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HIGH TEMPERATURE STORAGE OF SOLAR ENERGY USING PHASE CHANGE MATERIALS

Most of the focus on generating electrical power from solar energy is on use of photovoltaic solar cells, which produce electricity when placed in sunlight. However, another way to generate electricity from the sun is to use mirrors to concentrate the sun's rays onto a high temperature heat exchanger which, in turn, makes steam for use in a steam cycle power plant. One of the major R&D needs for solar thermal power plants is development of cost effective technologies to store high temperature thermal energy during periods when sunlight isn't available. A Lehigh University research team led by Sudhakar Neti is developing phase change thermal storage systems for use in this application.

Neti and four other Lehigh faculty researchers have funding from the U.S. Department of Energy (DOE) to study materials which change phase from solid to liquid and then back to solid in the right range of temperatures to be compatible with a solar thermal power plant. Besides Neti, the group includes Wojciech Misiolek, from Materials Science and Engineering; Alparslan Oztekin, from Mechanical Engineering and Mechanics; and Kemal Tuzla and John Chen, from Chemical Engineering.

Two energy storage technologies now used at some facilities involve pumping of compressed air into underground caverns and use of insulated tanks filled with molten salt. But neither is well suited for economically storing solar thermal energy. Neti's group believes encapsulated phase-change materials(EPCMs) offer a more promising alternative. EPCMs can be designed to have high melting points with constant temperature during a phase change. Materials undergoing phase changes are capable of storing and releasing large quantities of thermal energy as they change from solid to liquid and vice versa.

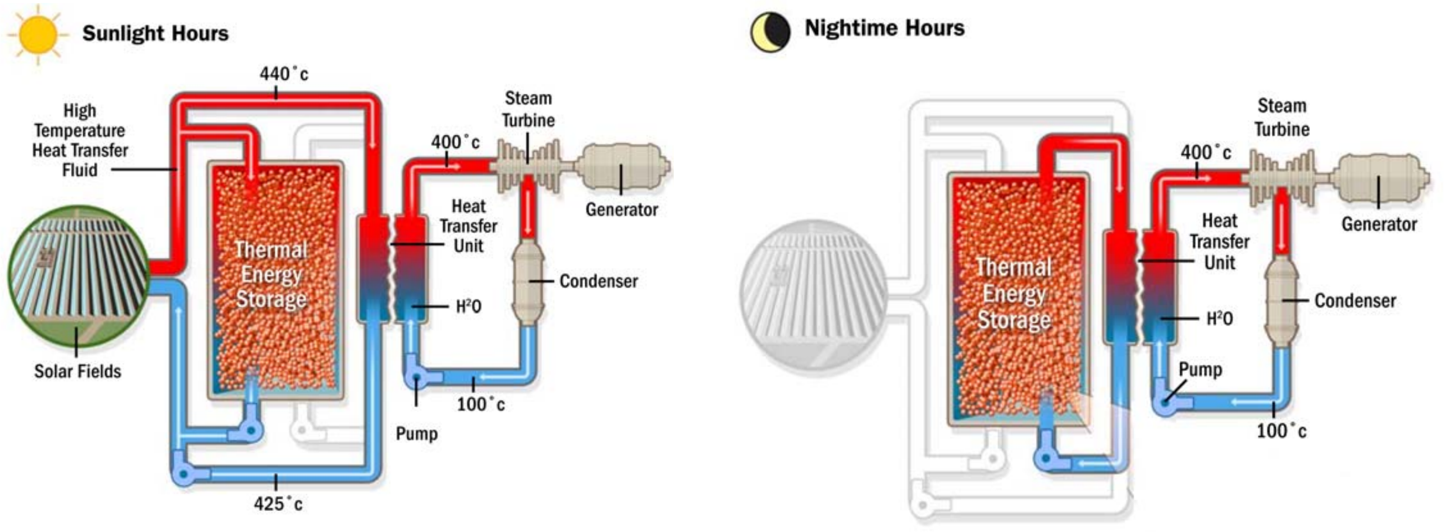
"In a solar thermal plant," says Neti, "the heat transfer fluid is heated by solar collectors to 400-450°C. We looked for materials that change phase in this temperature range and we settled on zinc as one possibility." It is safe and nontoxic and it has a melting point of 420°C, which is very good for our purposes. We are also investigating eutectic salt mixtures for this application.

