Address Distillation Process Control during Design Phase to Save Energy and Increase Capacity

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"How can we improve distillation efficiency before the plant is even built?"

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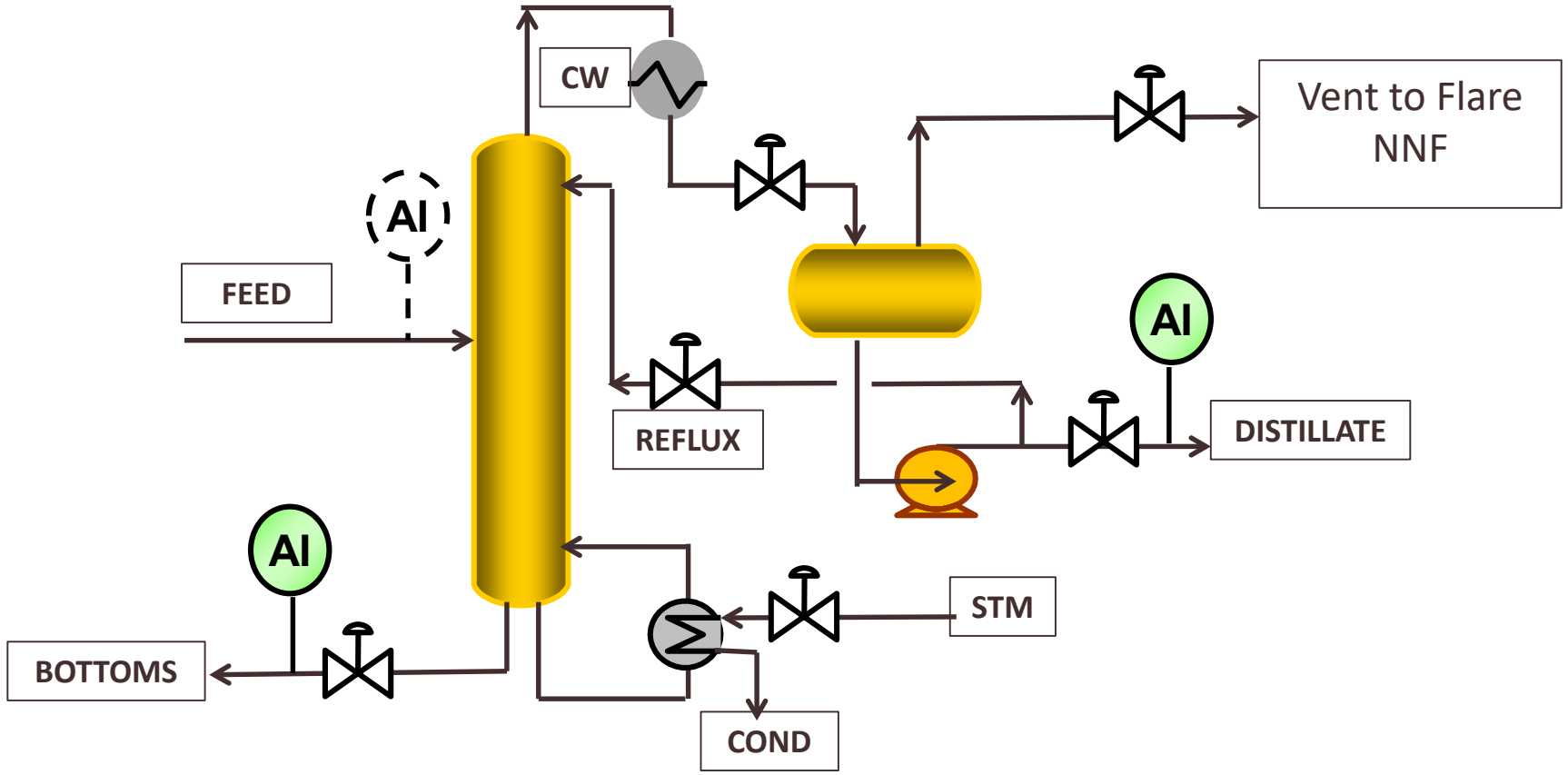
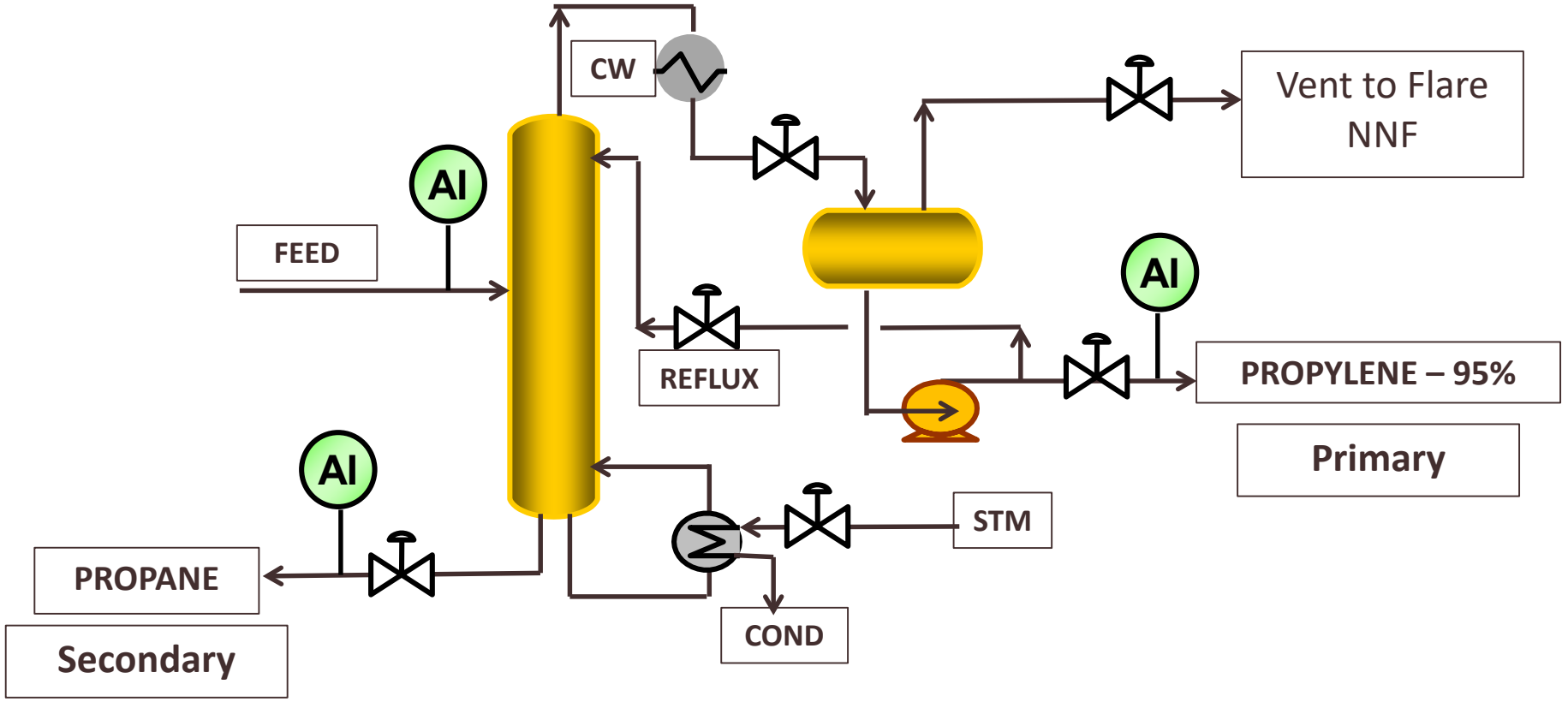
Design for **Reduced Process Variation**

