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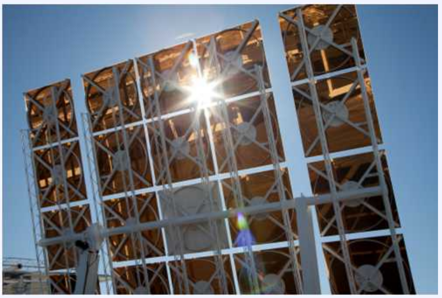

Novel Tubular Receiver Panel Configurations for Increased Efficiency of High-Temperature Solar Receivers

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SAND2015-XXXX

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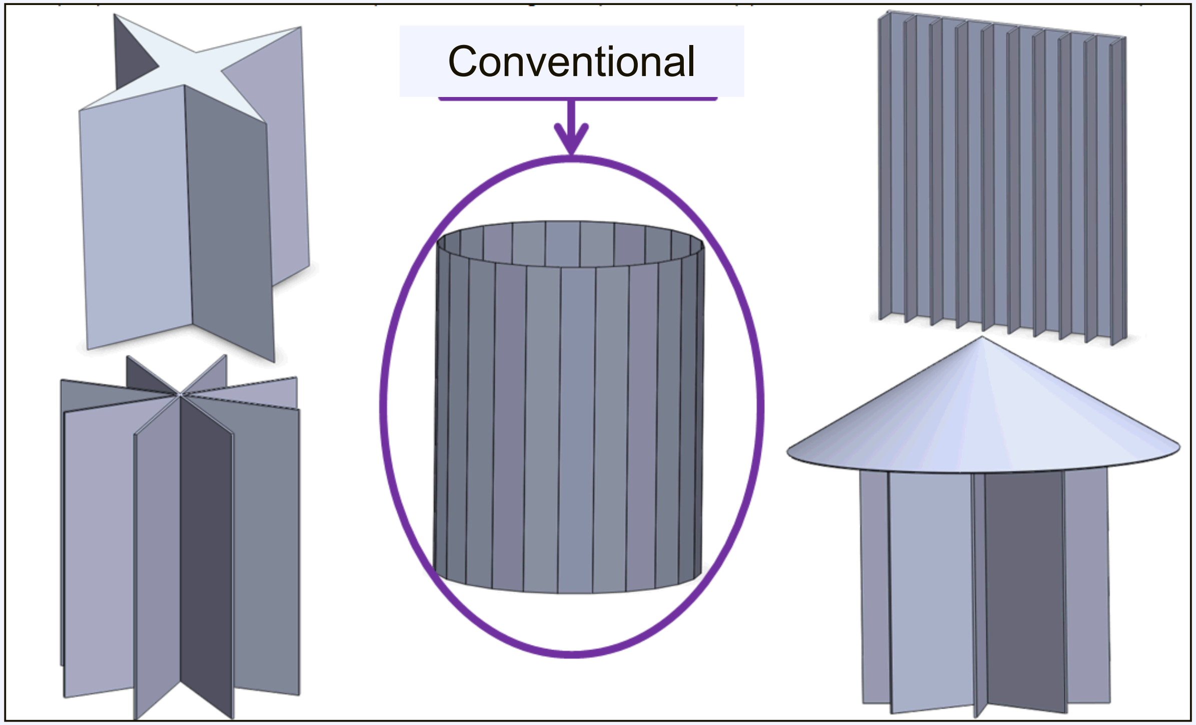
Presentation Overview

- Introduction and Objectives
- Approach
- Results
- Conclusions

Introduction

- Current receiver designs reflect and emit solar and thermal radiation to the environment
- Incident and emitted radiation can be "trapped" with new geometries

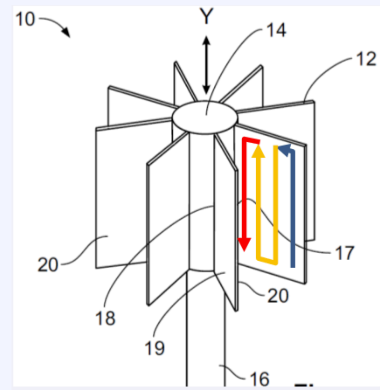


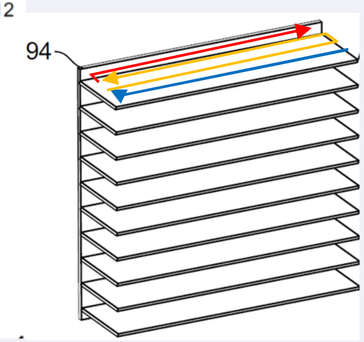
110 MW Crescent Dunes Plant
Tonopah, NV

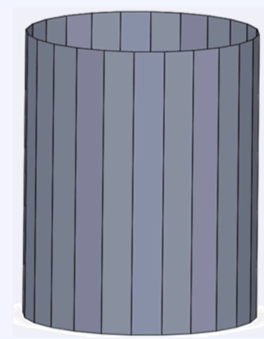
390 MW Ivanpah Solar Electric Generating System

Objectives

- Increase thermal efficiency of external receivers
  1. Increase the **light trapping** and effective solar absorptance
  2. Reduce the thermal emittance by **reducing local view factors in the hottest regions**
  3. Reduce heat losses by **increasing the concentration ratio** and reducing the overall footprint and aperture size







