PDR Presentation

Los Angeles, California

Architectural Engineer – Marc Sciarrino
Foundation Engineer – Marc Sciarrino
Structural Engineer – Scott Mason
Fluids System Engineer – Matt Owens
Building Thermal Engineer – Tim Christo
Solar Thermal Engineer – Andrew Baglio
PDR Agenda

Introduction
Floor Plan Layout
House Elevation Drawing
Foundation Analysis
Roof Truss Analysis
Hydronic Subsystem Analysis
Building Thermal Analysis
Solar Thermal Analysis
Floor Plan Layout

2nd Floor

- Bedroom or Office
- Bedroom or Office
- Bedroom or Office
- Half bath (possibly a shower stall)
- Over hang to 1st Floor

Dimensions:
- 54.00
- 12.00
- 7.00
- 13.00
- 30.00
- 15.00
- 17.00
- 13.00
- 5.00
- 27.00
- 9.00
House Elevation Drawing
Foundations Analysis

Important Information:

Soil Type: Silty Clay Loam
Dry Soil Density: 0.0462 lb/in$^3$
Frost Line: Approx. 12in
Frost Period: 40-90 days
Water table: > 80in below surface

Assumptions:

The weight of concrete ≈ 145 lb/ft$^3$
The weight of a house ≈ 1000 lb/ft$^2$
Allowable Bearing pressure on soil from the footer = 150kPa ≈ 3135 lb/ft$^2$

Foundations Analysis

Calculations

\[ W_{\text{House}} = \frac{\text{Weight of house}}{\text{ft}^2} \times (\text{Total ft}^2 \text{ of house}) \]

\[ W_{\text{Slab}} = \frac{\text{Weight of concrete}}{\text{ft}^3} \times (\text{Volume of the slab}) \]

\[ \text{Amount of footer needed} = \frac{W_{\text{House}} + W_{\text{Slab}}}{\text{Allowable pressure}} \]

\[
W_{\text{House}} = 3060000 \text{ lb} \\
W_{\text{Slab}} = 147900 \text{ lb} \\
\text{Amount of Footer Needed} \approx 1025 \text{ft}^2
\]
Structural Analysis

- Two common residential truss types
- Fink: Cheap, Common
- Howe: Also common, stronger

Images from www.ufpi.com
Structural Analysis

- Truss Design Factors
  - 6 in 12 roof (26.5°)
  - Asphalt Shingles
  - Douglas Fir Maximum Stress=1700psi in compression, 1668psi in shear
  - Pine Maximum Stress=1200psi in compression, 1438psi in shear
  - Roofing Material weight=4.4lb/sq. Ft
  - 85lb Flat Plate Collectors
  - 2' Truss Spacing

Information from engineeringtoolbox.com
Structural Analysis

- Truss Analysis

- Maximum Stress=415.32psi
- Minimum Factor of Safety=4.09
Structural Analysis

- Recommendation:
  - Use Fink type truss
  - 2x8 top rafters, 2x4 supports, and 2x8 joist
  - Consider pre-made truss from company such as Stone Truss Company
Hydronic System Design

Basic closed loop system with water as working fluid

Advantages
• Easy to install
• Low maintenance
• Efficient heat transfer
• Less dense working fluid
• Less heat loss
• Cheaper

Disadvantages
• Corrosion
• Needs filtration

Reference: www.dmcoles.com

KEY
A - 5 flat plate collectors
B - Hot water from collectors
C - Pump
D - Controller
E - Storage Tank w/ heat exchanger
F - Incoming cold water
### Assumptions
- 5 plat plate collectors
- 2.5 gpm flow rate through FPCs
- 8.2 ft of head loss through heat exchanger

### Results
- Max head = 33.26 ft.

#### Head Loss Analysis

<table>
<thead>
<tr>
<th>Section</th>
<th>Flow Rate</th>
<th>Pipe Diameter</th>
<th>Velocity</th>
<th>Friction Head Loss</th>
<th>Pipe Length</th>
<th># of Equivalent Elbows</th>
<th>Equiv. Length per elbow (ft of pipe)</th>
<th>Total Equiv. Pipe Length (ft of pipe)</th>
<th>Pipe Losses</th>
<th>Change in Elevation (ft head)</th>
<th>Other Losses</th>
<th>Total Losses</th>
<th>Cumul. Head Loss (ft)</th>
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<tbody>
<tr>
<td>Pump</td>
<td>12.50</td>
<td>1.50</td>
<td>2.20</td>
<td>1.50</td>
<td>1.00</td>
<td>0.00</td>
<td>4.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
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<td>Control Valve</td>
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<td>2.20</td>
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<td>10.00</td>
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<td>Reverse Return Pipe</td>
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<td>4.00</td>
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<td>1.00</td>
<td>2.00</td>
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<td>1.00</td>
<td>0.00</td>
<td>4.00</td>
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<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
<td>16.13</td>
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</table>
Pump Selection

