Cummins Energy Saving

Group Number 2

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Outline

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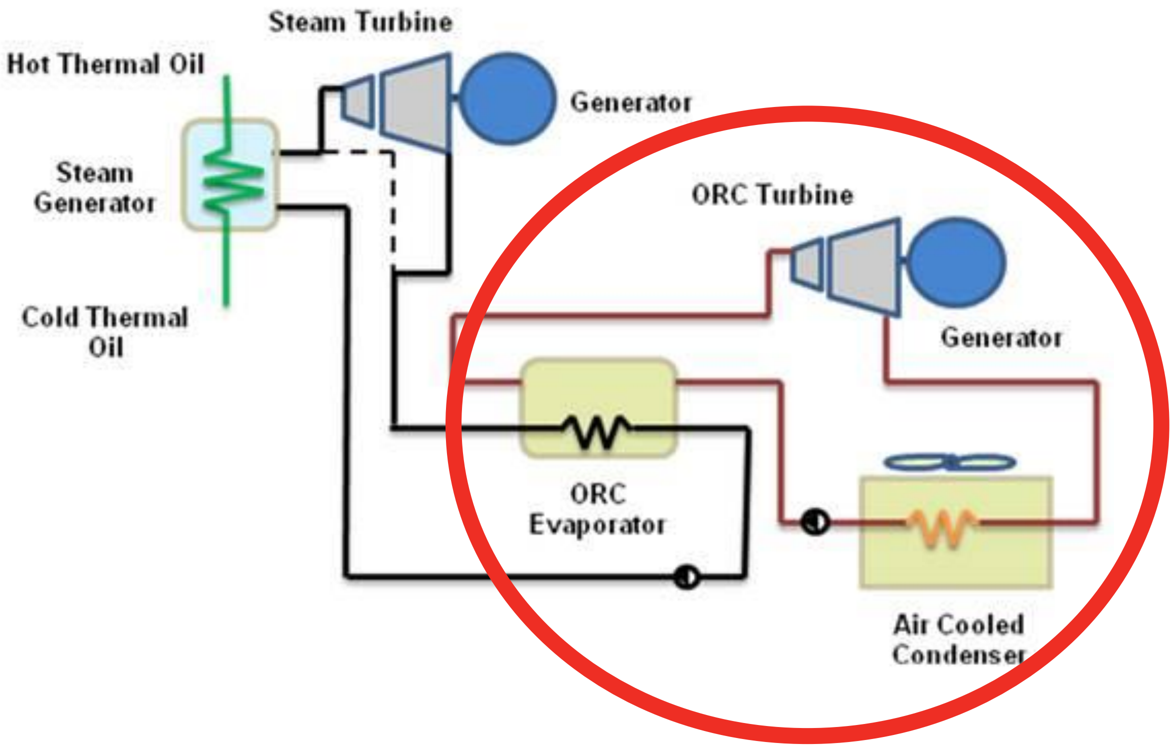
- Simulation Plan
- Design Overview
- Working Fluid Selection
- Pipe Material Selection
- Heat Exchanger
- Turbine
- Summary

Background

- Cummins uses 20,000 gallons of fuel a year in testing
- Organic Rankine cycles are a new solution to generate energy from low temperature heat sources
- Statistical research indicates that low-grade waste heat accounts for more than 50% of total heat generated in the industry

