Aspen HYSYS: Introduction to Dynamic Simulation

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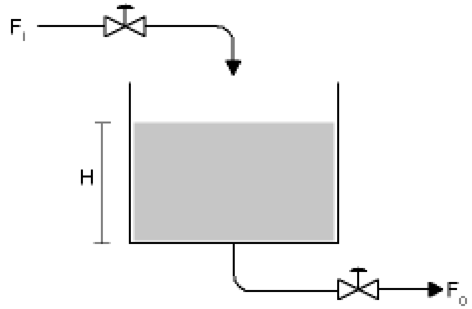
Contents

Modelling in HYSYS Dynamic

- HYSYS Dynamic uses “lumped” model i.e. there are no thermal or concentration gradients in space (x, y or z-directions), allowing it to be expressed as ordinary differential equations (ODEs)
- E.g*.



$$\frac{d(\rho_o V)}{dt} = F_i \rho_i - F_o \rho_o$$

where:

F_i = flowrate of the feed entering the tank

ρ_i = density of the feed entering the tank

F_o = flowrate of the product exiting the tank

ρ_o = density of the product exiting the tank

V = volume of the fluid in the tank

(*from HYSYS manual)

Introduction

Modelling in HYSYS Dynamic

- Fixed temporal discretization
- The ODEs are solved using simple but robust Implicit Euler Method
- Calculations are performed at different frequencies (specified by the user):
    - Volume (pressure-flow)
    - Control and logical operations
    - Energy
    - Composition

