Residential Grey Water Heat Recovery

Flüggen Industries
Agenda

- Project Recap/Update
- Final Design Selection
- Theoretical Analysis
- Detailed Design
- Procurement
- Model Construction & Testing Plan
- Cost Savings
- Risk, Safety, Sustainability
- Conclusions
Project Recap

- Residential waste water heat recovery unit for preheating potable boiler feedwater
- Mission Statement
  - “To design, develop and test a safe, reliable, and efficient method to recover heat traditionally lost from residential grey water in a manner which reduces the energy costs of a residential building.”
Since last meeting our group has:
- Selected a final concept – coil and tank modules
- Performed theoretical heat transfer calculations
- Initiated detailed design and optimization
- Created a bill of materials and cost estimate
- Established a construction plan and preliminary testing plan

Procurement stage is underway
# Schedule

## Project Schedule

*Fb open Industries*
*Residential Geothermal Heat Recovery Project*

<table>
<thead>
<tr>
<th>Course Deliverables &amp; Milestones</th>
<th>Jan 2 to Jan 8</th>
<th>Jan 9 to Jan 15</th>
<th>Jan 16 to Jan 22</th>
<th>Jan 23 to Jan 29</th>
<th>Jan 30 to Feb 5</th>
<th>Feb 6 to Feb 12</th>
<th>Feb 13 to Feb 19</th>
<th>Feb 20 to Feb 26</th>
<th>Feb 27 to Mar 5</th>
<th>Mar 5 to Mar 11</th>
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<th>Mar 19 to Mar 25</th>
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<th>Apr 2 to Apr 5</th>
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## Project Activities

| Problem Definition                                  |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Project Plan                                        |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Background Research                                 |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Design Criteria and Constraints                    |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Conceptual Design - Generation                     |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Conceptual Design - Assessment and Selection        |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Detailed Design - Graphics & Drafting              |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Solution Evaluation - Theoretical Analysis          |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Solution Evaluation - Model Test Preparation        |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Solution Evaluation - Model Construction & Testing  |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |
| Solution Evaluation - Review                        |                |                |                |                |                |                |                 |                 |                |                |                |                |                  |                |

*Original Schedule* - Planned Correction - Current Week
Success dependant on:
- The effective recovery of heat from wastewater and the transfer of heat to potable boiler feedwater
- Adherence to safe potable water standards
- Require a very efficient and safe device to accomplish this
Final Design Selection

- Concept Design Process
  - Establish design criteria
  - Concept generation and discussion
  - Concept refinement
    - Beneficial aspects of different designs
  - Screening and Evaluation Matrices
- Ensure we have the most attractive design including as many beneficial features as possible
Final Design Selection

- Final concept design
  - Coil and Tank type modular design
Final Design Selection

- Design Features:
  - Modular Design – Increase capacity
  - Coil type module – Simultaneous flow
  - Tank type module – Batch flow
  - Overspill feature in greywater reservoir
  - Potable water tubes/pipes
  - Two layers of separation between grey and potable
  - No potable water joints exposed to greywater
  - Sediment filtration, Pipe trap
Theoretical Analysis - Simultaneous

- Internal flow through coiled copper tube

\[
Nud = \frac{hD}{k} = \left[ \left( 3.66 + \frac{4.343}{a} \right)^3 + 1.158 \left( \frac{Re \left( \frac{D}{C} \right)^{\frac{1}{2}}}{b} \right)^{\frac{3}{2}} \right]^{\frac{1}{3}} \left( \frac{M}{M_s} \right)^{0.14}
\]

\[
a = \left[ 1 + 927 \left( \frac{\frac{C}{D}}{Re^2 \cdot Pr} \right) \right]
\]

\[
b = 1 + 0.477 / Pr
\]

\[
\frac{T_{\infty} - T_{m,o}}{T_{\infty} - T_{m,i}} = \exp \left[ \frac{-U \cdot A}{m \cdot cp} \right]
\]

\[
T_{m,o} = T_{\infty} - (T_{\infty} - T_{m,i}) \cdot \exp \left[ \frac{-U \cdot A}{m \cdot cp} \right]
\]
Theoretical Analysis - Idle

- Define initial conditions
- Calculate initial thermal energy of each state
- Calculate energy transfer rates between states
- Calculate new energy of state after time step
- Set "new" energy of previous time step equal to "old" energy of next time step
- Find temperature vs time of potable and grey water
Detailed Design

- Coil Module in series with tank module as basic GWHR system.
- Working model testing and optimization calculations will be performed to determine the volumes of greywater and potable water in each module that give maximum heat transfer efficiency.
After the dimensions of modules 1 and 2 are determined, calculations and tests will be performed with additional modules in parallel and series.
- Determine domestic hot water loads where additional modules would be beneficial.
Procurement

