

Guidelines for Dynamic Modeling of Column Startup

Chemstations, Inc.

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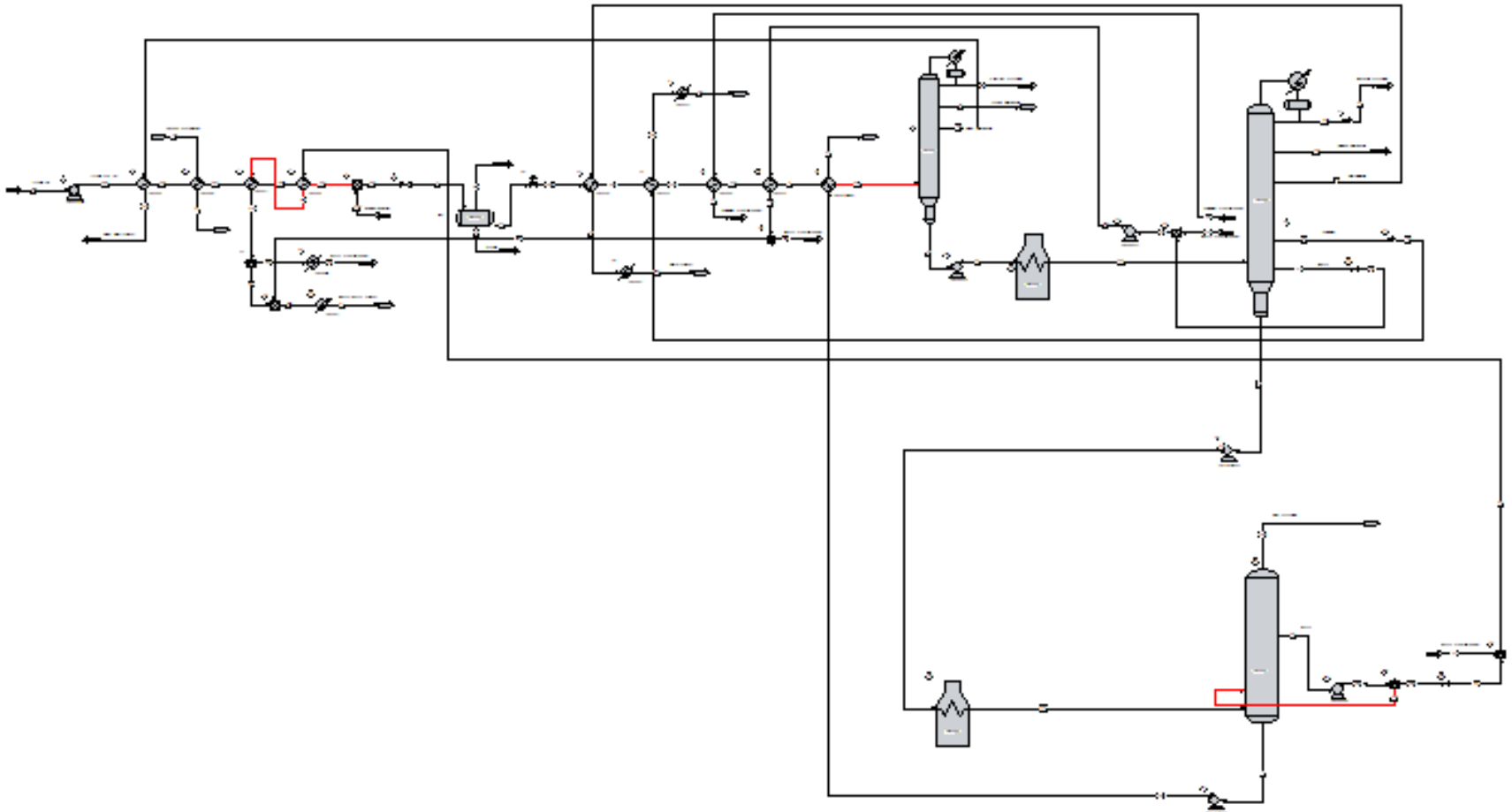
Agenda

