UITF Buncher Heater System

Power required, warm up time and heater Element/system wiring design analysis.

Inputs:

Heater Elements: 10 Elements 350W@120V

Buncher: $13\frac{5}{16}" \times 13\frac{5}{16}" \times 8\frac{9}{16}"$ Copper Block

Calculate heater Element Resistance

$$R_e = \frac{V^2}{P}$$

$$R_e = \frac{120^2 V}{350 A}$$

$$\boxed{R_e = 41.14\ \Omega}$$

Calculate current with 120V across terminals

$$I = \frac{V}{R}$$

$$= \frac{120\ V}{41.14\ \Omega}$$

$$\boxed{I_{e120} = 2.92\ A}$$

Determine Bunder Mass

$V = H \times W \times L$

$= 13.3125'' \times 13.3125'' \times 8.5625''$

$= 1517.5\ in^3$

$V = 1517.5\ in^3 \times 2.54^3 \frac{cm^3}{in^3}$

$\boxed{V_B = 24,867\ cm^3}$

Assume the cavity is $\approx$ 10% of total Volume

Volume of Copper

$V_{cB} = V_B \times 0.9$

$\boxed{V_{cB} = 22380\ cm^3}$

Mass of Bunder

$M_B = \rho_{Cu} \times V_{cB}$

$= 8.95\ g/cc \times 22380\ cm^3$

$= 200,303\ g$

$\boxed{M_B = 200\ kg}$

Analyze Energy Needed to warm Bunder to operating temp

$T_{amb} = 70°F$

$T_{opp} = 180°F$

$\Delta T = 110°F$

$\boxed{\Delta T = 61°C}$

Specific Heat of Copper

$C_p = 384 \frac{J}{Kg\,°C}$

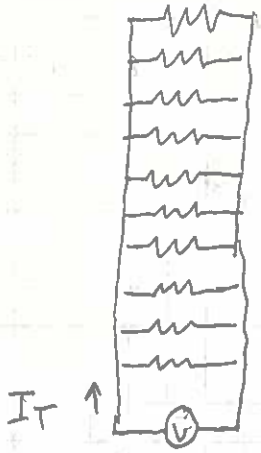
$Energy = M \times \Delta T \times C_p$

$= 200\,Kg \times 61°C \times \frac{384\,J}{Kg\,°C}$

$\boxed{E_{wu} = 4.68\ E6\ J}$

Analyze Heater Array as presently wired

All heaters in parallel



$Q_T = n \; Q_{HE}$

$= 10 \times 350\,W$

$\boxed{Q_T = 3500\,W}$

$I_T = n \times I_{e120}$

$= 10 \times 2.92$

$\boxed{I_T = 29.2 \quad A}$

* To provide 29A at 120 Volt will require two separate circuits or a special transformer and 10 gauge wires

Analyze warm up time

$$T_{wu} = \frac{E_{wu}}{Q_T}$$

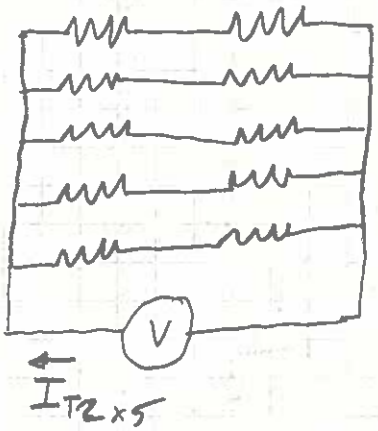
$$= \frac{4.68\,E6\,J}{3500\,\frac{J}{s} \quad \frac{60\,s}{min}}$$

$\boxed{T_{wu} = 22.3 \text{ minutes}}$

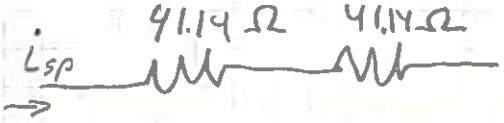
* Probably much faster than Needed

Propose New wiring arrangement

Wire 5 sets of 2 heaters in series



Analyze 2 heaters in series



$$R_{s2} = R_e + R_e$$

$$\boxed{R_{s2} = 82.28\ \Omega}$$

Current in series pair

$$i_{sp} = \frac{V}{R_{s2}} = \frac{120\,V}{82.28}$$

$$\boxed{I_{sp} = 1.46\ A}$$

$$I_{T2\times5} = 5 \times I_{sp}$$

$$\boxed{I_{T2\times5} = 7.3\ A}$$

Power in each Series pair

$P_{sp} = V \times I$

$= 120 \times 1.46$

$\boxed{P_{sp} = 175.2\ W}$

Total power of the 5 series pairs

$Q_{Tsp} = P_{sp} \times 5$

$\boxed{Q_{Tsp} = 876\ W}$

Warm up time with No heat loss (ie insulated) for series pair wiring

$$T_{wusp} = \frac{E}{Q_{Tsp}}$$

$$= \frac{4.68\,E6\ J}{876\ W}\ \frac{60\ sec}{min}$$

$\boxed{T_{wusp} = 89\ minutes}$

Summary:

I suggest the system be wired with 5 series pairs of heating elements. This will reduce the current draw of the system. It will also reduce the peak temperature of each heater element which will increase its lifetime.

Warm up time of 90 minutes should be acceptable