

# Design of a Hot Glue Pot for First Year Engineering Lab

Gerald Recktenwald

[gerry@pdx.edu](mailto:gerry@pdx.edu)

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Problem/opportunity: Design a device to keep hot glue in a molten state for dipping





# Project Objective Statement

Buy or design, fabricate and test a small (8-12 oz.) pot for melting hot glue ( $\sim 121^{\circ}\text{F}$ ) for a prototyping cost of \$300 by 8 June 2018.

# Client/Market Requirements

## Primary requirements

1. Safe
2. Melts glue quickly
3. Auto startup/shutdown
4. Cleanable
5. Adjustable temperature, but not by ordinary user
6. User controls: On/Off, light(s) to indicate activity
7. Economical



# External Search



Darice 115-62 40W  
\$7.30  
one temperature  
shallow



Surebonder 805 4" dia  
\$9.41  
one temperature  
shallow

# External Search



Brentwood 6" Electric Skillet  
Adjustable, large footprint  
\$11.68



Hold Heet Electric glue pot  
One temperature  
\$135



# External Search



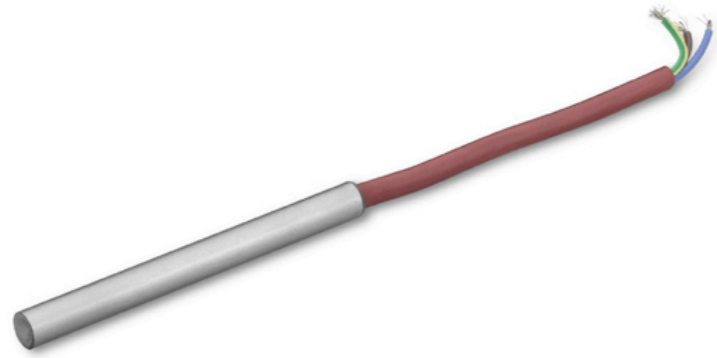
Hamilton Beach 33101 Party Dipper  
Fixed temperature, doesn't melt glue  
\$17.99

# Summary of benchmarking

Product	Source	Price	Pro/con	Features	Amazon rating	N rating
Darice 115-62 40W	Amazon	\$ 7.30	small, shallow	one temperature	3.3/5	57
Surebonder 805 4" dia. Glue skillet	Amazon	\$ 9.41	small, shallow	Fixed temperature	3.6/5	31
Surebonder 802 7" dia electric glue skillet	Amazon	\$ 35.99	too large? shallow	Temperature control 40W 380F max temperature	4.1/5	61
Brentwood 6" Electric Skillet Model SK-45	Amazon	\$ 11.68	too large? shallow	Ajustable temperature	3.2/5	174
Hold Heet Electric Glue Pot (1 Quart)	Amazon	\$ 134.99	too large?	Fixed thermostat Removable glue pot Designed for woodworking	5/5	1
Hamilton Beach 33101 Party Dipper Food Warmer	Amazon	\$ 17.99	Doesn't melt	Fixed temperature	4.1/5	333



# External Search: Cartridge Heaters



Next Thermal Cartridge heaters



National Plastic Heater, Sensor  
& Control inc.

# Preliminary Engineering Model:

## How fast can it heat up?

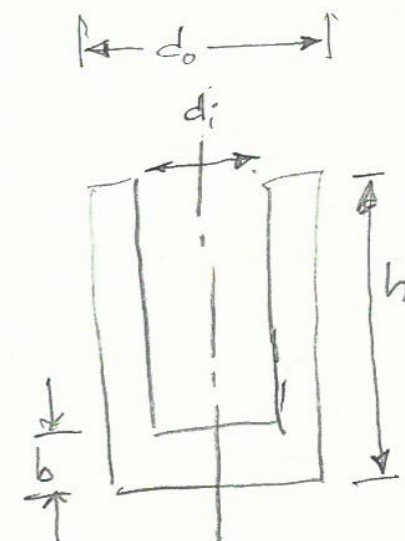
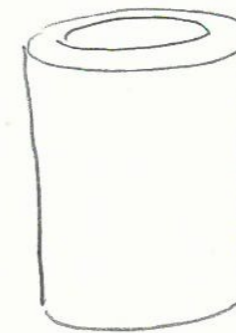
### Sizing of Heater for Hot Glue Pot

