# Commonly Missed Overpressure Scenarios

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# *Today's Presenter*


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# *Smith & Burgess*

- **Formed Smith & Burgess to have a company that provides the highest level of customer service.**
- **Founders have over 25+ years of Process Safety experience each.**
- **Over 250 years of combined Process Safety experience.**
- **Members of API & participants on the 520/521 Safety Committees.**
- **Saved our clients an estimated $100+ million in unnecessary costs.**

# *Smith & Burgess*

- **Over 1500 completed national and international projects.**
- **50+ process safety engineers on staff.**
- **Over 15 research papers published nationally.**
- **Created "Salus Solutions"- the ONLY customizable relief systems documentation tool.**
- **2015 Houston Business Journal's *"Best Places to Work - Top 20"***

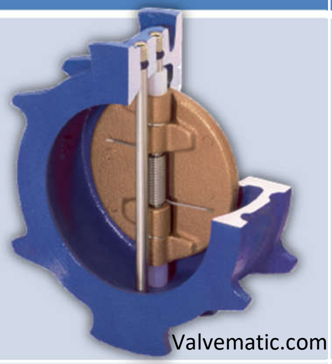
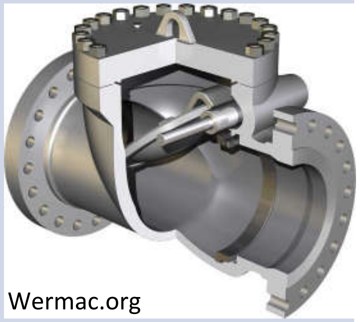
# *Today's Topics*

- Reverse Flow
- Vapor Breakthrough
- Partial Power Failures

# *Reverse Flow*

- Historically, check valves were used to protect assets
  - Contamination
  - Reverse rotation – damage to bearings, seals
- Not effective means of preventing overpressure
- Check valves can leak or fail

# *Reverse Flow*

| | Double Disk | Lift | Stop-Check | Swing |
|---|---|---|---|---|
| |  |  |  |  |
| Significant Failure Rate* | 1/114 yrs | 1/63 yrs | 1/438 hrs | 1/87 yrs |

*Significant Failure Rate: Broken/Damaged, Restricted Motion, Stuck Open, Stuck Closed, Improper Seating

"Failure Modes and Causes for Swing and Lift Type Check Valves"
Nuclear Industry - Oak Ridge National Laboratory

# Reverse Flow

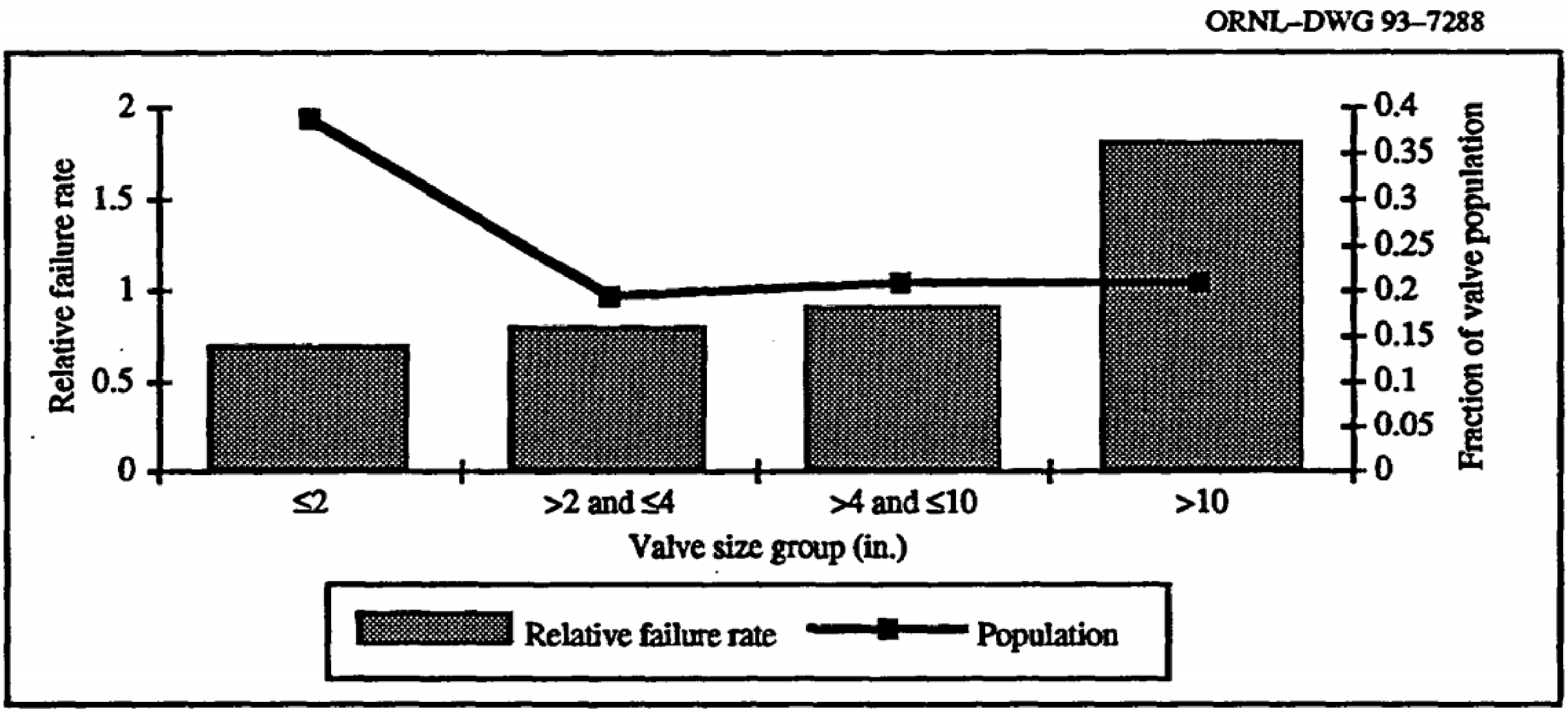



**Figure 3.3 Relative failure rate and population by size group**

Oak Ridge National Laboratory (Nuclear Industry),
Study of failures that occurred between 1984 and 1990

# *Reverse Flow*

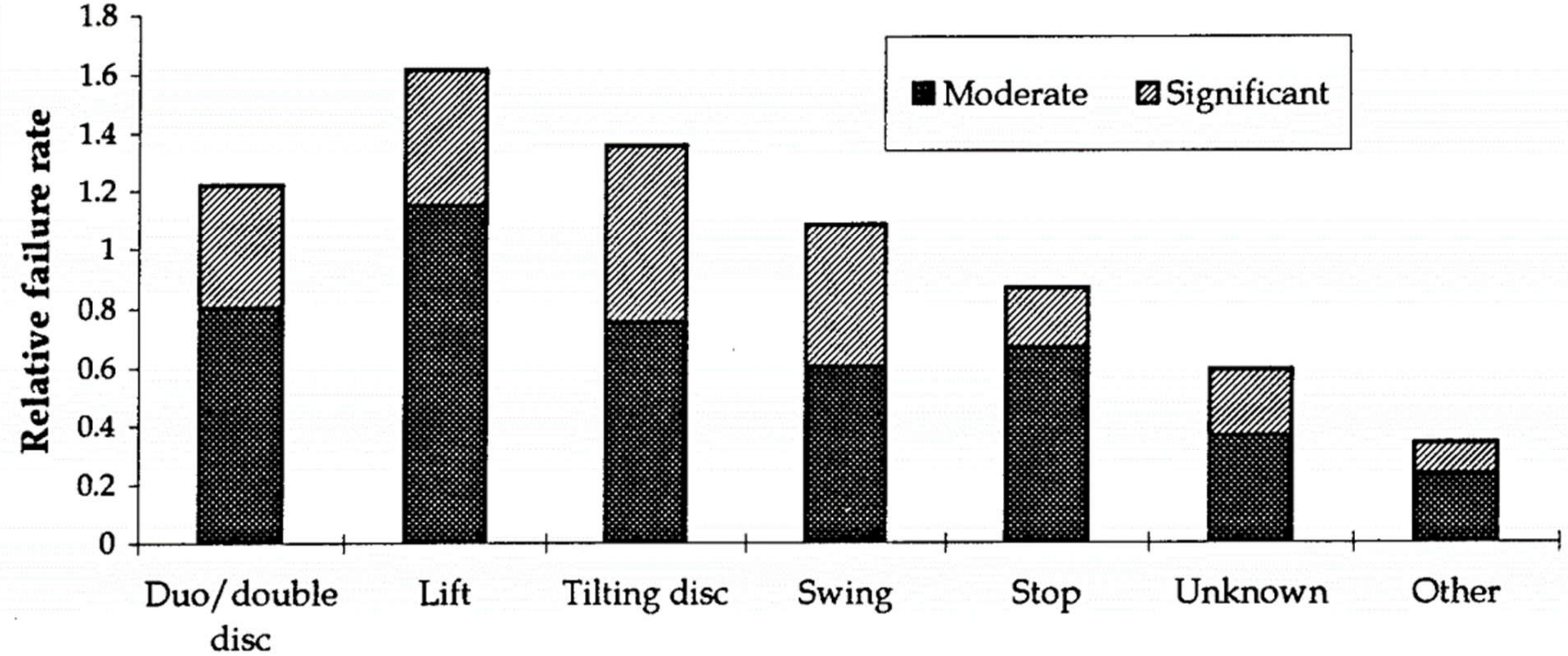



**Figure 1. Relative Failure Rate and Extent of Degradation by Valve Type for All Failures 1991-1996**

Oak Ridge National Laboratory (Nuclear Industry)