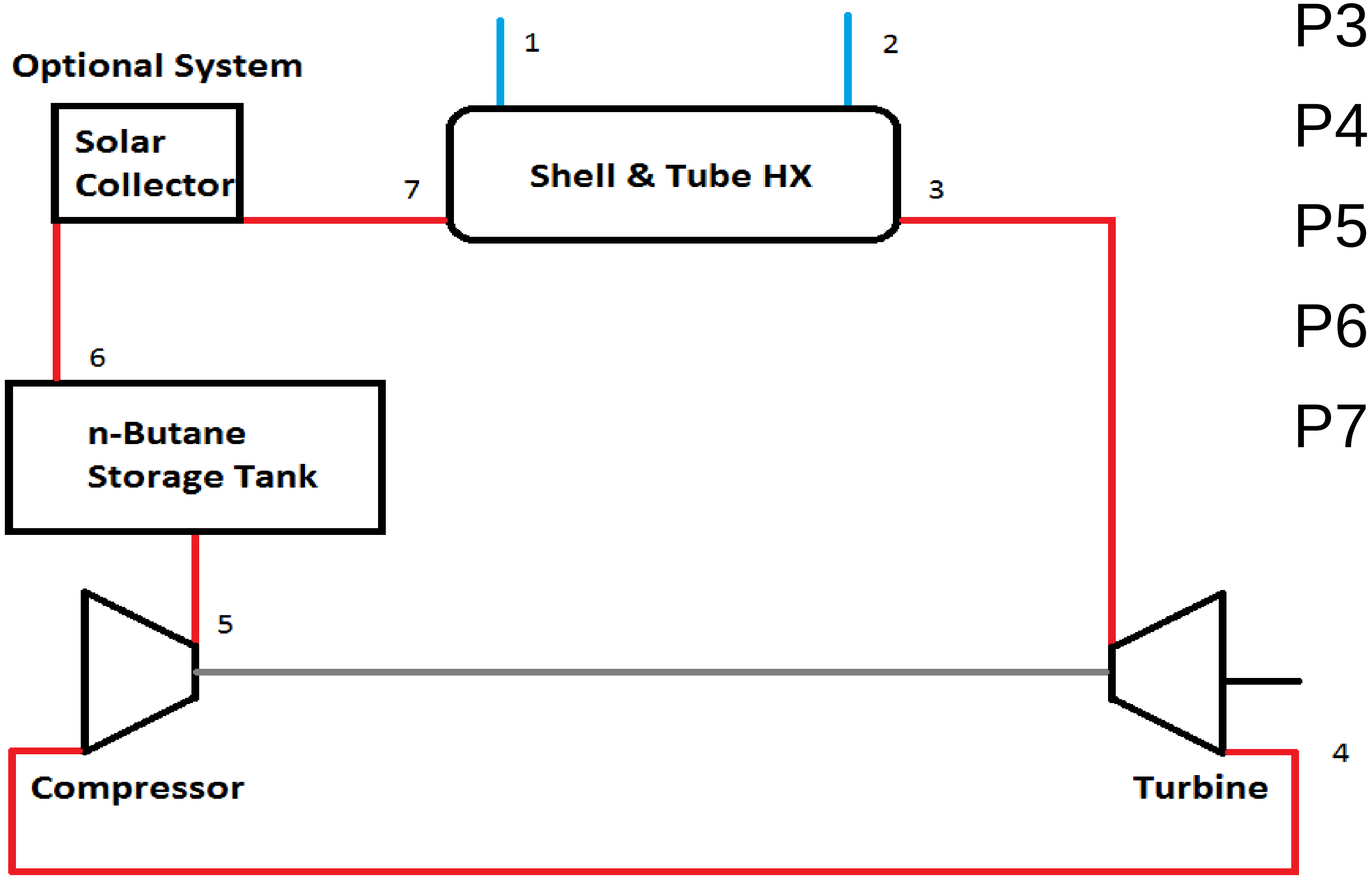


Simulation Plan

- Simulation Design Package includes the following:
  - MATLAB program that allows user to vary several input parameters
    - Engine types running at the center - (ISX, ISB, etc.)
    - Number of engines currently running – (Use average of 50 engines running, though can vary to accommodate more or less engines)
    - External weather conditions – (Low temps in Winter, High in Summer)
    - Output parameters: power, total system efficiency.
  - Pro-E/Solidworks
    - Dimensioned drawings of the piping system and heat exchanger components, visual representations of turbine, compressor, solar collectors.
    - Thermal analysis/FEA
    - Professional looking assembly of system
  - Overall System Cost Analysis

