

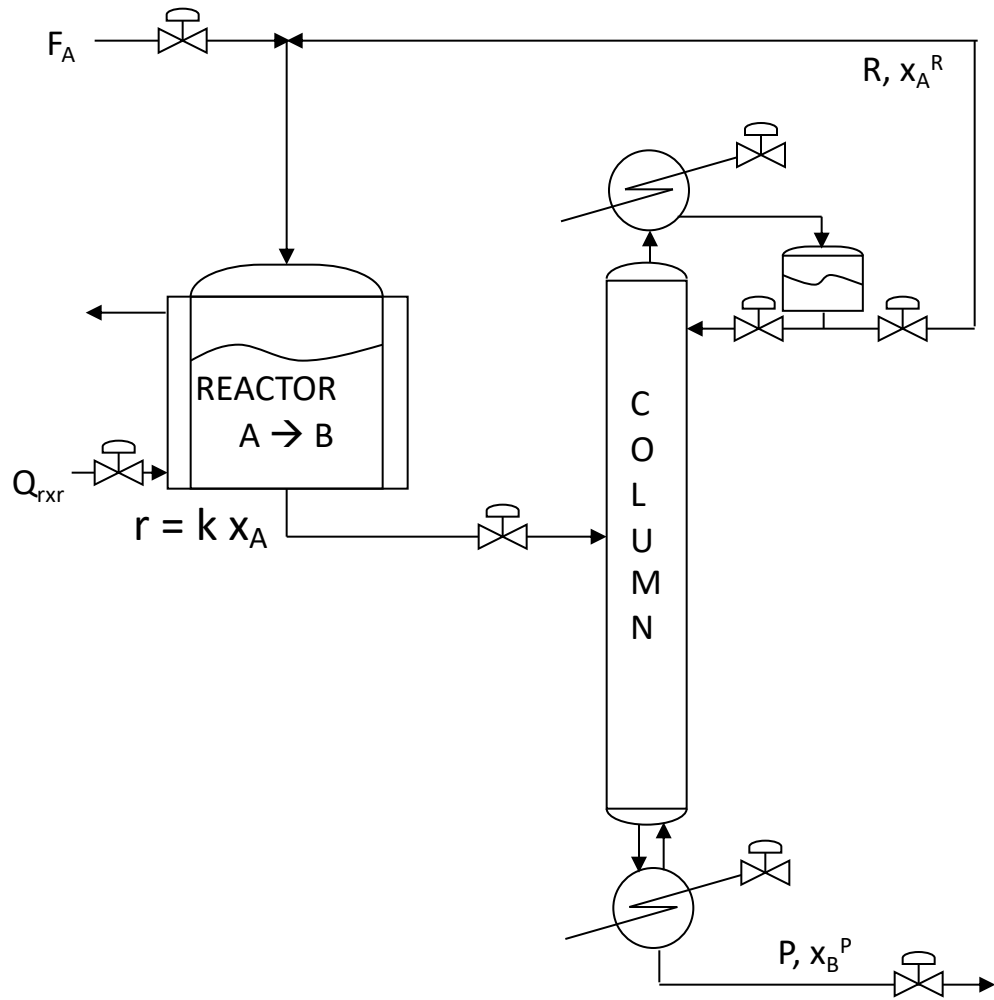
Module # 7.2

Plantwide Control Fundamentals

Recyle Loop Issues: Snowball Effect

Process Dynamics and Control
Supplementary Material
Indian Institute of Technology Kanpur

Snowball Effect Analysis



Overall Material Balance

$$k x_A V = P x_B^P$$

Combine and rearrange

$$R = \frac{P^2 x_B^P + P k V x_A^P}{k V x_A^R - P x_B^P}$$

$$\frac{R}{P^{MAX}} = \frac{\left(\frac{P}{P^{MAX}}\right)^2 - \frac{P}{P^{MAX}} \frac{x_A^P}{x_A^R}}{1 - \frac{P}{P^{MAX}}}$$

$$r = \frac{p^2 - p \frac{x_A^P}{x_A^R}}{1 - p}$$

Column Material Balance

$$x_A = \frac{R x_A^R + P x_A^P}{R + P}$$

As $R \rightarrow \infty$, $P \rightarrow P^{MAX}$. So

$$k V = P^{MAX} \frac{x_B^P}{x_A^R}$$

$$\frac{dr}{dp} = \frac{2p - p^2 - \frac{x_A^P}{x_A^R}}{(1 - p)^2}$$

Snowball Effect Analysis Continued

$$r = \frac{p^2 - p \frac{x_A^P}{x_A^R}}{1 - p}$$

Blows up as $p \rightarrow 1$
(ie $P \rightarrow P^{\text{MAX}}$)