- Objective 3 is the focus of this work

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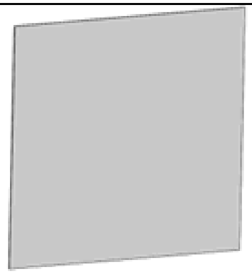
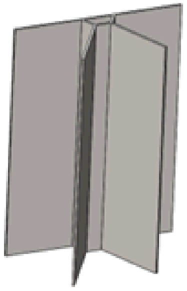
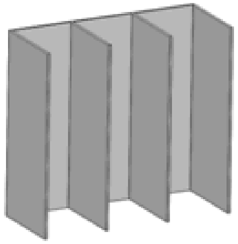
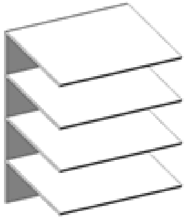
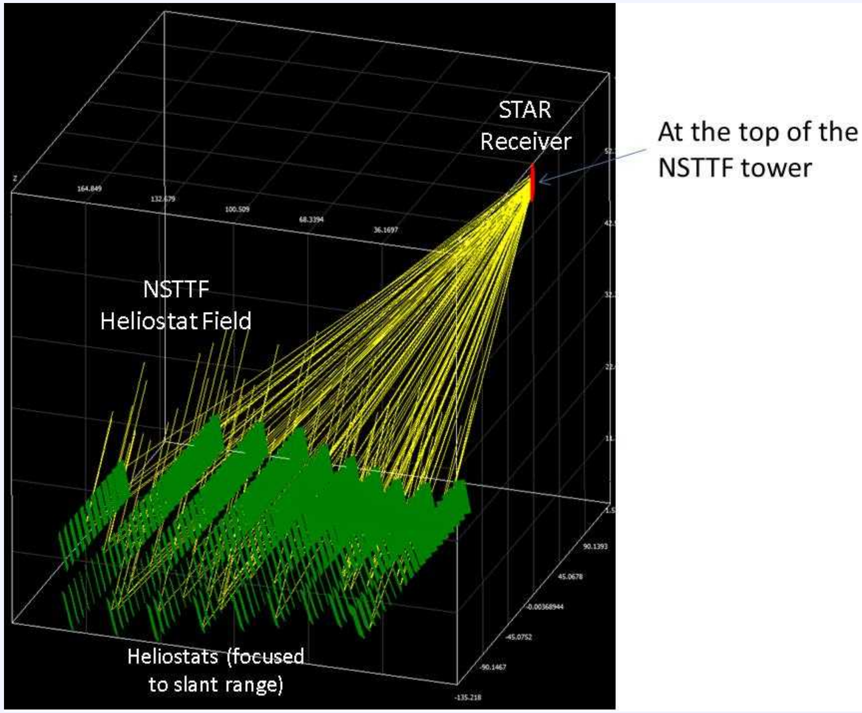
Receiver Designs

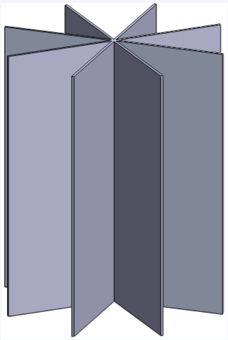
Base Case Study-Flat Plate Receiver; Height = 2 m; Width = 2 m; Exposed Surface Area = $4m^2$	
Radial Finned Receiver; Height = 1.5 m; Width = 1 m; Exposed Surface Area = $4m^2$; Fin length = 0.4 m	
Linear Vertical Fin Receiver; Height = 0.95 m; Width = 1 m; Exposed Surface Area = $4m^2$; Fin length = 0.4 m	
Horizontal Slate Fin Receiver; Height = 0.84 m; Width = 1 m; Exposed Surface Area = $4m^2$; Fin length = 0.4 m	