Design Overview

ORC w/ Solar Collectors



Pressures Calculated using MATLAB

P3 = 1.00 MPa

P4 = 0.50 MPa

P5 = 1.10 MPa

P6 = 1.05 MPa

P7 = 1.04 MPa

Working Fluid Selection

	Molecular Weight (g/mol)	Boiling Point (^{O}C)	Wet or Dry	Heat of Vapor @ 1 atm (kJ/kg)
Water	18	100	W	2256
Methanol	32	64	W	1098
2-M-P-H2O	33	93	W	879
Fluorinol 85	88	75	W	442
Toluene	92	110	D	365
R-113	187	48	D	1370
Ammonia	17	-330	D	1370
Isobutane	58	-12	D	367
n - butane	**58**	**-0.4**	**D**	**385**
n - pentane	72	36	D	325

Pipe Material Selection

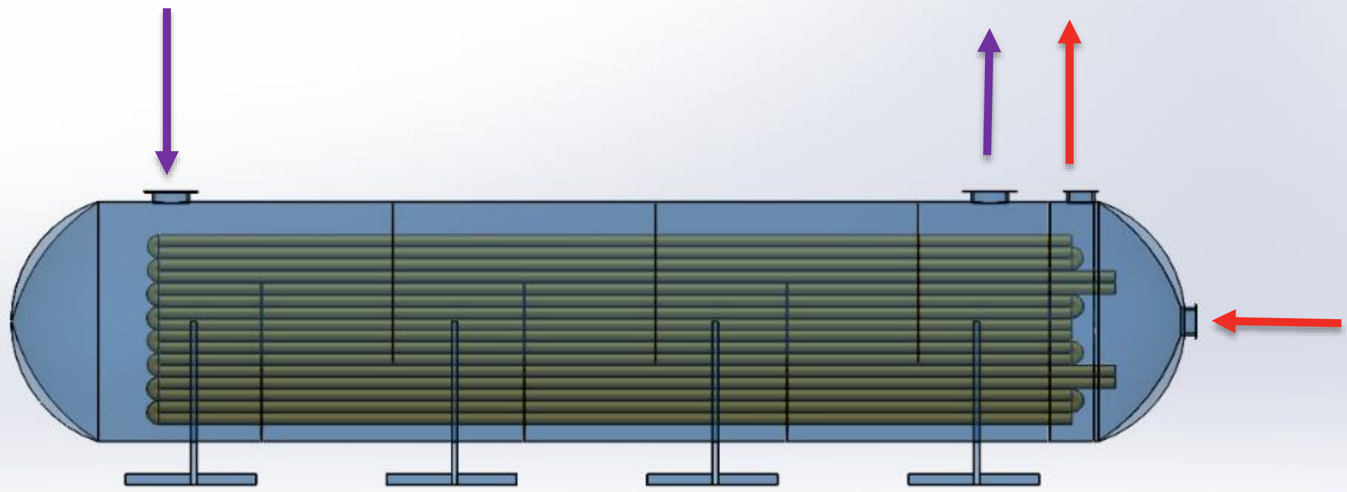
Material	Therm. Cond. k (W/m*K)	Melting T (F)	Density (kg/m^3)
Black steel	43	2600	7850
304 SS	16	2750	8030
Brass	109	1700	8400
Copper	401	1983	8900

Pipe Insulation Selection

Property	Temperature Range (F)	Conductivity k	Density (lb/ft^3)	Safety
Fiberglass	To 500	0.20-0.31	1.5-3.0	Fire Resistant