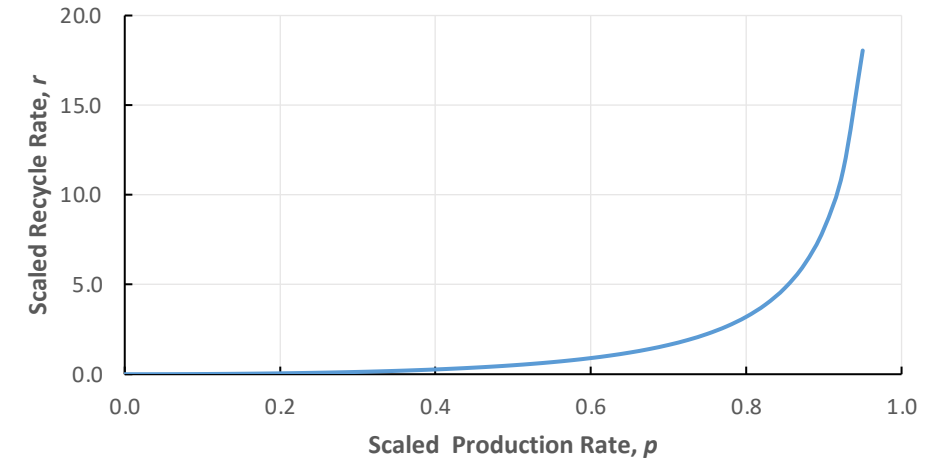
$$\frac{dr}{dp} = \frac{2p - p^2 - \frac{x_A^P}{x_A^R}}{(1 - p)^2}$$

Blows up faster as $p \rightarrow 1$
(ie $P \rightarrow P^{\text{MAX}}$)

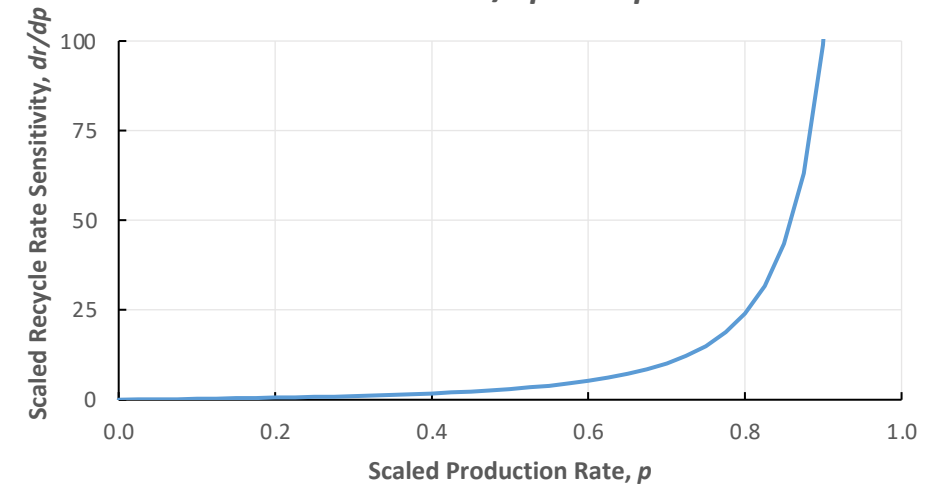
For pure P and R ($x_A^P = x_B^R = 0$)

p	r	dr/dp
0.1	0.0111	0.2346
0.2	0.0500	0.5625
0.3	0.1186	1.041
0.4	0.2667	1.778
0.5	0.5000	3.000
0.6	0.9000	5.250
0.7	1.633	10.11
0.8	3.200	24.00
0.9	8.100	99.00

