Distillation Trays as Mechanical Equipment

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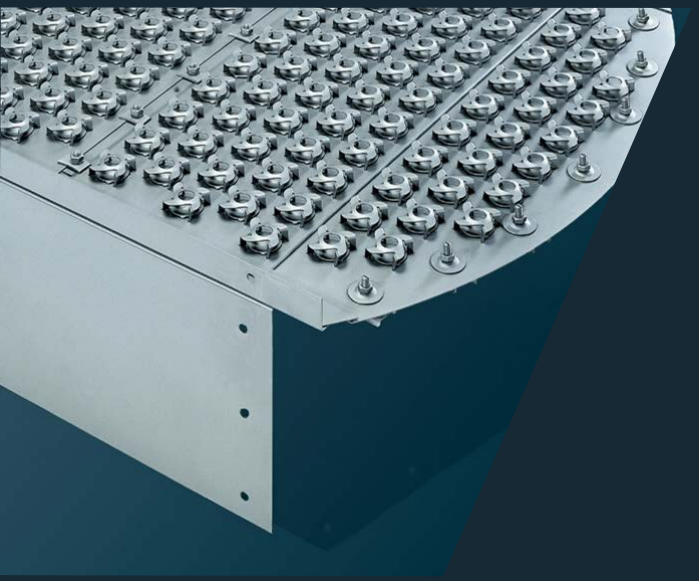
Distillation Trays



Caged-valve tray
Courtesy of RVT Process Equipment

One equipment choice for distillation

Other choices

- Packing
- Exotics
  - Spinning band
  - Spinning disc
  - Fibers

Trays also used in liquid-liquid extraction

Coverage Today

Conventional cross-flow trays

- With downcomers
- Without downcomers

High-capacity trays

- With hanging downcomers (truncated downcomers)

This is the most common type

Other types available for specific applications

1. What trays need to do
2. Tray flow
3. Tray types
4. Mechanical construction
5. Specification
6. Reliability

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Distillation Requirements

Transfer lightest liquid into the vapor (vaporization)

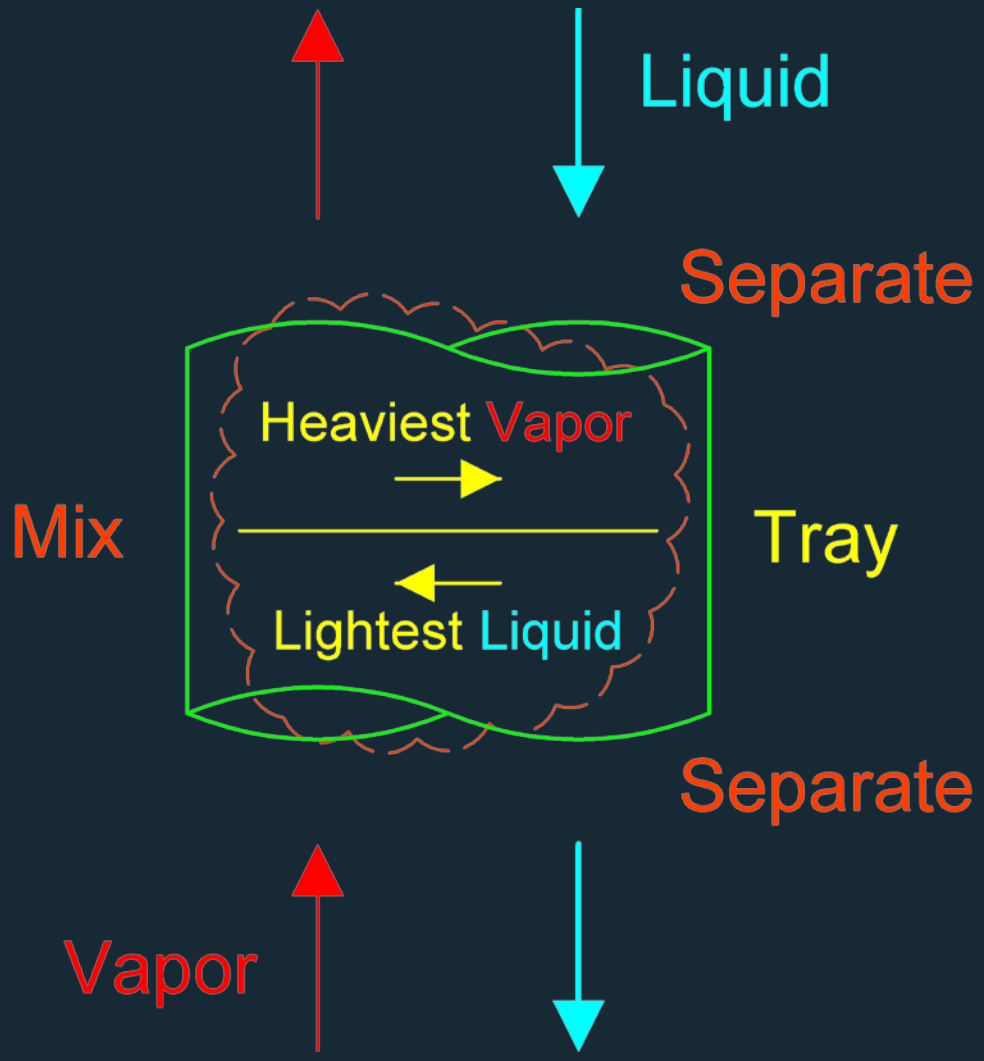
Transfer heaviest vapor into the liquid (condensation)