- Background of case study
- Determining scope of model
- Simulation Guidelines
- Case Study
- Summary

Background of Case Study

- Customer – Calumet Montana Refining, LLC
- Had existing steady-state model of entire facility
- Shared P&IDs, PFDs, procedures, & process data from previous start-up
- New crude unit being built & would like accurate simulation of startup conditions

Original Steady State Simulation



Goals of Case Study

- Simulate crude unit only
- Model existing tower startup
- Compare to historical startup data
- Determine if dynamic simulation could be used as tool to predict startup performance of new crude unit

Determining Scope of Model

Use operating procedure to determine sequential steps & model targets:

- 1) Crude charge introduced to tower at increasing temp & flow rate
- 2) Target level reached in overhead accumulator
- 3) Reflux system placed in service
- 4) Stripping steam introduced to tower
- 5) Product streams reach specification

Simulation Guidelines

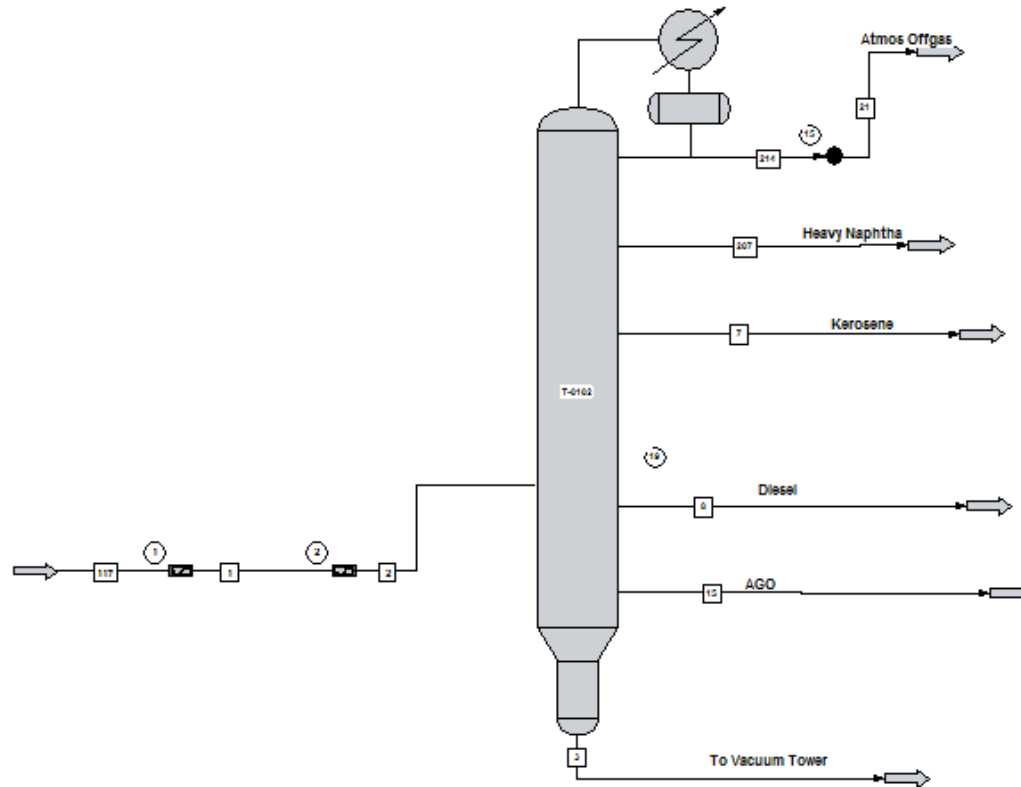
- Start with a simple model
- Get model to converge
- Validate results
- Add complexity as required to reach desired engineering solution

Start with a Simple Model

- Crude tower only
- Change to dynamic simulation mode
- Pumparounds/side strippers not in service
- Crude Heater modeled as temp & flow ramps
- Use actual data & equipment parameters
 - Feed temps & flows from actual data
 - Accumulator dimensions & condenser setpoints
 - # trays, feed stage, etc.