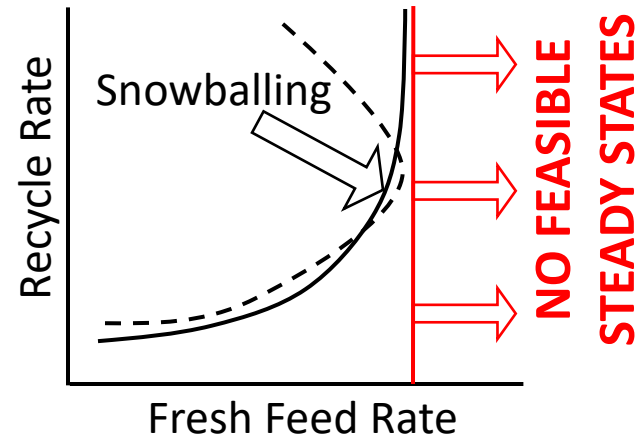
Variation of r with p



Variation of dr/dp with p



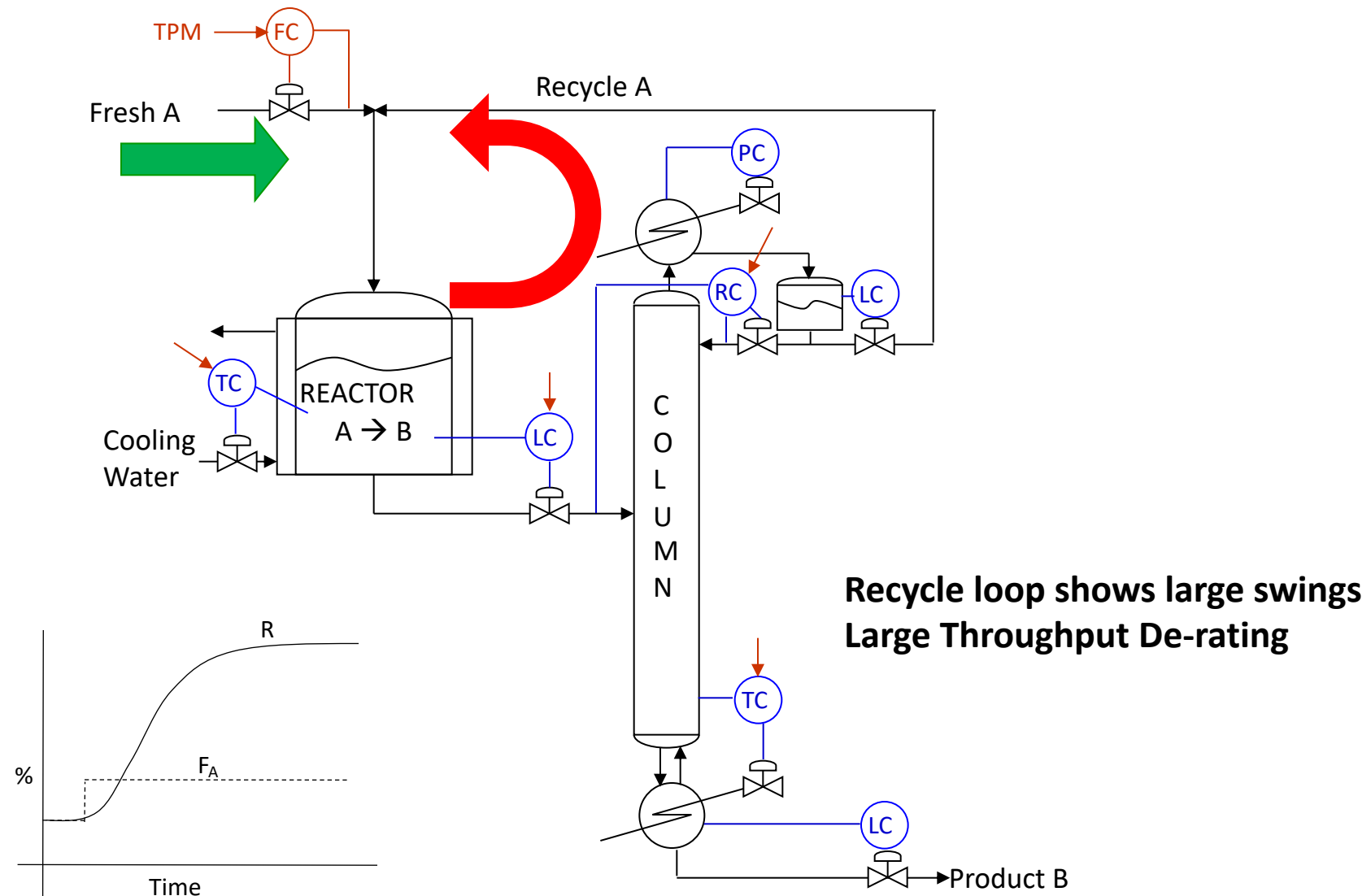