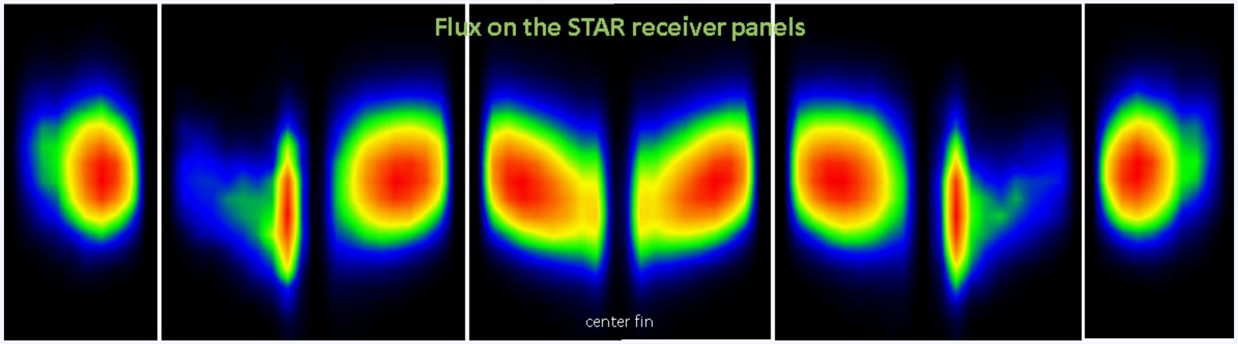
Modeling

1. Ray trace model (SolTrace) used to predict flux patterns on receivers using NSTTF heliostat field

2. CFD (FLUENT) utilized to predict thermal efficiency of receiver designs

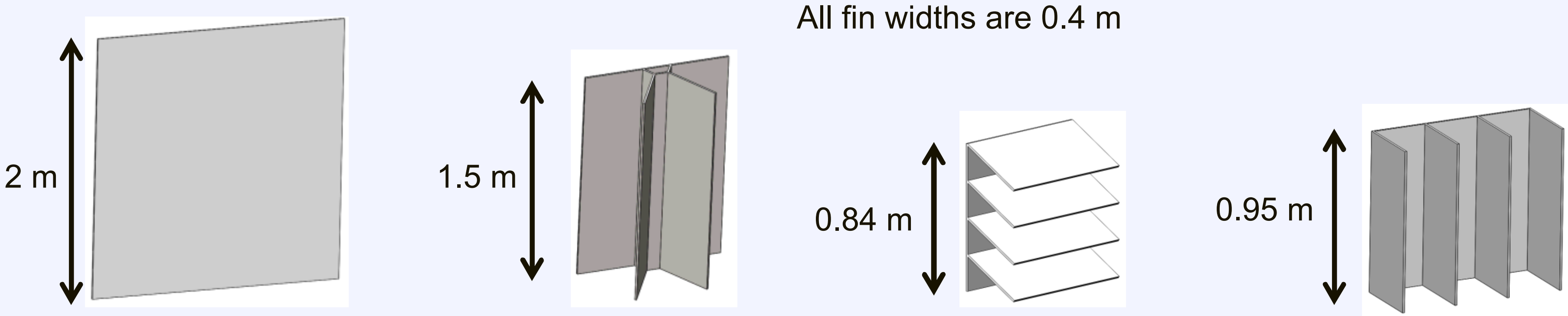






Assumptions

- Receiver surface areas are identical (dimensions differ)
- 2 MW incident power
  - Uniform flux
  - Ray trace distributed flux (single and multiple aim points)
- 600 C internal temperature
- Natural convection and radiation losses considered

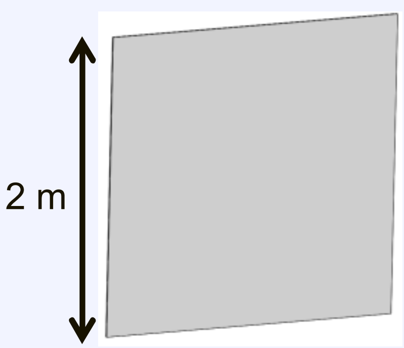


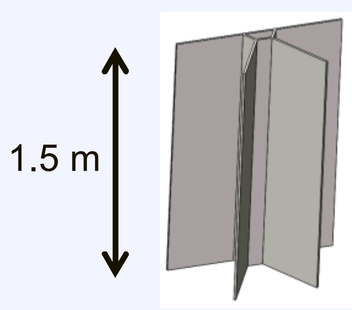
Modeling Parameters

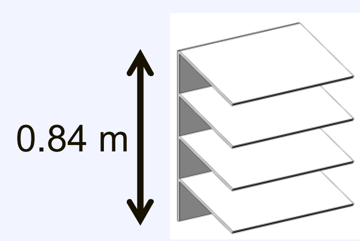
- Ray Trace
  - Concentrated flux from NSTTF heliostat field
    - Solar noon, equinox
  - Reflectivity = 0.04
    - Re-reflections considered
  - 2 MWt incident power

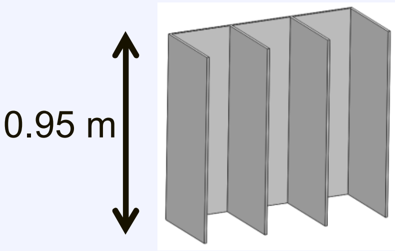
- CFD
  - Wall thickness = 3.2 mm
  - Internal temperature = 600°C
  - Haynes 230 material properties
  - Discrete Ordinates radiation model
  - k-ω SST turbulence model