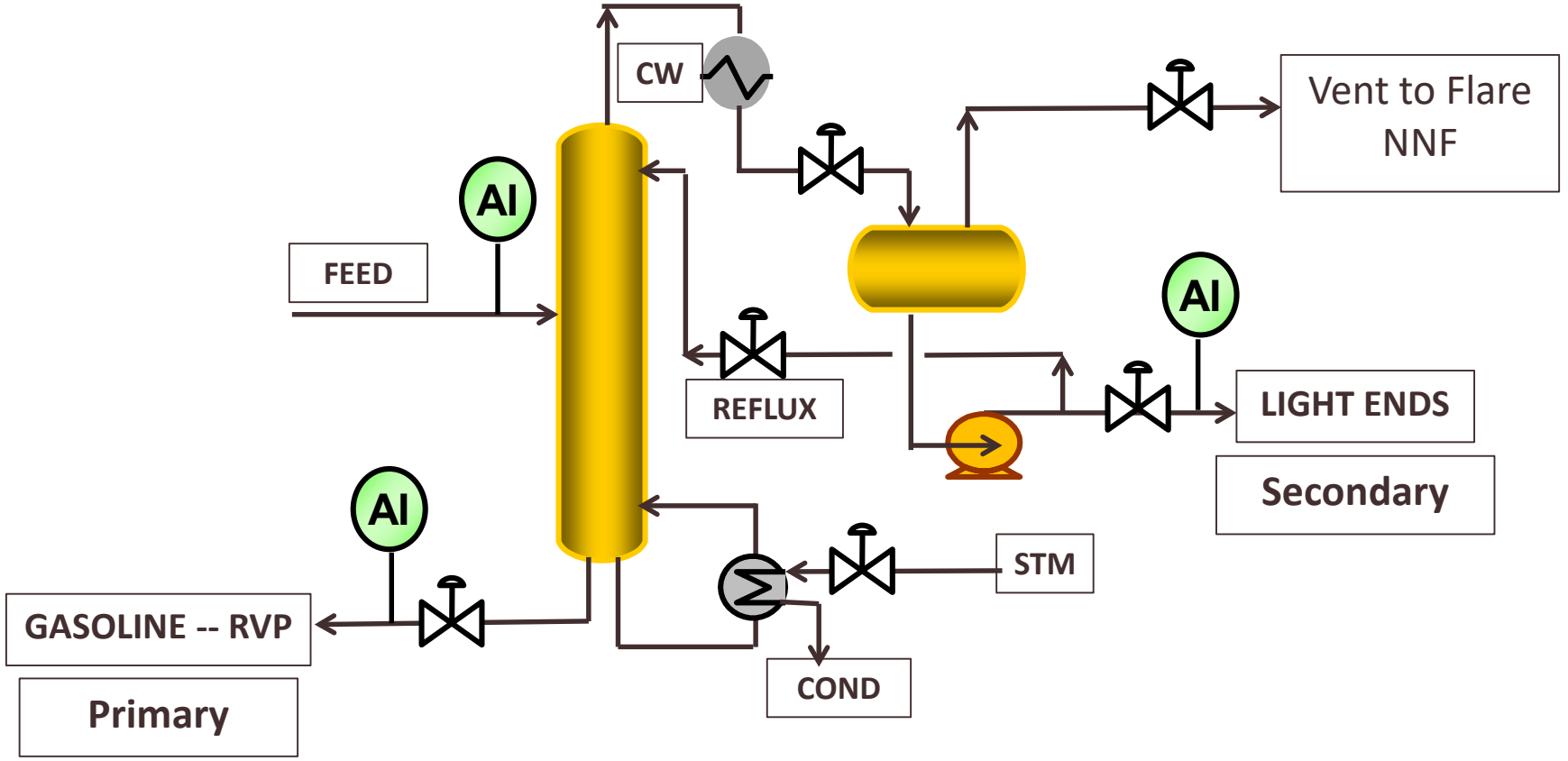
Typical Distillation System



C3 Splitter – Overhead Primary Product



FCC Debutanizer – Bottom Primary Product



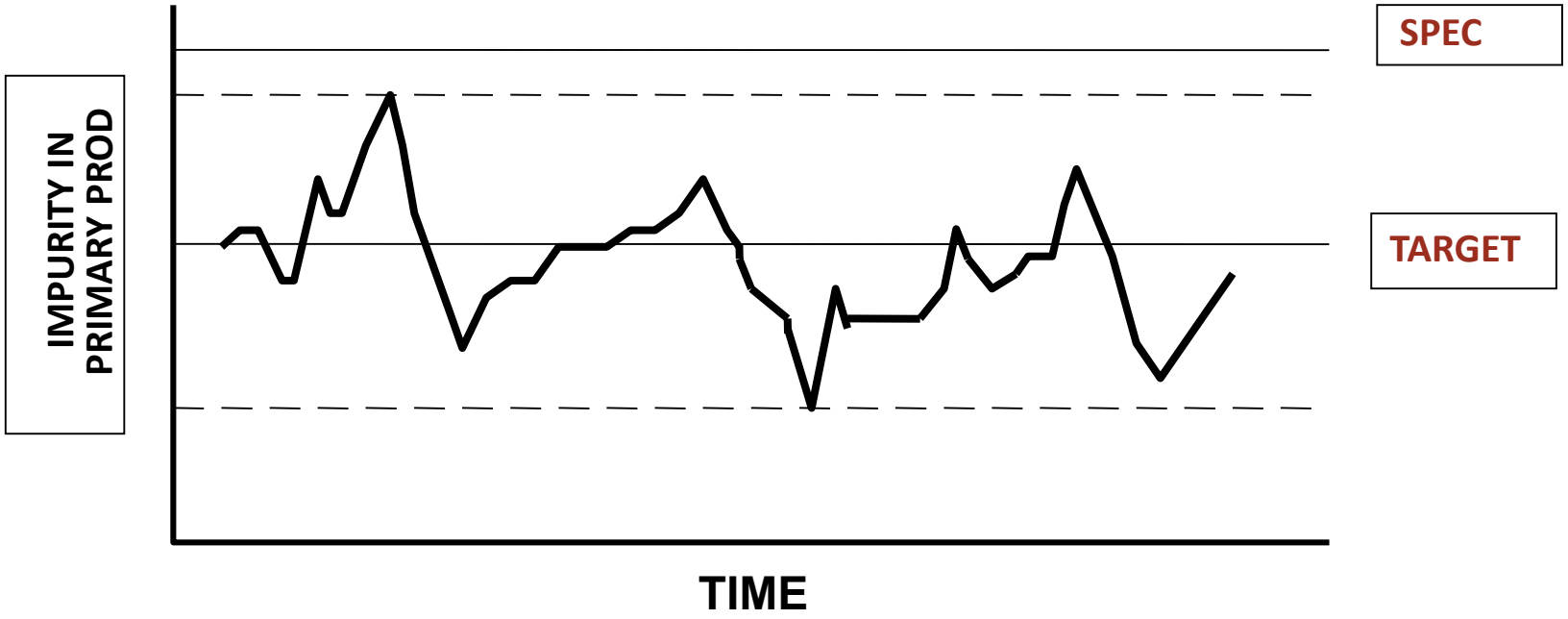
Reduce Energy Use and Increase Capacity

- Move target closer to spec
- Reduce reflux and heat per unit feed
- Reduce process variation to stay on-spec

