

Ground-Source Heat Pump Coil Optimization

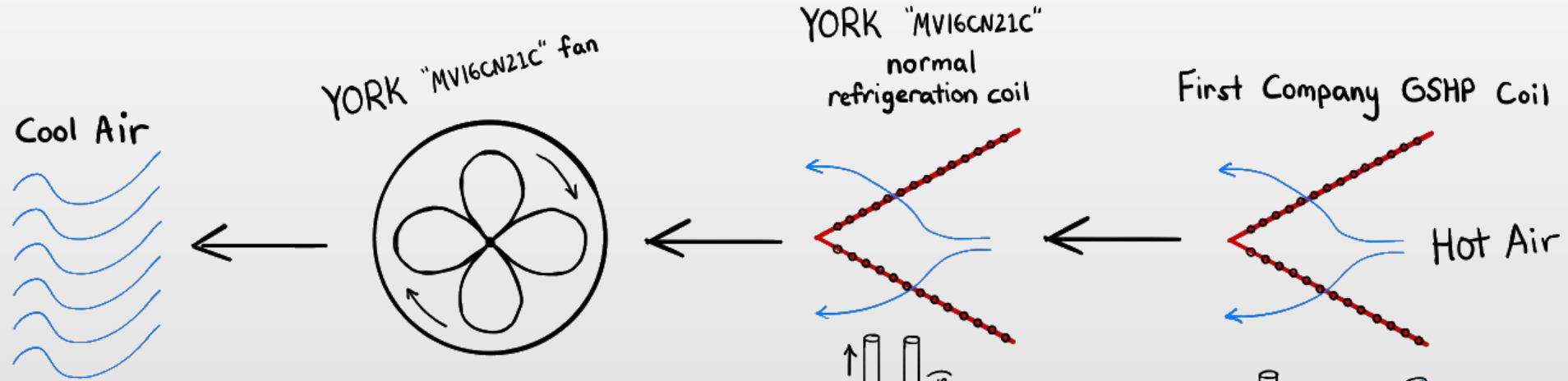
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for: MATH 319



Airflow Diagram

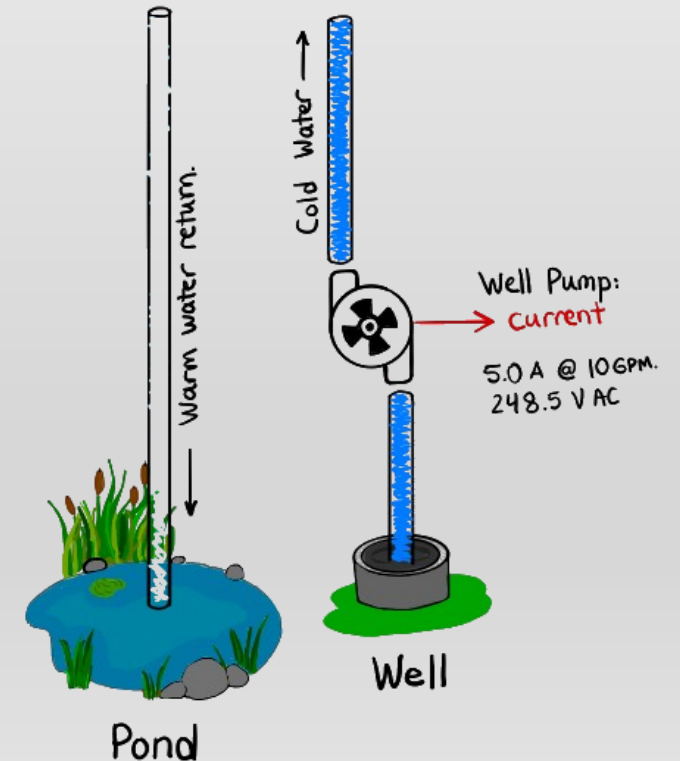
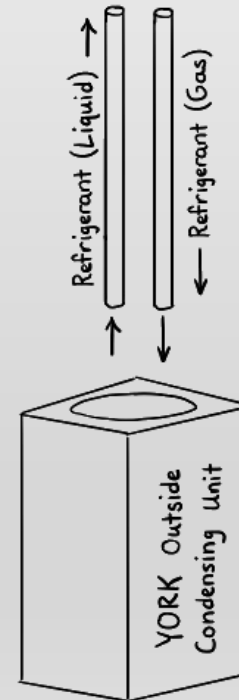


