

# Trayed Distillation Towers: Tray Types, Operation and Troubleshooting

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# Today's Topics

- Introduction: Tray Types
- Distillation Tray Operation  
(Fractionation Research, Inc. (FRI) "Film A")
- Tray Flooding Mechanisms
- Troubleshooting Trayed Tower Flood
- Multipass Flow Balance

# Introduction:

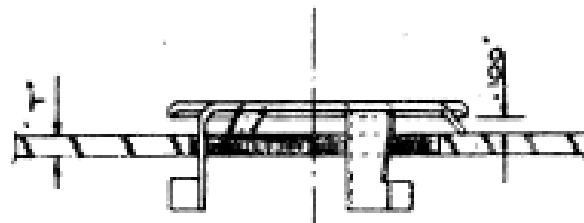
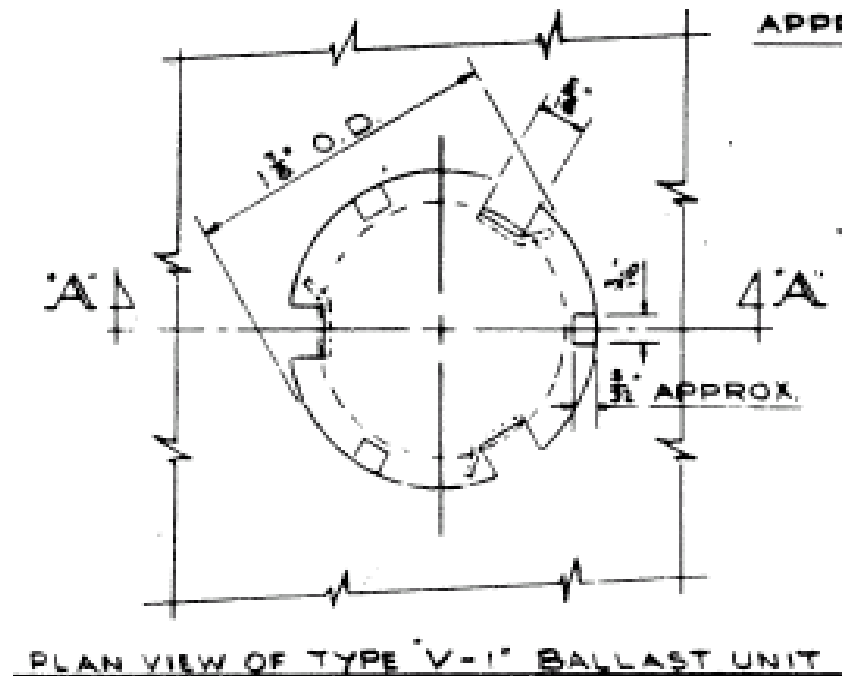
## Conventional Tray Types