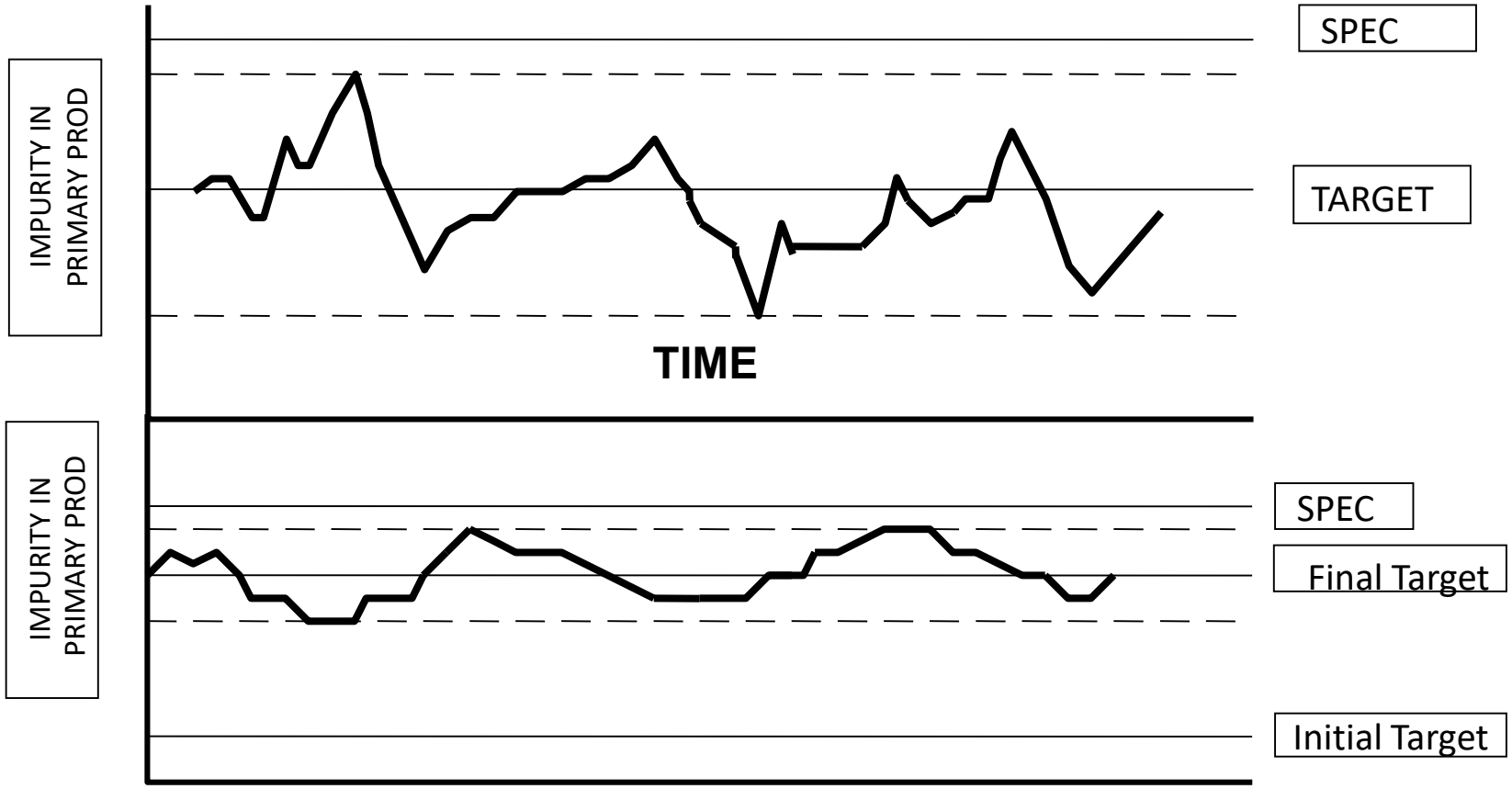
Take These Steps to Reduce Variation

- Select target using data from existing columns
- Identify capital upgrades to reduce variation
- Develop inferential model for '**analyzer down**'
- Prioritize ***primary*** product via basic controls

Select Target based on Predicted Variation



Reduce Variation to Operate Near Product Spec



Address Normal and Maximum Variation

- Estimate standard deviation from data
- Estimate max variation from disturbances
- **Evaluate off-spec incidents at existing unit**

Consequences of Off-Spec Operation

- Product may have to be diverted or flared
- Off-spec tank may be required
- Off-spec material may need reprocessing
- Customer's operation is adversely affected
- **Supplier's reputation is tarnished**

On-Spec Operation is a **Requirement**

- Must be on-spec to achieve efficiency gain
- **Prevent off-spec incidents through design**

Most Disturbances are Predictable

- Feed rate change
- Feed composition change
- Rainstorm

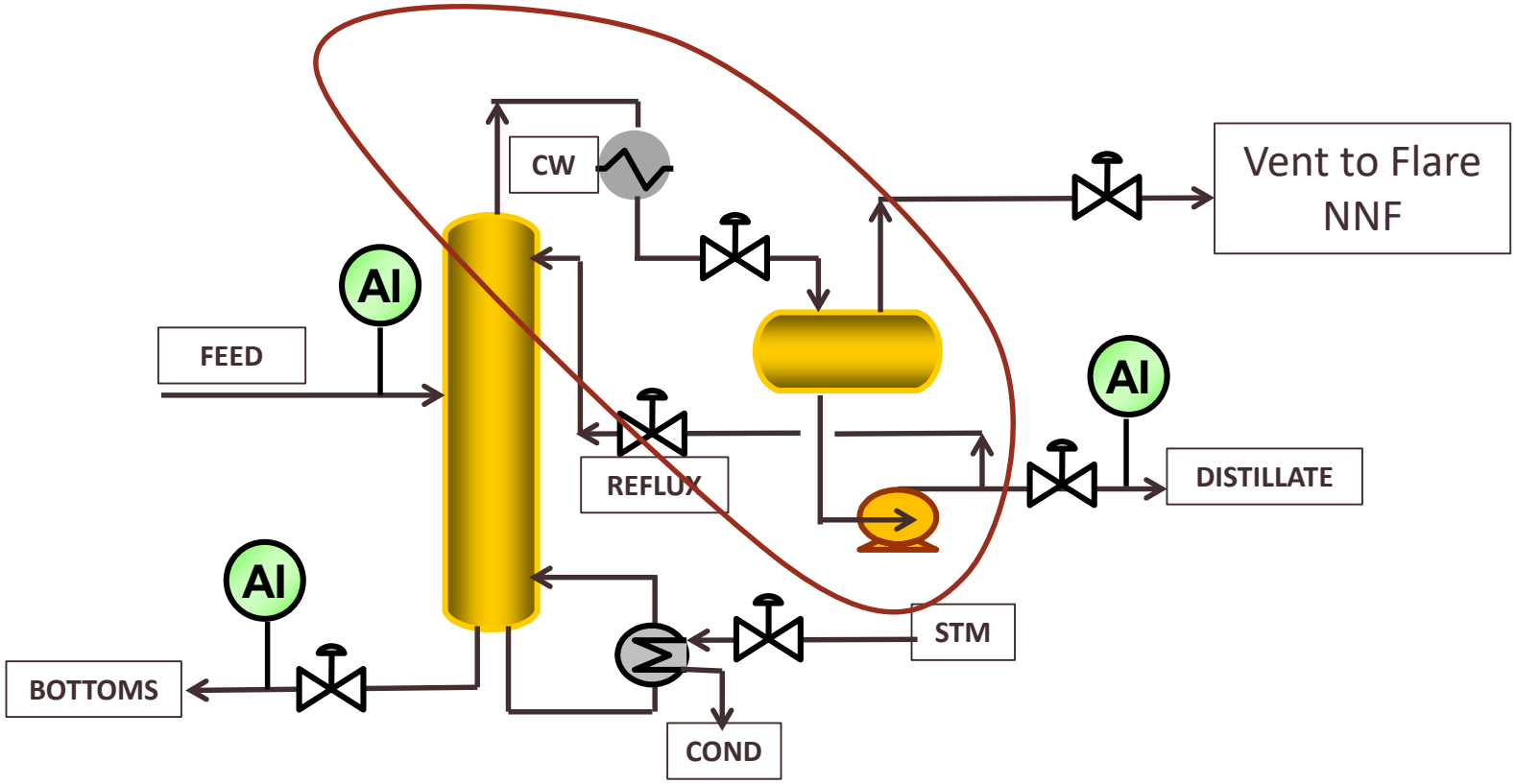
Design the plant to stay on-spec in these scenarios

Capital Upgrades to Reduce Variation

- Insulate overhead equipment and pipe
- Increase primary product residence time
- Increase size of feed drum
- Add instruments to support inferential model

Insulate Overhead Equipment and Pipe

Many Overhead Systems are **NOT** Insulated



Benefits of Insulation

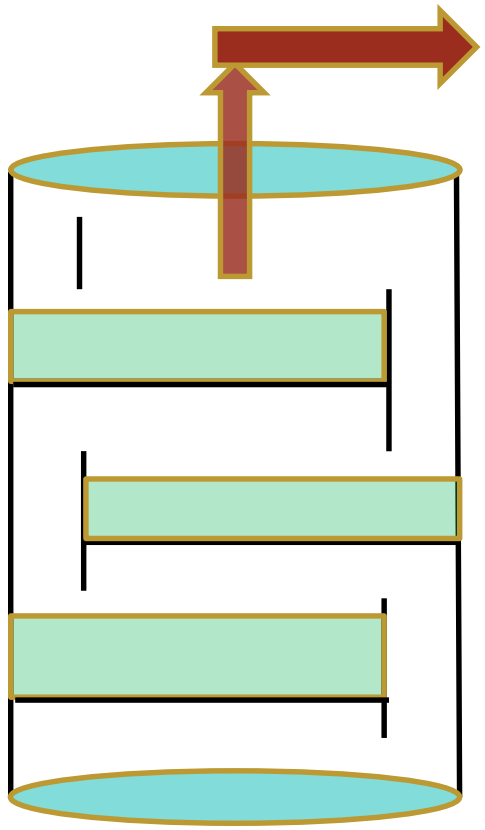
- Reduce losses from light-ends vent
- Reduce solar heating of reflux liquid
- **Stay on-spec during rainstorm**

What Happens During a Rainstorm?

