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High heat flux engineering in solar energy applications[1]

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ABSTRACT

Solar thermal energy systems can produce heat fluxes in excess of 10,000 kW/m^2. This paper will provide an introduction to the solar concentrators that produce high heat flux, the receivers that convert the flux into usable thermal energy, and the instrumentation systems used to measure flux in the solar environment. References are incorporated to direct the reader to detailed technical information.

1. INTRODUCTION

Solar thermal energy systems collect the thermal energy of the sun for direct use, to drive a chemical process, or for conversion to mechanical or electrical energy. The systems of interest for the purpose of this paper are those which use mirrors to concentrate the sunlight to high levels. The United States Department of Energy supports research in concentrated solar thermal energy through two programs. The Solar Thermal Electric program emphasizes conversion of the solar thermal energy to electricity and also includes applications that displace use of electricity. Sandia National Laboratories in Albuquerque is the lead laboratory for the electric program. The Solar Industrial Program deals both with processes that use the thermal energy directly and with processes that use the thermal or photolytic energy of the sun to drive chemical processes. The National Renewable Energy Laboratory in Golden, Colorado, is the lead laboratory for the industrial program; however, both laboratories support both programs.

2. SOLAR THERMAL ENERGY SYSTEMS

Sunlight is divided into two components: direct and diffuse. The nominal strength of direct component, measured in a plane normal to the sun's rays, is 1 kW/m^2. To achieve higher flux levels for solar energy applications, three types of solar concentrators are commonly used, as shown in figure 1. Each uses an automatic tracking system to follow the sun's position.

Parabolic troughs typically track the sun in one axis, and focus the sunlight on a linear receiver. Maximum flux levels for parabolic troughs are ~100 kW/m^2. Heliostats are nearly-flat, two-axis tracking mirrors used in groups to concentrate sunlight onto a stationary receiver located on top of a tower. Peak flux levels achieved for heliostat fields are as high as 3,000 kW/m^2. Parabolic dishes also track the sun in two axes; however, the receiver is attached to and moves with the concentrator. As a result these systems achieve the highest flux levels, up to 15,000 kW/m^2. A fourth system type, the solar furnace, is primarily used for research. Solar furnaces use a flat, tracking heliostat to reflect the incident sunlight into a stationary dish.

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