Fundamentals of Distillation Column Control

by Terry Tolliver

ISA Automation Week 2011
PRESENTER – Terry Tolliver

- Terry is a retired Senior Fellow from Solutia/Monsanto and presently provides contract engineering at ConocoPhillips Wood River refinery. He has 40+ years of experience in process control, simulation, operations, troubleshooting and optimization.
- Terry graduated from the Missouri University of Science and Technology with BS, MS & PhD ChE and was recently inducted into their Academy of Chemical Engineers in 2009. He was inducted into the CONTROL Automation Hall of Fame in 2002.
- He has received several ISA awards including the Distinguished Society Service Award in 1997, the E. G. Baily Award in 1993 and the Excellence in Documentation award in 1987.
- Terry has been an adjunct professor for Washington University from 2004-2008, a Lehigh University Biannual Lecturer from 1974-1986, an ISA Fellow in 1990, an AIChE Fellow in 2000 and a PE since 1974.
DISTILLATION CONTROL TOPICS

- Levels of control
- Classification and pairing of variables
- Control objectives and constraints
- Dynamic responses
- Material and energy balances
- Separation
- Pressure control
- Material balance control
- Temperature control
- References
DISTILLATION CONTROL

- **BASIC**
  - Inventory Control
  - Composition Control

- **SUBOPTIMIZING**
  - Feedforward Control
  - Two Point Composition Control

- **OPTIMIZING**
  - Floating Pressure
  - Maximum Profit
CLASSIFICATION and PAIRING of VARIABLES

CONTROLLED VARIABLES
distillate composition
bottom composition
accumulator level
sump level
column pressure

\[
\begin{align*}
Y & \quad Y \\
X & \quad X \\
\text{La} & \quad \text{La} \\
\text{Ls} & \quad \text{Ls} \\
P & \quad P
\end{align*}
\]
CLASSIFICATION and PAIRING of VARIABLES

MANIPULATED VARIABLES

- distillate flow
- bottom flow
- reflux flow
- reboiler duty
- condenser duty
DISTURBANCE VARIABLES
- feed flow
- feed composition
- feed temperature
- reboiler heat supply
- condenser cooling
  supply and weather
# CLASSIFICATION and PAIRING of VARIABLES

<table>
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<th>CONTROLLED VARIABLES</th>
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<td>distillate composition</td>
<td>distillate flow</td>
<td>feed flow</td>
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<td>bottom composition</td>
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CONTROL OBJECTIVES

Cost of Product Lost

Cost of Energy

Total Operating Cost

$ / F

RECOVERY
COLUMNS CONSTRAINTS

- Column Pressure
- Boilup rate
- Vessel Limit
- Weep
- Flood
- Reboiler
- Condenser

Boilup rate vs. Column Pressure Graph:

- Condenser
- Flood
- Weep
- Reboiler
- Vessel Limit
COLUMN INTERNALS

TRAYS
- SIEVE TRAYS
- VALVE TRAYS
- BUBBLE CAP TRAYS
- DUAL FLOW TRAYS

PACKING
- RANDOM PACKING
- STRUCTURED PACKING
- *LIQUID & VAPOR DISTRIBUTORS*
COLUMNS DYNAMICS

RELATIVE RESPONSE TIMES

VAPOR - FAST
LIQUID - MEDIUM
COMPOSITION - SLOW

Response

time
MATERIAL & ENERGY BALANCES

MATERIAL BALANCE

\[ F = D + B \]
\[ zF = yD + xB \]

\[ \frac{D}{F} = \frac{(z-x)}{(y-x)} \]

ENERGY BALANCE

\[ hF + Q_{reb} = hD + hB + Q_{cond} \]
TOTAL REFLUX

\[ \alpha^n = \frac{y(1-x)}{x(1-y)} \]

NORMAL OPERATION

\[ S = f(\alpha, N, N_F, V/F, z, E) \]
PRESSURE CONTROL
CONDENSER DUTY

\[ Q_{\text{cond}} = UA(T_p - T_c) \]
“BLOCK & BLEED” PRESSURE CONTROL
MATERIAL BALANCE CONTROL - TYPE 1
MATERIAL BALANCE CONTROL - TYPE 2
PROCESS SIMULATION

STEADY STATE
- PARAMETRIC CASES
- CONTROL STAGE LOCATION
- SENSITIVITY ANALYSIS
- DISTURBANCE ANALYSIS

DYNAMIC
- STUDY CONTROL RESPONSE
- STARTUP AND SHUTDOWN
CONTROL STAGE LOCATION

Benzene-Toluene Column Temperature Profiles

Stage Number

Temperature, DegC

+1%D/F

-1%D/F
TEMPERATURE SENSITIVITY

CONTROL STAGE TEMPERATURE, degF

COMPOSITION, wt% BOTTOM PRODUCT

DISTILLATE PRODUCT

BOTTOM PRODUCT
REFERENCES


