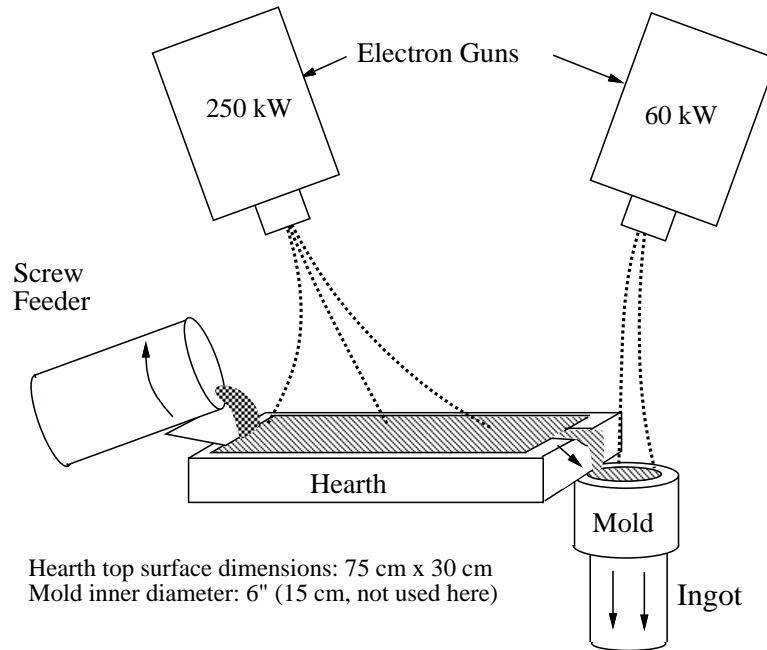


1. Titanium nitride inclusion removal in an electron beam melting hearth (35 pts)



In the sponge titanium fed into an electron beam melting furnace, there are porous titanium nitride inclusions (solid high-melting point particles) with a variety of sizes and densities.<sup>1</sup> Those with significantly lower density than the molten metal will rise to the surface and be swept back by surface tension gradient forces and held until they dissolve; those with higher density will sink to the bottom and dissolve there. Assume that inclusions enter the hearth uniformly mixed with the metal.

In the hearth, the maximum liquid titanium depth is 5 cm, the total liquid titanium volume is 8750 cm<sup>3</sup>, and the flow rate is 22  $\frac{\text{cm}^3}{\text{sec}}$ .

- (a) Use the Sphlow Java applet to calculate the shape of the regions in diameter-density space in which all, 75%, and 50% of the particles are removed. Provide a printout of a graph with all three curves, with a maximum diameter of 5 mm and density range which shows the curves clearly. (Java applets sometimes do not print well from the browser, so you may need to use a screen grabbing utility.)

Sphlow Java HTML front-end: <src/sphlow/sphlow.html>

- (b) In an actual hearth, there is a vertical component to the flow; also flow is not uniform. For this reason, some particles have shorter residence time than others. As a conservative estimate, change your critical velocities above by a factor of five, and redo the calculations in part 1a.
- (c) Using a dissolution rate of 0.15 mm/min, calculate the maximum particle size which is guaranteed to dissolve completely within the average residence time under the assumptions in part 1a.
- (d) As the particles dissolve, their diameter decreases, and their terminal velocities change. Explain how this will affect your answers above, in terms of the sizes and numbers of inclusions you would expect to survive through the process.

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<sup>1</sup>The density of titanium nitride is 5.2 vs. liquid titanium's 4.1, but the inclusions are porous, so their average density varies from 5.2 down to as low as 2.