Nonlinearity



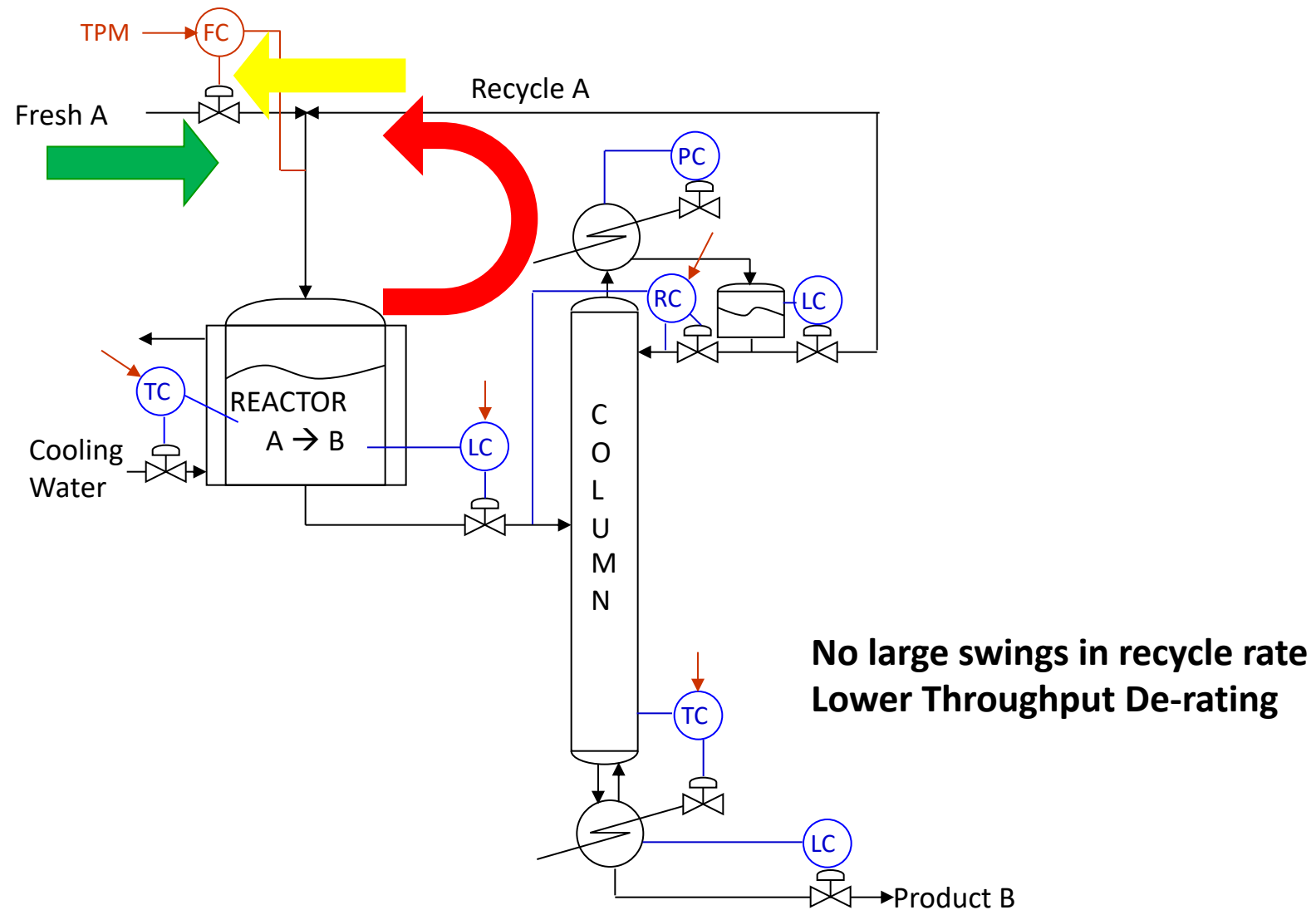
Fixing the fresh feed rate of a recycled component is NOT a good idea