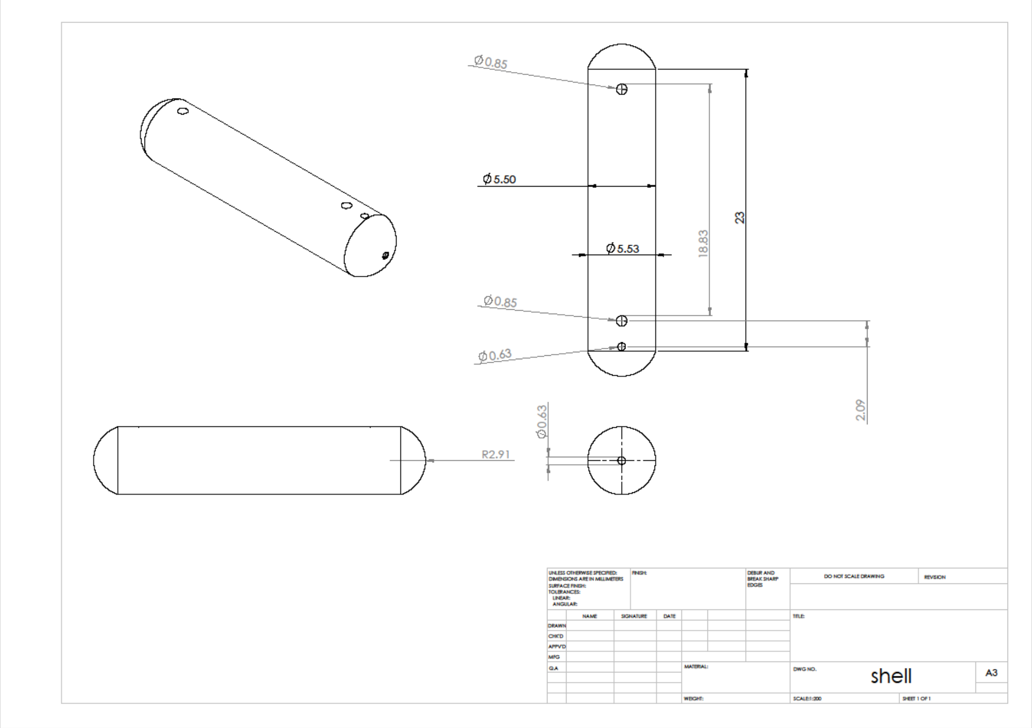
Heat Exchanger

Shell Material: Stainless Steel
Tube Material: Polished Brass



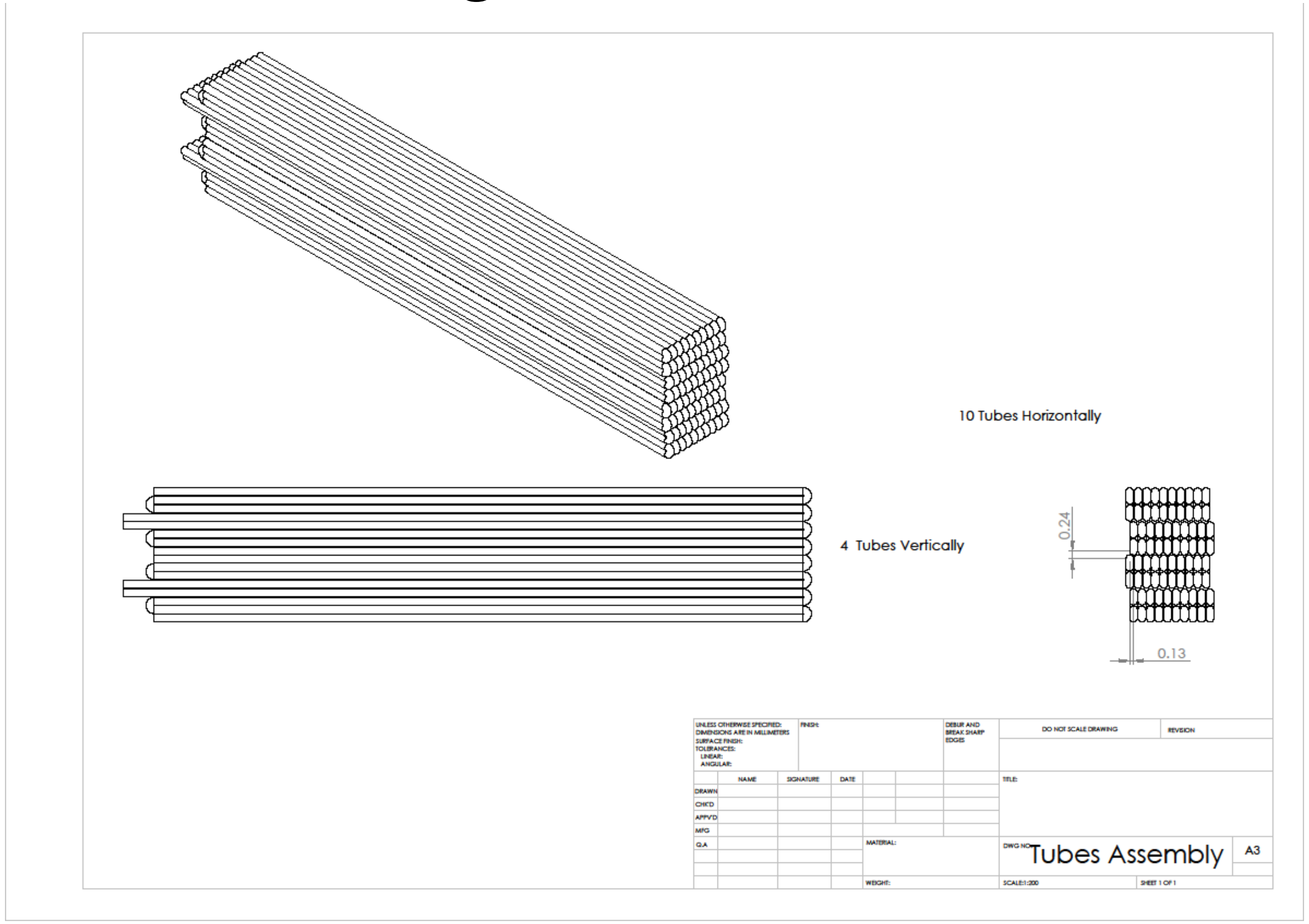
Overall Heat Transfer (kW)	Pressure Drop n-Butane (kPa)	Weight of System (tons)	Velocity of n-Butane (m/s)	Velocity of Exhuast (m/s)
4774	39.9	101.02	32.5	39.6