Simplified Flowsheet

Startup from Dry Column



Change to Dynamic Simulation Mode

- Convergence Parameters -

Take a snapshot before running flowsheet

Recycle Convergence Methods

Convergence method:

Direct substitution

Wegstein

Dominant Eigenvalue (DEM)

Max. flowsheet iterations: 40

Speed up frequency: 4

Plot stream history

Cut stream method: Smart cut

Recycle Tolerances

Flow rate: 0.001

Temperature: 0.001

Pressure: 0.001

Vapor fraction: 0.001

Enthalpy: 0.001

Flash Calculations

Flash algorithm: Normal

Flash damping factor: 1

Flash tolerance: 1e-005

Thermo Accel. tolerance: 0.001

Calculation sequence: Sequential modular

Steady state/dynamics: Dynamics

Flow/pressure conversion: Steady state
Dynamics

Display trace window

Generate run history

Refresh data boxes after each run

Refresh data boxes after each iteration

Run Data Map at each dynamic time step

Run one time step for dynamic simulation

Allow dynamic editing any time

O/S real time scale: []

Help Cancel OK

Startup Conditions

DOC - General Information - ID: 19

Initial Column Conditions

Steady state continuous process

Startup the column

Dry tray startup

Continue from previously saved state

Tray holdup calculation

Ignore liquid holdup Ignore vapor holdup

Constant liquid holdup Calculate vapor holdup

Variable liquid holdup

Pressure Calculation

Fixed Pressure

Display plot during simulation

Record frequency 1

Include column metal heat transfer

Use operator training algorithm.

Help Cancel OK

Tower & Feed Configuration

- Tower Configuration -

ID: 19

Tower Plus Configuration:

Number of strippers

Number of pumparounds

Number of exchangers

Number of side products

Help Cancel OK

- RAMP for Equipment / Stream Parameters -

ID: 1

Type

Equipment Variable

Stream Component

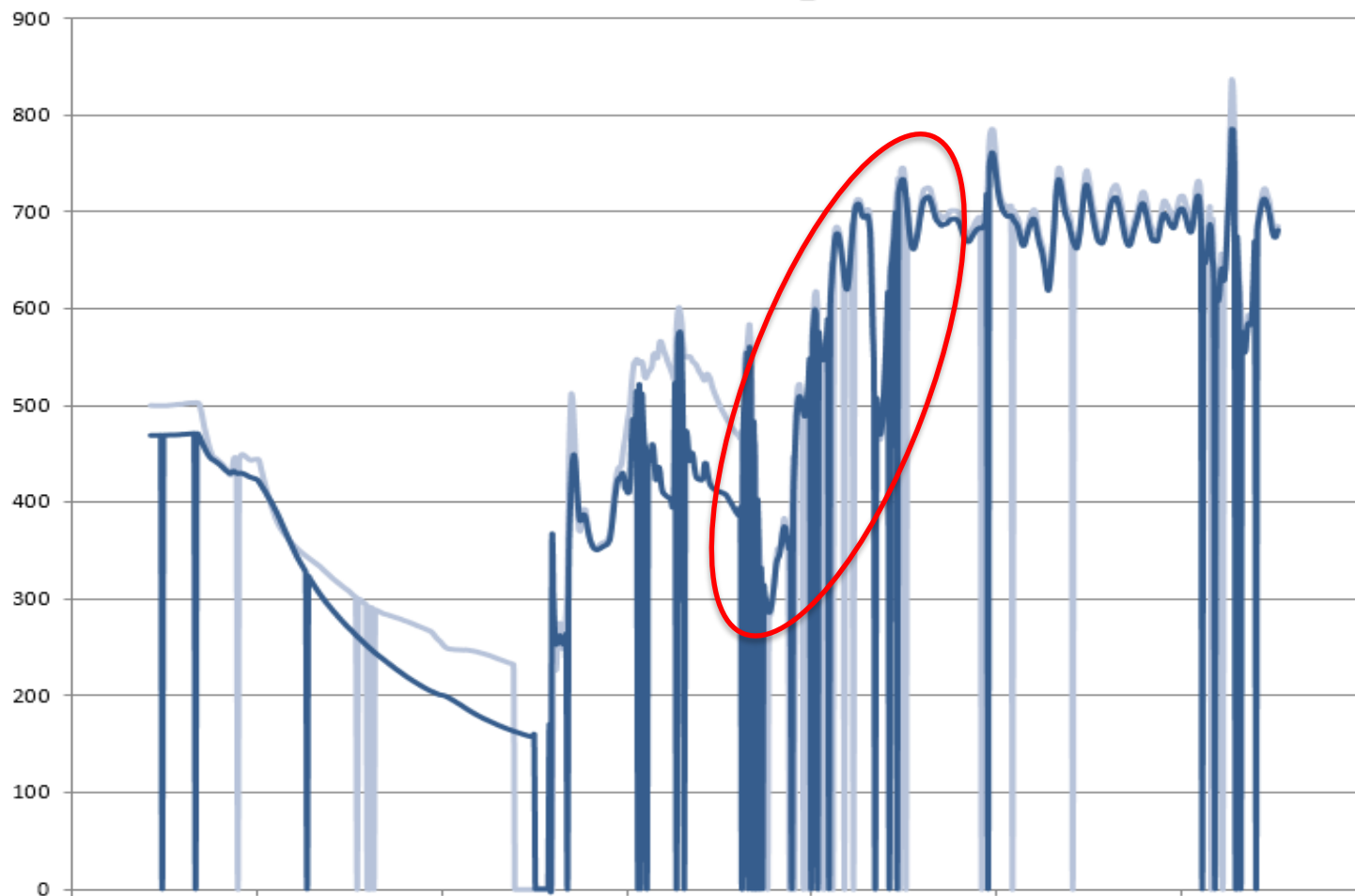
Variable units

Use the table below

Time (min)	Value	Time (min)	Value
0	325		
60	700		
120	717		

Help Additional time steps... Cancel OK

Actual Data Determined Ramp Settings



Scope of Model

- 1) Crude charge introduced to tower at increasing temp & flow rate ✓
- 2) Target level reached in overhead accumulator
- 3) Reflux system placed in service
- 4) Stripping steam introduced to tower
- 5) Product streams reach specification

Accumulator Dimensions & Reflux

Set reflux
to zero
initially

Dynamic Column Specifications - ID: 19

Condenser | Reboiler

Condenser holdup option: Variable Holdup

Reflux specification: Liquid reflux mass rate

Reflux rate: 0 lb/h

Liquid distillate specification: Liquid distillate mass rate

Distillate rate: 0 lb/h

Distillate Control Valve ID #:

For a condenser with a UA specification:

Utility stream inlet ID #:

Utility stream outlet ID #:

Utility control valve ID #:

Utility pressure drop: psia

Condenser U: Btu/hr-ft²-F

Condenser A: ft²

Optional level specifications:

Orientation: Horizontal

Head type: Ellipsoidal

Radius/depth head ratio:

Diameter: 4.83333 ft

Cylinder length: 20.5 ft

Initial liquid level: 1 ft

Buttons: Help, Cancel, OK

Accumulator Level Target Specification

DOC - Startup Condition - [X]

For column startup only: ID: 19

Duration time h

Reboiler heat duty MMBtu/h

Accumulator holdup unit:

Max. accumulator holdup ft³

Initial holdup ft³

Pressure Calculation

Get Dynamic Model to Converge

- Set initial run time based on actual data if available
- Modify step size:
 - If needed to assist with convergence
 - Depending on target parameter's rate of change
- Run one time step manually & view results
- Other convergence adjustments:
 - # of iterations
 - tolerances

Run Time Parameters

Dynamic Run Time Schedule - ✖

General | Step 1

Operation Step 1

Time Run time min. Step size min.

Stream Calc. time min.