- Movable or “Floating” Valve
- Fixed Valve
- Sieve
- Bubble Cap

# V-1 & V-1X Valves



# "Leg-Type" Moveable Valves



# Rectangular "Float" Valves

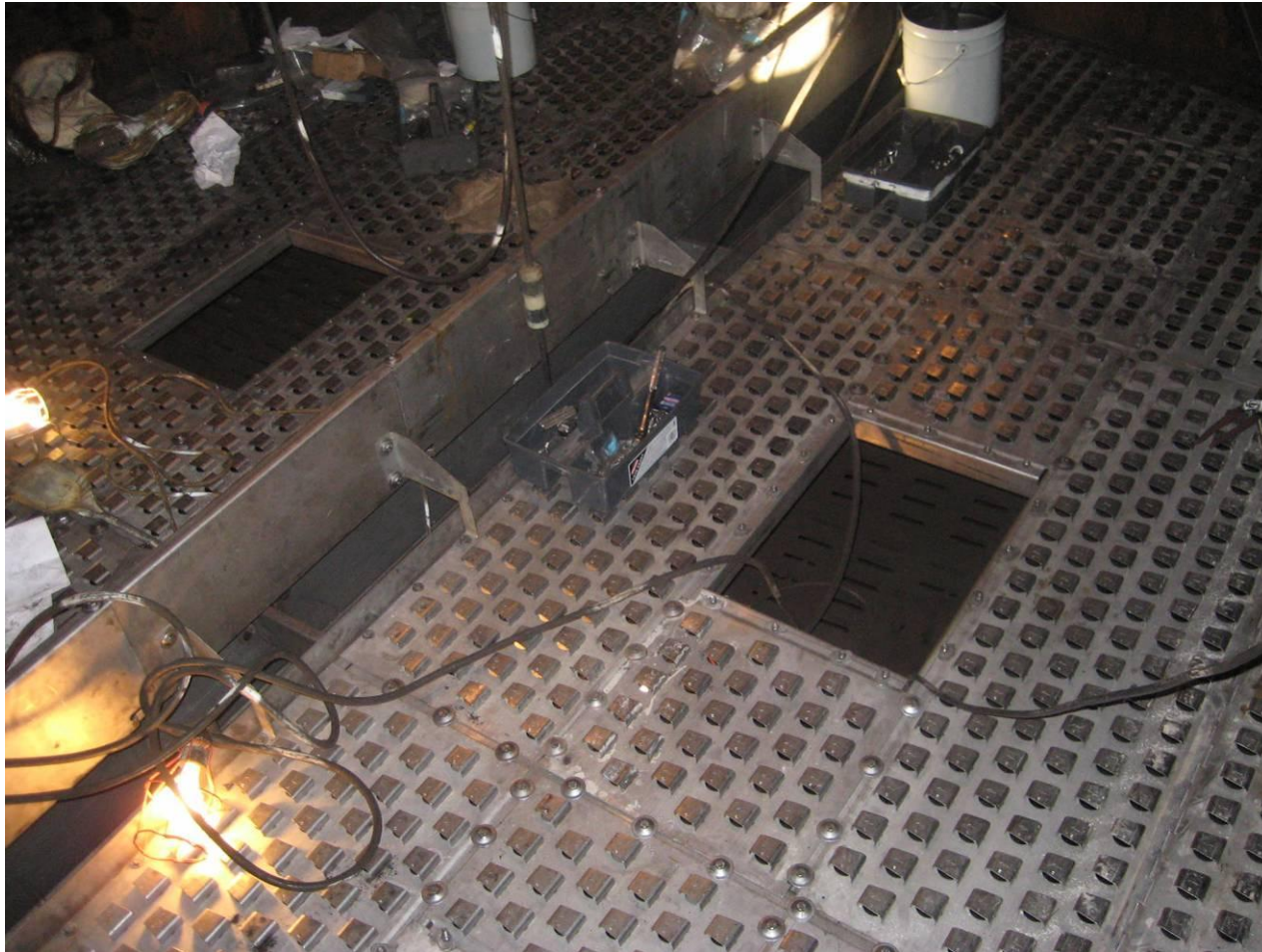




# Moveable Valve Characteristics

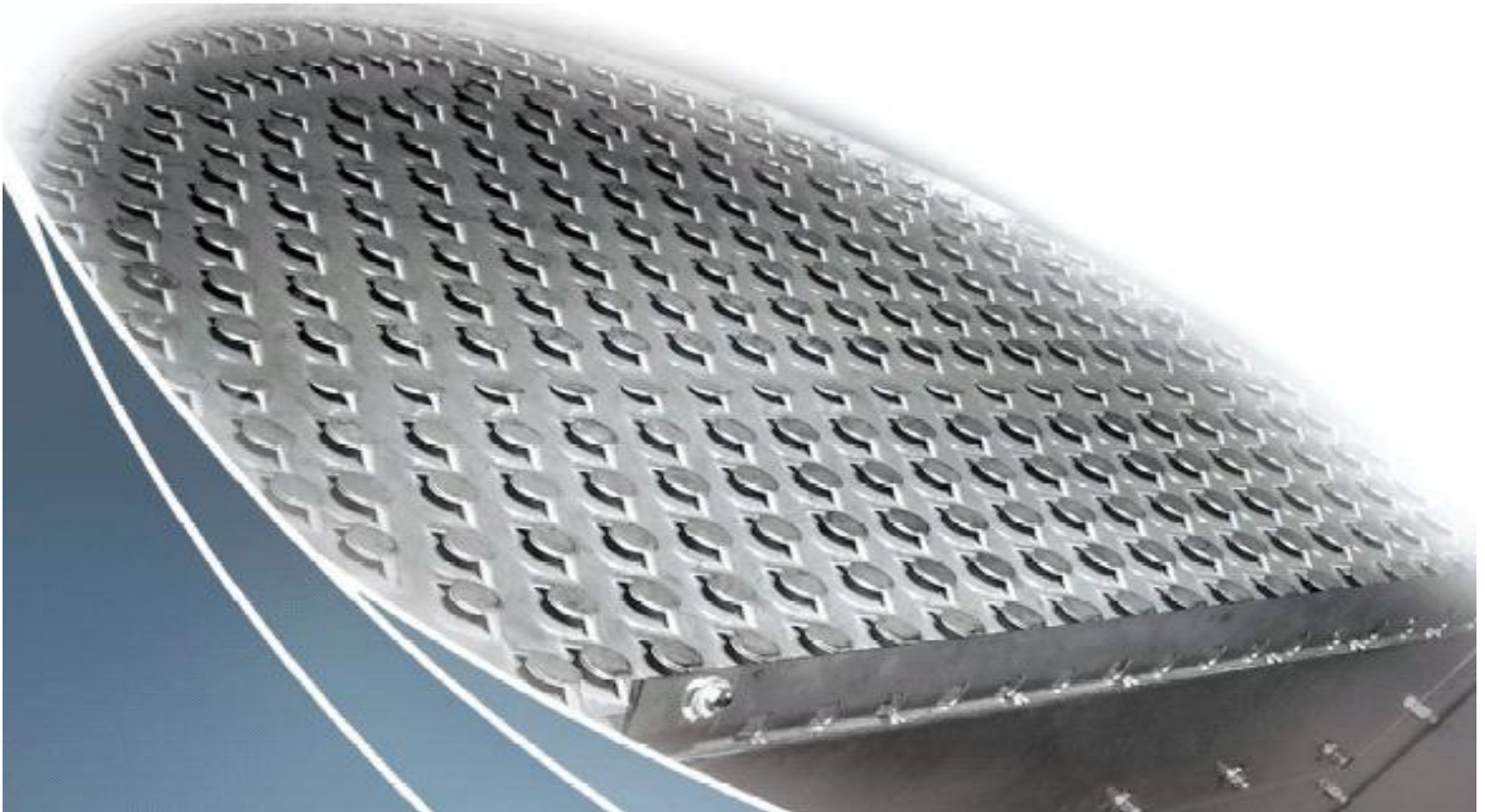
- Excellent capacity, especially at low pressures
- Very good turndown, valves mitigate “weeping”
- Not recommended in fouling/coking services
- “Tabs” or “dimples” prevent flush seating; valves without these are ***not*** recommended
- Valve units can have various thicknesses, typically 16 to 10 gauge
- Use of *dual valve weights* on a given tray said to improve turndown; usually in pairs of rows
- For rectangular valves, dimples must be on *downstream* side