# *Reverse Flow*

## RAGAGEP

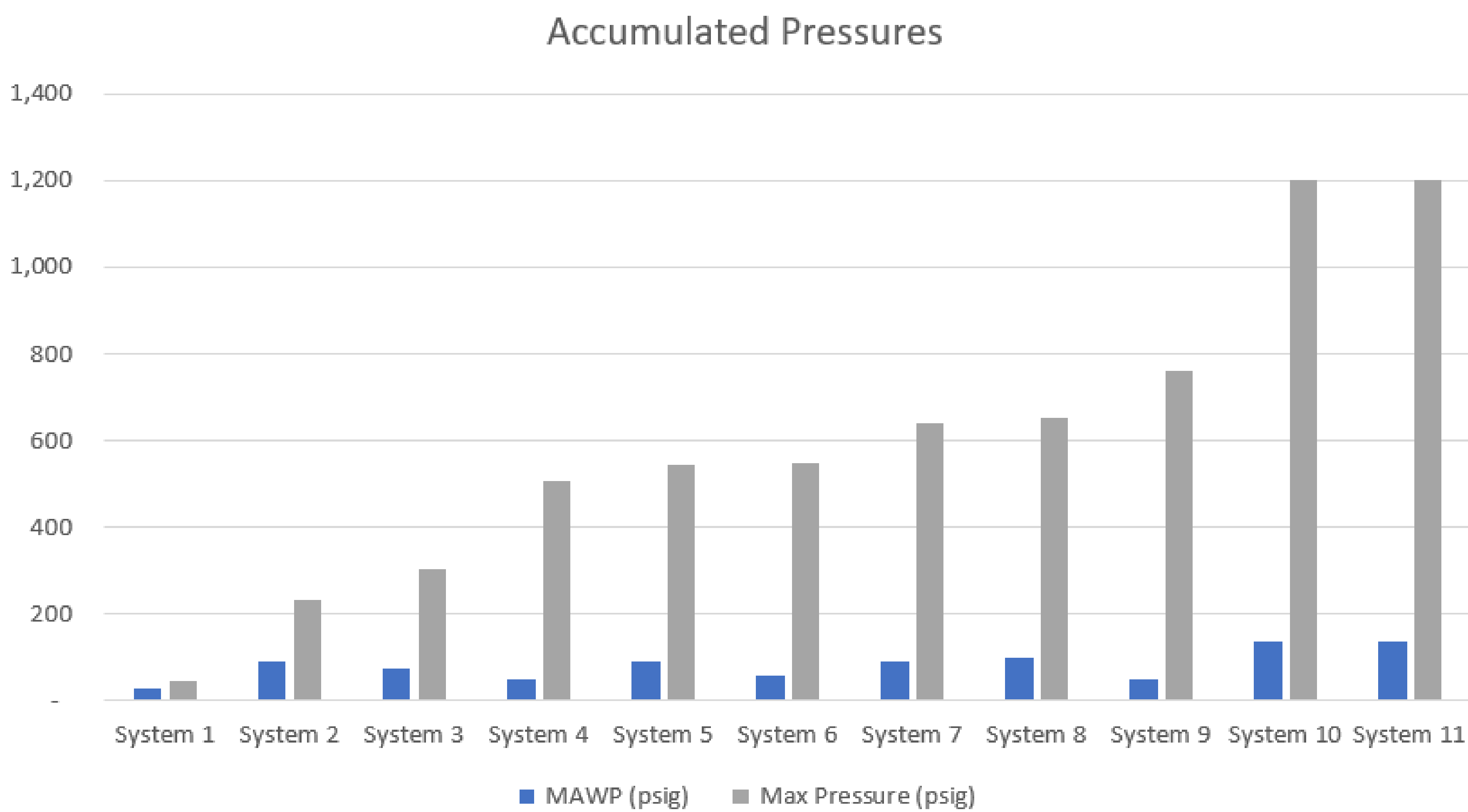
| | Single Check Valve | Dual Check Valves | Single Safety Critical Check Valve | Dual Safety Critical Check Valves |
|---|---|---|---|---|
| Normal Leakage | Yes | Yes | Yes | Yes |
| Severe Leakage | Yes | Yes | Yes | Yes |
| Complete Failure | Yes | Yes | Yes | No |

*Normal leakage*: associated with normal wear
*Severe leakage*: check valve seat damage or obstruction
*Complete failure*: stuck wide open

# *Reverse Flow*

| | Plant #1 | Plant #2 | Plant #3 | Plant #4 |
|---|---|---|---|---|
| Facility Type | West Coast Refinery | West Coast Refinery | Gulf Coast Refinery | Europe Refinery |
| Total PRV Systems Evaluated | 1300 | 2200 | 600 | 600 |
| # of Systems with Applicable Reverse Flow Scenario | 30 | 35 | 15 | 20 |
| # of Systems w/ Inadequate Overpressure Protection | 10 | 10 | 11 | 8 |
| % Inadequate | 33% | 29% | 73% | 40% |
| Average Expected Accumulation | 4 X MAWP | 3 X MAWP | 7 X MAWP | 3 X MAWP |
| Range of Expected Accumulation | 1.4 – 18 X MAWP | 1.2 – 8 X MAWP | 1.5 – 15 X MAWP | 1.3 – 6 X MAWP |

# Reverse Flow



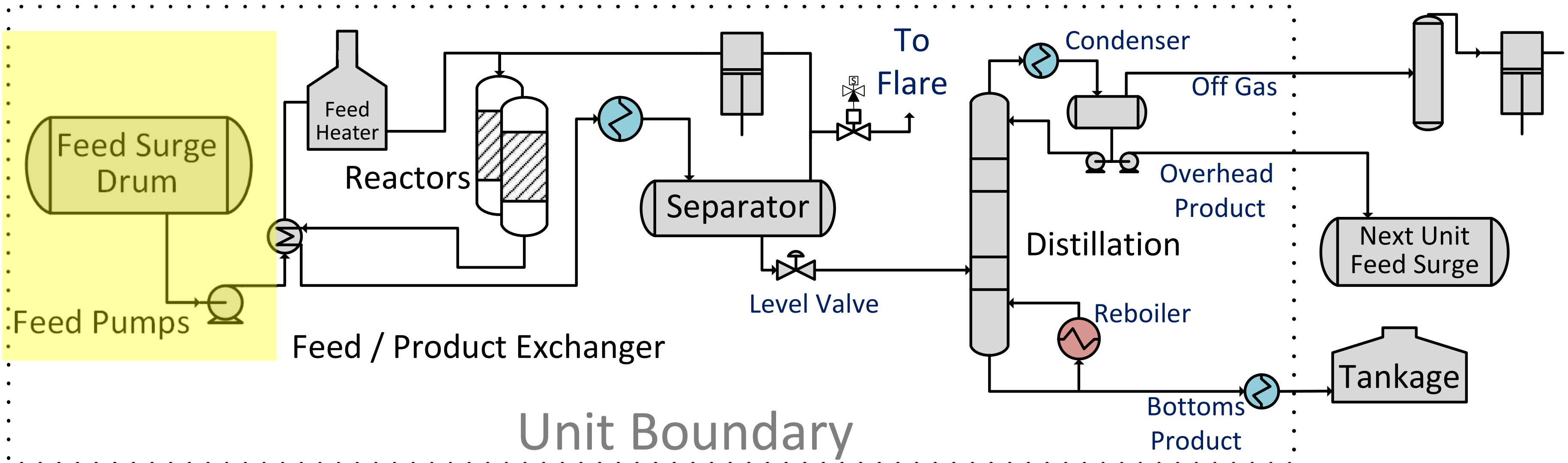
# *Reverse Flow*

Common systems where check valve failure scenario is applicable:

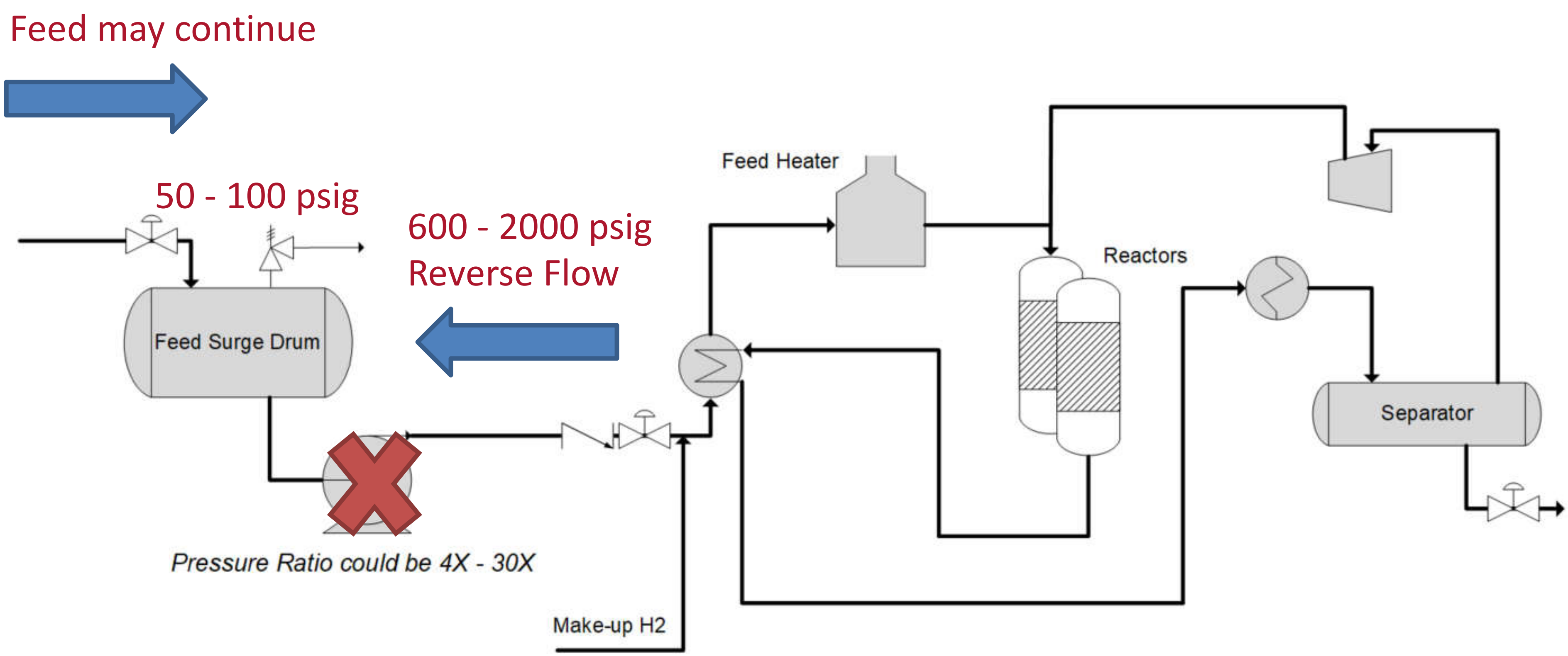
- Feed Surge Drums
- Deaerators
- Compressor Suction Drums
- Wash Water Drums