Vaporization and condensation require heat transfer and mass transfer

Surface-area required between different phases

Phase separation required to keep benefits of separation

Tray Function



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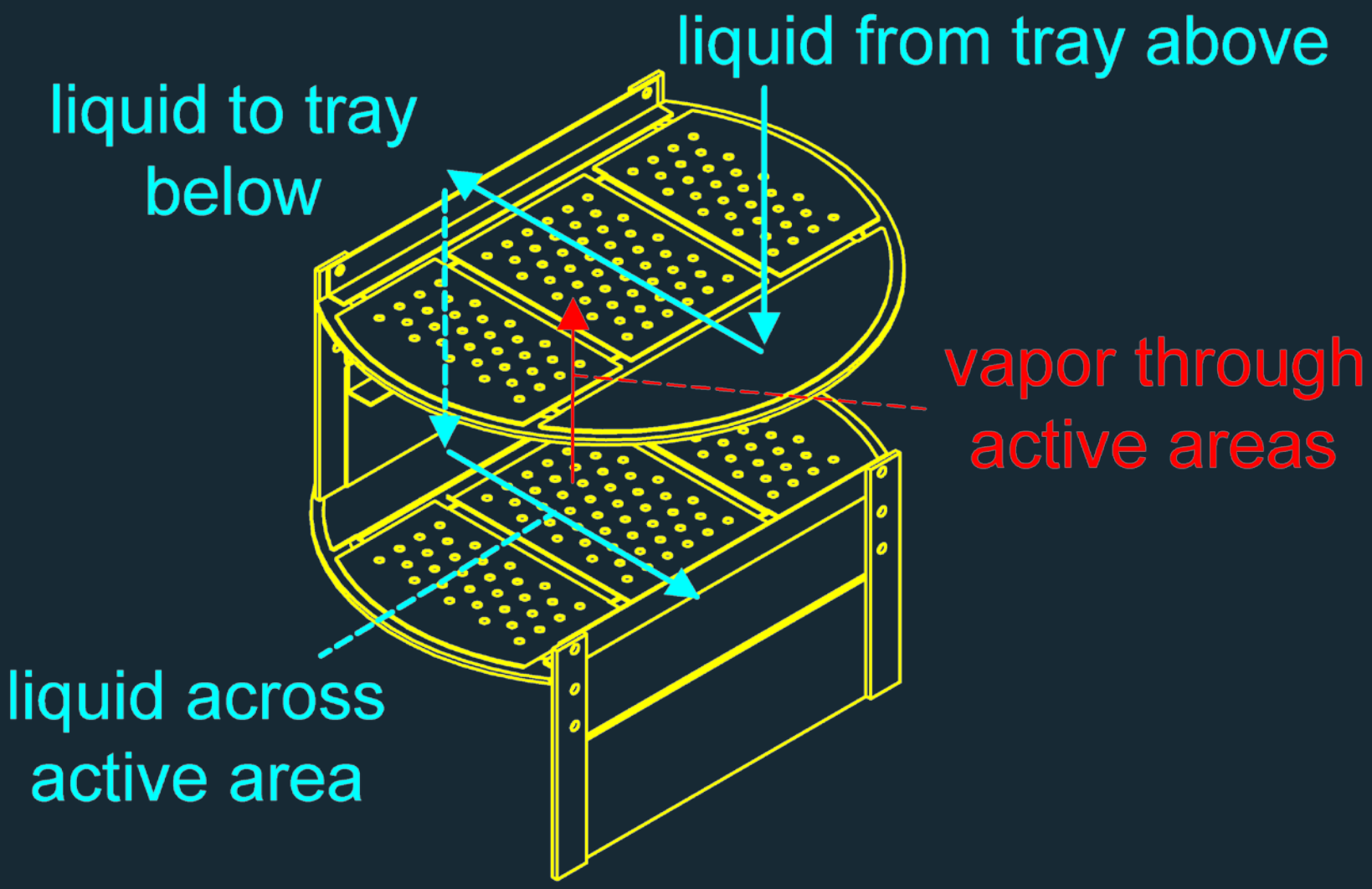
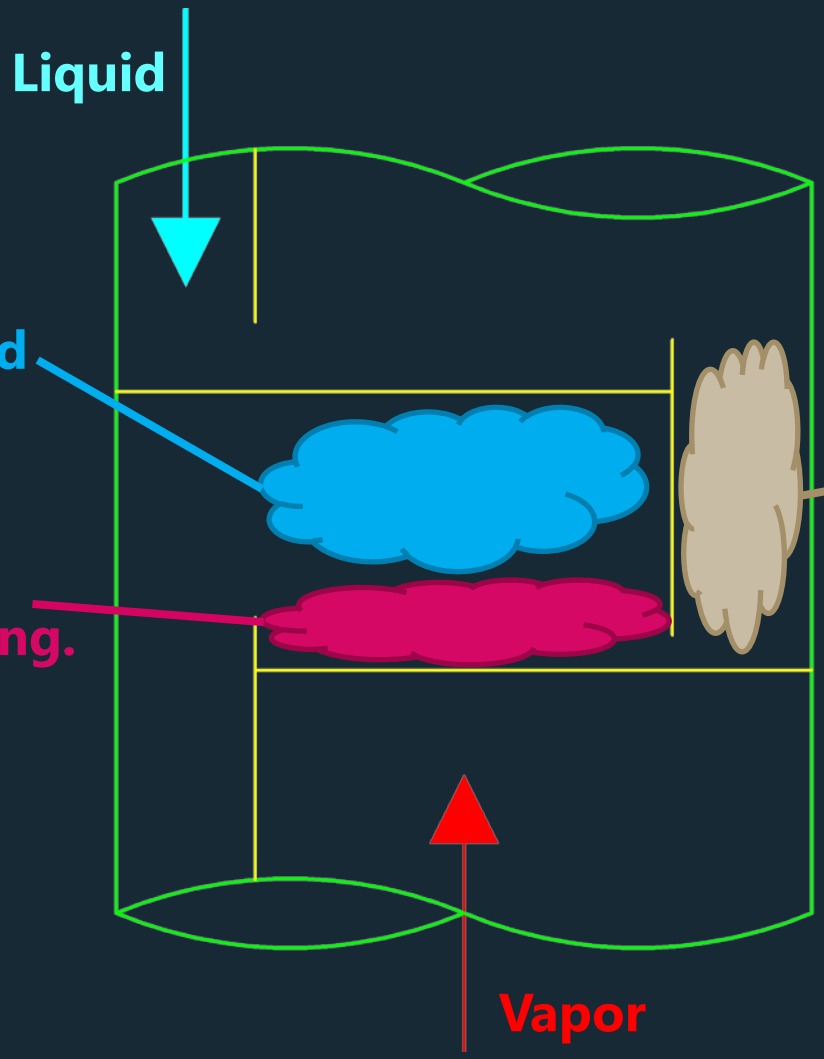
Cross-Flow Trays



