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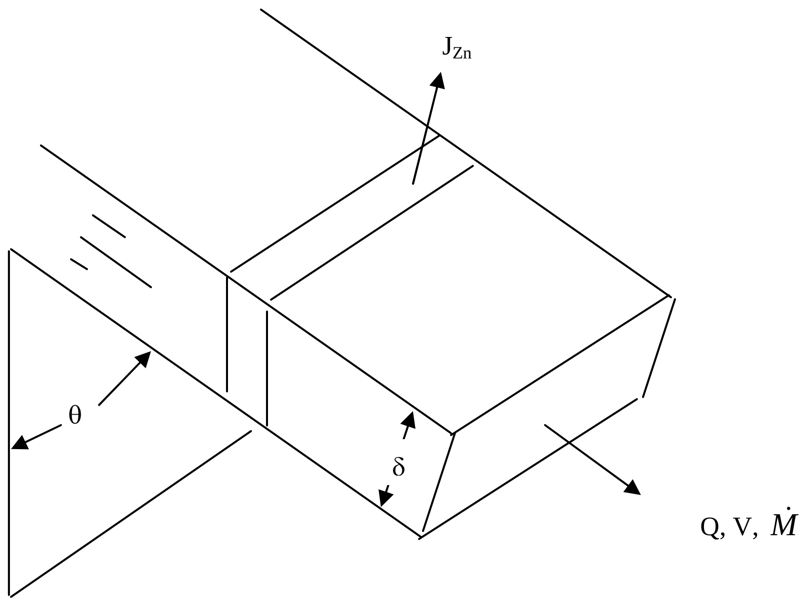
Vacuum Dezincer Inclined Plane Zn Mass Balance

A film of Pb-Zn alloy flows down an inclined plate as show below.



Performing a rate of mass balance for Zn on a packet moving down the an inclined plate gives

$$\text{In} - \text{Out} + \text{Gen} = \text{Acc} \tag{1}$$

$$-A * J_{Zn} = \frac{\rho A \delta}{100\%} \frac{d(\%Zn)}{dt} \tag{2}$$

where the mass vaporization rate is

$$J_{Zn} = a_{Zn} P^{\circ}_{Zn} \sqrt{\frac{MW_{Zn}}{2\pi RT}} = x_{Zn} \gamma^{\circ}_{Zn} P^{\circ}_{Zn} \sqrt{\frac{MW_{Zn}}{2\pi RT}} \approx \frac{wt\%Zn * MW_{Pb}}{100\% * MW_{Zn}} \gamma^{\circ}_{Zn} P^{\circ}_{Zn} \sqrt{\frac{MW_{Zn}}{2\pi RT}} \tag{3}$$

Combining Eqs. [2] and [3] and rearranging gives

$$dt = -\frac{\sqrt{2\pi RTMW_{Zn}}\,\rho\delta}{\gamma^{\circ}_{Zn} P^{\circ}_{Zn} MW_{Pb}}\, d\ln(wt\%Zn) \tag{4}$$

which may be integrated to give

$$t = \frac{\sqrt{2\pi RTMW_{Zn}}\,\rho\delta}{\gamma^{\circ}_{Zn} P^{\circ}_{Zn} MW_{Pb}} \ln \frac{(wt\%Zn)_i}{(wt\%Zn)_f} \tag{5}$$

where t is the time for the packet to flow down the plate. The volumetric flow rate down the plate is given by

$$Q = \frac{\rho g \delta^3 W \cos\beta}{3\eta} \tag{6}$$

This may be used to determine the velocity down the plate as

$$V = \frac{Q}{W\delta} \tag{7}$$

that in turn may be used to determine the time for flow down the plate

$$t = \frac{L}{V} = \frac{LW\delta}{Q} \tag{8}$$

Eq. [8] may be expressed in terms of mass flow rate $\dot{M} = Q\rho$.

$$t = \frac{LW\rho\delta}{\dot{M}} \tag{9}$$

Equating Eqs. [5] and [9] then gives the surface area of the inclined plate needed to reduce the wt % Zn given the system parameters appearing in Eq. [5].

$$LW = \frac{\dot{M}\sqrt{2\pi RTMW_{Zn}}}{\gamma^{\circ}_{Zn} P^{\circ}_{Zn} MW_{Pb}} \ln \frac{(wt\%Zn)_i}{(wt\%Zn)_f} \tag{10}$$

or

$$LW = \frac{\dot{M}\sqrt{2\pi RTMW_{Zn}}}{\gamma^{\circ}_{Zn} P^{\circ}_{Zn} MW_{Pb}} \ln\left[\frac{x_{Zn,i}}{x_{Zn,f}}\right] \tag{11}$$

It is important to check that the Zn back flux arising from the pressure of pure Zn from the solid-liquid interface is small compared to the Zn flux from the alloy at its finished composition. If this is not the case, than the pressure of Zn in Eq. [3] must be modified to the difference between the Zn pressure from the alloy and the pressure of pure Zn at the melting point. Eq. [10] would then have to be reformulated to take this modification into account.

Nomenclature

A = Melt Surface Area

a_{Zn} = Activity of zinc

β = Angle of the plate from the vertical

δ = Film thickness

γ°_{Zn} = Activity coefficient of zinc

L = Plate length

$\dot{M}$ = Mass flow rate

MW_i = Molecular weight of i

Q = Volumetric flow rate

ρ = Density of the Pb – Zn alloy

R = Gas constant

t = Time

T = Temperature of the gas phase

V = Velocity of the film down the plate

W = Plate width