Assume that the glue pot is made of a highly conductive metal

Goal is to heat the metal from  $T_i$  to  $T_f$  in a desired time interval  $\Delta t$ . The average heating rate is

$$Q = \frac{mc(T_f - T_i)}{\Delta t} \quad (1)$$

$m = \rho V$  = mass of metal  
 $V$  = volume of metal  
 $c$  = specific heat of metal  
 $T_f$  = final temperature = steady operating  $T$   
 $T_i$  = initial temperature  
 $\Delta t$  = time it takes glue pot to heat up



$$\begin{aligned} V &= \frac{\pi}{4}(d_o^2 - d_i^2)(h - b) \\ &\quad + \frac{\pi}{4}d_o^2 b \\ &= \frac{\pi}{4}d_o^2 h - \frac{\pi}{4}d_i^2(h - b) \end{aligned}$$



# Preliminary Engineering Model:

How fast can it heat up?

Example: Schedule 40 Aluminum pipe, nominal 1.25 inch for a pipe, use  
the operating  
temperature

$$d_o = 1.66 \text{ inch} = 4.216 \text{ cm}$$
$$d_i = 1.38 \text{ inch} = 3.505 \text{ cm}$$

choose  $b = 0.25 \text{ inch} = 0.635 \text{ cm}$ ,  $h = 2.5 \text{ inch} = 6.35 \text{ cm}$

$$V = \frac{\pi}{4} \left[ (4.216 \times 10^{-2} \text{ m})^2 (6.35 \times 10^{-2} \text{ m}) - (3.505 \times 10^{-2} \text{ m})^2 (6.35 \times 10^{-2} \text{ m} - 0.635 \times 10^{-2} \text{ m}) \right]$$
$$V = 4.266 \times 10^{-5} \text{ m}^3$$
$$V = 3.35 \times 10^{-5} \text{ m}^3$$
$$M = \left( 2700 \frac{\text{kg}}{\text{m}^3} \right) (3.35 \times 10^{-5} \text{ m}^3) = 0.0905 \text{ kg} \quad (91 \text{ g})$$

↖ density 6061-T6 Al

# Preliminary Engineering Model:

## How fast can it heat up?

2/

Sizing of Heater for Hot Glue Pot (continued)

$\Delta t = 10 \text{ min} = 600 \text{ s}$

$T_i = 20^\circ\text{C}$

$T_f = 135^\circ\text{C}$  (low temperature hot glue melts at  $121^\circ\text{C}$ )

$Q = (0.0905 \text{ kg}) \left( 896 \frac{\text{J}}{\text{kg}\cdot\text{C}} \right) \left( \frac{130 - 20^\circ\text{C}}{600 \text{ s}} \right)$

$Q \approx 15 \text{ W}$

instead use  $\Delta t = 5 \text{ min} = 300 \text{ s} \Rightarrow Q \approx 30 \text{ W}$

Use DC Power

$Q = \frac{V^2}{R}$        $12 \text{ V}$        $R = \frac{V^2}{Q} = \frac{144 \text{ V}^2}{30 \text{ W}} = 4.8 \Omega$



# Preliminary Engineering Model

Heater\_sizing\_hot\_glue\_pot.xlsx

## ME 122 Design Problem

Size the heater for a new hot glue melting pot

### Formulas

$$\text{Heater power} = Q = m \cdot c \cdot (T_f - T_i) / \Delta t$$

$$\text{Mass of metal} = m = \rho \cdot V$$

$$\text{Volume of metal} = V = (\pi/4) \cdot (h \cdot d_o^2 - (h-b) \cdot d_i^2)$$

Properties of 6061-T6 Aluminum from <http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6>

