Thermal Storage Solution

Created by: Group 17

Belal Nabulsi
Cory Nelson
Bruce Orozco
Jhamal Holliday

Sponsor : Verdicorp

Advisor: Dr. Ordonez

Instructors: Dr. Gupta, Dr. Helzer, Dr. Shih

Background

- Verdicorp's Organic Rankine Cycle (ORC)
  - Serves same purpose as steam Rankine cycle, to produce useable electric power
  - Uses environmentally friendly fluids as the working fluid
  - Uses waste heat from a number of sources

Figure 1. Image of Verdicorp ORC System

Group 17
Jhamal Holliday

Goals & Objectives

- Our aim is to produce a commercially viable thermal storage solution for Verdicorp's Rankine Cycle utilizing environmentally friendly materials.
  - Prototype should be serviceable
  - Operation cost of 23 cents per kW-h or less
  - Supply energy for 4 hours
  - Applicable in developing markets such as China and northern Africa
  - Supply power as demand calls for it

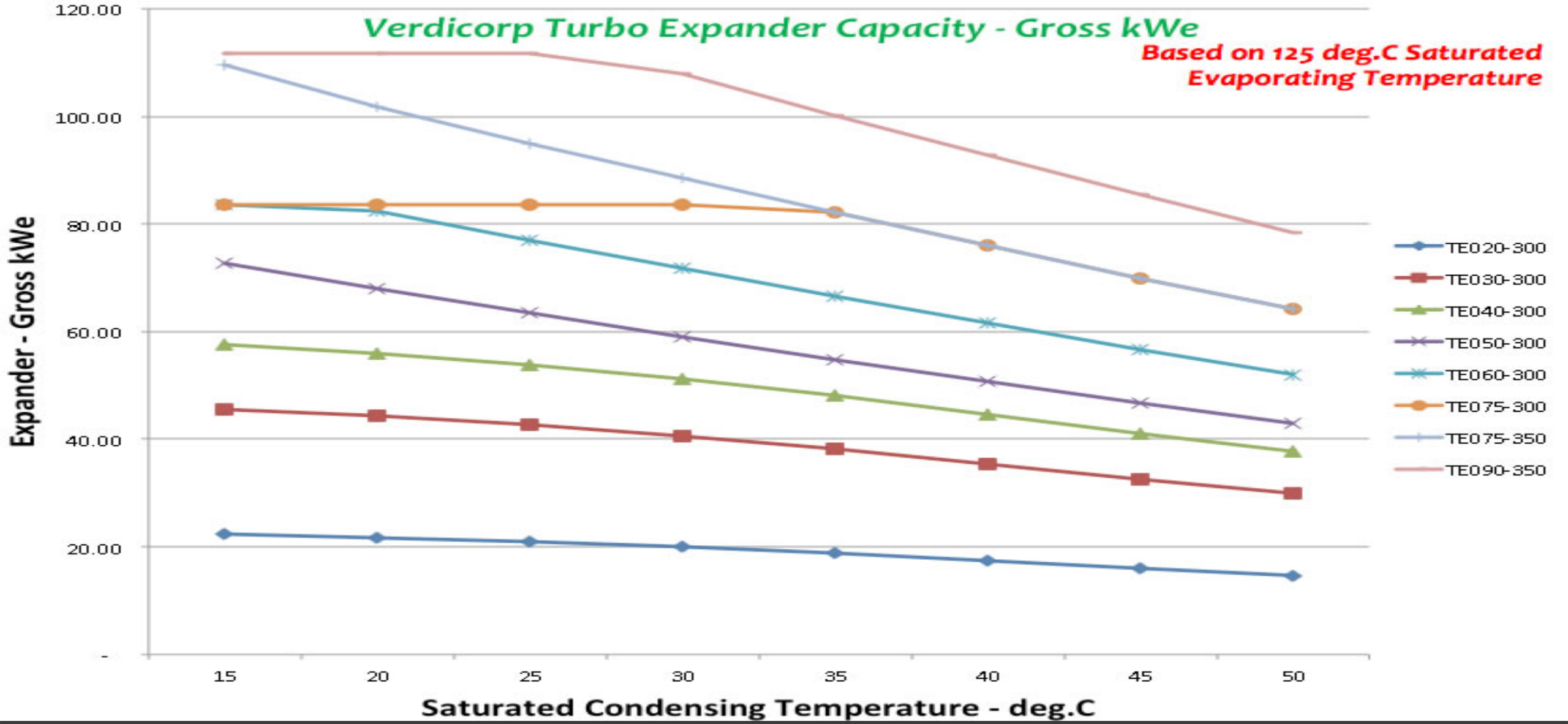


Figure 2. Electrical Output ORC Maximum of 115kWe

Design Metrics

- $\eta\downarrow thermal \approx 12\%$, ratio of electrical energy to thermal
- 4 hour desired time of operation
- Assumed 115kWe peak electrical work output

$$E\downarrow thermal\ storage = W\downarrow out\ electric \times time\ of\ operation / \eta\downarrow thermal$$ = 13.8GJ

Design Metrics

1. Mass needed for storage
   - Sensible heat $E_{thermal\ storage} = m\, c_p \Delta T$
   - Latent heat $E_{thermal\ storage} = m \times [c_p \Delta T + h_{heat\ of\ fusion}]$
2. Material cost per energy stored $cost = m \times cost/kg$