- Must overcome max head of 33.26 ft.
- Must provide flow rate of 12.5 gpm.
- Select either UP 26-96F or UP 26-64F
- Put two pumps in series to overcome max head

References:
(1) Sykes Innovative Solutions
(2) www.Grundfos.com
Storage Tank

- 120 gallon tank
- Painted steel exterior
- Glass lined
  - Cheaper
- Cobalt enriched lining
  - Prolonged life
  - Greater durability
  - Expensive
- Foam insulation with R=19
- Internal heat exchanger

Reference: SunMaxx Solar
<table>
<thead>
<tr>
<th><strong>PEX</strong></th>
<th><strong>Copper</strong></th>
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<tbody>
<tr>
<td>Less leaks</td>
<td>Corrosion</td>
</tr>
<tr>
<td>Flexible</td>
<td>Develops leaks</td>
</tr>
<tr>
<td>No knocking</td>
<td>Knocking</td>
</tr>
<tr>
<td>Less fittings</td>
<td>Weather resistant</td>
</tr>
<tr>
<td>Shut-off valves at each supply line</td>
<td>Bacteria resistant</td>
</tr>
<tr>
<td>Can’t be used outside</td>
<td>Unaffected by UV rays</td>
</tr>
<tr>
<td>Can’t be recycled</td>
<td>Recyclable</td>
</tr>
<tr>
<td>Cheaper</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

Reference: http://www.plumbingnetworks.com/info/pex-copper/
Window & Door Placement: 1st Floor

- Tank Room
- Master Bedroom
- Master Bathroom
- Laundry Room
- 1.5 Car Garage
- Kitchen Area
- Living Room
- Doors
Window & Door Placement: 2nd Floor

- Bedroom or Office
- Bedroom or Office
- Half bath (possibly a shower stall)

Dimensions:
- 17.00
- 13.00
- 5.00
- 9.00
- 5.00
- 12.00
- 7.00
- 7.00
- 54.00
- 13.00
- 30.00
- 15.00
Wall Cross Section

- Gypsum (t = \(\frac{1}{2}\)”, 4’ x 10’, $8.55)
- Studs (t = 5.5”, 2” x 6” x 8’, $3.43)
- Insulation
  - t = 5.5”, 5.5” x 15” x 93”, R = 21, $44.75
  - t = 5.5”, 5.5” x 23” x 93”, R = 21, $58.82
Wall Cross Section

- Plywood (t = 15/32”, 15/32”x4’x8’, $12.47)
- Siding (t=.042”,12.5’x8”.042”,$128/24 pieces)
Windows & Doors

• Windows (31.25” x 49.25”, U = .3, $164)
• Front Door (36” x 80”, U = .23, $329)
• Back Door (72” x 80”, U = .29, $676)
• Side Door (36” x 80”, U = .15, $139)
Assumptions

• Roof R-value is 38.
• Installation costs are not included.
• Worst case scenario: $T_{\text{summer}} = 105 \, ^\circ\text{F}$, $T_{\text{winter}} = 25 \, ^\circ\text{F}$, $T_{\text{inside}} = 70 \, ^\circ\text{F}$.