- Uncontrolled increase in condenser duty
- Pressure decreases rapidly—as much as 20%
- Tray liquid vaporizes, goes to reflux drum
- Heavy ends contaminate distillate product

Pressure Loss Contaminates Distillate

Equilibrium
Liquids Vaporize during Rainstorm

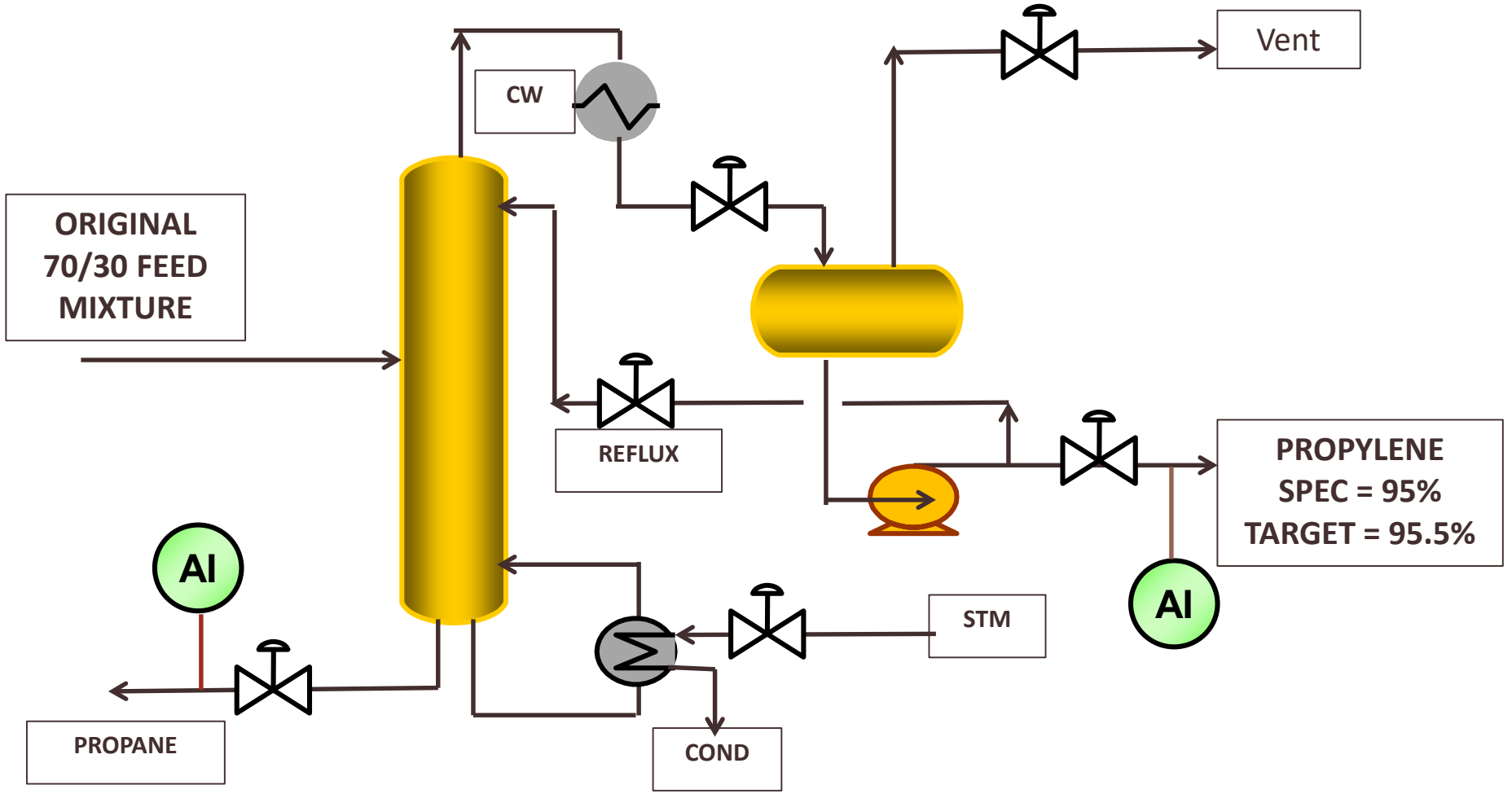


Off-Spec Material from Trays Contaminates Distillate

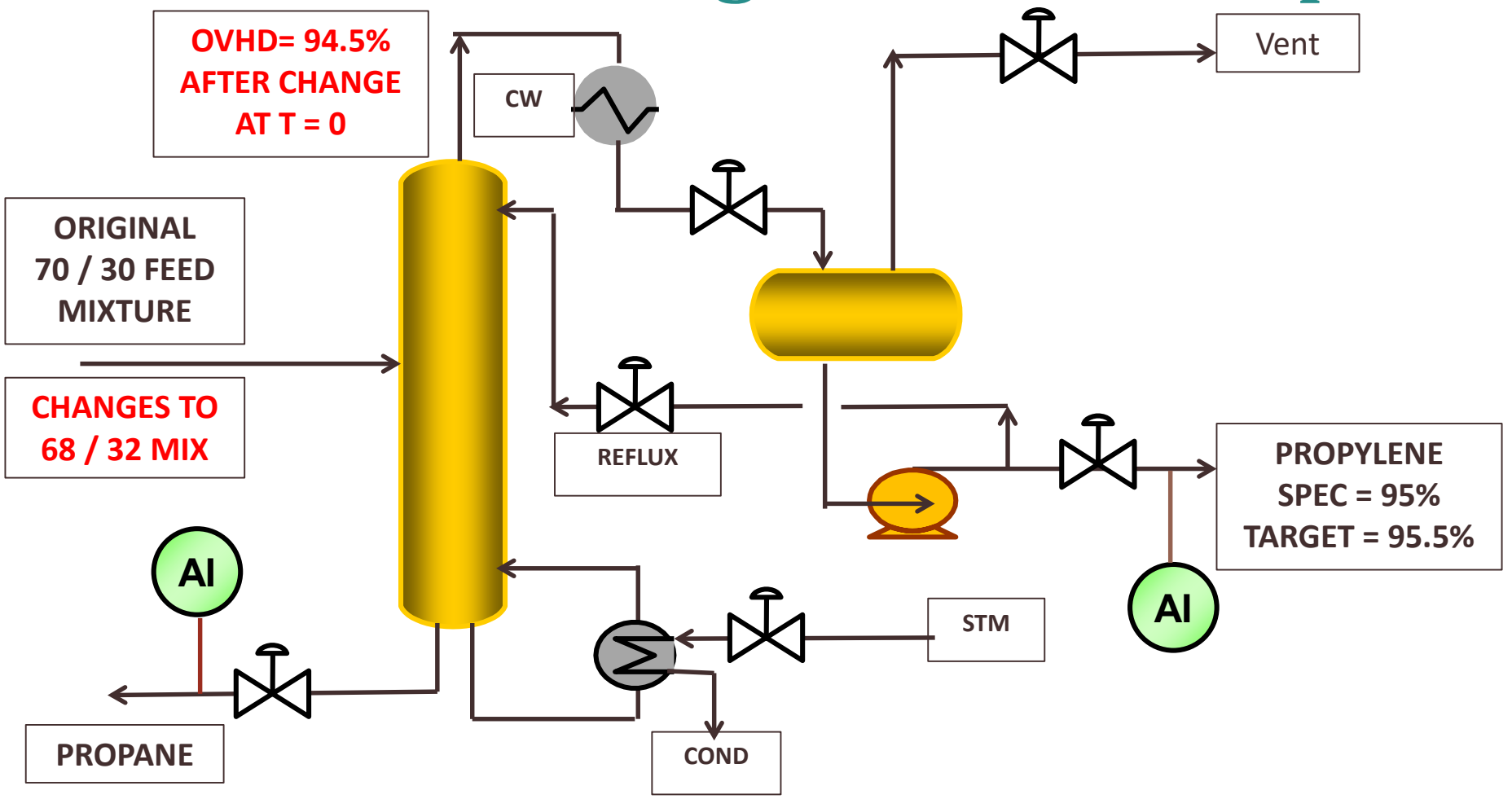
Increase Primary Product Residence Time

- Increase size of reflux drum or column bottom
- Increase level control setting on existing drum
- ***Dampens all disturbances automatically!!***
- **Gives operator time to react and stay on-spec**

