effective at producing higher temperatures.

While evacuated tubes can be used for domestic hot water, these applications are not their optimum use. Instead, they have huge potential in solar cooling and industrial processing.

As mentioned above, although there have been significant improvements in the construction of both evacuated tubes and flat plates, the elements of physics that were tested have not changed. A flat-plate absorber will still react in the same manner to lower angles of solar exposure. An evacuated tube still has double glazing, and the curvature will reflect short waves in the same manner as it tested.

The ongoing relevance of this 30-year-old report from PG&E was proven in 2005, when the Center for Excellence for Solar Engineering presented a paper on the same topic at Ingolstaad University in Bavaria, Germany. This paper compared two commercial systems located near each other: a flat-plate system and an evacuated-tube system.

The results, measured in Btu output, confirmed the conclusion of the results cited in the earlier study. Once again, the flat-plate system outperformed the evacuated-tube system on an annual basis, from October through March.

The researchers also observed that weather elements, such as snow and frost, contributed to the comparatively poor performance of the evacuated-tube system. Specifically, the same insulative qualities that allow good performance under ideal conditions melted the snow at a slower rate off the evacuated tubes.

Studies can best utilized in understanding the weak points of the collectors that the reader is considering. By obtaining data that show performance of the collector under the particular circumstances under which the collector would be used, the buyer can make an educated decision.

For example, a buyer evaluating a flat-plate collector should look closely at its performance in severe ambient temperatures. When considering evacuated tubes, the buyer must examine the performance of the collector during the winter. Because ASHRAE testing methods are generally used, manufacturers will have these data.

In general, for either flat plates or evacuated tubes, the selection should be based on how much energy could be collected per dollar spent for the desired application.