Tray Functional Zones



1. What trays need to do
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3. **Tray types**
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The Naming of Trays

Downcomers

- With and without
- Conventional and hanging (truncated)

Passes

- Defined by flow paths available for liquid

Devices

- Defined by equipment in active area

Downcomers

Trays with Downcomers

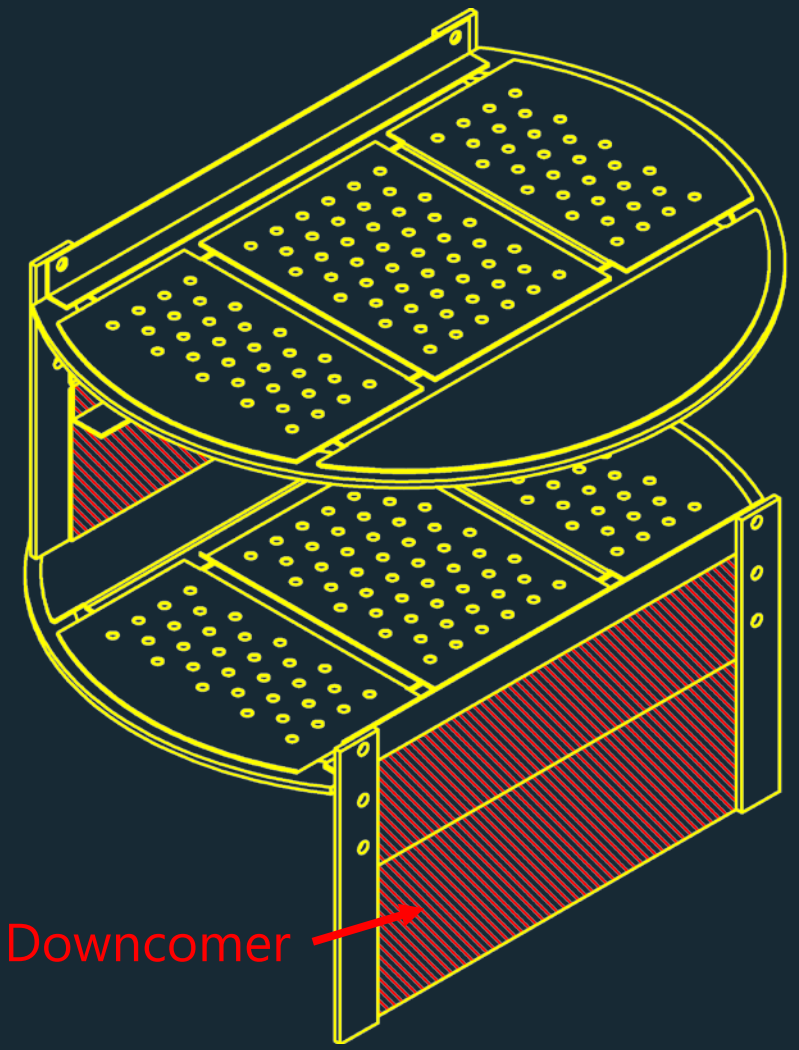
Most common type

Reliable, flexible, and predictable operation

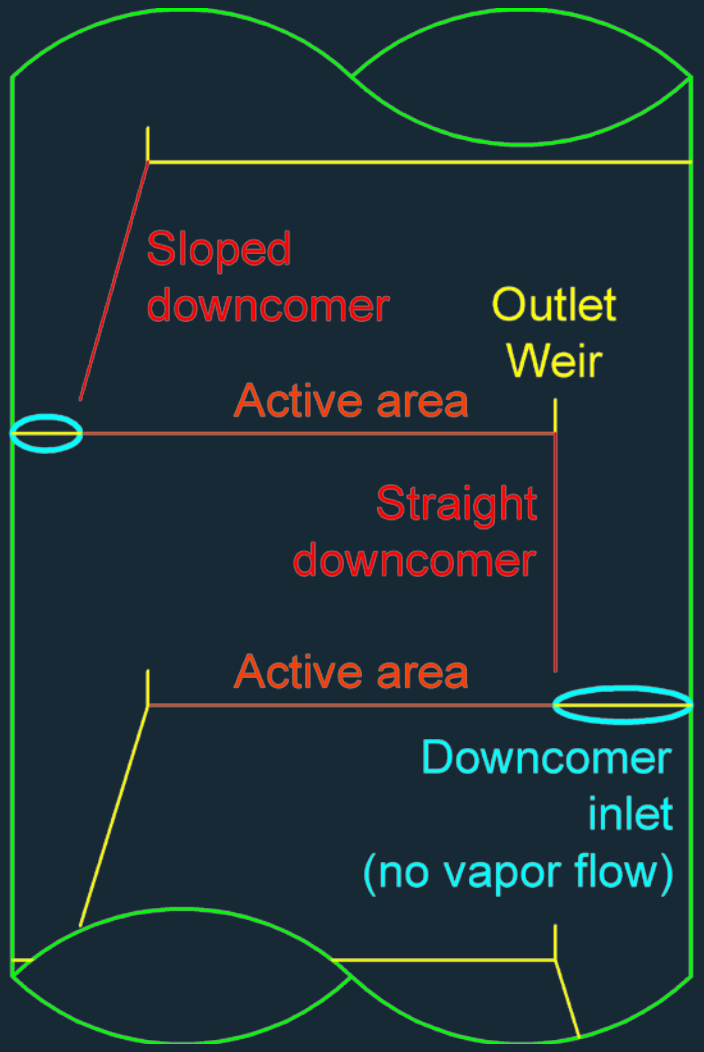
Segregated area for:

- Liquid degassing
- Accumulating liquid height for pressure balance

Downcomer may be straight (vertical) or sloped



Conventional Downcomers

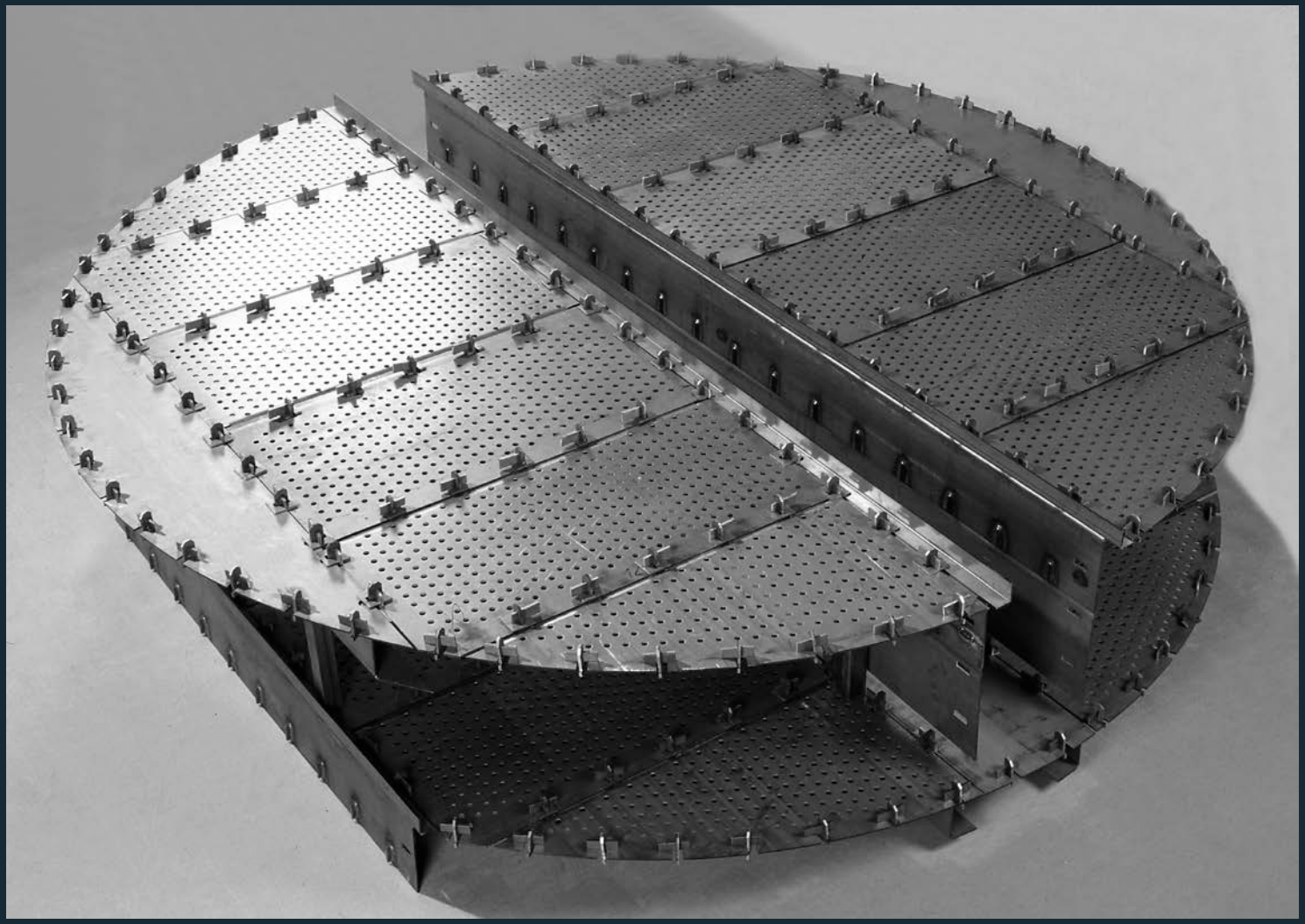


Area under downcomer solid, no vapor flow

Outlet weir usually holds a liquid level on the tray

(zero or positive seal)