Introduction

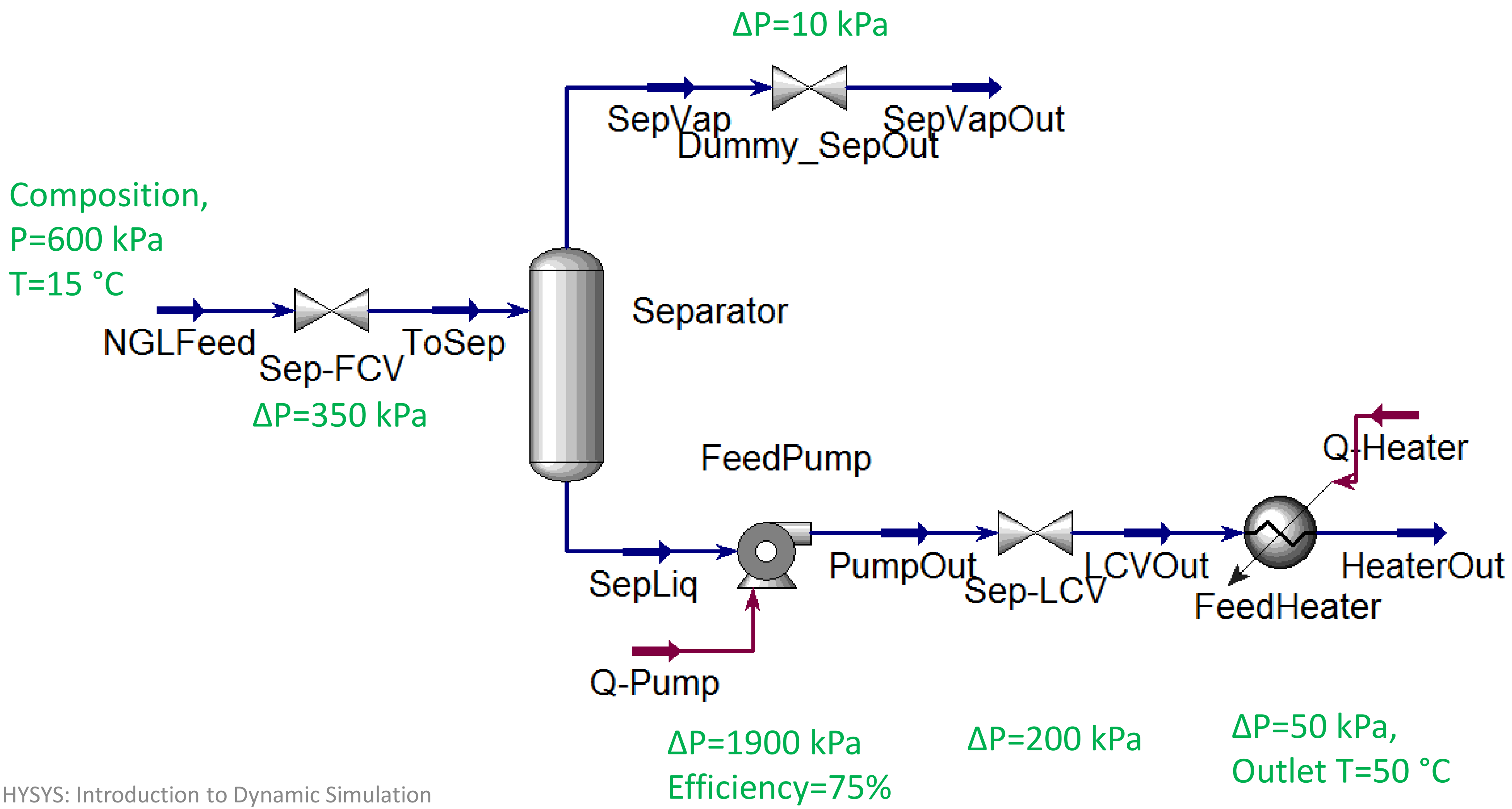
Applications

- Steady state
  - Design
  - Heat and material (HMB) generation
  - Equipment sizing
- Dynamic
  - Control system verification
  - Equipment sizing
  - Safety review/assessment
  - Operator training system (OTS)
  - Commissioning
  - Troubleshooting

Dynamic scenarios: start-up, emergency shutdown, valve fail-close/open, machine power loss

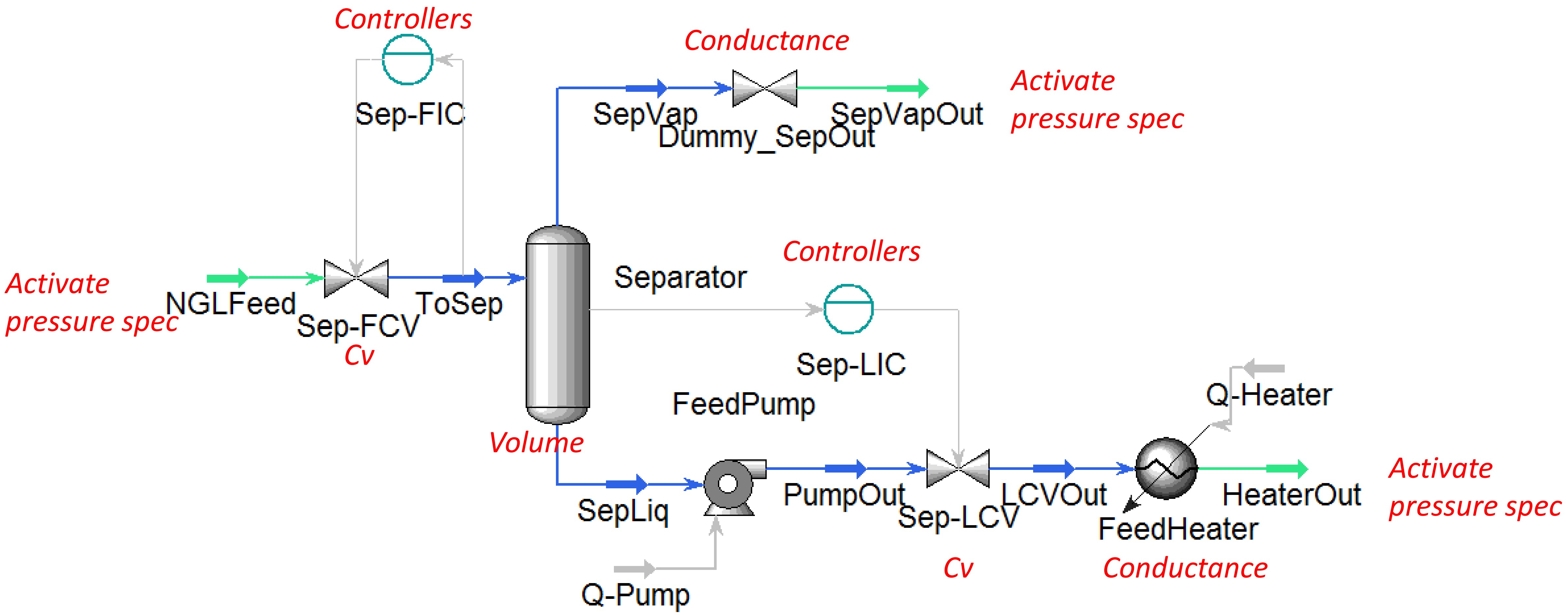
Lesson 0

Steady state model



Lesson 1

Dynamic model



Lesson 1

Pressure-flow relationship

- All pressure-flow relationships are reduced to:

$$Flow = k \times \sqrt{\Delta P}$$

- Which is analogous to:

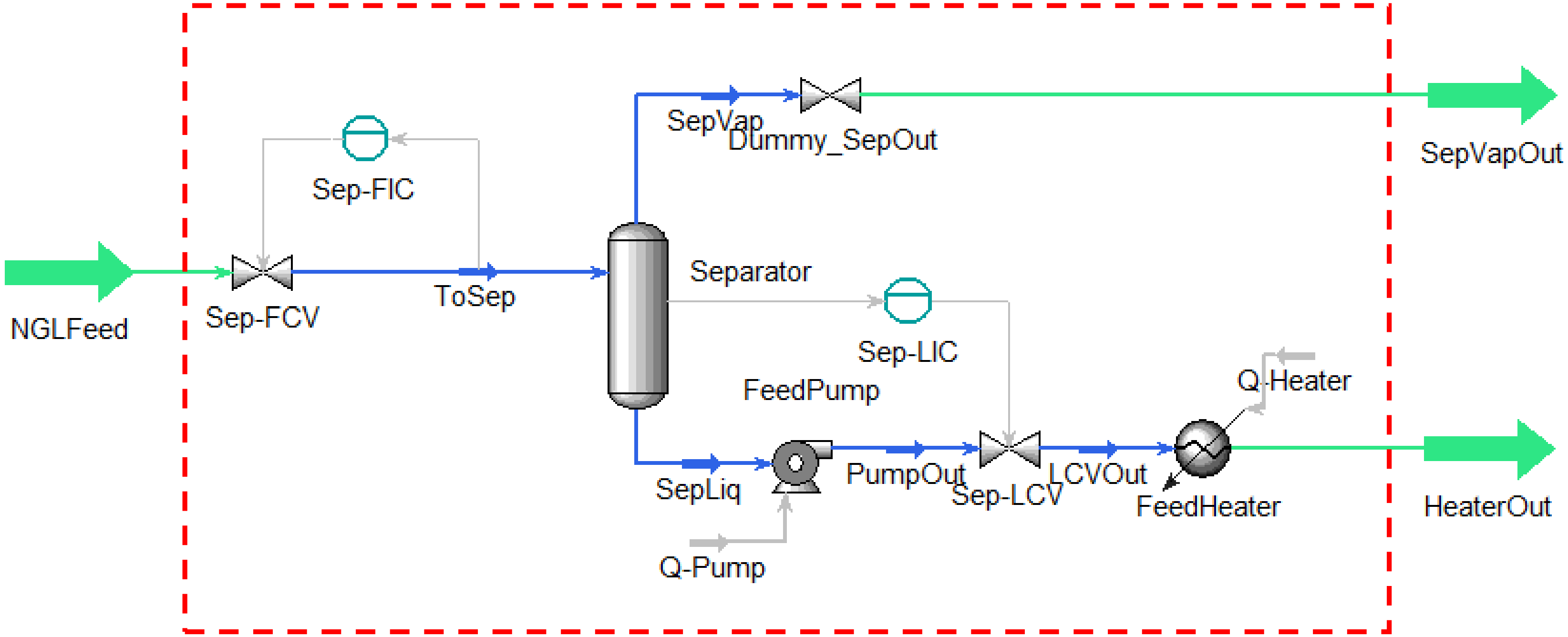
$$I = \frac{1}{R} \times \Delta V$$

- This simplification allows more room for thermodynamic and control computations, at the expense of rigorous hydraulic modelling
- In most cases this is acceptable, except for cases that require better transient hydraulic representation such as multiphase flow in pipelines (use OLGA) or single phase liquid (use PIPENET etc.)

Lesson 1

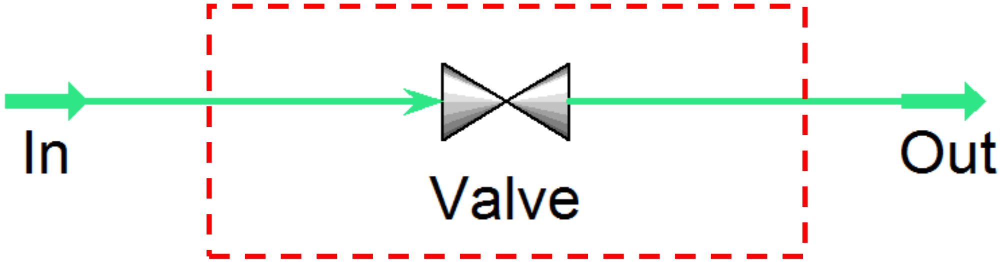
Boundary specifications

- Pressure or flow specifications need to be specified at all the boundary streams
- There cannot be any dangling streams without pressure/flow specifications



