Solar Power & Xceltherm® Heat Transfer Fluids

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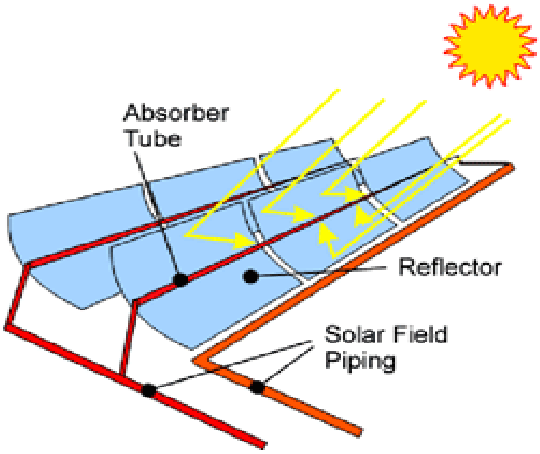
To the best of our knowledge, Planet Earth is the only place in the entire universe that can sustain over 100 million living species, including our ever-increasing human population, which is currently inching close to 6.8 billion. In order to ensure the longevity of our world, many countries are striving for a greener tomorrow, and the movement can be observed everywhere. Automobile manufacturers are rolling out their new lines of eco-friendly vehicles, while computer and cell phone companies are recycling components of their old electronics to make their newest products. Even the US government is making strides to create alternative forms of clean, low-cost renewable energy, including hydroelectricity, wind energy, and solar energy. It is becoming increasingly popular to install solar panels on the roofs of residential home for water heating and electricity generation. However, many people do not realize that advanced technology for harnessing solar energy commercially has actually been around since the mid-1980s.

Although there are several types of solar thermal energy systems currently in operation throughout the world (this includes power towers, dish systems, and Fresnel reflector plants, most prevalent among today's commercial solar power plants are parabolic trough systems. The first significant, and still largest, solar energy generating facility in the world is known as Solar Energy Generating Systems (SEGS). This facility was built during the 1980s, and is made up of nine different trough power plants. Located in the Mojave Desert, in the vicinity of Barstow, California, these plants have a total combined capacity of 354 megawatts (MW) and produce enough electricity to meet the energy needs of nearly 500,000 people.

Solar Around the World

While the United States houses the largest solar energy generating facility in the world with the Solar Energy Generating Systems (SEGS), there are other very significant solar thermal power stations located around the globe. Spain is emerging as a main player in solar technology, with numerous parabolic troughs currently under construction in several of its cities, including Seville and Badajoz. The Liddell Power Station Solar Steam Generator in New South Wales, Australia uses Fresnel reflector technology. The THEMIS solar power tower plant in France has been in operation since 1983, and was restored in 2004. Solar power towers in Jülich, Germany were completed as recently as late 2008. Other countries that have announced plans to construct solar plants include: Israel, Abu Dhabi UAE, Iran, Italy, India, and South Africa.

Trough Systems



Typical construction of a parabolic trough

Basically, trough systems convert heat given off the sun into electricity. Parabolic troughs consist of a long parabolic mirror (mostly silver coated/polished aluminum), and a Dewar tube running its length (see illustration below). A Dewar tube is designed with one tube contained inside another tube, and a vacuum space between them. This reduces heat transfer by conduction. For solar applications, both tubes are usually made of glass and coated in silver, to reduce heat loss caused by radiation. Sunlight is reflected by the mirror at several angles and directed on the tube. The parabolic design of the mirrors allows the troughs to focus the sunlight at 30 to 80 times its normal intensity on an absorbing receiver pipe located along the focal line of the trough. Heat transfer fluid captures this heat as it circulates through the pipe, reaching temperatures in ranges as high as 288-390°C (550-735ºF). The heated thermal hot oil is pumped to a generating station and sent through a series of shell-in tube heat exchangers to heat water and produce steam, which drives a Rankine steam turbine to generate electricity.

