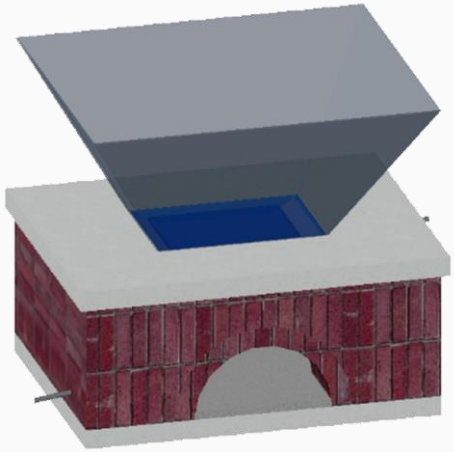
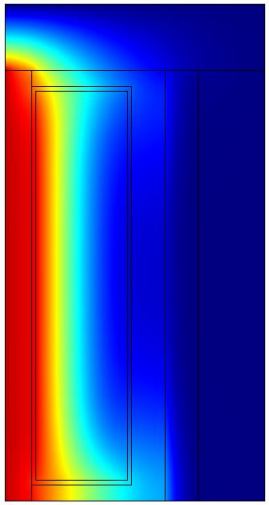
HEAT TRANSFER OPTIMIZATION OF A SOLAR RADIATION CONCRETE OVEN FOR RURAL AREAS





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COMSOL CONFERENCE 2016 BOSTON

COMSOL

October 5-7, 2016 | Boston, MA

Outline

1. Introduction
2. Oven Design
3. Heat Transfer Studies
4. Conclusions

Energy Sources in Rural Areas:

(*Minter, 2016)*

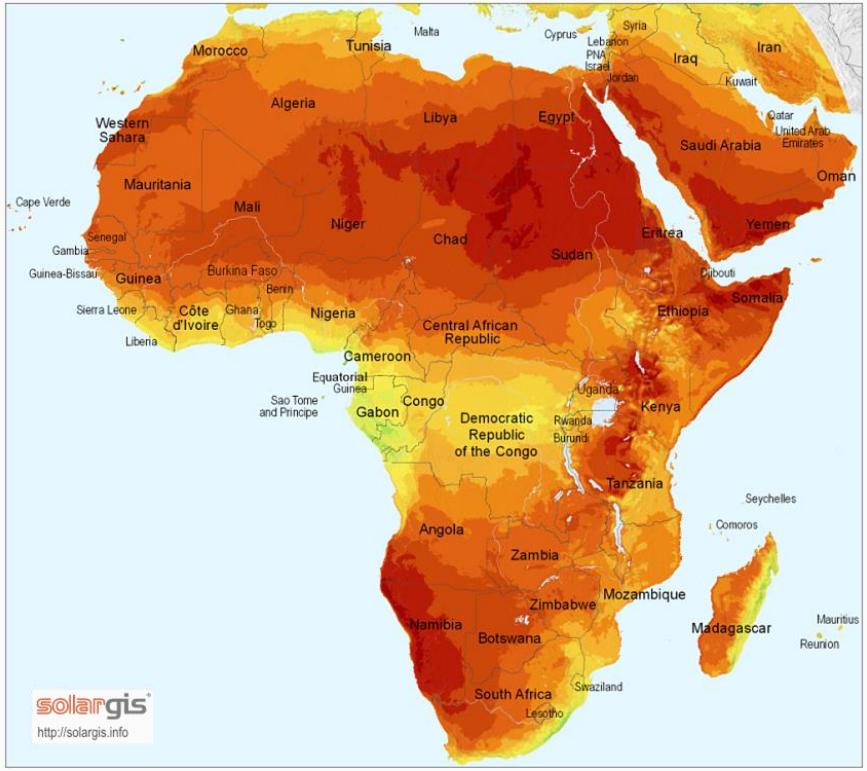
Trash

(*Shapiro, 2014)*

Wood, Dung, Crop Residue

Solar Energy:

Global Horizontal Irradiation (Africa)



(GHI Solar Map © 2016 Solargis)

Average Annual Sun (4/2004 – 3/2010)

< 1600 1800 2000 2200 2400 >

(kWh/m^2)

Majority of United States < 2000 kWh/m^2

Solar Technology:

(*Hedrick, 2015)*

Solar Cookers

(Regattieri et al., *2016)*

SODIS – Solar Water Disinfection

Concerns:

- ***Durability***

  - Exposure to natural elements (Wind, Fire, etc.)