1. Simplistic model (no pump startup cost)

$$C_{pump} = 2.070833 \cdot 60 \cdot (GPM)$$

2. Advanced model (w/ pump startup cost)

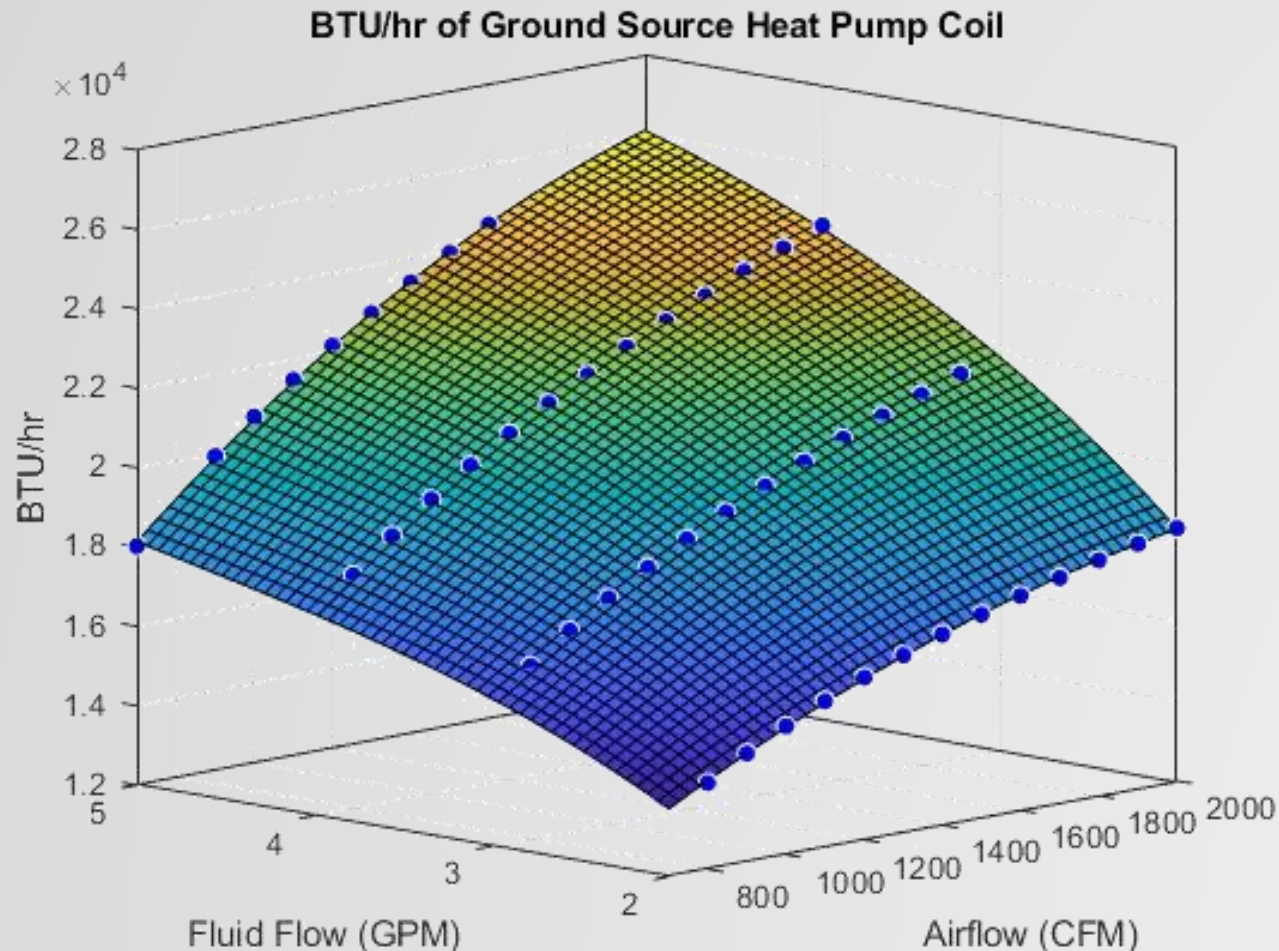
$$C_{pump} = 500 \times \frac{(GPM)(10 - GPM)}{6.0383} + 2.070833 \cdot 60 \cdot (GPM)$$



