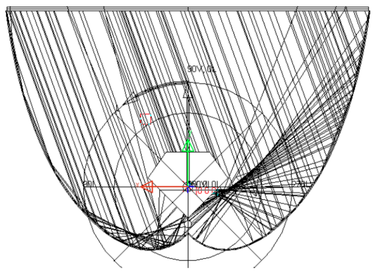
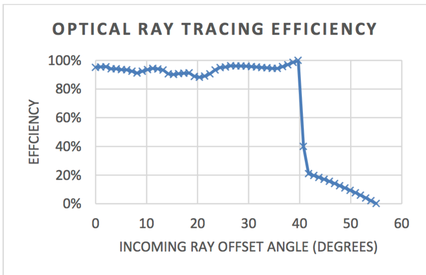
Mid-Temperature Thermal XCPC

Jordyn Brinkley, Kaycee Chang, Bennett Widyolar, Lun Jiang, Roland Winston
University of California, Merced: School of Engineering; 5200 North Lake Road Merced, CA 95343

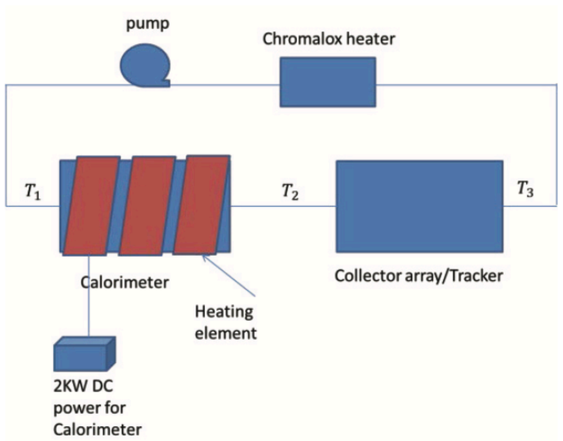
Pentagonal Absorber Shape

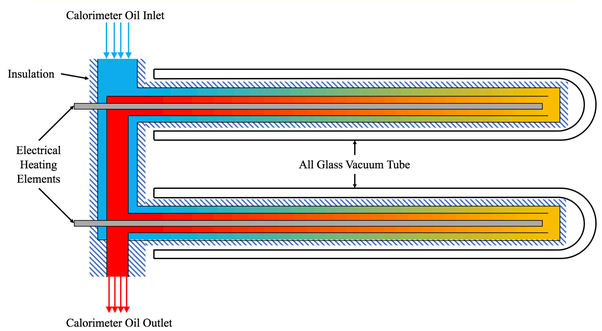




The pentagonal shaped receiver shows to be the most effective for heat transfer and collector design. For absorbers, the main issues lie in manufacturing. Although a round absorber may prove to have higher efficiency, manufacturing round absorber is extremely difficult and non cost effective. Therefore, the pentagonal shaped receiver was developed to compete with the round absorber.

Mineral Oil Test Loop Design





$$Q_{collector} = \dot{m}\, C_p (T_2 - T_3) = \dot{m}\, C_p \Delta T_{collector}$$

$$Q_{calorimeter} = \dot{m}\, C_p (T_1 - T_2) = \dot{m}\, C_p \Delta T_{calorimeter}$$

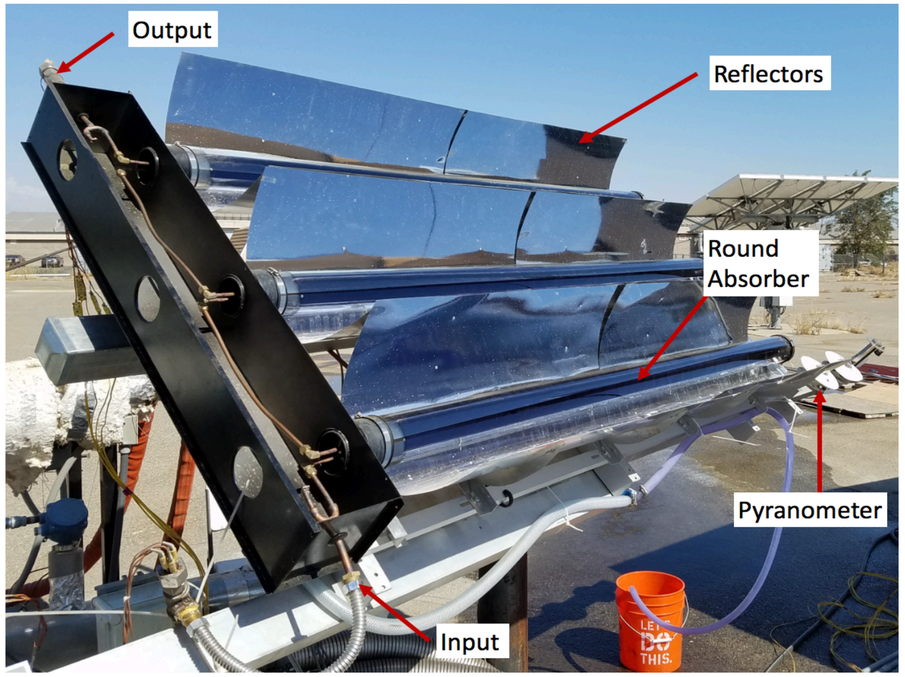
$$Q_{collector} = \frac{\Delta T_{collector}}{\Delta T_{calorimeter}} \cdot V_{cal} \cdot I_{cal}$$