http://www.laalmanac.com/weather/we01.htm
## Design Analysis

<table>
<thead>
<tr>
<th>West Wall:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Wall Length (ft):</td>
<td>30</td>
</tr>
<tr>
<td>Wall Height (ft):</td>
<td>18</td>
</tr>
<tr>
<td># of Windows:</td>
<td>2</td>
</tr>
<tr>
<td># of Doors:</td>
<td>1</td>
</tr>
<tr>
<td>Total area (ft²):</td>
<td>540</td>
</tr>
<tr>
<td>Window Area (ft²):</td>
<td>21.37586806</td>
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<tr>
<td>Door Area (ft²):</td>
<td>20</td>
</tr>
<tr>
<td>Stud Area (ft²):</td>
<td>45.32946654</td>
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<tr>
<td>Insulation Area (ft²):</td>
<td>453.2946654</td>
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<tr>
<td>fraction area of windows:</td>
<td>0.039584941</td>
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<tr>
<td>fraction area of doors:</td>
<td>0.037037037</td>
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<tr>
<td>fraction area of studs:</td>
<td>0.083943457</td>
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<tr>
<td>fraction area of Insulation:</td>
<td>0.839434566</td>
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<tr>
<td>Stud U-value (Btu/(h<em>ft²</em>F)):</td>
<td>0.114706996</td>
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<tr>
<td>Insulation U-value (Btu/(h<em>ft²</em>F)):</td>
<td>0.038046145</td>
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<tr>
<td>Window U-value (Btu/(h<em>ft²</em>F)):</td>
<td>0.3</td>
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<tr>
<td>Door U-value (Btu/(h<em>ft²</em>F)):</td>
<td>0.15</td>
</tr>
<tr>
<td>Total U-Value (Btu/(h<em>ft²</em>F)):</td>
<td>0.058997189</td>
</tr>
</tbody>
</table>

http://knovel.com.ezproxy.rit.edu/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=2554&VerticalID=0
Design Analysis

15” Insulation
- UA = 315.14 Btu/(h*F)
- $Q_s = -11029.8$ Btu/h
- $Q_w = 14181.1$ Btu/h
- P = $27,097.87$

23” Insulation
- UA = 306.59 Btu/(h*F)
- $Q_s = -10,730.6$ Btu/h
- $Q_w = 13,796.5$ Btu/h
- P = $22,117.87$
Flat Plate Collectors

5 Collectors

Sol 25 Plus

## F-Chart

### Water Storage House Heating System

<table>
<thead>
<tr>
<th>Location</th>
<th>LA CROSSE MUNICIPAL ARPT WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water volume / collector area</td>
<td>2.20 gallons/ft^2</td>
</tr>
<tr>
<td>Building UA (0 if only DHW)</td>
<td>321 Btu/hr-FF</td>
</tr>
<tr>
<td>Fuel</td>
<td>Gas</td>
</tr>
<tr>
<td>Efficiency of fuel usage</td>
<td>90.00 %</td>
</tr>
<tr>
<td>Domestic hot water)</td>
<td>Yes</td>
</tr>
<tr>
<td>Daily hot water usage</td>
<td>65.0 gallons</td>
</tr>
<tr>
<td>Water set temperature</td>
<td>130.0 F</td>
</tr>
<tr>
<td>Environmental temperature</td>
<td>68.0 F</td>
</tr>
<tr>
<td>UA of auxiliary storage tank</td>
<td>3.12 Btu/hr-F</td>
</tr>
</tbody>
</table>

### Flat-Plate Collector

| Number of collector panels | 5 |
| Collector panel area       | 27.93 ft^2 |
| FR*UL (Test slope)         | 0.755 Btu/hr-ft^2-F |
| FR*TAU*ALPHA (Test intercept) | 0.660 |
| Collector slope            | 47 degrees |
| Collector azimuth (South=0) | 0 degrees |
| Incidence angle modifier calculation | Glazings |
| Number of glass covers     | 1 |
| Collector flowrate/area    | 14.950 lb/hr-ft^2 |
| Collector fluid specific heat | 1.00 Btu/lb-F |
| Modify test values         | No |

Economics

Cost per unit area 35 $/ft^2
Area independent cost 2000.00 $
Price of natural gas 0.41 $/100ft^3
Annual % increase in natural gas 12.0 %
Period of economic analysis 30 years
% Down payment 100 %
Annual mortgage interest rate 6.0 %
Term of mortgage 30 years
Annual market discount rate 4.0 %
% Extra insur. and maint. in year 1 0.0 %
Annual % increase in insur. and maint. 8.0 %
Eff Fed.+State income tax rate 30.0 %
True % property tax rate 1.5 %
Annual % increase in property tax 2.5 %
% Resale value 100.0 %
% Credit rate in tier 1 30.0 %
Maximum investment in tier 1 15000

tax credits
http://www.energystar.gov/index.cfm?c=tax_credits.tx_index
http://tonto.eia.doe.gov/dnav/ng/hist/n3010ca3a.htm

cost of nat gas
http://www.socalgas.com/residential/prices/table
Questions?