System Characterization



BALTIMORE
AIRCOIL COMPANY



The heat transferred from the coil is:

$$\begin{aligned} Q_{coil}(\bar{x}) = & -0.102(CFM)^2(GPM) \\ & -0.0005(CFM)(GPM)^2 \\ & +1.7 \cdot 10^{-6}(GPM)^3 - 63.21(CFM)^2 \\ & +2.948(CFM)(GPM) - 0.0846(GPM)^2 \\ & +15.766(GPM) + 2328.35 \end{aligned}$$

System Characterization

We seek to minimize:

$$\min \quad J(\bar{x}) = \frac{C_{fan}(\bar{x}) + C_{pump}(\bar{x})}{Q_{coil}(\bar{x})}$$

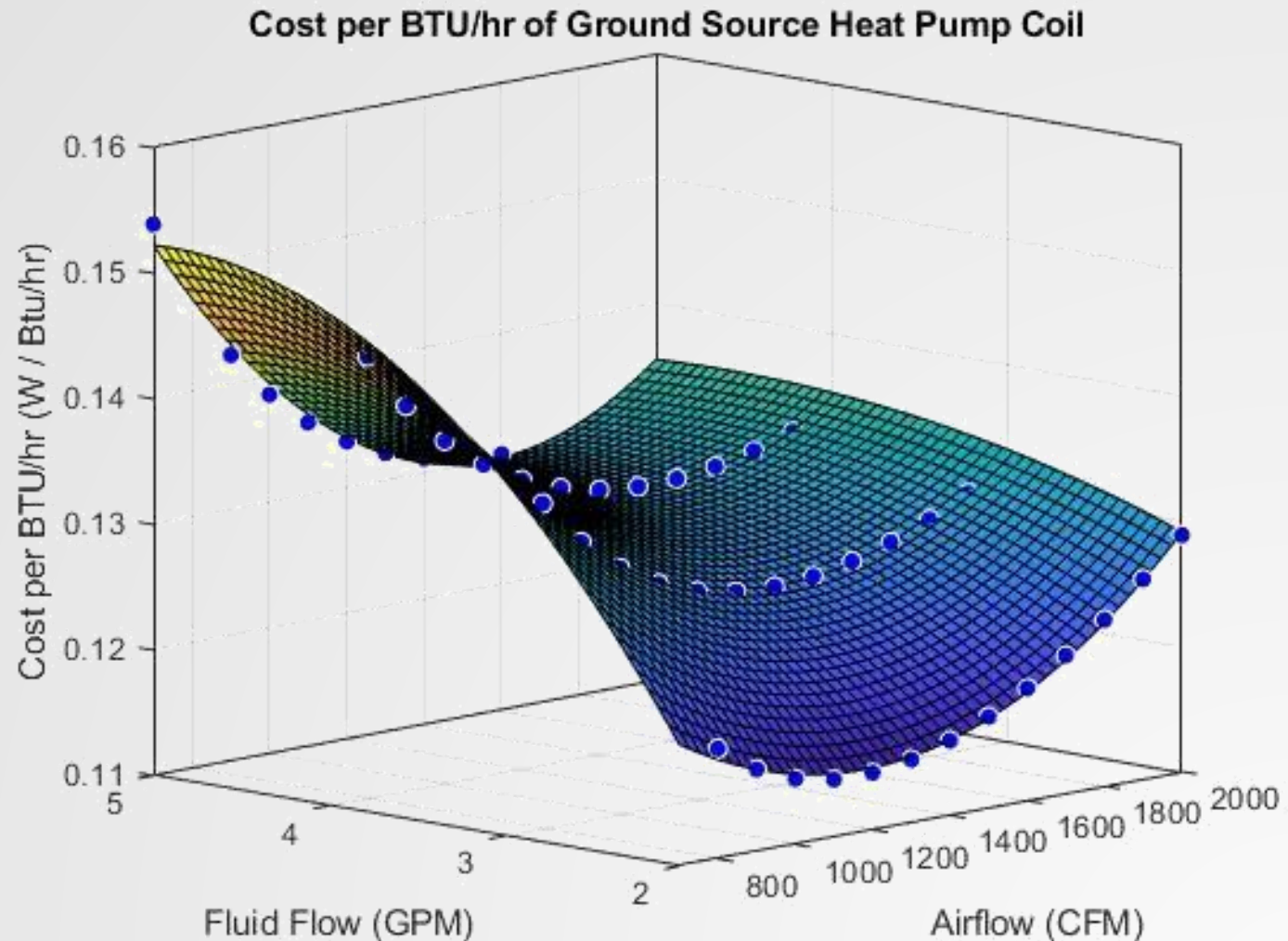
$$\text{w.r.t.} \quad \bar{x} = \{CFM, GPM\}$$

