Lens Electrode Baking

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Preparation of the high voltage electrodes for the lens involves electropolishing, cleaning and baking. To perform the last step, I made a small bakeout chamber from a long nipple, wrapped in heater tape. Inside the nipple are a couple of PEEK pieces which hold the electrode in the centre of the nipple. The glass transition temperature of PEEK is 416 K so we should keep the nipple temperature below that.

I wanted to work out how long it would take for the electrode to thermally equilibrate to the surrounding nipple.

The net thermal energy flow for the electrode is given by the radiated heat absorbed from the surrounding bath (the nipple) minus the heat radiated from the electrode. We can write that, using the Stefan-Boltzmann law as:

$$P_{\text{in}} - P_{\text{out}} = \sigma \epsilon_{\text{electrode}} A_{\text{electrode}} (T_{\text{nipple}} - T^4), \tag{1}$$

where σ is the Stefan-Boltzmann constant, $\epsilon_{\text{electrode}} \approx 0.075$ is the emissivity of the electrode (polished stainless), $A_{\text{electrode}} = \pi \times 0.025 \text{ m} \times 0.6 \text{ m} = 0.05 \text{ m}^2$ is the surface area of the electrode, $T_{\text{nipple}} = 400$ K is the temperature of the nipple (constant), and T is the temperature of the electrode (the thing we want to know).

The power and the temperature of the electrode are related according to the heat capacity, $C = 500$ J/K/kg and mass, $M = 2.3$ kg:

$$E = CM \ \ dT, \tag{2}$$

so the power is given by

$$P = dE/dt = CM \ \ dT/dt. \tag{3}$$

Thus we can write

$$\dot{T} = \sigma \epsilon_{\text{electrode}} A_{\text{electrode}} (T_{\text{nipple}} - T^4)/CM. \tag{4}$$

We can then solve this equation to find the dynamics: Here we have ignored heat which is conducted through the

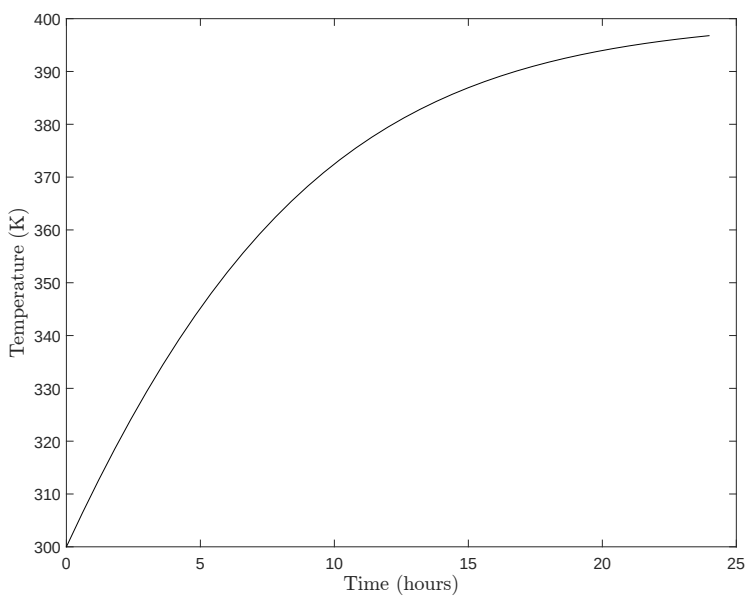

Figure 1: Electrode temperature as a function of time whilst being baked inside a 400 K nipple.

PEEK mounts to the electrode, assuming it to be negligible; the time required is thus a conservative estimate. We see it takes around a whole day to reach the temperature of the nipple.

In practice, this equilibration happens much more quickly — after heating an electrode in the nipple for around 3 hours, it was found to be approximately equilibrated. Additionally it was found that the mounting scheme where the electrode is held in peak rings inside the nipple was quite cumbersome, causing the electrode to knock against the nipple during insertion and removal. It was decided instead to slide the electrode in and out whilst sitting on aluminium foil. This was much more gentle, still prevented the electrode being scratched, and also allowed conduction of heat from the nipple, so we can be sure it would equilibrate quickly.