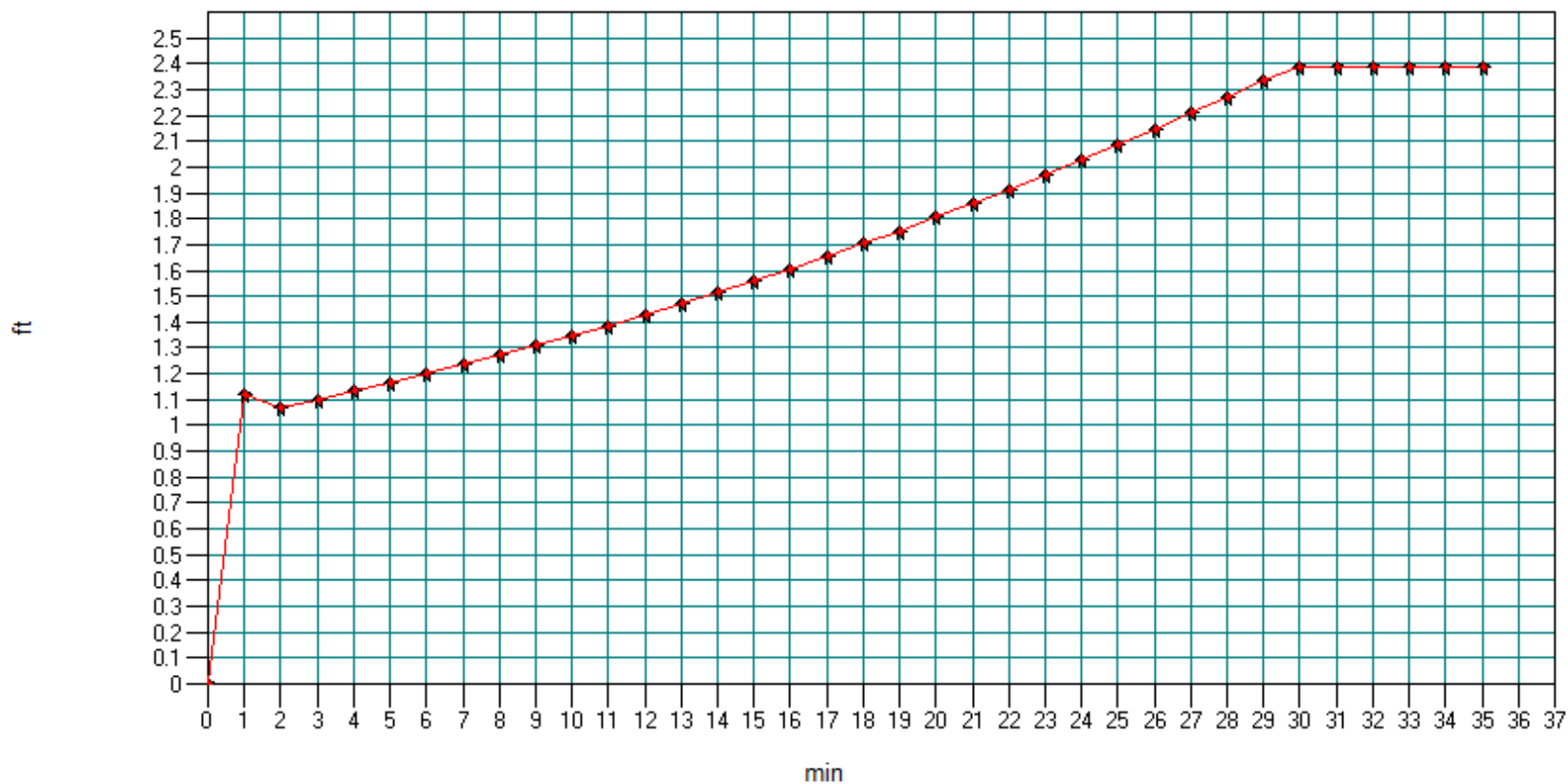
Equipment

ID number Variable Units

 Component

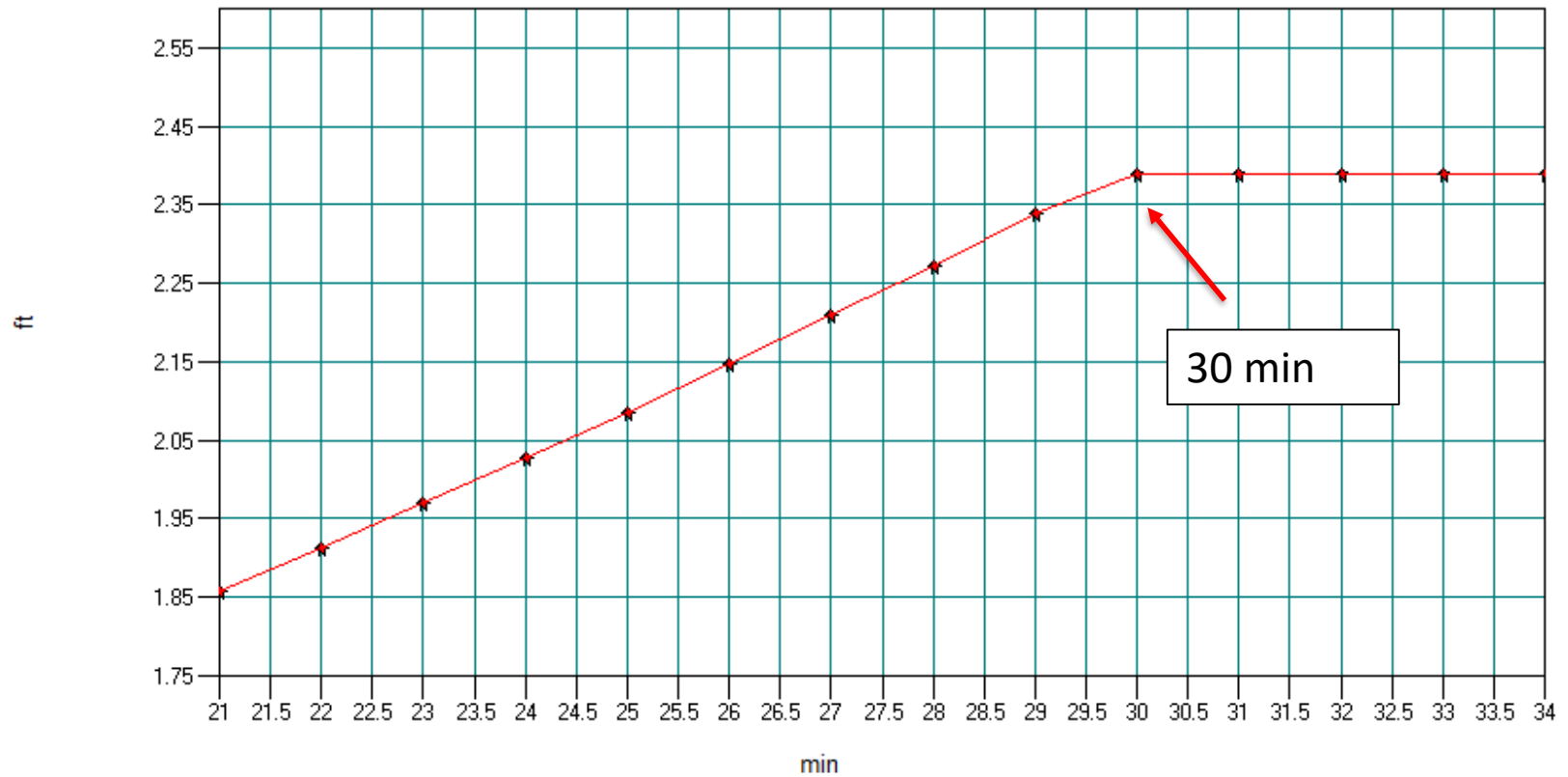
Stop Mode Stop Value Tolerance

Accumulator Level Plot



★ Accumulator liq. level(ft)

Accumulator Level Target Reached



★ Accumulator liq. level(ft)

Scope of Model

- 1) Crude charge introduced to tower at increasing temp & flow rate ✓
- 2) Target level reached in overhead accumulator ✓
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Place Reflux System In Service