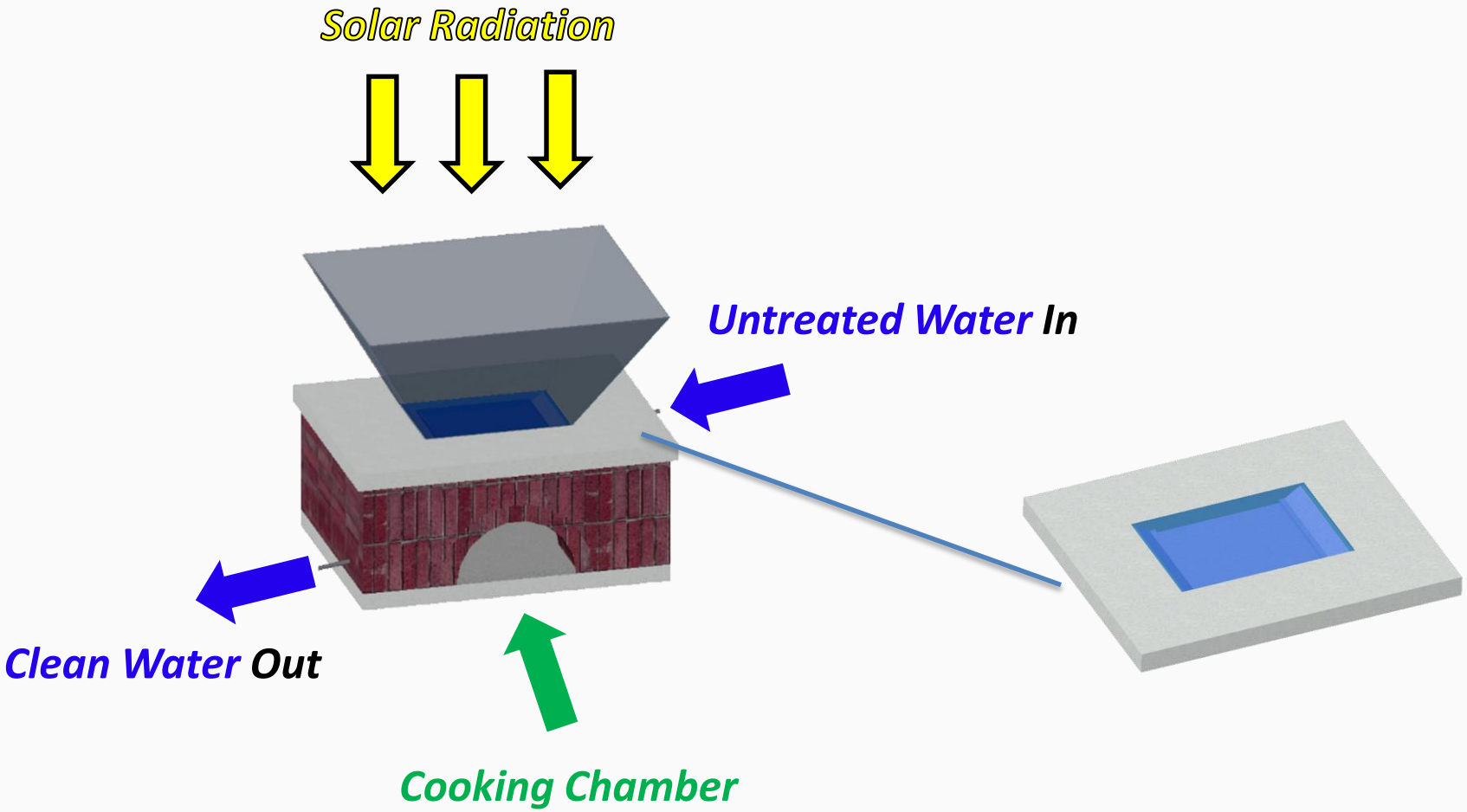
- ***Inefficient methods for an entire village***

  - Is it possible for one device to treat a village?

- ***Theft Susceptibility***

  - How valuable are the scrap parts? How robust is the device?