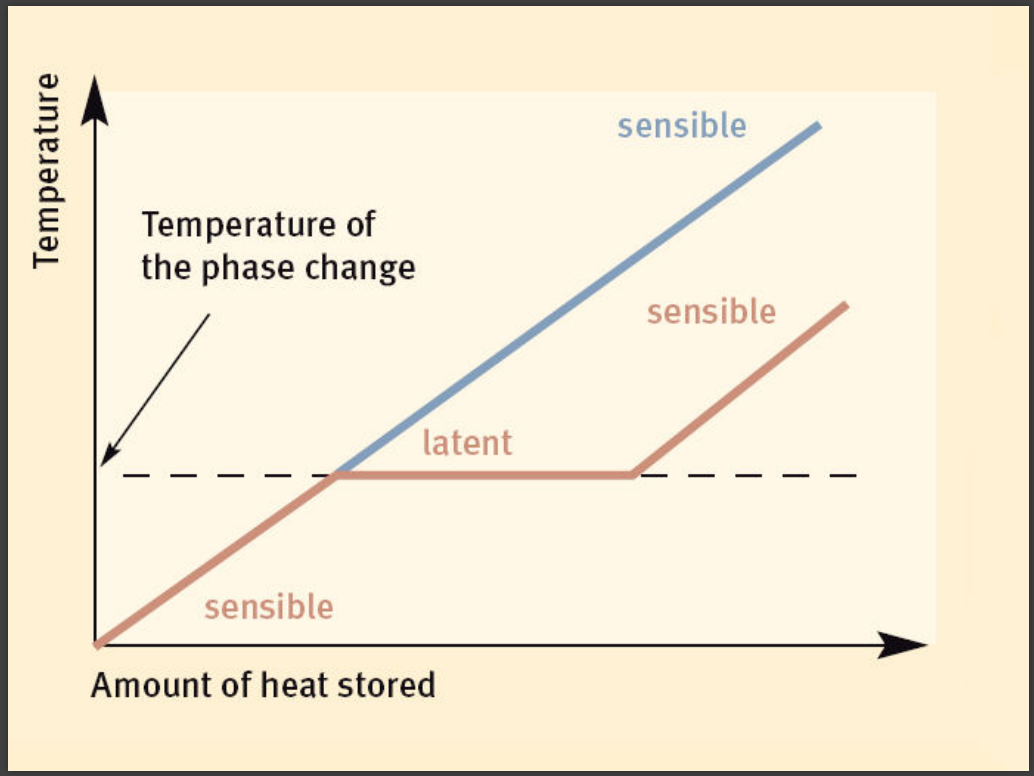


Figure 3. Heat Storage Forms

Proof of Concept

- Test Proposal
  - Controls
  - Measurements

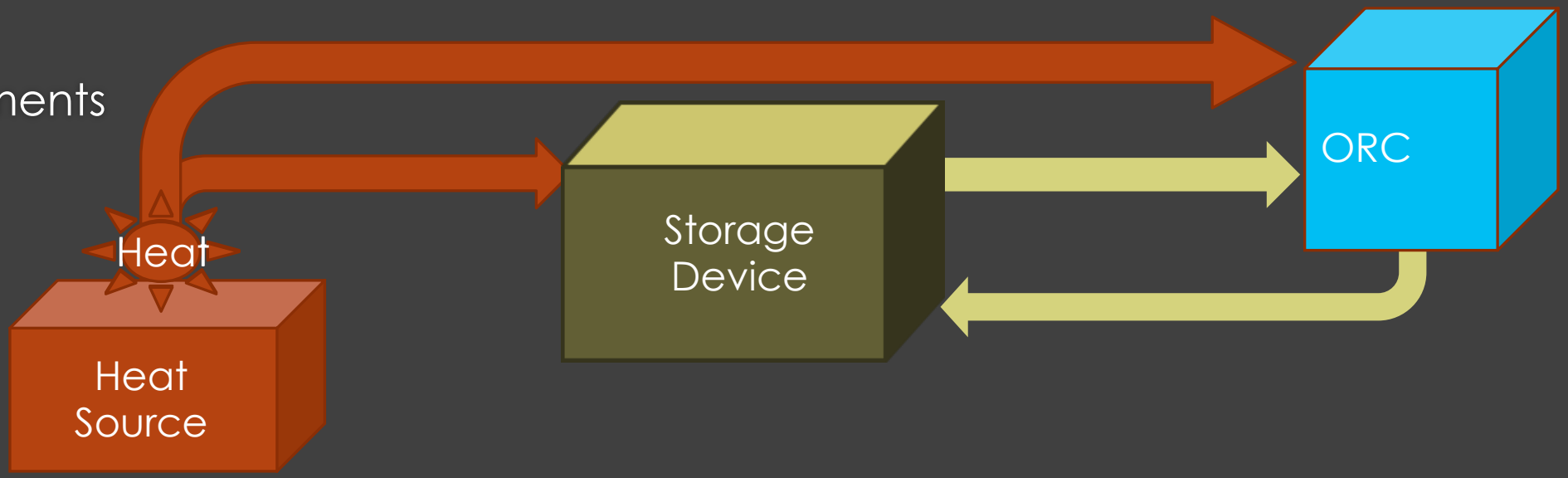


Figure 4. Testing Method Diagram

Concept 1

Concept Diagram

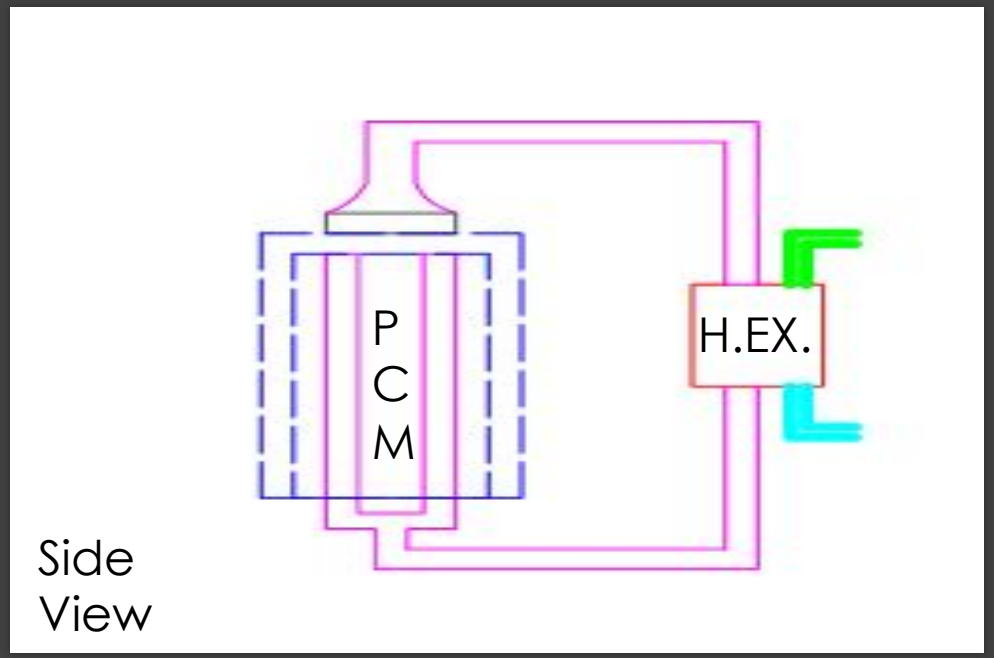