Boundary specifications (cont'd)

- Consider a simple dynamic case with only one valve:



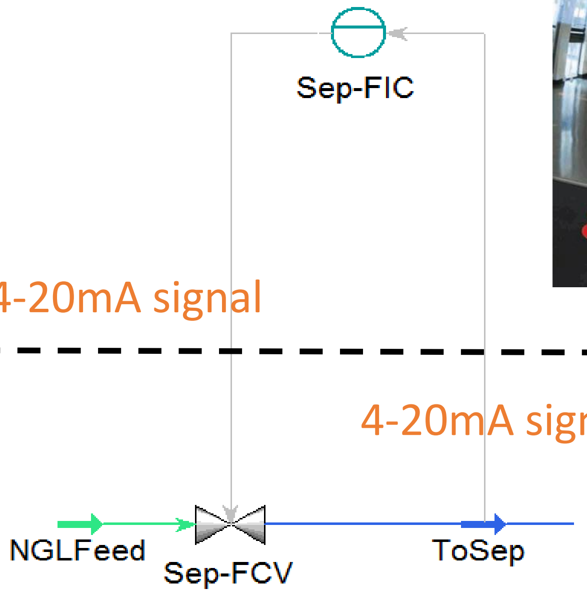
- Possible combination for boundary specifications:
  - Pressure-Pressure
  - Flow-Pressure
  - Pressure-Flow
- Flow-Flow is not possible because it needs at least one reference pressure

Lesson 1

Control loop: e.g. flow control

Control room

Distributed control system, DCS



4-20mA signal

Field

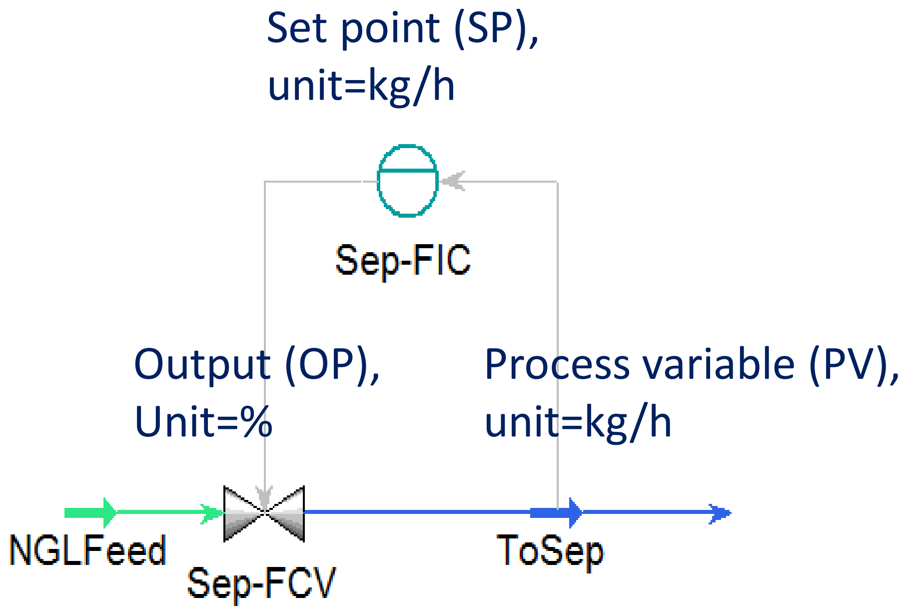
4-20mA signal

Valve

Flowmeter

(*pictures from new.abb.com, www.geoilandgas.com)

Control loop: e.g. flow control (cont'd)