Solar Radiation Concrete Oven:



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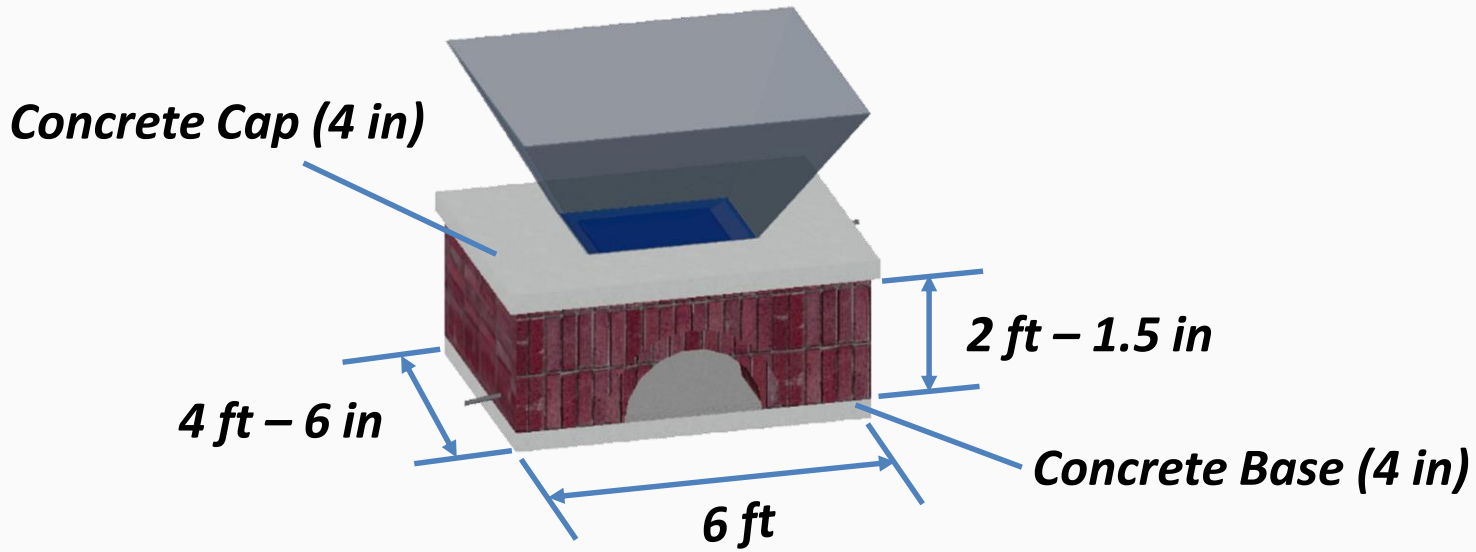
Solar Radiation Concrete Oven:



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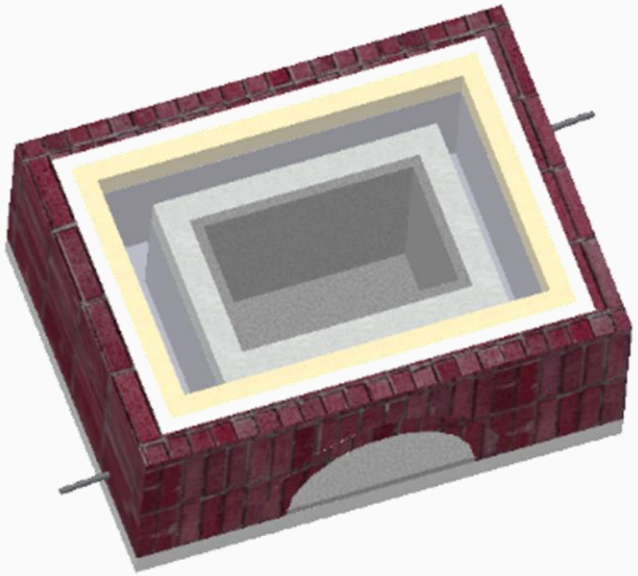
Solar Radiation Concrete Oven:



Material	Thickness
Brick	*4 in*
Styrofoam	*2 in*
Rockwool	*3 in*
Concrete	*4 in*
Soapstone	*1.5 in*