Figure 5. PCM Concept

Metric Analysis

- Positives
  - Latent heat capability
  - Predictable discharge rate
  - Less material required
- Drawbacks
  - Expensive
  - Small temperature range
  - Supercooling
  - Behavior diminishes over time

Concept 2

Concept Diagram

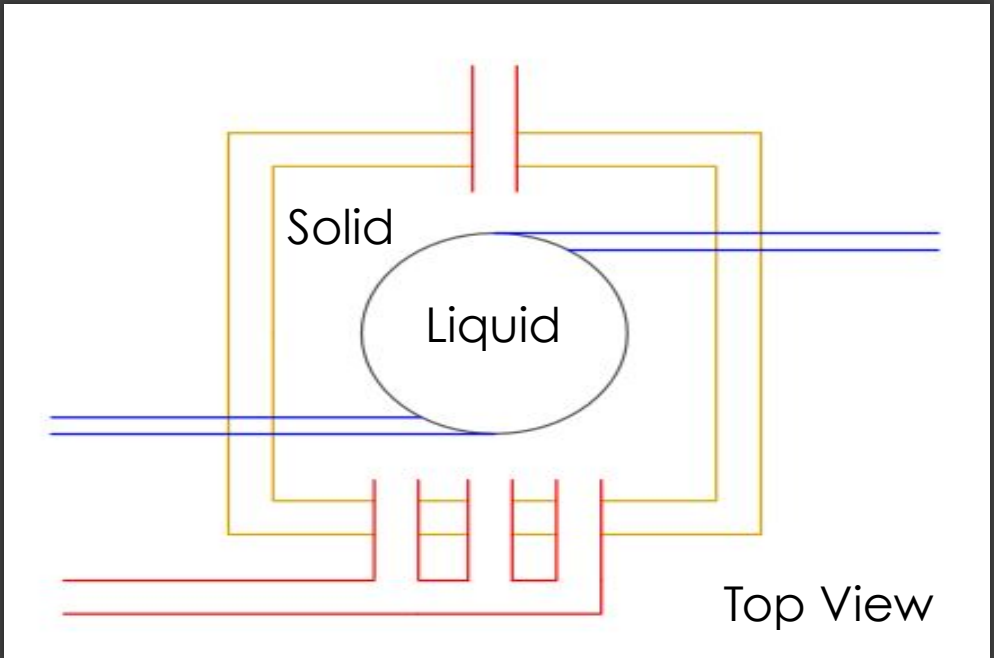


Figure 6. Sensible liquid/solid Combo

Metric Analysis

- Positives
  - Affordable
  - Simplicity
  - Highly abundant materials
  - High temperature range
  - Low Thermal Expansion
- Drawbacks
  - Space and weight
  - More Insulation
  - Difficult temperature control