# "ProValve" Fixed Valves





# VG-0 Deck w/ VG-9 "Push" Valves



## Fixed Valve Characteristics

- Fixed valve trays sacrifice some turndown flexibility for enhanced fouling resistance
- Two types:
  - Punched directly from tray deck (e.g. VG-0, SVG)
  - Separate cap piece over a deck orifice (ProValve)
- Better capacity in low pressure services than equivalent hole size sieve trays
- Most fixed valve types are *directional*; attention must be paid during installation

# Sieve Tray



## Sieve Tray Characteristics

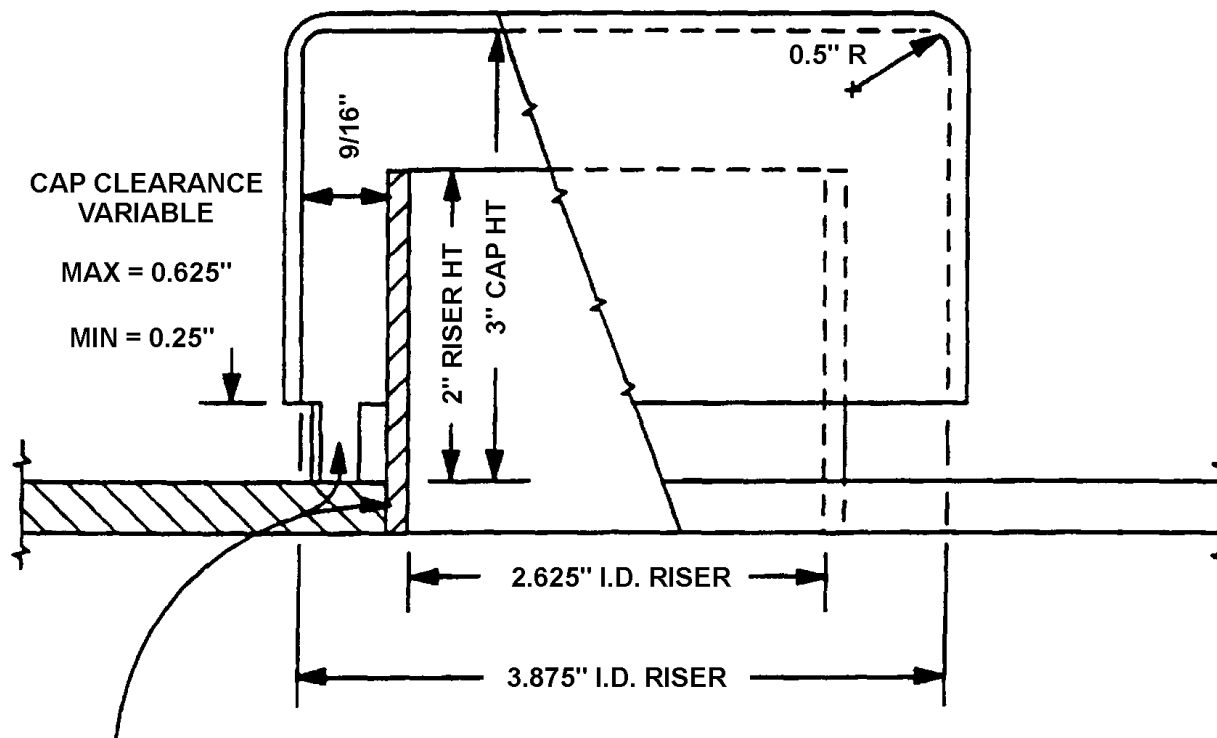
- Simple and relatively inexpensive!
- Good efficiency
- 2:1 turndown at low pressures; 3:1 turndown at higher pressures
- Larger hole sizes (1 to 1½") can be very fouling resistant
- Very easy to clean when fouled

# Slotted Bubble Cap





## FRI "Standard" Bubble Cap



METHODS OF CAP SUPPORT AND RISER

# "Tunnel Caps"



## Bubble Cap Characteristics

- Great performance at low liquid rates, even with high vapor rates
- Can be turned down to very low vapor rate without loss of efficiency
- Poor performance at high liquid rates due to hydraulic gradient
- Reasonable resistance to fouling, but hard to clean!
- Expensive

## Tray Operation:

- A few things to look for:
  - Flow regimes (spray, mixed, froth  $\equiv$  bubbly)
  - Tray flood by “massive entrainment” (jet flood)
  - Downcomer backup flood
  - Downcomer entrance flood (choke)
  - Flood by *System Limitation*
  - Weeping & dumping
- Trays *without* downcomers (a.k.a “Dual-flow”) – **not** typically used in refining