All fin widths are 0.4 m









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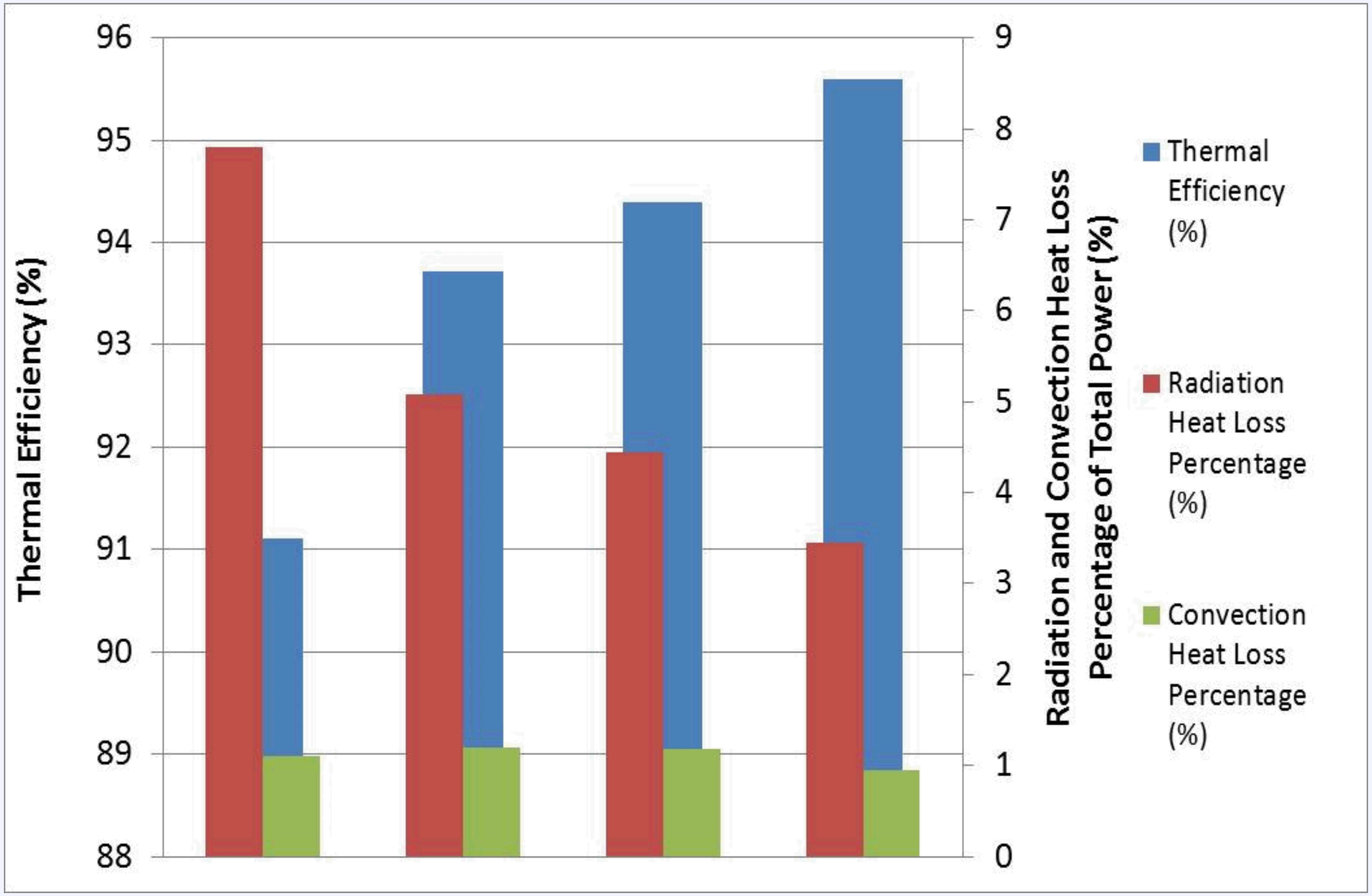
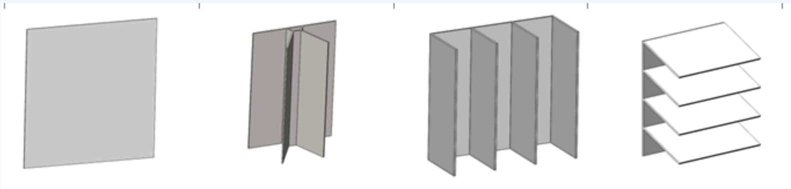
Uniform Flux Results

- Uniform flux = 500 kW/m^2 for all receiver models



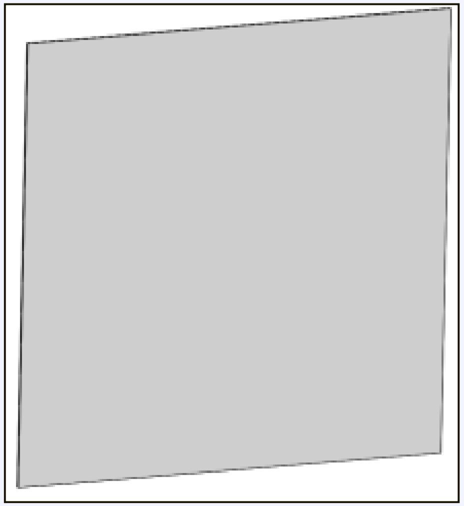


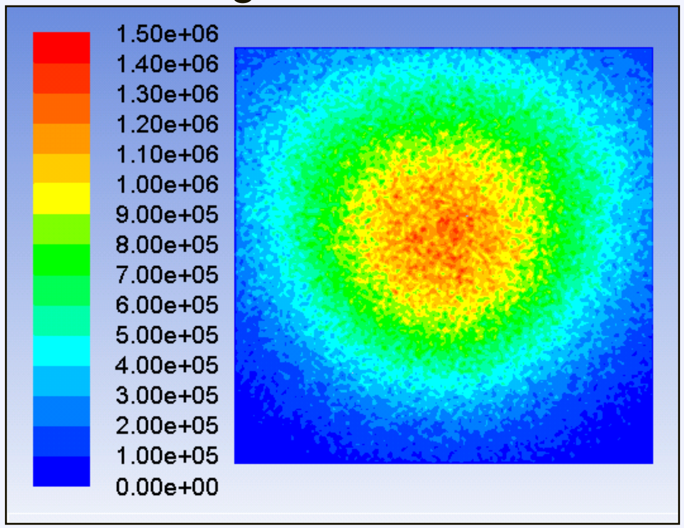
$$\eta = \frac{Q_{in} - Q_{radiation} - Q_{convection}}{Q_{in}}$$

