Solar Autoclave for Rural Areas

UGRADS Presentation

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Presentation Overview

- Introduction
- Research
- Methods
- Final Design
- Manufacturing
- User Interface
- Cost Analysis
- Results
- Conclusion
- References

Problem Statement

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

- **OUR GOAL**: To create a solar autoclave that can be easily used at remote clinics in rural areas.

Figure 1: Western Design Autoclave
Source: http://www.trojanmedical.co.za/?page_id=205

Need Identification

- **Objectives**
  - Provide remote clinics in rural areas with the means to sterilize medical equipment
  - Create a flexible design from location to location
  - Parts can be repaired/replaced from local, readily available materials
- **Constraint**
  - Temperature of the steam must reach and hold 121°C for at least 15 minutes

Research

- Dry Heat Sterilization
  - **Pros**:
    - Does not require water
    - Lower gauge pressure, meaning safer to use
  - **Cons**:
    - Takes 2 hours at 160°C to “sterilize” equipment
    - Does not kill all proteins associated with bacteria

- Saturated Steam Sterilization
  - Takes 15 minutes at 121°C to fully sterilize equipment

Research

- Thermal Capture
  - Fresnel lens, parabolic dish and trough

Figure 2: Fresnel Lens

Courtesy of WN
http://article.wn.com/view/2008/01/16/Fresnel_lens_sheet_rear_projection_screen_and_rear_projectio/

Figure 3: Parabolic Dish

Courtesy of Inhabitat
http://inhabitat.com/19-year-old-teenager-makes-homemade-solar-death-ray/solarray2/

Figure 4: Parabolic Trough

Courtesy of Tech Bells
http://techbells.blogspot.com/2012/07/working-of-csp-parabolic-trough.html

Research

Figure 5: Fiberglass
Courtesy of Unipro
http://www.alibaba.com/product-tp/12283858/FiberGlass_wool_Insulation

Figure 6: Foam Hose Insulation
Courtesy of WJDennis
http://www.wjdennis-rcr.com/Products/Weatherstripping/PipeInsulation.aspx

Table 1: Thermal Conductivity of Various Materials [k]

Insulation Material	k, $[\frac{W}{m \cdot K}]$
Thermablok Aerogel	0.014
Balsa Wood	0.048
Cork	0.07
Cork, regranulated	0.044
Corkboard	0.043
Mineral Wool	0.04
Fiberglass	0.04
Styrofoam	0.033

Methods

- Thermodynamic Properties of Water

Table 2: Properties of Saturated Water at Desired Temperatures

Temperature [°C]	Pressure [bar]	Internal Energy [kJ/kg]
20	0.02	83.95
121	2.05	507.75

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

Where:

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

Methods

- Thermal Capture
  - $q_{rad} = \alpha \cdot \rho \cdot G \cdot A_{proj}$
  - $A_{proj} = \frac{E}{t \cdot \alpha \cdot \rho \cdot \varepsilon \cdot G}$

Where:

α = absorptivity of boiler

ρ = reflectivity of Mylar

G = solar irradiance, $[\frac{W}{m^2}]$

A_{proj} = projected area, $[m^2]$

E = energy required to raise temperature, [J]

t = time allotted to reach temperature, [s]

ε = efficiency of the trough

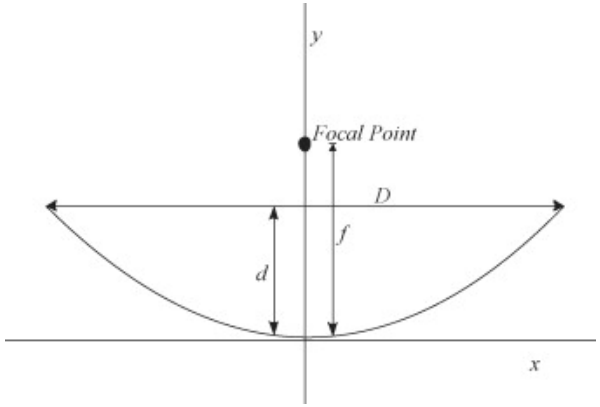


Figure 7: Parabolic Trough with Focal Point
Courtesy of Science Direct
http://www.sciencedirect.com/science/article/pii/S1364032110001206

$$y = \frac{x^2}{4f}$$

Where:

f = focal length, $[m]$

y = equation of curve

Final Design

Figure 8: Solar Autoclave Final Design

Manufacturing the Design – Boiler

List of Actual Materials:

- 1.5” Schedule 40 galvanized pipe
- Reducing tee
- Square plug
- Cap
- Brass ball valve
- Stainless steel hose barb
- Krylon BBQ Spray paint

Figure 9: Boiler Design

Manufacturing the Design – Trough

List of Actual Materials:

- **Sheet metal**: Zinc 24 gauge (8ft x 4ft)
- **Particle board**: 2 x 5/8" (8ft x 4ft)
- **Screws**: 2.5" inch Zinc Plated (100 count)
- **Nails**: 1.5" Galvanized roofing nails (100 count)
- **Spray adhesive**: "3m super 77 16.75 fl. oz. multi purpose spray adhesive"
- **Mylar**: "Viagrow 25ft Mylar 2mil reflective film"
- **Clear Plastic**: 1/16" (8ft x 4ft)
- **Classic Dolly**
- **Scrap Metal**

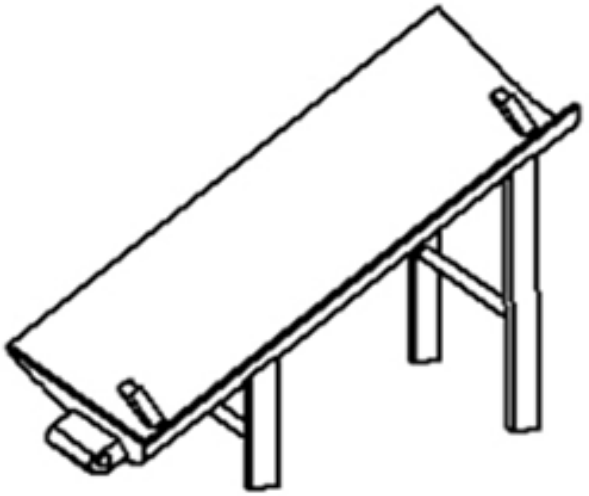


Figure 10: Parabolic Trough

Manufacturing the Design – Trough

- Initial construction:
  - Parabolic ribs
  - Side and end panels
  - Boiler stopper
- Wood finish
- Drilled holes

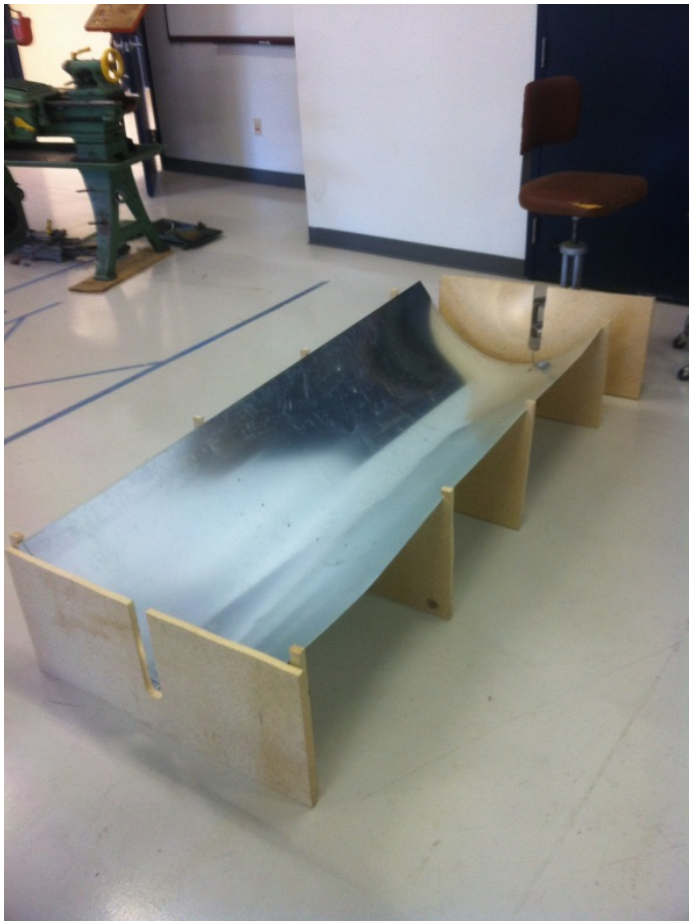


Figure 11: Parabolic Trough

Manufacturing the Design – Trough

- Trough assembly
- Sun dial
- Weight reduction
- Edge protectors
- Spray adhesive
- Clear plastic

Figure 12: Final Trough Design

Manufacturing the Design – Pressure Vessel

- Contains all the medical equipment in need of sterilization
- Used and modified a Mirro-Matic 394M 4 Qt. pressure cooker

List of Actual Materials:

- Mirro 9898 Pressure Regulator
- Honeywell TD-165 Tridicator
- Dixon Stainless Steel 316 1/4" NPT Male 3/4" Hose Barb
- 3/4" x 1/2" Galvanized Hex Bushing
- 1/2" Conduit Nipple
- Apollo 1/2" Brass Ball Valve NPT Full-Port
- 3/4" Locknut
- 2 Washers