# Reverse Flow

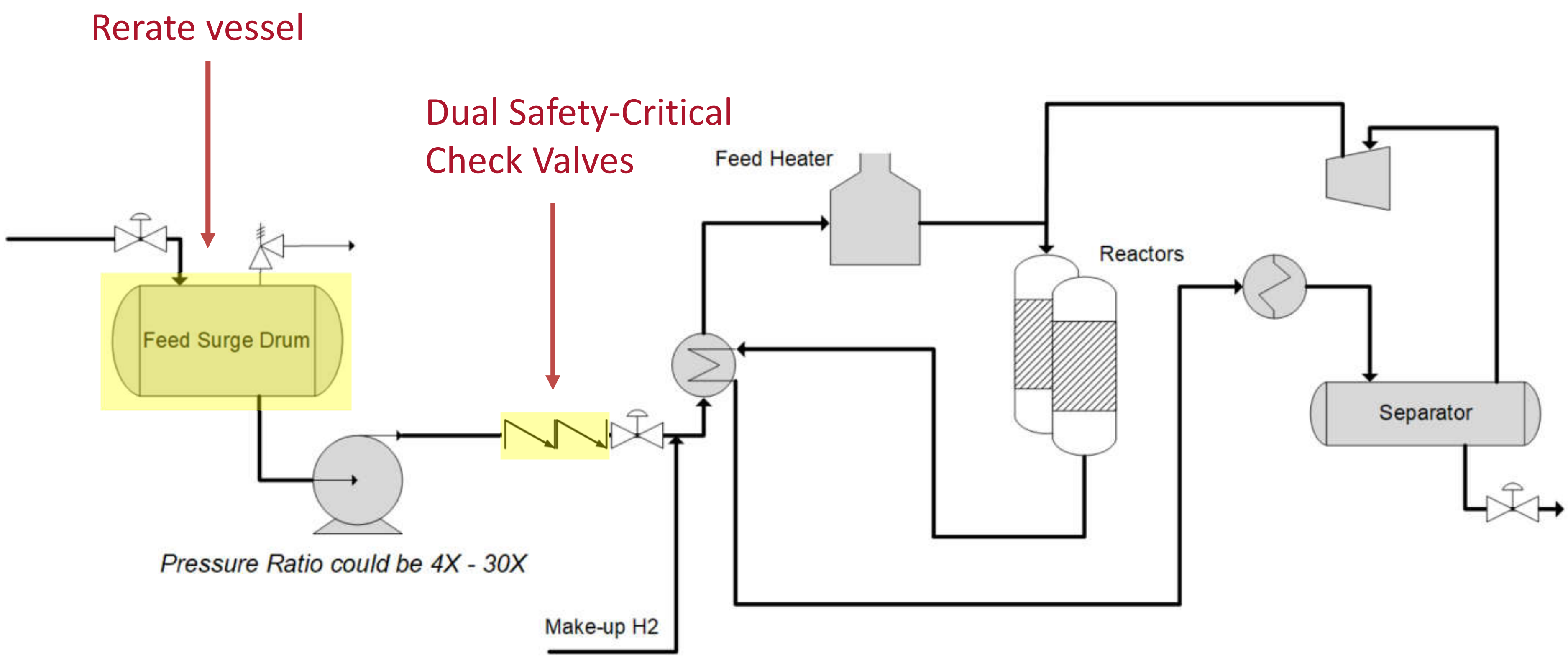
## Feed Surge Drums



# Reverse Flow



# Reverse Flow



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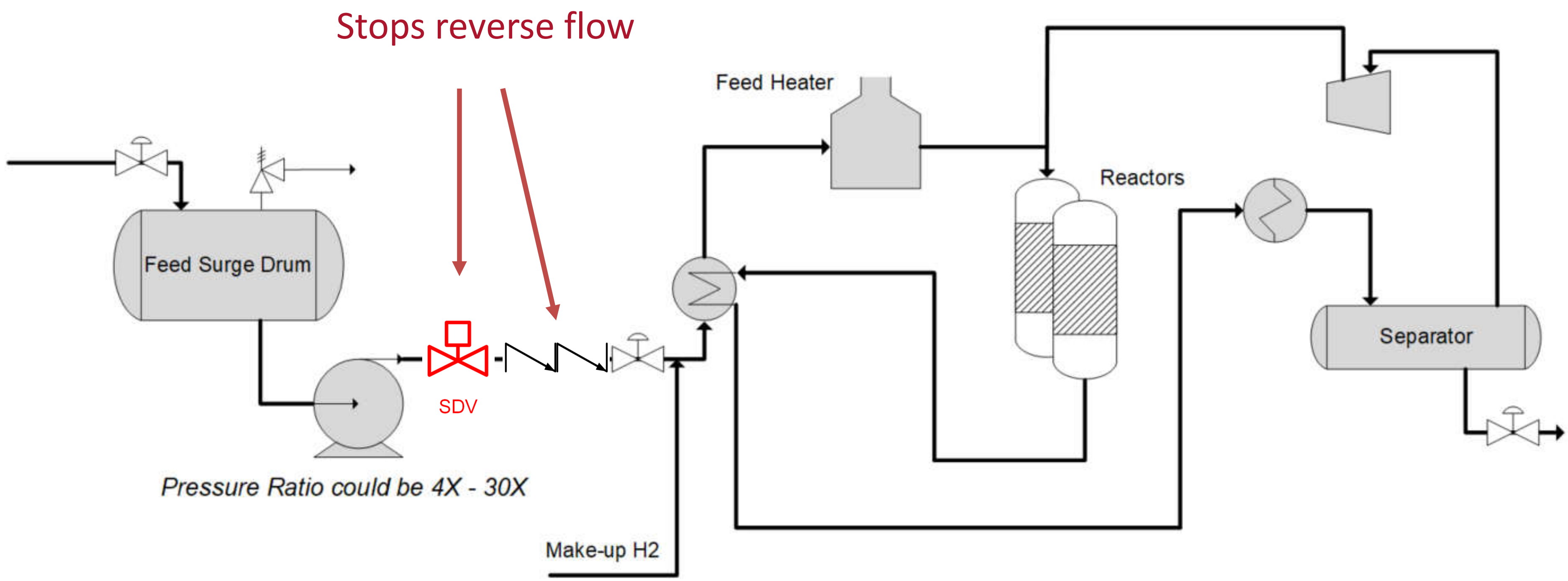
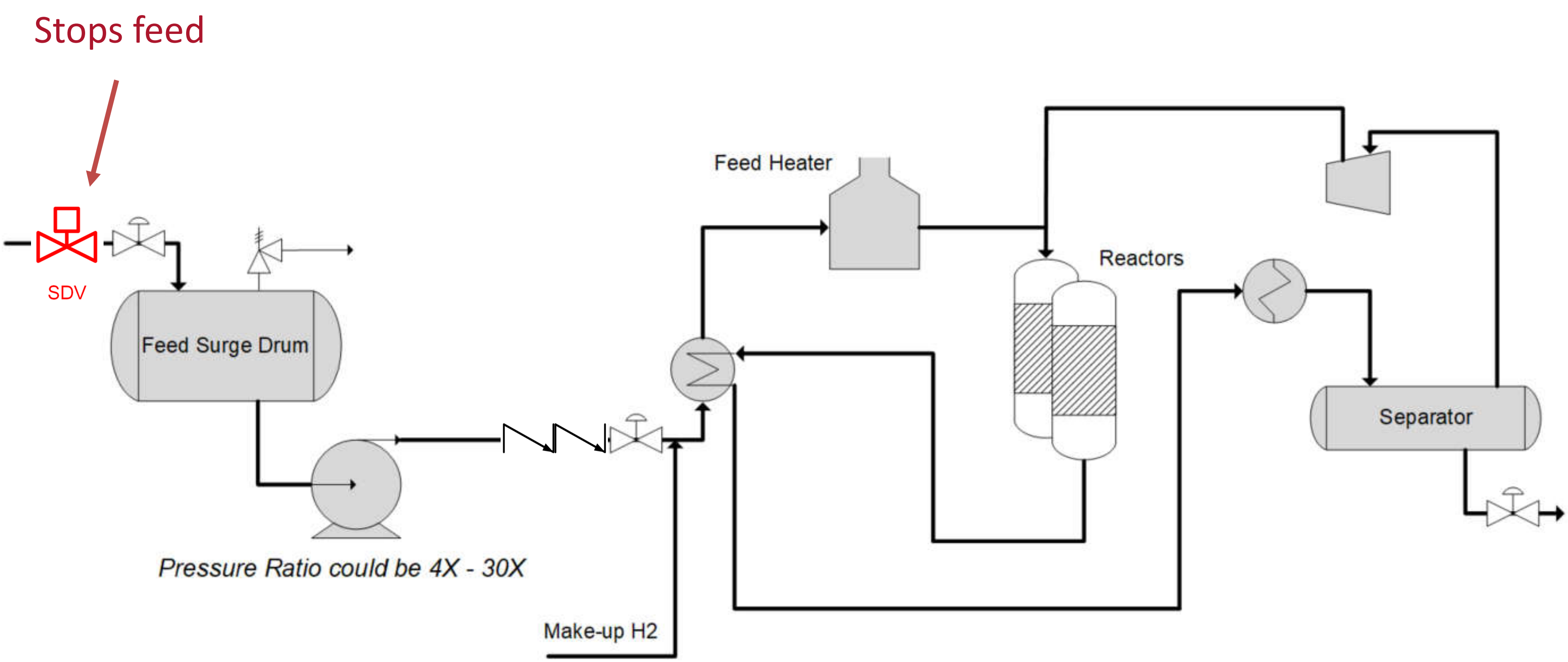
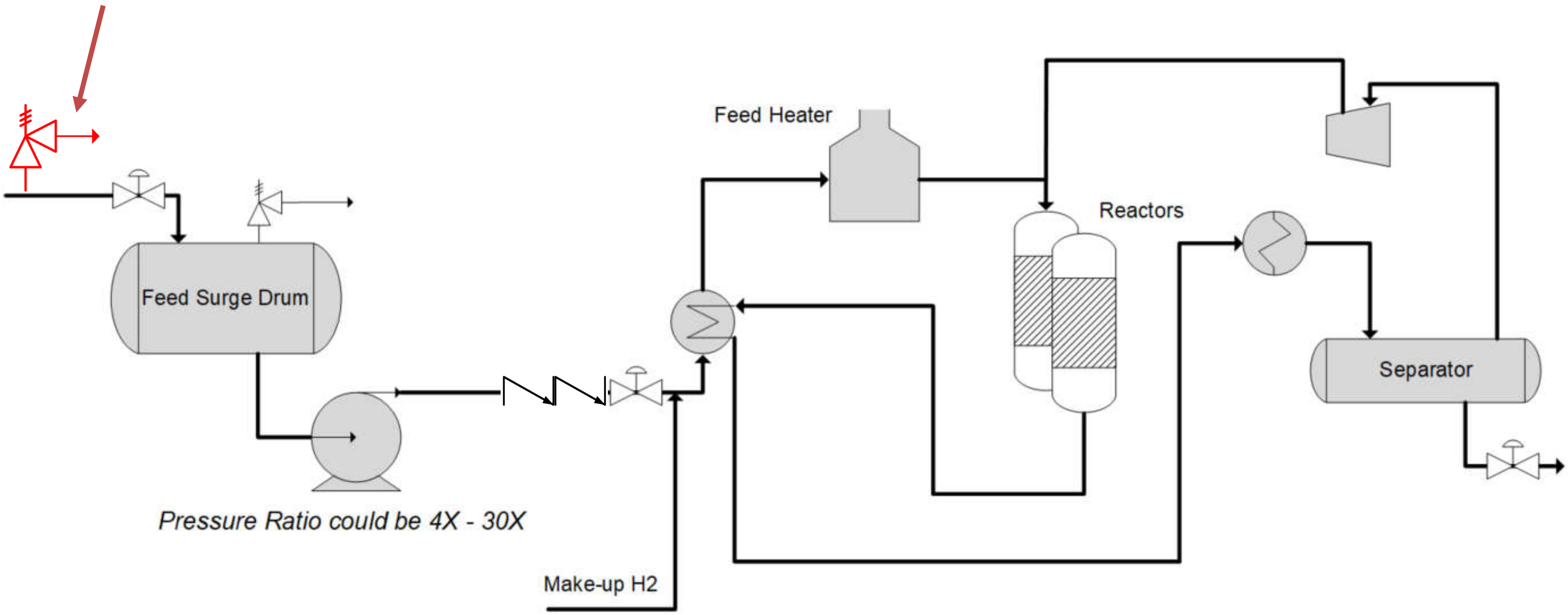