$$OP(t) = K_c E(t) + \frac{K_c}{T_i} \int E(t) + K_c T_d \frac{dE(t)}{dt}$$

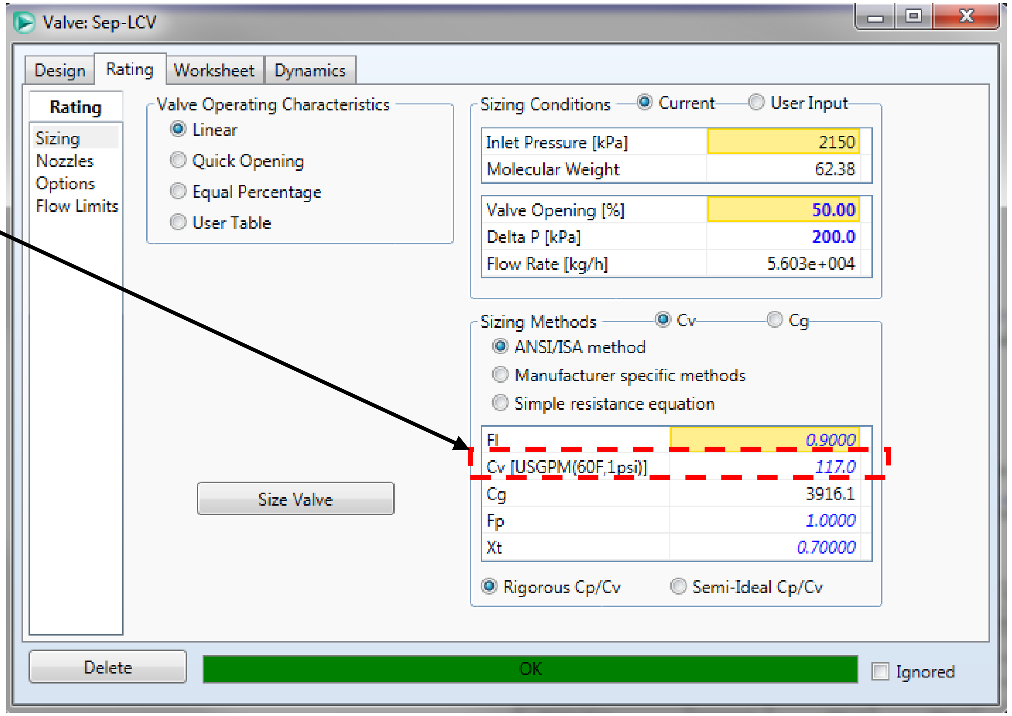
$K_c =$ proportional gain
$T_i =$ integral time constant
$T_d =$ derivative time constant
$E(t) = SP(t) - PV(t)$ (reverse acting)
$E(t) = PV(t) - SP(t)$ (direct acting)

In this case,
If PV(flow)↓, we need OP(valve opening) ↑
If PV(flow)↑, we need OP(valve opening) ↓,
So action is REVERSE

In most cases, derivative term is not used because it is very sensitive to noise. Hence usually we only use PI control, instead of PID.