Example for Increased Residence Time



Un-Measured Change in Feed Composition



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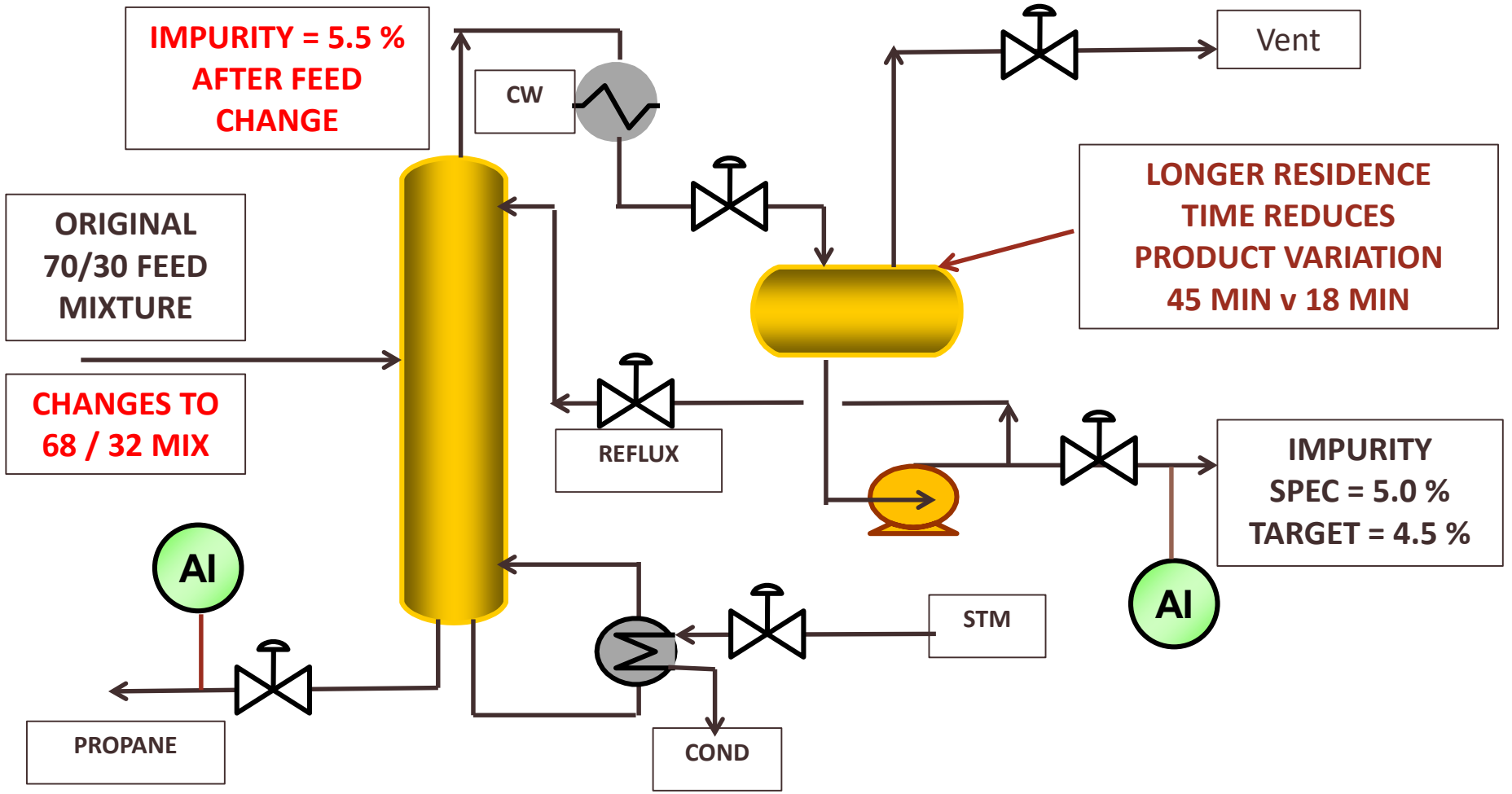
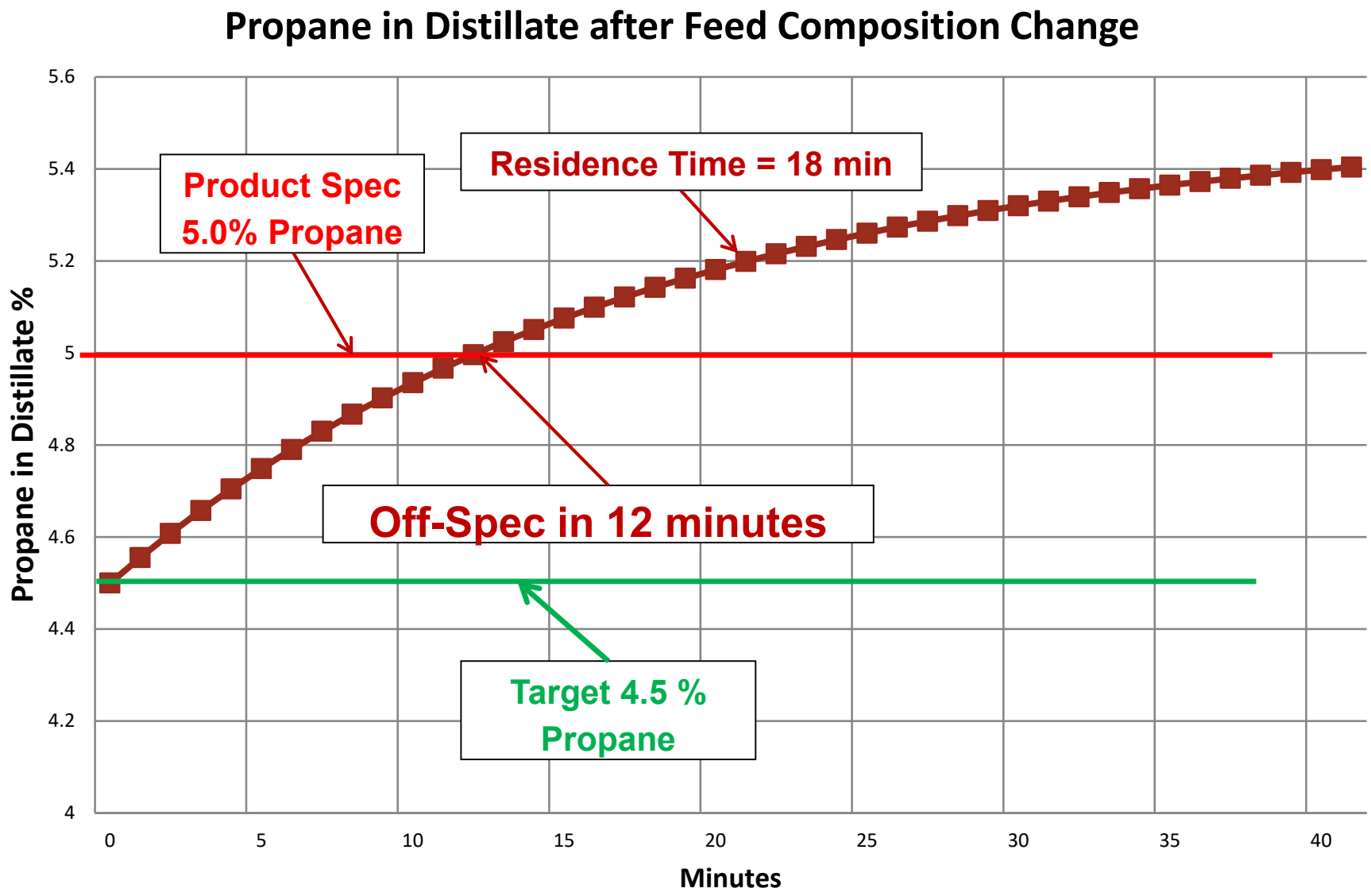
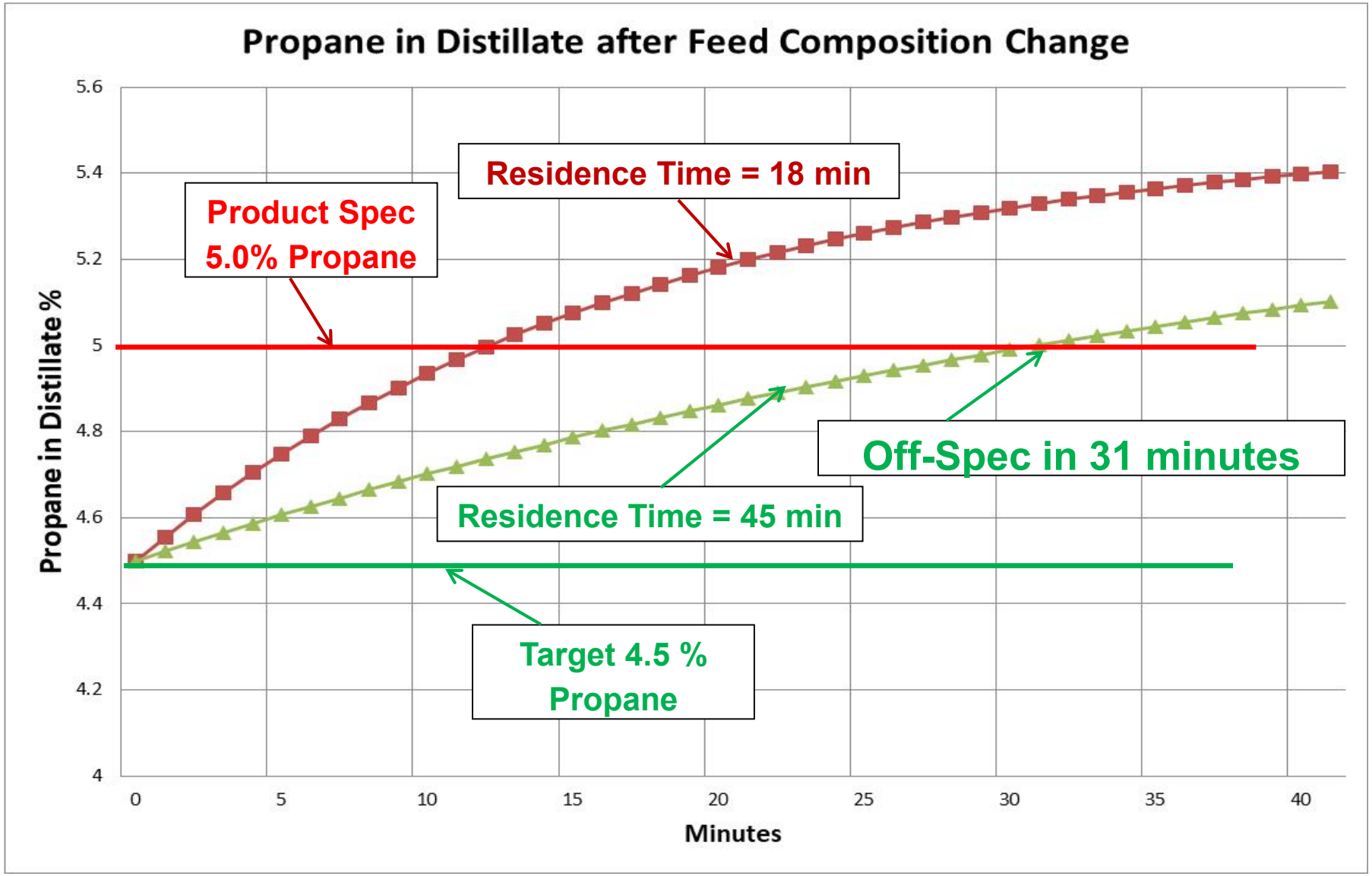