## Four Tray Flood Mechanisms

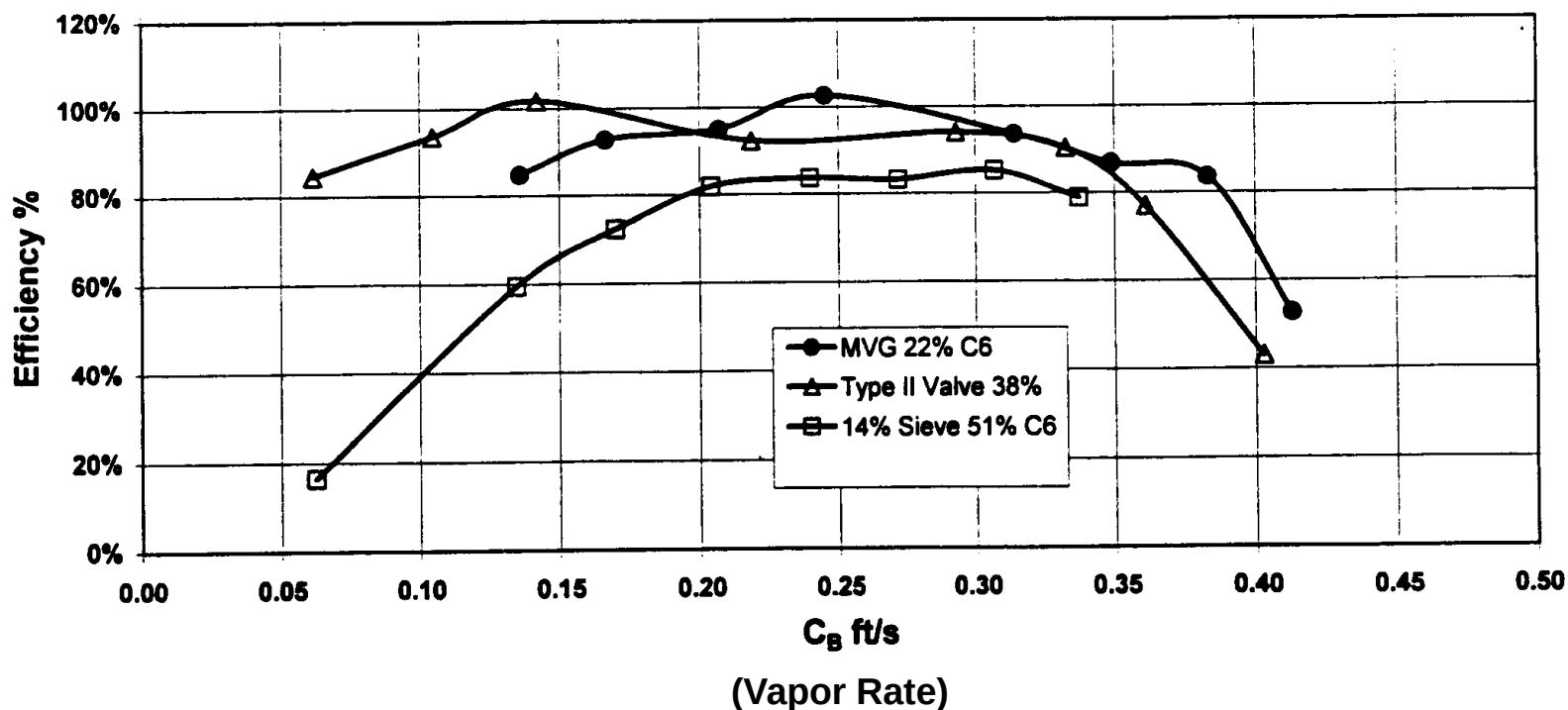
- Jet flood (entrainment)
  - Downcomer flood by backup
  - Downcomer top choke
  - System limit
- 
- All of these are aggravated by foaming



## Jet Flood (Mech #1)

- Jet flood occurs when the spray or froth reaches the tray above and liquid is aspirated wholesale through the vapor-handling elements
- Also known as 'entrainment flood'
- Tends to occur at low pressures (<50 psig)
- Tray efficiency drops as jet flood is approached and entrainment picks up

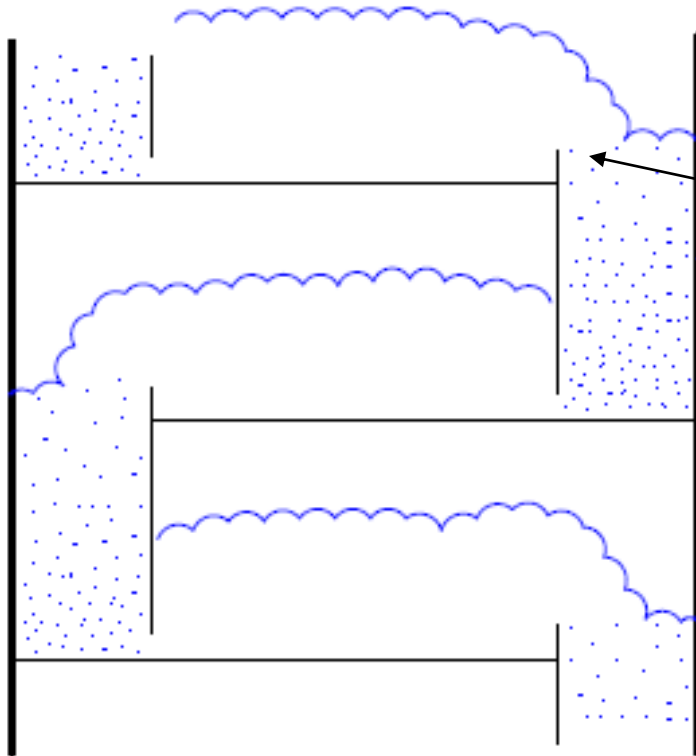
# Efficiency Drop with Entrainment



## Downcomer Flood (Mech #2)

- Downcomer flood occurs when aerated liquid fills the downcomer and begins backing up onto the tray deck
- Flood can be sudden: tray efficiency is generally not affected as downcomer flood is approached (some cases do show an effic. drop caused by vapor undercarry)
- Downcomer backup is not linear with fluid rates – it increases approx. with the square of rate
- Downcomer flood tends to occur at high liquid rates, e.g. at high pressures

# Downcomer Flood: DC Full of Froth



Downcomer backs up to top of weir due to a combination of

- Tray pressure drop
- Insufficient disengaging volume causing fluid friction between liquid & bubbles or against walls
- Head loss thru exit opening