$\rho$	2.7 g/cm <sup>3</sup>	2700 kg/m <sup>3</sup>
$c$	0.896 kJ/kg/C	896 J/kg/C

### Glue melting parameters

$T_i$	20 C
$T_f$	130 C
$\Delta t$	10 min

initial temperature = room temperature

operating temperature = 10C + melting point of low temp hot glue, which is approx 121 C

<https://www.hotmelt.com/blog/high-temp-hot-melt-vs-low-temp-hot-melt>

Standard sizes for Alum <https://www.onlinemetals.com/merchant.cfm?id=73&step=2>

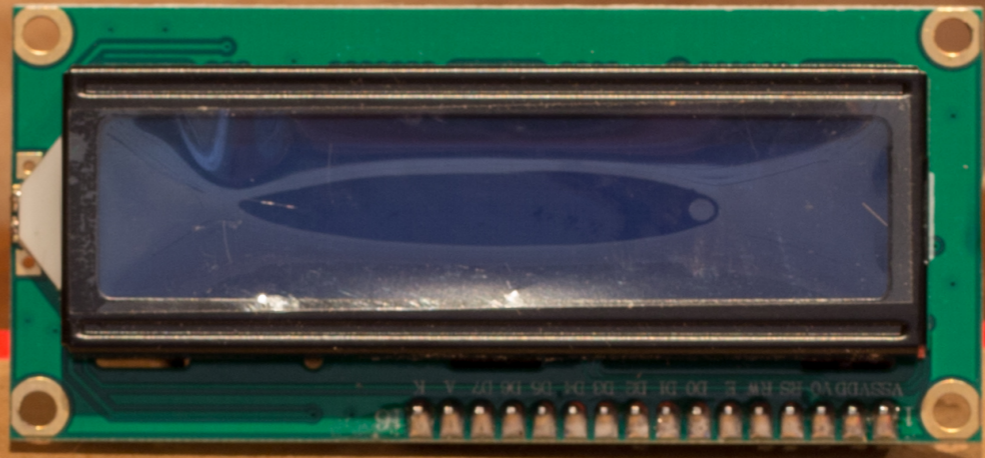
Schedule 40:

Nominal	$d_o$	$d_i$
1.25"	1.66	1.38
1.5 incl	1.9	1.61

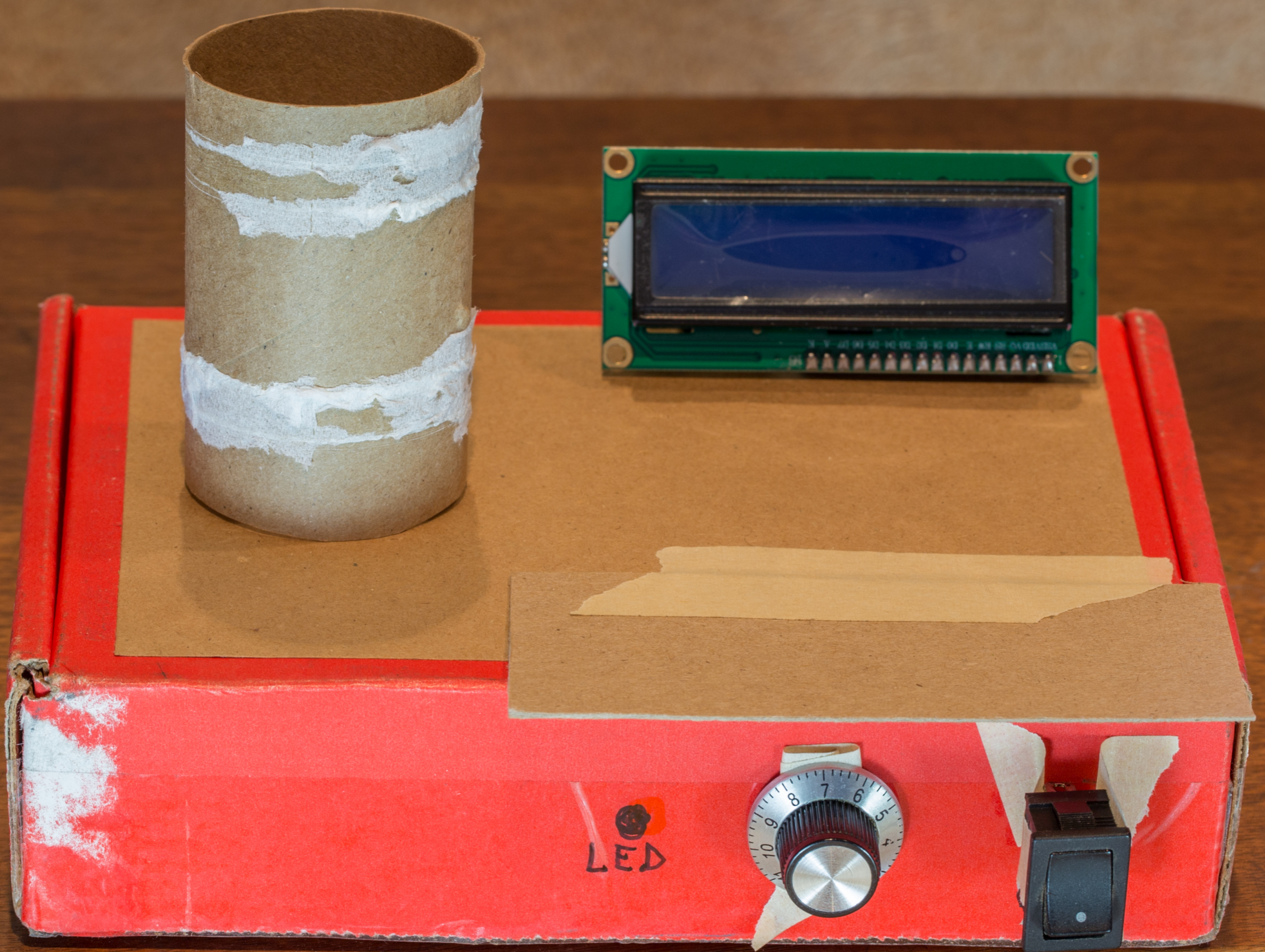
$d_o$ (in)	$d_i$ (in)	$h$ (in)	$b$ (in)	$V$ (in <sup>3</sup> )	$V$ (m <sup>3</sup> )	$m$ (kg)	$Q$ (W)
1.66	1.38	2.5		0.25	2.04525536	3.35157E-05	0.09049247
							14.9

# Conceptual Prototypes









LED





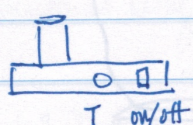
# Concept Sketches

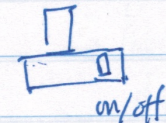
# Design Concepts

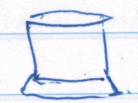
2017-07-16  
Detailed Design


Glue Hot Pot - Design Case Study

Conceptual Design

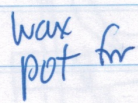
1a  problem: student will turn up heat when impatient and burn the glue

1b  can use alternative shapes

2 External search  hacked heater for pot potini ⇒ shifts design problem to selection of heater

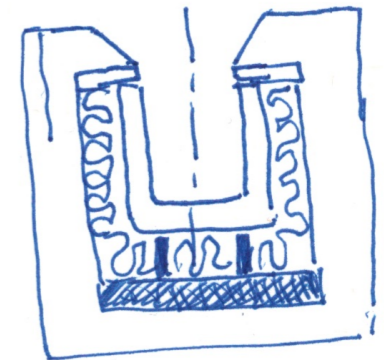
3  small crock pot - smallest is 2 quart  

$$\frac{2 \text{ cup}}{\text{pint}} * \frac{2 \text{ pint}}{\text{quart}} * 2 \text{ quart} = 8 \text{ cups}$$

