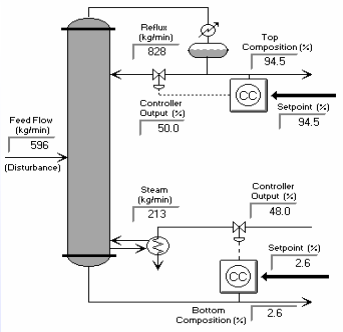
Distillation Column is a 2 x 2 Multivariable Challenge



Results of Open-Loop Step Tests on Top and Bottom

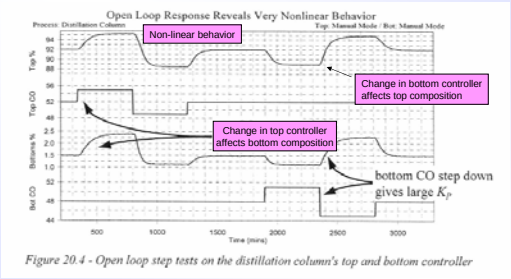


Figure 20.4 - Open loop step tests on the distillation column's top and bottom controller

Control Loop Interaction

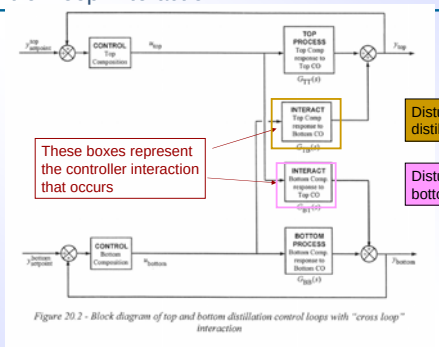


Figure 20.2 - Block diagram of top and bottom distillation control loops with "cross loop" interaction

Using PI Controllers for Top and Bottom

Set point change from 92 to 94% benzene in top

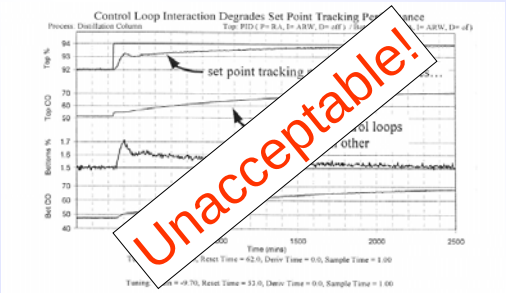


Figure 20.8 - Top and bottom loop fight each other, thus degrading set point tracking performance of top loop

Solution.... Decouplers!!!

- Act kind of like a feed-forward controller
- Model what the interaction will be, and compensate
  - Treat the bottom composition as a disturbance with a feedforward loop to the top controller
  - Treat the top composition as a disturbance with a feedforward loop to the bottom controller
- Remember that a feedforward controller has the form:
  - $G_{FF} = - G_{dist}/G_{process}$
- So the decoupler transfer functions become:
  - $D_{top\ decoupler} = - G_{TB}(s)/G_{TT}(s)$
  - $D_{bottom\ decoupler} = - G_{BT}(s)/G_{BB}(s)$

G_{TB} is response of top composition to change in bottoms controller, etc.

Decoupling Structure

D here means a transfer function for a decoupler

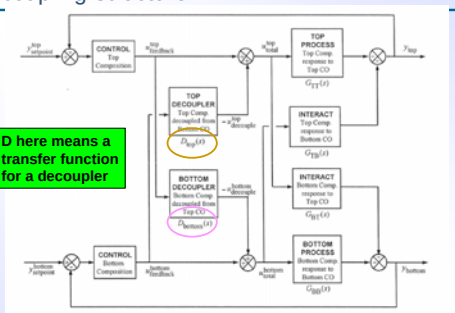


Figure 20.3 - Block diagram of top and bottom distillation control loops with cross loop interaction and decouplers

Decouplers are Feed Forward Controllers

- A decoupler is comprised of a process model and a cross-loop disturbance model:
  - The cross-loop disturbance model receives the cross-loop controller signal and predicts an "impact profile," or when and by how much the process variable will be impacted
  - Given this predicted sequence of disruption, the *process* model then back calculates a series of control actions that exactly counteract the cross-loop disturbance as it arrives so the measured process variable remains constant at set point
- A new sensor is not needed because the cross-loop controller signal is readily available for use by the decoupler
- Developing and programming the dynamic process and cross-loop disturbance models is required for implementation

Tuning Procedure

- Get process responses to top and bottom controllers in open-loop mode
  - Do a pulse, not a doublet, to get highest K_p (and hence lowest K_c) for top and for bottom
  - Fit FOPDT models to:
    1. G_{TT} (top response to change in top controller output)
    2. G_{BB} (bottom response to change in bottom controller output)
    3. G_{TB} (top response to change in bottom controller output)
    4. G_{BT} (bottom response to change in top controller output)
- Get PI Controller parameters from IMC correlation
- Put in FOPDT parameters for G_{TT}, G_{BB}, G_{TB}, and G_{BT} into decouplers
  - G_{BT} goes into bottom decoupler

Improved Performance with Decouplers

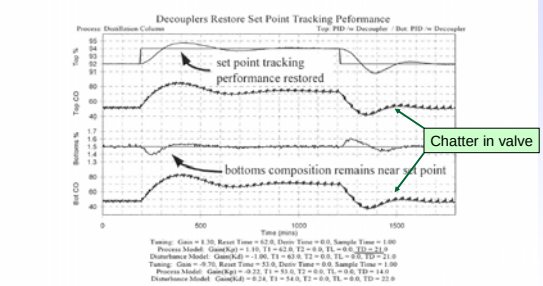


Figure 20.11 - Improved set point tracking capability of top loop and reduced interaction with bottom loop when both are under PI control with decouplers

Subtle Problem

- $K_{P,BB}$ = -0.22 %/%
- $K_{D,BT}$ = 0.24 %/%
- If the disturbance gain is greater than the process gain, things don't work well!
- Solution:
  - Set $|K_{D,BT}| = |K_{P,BB}|$, or $K_{D,BT}$ = 0.22 %/%

Final Result

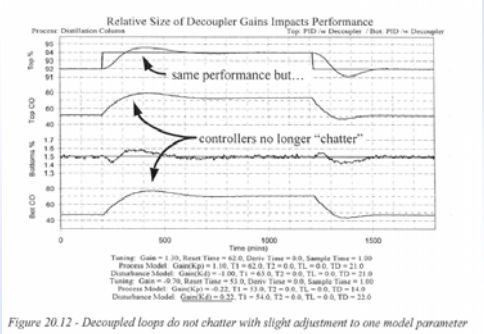


Figure 20.12 - Decoupled loops do not chatter with slight adjustment to one model parameter

Conclusion

- With just 2 controllers, controller interaction was significant!!
  - Decouplers used, but somewhat complicated
- Imagine what will happen with multiple controllers!
- Specialists needed in this area!!