Propane in Distillate after Feed Composition Change
Propane in Distillate %
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
0
5
10
15
20
25
30
35
40
Minutes
Product Spec
5.0% Propane
Residence Time = 18 min
Off-Spec in 12 minutes
Target 4.5 %
Propane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5.6
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4.6
4.4
4.2
4
0
5
10
15
20
25
30
35
40
Minutes
Residence Time = 18 min
Product Spec
5.0% Propane
Off-Spec in 31 minutes
Residence Time = 45 min
Target 4.5 %
Propane

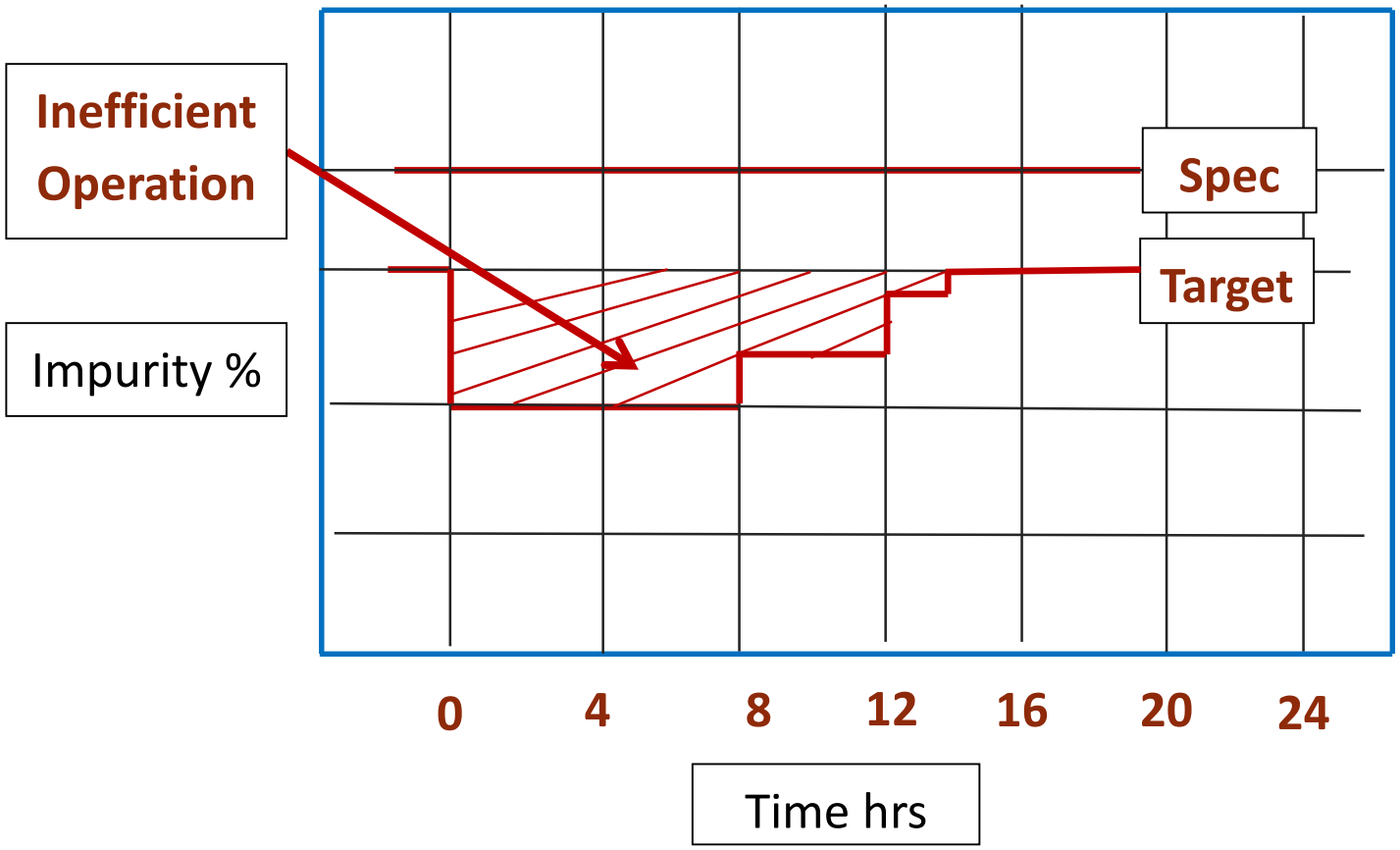
Increase Size of Feed Drum

- Larger drum leads to steadier feed
- Steadier feed leads to steadier product
- Feed composition changes also dampened

What Happens During Analyzer Calibration?

- Advanced control loops (APC) turn OFF
- Operator makes large increase in reflux
- Column operation is shifted to inferior place
- Inefficiency lasts for hours following calibration