## Downcomer Choke (Mech #3)

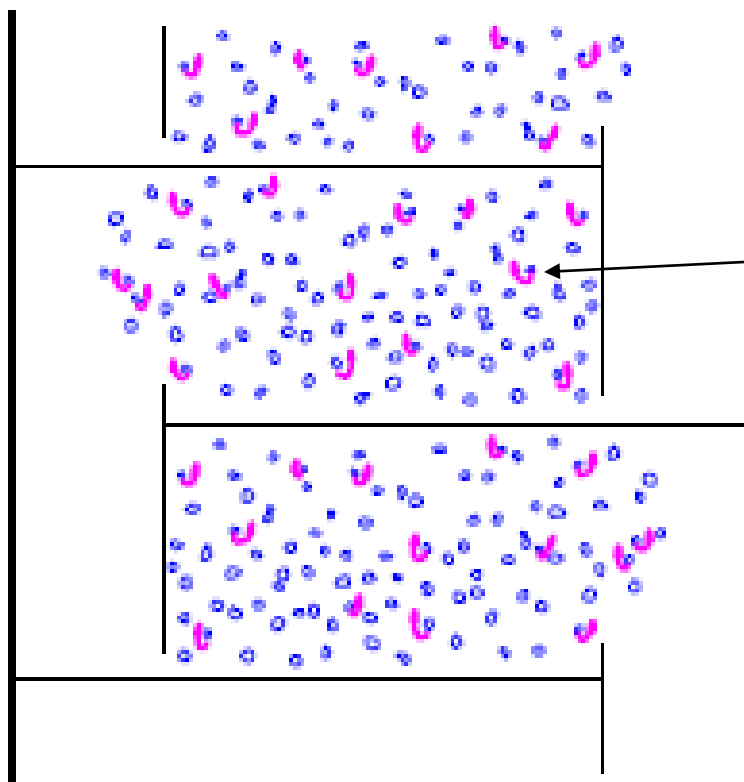
- Downcomer choke occurs when there is not enough area at the top to admit the frothy liquid while disengaged vapor is trying to escape
- Like downcomer backup flood, choke occurs suddenly and without an efficiency drop
- Like backup flood, choke tends to occur at high liquid rates and high pressures

## System Limit (Mech #4)

- System limit is the inability of liquid droplets to fall via gravity in the upflowing vapor stream
- System limit capacity is dictated by fluid rates and properties. When system limit is controlling, changes to the active element type or size do **not** increase capacity
- System limit tends to govern at high pressures (>150 psig) and at low pressures (<10 psig)



# System Limit Flow Pattern



Many of the smaller droplets cannot fall in the rising vapor, and are carried upward

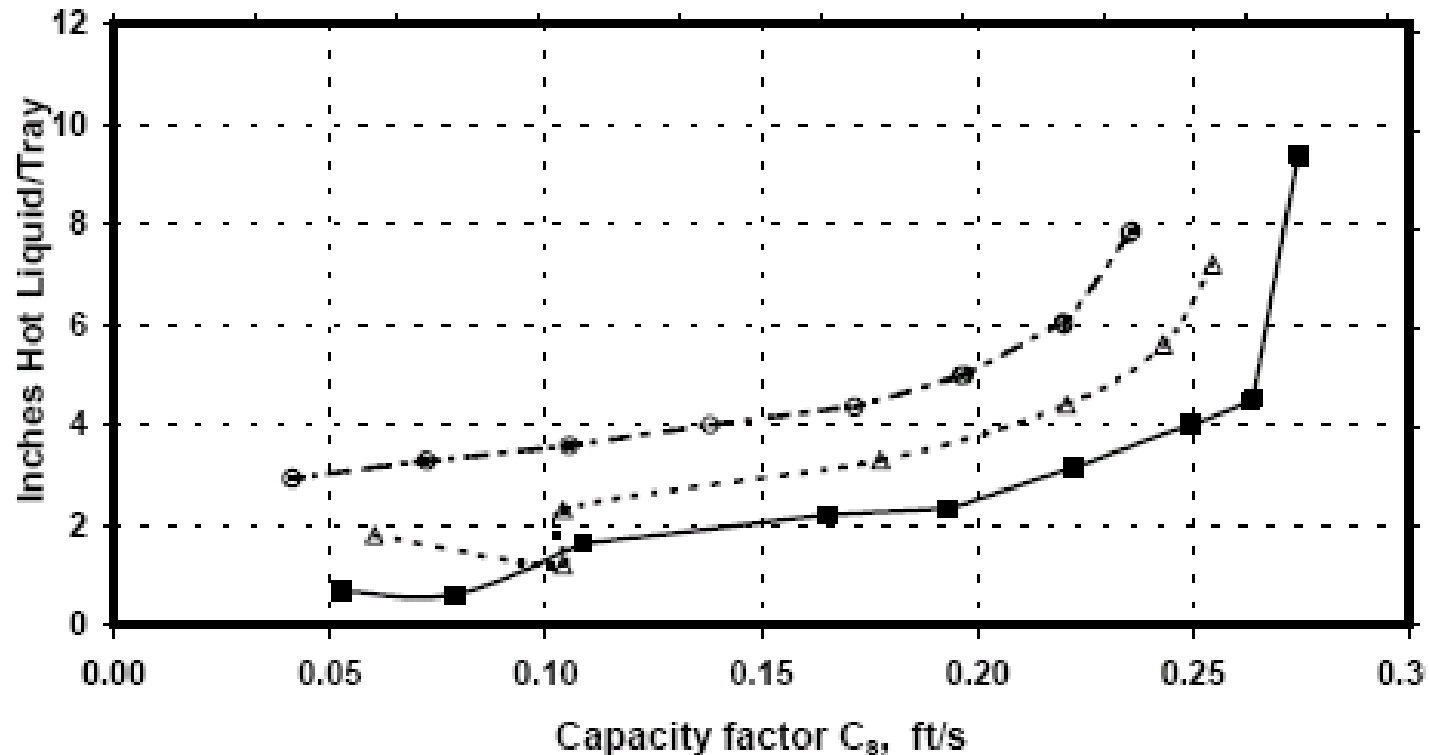
The vapor can even shear some of the larger droplets into smaller ones

# Troubleshooting Flooded Towers

## Basic Questions to Ask

- Start with operating data for a flooding event
  - Where is pressure drop *before* onset of flood?
  - Is there a loss in separation before flood occurs?
  - Do you believe your instrumentation?
  - Did the flooding begin one day (e.g. after upset)?
  - Is water getting into your hydrocarbon system?