Example Downcomer Tray



Sieve tray, Two-Pass

Courtesy of RVT Process Equipment

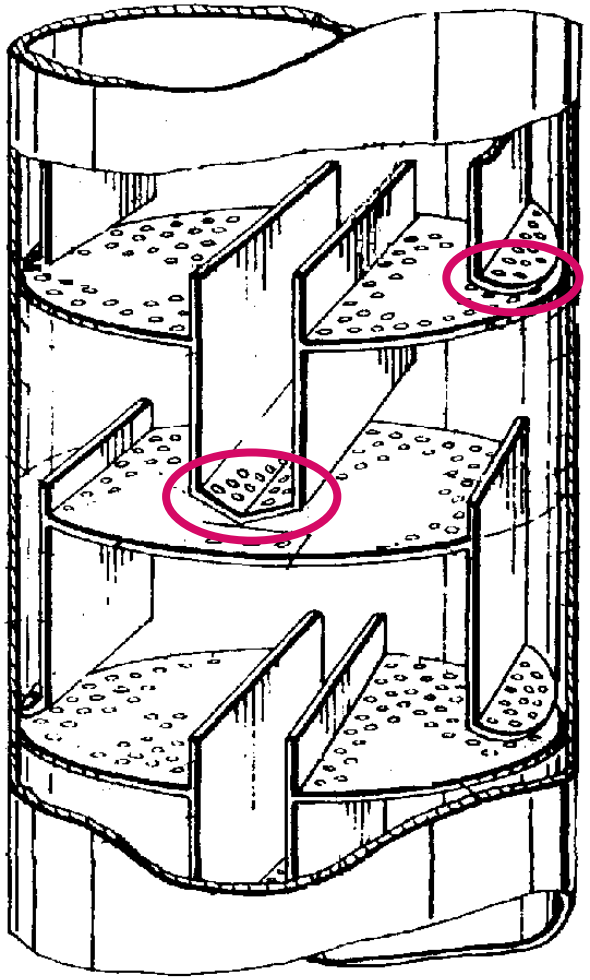
Hanging or Truncated Downcomer

Downcomer is short

Orifice plate in downcomer holds a dynamic seal on the liquid in the downcomer

Increases tray capacity

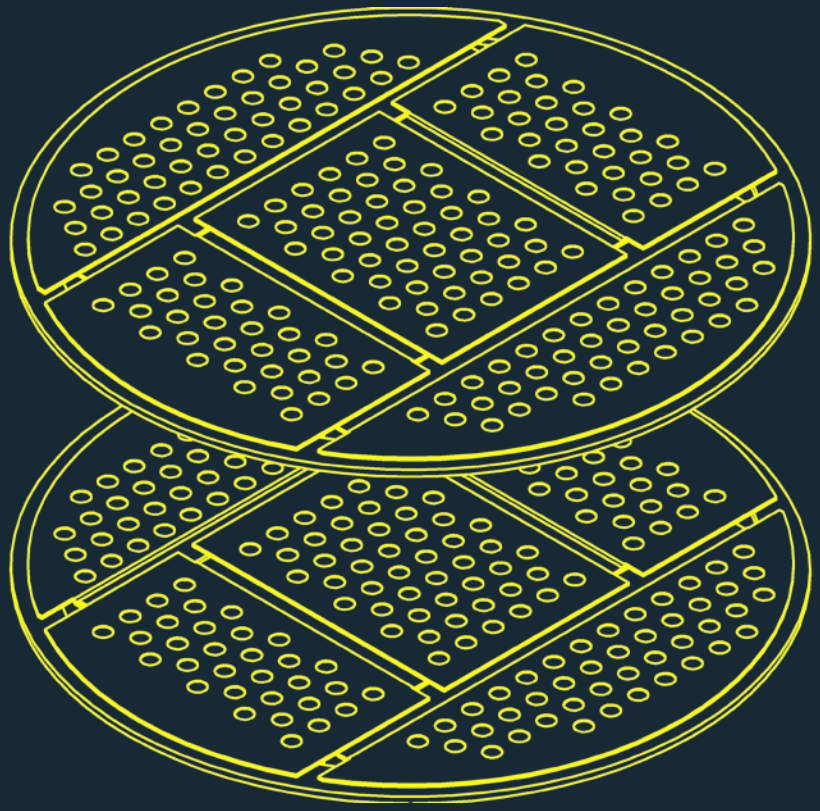
Decreases downcomer rate flexibility (reduces downcomer height and volume)



From USA Patent 4,504,426

Example Hanging Downcomer Tray

Trays Without Downcomers



Liquid and vapor flow through same hole on tray

High capacity, Low flexibility

Lower efficiency

Usually reserved for very fouling services

Some other applications

Example Trays Without Downcomers

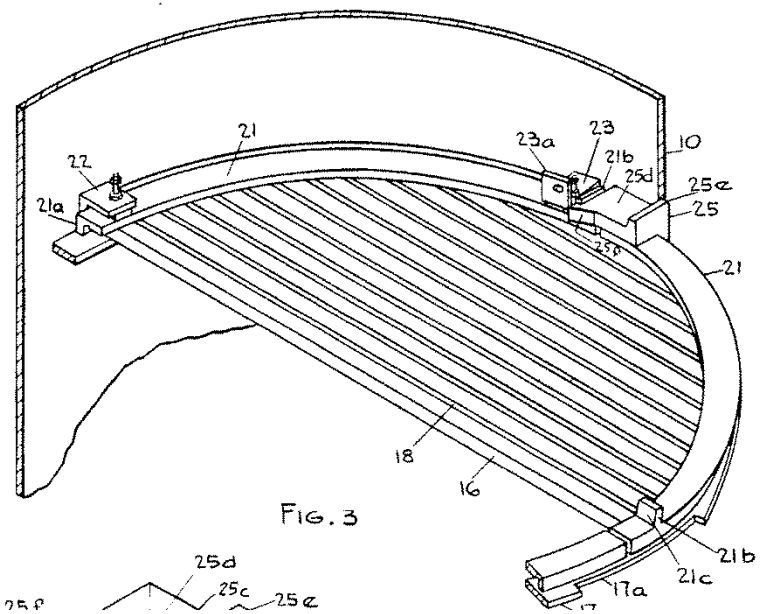
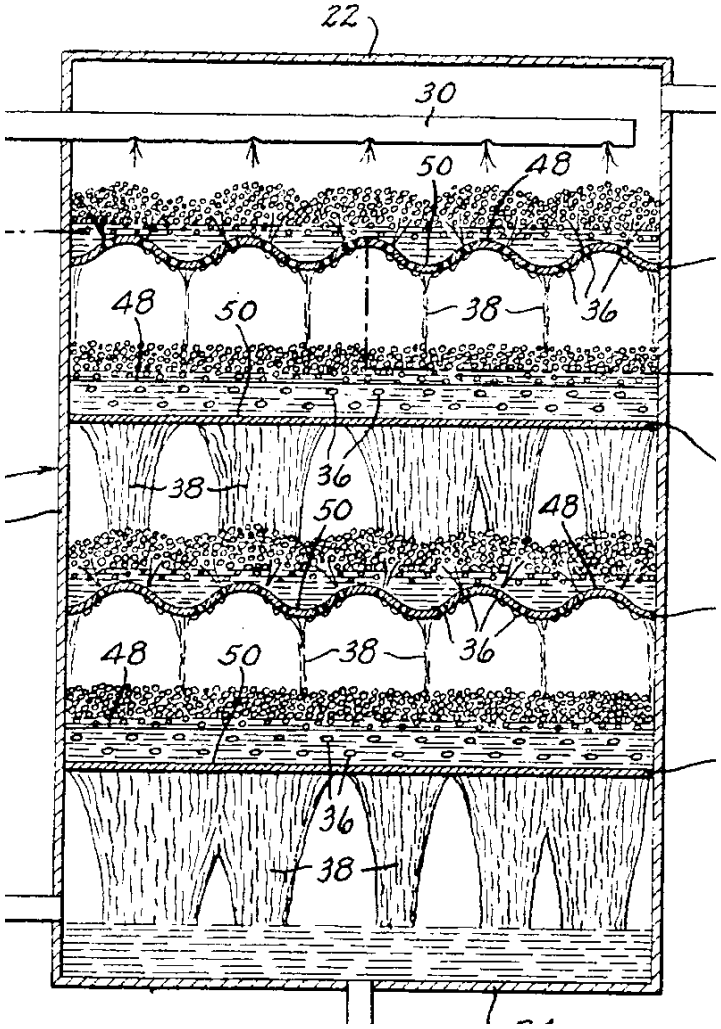