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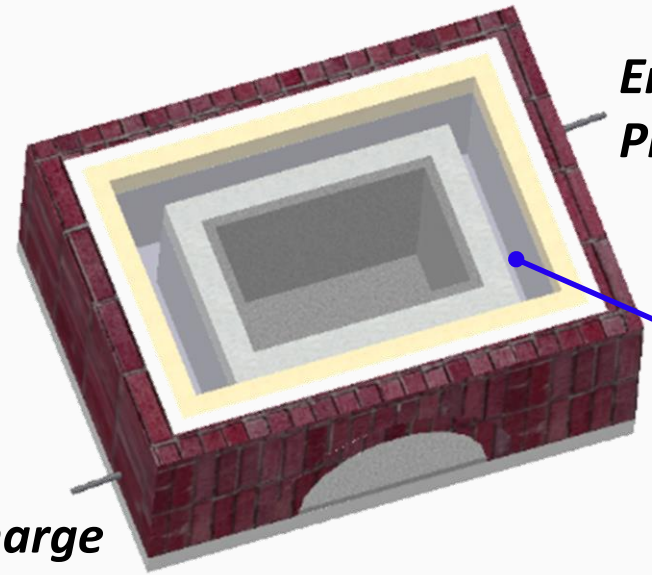
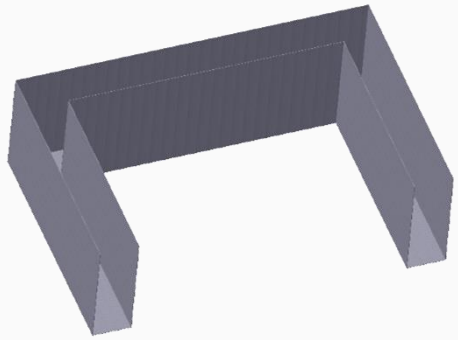
Solar Radiation Concrete Oven:





Steel Retention Channel

- *Treats* ***40 – 50*** *Gal of water/day*
- *Water must remain at* ***104^{o} F (313 K)*** *for* ***8-12 hours***

(*McGuigan et al., 2012*)

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Questions:

- ***Thermal Conduction of heat to water in steel chamber***

  - How long will it take for water to be heated to ***104^{o} F (313 K)***?

- ***Heat loss in water***

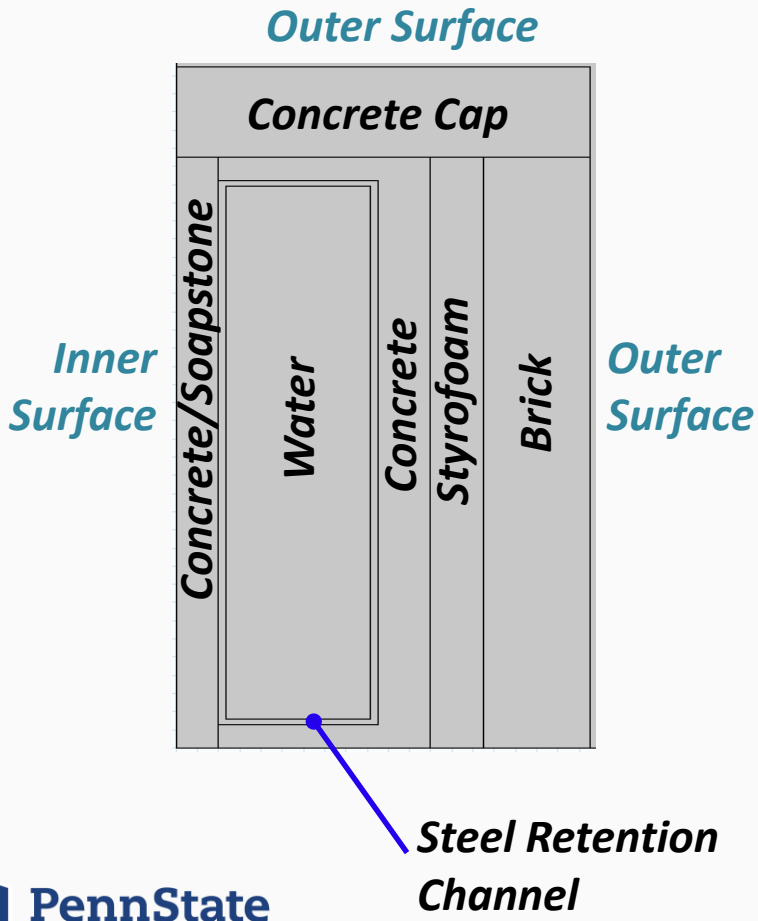
  - How long will the water remain at ***104^{o} F (313 K)***?