# Tray Pressure Drop Approaching Jet Flood



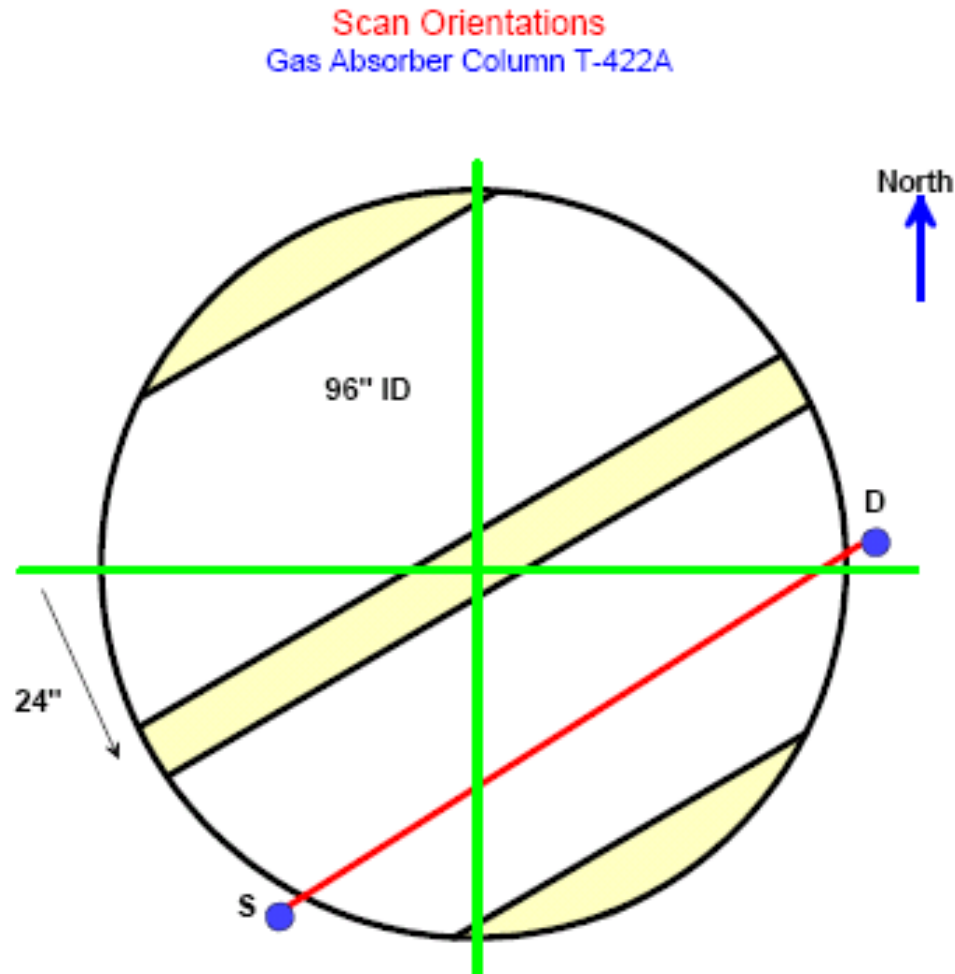
# Jet or Downcomer Flood?

- Jet Flood
  - As you approach flood, efficiency falls off
  - Pressure drop builds
- Downcomer Flood
  - Tower floods suddenly, unexpectedly
  - No decrease in efficiency or buildup of  $\Delta P$  before flood