# Reverse Flow



# Reverse Flow

Relieves feed

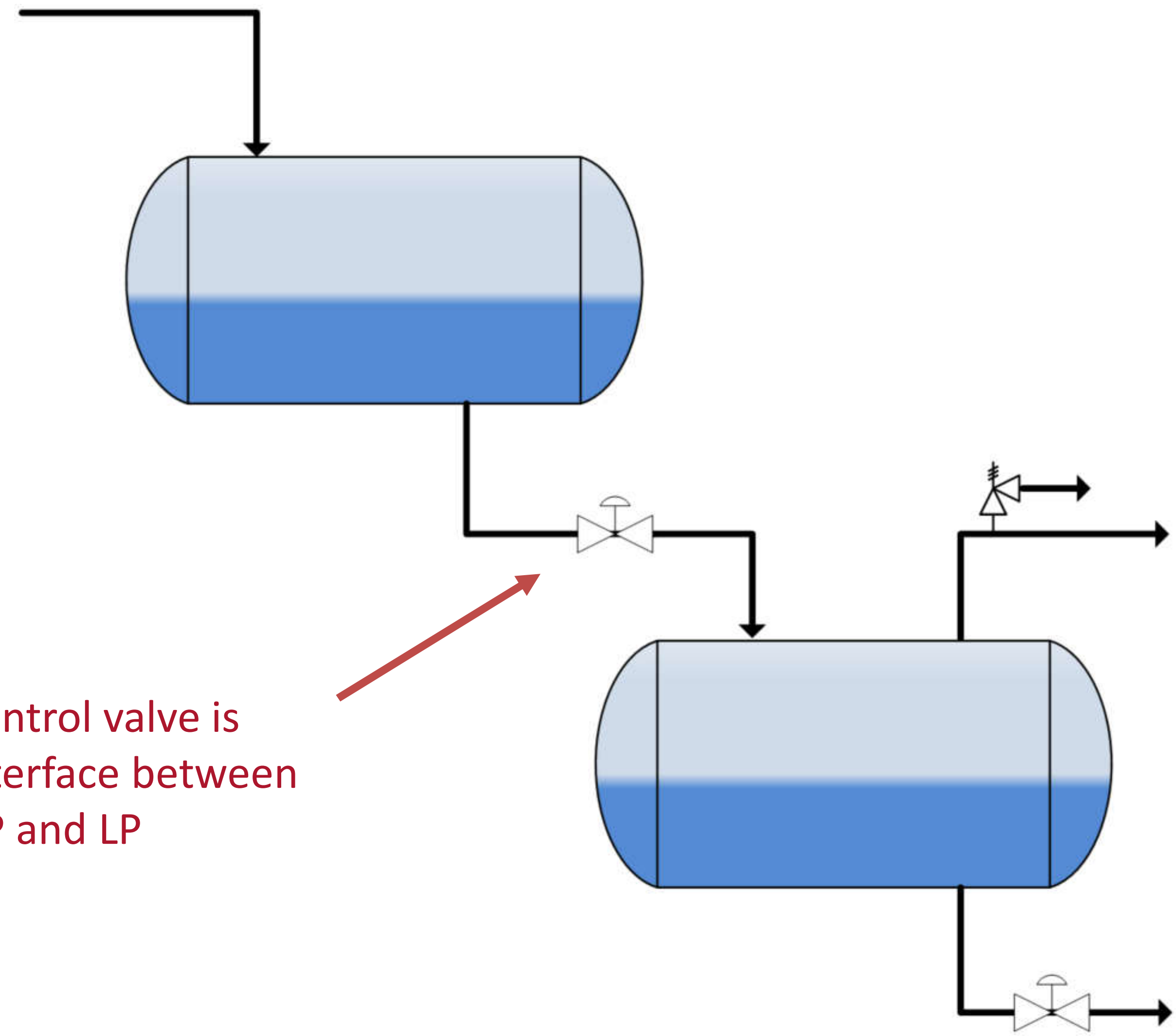


# *Reverse Flow*

**Summary**

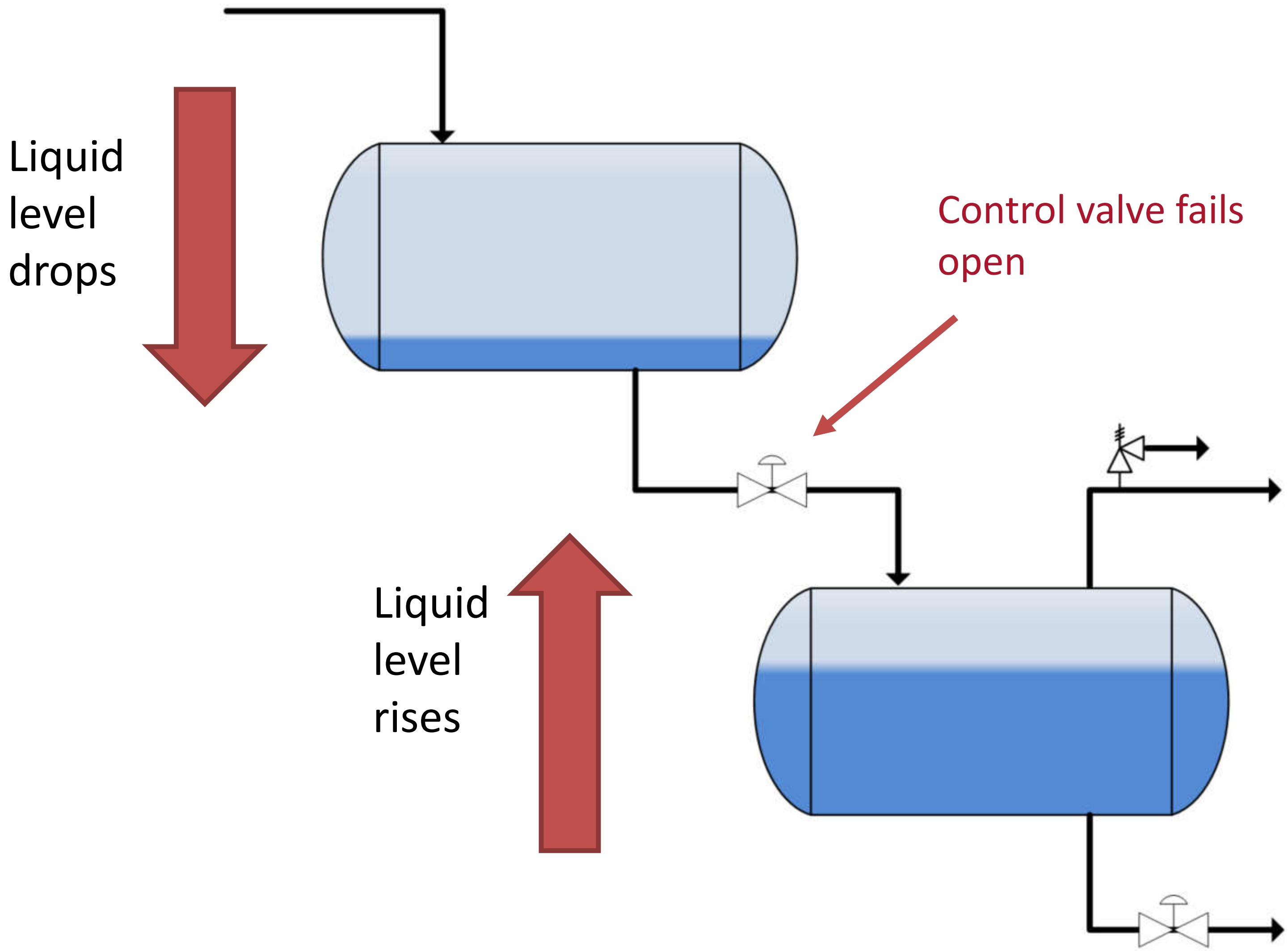
- Reverse flow can result in extremely high accumulation pressures if not properly mitigated
- Mitigate with:
  - Higher design pressures
  - Minimum dual safety critical check valves
  - Instrumentation may be required