Heat Exchanger



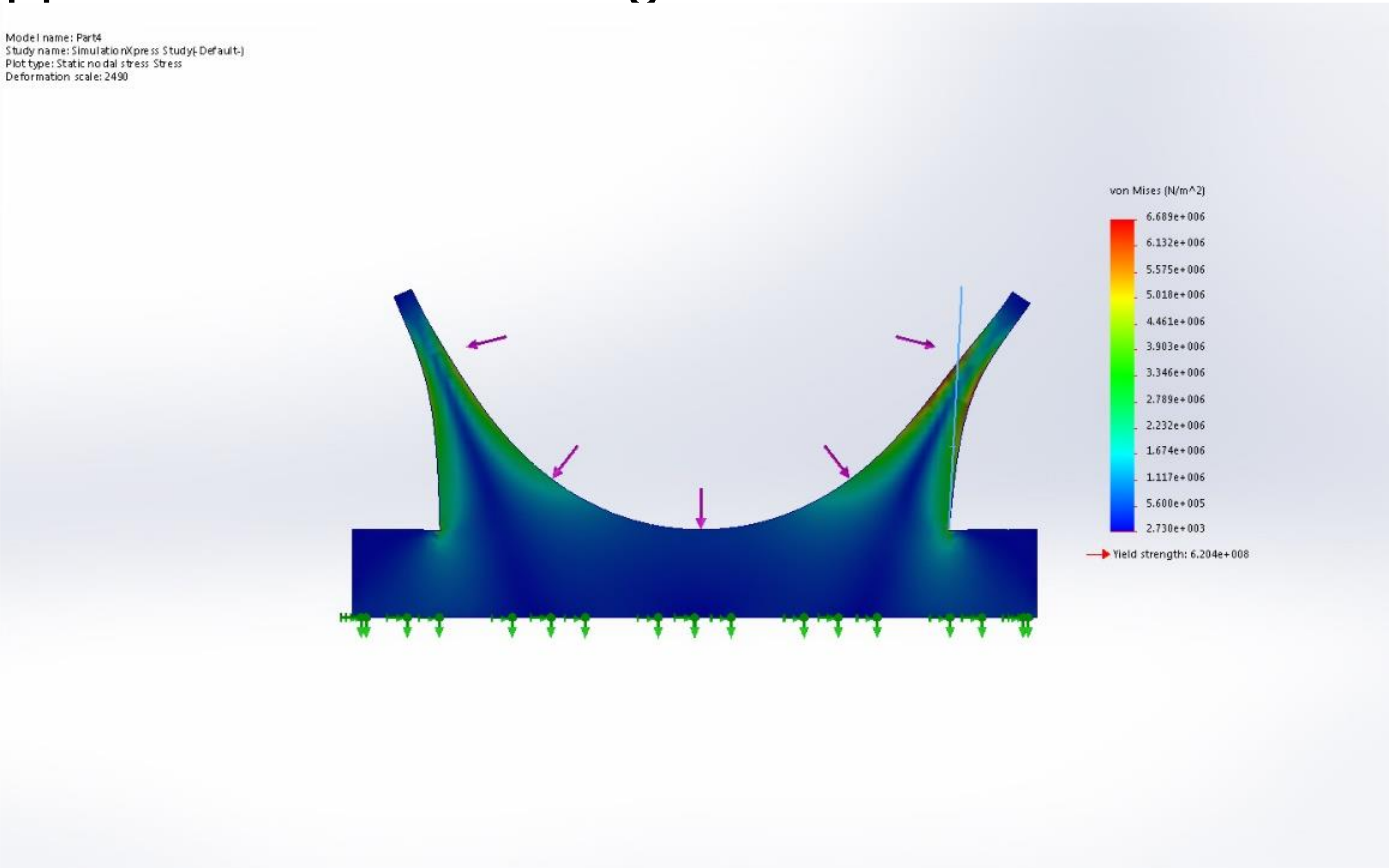
	Shell Parameters
Inner Diameter (m)	5.5
Outer Diameter (m)	5.525
Number of Baffles	7
Baffle Spacing (m)	3

Heat Exchanger



	Tube Parameters
Tube Inner Diameter (mm)	245
Tube Outer Diameter (mm)	250
Clearance Between Tubes(mm)	25
Number of Passes (per Tube)	4
Number of Tubes	40