Switch to
maintain
level &
adjust
reflux rate

The screenshot shows the 'Dynamic Column Specifications' dialog box for a condenser. The 'Condenser' tab is active. The 'Condenser holdup option' is set to 'Constant Holdup'. The 'Reflux specification' is set to 'Liquid reflux mass rate', with a 'Reflux rate' of 0 lb/h. The 'Liquid distillate specification' is set to 'Liquid distillate mass rate', with a 'Distillate rate' of 0 lb/h. The 'Distillate Control Valve ID #' is empty. The 'Optional level specifications' section shows 'Orientation' as Horizontal, 'Head type' as Ellipsoidal, 'Radius/depth head ratio' as empty, 'Diameter' as 4.83333 ft, 'Cylinder length' as 20.5 ft, and 'Initial liquid level' as 1 ft. The 'For a condenser with a UA specification' section has empty fields for 'Utility stream inlet ID #', 'Utility stream outlet ID #', 'Utility control valve ID #', 'Utility pressure drop', 'Condenser U', and 'Condenser A'.

Dynamic Column Specifications - ID: 19

Condenser holdup option: Constant Holdup

Reflux specification: Liquid reflux mass rate
Reflux rate: 0 lb/h

Liquid distillate specification: Liquid distillate mass rate
Distillate rate: 0 lb/h
Distillate Control Valve ID #:

For a condenser with a UA specification:

Utility stream inlet ID #:
Utility stream outlet ID #:
Utility control valve ID #:
Utility pressure drop: psia
Condenser U: Btu/hr-ft²-F
Condenser A: ft²

Optional level specifications:

Orientation: Horizontal
Head type: Ellipsoidal
Radius/depth head ratio:
Diameter: 4.83333 ft
Cylinder length: 20.5 ft
Initial liquid level: 1 ft

Buttons: Help, Cancel, OK

Scope of Model

- 1) Crude charge introduced to tower at increasing temp & flow rate ✓
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Start Stripping Steam to Tower

DOC - Main Column -

ID: 19

Column Number of stages: 17

Pressure of colm top: 21 psia

Column pressure drop: 7.5 psi

Steam

Bottom steam rate: 59.111 lbmol/h

Steam temperature: 760 F

Steam pressure: 163.1 psia

Stage efficiency

Top stage:

Bottom stage:

Feed Stages

1st feed stage #: 15

2nd feed stage #:

3rd feed stage #:

4th feed stage #:

5th feed stage #:

6th feed stage #:

7th feed stage #:

8th feed stage #:

9th feed stage #:

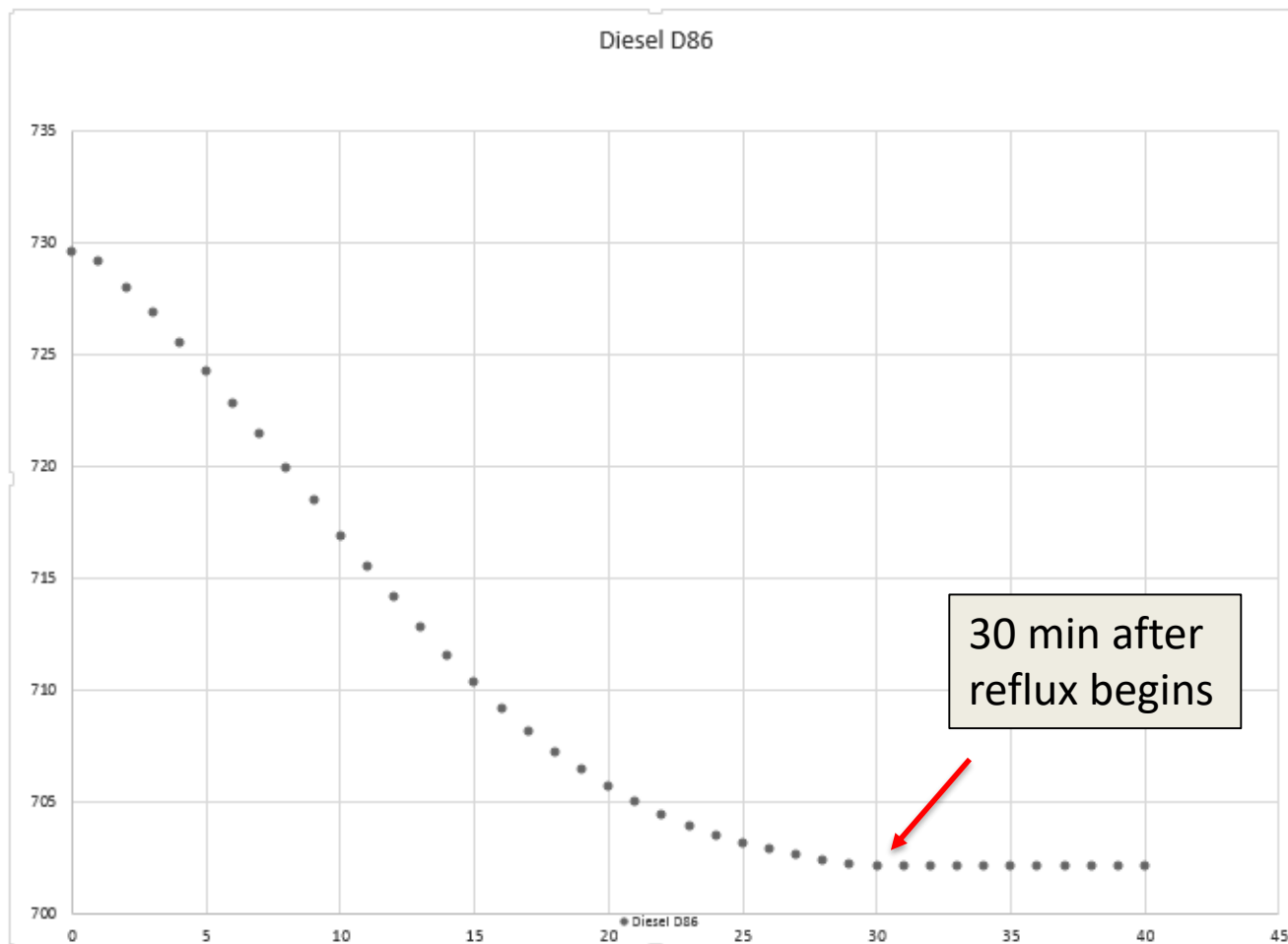
10th feed stage #:

Help Cancel OK

Scope of Model

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Product Stream Reaching Specification



Scope of Model

- 1) Crude charge introduced to tower at increasing temp & flow rate ✓
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Validating Results

- Time to reach accumulator level:
 - Model → 30 min
 - Actual → 20 min
- Time to side product specs after reflux begins:
 - Model → 30 min
 - Actual → 40 min

Further Validation of Results

- Compare to additional sets of startup data
 - Is the delta between the model & actual consistent?
- Add complexity as required to get desired results
 - How close is close enough?

Add Complexity As Required

- Fired heater
- Reflux/distillate control valves
- Pumparounds/side strippers
- Relief valve studies
- Additional upstream / downstream units

Switch Back to Steady State Model

- Convergence Parameters -

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Recycle Convergence Methods

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Calculation sequence: Sequential modular

Steady state/dynamics: Dynamics

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Run one time step for dynamic simulation

Allow dynamic editing any time

O/S real time scale: []

Display trace window

Generate run history

Refresh data boxes after each run

Refresh data boxes after each iteration

Run Data Map at each dynamic time step

Help Cancel OK

Review Simulation Guidelines*

- Start with a simple model
 - Fix what you can, i.e. pressures, etc.
 - Ignore what you can, i.e. utilities, etc.
- Get model to converge
- Validate results
- Add complexity as required to reach desired engineering solution
 - more detail may not be better!
 - i.e. don't add utilities controls systems to flowsheet just because they're on the P&ID

* True for steady state & dynamic simulations!

Special Thanks

Ron Colwell, PE – Engineering Manager

David Fleming – Senior Process Engineer

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Calumet Montana Refining processes Canadian heavy crude oil to produce gasoline, middle distillates and asphalt which they market primarily into local markets in Washington, Montana, Idaho and Alberta, Canada.