# Vapor Breakthrough



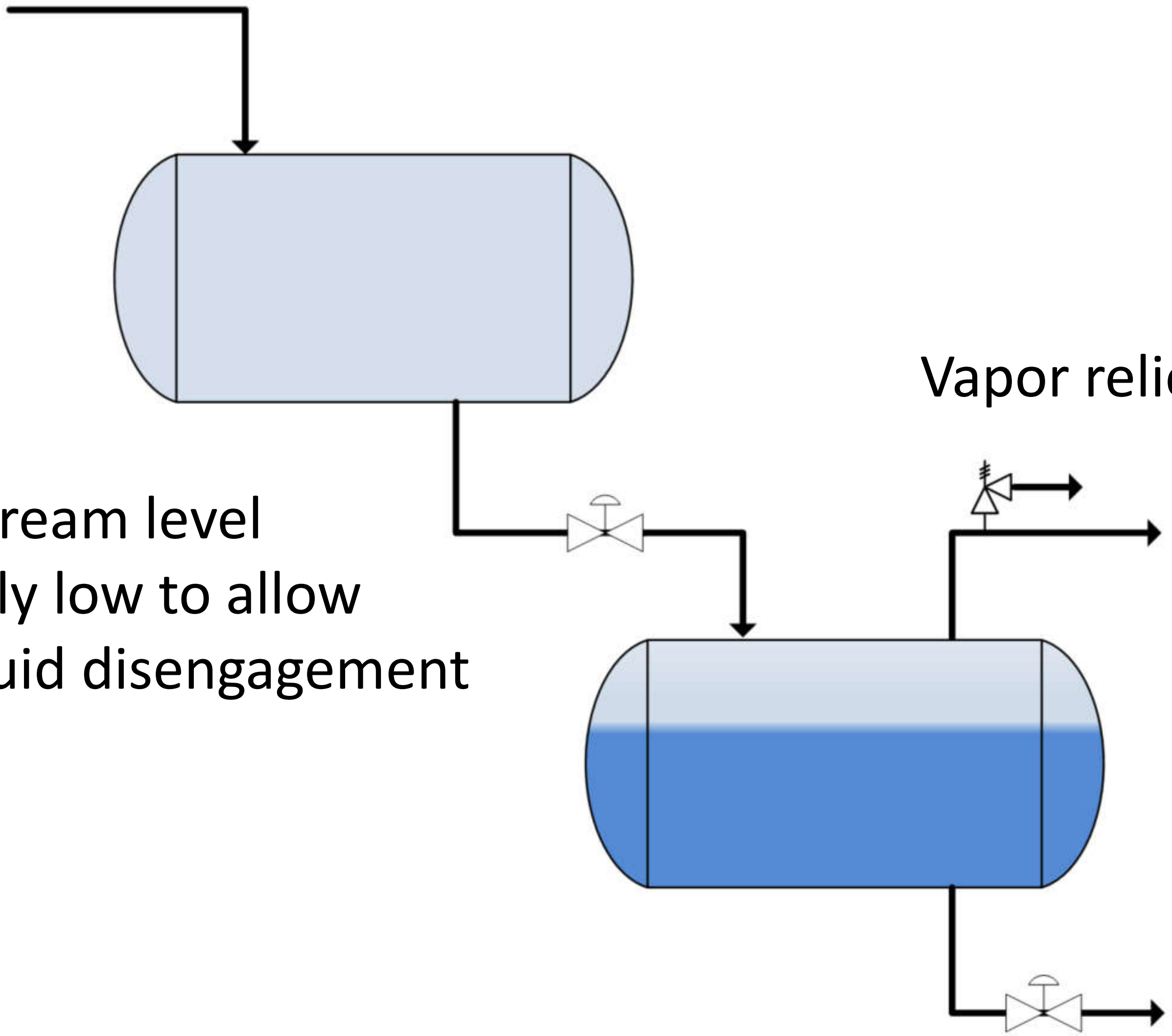
Control valve is interface between HP and LP

