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Concentrating Solar Thermal For Industrial Applications

Parabolic troughs focused on small absorber areas allow concentrating solar thermal to generate large quantities of heat.

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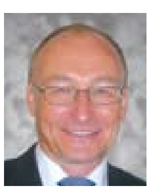
Photo courtesy of NEP Solar.

A field of solar collectors outside of Modesto, Calif., is one of the most high-profile examples of concentrating solar thermal (CST) for industrial applications. This installation, located at SunChips' manufacturing plant, represents a technology that is rapidly gaining momentum in the industry.

By using rows of shiny metal mirrors to concentrate the sun onto an absorber tube, CST technology can attain higher temperatures than those seen in other solar thermal applications. This technology has the potential to dramatically affect energy efficiency and the industrial sector's traditional reliance on fossil fuels.

The technology itself borrows from both solar thermal and concentrating solar power (CSP) systems. As in solar thermal, the core of the system is an absorber material that transfers heat to a fluid for use in heating or cooling applications.



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But unlike the flat-plate collectors used in solar thermal, CST uses concentrating technology, as in CSP. These parabolic troughs capture a large amount of sunlight and then focus it on a very small absorber area. This efficient use of sunlight and heat transfer enables CST to heat fluids beyond their boiling point.

CST technology evolved to fill a hole in the market. Solar thermal applications are most appropriate for residential heating and cooling applications, while CSP is generally used in large-scale applications to generate electricity that is then sold to utilities or industrial customers. The niche in between solar thermal and CSP is large industrial applications that require process heat.

In fact, in Organization for Economic Co-operation and Development (OECD) countries, the industrial sector is the biggest consumer of energy among industrial, transportation, household and service sectors, consuming 30% of total energy.

Two-thirds of that energy is related to heat, which is needed for production, processing, and facility heating and cooling. This need is prevalent in a wide range of industries, including dairy, meat and food processing; beverage bottling; textile manufacturing; pharmaceuticals; and many other industries.

Traditionally, most of these applications are driven by fossil fuels. CST provides a compelling and cost-effective alternative.

System design

CST systems employ parabolic-trough collectors that concentrate sunlight before it strikes an absorber. The trough is lined with a mirrored surface - usually metal or glass - that focuses sunlight onto a tube that contains a thermal absorber. Fluid is pumped through this tube and the overall solar loop for heat transfer.

These trough systems are designed to reach temperatures of over 150 degrees C (300 degrees F) and sometimes up to 300 degrees C (570 degrees F). They can operate at a higher level of efficiency than flat-plate collectors, because they have a large collection area for higher concentration, while a smaller absorbing area minimizes heat loss.

The parabolic nature of CST systems reflects sunlight onto a single axis - occupied by the absorber tube - from all points on the mirror. To maintain the proper alignment, the trough must track the sun throughout the day.

This design presents a number of advantages and disadvantages when compared to traditional flat-plate collectors. The largest advantage is the system's overall efficiency and ability to operate at higher temperatures. This allows CST to offset fossil fuels in new applications.

This capability is possible because the area of heat loss is so much smaller, while the system's collector area or concentration ability is much greater. But to attain this level of efficiency, the system must also track the sun, which adds to cost, complexity and operation.

The system must also be cleaned regularly to maintain an adequate level of reflection. Finally, because it cannot use diffuse sunlight to create heat, this technology is not as effective as others in generating power on cloudy days.

The trough itself is usually made of metal or curved glass to maintain its reflecting shape. The reflective surface can be made of glass or a highly reflective aluminum sheet. Many newer systems use metal frames in conjunction with aluminum sheets, because this material is lighter, less likely to break and more formable in installation, and does not sacrifice performance or durability.

The absorber tube is coated with a selective coating and is covered with either a glass jacket tube or a vacuum tube that is designed to absorb as much solar radiation as possible. It is usually connected to a series of metal tubes through which the heat-exchange fluid flows.

The shape of the parabolic trough itself gives it less optical efficiency than flat-plate collectors or evacuated-tube collectors. Manufacturing processes prevent it from being a perfect parabola; therefore, the reflectivity of the mirror is always less than 100%.

However, most surfaces obtain close to 95% reflectivity in real-world testing. Recent testing from the U.S. Department of Energy's National Renewable Energy Laboratory and the German Aerospace Center has shown that some metal surfaces can sustain that level of reflectivity over many years, even under duress.

Regardless, the minimal heat loss achieved through the small absorptive surface area makes up for this loss in reflectivity. At temperatures above 100 degrees C, this level of performance becomes even more apparent.

Heat capabilities

Trough design breaks down into different categories of size, and each size is able to heat fluids to a different temperature. Units that are able to reach temperatures above 300 degrees C are heavier than others and have a larger aperture width of up to six meters.

For CST applications where liquids can be heated between 100 degrees C and 250 degrees C, the troughs normally have a smaller aperture of between 50 cm and two meters. These systems are also smaller and lighter, allowing them to be installed in less conventional locations - even on rooftops.

Most small parabolic-trough collectors and systems are best used to generate steam for powering a generator. Additionally, they can drive absorption chillers for cooling applications. The high temperature range of CST allows a double-stage absorption chiller to be used. This is a much more efficient system that has great promise because of its lower operating temperature.

At SunChips' factory, water is heated to roughly 232 degrees C before it passes through a boiler system that generates steam. This steam is used to both cook the wheat and heat the cooking oil used for the production of the chips. Built by American Energy Assets, the facility has a total annual capacity of 14,700 million Btu.

There are a number of other compelling examples of CST in action around the world today. For instance, Sopogy solar collectors are currently producing cooling for the Southern California Gas Co.'s Energy Resource Center's air-conditioning system. In Turkey and Jordan, a number of facilities are generating steam and air conditioning from a CST system for hotels.

Additionally, in Australia, a system from NEP Solar will be used as part of a solar cooling system for the Charlestown Square shopping center, which is located just north of Sydney. The project is being funded by New South Wales Government's Climate Change Fund.

As these early CST systems begin to validate the technology, the market for industrial process heat solar systems will expand. Coupled with government incentives, the demand for CST systems could begin to outpace that of many other solar technologies, simply because the market potential is so large and the companies installing the systems have both the motivation and the financial resources.

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