$$\text{s.t} \quad Q_{coil}(\bar{x}) \geq 18,000$$

$$688.5 \leq CFM \leq 1524$$

$$0 < GPM \leq 5$$

where $J(x)$ is the cost function in W / Btu/hr, and $C_{fan}(x)$, $C_{pump}(x)$, and $Q_{coil}(x)$ are defined as shown to the right.



Algorithm Selection and Analysis Tool

Key criteria used when selecting the optimization algorithm:

- Repeatable convergence to optimum value.
- Ease of use.
- Low computational demand.

! GRG ! (generalized reduced gradient)
aka... the method of feasible directions.

Advantages:

- Fast convergence
- Implemented in Excel.

Disadvantages:

- Dependent on IC's
- Needs smooth, continuous functions.

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Options

Help Solve Close

Solver
What-if analysis tool that finds the optimal value of a target cell by changing values in cells used to calculate the target cell.

Optimization Results

Our optimization led to a constrained minimum of:

$$J(\bar{x}) = 0.1198 \text{ W/(Btu/hr)} \quad \text{located at:}$$

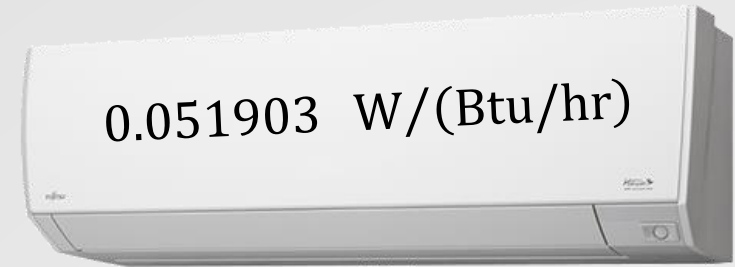
$$\bar{x} = \{1518.95, 2.308\}$$

Assumptions made:

1. Efficiency of coil.
2. Pump starting power.

No startup power: $J(\bar{x}) = 0.031965 \text{ W/(Btu/hr)}$
(pressurized system)

Breakeven point: $W_0 = 78.42 \text{ W}$



0.11812 W/(Btu/hr)



Questions?

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or.... message me on teams.