Supports for heat exchanger



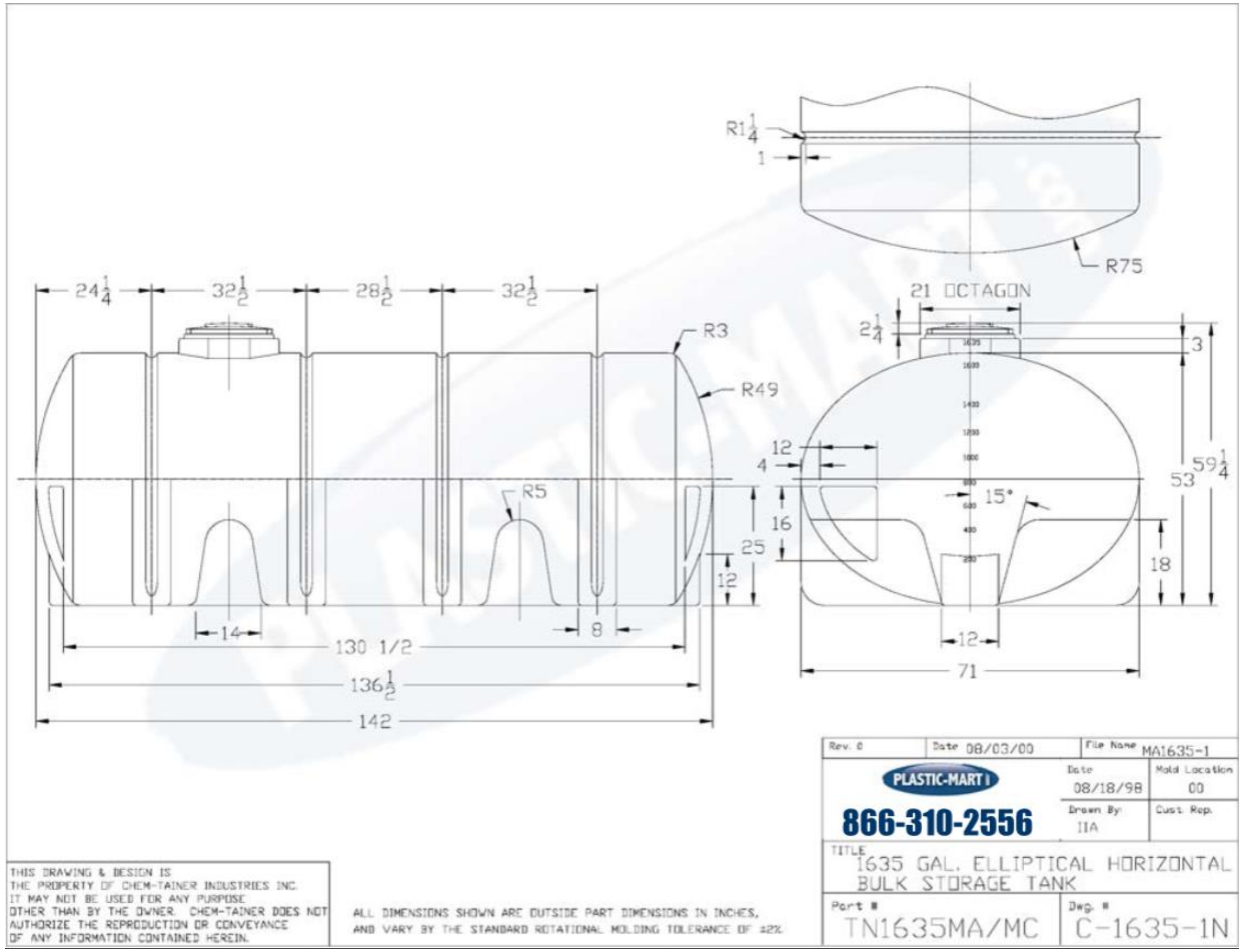
Storage Tank

Details

- Part Number: N-40387
- Mfr. Part Number: 40387
- Capacity: 1635 Gallons
- Dimensions: 142"L x 71"W x 58"H
- Weight: 470 lbs.
- Ships From: CA, GA, MN, OH, OK, TX, UT
- Manufacturer: Norwesco
- Material: Polyethylene
- Price: $1,965.99

Capacity determined by volume of butane needed in heat exchanger.

