Collector/Receiver Characterization

The National Renewable Energy Laboratory (NREL) tests the performance of concentrating solar power (CSP) system components—often while plants remain in operation—to determine durability, performance, and heat loss as well as to identify potential enhancements. Our work falls primarily within the following five capabilities.

Determining Optical Efficiency

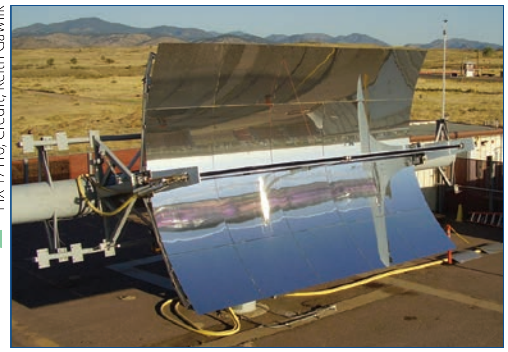
At our outdoor Solar Concentrator Optical Efficiency Test Loop, we determine the optical efficiency of a parabolic trough by comparing the direct solar radiation falling on the trough aperture operating near ambient temperature to the thermal energy collected by the fluid flowing through the receiver tube.

A parabolic trough, up to 16 meters long, is mounted on a two-axis tracker that points directly at the sun throughout the day. The trough's receiver is connected via flexible lines to a closed-loop system that maintains the fluid at specified temperatures and cools the fluid after it passes through the receiver tube. A water-based coolant, at near-ambient temperature and low pressure, is pumped to the receiver. Because heat loss is extremely low, optical efficiency can be determined independent of thermal efficiency. Both are needed to determine the overall efficiency of a parabolic trough, but thermal efficiency is calculated separately (see Measuring Heat Loss).

Our researchers test commercial collectors and identify where performance gains can be made, allowing designers of new collectors to improve their products before production. Contact Chuck Kutscher, Chuck.Kutscher@nrel.gov, 303-384-7521.

PIX 17117; Credit, Frank Burkholder

In our Receiver Test Laboratory, a receiver for a solar collector is mounted on this Heat-Loss Test Stand and tested for heat loss at temperatures between 100° and 500°C. Results can show the impact of reduced heat loss on both the cost of electricity and amount of electricity produced by a solar plant.



PIX 17116; Credit, Keith Gawlik

A parabolic trough is mounted on a two-axis tracker at our Solar Concentrator Optical Efficiency Test Loop. As the trough tracks the sun, we can determine its optical efficiency.

Measuring Heat Loss

Our Receiver Test Laboratory measures heat loss in the receiver tubes of parabolic trough collectors. Heat loss results can be combined with collector optical efficiency tests (see Determining Optical Efficiency) to create an overall collector efficiency curve.

Testing takes place indoors under controlled conditions. A receiver is mounted on the Heat-Loss Test Stand, and electric heaters are placed inside the receiver to heat the absorber tube to desired test temperatures. Currently, testing occurs between 100° and 500°C and requires one to two weeks.

We work in partnership with private companies to test their latest receiver designs. Entering the results into the Solar Advisor Model, we can determine the effect that the reduced heat loss of a new receiver tube would have on a solar plant's levelized cost of electricity. For example, annual, hourly simulations of one recently-tested design showed that its reduction in heat loss—compared to the previous mode—would reduce the cost of electricity by half a cent per kilowatt-hour and would increase annual electricity production by 5%. Contact Frank Burkholder, Frank.Burkholder@nrel.gov, 303-384-7564.

Developing and Testing Concentrators

Researchers at our Concentrator Optical Measurements Laboratory develop and test concentrators for concentrating

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solar power systems. The Video Scanning Hartmann Optical Test (VSHOT) characterizes the optical performance of both point-focus and line-focus optical concentrators.

VSHOT, which can be used both in laboratory and field settings, combines laser ray tracing with fast video imaging to mathematically describe the mirror concentrator surface and determine the deviation from the desired surface. It reports slope errors and provides plots of error location, magnitude, and direction. VSHOT testing of a new, commercial parabolic trough collector led to significant design improvements and helped garner an R&D 100 Award from *R&D Magazine*, which NREL shared with the manufacturer.

PIX 17033; Credit, Allison Gray

The Video Scanning Hartmann Optical Test (VSHOT) is conducted on a parabolic trough concentrator at NREL's Concentrator Optical Characterization Laboratory.

We use the Receiver Infrared Imaging System (RIIS) in the field to locate and document unacceptable heat losses of receivers in operating parabolic trough plants. The RIIS consists of a vehicle equipped with an infrared camera and a Global Positioning Satellite (GPS) system. As the vehicle is driven down each row of a solar field, a computer-controlled data acquisition system uses the camera to identify, photograph, and process the receiver glass temperatures. One operator can determine the glass temperatures of about 6,000 receivers in a single day. Contact Tim Wendelin, Tim.Wendelin@nrel.gov, 303-384-7475.

Concentrating the Sun's Power

At our Concentrated Solar Radiation Facility, the High-Flux Solar Furnace (HFSF) and the Ultra-Accelerated Weathering System (UAWS) concentrate the power of the sun to test the durability of materials and coatings, conduct high-temperature experiments, and demonstrate the potential of solar power in industrial processes.

In operation since 1990, our 10-kilowatt High-Flux Solar Furnace can quickly generate up to 1,800°C over an area of 1 cm^2—3,000°C with a secondary concentrator—and can create heat equal to the intensity of more than 20,000 suns. Used in myriad research applications, it is ideal for high-temperature processes. The furnace is also a clean, lower-cost alternative to laser and electric furnaces used in industry.

PIX 06975; Credit, Warren Gretz

At our High-Flux Solar Furnace, a heliostat redirects sunlight onto the primary concentrator, shown here, which focuses the light to a point inside our test facility, part of the Concentrated Solar Radiation User Facility. The furnace can generate temperatures that exceed the intensity of 20,000 suns.

The UAWS, a winner of an R&D 100 Award, is an ultraviolet (UV) concentrator that can simulate 10 years of UV damage in just two months. It uses a parabolic dish with special mirror facets to concentrate and focus the sun's UV rays to simulate aging on a wide variety of surfaces, from automotive paint and building materials to coatings on solar panels. Contact Judy Netter, Judy.Netter@nrel.gov, 303-384-6258 (HFSF); Matthew Gray, Matthew.Gray@nrel.gov, 303-384-3917 (UAWS).

Taking a Step Forward in Optical Characterization

Our prototype Distant Observer (DO) tool is a dramatic step forward in the optical characterization of CSP plants. When operational, the DO will be able to rapidly characterize a single module and, in the future, survey a large parabolic trough field in less than four hours, identifying collector and/or receiver misalignments, mirror slope errors, and tracking errors while the collector field remains online. An improvement of 1% in optical efficiency is worth about $600,000 in annual revenue for a typical CSP plant.

Among the important advantages of the DO are its speed and its ability to characterize collectors in operational orientations. Our technique uses an aerial platform (such as an aerostat or remote-controlled plane) deployed above a trough field. The aerial platform incorporates a high-resolution (16 megapixel) optical camera, which can be operated by just one person on the ground. Once problem areas are pinpointed, they can be revisited for more quantitative analyses. Contact Gary Jorgensen, Gary.Jorgensen@nrel.gov, 303-384-6113.

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NREL/FS-550-48659 • August 2010