Typical Calibration Time Line



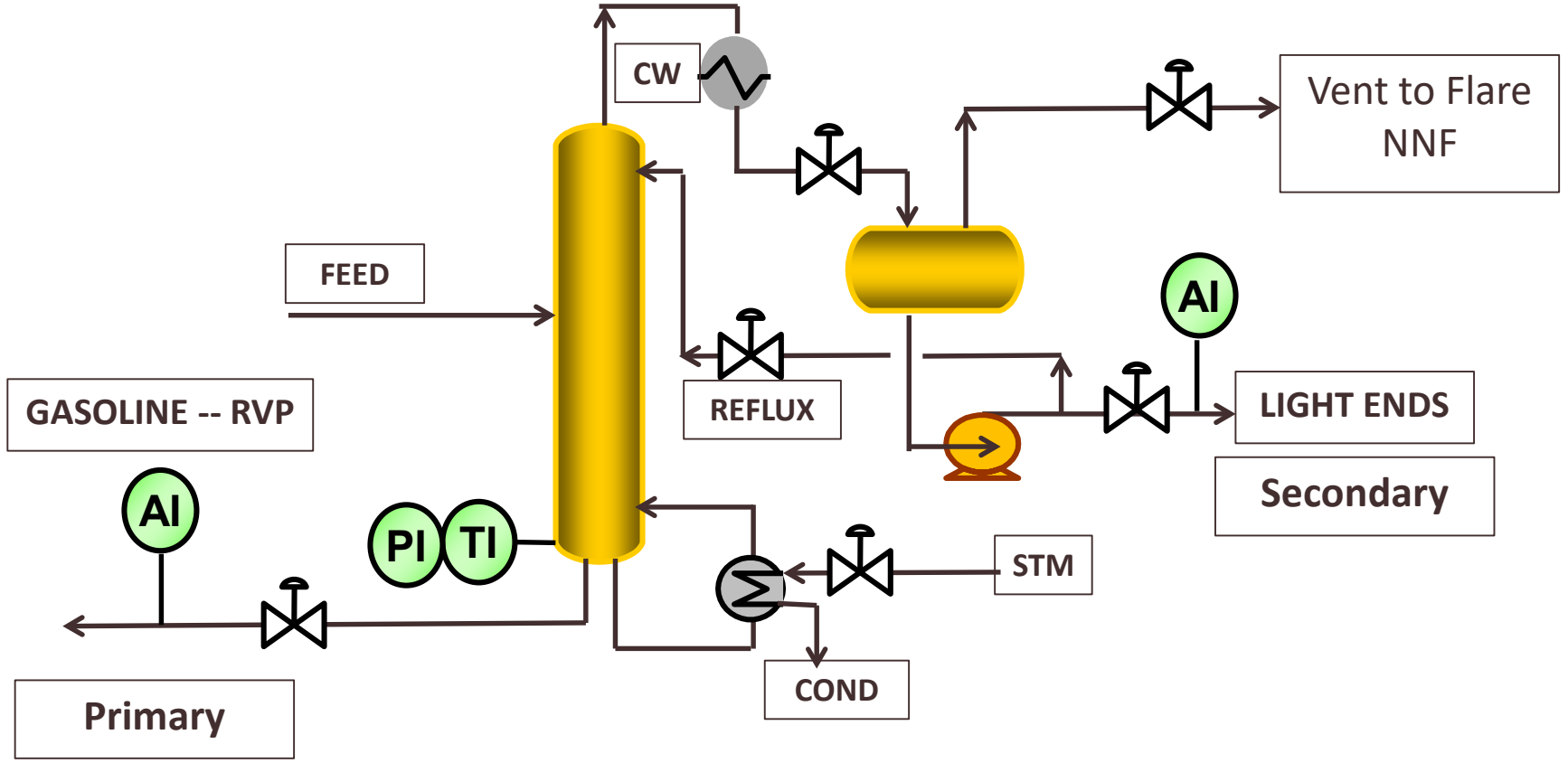
Maintain Efficiency during Calibration Period

- Consider adding redundant analyzer
- Develop inferential composition model
- **Maintain operation at normal target**

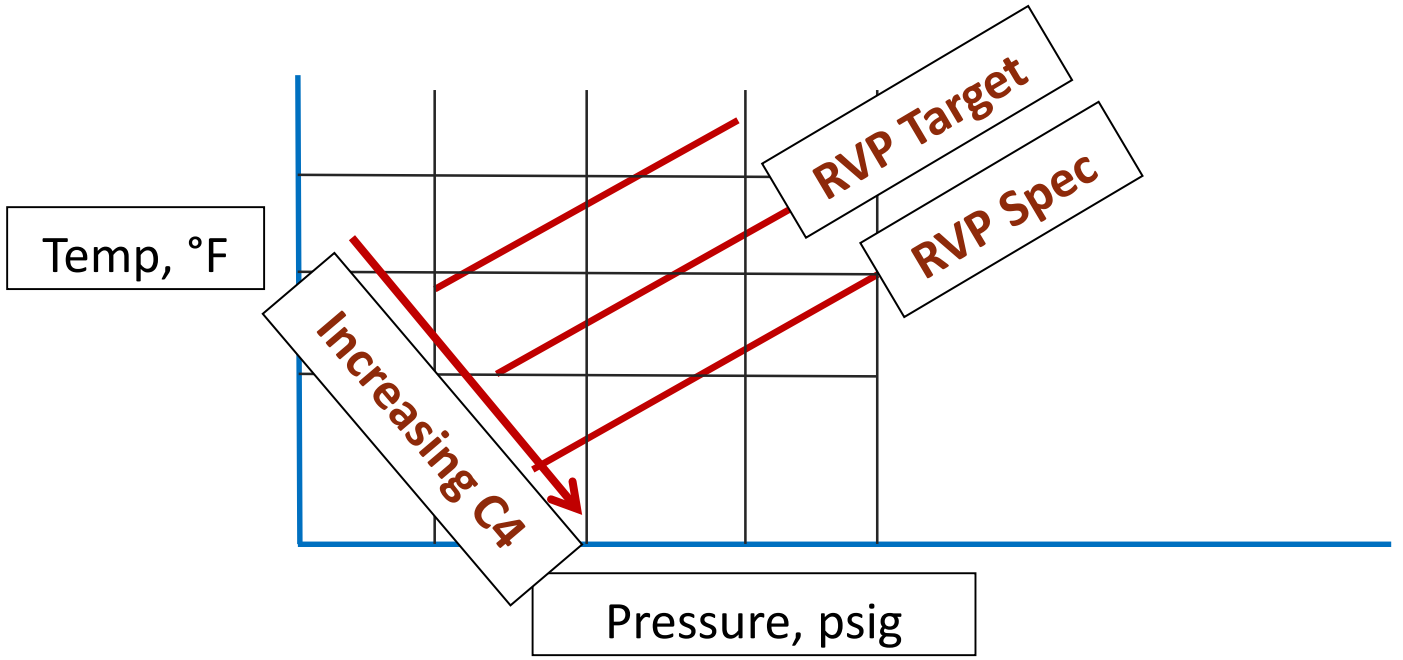
Designing a Practical Inferential Model

- Use press / temp for wide-boiling mixtures
- Use component balance for pure product
- Validate the model using a ‘bias’ term
- Operator must have confidence in the model

FCC Debutanizer – Bottom Primary Product



Pressure—Temperature Models
Use Tower Design Simulation to Generate Model



Validate the Model with Analyzer in Service

- Use model to estimate *RVP* from **P-T** graph

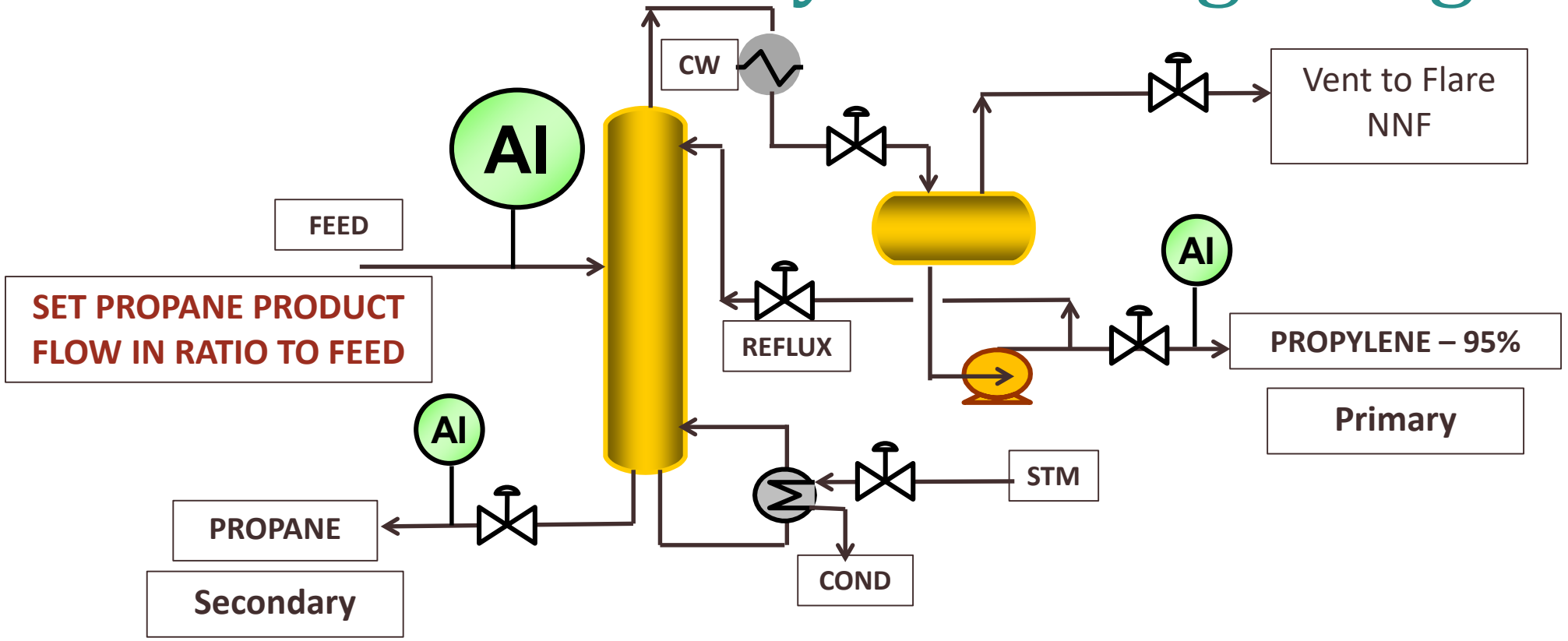
BIAS = ANALYZER RVP – MODEL RVP

- Unchanging bias indicates good model
- Highly variable bias indicates model error