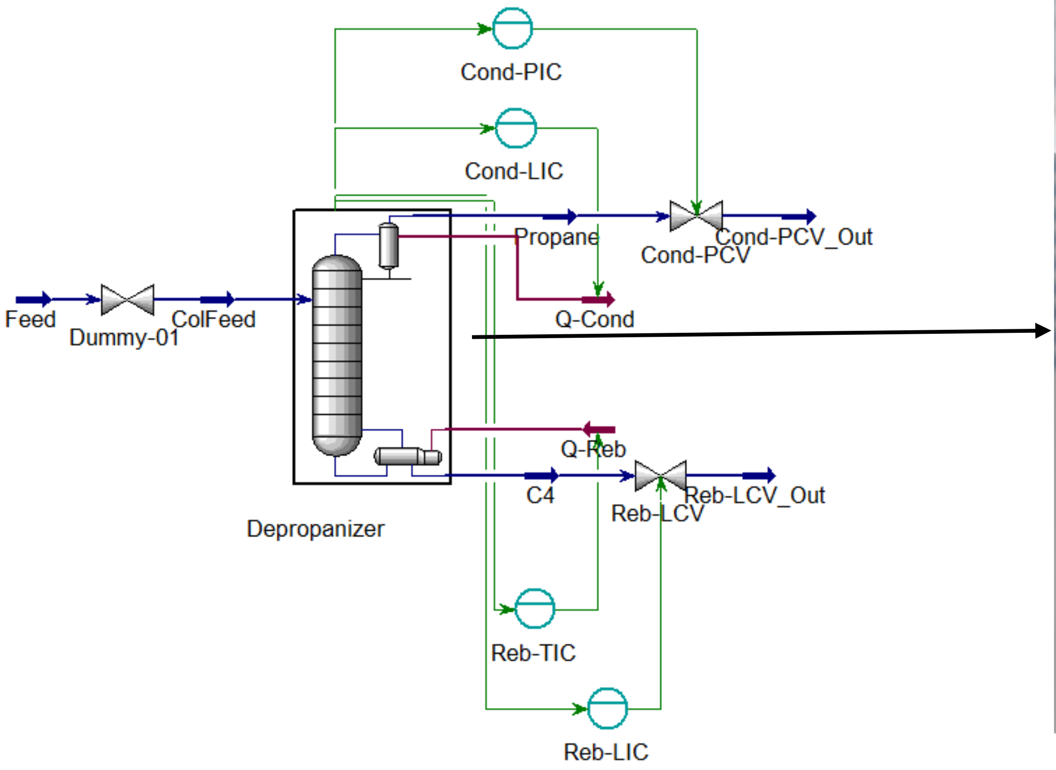
Valve sizing in HYSYS

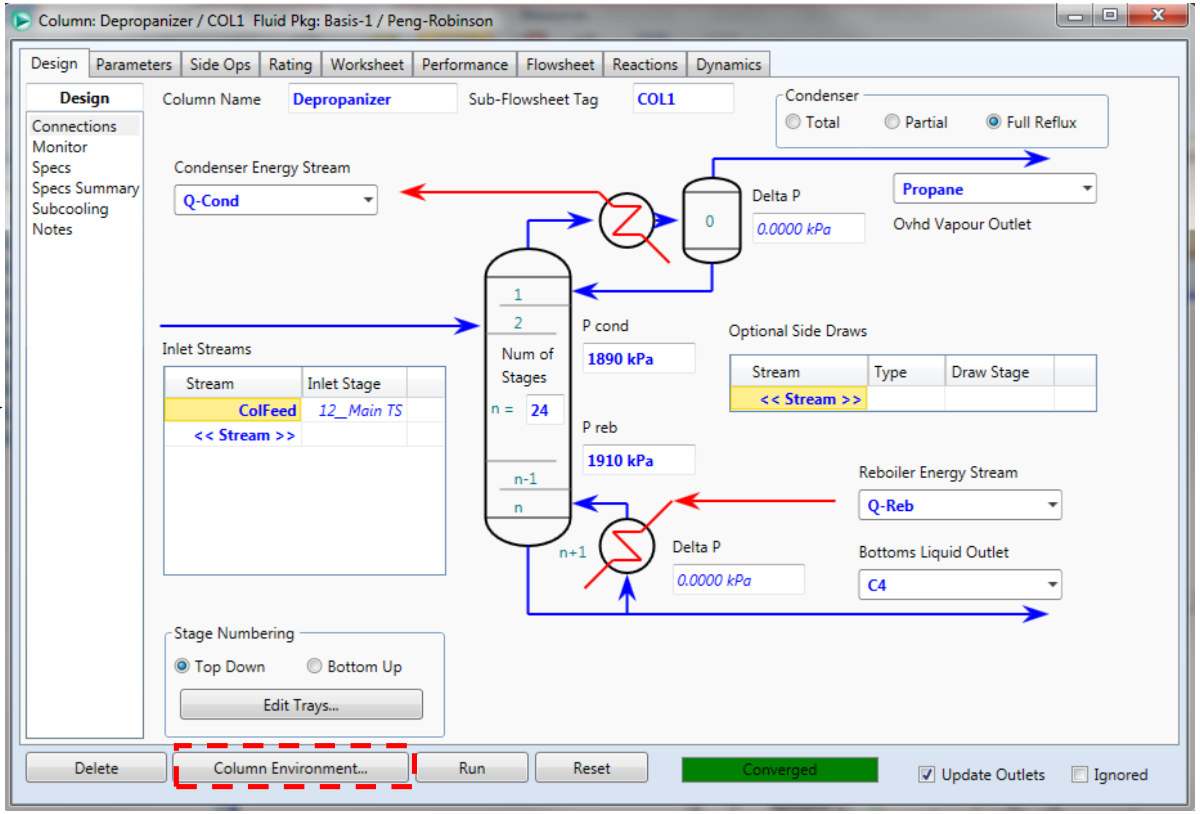
- Whenever "Size Valve" feature is used, HYSYS follows the following steps to determine the valve's Cv:
    1. Calculate the Cv at the specified conditions (molecular weight, inlet temperature, pressure drop etc.) using the selected sizing correlation. This is the Cv at the current opening (default value=50%)
    2. Extrapolate Cv at 100% opening based on the specified characteristics (under "Valve Operating Characteristics"). The default relationship is linear. The resultant value is the valve's Cv shown here:



Steady state model

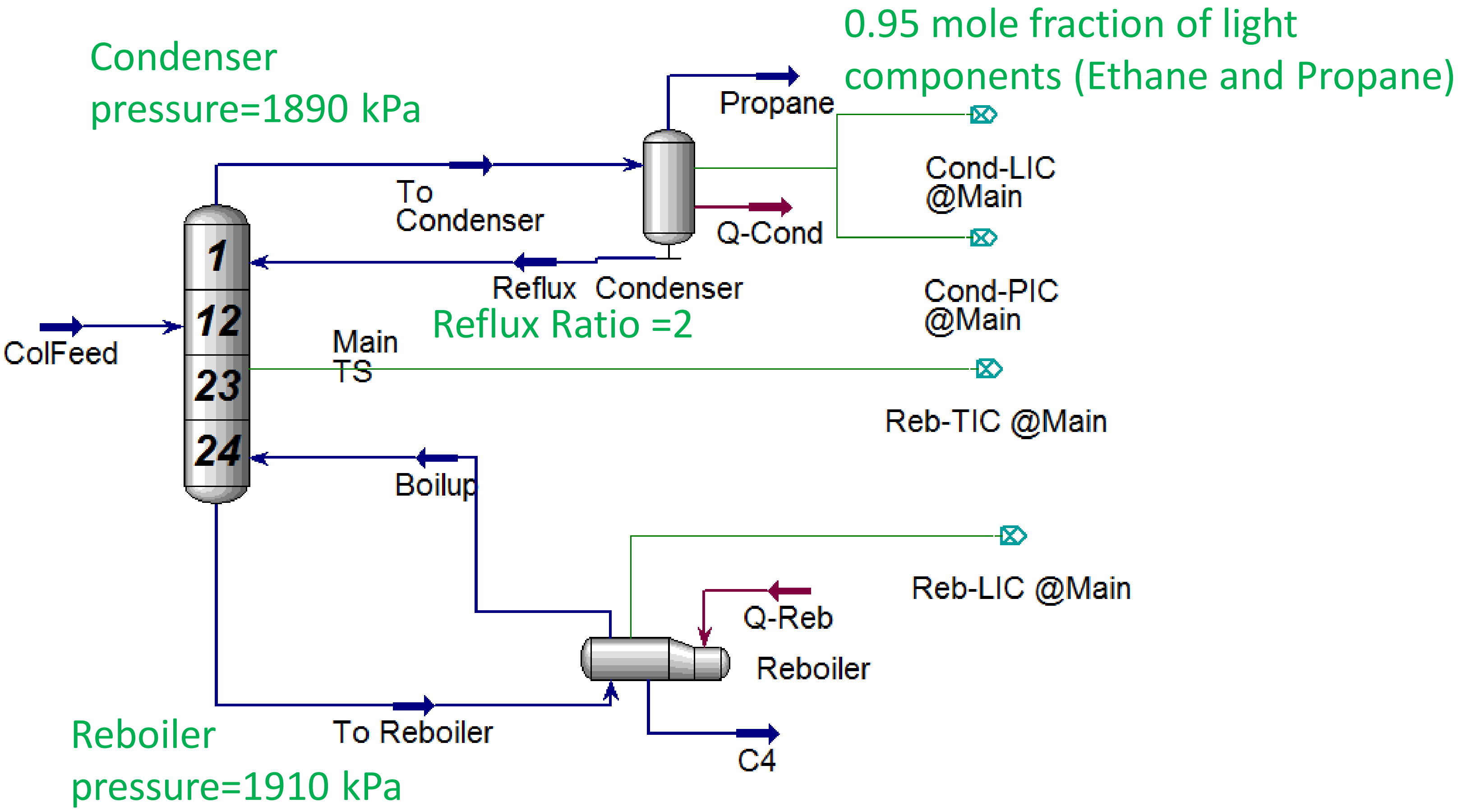
- A built-in sub-flowsheet called Distillation Column is used to model the Depropanizer





Steady state model (cont'd)

- Sub-flowsheet environment and the column steady state specifications



Final Remarks

Data requirements

- In general, dynamic modelling is a very data intensive exercise. Consider some of the typical data required for a control valve:

Steady state	Dynamic
• Pressure drop/Cv	• Pressure drop/Cv • Opening/closing times • Trim curve (Cv vs. opening relationship) • Air to open/close, fail-open/close • Hold-up volume • Inlet/outlet diameter • Elevation from datum level

