Solar Autoclave for Rural Areas

Engineering Analysis

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Presentation Overview

- Problem Statement
- Engineering Analysis
  - Thermal Capture
  - Thermal Circuit
  - Thermodynamic Properties of Water
  - Pressure Vessel
  - Insulation
- Gantt Chart

Problem Statement

- <u>**NEED STATEMENT**</u>: Certain developing areas around the world have limited availability to sterilized medical equipment.

- <u>**Our goal**</u>: To create a solar autoclave that can be easily used at remote clinics in rural areas.

Engineering Analysis

Thermal Capture

- $\rho = 1 - \epsilon$

Table 1: Material properties for thermal capture

Reflective Material	Emissivity, ε	Reflectivity, ρ
Aluminum - Highly Polished	0.039	0.961
Aluminum - Commercial Sheet	0.090	0.910
425-3M Aluminum Foil	0.030	0.970
Y9360-3M Aluminized Mylar	0.030	0.970

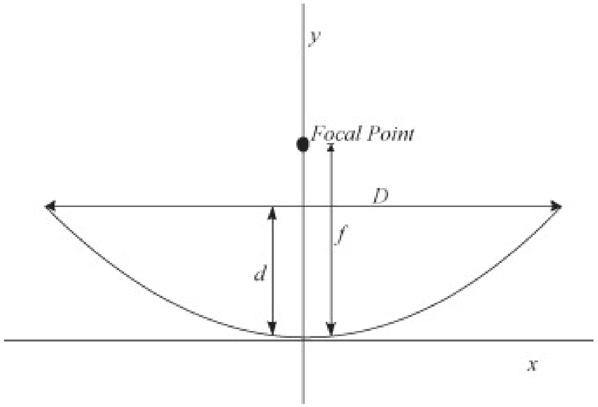
Engineering Analysis

Thermal Capture

- $q_{rad} = \alpha * \rho * G * A_{proj}$

Where:

α = absorptivity of pressure vessel
ρ = reflectivity of mirror
G = solar irradiance, $[\frac{W}{m^2}]$
A_{proj} = projected area, $[m^2]$



Courtesy of Science Direct
http://www.sciencedirect.com/science/article/pii/S1364032110001206

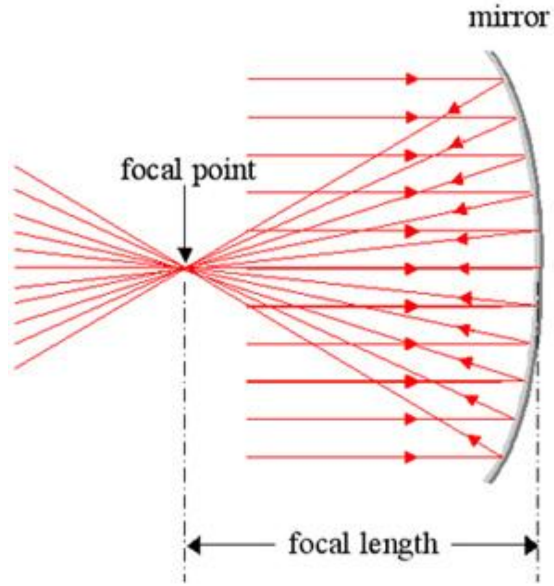
Engineering Analysis

Thermal Capture

- $f = \frac{r}{2}$

Where:

f = focal length, [m]
r = radius of curvature, [m]



Courtesy of DiracDelta
http://www.diracdelta.co.uk/science/source/f/o/focal%20point/image002.jpg