Possibility of overfeeding induced instability

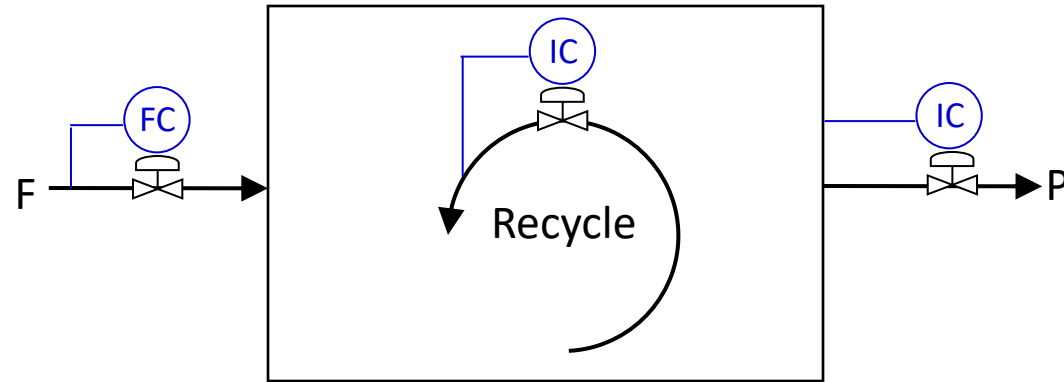
Control Implication of Snowballing



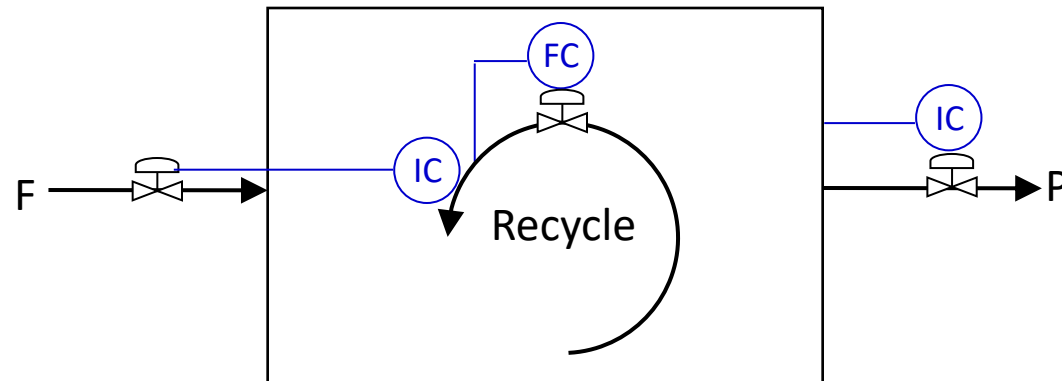
Control Implication of Snowballing continued



TPM Location Flexibility



**Transforms variability
into recycle loop**



**Transforms variability
out of recycle loop**

Summary

- Recycle rate typically highly sensitive to production rate changes (snowball effect)
- TPM at fresh feed will likely result in large swings in recycle rate, thus disturbing the entire plant.
- May also result in overfeeding induced instability
- When TPM location is flexible, fix a flow inside the recycle loop (Luyben's rule) and bring in fresh feed(s) as make-up stream(s) under inventory control.
- The fixed flow rate inside the recycle loop may be used as TPM.