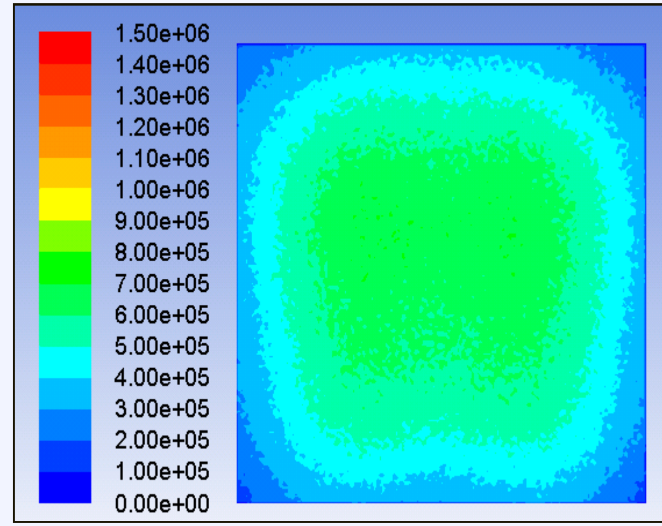
Distributed Flux Results: Flux Distributions

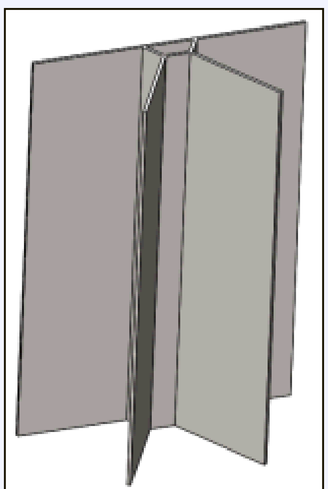
Single Aim Point

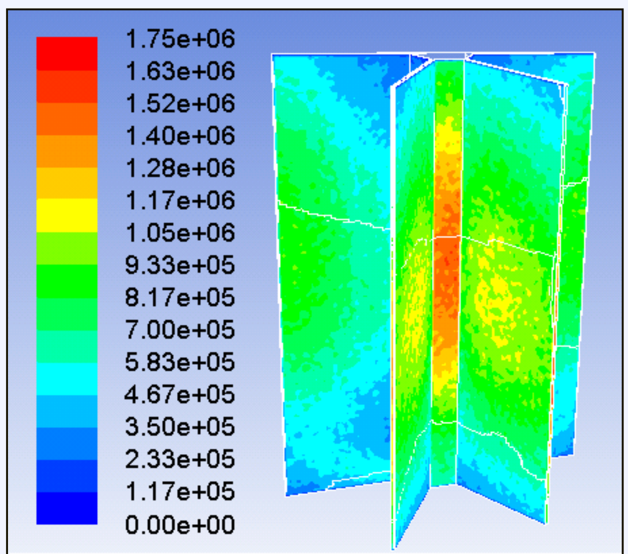
Four Aim Points

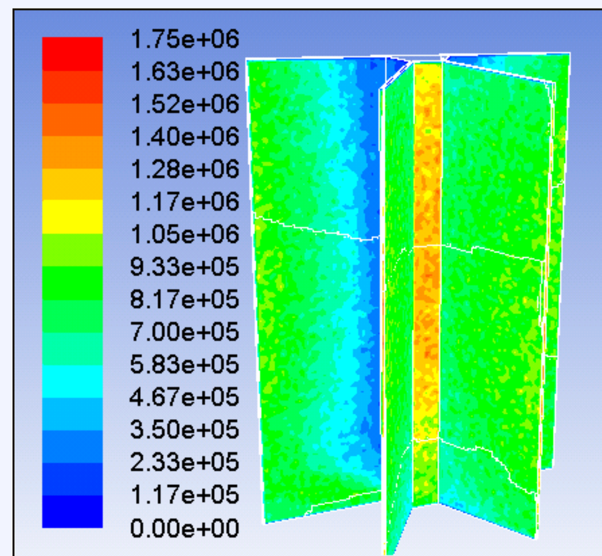








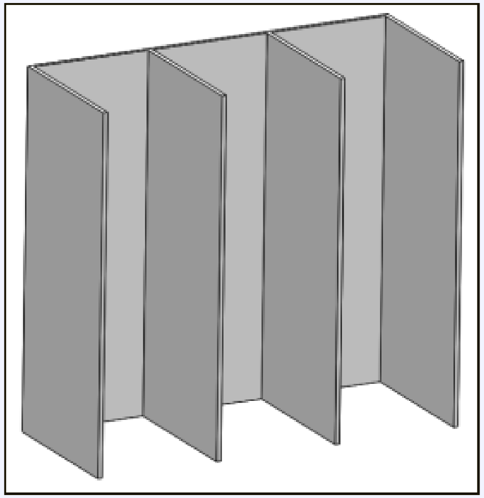


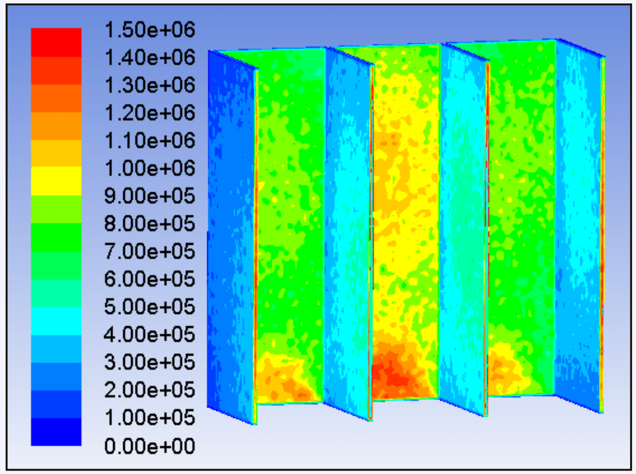


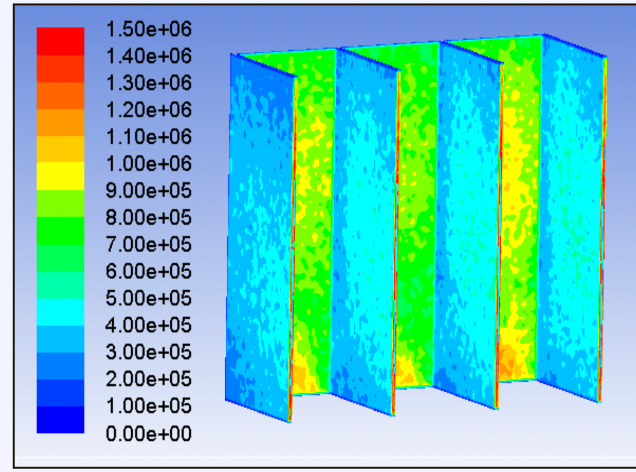
Distributed Flux Results: Flux Distributions