Use Model during Analyzer Calibration

- Application monitors Analyzer Status via DCS
- **Predicted RVP = Model RVP + BIAS**
- Model can reset temp as pressure varies

C3 Splitter – Propane Balance Model Add Feed Analyzer during Design



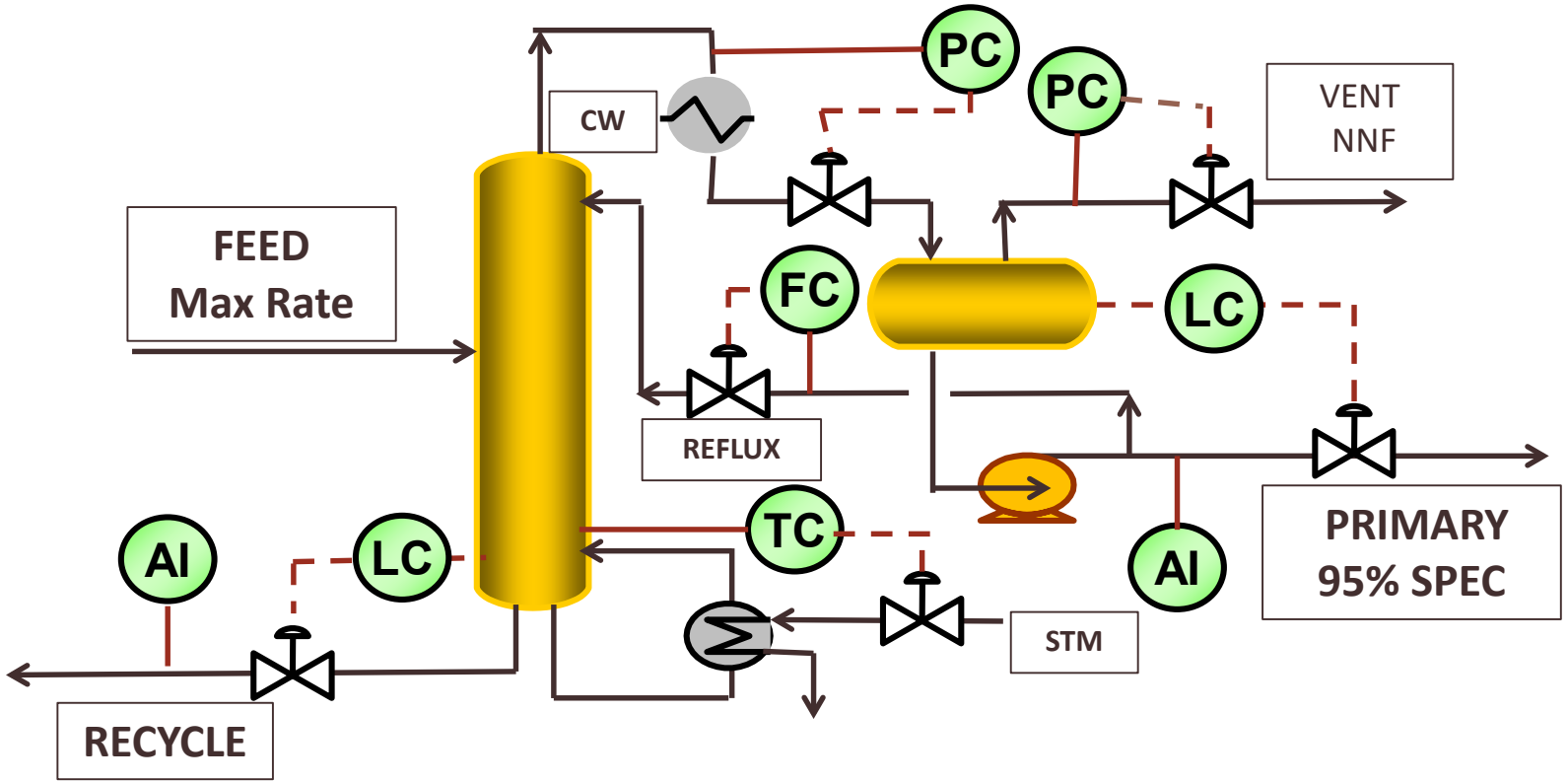
Propane Balance Model

- Use feed analyzer to calculate propane in feed
- Subtract propane in bottom product
- Difference is propane in distillate
- Operator uses bottoms-to-feed to stay on spec

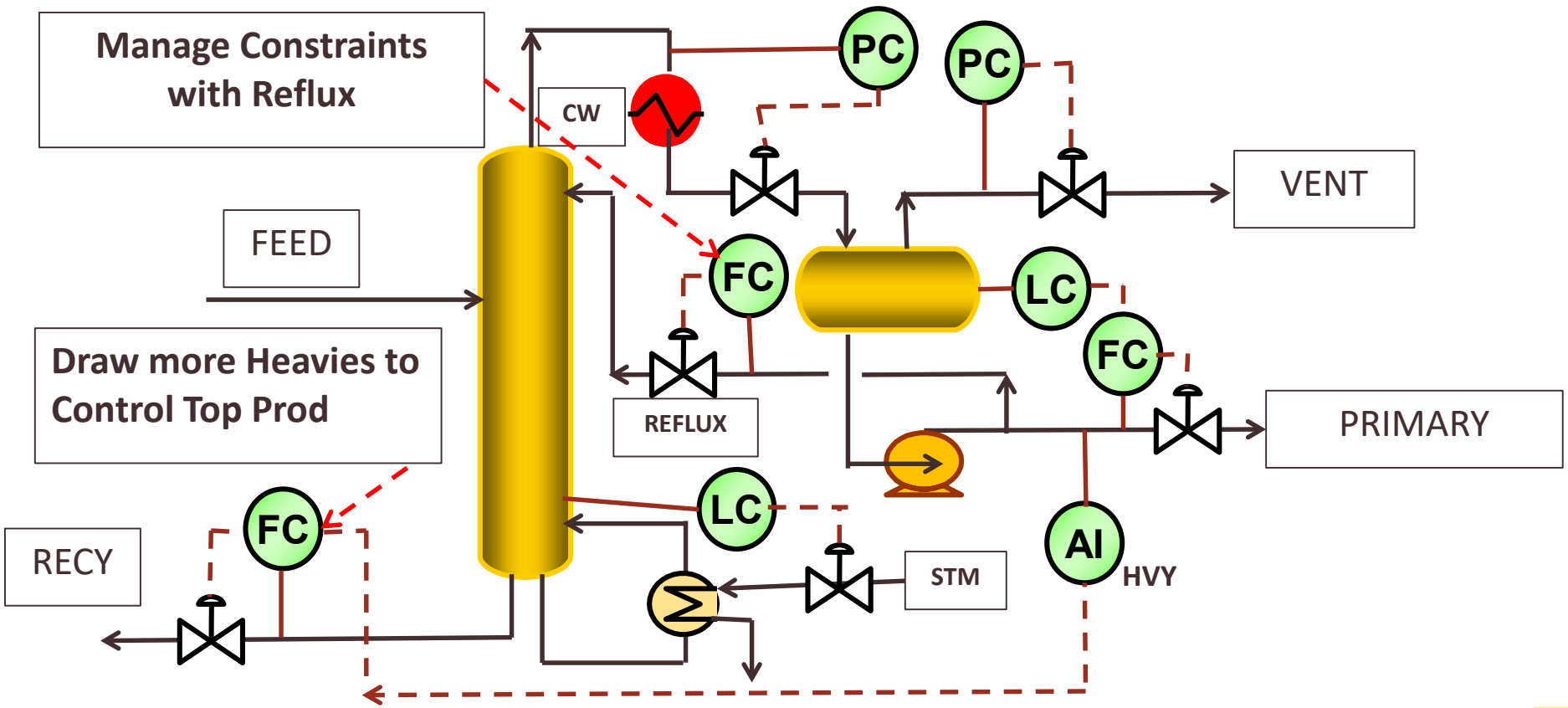
Perform Basic Control System Design Early

- Primary product determines the design
- No longer can we defer until after startup
- Operator training based on P&IDs
- Difficult to change controls after HAZOP

Control Strategy Prioritizes Wrong Product



Control Purity via Material Balance



Thank You