Thermal Circuit

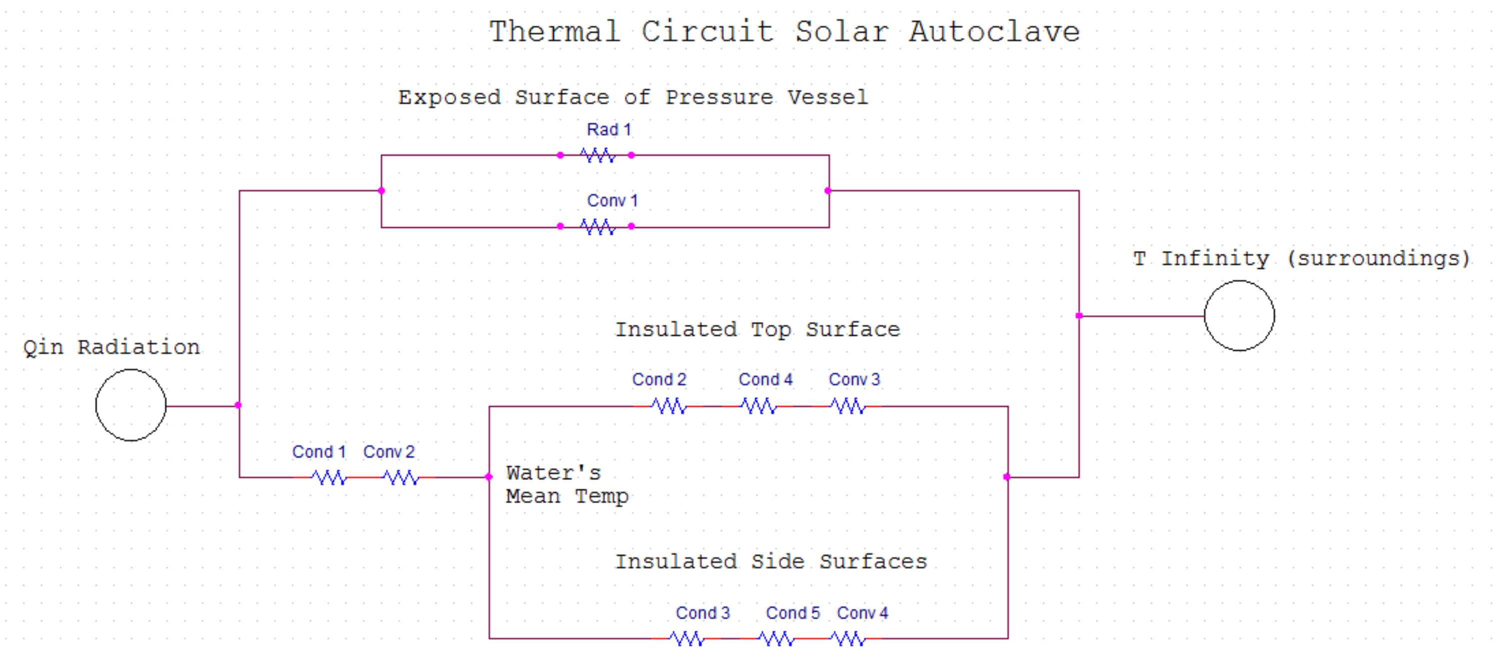


Figure 1: Thermal Circuit

Governing Equations for Resistance:

$$R_{cond} = \frac{L}{kA}\ ,\ [\frac{K}{W}] \qquad q = \frac{\Delta T}{R}\ ,\ [\mathrm{W}]$$