History of the Dewar Tube

More generally known as the vacuum flask, the Dewar tube was invented in 1892 by Scottish chemist and physicist Sir James Dewar to store liquefied gases. The same technology is used in a thermos, which people widely use to keep coffee and other beverages warm or cold.

For smaller applications (from 100kW to 10mW), an organic Ranking cycle is preferable. Instead of water, organic fluids, such as butane or pentane, allow for lower temperatures and pressures, and lower the associated costs of system components. Organic components also have the advantage of condensing at or above atmospheric pressures, eliminating the need for a vacuum in the condenser.

What is a Rankine cycle?

A Rankine cycle consists of 4 main stages, which converts heat energy to work energy. **Step 1**: the working fluid, in this case, water (or butane/ pentane) is pumped in liquid form from an area of low pressure to high pressure. **Step 2**: this pressurized fluid is heated (by absorbed energy from the sun) to become a vapor. **Step 3**: the heated vapor expands through a turbine, generating power. Subsequently, the vapor drops in temperature and pressure. **Step 4**: The vapor is sent to a condenser and becomes a saturated liquid, and the cycle is repeated.

The trough is usually lined up parallel to the north-south axis, and rotated to follow the sun as it moves across the sky every day. In addition to operating on solar energy, the SEGS plants are also configured as hybrids to operate on natural gas on cloudy days or after dark.

MicroCSP

One type of technology that is emerging is the Micro Concentrating Solar Power (MicroCSP) system. In contrast to traditional CSP systems, MicroCSP systems are built smaller (about ¼ of the size of desert troughs) and lighter and consequently generate smaller amounts of energy. The major advantage of these systems is cost-effectiveness. They cost a fraction of CSP or other systems.

MicroCSP field located at Keahole Point, Hawaii.

The Natural Energy Laboratory of Hawaii Authority, USA, inaugurated the first MicroCSP solar thermal power plant by Hawaiian manufacturer Sopogy, together with Keahole Solar Power LLC, consisting of 1,000 MicroCSP solar panels (see image). The project is named “Holaniku at Keahole Point” which comes from the Hawaiian term for a location that has everything required for self-sufficiency. Sopogy was founded in 2002 and pioneered the MicroCSP industry providing technologies that efficiently and cost-effectively generates electricity, steam, solar air conditioning and other thermal energy forms. A leader in MicroCSP development, their website explains that “Through the use of mirrors and optics and an integrated sun tracker, these panels achieve an efficiency of 20 to 40 %, which is much higher than the average efficiency of crystalline photovoltaic modules with about 15 %.” To date, Sopogy has 8 solar thermal energy facilities with MicroCSP technology in operation around the world.

MicroCSP systems are generally designed to operate at temperatures below 600°F. This allows usage of petroleum based thermal fluids (also known as “hot oils”), rather than more expensive, and usually hazardous, synthetic alternatives.

Heat Transfer Fluid Solution

Radco Industries, Inc. has engineered ***Xceltherm®600*** heat transfer fluid for such applications. It is a thermal fluid that is specially formulated and refined to be a non-toxic petroleum based oil that is ideal for solar applications that demand the optimum in purity and performance. It has superior heat transfer compared to other fluids in its class (data and product comparisons available upon request). Improved heat transfer efficiency reduces a system’s total energy requirements, and increases system longevity. The more efficient the heat transfer system is, the less energy that is required to maintain the bulk operating temperature of the fluid. There is an immediate depreciation of energy costs, and it also reduces the system’s environmental impact.

The purity of ***Xceltherm®600*** begins in its selection of raw materials and its two-cycle hydrogenation process. The raw materials of ***Xceltherm®600*** are severely hydrogenated to eliminate any contaminants that decrease heat transfer efficiency and thermal stability. Initially, raw mineral oils are a mixture of paraffins, napthenes, and other trace compounds. These trace compounds consist of sulfur, nitrogen and aromatic molecules that have remained from the initial distillation of petroleum oil.

