Compost Heat Exchanger

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Motivation – With a need to utilize clean, readily available energy, the Compost Heat Exchanger project attempts to assess the difficulties with using compost as a means of heat generation.

Objective – Utilize an existing compost heat exchanger to effectively create a closed loop system for heating a working fluid.

Customer – Wasatch Community Garden

Customer Needs – Mobile compost system capable of supplying a heated working fluid

Prototype:

Tests

- Water was forced through the coil inside the grill which was set to a temperature between 165 - 167°F.
- Temperature and volumetric flow rate were recorded at the outlet.

Results

Experiment #	Initial Water Temperature (°F)	Final Water Temperature (°F)	Ambient Air Temperature (°F)	Coil Length (feet)	Volumetric Flow Rate (mL/min)
1	63.4	66.8	165-167	6.3	220
2	63.5	70.2	165-167	11.2	200
3	63.5	77.2	165-167	74.6	225

Interpretations

- The experiment allowed us to develop a theoretical model of the compost system.

Methods:

Theoretical Model

Our Governing equation for flow inside a pipe with a constant wall temperature.

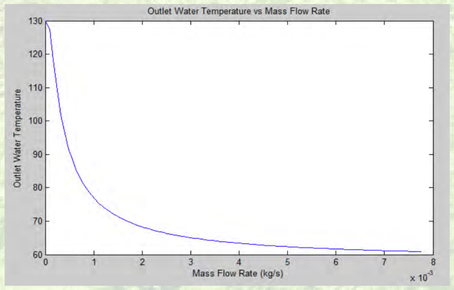
- $\frac{T_{outlet}-T_{compost}}{T_{inlet}-T_{compost}} = e^{-\frac{UA}{\dot{m}c_p}}$

Finding overall Heat Transfer Coefficient:

- $UA = \frac{2\pi r_i}{\frac{1}{\bar{h}_{water\_flow^*}} + \frac{\ln(\frac{r_o}{r_i})}{k_{copper}}}$

Assuming Laminar flow inside a pipe

- $3.66 = \frac{\bar{h}_{water\_flow} D_{inner}}{k_{water}}$



Mechanical Model:

Submersible Pump

- A 12V DC 35 Ah submersible pump was added into the system to allow water to be regulated throughout the system.

Wheels

Specifications

- 8 5” Swivel Caster wheels were welded to the frame of the compost system to provide mobility

Testing

- Tested T-welds that secured the swivel wheels to the system frame using a standard ISTA threshold board.

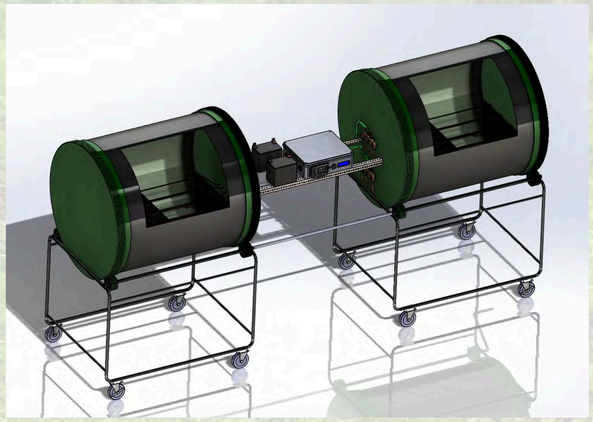
Piping

Specification

- Replaced old garden hose with PEX piping because of its versatile fitting options and permanent connections mitigating the leaks in the system

Testing

- Volume of water lost due to leaks was measured after pumping 1 liter of water through the system.



Electrical Model:

Thermocouples

- Thermocouple shield and additional Arduino were integrated into the system to allow use of 4 temperature measurement devices.
- Each tumbler has a thermocouple housed at the center of the tumbler to allow for continuous compost temperature measurements.
- The remaining two thermocouples were placed at the inlet and outlet of the working fluid.

PID Controller

- Customer can input desired temperature of the outlet working fluid.
- Modulates the pump until desired temperature is achieved.
- Tuned by running multiple system tests and adjusting the proportional, integral and derivative gains depending on the system response.

Results:

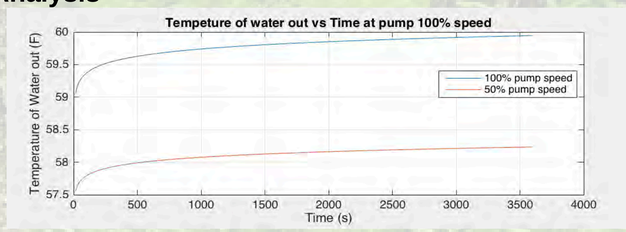
Design Specifications

Description	Goal	Result	Passed/Fail
Welds support system filled with compost.	830 lbs.	850 lbs.	Passed
Water can be heated using system during winter	95°F	59.7°F	Failed
PID error	±2.5°F		
Plumbing leaks	5 mL/L	2.5 ml/L	Passed
Flow rate of closed system	0.424 g/s		

Test Data

Volumetric Flow Rate (mL/min)	Compost Temperature (°F)	Inlet Fluid Temperature (°F)	Outlet Fluid Temperature (°F)
	82	56.4	57.4
	81	58.1	58.7

Analysis



Conclusions:

Our system has the theoretical potential of achieving a final temperature of 95 degrees Fahrenheit when water as the working fluid is pumped at 0.424 grams per second. Due to lack of viable compost, this result could not be confirmed. The PID controller can successfully vary the pump speed as a function of the working fluid temperature with the goal of achieving the target temperature.

Obstacles

- Outside ambient air temperature forces the bacteria to go dormant.
- Compost losing roughly 25 – 30°F during transportation to compost tumblers.

Recommendations

- Further tuning of the PID controller
- Storing the system inside a greenhouse to ensure less heat is lost during compost loading/unloading

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