Concept Cost/Space Comparison

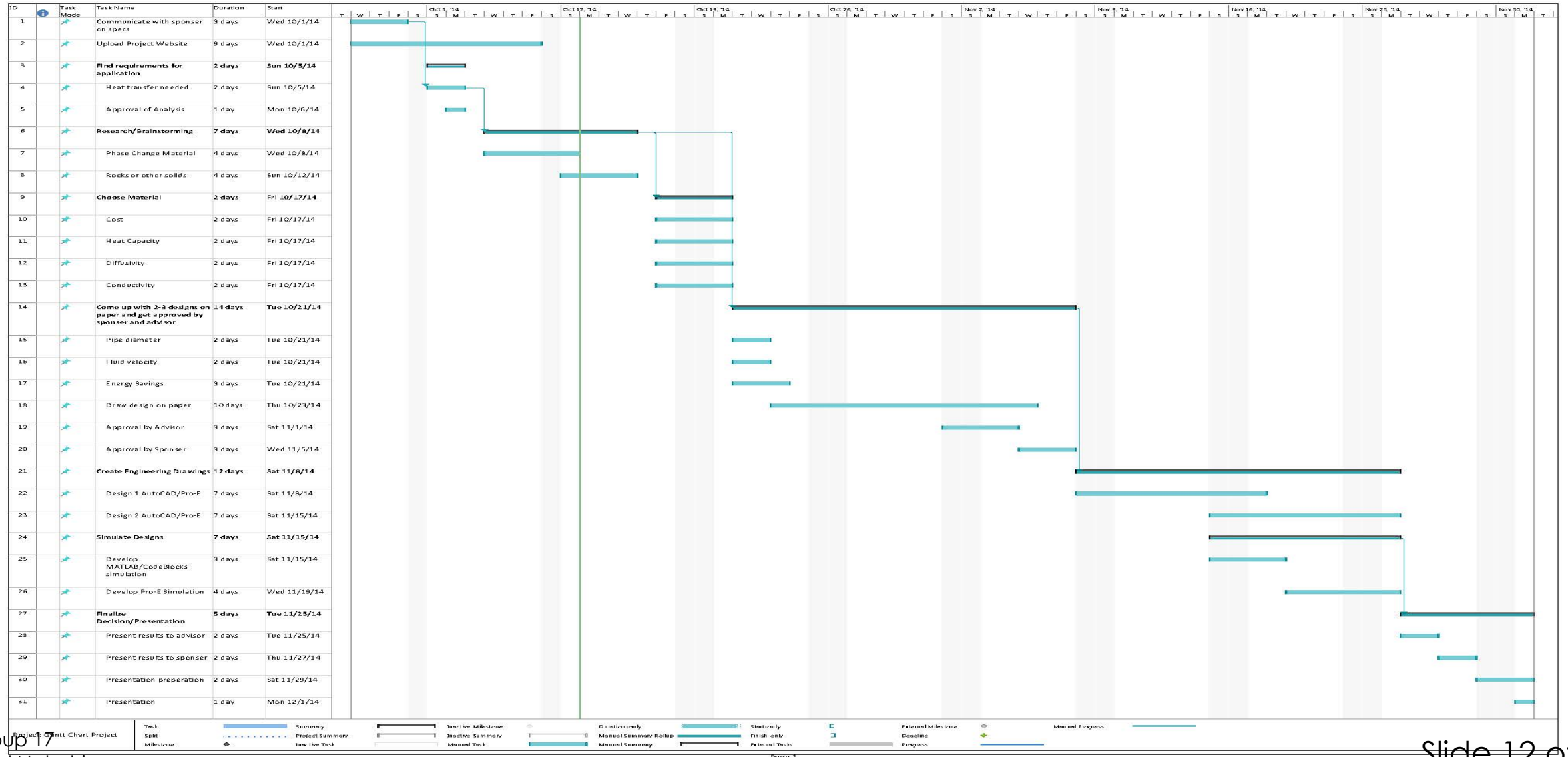
Table 1. Cost/space Comparison

Material	Mass (kg)	Volume (m^3)	Cost ($)
Concrete	123,478	53.68	12,347
Clay	123,478	84.57	108,661
PCM A-144	34,989	39.76	57,733-192,444
Mineral Oil	65,066	81.33	266,773