Xceltherm®600 is hydrogenated in two cycles to ensure its purity and consistency of performance. The hydrogenation process uses pressurized hydrogen gas to saturate the raw mineral oil, resulting in the reduction of trace compounds. Petroleum based fluids used for heat transfer that undergo one cycle of hydrogenation have a small percentage of impurities in the mineral oil mixture. Applying a second, *more* severe hydrogenation process reduces the concentration of impurities. That increases thermal stability and heat transfer coefficient, the two most important characteristics of quality thermal fluid. During severe hydrogenation, a higher pressure of hydrogen gas is introduced to the fluid than in the first cycle. This reduces the impurities down to a less than 0.00005%. The final product is a true “white mineral oil” that is nontoxic, non-hazardous, and safe for incidental food contact.

Biodegradability of Heat Transfer Fluids

The Organisation for Economic Co-Operation and Development’s (OECD) Modified Strum Test, or OECD 301B, measures the *ready biodegradability* of oils.

The test measures the rate of degradation of an oil sample inoculated with bacteria over the course of 28 days.

- ***Persistent Biodegradable Oils***: 0% < 20. This means after 28 days, 0% to 20% of the oil sample biodegraded.
- ***Inherently Biodegradable Oils***: 20% < 60%. Highly refined, white mineral oils, including ***Xceltherm® 600***, are inherently biodegradable, and show an average percentage of biodegradability between 25% and 45%.
- ***Readily biodegradable Oils***: 60% < 100%. Most vegetable oils fall into this classification.

End users still need to adhere to their local and federal guidelines in the handling, and cleanup of any oil spills. Always read Material Safety and Datasheets.

Source: (Haus et al. 2004).

The high purity of ***Xceltherm®600*** also makes it “inherently biodegradable,” according to The Organisation for Economic Co-Operation and Development (OECD) guidelines. ***Xceltherm®600*** thermal fluid measures an average percentage for biodegradability of between 25% and 45%, observed over a 28 day test period.

High Temperature Systems

Large, high temperature parabolic solar systems use heat transfer fluids that are a eutectic mixture of 73% diphenyl-oxide and 27% biphenyl (DPO/BP). Currently, DPO/BP heat transfer fluids are the dominant choice for solar applications that have a maximum bulk operating temperature of 400°C (750°F) because it is relatively inexpensive and resists thermal degradation at the rated temperature.

Biphenyl is classified by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and Title 40 CFR Section 372 as a toxic and hazardous chemical. The reportable spill quantity of biphenyl is 45.4kg (100 pounds) – that is equivalent to 166.6 liters (44 gallons) of DPO/BP heat transfer fluid. For these systems, most of which have very large solar collection fields of many thousands of gallons, even small leaks or releases can negatively impact the environment. Furthermore, workers and personnel are at increased risk of biphenyl exposure. OHSA recommends biphenyl exposure to be limited to 0.5 ppm per year (see MSDS).

For solar applications that have a bulk operating temperature near 371°C (700°F), Radco manufactures a biphenyl free alternative to DPO/BP: ***Xceltherm®LV1***. It is diphenyl oxide based heat transfer fluid; however, it does not have biphenyl like DPO/BP. Instead ***Xceltherm®LV1*** is a patented mixture of diphenyl oxide and 1,1-diphenylethane (1,1-DPE). Another positive is that it has been demonstrated that 1,1-DPE is also biodegradable (Guatam and Suresh 2009).

Every other year, Chemical Processing magazine honors chemical industry innovations through the John C. Vaaler Awards program. The Vaaler Awards program is the chemical industry's only awards program judged by an independent panel of experts. Judges are asked to evaluate each entry on the significance of its contribution to the chemical industry, on its novelty or uniqueness. ***Xceltherm®LV1*** was given this award in 2003, giving Radco Industries national recognition for their unique contribution to environmental safety.

Radco Industries, Inc. is a chemical manufacturer that has been years ahead of the demand for products that are sustainable, more efficient, made with higher purity, are higher performing and better for the environment. ***Xceltherm®*** heat transfer fluids are ready today for a "greener tomorrow."

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