FIG. 3

From USA Patent 2,750,174



From USA Patent 2,767,967

Passes

Tray Passes

Paths for liquid flow

The more paths for liquid flow, the higher the liquid handling capacity

Liquid flow paths change pressure balance, multiple flow paths can increase vapor capacity as well

1, 2, 4 paths common

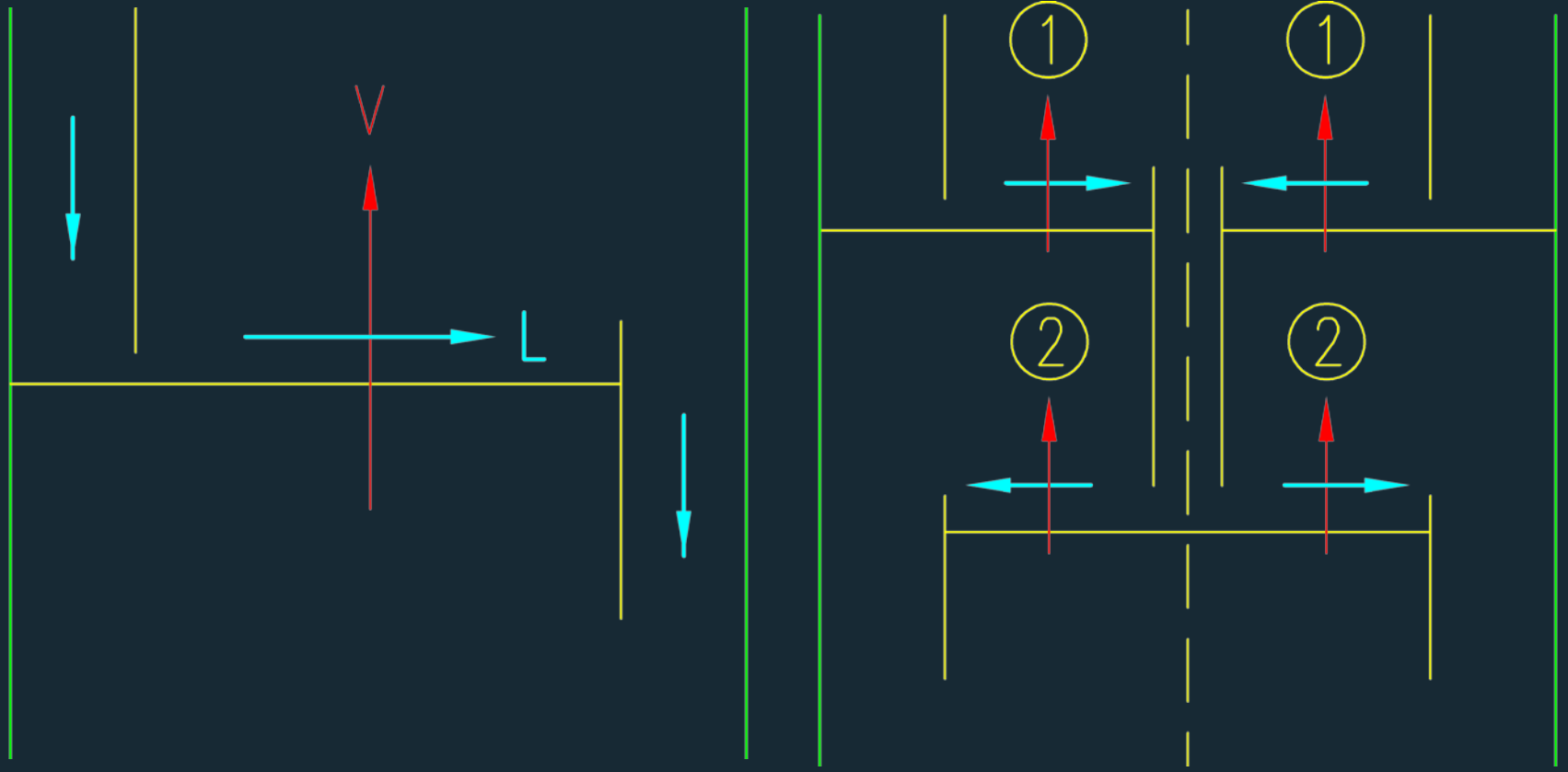
3 used occasionally

5+ not common

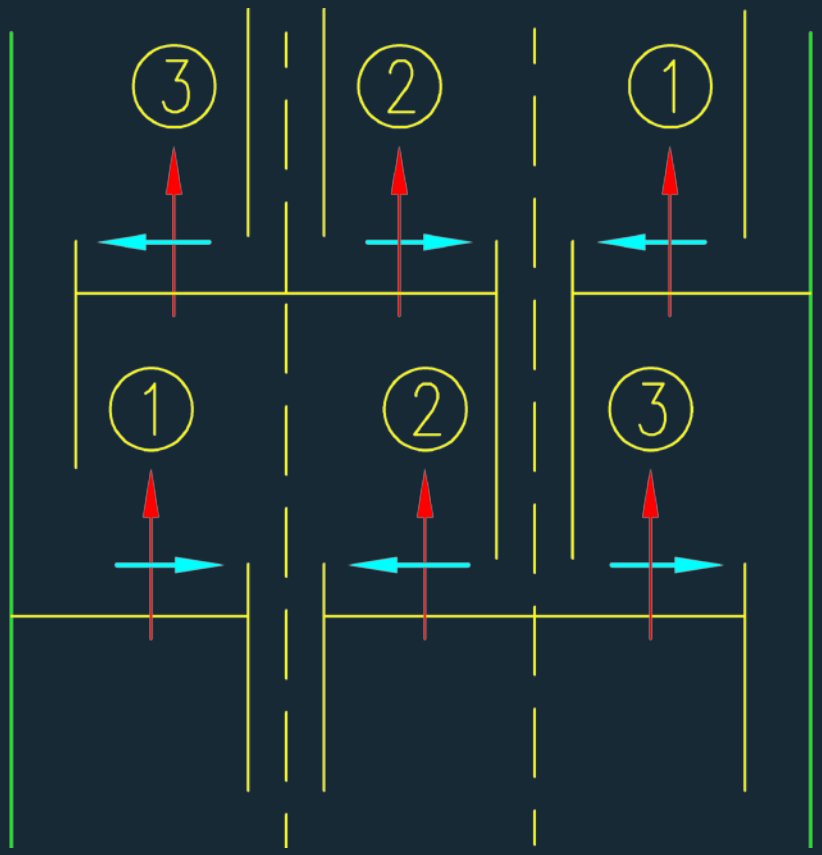
The more passes, the larger the tower minimum diameter

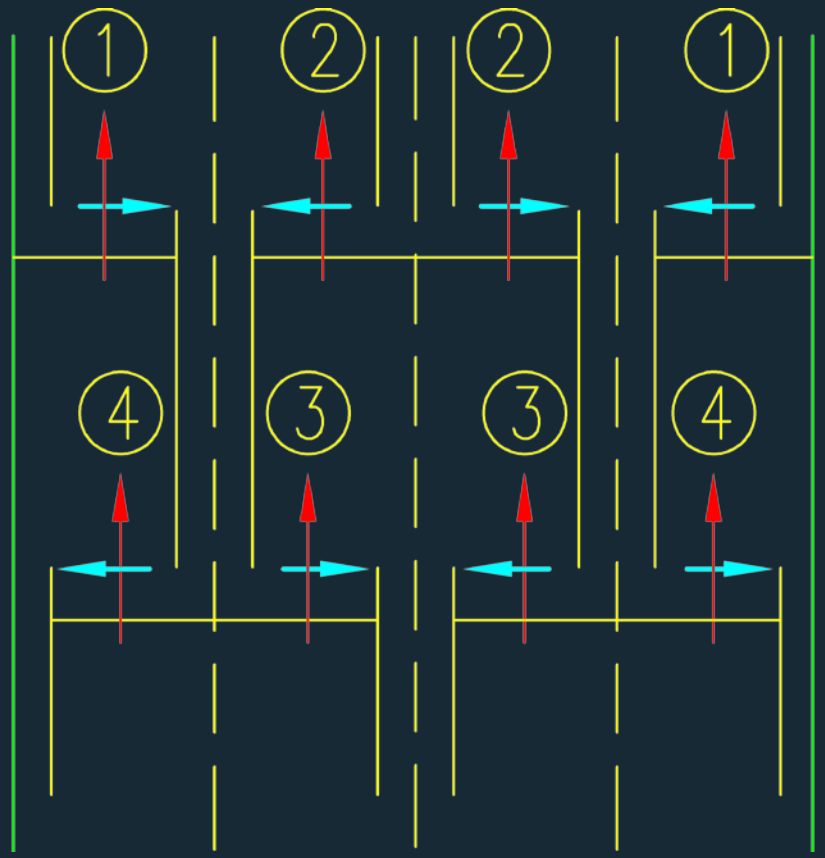
The active area should be a minimum width to allow for manways

One-Pass and Two-Pass



Three-Pass and Four-Pass





Two-Pass Tray, In Service

Devices

Active Area Devices: 1

Mix vapor and liquid

Valves most common

- Help keep liquid on the tray, increase operating flexibility
- More expensive
- Directional valves, help push liquid
- Fixed valves, reduce fouling problems

Active Area Devices: 2

Sieve holes (perforated trays)

- Cheapest
- Reasonable flexibility

Bubble caps

- More expensive
- Maximum flexibility
- When used properly, suitable for very low liquid rates