4  wax pot for hair removal  
 @ Amazon 100W, 500 mL ≈ 16.91 oz  
 ≈ 2 cups

5 existing hot plate modify heating element to limit temperature

unheated, sloped lid  
 safety & cleaning feature



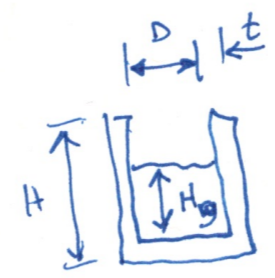
criteria

- minimize heat loss
- minimize surface temperature of exposed surfaces

parameter optimization

- well thickness,  $t$
- $D$
- $H/D$
- $H_g$  = depth of glue
- Heater design

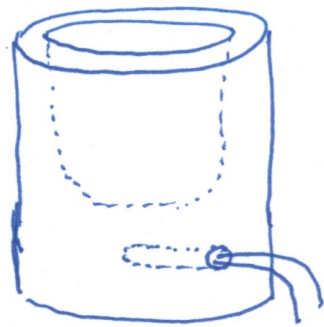
Analysis: heat up time



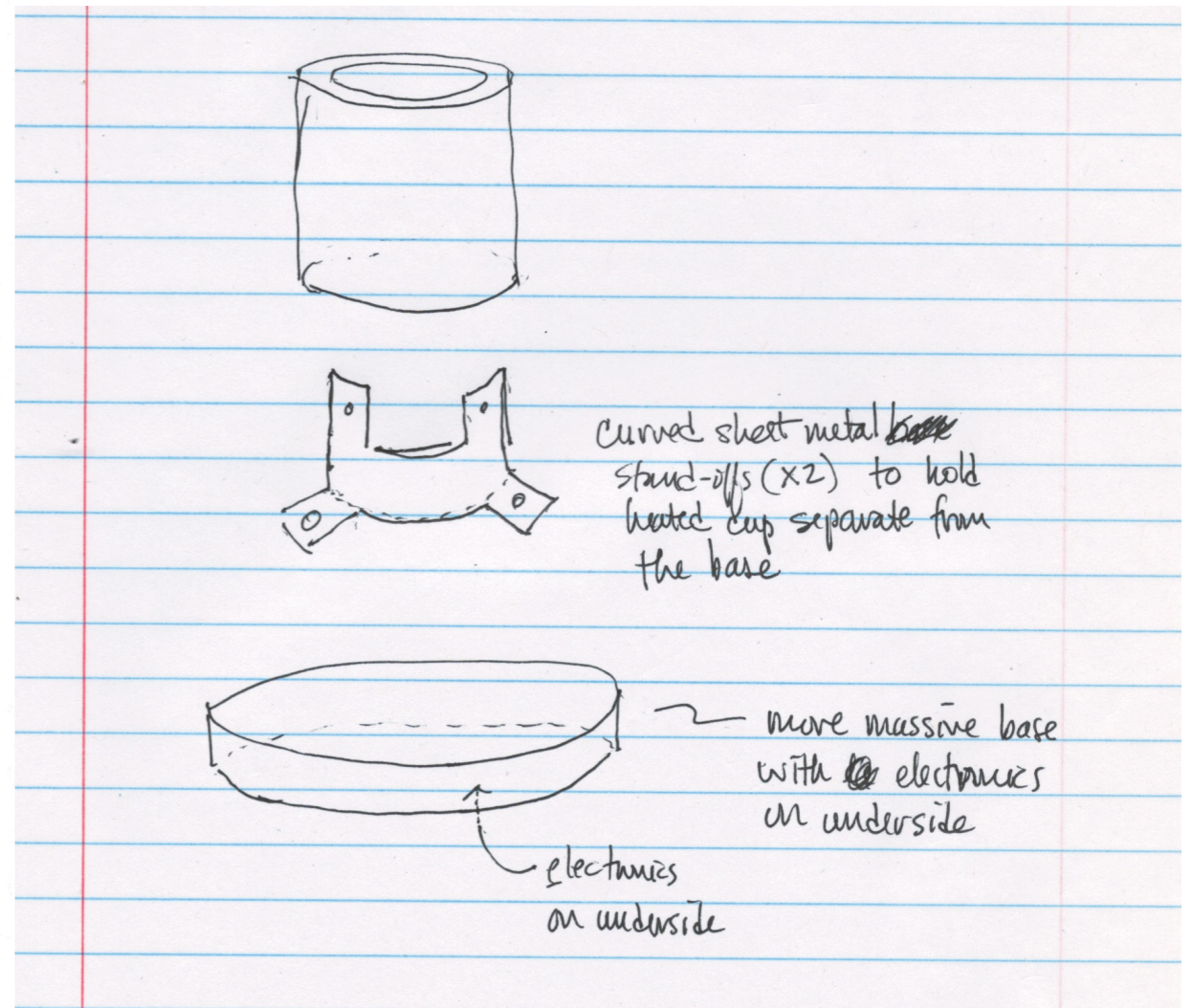


# Design concepts

Minimal footprint base

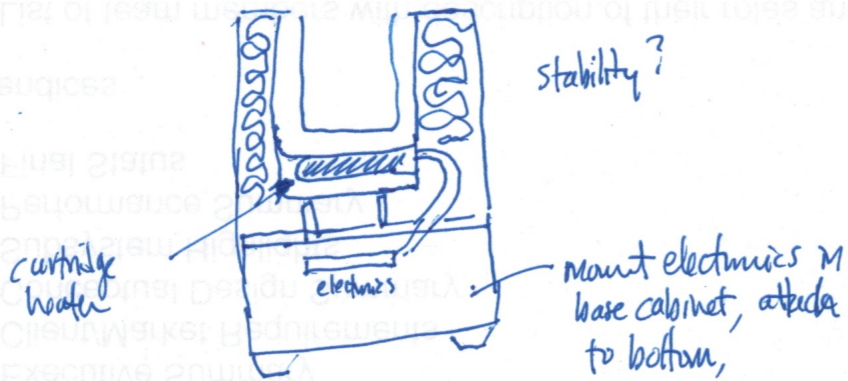


bent sheet metal support  
- holds heated cup securely  
while minimizing conductive  
conduction