# Vapor Breakthrough

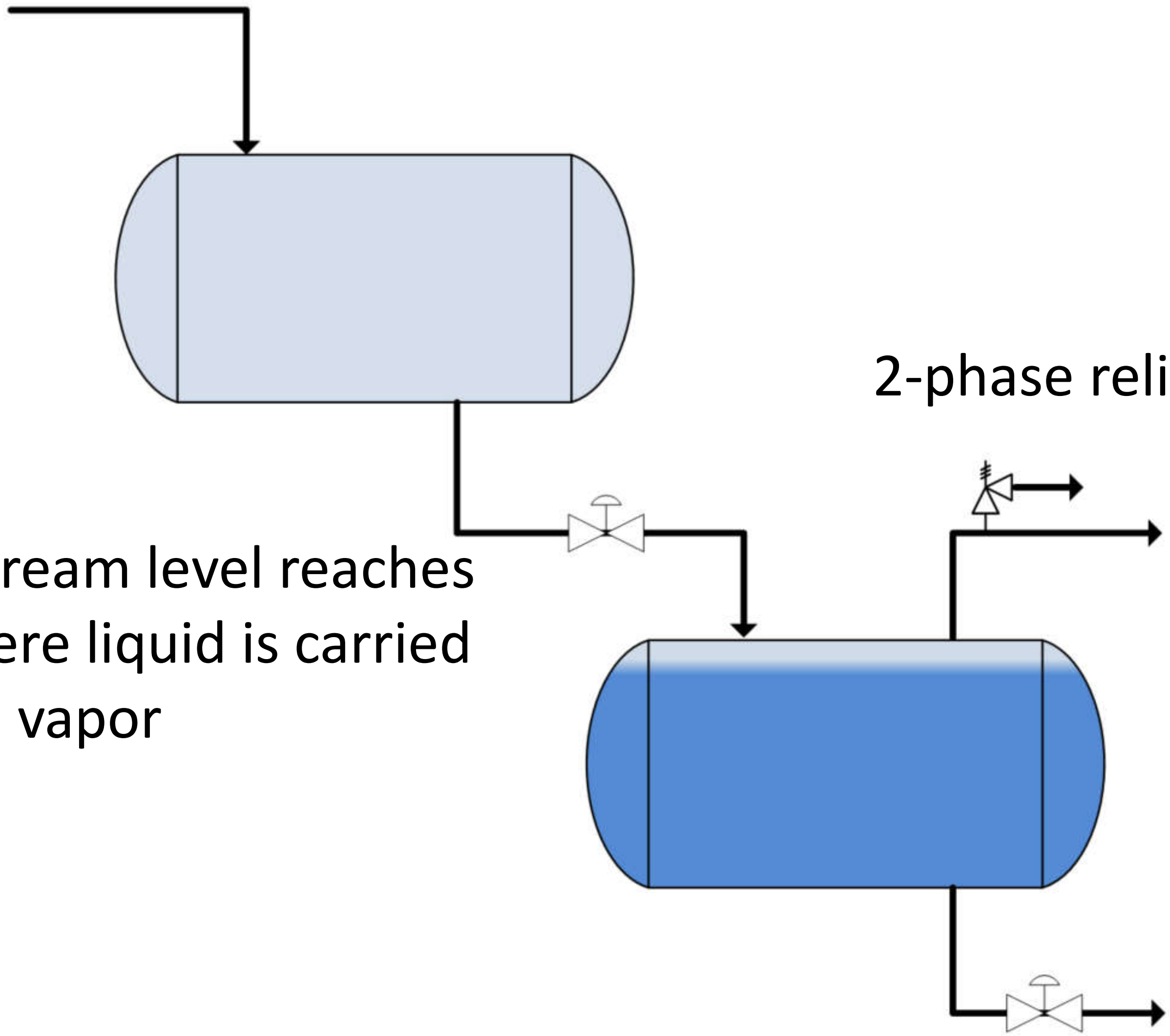


# *Vapor Breakthrough*

If downstream level sufficiently low to allow vapor-liquid disengagement



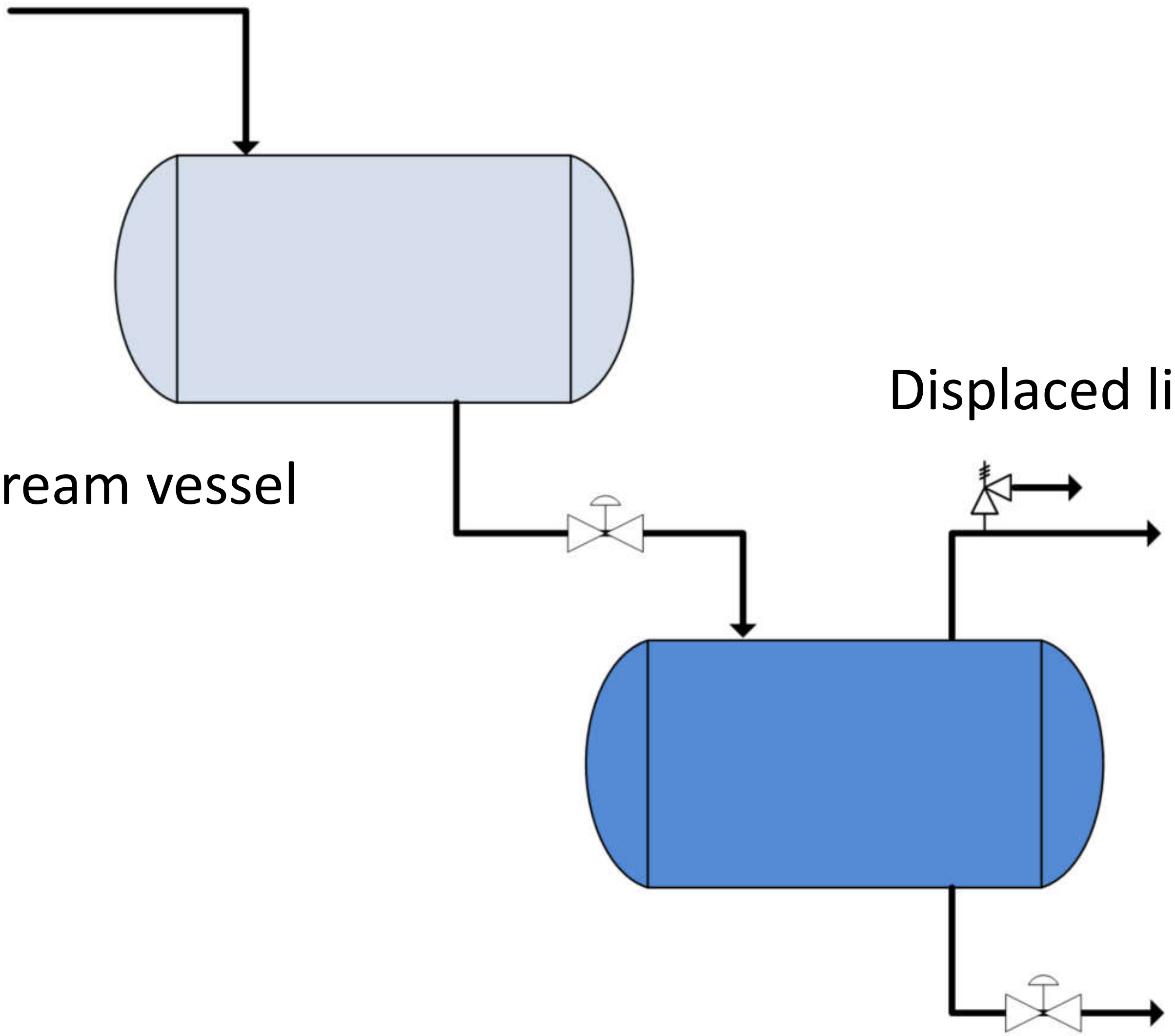
# *Vapor Breakthrough*



2-phase relief

If downstream level reaches point where liquid is carried over with vapor

# *Vapor Breakthrough*



If downstream vessel overfills

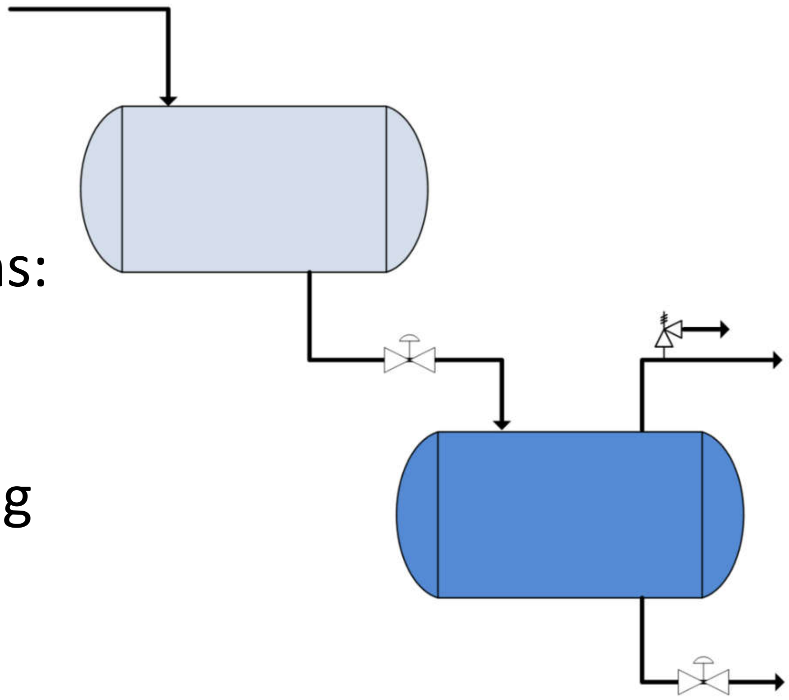
Displaced liquid

# *Vapor Breakthrough*

- Sophisticated methods should be used to determine relief phase
- Phase quality and flow rate depend on:
  - High and Low P/T
  - Compositions
  - Liquid levels
  - Vapor velocity
  - Vessel orientation
  - Inlet nozzle elevation
  - Location of relief device
- But…
- Generally, 14 inches of freeboard height between liquid level and outlet nozzle may be sufficient to minimize liquid carryover

# *Vapor Breakthrough*

- Liquid displacement often results in substantial relief requirements
- Design options:
  - Increase downstream MAWP
  - Increase downstream vessel size
- Existing installation mitigation options:
  - Size PSV for liquid displacement
  - Credit for liquid feed
  - Credit for flow resistance of piping
  - Restrict inlet flow
  - Modify liquid levels
  - HIPS



# Reverse Flow

## Summary

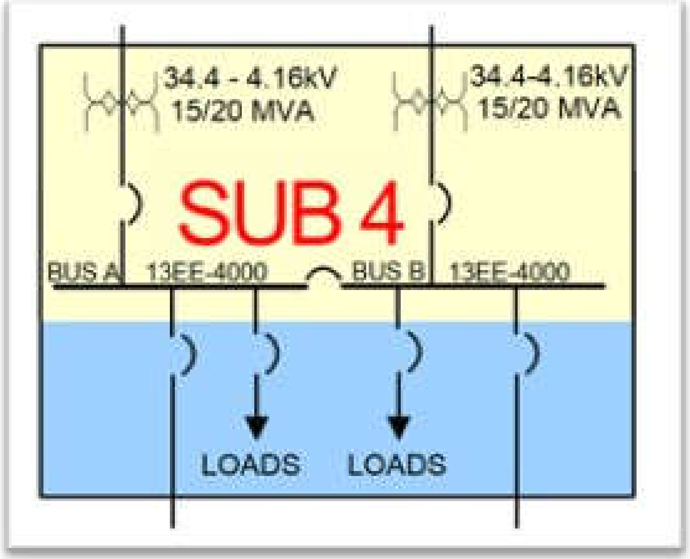
- Vapor breakthrough can result in high accumulation pressures if not properly mitigated
- Check effects of downstream liquid level on relief phase
- Prevent liquid displacement scenario

# Partial Power Failures

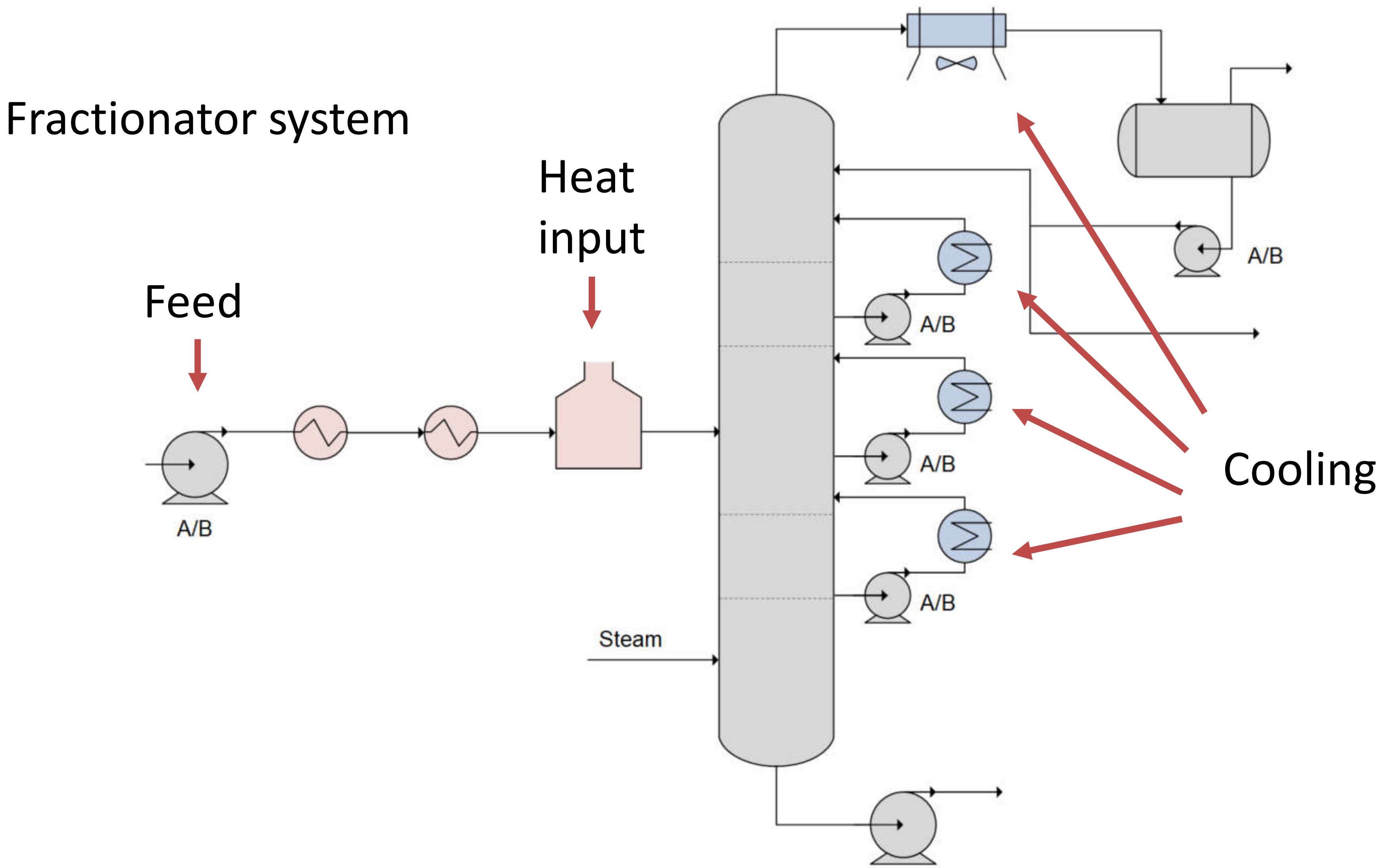
- Power failures generally belong to three different categories:
  - Loss of individual equipment
  - Total Power Failure
  - Partial Power Failures

- Equipment affected from partial power failures are determined using one-line drawings

- Partial power failures often result in worst-case scenarios for relief device sizing and for flare system analysis