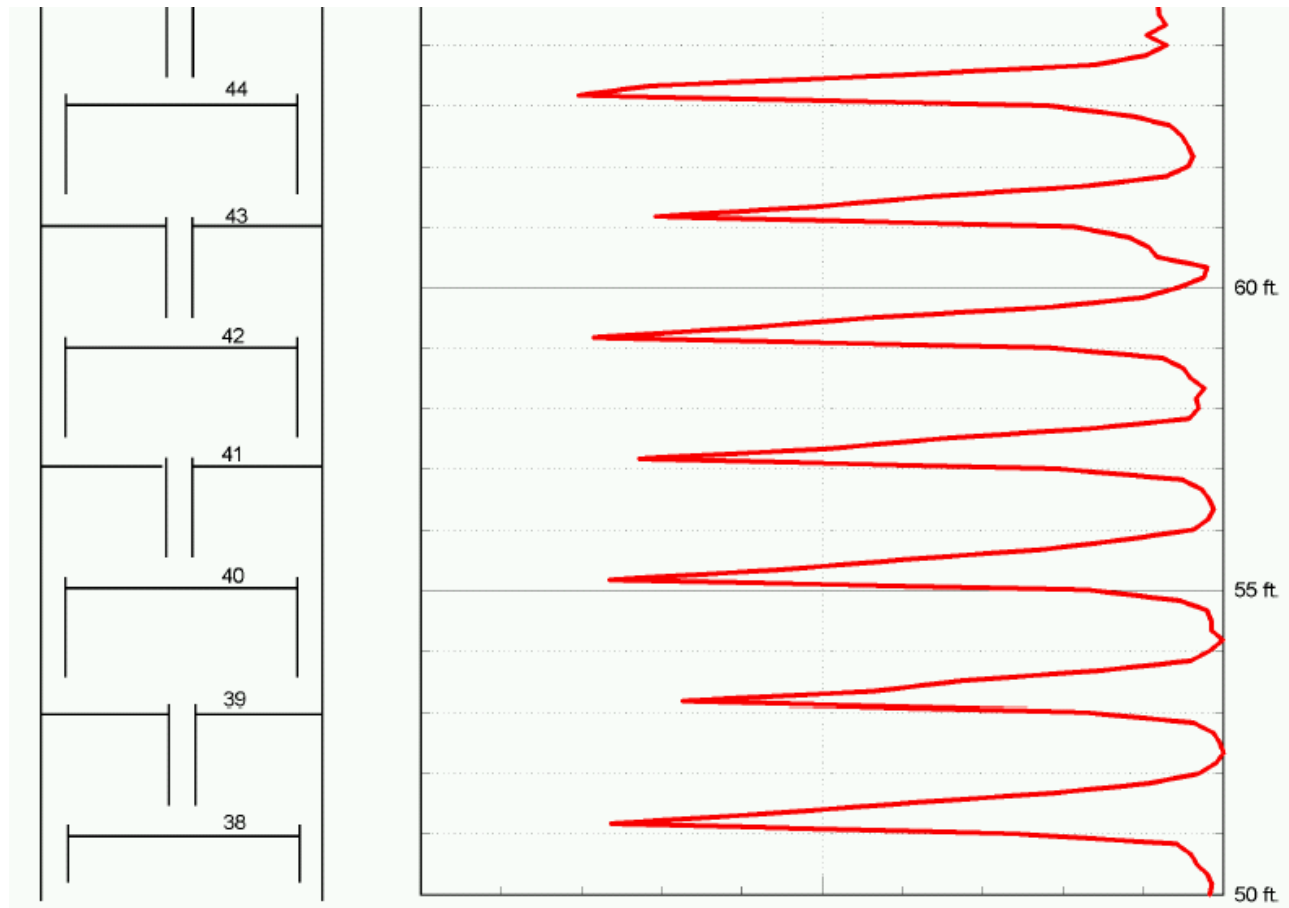
## Further Troubleshooting Checks

- Do tray ratings – this requires a reasonably well-matched simulation (for loads & properties)
- Try to get gamma scans at incipient flood
- Better: gamma scans *and* tray ratings
  - Ratings can support or downplay observations from the gamma scan
  - Gamma scan data and rating results can be assessed alongside operating behaviors for a multi-faceted view of the problem