- ***Material Optimization***

  - What is the optimum amount of insulation in the oven?

Heat Transfer Studies:

- *Thermal Conduction* of heat to water in *steel chamber*



Boundary Conditions

260° F (400 K) - Inner Surface

68° F (293 K) - Outer Surface

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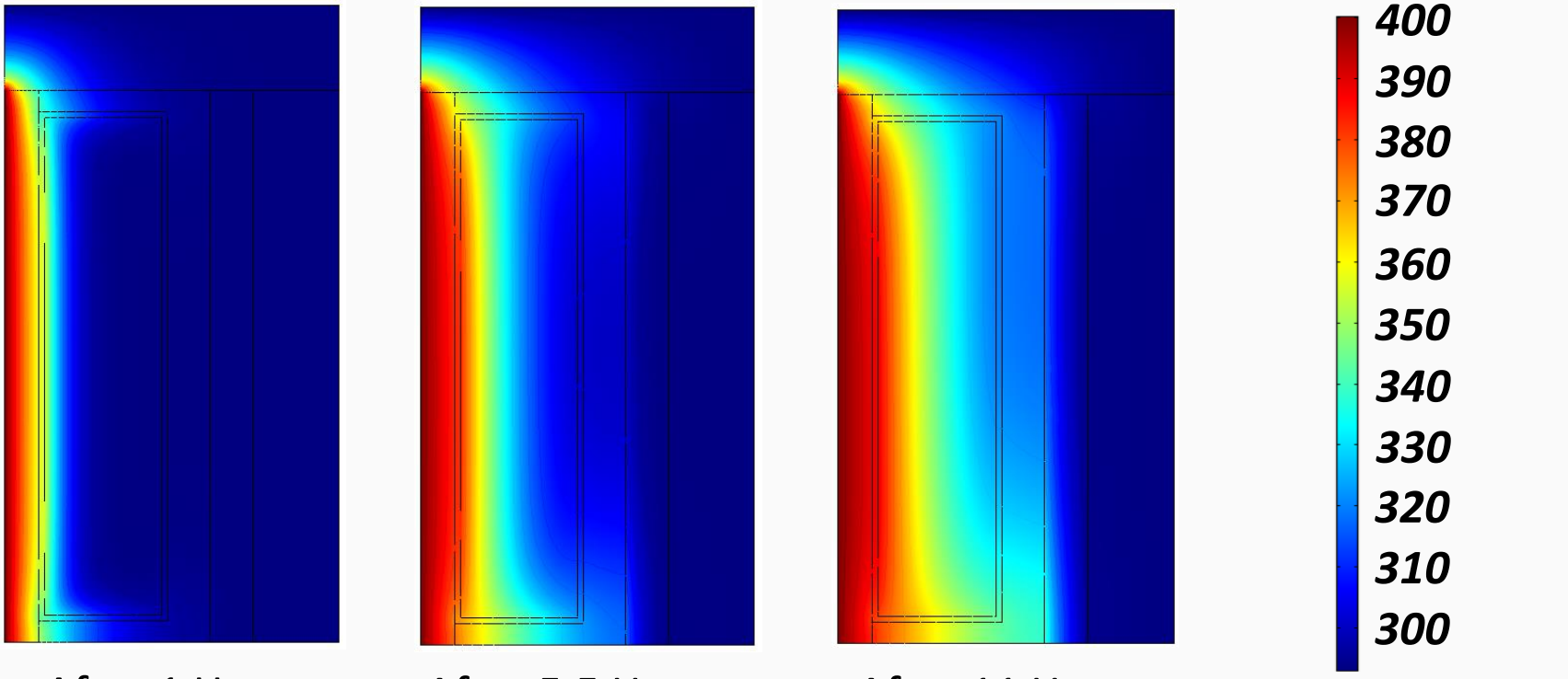
Heat Transfer Studies:

- *Concrete Inner Surface*



After 1 Hour | After 5.5 Hours | After 11 Hours

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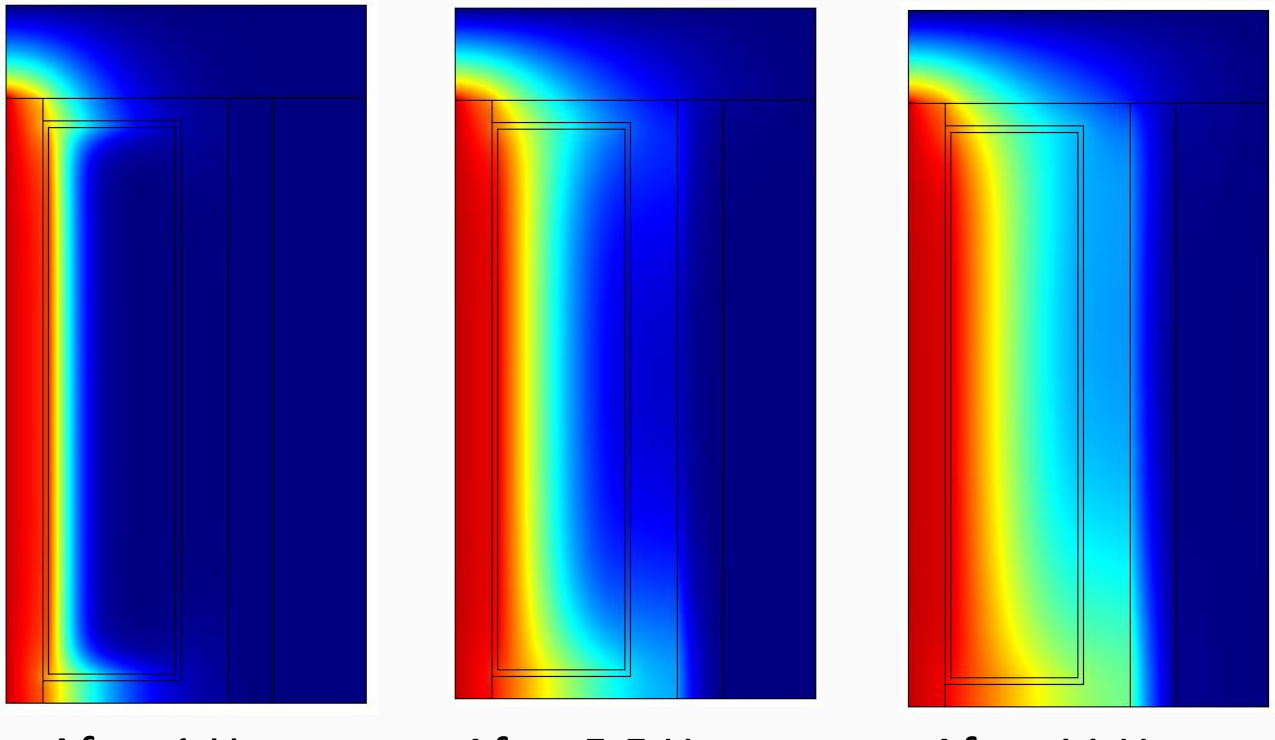
Heat Transfer Studies:

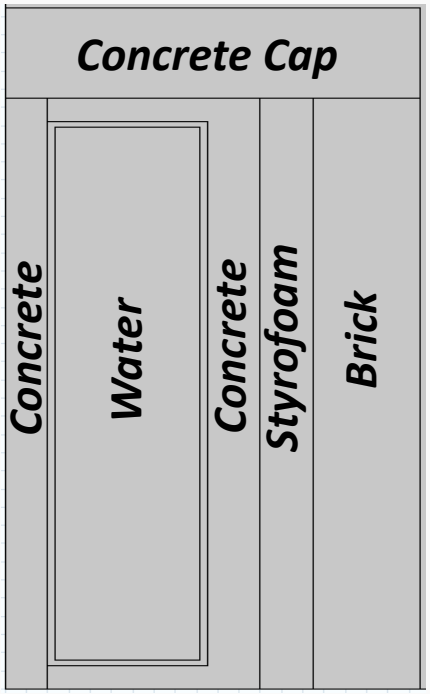
- ***Soapstone Inner Surface***



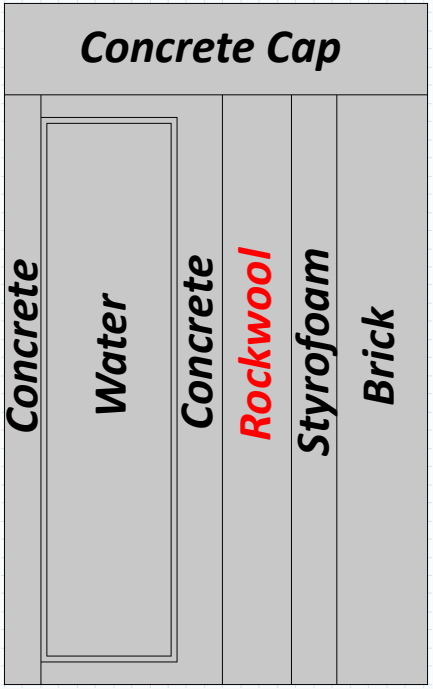
After 1 Hour | After 5.5 Hours | After 11 Hours

Heat Transfer Studies:

- *Heat loss investigation*



Design I



Design II

Boundary Conditions

68^{o} F (293 K) - *Inner Surface*

68^{o} F (293 K) - *Outer Surface*

104^{o} F (313 K) - *Water*

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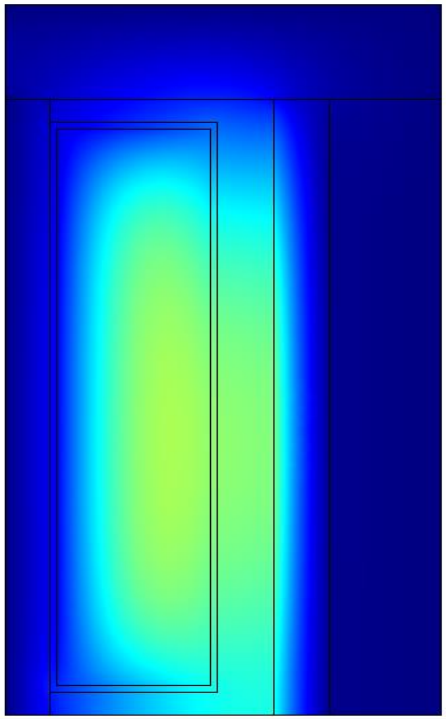
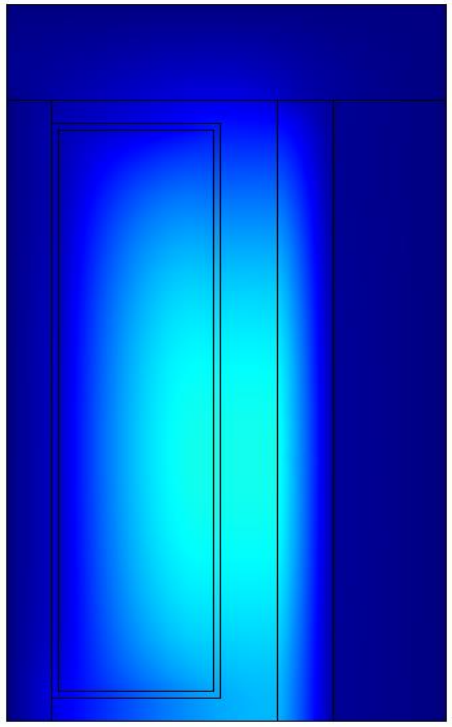
Heat Transfer Studies:

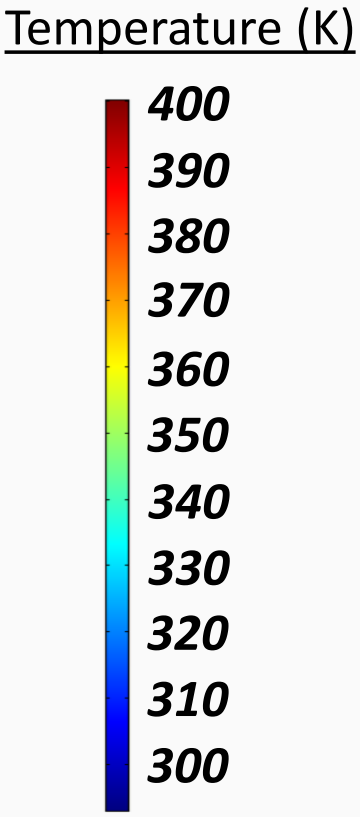
- *Design I (without Rockwool)*



After 5.5 Hours



After 11 Hours



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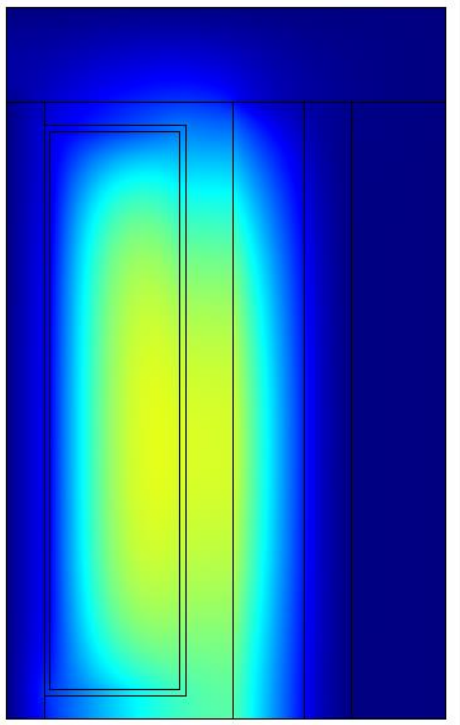
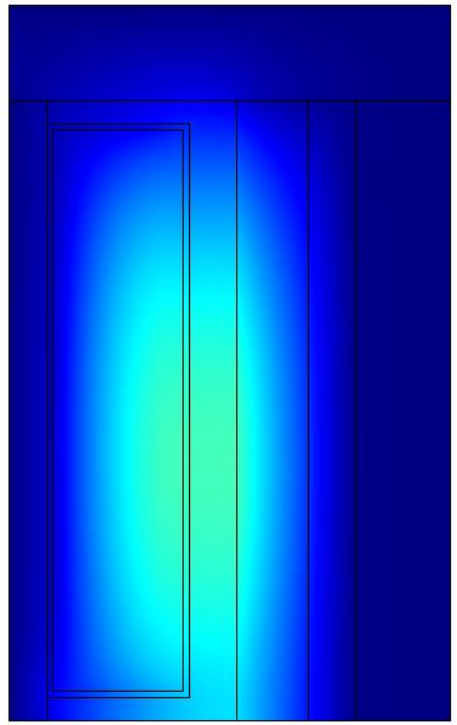
Heat Transfer Studies:

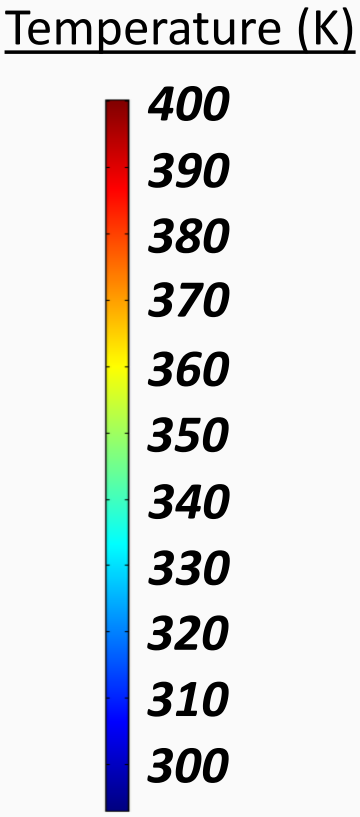
- *Design II(with Rockwool)*



After 5.5 Hours



After 11 Hours



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Conclusions:

- ***Heat transfer studies show:***

  - Heat is conducted efficiently to reach the target temperature ***104^{o} F (313 K).***

  - Water mostly stays at or above target temperature for 8 – 12 hours.

  - Rockwool insulation can be removed with minimal heat loss effects.

  - Soapstone is not needed in front of steel retention chamber.

- ***Future work:***

  - Further optimization using COMSOL Optimization Module.

  - Implementation of 3D COMSOL Model.

  - Construction of prototype oven.

  - Experimental testing of prototype oven using thermocouples.

Thank You

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