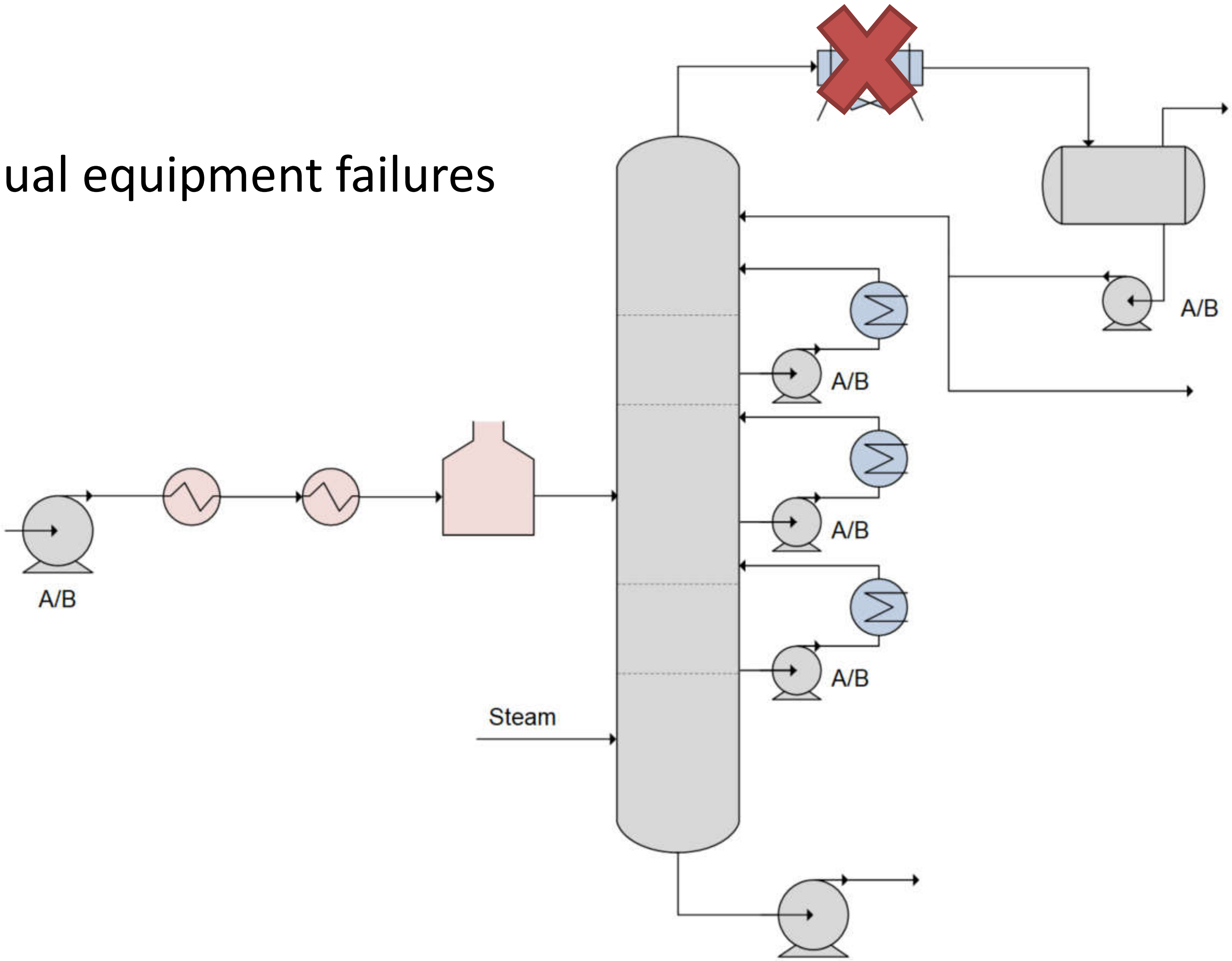


# *Partial Power Failures*



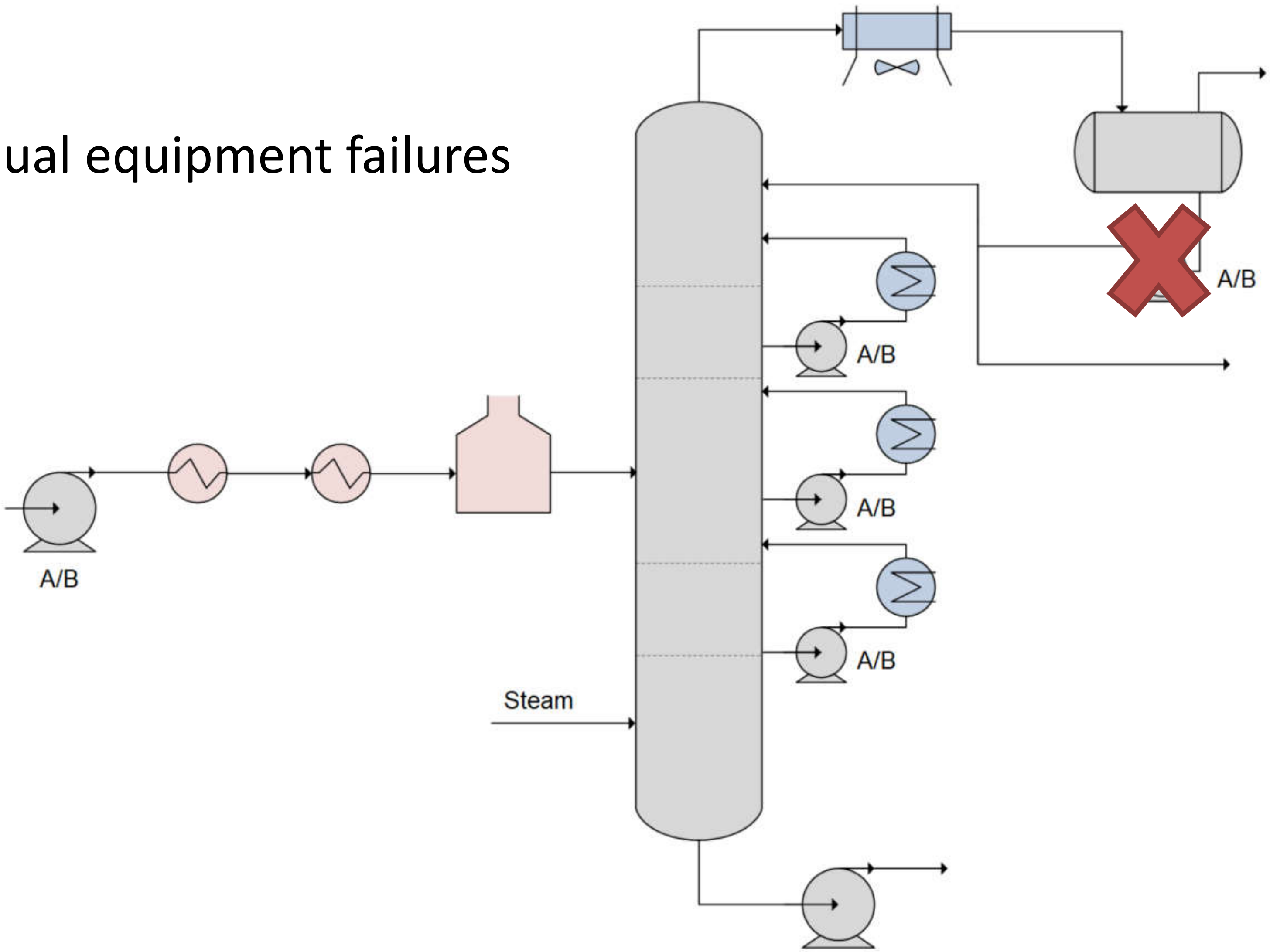
# *Partial Power Failures*

Individual equipment failures



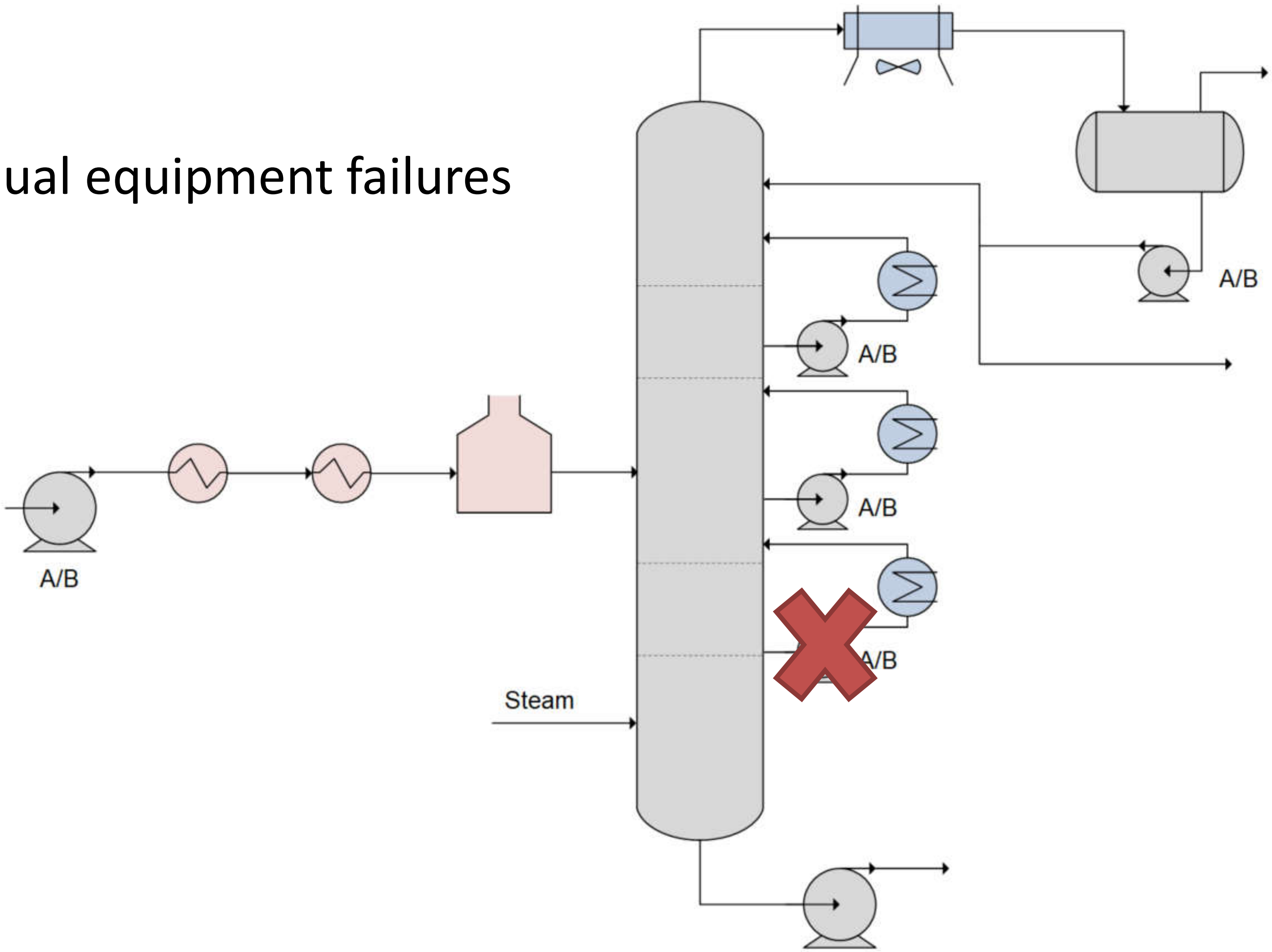
# Partial Power Failures

Individual equipment failures



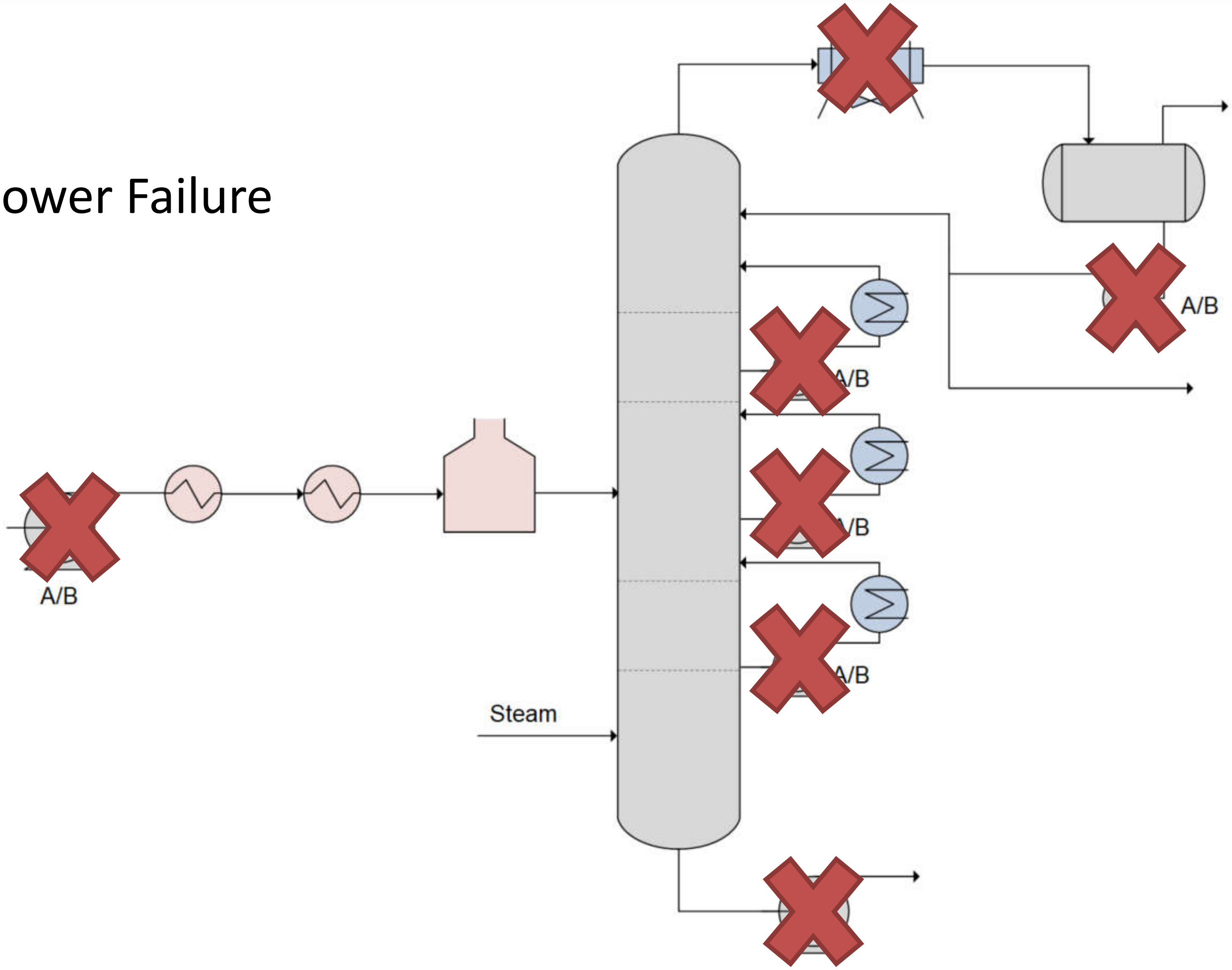
# Partial Power Failures

Individual equipment failures



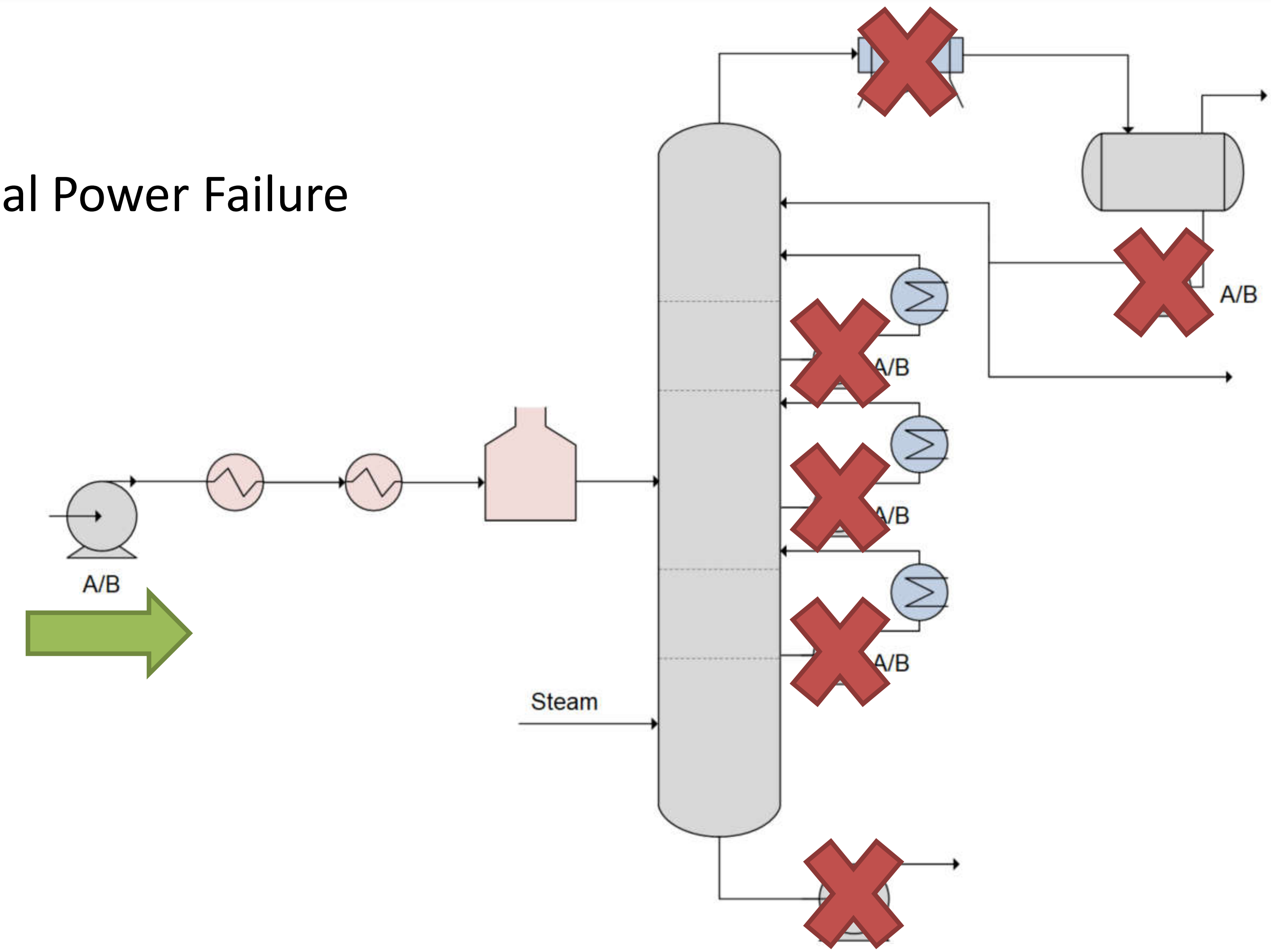
# Partial Power Failures

Total Power Failure



# *Partial Power Failures*

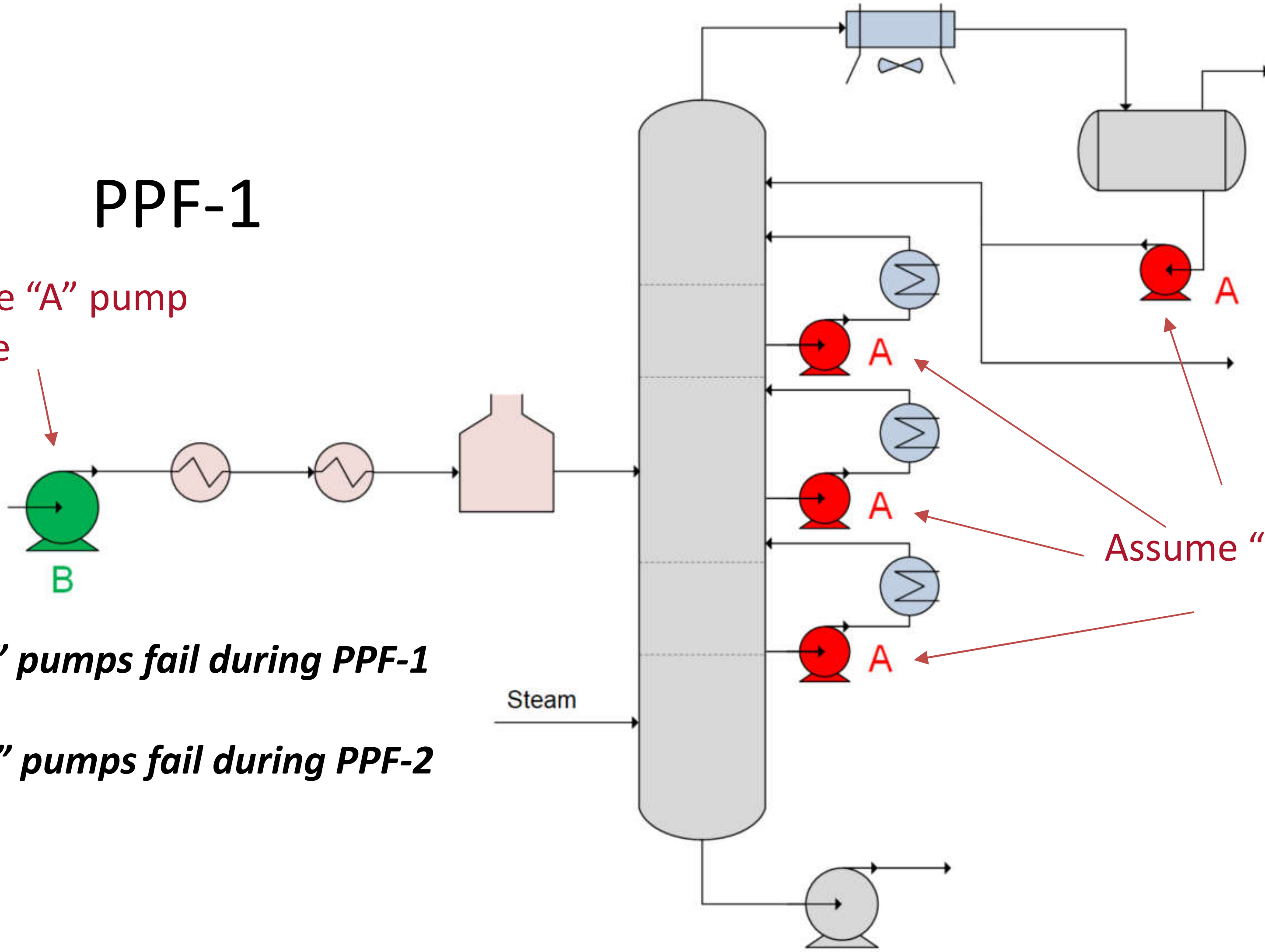
Partial Power Failure



# *Partial Power Failures*

## PPF-1

Assume “A” pump is spare




Assume “B” pump is spare

***All “A” pumps fail during PPF-1***

***All “B” pumps fail during PPF-2***

# Partial Power Failures

| | CW Failure | Steam Failure | Instrument Air Failure | TPF | PPF #1 | PPF #2 | PPF #3 |
|---|---|---|---|---|---|---|---|
| Total load (lb/hr) | 650,000 | 1.5 MM | 2 MM | 2.5 MM | 3.5 MM | 3.5 MM | 4.5 MM |
| # BP Concerns | 2 | 2 | 3 | 5 | 13 | 17 | 21 |

***Refinery example with ~2000 relief device systems***

# *Partial Power Failures*

## Potential Impacts of Partial Power Failures

- Larger relief requirements
- Higher total flaring load
- Higher backpressures
- Higher header velocities
- Possibly significantly larger loads in certain subheaders
- Higher radiation
- Higher liquid flows
  - Higher liquid load to flare KO drum
  - Slug flow in flare header

# Recap

- Reverse Flow
- Vapor Breakthrough
- Partial Power Failures

# *Questions & Answers*

Thank you for attending today's presentation:

**Commonly Missed Overpressure Scenarios**

Please reach out to either Waheed
if you would like more information:

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