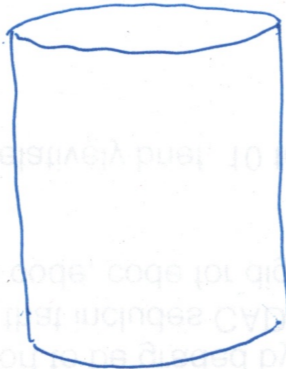


# Design concepts

minimal footprint



Sheet metal skin  
- slides down, over the guts



how is insulation attached to guts so that cover slides freely? - air gap is good, how to make sure sheet metal is snug (not wobbly)



base contains electronics, switcher

how to connect heater wires?

glue pot is attached to base

insulation is attached to glue



# Design concepts

Alt design of ~~sheet~~ sheet metal cup holder

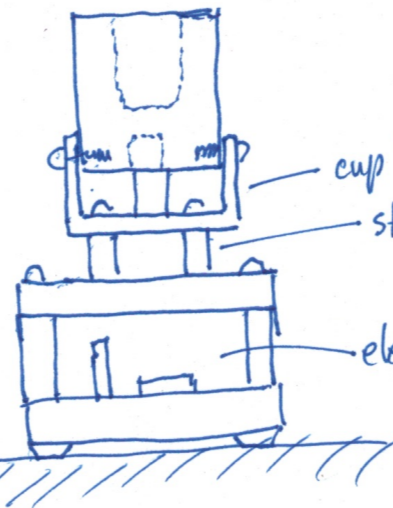
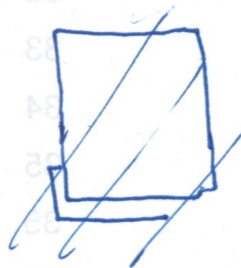


tabs  
fold up



screws secure  
cup holder to  
cup

metal stand-offs provide  
additional separation and  
reduced heat flow path



cup holder  
stand-offs  
electronics



# Design concepts