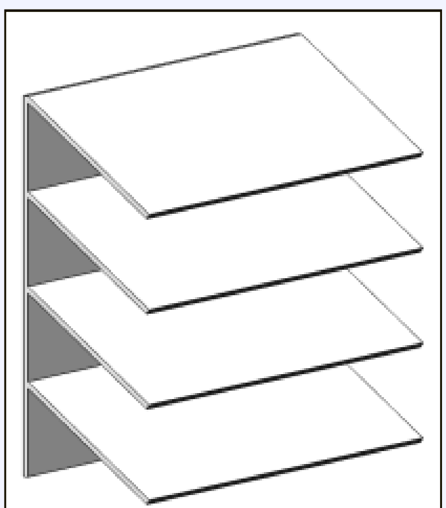
Single Aim Point

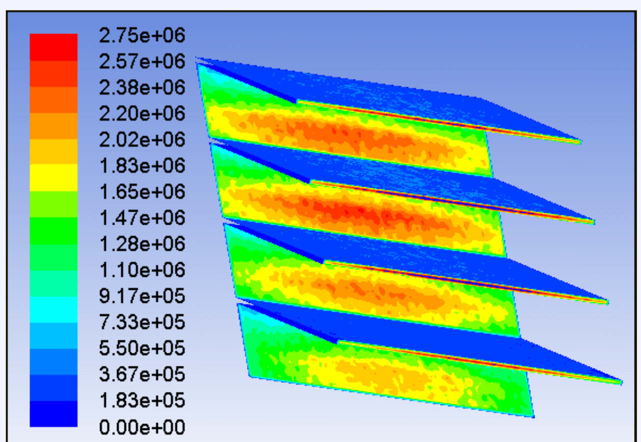
Four Aim Points

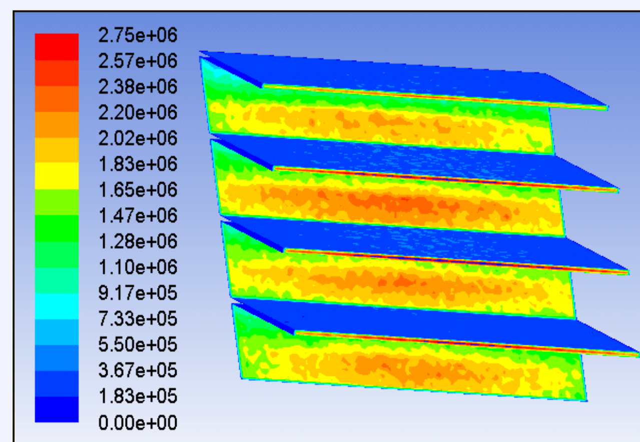




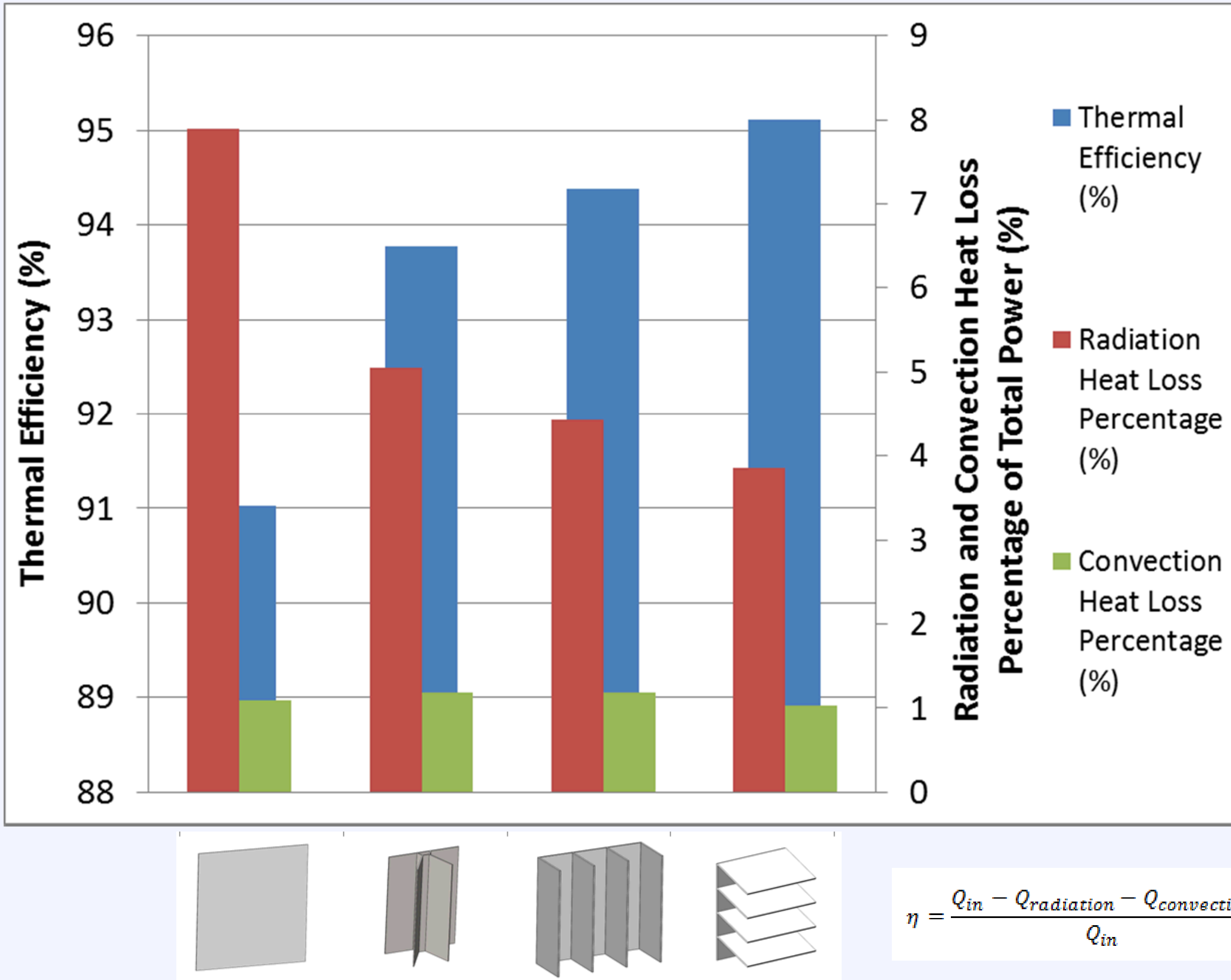






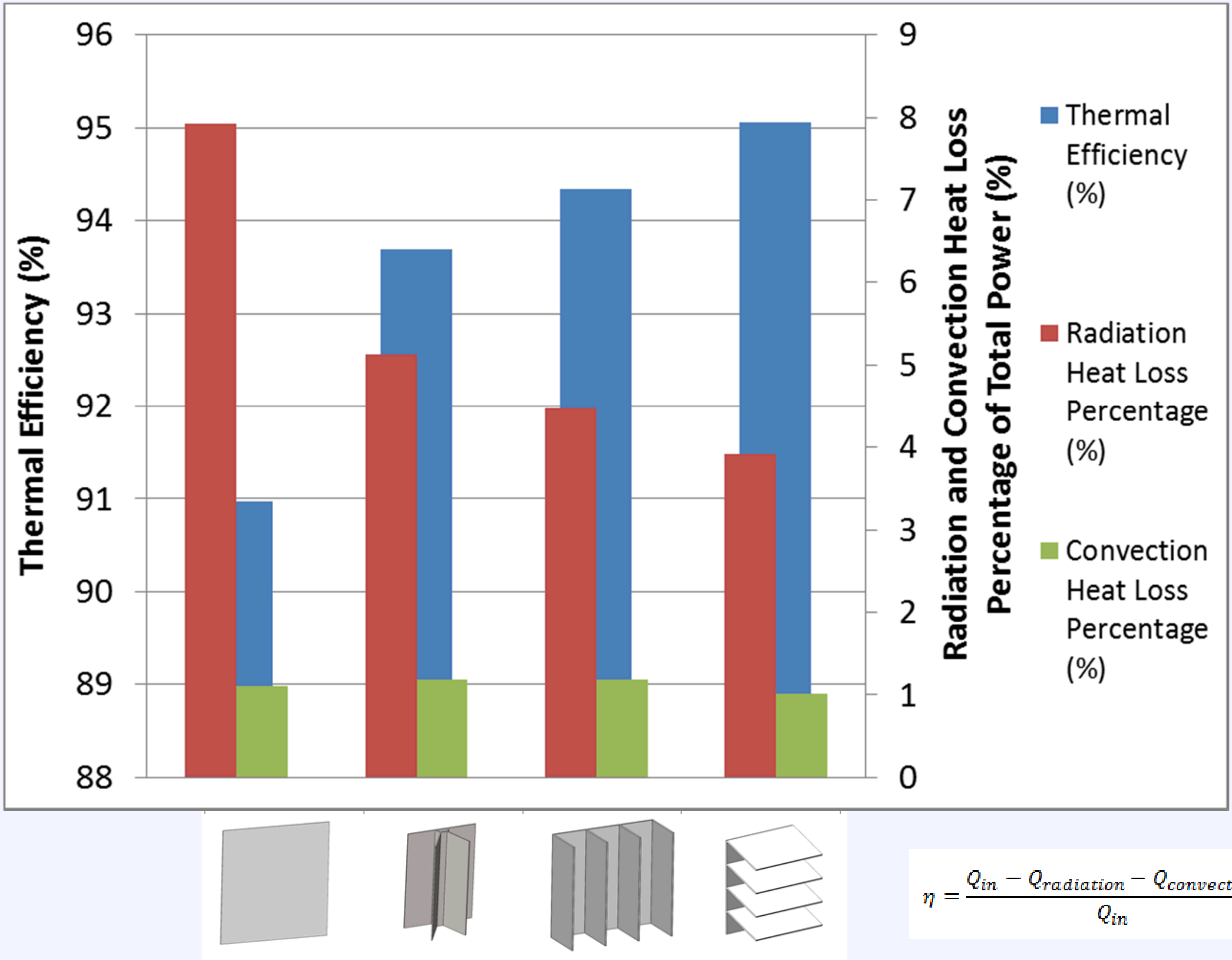


Distributed Flux Thermal Efficiency: Single Aim Point



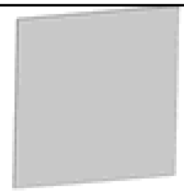
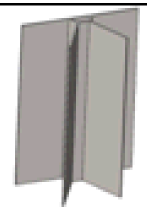
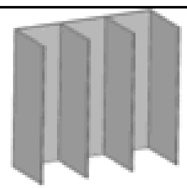