With our approach, the zinc phase change material is contained within a small spherical or cylindrical capsule made of appropriate encapsulating material. The encapsulation, with a significantly higher melting point than the phase change material (PCM), will maintain its integrity, acting as a shield while the PCM changes phase, thus preserving the PCM's very good heat-transfer and phase change qualities."

Over the last year, the Lehigh team conducted laboratory-scale experiments to study the melting-solidification cycle which the encapsulated zinc capsule undergoes, with emphasis on corrosion, stability of the zinc, and stresses on the encapsulation coating under repeated cycles of heating and cooling.

"Encapsulated zinc pellets could conceivably store and release thermal energy indefinitely," says Misiolek, "but there are a number of questions must be answered, such as:

What is the optimal size of the pellets? Which size enables the most uniform



One Possible Configuration of a Solar Thermal Power Plant with Thermal Energy Storage. The Two Diagrams Show Daytime and Nighttime Operations.

heating? What is the optimal ratio of PCM and encapsulation? What type of thermal storage vessel would it be best to use? What is the optimal thickness of the encapsulation?"

"There are also other challenges such as how to fabricate the zinc pellets cheaply and how best to coat the zinc," says Misiolek, whose former graduate student Suradej Lorcharoensery successfully coated microparticles of iron with nickel several years ago as part of his doctoral dissertation.

Neti's team has performed theoretical analyses to model the heat transfer and phase change processes within individual capsules during melting and solidification, and the results suggest use of cylindrical capsules with diameters ranging from 25 to 75 mm would be best. Other analyses looked at a system of capsules within a large tank with hot and then cold fluid circulating through the bed of capsules during the melting/solidification cycle.

The Lehigh team is now in the process of fabricating a 2 ft diameter x 3 ft long tank which will be filled with EPCM storage capsules. During the thermal storage portion of the cycle, air at temperatures above 500°C will flow into the tank and be cooled by heat transfer to the capsules. During thermal discharge, the stored heat will be transferred from the capsules to cool air circulating through the tank.

After completing testing of the laboratory-scale packed bed reactor, Neti's group plans to design and build a pilot-scale thermal energy storage system for installation and testing at an existing solar thermal power plant. This would make it possible to characterize the thermal response of the storage system to hourly and daily changes in captured sunlight.

"The future of solar energy will depend in large part on cost and availability," says Neti. "And this will require novel heat-transfer methods as well as new materials that enable solar facilities to store energy long enough so power can be generated on cloudy days and at night."

"We do not yet have the means of storing energy to make solar energy viable on a large scale," says Neti. "Even in places like Arizona where sunshine is abundant, we need thermal storage for the night. We are optimistic that our encapsulated phase change materials approach will provide a very good solution for this problem." ■

(This article was adapted from an article in Resolve, Lehigh University, Vol. 1, 2010)

RESEARCHERS' PROFILES

- ***John Chen*** is a Professor Emeritus of Chemical Engineering. His research emphasizes the fundamentals of heat transfer and two-phase flow processes occurring within energy systems.
- ***Edward Levy*** is Professor of Mechanical Engineering and Mechanics and Director of the Energy Research Center. His research deals with emissions control and performance improvement in coal-fired power plants.
- ***Wojciech Misiolek*** is a Professor of Materials Science and Engineering. His research deals with metal forming and mechanical properties of materials.
- ***Sudhakar Neti*** is a Professor of Mechanical Engineering and Mechanics with a specialty in heat transfer and fluid mechanics. His research focuses on application of the thermal fluids area to renewable energy systems.
- ***Alparslan Oztekin*** is an Associate Professor of Mechanical Engineering and Mechanics with a specialty in computational heat transfer and fluid mechanics. His research focuses on computational modeling of fluid flow and heat transfer phenomena in energy systems.
- ***Carlos Romero*** is a Principal Research Scientist and Associate Director of the Energy Research Center. He is a specialist in combustion kinetics and emissions control.
- ***Nenad Sarunac*** is a Principal Research Scientist and Associate Director of the Energy Research Center. His research focuses on power plant heat rate improvement, emissions control and process optimization.
- ***Kemal Tuzla*** is a Professor of Practice in Chemical Engineering with a specialty in heat transfer.
- ***Zheng Yao*** is a Research Scientist in the Energy Research Center. His research responsibilities include development of coal drying systems.