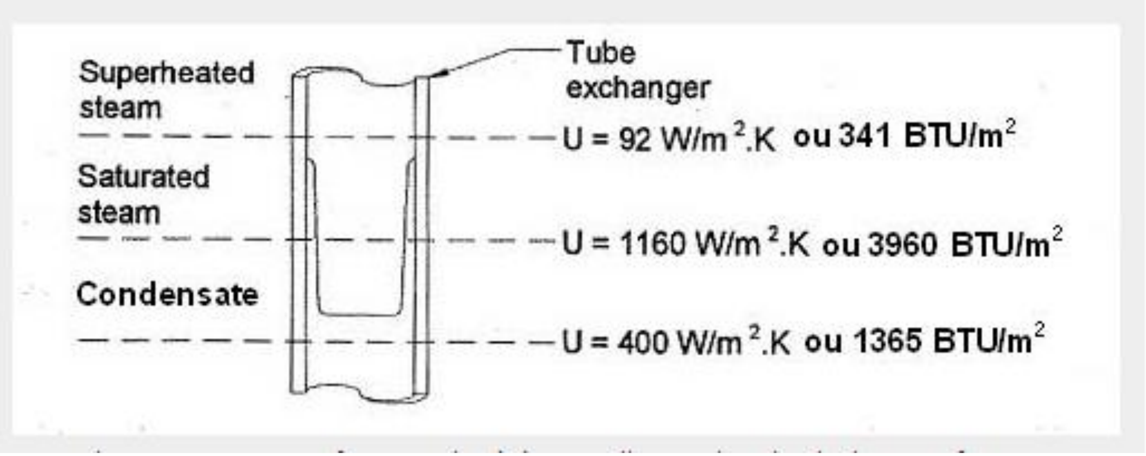
$$R_{conv} = \frac{1}{hA}\ ,\ [\frac{K}{W}]$$

Figure 2: Pressure Vessel

Engineering Analysis

Thermodynamic Properties of Water

Saturated steam vs. Superheated steam



Courtesy of Systhermique
(http://www.systhermique.com/steam-condensate/services/troubleshooting/superheated-steam/)

Engineering Analysis

Thermodynamic Properties of Water

Table 2 – Properties of Saturated Water (Liquid–Vapor)

		Internal Energy, u [$\frac{kJ}{kg}$]
Temperature [°C]	Pressure [bar]	Saturated Liquid
20	0.02339	83.95
121	2.05050	507.752

$$Q = m \cdot (u_2 - u_1)$$

Where:

$Q =$ Heat transfer, [kJ]
$m =$ Mass, [kg]
$u =$ Internal energy, [$\frac{kJ}{kg}$]

Engineering Analysis

Pressure Vessel

Tangential stress max:

$$(\sigma_t)_{max} = \frac{p(d_i + t)}{2t}$$

Longitudinal stress:

$$\sigma_l = \frac{pd_i}{4t}$$

Where:

p = pressure inside vessel, [Pa]
d_i = inner diameter of vessel, [m]
t = wall thickness, [m]

Figure 3: Pressure Vessel

Engineering Analysis

Pressure Vessel

The gauge pressure creates stress in bolts, defined as:

$$\delta_b = \frac{F_b L}{A_b E_b}$$

F_b is the force applied at each bolt due to gauge pressure, calculated as:

$$F_b = \frac{p(\pi r^2)}{N}$$

Where:

L = overall length of the cylinder, [m]
A_b = area of each screw, [m]
E_b = modulus of elasticity, [Pa]
r = inner radius of the vessel, [m]
N = number of bolts used