External Compound Parabolic Concentrators

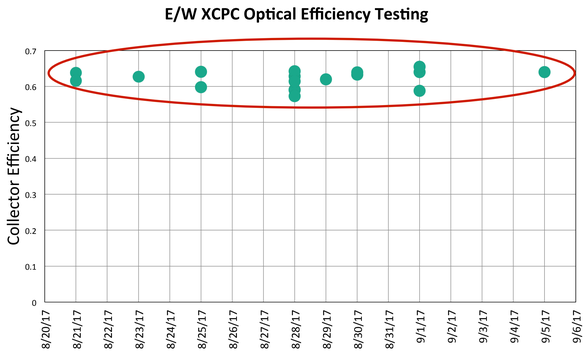
Dr. Winston has designed an innovative low-cost, mid temperature, non-tracking solar thermal collector system called the External Compound Parabolic Concentrator (XCPC). The XCPC was designed to efficiently heat fluid between a 100°C - 300°C range. The system consists of a series of evacuated solar thermal absorbers paired with wide-angle, non-imaging reflectors that gather and concentrate both direct and indirect sunlight. The XCPC has fewer moving parts than tracking systems, making it easier to install and maintain, and its lightweight design enables it to be mounted on rooftops. The XCPC also performs well in diffuse conditions, where tracking systems produce little heat. Applications of XCPC's include food processing, absorptive chilling, boiler preheating, desalination, and more. XCPC's prove to provide the highest efficiencies of solar thermal technology.

Mid-Temperature XCPC Thermal Testing

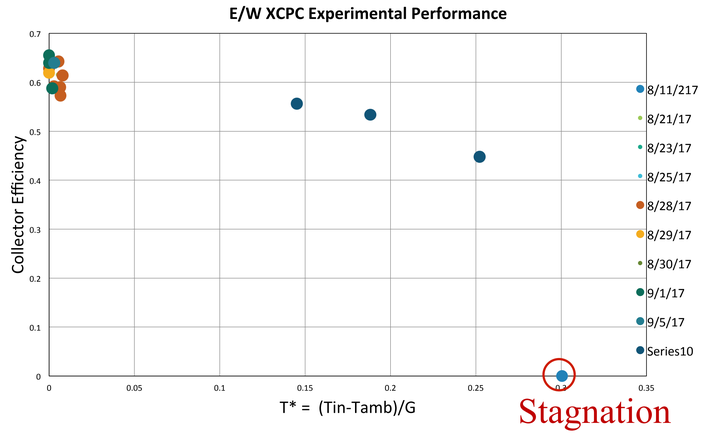
The XCPC used in these experiments have a pentagonal shaped receiver(shown on the left). To test the optical and thermal efficiencies, water and mineral oil were used as the heat transfer fluids. Since the heat capacity is unknown for mineral oil, a calorimeter is used in the loop in order to calculate it. The oil loop for testing consisted of a heater, pump, collector array, and calorimeter shown to the left. The calorimeter verifies the heat capacity of the oil, and eliminates the need of a flow meter. By calculating the calorimeter's energy input through current and voltage, we find the efficiency of the XCPC is the ratio of the temperature changes of the collector over the calorimeter. Through water testing, the XCPC's showed optical efficiency around 60%. The lowest being high fifties. The thermal efficiencies in the system show best results when T*=0, with around 60% efficiency. As T* increases the efficiency decreases due to the increasing inlet temperature, and decreasing global irradiance. The XCPC array stagnates around 320°, with almost zero efficiency. This is the mid-temperature limitation to the XCPC.
Possible errors can be the deformation of the reflectors shape over time. This can be solved by adding ridged to the frame to hold the shape.



Results



60-70% Optical Efficiency



Stagnation