Challenges & Contingencies

- Design
  - Accounting for a range of intermittent input heat sources and effect on materials
  - Compensating for phase changes in working fluids
  - Environmentally friendly materials
  - Machining enclosures and other components to correct scale
- Applicability
  - Variety of outside environments in a variety of countries
- Project constraints
  - Keeping the scaled model beneath 50 psi
  - Must output R245a temp of no more than 150°C
  - Minimize electric input

Schedule



ID	Task Mode	Task Name	Duration	Start
1		Communicate with sponser on specs	3 days	Wed 10/1/14
2		Upload Project Website	9 days	Wed 10/1/14
3		**Find requirements for application**	**2 days**	**Sun 10/5/14**
4		Heat transfer needed	2 days	Sun 10/5/14
5		Approval of Analysis	1 day	Mon 10/6/14
6		**Research/Brainstorming**	**7 days**	**Wed 10/8/14**
7		Phase Change Material	4 days	Wed 10/8/14
8		Rocks or other solids	4 days	Sun 10/12/14
9		**Choose Material**	**2 days**	**Fri 10/17/14**
10		Cost	2 days	Fri 10/17/14
11		Heat Capacity	2 days	Fri 10/17/14
12		Diffusivity	2 days	Fri 10/17/14
13		Conductivity	2 days	Fri 10/17/14
14		**Come up with 2-3 designs on paper and get approved by sponser and advisor**	**14 days**	**Tue 10/21/14**
15		Pipe diameter	2 days	Tue 10/21/14
16		Fluid velocity	2 days	Tue 10/21/14
17		Energy Savings	3 days	Tue 10/21/14
18		Draw design on paper	10 days	Thu 10/23/14
19		Approval by Advisor	3 days	Sat 11/1/14
20		Approval by Sponser	3 days	Wed 11/5/14
21		**Create Engineering Drawings**	**12 days**	**Sat 11/8/14**
22		Design 1 AutoCAD/Pro-E	7 days	Sat 11/8/14
23		Design 2 AutoCAD/Pro-E	7 days	Sat 11/15/14
24		**Simulate Designs**	**7 days**	**Sat 11/15/14**
25		Develop MATLAB/CodeBlocks simulation	3 days	Sat 11/15/14
26		Develop Pro-E Simulation	4 days	Wed 11/19/14
27		**Finalize Decision/Presentation**	**5 days**	**Tue 11/25/14**
28		Present results to advisor	2 days	Tue 11/25/14
29		Present results to sponser	2 days	Thu 11/27/14
30		Presentation preperation	2 days	Sat 11/29/14
31		Presentation	1 day	Mon 12/1/14

Figure 7. Gantt Chart for Current Project Plan

Summary

- Task: Design and build a fully functional storage model
- Relative cost of a PCM to sensible material
- Accurately account for properties of materials under various temperatures
- Proposed test method and foreseeable challenges

Resources

- Hasnain, S.M., "Review on Sustainable Thermal Energy Storage Technologies, Part 1: Heat Storage Materials And Techniques," Energy Conversion Mgmt., Vol. 39 No. 11 pp1127-1138, 1997.
- Sharma, Atul, Tyagi, V.V., Chen, C.R., Buddhi, D., "Review on Thermal Energy Storage with Phase Change materials and applications," Renewable and Sustainable Energy Reviews 13, pp318-345, 2009.
- Cengel, Yunus, and Cimbala, John M., and Turner, Robert, *Fundamentals of Thermal Fluid Sciences*, 4th ed., New York, New York, 2011

Group 17
Jhamal Holliday
Cory Nelson
Bruce Ororzco
Belal Nabulsi