# Gamma Scan Lines – Active Area

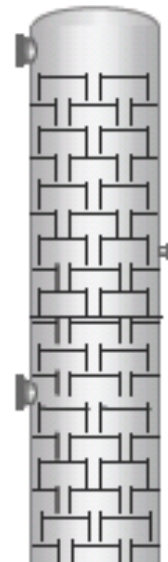


# Gamma Scan – Well Behaved Tower

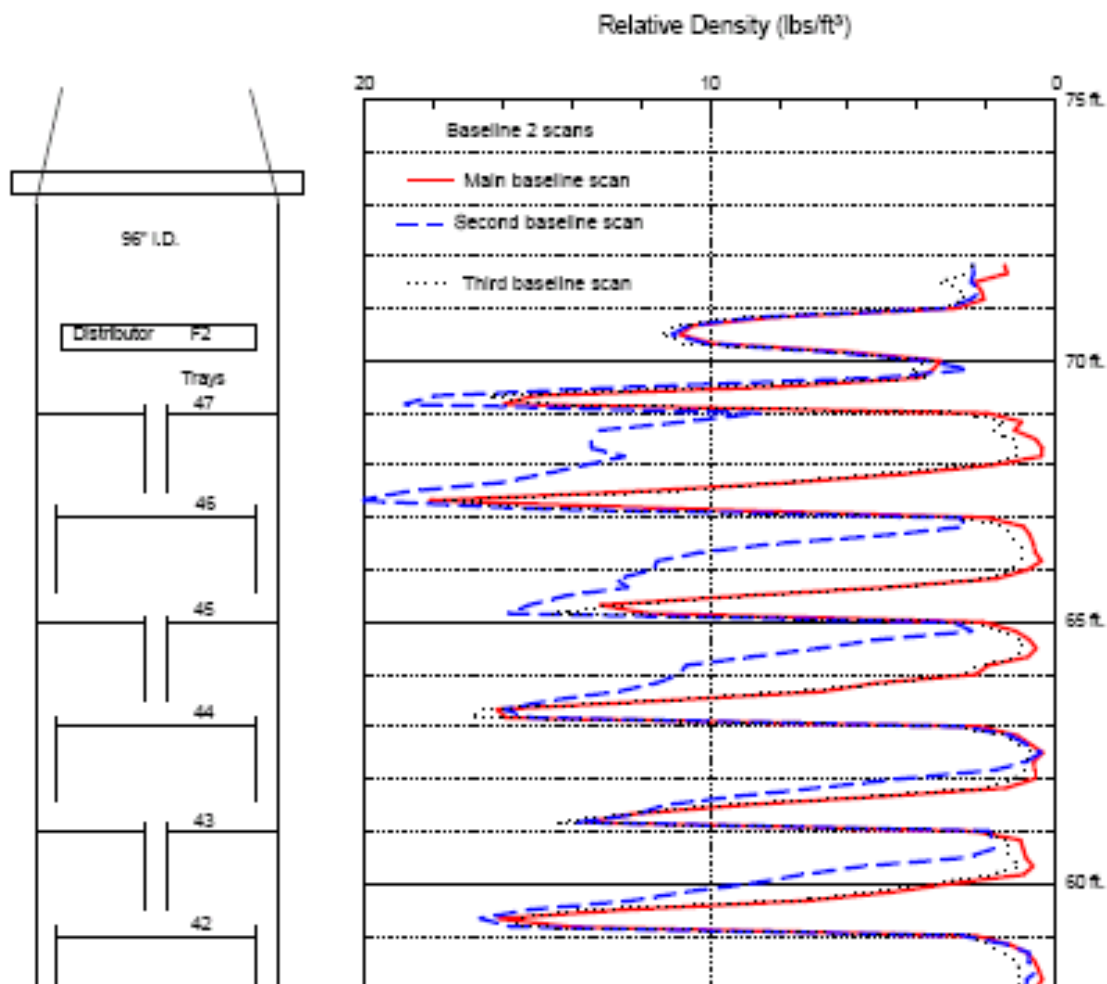


□ Increasing Relative Density



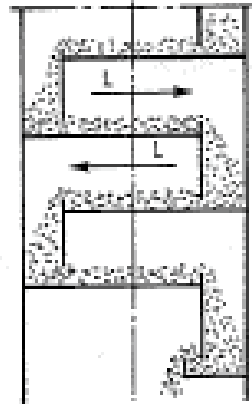


# Gamma Scan – Foaming

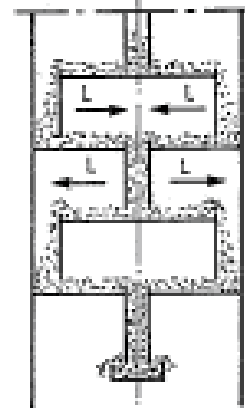


# Multipass Tray Flow Balance

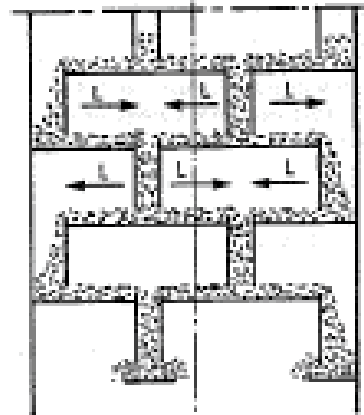
Single Pass



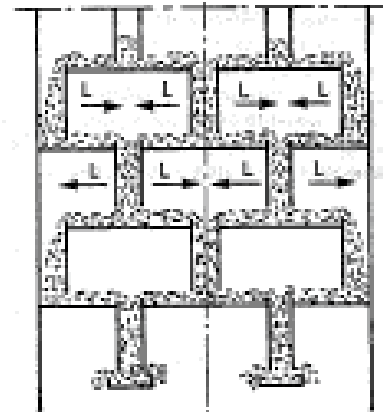
Double Pass (2 Pass)



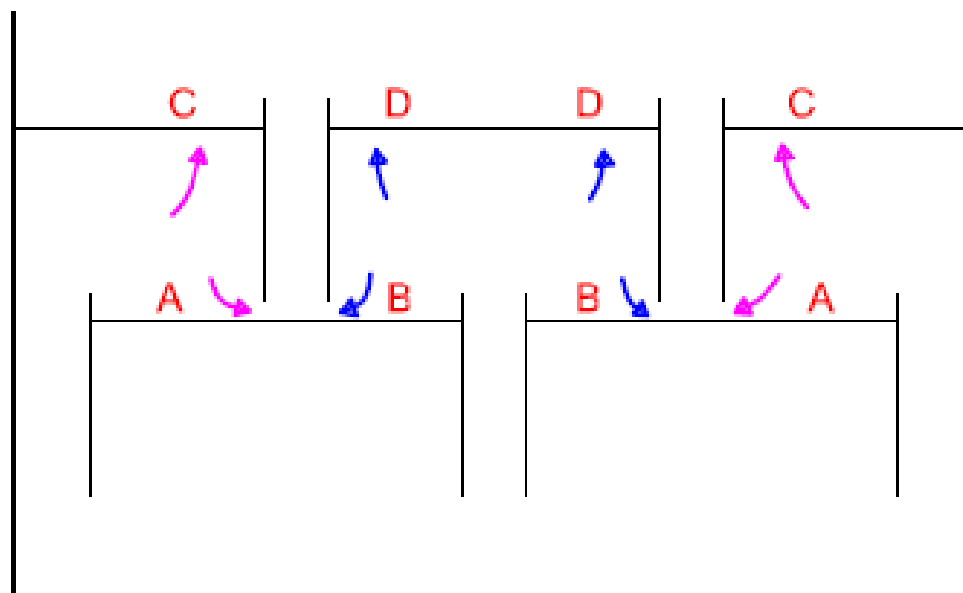
Three Pass



Four Pass



# Flow Splits by $\Delta P$ and Weir Load



- Panels act in pairs
- $\Delta P$  of panels A+C must equal B+D
- Weir load affects liquid hold-up (crest)
- Imbalance in the flow splits can lead to premature flood



# Picket Weir at Center Downcomer



## How Picket Weirs Work

- Picket weirs increase liquid holdup on tray
- Affect Entrainment
  - Greater liquid inventory increases breakup of vapor jets issuing from active elements
  - Breakup of vapor eddies reduces droplet carry-up (entrainment)
- Affect Pressure Drop