**Class 7**  
Material and Energy Balances – Recycle and Purge  
Wednesday, September 8th

**Why recycle?**
- Not all of the reactants are consumed in the reaction, and reactants cost money.
- Recovery of catalyst
- Dilution of a process stream
- Circulation of a process variable
- Control of a process variable

Consider an evaporation-crystallization process. The fresh feed to the process contains 19.6 wt % K₂SO₄. The wet filter cake consists of solid K₂SO₄ crystals and a 40 wt% solution in a ratio 10 kg crystals/kg solution. The filtrate, also a 40 wt% solution is recycled to join the fresh feed. Of the water fed to the evaporator, 45.0 % is evaporated. The evaporator has a maximum of 175 kg water evaporated. Find the fresh feed rate, the production rate of crystals, and the ratio of the recycle to the fresh feed.
Fresh feed: $m_1$
Production rate of crystals: $10 \text{ m}_2$
Recycle ratio: $m_3/m_1$

Which will give you zero degrees of freedom?

a) Around the evaporator
b) Overall
c) At the mixing point
d) Around the crystallizer

Strategy:
Overall to find $m_1$ and $m_2$

$$m_1 = \frac{78 \times 11}{6} \text{ m}_2 - \text{overall}$$
$$m_1 = 22 \text{ kg/s} - \text{overall}$$
$$m_2 = 4.16 \text{ kg/s}$$

Strategy:
% evaporation to find $m_5$

$$m_5 = 78 \text{ kg/s}$$
$$m_5 = 389 \text{ kg/s}$$
Why Bypass a Stream?

By varying the fraction of the feed that is bypassed, we can vary the composition and properties of the product.

For example: Fresh orange juice contains 20 wt% solids and the balance water, and concentrated orange juice contains 40% solids. Initially, a single evaporation process was used for the concentration, but volatile constituents of the juice escaped with the water, leaving the concentrate with a flat taste. The present process overcomes this problem by bypassing the evaporator with a fraction of the fresh juice; the juice that enters the evaporator is concentrated to 60 wt% solids, and the product is mixed with the bypassed fresh juice to achieve the desired final concentration of solids. Calculate the amount of product produced per 100 kg/hr of fresh juice fed to the process and the fraction of the feed that bypasses the evaporator.

Which balance gives you zero degrees of freedom?

I. Overall  II. Evaporator  III. Splitting point

Evaporator

Fresh Juice 100 kg/h

m_f (kg/h) m_c (kg/h) m_e (kg/h)

a) I  b) II  c) III  d) I or II  e) I or III
Evaporator

Fresh Juice
100 kg/h

m3 (kg/h)
x_w = 1
100 kg/h
xs=0.2
x_w=0.8

m2 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporator

Fresh Juice
100 kg/h

m5 (kg/h)
x_s=0.4
x_w=0.6

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m5 (kg/h)
x_s=0.4
x_w=0.6

Evaporator

Fresh Juice
100 kg/h

m5 (kg/h)
x_s=0.4
x_w=0.6

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporator

Fresh Juice
100 kg/h

m5 (kg/h)
x_s=0.4
x_w=0.6

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m5 (kg/h)
x_s=0.4
x_w=0.6

Evaporator

Fresh Juice
100 kg/h

m5 (kg/h)
x_s=0.4
x_w=0.6

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m5 (kg/h)
x_s=0.4
x_w=0.6

Evaporator

Fresh Juice
100 kg/h

m5 (kg/h)
x_s=0.4
x_w=0.6

m4 (kg/h)
x_s=0.6
x_w=0.4

Evaporated Water

Concentrated Juice

m5 (kg/h)
x_s=0.4
x_w=0.6