- Materials to order through MUN
  - ½” Copper tubing (20ft)
  - 3ft 3” ID Copper pipe
  - 2 Reservoirs
  - Tech Services Charges
  - Epoxy
## Vendor List

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<tr>
<th>Vendors</th>
<th>Item</th>
<th>Cost/Length</th>
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<tbody>
<tr>
<td><strong>Kent Building Supplies</strong></td>
<td>Copper 3/4&quot; tube</td>
<td>2.77$/ft</td>
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<tr>
<td></td>
<td>Pex 3/4&quot; tube</td>
<td>80 cents/ft</td>
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<td>Black ABS 3ft @ 4&quot; pipe</td>
<td>7.29$/ft</td>
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<td><strong>Smith &amp; Stockley Plumbing Supplies Ltd</strong></td>
<td>ABS 6&quot; pipe</td>
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<td></td>
<td>Pex 3/4&quot; tube</td>
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<td>Copper 3/4&quot; tube</td>
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<td><strong>Rona</strong></td>
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<td><strong>WaterWorks</strong></td>
<td>HDPE 12&quot; pipe</td>
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<td>15&quot;</td>
<td>49$/m</td>
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<td>18&quot;</td>
<td>62$/m</td>
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<td><strong>Crawford</strong></td>
<td>Pex 3/4&quot; @ 20ft</td>
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<td>Copper 3/4&quot; Type M</td>
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<td></td>
<td>Fittings Various</td>
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## Bill of Materials

<table>
<thead>
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<th>Material</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost ($)</th>
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<tr>
<td>Copper Tube 1/2&quot;</td>
<td>20ft</td>
<td>2.00$/ft</td>
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<td>Copper Pipe 3&quot;</td>
<td>2.5ft</td>
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<td>Resevoir for Sheath Comp.</td>
<td>1 ea.</td>
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<td>Second Resevoir</td>
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<td>City Water Resevoir</td>
<td>1 ea.</td>
<td>DONATION</td>
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<tr>
<td>Hoses and Connectors</td>
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<td>Work Space</td>
<td>Fluids</td>
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<td>Hose Clamps</td>
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<tr>
<td>Epoxy</td>
<td>3 ea.</td>
<td>10$ ea.</td>
<td>$30.00</td>
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**Total: $205.00**
- Preparation for construction underway
  - Testing location: Thermal lab
  - Procurement ongoing
- Model prototype to be constructed for testing
  - Including all features of our design concept (Depending on budget and time constraints)
- Goal is to determine the performance characteristics of our concept
Model Testing Plan

- Testing Preparation
  - Acquisition of tools and materials – Temperature readers, thermocouples, hoses, etc.
- Testing will be used to determine the heat transfer of our device and the energy savings
- Testing plan will include:
  - Setting up equipment
  - Temperatures at different intervals for transient and steady state (Simultaneous and batch flow)
Final arrangement will be determined from a series of tests:
- Series, Parallel setup
- Coil-tank and tank-coil setup
- Increased reservoir size

Testing results analysis to be performed
By comparing with theoretical calculations, this will constitute our device optimization
Governed by the following equation

\[ UEC = \frac{(Use \times TempRise \times SHW \times 365)}{[3413 \times (EF/100)]} \]

- **UEC** = Unit Energy Consumption (kWh/yr)
- **Use** = household hot water use (gallons/day)
- **TempRise** = annual average temperature rise between incoming cold water and tank temperature setting. (F)
- **SHW** = specific heat of water (8.2928 Btu/gallon-F)
- **EF** = energy efficiency factor from DOE test procedure (%85 assumed)
Target cost savings

- Target energy saved 701.05 KW-Hr/Yr
- Target savings registered by end user = 72.91$/year
  - Based on a 10 degree Celsius rise in cold water entering hot water tank.
  - Based on assumed average conditions for Canadian households
Risk, Safety & Sustainability

- Greatest risk to home owner is contamination
  - Two layers of separation between potable water and greywater.
  - No potable water joints exposed to graywater.
  - Leak indicator.
  - Potable water always contained within materials approved by the safe drinking water act.
- Sustainability
  - All materials used are environmentally safe
  - Majority of parts are recyclable.
Look Ahead

- Detailed design (con’t)
- Procurement (con’t)
- Model Construction
- Model Testing
- Testing Analysis
- Optimization
- Project Review
Conclusions

- Project Recap & Update
- Final Design Selection
- Theoretical Analysis – Coil and Tank
- Detailed Design
- Procurement
- Model Construction
- Model Testing Plan
- Cost Savings
- Risk, Safety & Sustainability
Questions?

ResidentialHeatRecovery.weebly.com