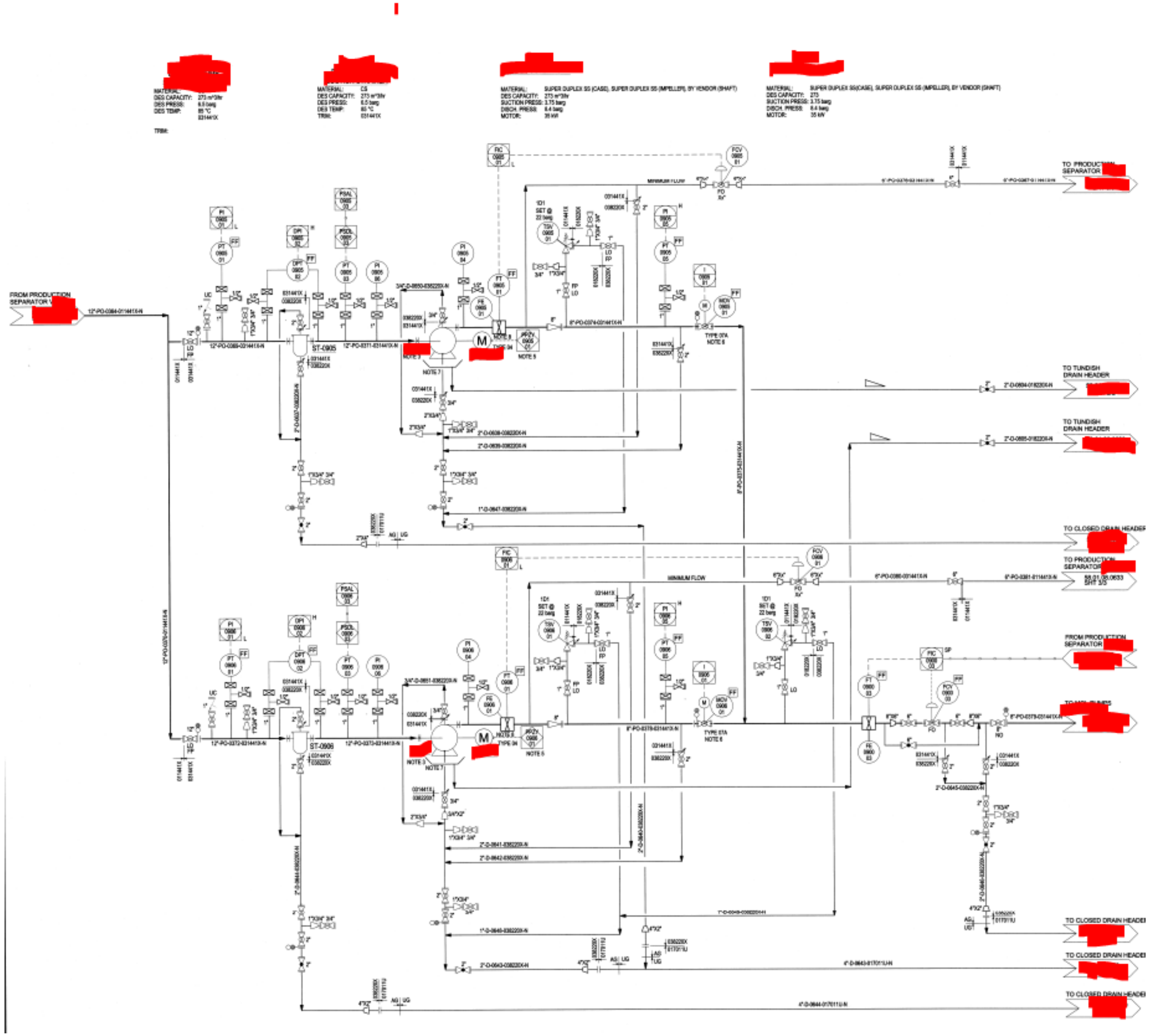
- Understanding the objectives of the study (i.e. what we expect to achieve from the model) is the first step in identifying the important parameters to be included

Final Remarks

Typical data sources

- Basis of design
- P&IDs, PFDs
- HMB
- Piping isometrics
- Vendor/manufacturer datasheets
- Operating manual
- Instrument/alarm schedule
- Cause & effect diagram
- Live plant data or data historian

Final Remarks



Final Remarks

Some rules to increase dynamic model robustness

- Introduce pressure-flow relationship around vessel, stream mixer/tee, and model boundaries by using fake valves with very large conductance k
- In general, try to avoid using flow specification. If flow needs to be specified, use a control valve with a flow controller
- Avoid introducing instantaneous or very rapid change in flow/pressure – use ramp limiter in Transfer Function block if necessary
- Introduce check valve if no backflow is expected
- Make sure the time step is small enough to capture all the dynamic behavior. Also pay attention to other options in Integrator as they control the overall computations in Dynamic mode