$$\eta = \frac{Q_{in} - Q_{radiation} - Q_{convection}}{Q_{in}}$$

Distributed Flux Thermal Efficiency: Four Aim Points



$$\eta = \frac{Q_{in} - Q_{radiation} - Q_{convection}}{Q_{in}}$$

Receiver Front Surface Temperatures (K)

Geometry	Max. Temp. (K) Uniform Flux	Max. Temp. (K) Single Aim Point Flux	Average Temp. (K) Uniform Flux	Average Temp. (K) Single Aim Point Flux
	943.0	1048.7	941.1	939.8
	990.0	1197.7	939.7	938.9
	990.5	1257.2	944.6	945.4
	991.6	1469.6	945.6	943.5

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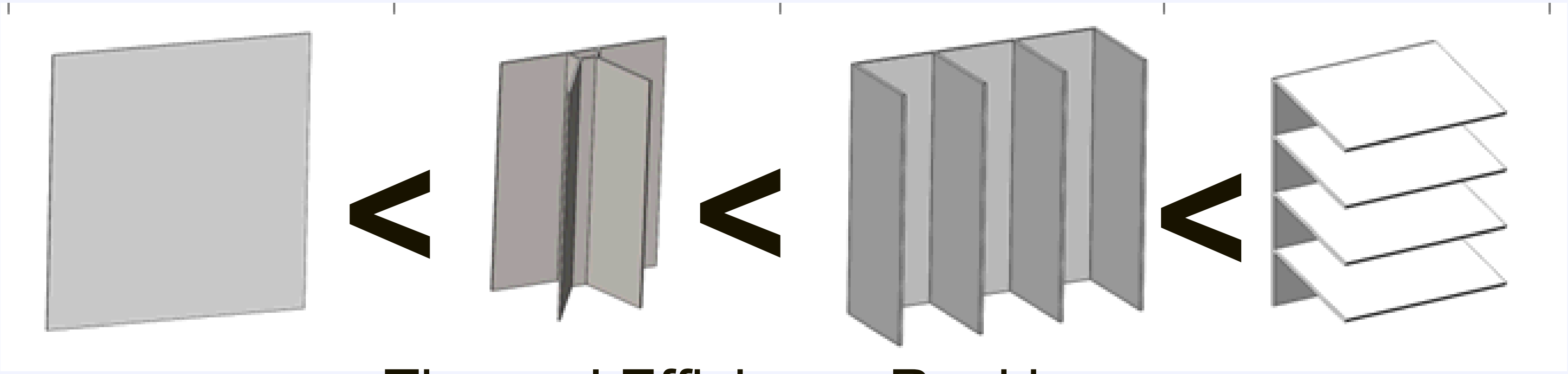
Conclusions

- Horizontal slate fin receiver had the highest thermal efficiency of 95.5% (4.5% increase over flat plate)
- Maximum wall temperatures for distributed flux models need to be addressed (hottest regions at tips of fins)
- Need to perform structural and modal analyses



Thermal Efficiency Ranking