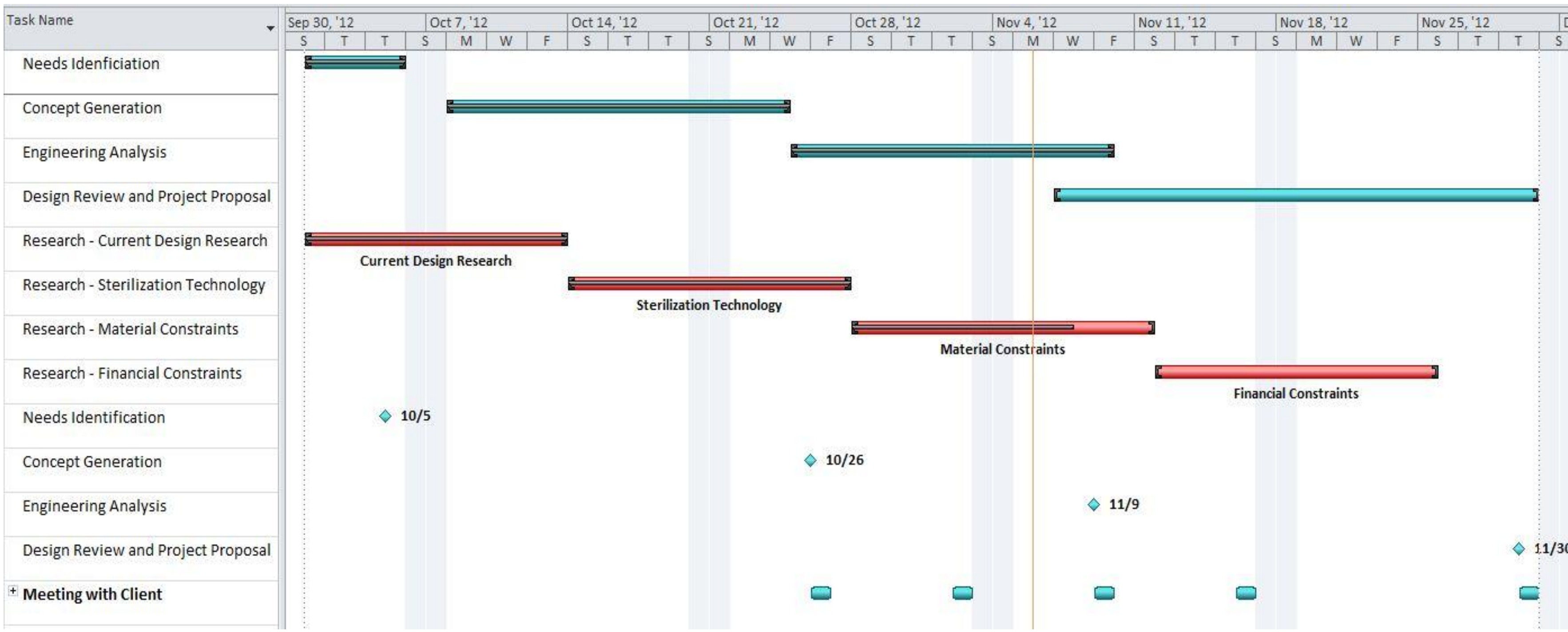
Engineering Analysis

Insulation

Table 3: Thermal conductivity of possible insulation materials

Insulation Material	k value $[\frac{W}{mK}]$
Thermablok Aerogel	0.014
Balsa wood	0.048
Cork	0.07
Cork, regranulated	0.044
Corkboard	0.043
Fibreglass	0.04
Mineral wool	0.04
Styrofoam	0.033

Gantt Chart



Task Name
Sep 30, '12
Oct 7, '12
Oct 14, '12
Oct 21, '12
Oct 28, '12
Nov 4, '12
Nov 11, '12
Nov 18, '12
Nov 25, '12
Needs Idenficiation
Concept Generation
Engineering Analysis
Design Review and Project Proposal
Research - Current Design Research
Research - Sterilization Technology
Research - Material Constraints
Research - Financial Constraints
Needs Identification
Concept Generation
Engineering Analysis
Design Review and Project Proposal
Meeting with Client
Current Design Research
Sterilization Technology
Material Constraints
Financial Constraints
10/5
10/26
11/9
11/30

References

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  - brent.nelson@nau.edu
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  - Richard Budynas and Keith Nisbett. Shingley's Mechanical Engineering Design 9th. 2010. Print.
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  - http://www.cefns.nau.edu/interdisciplinary/d4p/EGR486/ME/13-Projects/SolarAutoclave/
- **Web Sources:**
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  - Global Challenge:
    - http://globalchallenge.mit.edu/teams/view/171
  - Solar Sterilisator:
    - http://www.solare-bruecke.org/projekte-Dateien/Solarsterilisator/summary%20english.html
  - TravelState.gov:
    - http://www.travel.state.gov/
  - Science Direct:
    - http://www.sciencedirect.com/science/article/pii/S1364032110001206

Questions?