Figure 13: Mirro-Matic 394M Pressure Cooker

Courtesy of Ebay
http://i.ebayimg.com/t/Mirro-Matic-4-Qt-Aluminum-Pressure-Cooker-/00/s/NzIwWDk2MA==/z/9EEAAOxyY9VROnWm/$T2eC16VHJF0E9nmFRoweBROnWmTJeQ~~60_57.JPG

Manufacturing the Design – Pressure Vessel

- **Manufacturing Process:**
  - **Lid modifications**
    - Hose barb
    - Tridicator
    - Pressure Regulator
    - Handle
  - **Base modifications**
    - Ball valve

Figure 14: Modified Pressure Vessel

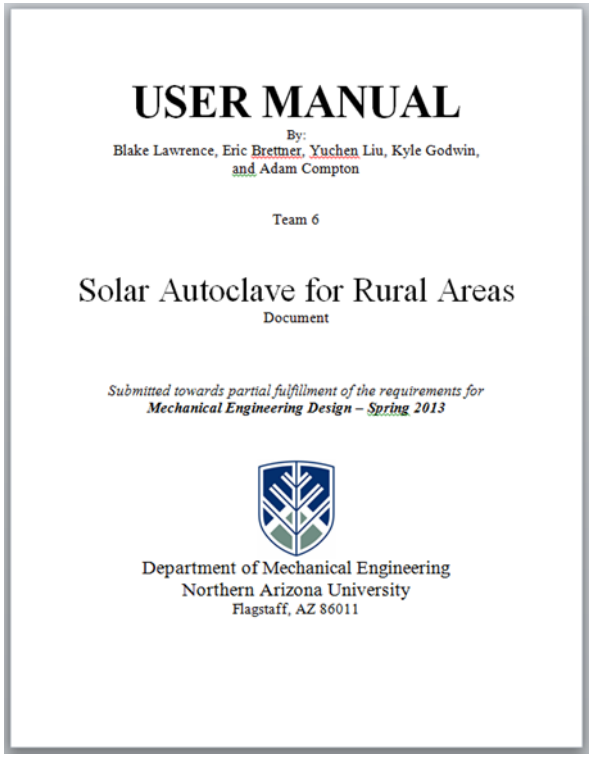
Figure 15: Pressure Regulator with Added Weight

Homemade Pressure Vessel Design

Figure 16: Homemade Pressure Vessel

Importance of User Interface

- User interface definition:
  - *The way in which the user and the system interact*
- **Goal:**
  - User can independently operate system
  - To keep the user safe



USER MANUAL

By:
Blake Lawrence, Eric Brettner, Yuchen Liu, Kyle Godwin, and Adam Compton

Team 6

Solar Autoclave for Rural Areas
Document

Submitted towards partial fulfilment of the requirements for
Mechanical Engineering Design – Spring 2013

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Figure 17: User Manual

User Interface

- Used smaller prototype modeling the solar autoclave
- Operate system with a given list of instructions
- Candidates:
  - No prior knowledge
  - No engineering background

Figure 18: User Interface Prototype

User Interface

Results:

- Volunteers made suggestions:
  - Change order of certain instructions
  - Use simple language
  - Clearly identify parts involved
  - Add pictures
- Improved list of instructions
- Made system safer and easier to operate

Cost Analysis

Allowable Budget: $500

Actual Cost: $336

Table 3: Cost Analysis of Materials

	Material	Cost
Boiler	Pipe	$22.00
	Fittings	$26.00
	Ball Valve	$24.00
	Spray Paint	$7.99
	Hose	$37.00
	Hose Barb	$20.00
	Insulation	$1.27
Trough	Sheet Metal	$24.99
	Mylar	$20.00
	Nails	$6.00
	Particle Board	$40.00
	Adhesive	$7.99
	Screws	$6.00
Pressure Vessel	Vessel	$13.99
	Tridicator	$20.00
	Hose Barb	$16.00
	Jiggler	$17.00
	Fittings	$10.00
	Insulation	$6.00
	Ball Valve	$8.00
Misc.	Clamps	$2.00
	Total	$336.23

Results

- Continuous steam produced after 15-20 minutes
- Additional 40 minutes to reach steady-state pressure and temperature
- Best results at 1.24 bar (gauge), 118°C

Recommendations

- Weather conditions
- Shorter hose
- Better insulation

Figure 19: Solar Parabolic Trough

Conclusion

- Met client's needs
  - Readily available materials
  - Easily repaired and maintained
  - Interchangeable parts depending upon availability
  - Grid power independent
  - Low cost
- Concept proven successfully

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Books:

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[12] World Health Organization. Web. 1 October 2012. URL: http://www.who.int/en/

Additional Resources:

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Project Website:

[14] http://www.cefns.nau.edu/interdisciplinary/d4p/EGR486/ME/13-Projects/SolarAutoclave/

Sponsor:

[15] Dr. Brent Nelson. Email: Brent.Nelson@nau.edu

Questions?