V = 6.05 m^3 = 1598 gal (Butane in HE)



Turbine/Expander

- **Compact steam turbine for output ranges of up to 6 MW**

Power output	Up to 6 MW
Speed	According to driven machine
Inlet steam pressure	up to 131 bar (a)
Inlet steam temperature	Dry saturated steam up to 530°C

Typical dimensions of the SST-060 series
Length: 1.5 m* / Width: 2.5 m* / Height: 2.5 m*
* Turbine only

SST-060 Series Siemens Steam Turbines

Turbine/Expander

- Temperature Turbine Inlet 145^{O}C
- Ideal gas, $dh = c_p \, dT$
- C_p = 2.2 kJ/kgK [NIST]
- Butane mass flow = 23.79 kg/s [assuming 50 engines, running 24/7]
- Calculated that with ~ 4.7 MW coming in, power output of turbine is **2.35 MW.**
  - 75% efficient turbine system minus compressor losses (-25%) yields a conversion of 50%
- Overall exhaust gas heat provided is 9,319 kW
- Overall system efficiency: = P_gen / P_heat_input = 2.35/9.32

Overall system efficiency = 25%

Turbine/Expander

Overall system efficiency = 25%

Annual energy provided = 2.35 MW * 3600s*24hours*365day/year

Annual energy = 74,109 GJ/year

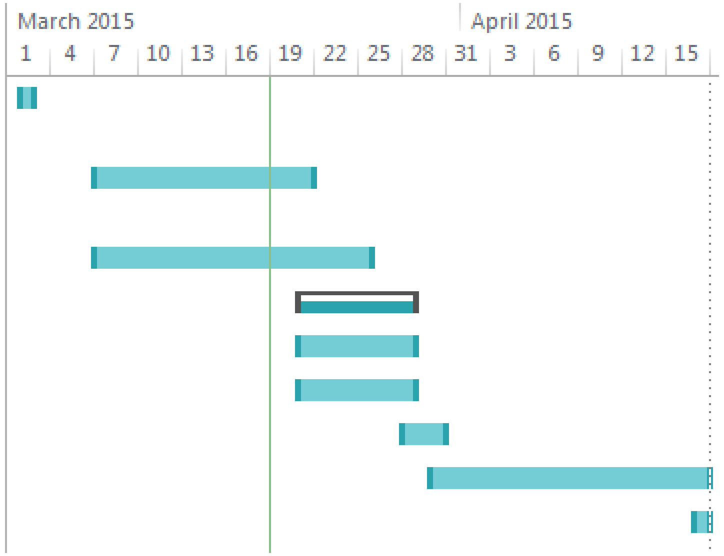
Annual energy consumption = 760,000 GJ/year

Annual energy saved = 9.75%

Future Work

- March 28th: Assembly of system should be finalized with Thermal Analysis/FEA.
- April 2nd: Operation Manual and Design for Manufacturing, Reliability, Economics Due.
- April 10th: Final Report due
- April 17th: Open House/Final Presentations

Task Name	Duration	Start	Finish
Sponser/Advisor Meeting	1 day	Mon 3/2/15	Mon 3/2/15
System Component Design	12 days	Sat 3/7/15	Sat 3/21/15
Simulation Coding	14 days	Sat 3/7/15	Wed 3/25/15
Assembly Analysis	**7 days**	**Sat 3/21/15**	**Sat 3/28/15**
Thermal Anaylsis	7 days	Sat 3/21/15	Sat 3/28/15
FEA	7 days	Sat 3/21/15	Sat 3/28/15
Final System Review	2 days	Sat 3/28/15	Mon 3/30/15
Class Deliverables	15 days	Mon 3/30/15	Fri 4/17/15
Final Presentation	1 day	Fri 4/17/15	Fri 4/17/15



Summary

- Heat Exchanger dimensioned and designed
- Power Output analyzed with total system efficiency
- Pressure drops and temperature changes calculated for each component
- Overall system calculations complete for ORC
- Solar Collector, Compressor portion is underworks

Questions

References

- http://energy.gov/public-services/homes/home-weatherization/home-energy-audits
- http://cumminsengines.com/isx15-heavy-duty-truck-2013#specifications
- http://www.maine.gov/mdot/ofbs/documents/pdf/atrimainereport.pdf
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