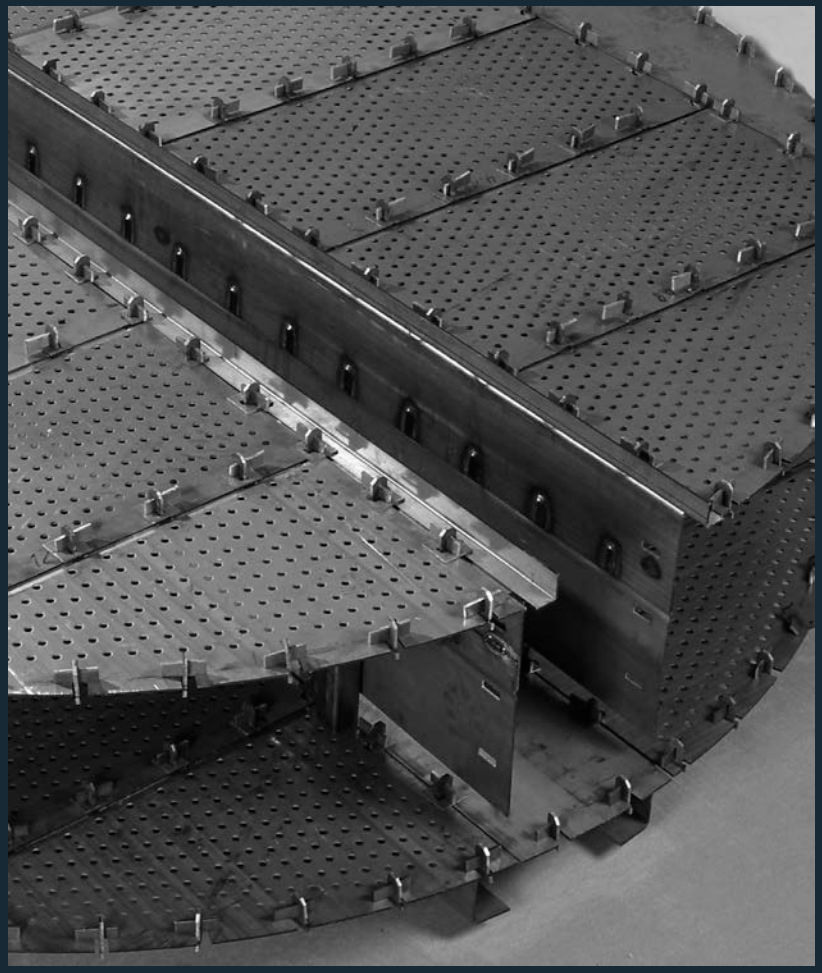
Other options less common

Valves

Valve
Courtesy of Sulzer Chemtech

Caged Valve
Courtesy of RVT Process Equipment

Sieve (Perforated) and Bubble-Caps



Sieve
Courtesy of RVT Process Equipment

Bubble Cap
Courtesy of RVT Process Equipment

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Modern Trays

Constructed in panels

Panels have integral trusses

Some components may be beams or stand-alone beams may be included

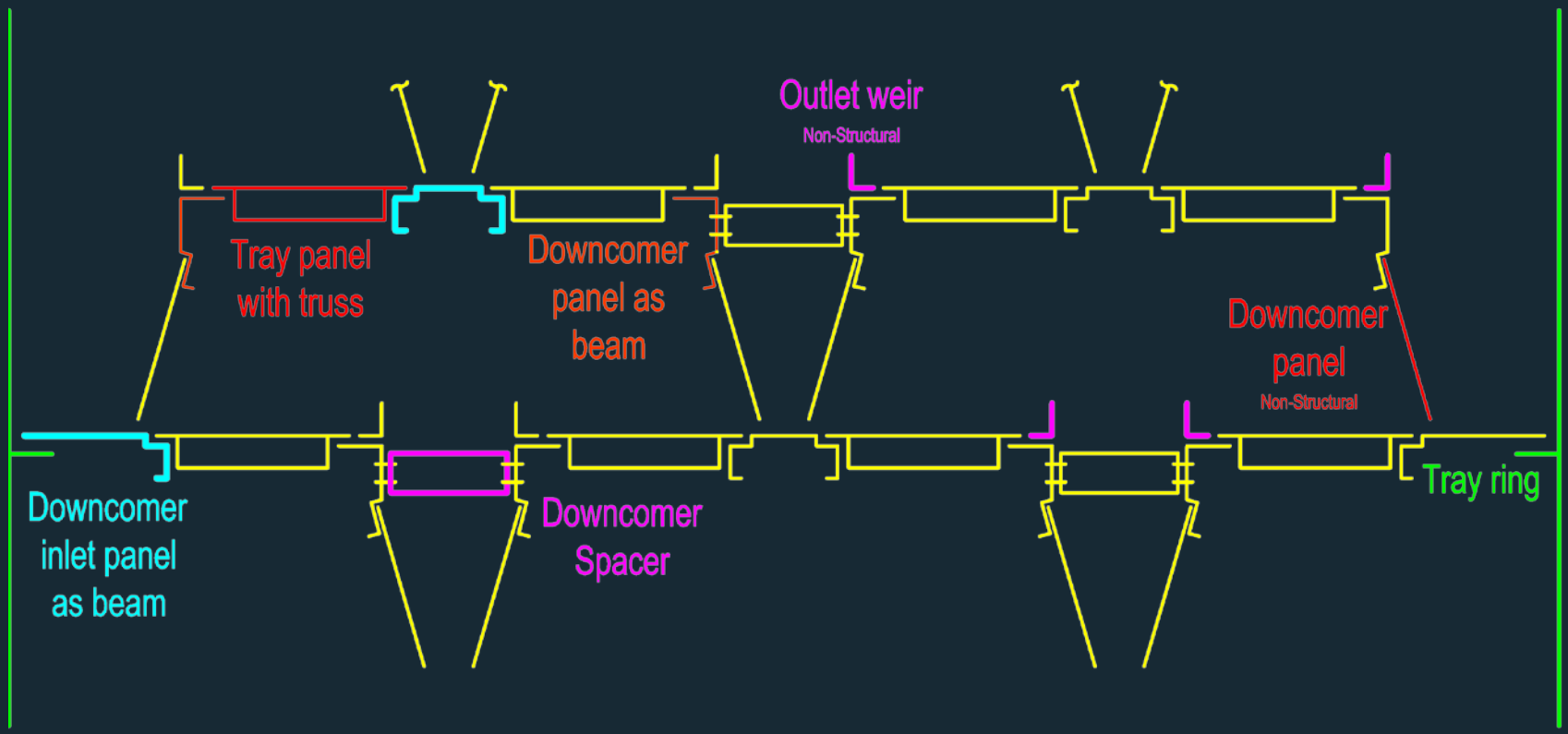
- Example: use a downcomer panel as a beam

Tray ring holds tray edge in place

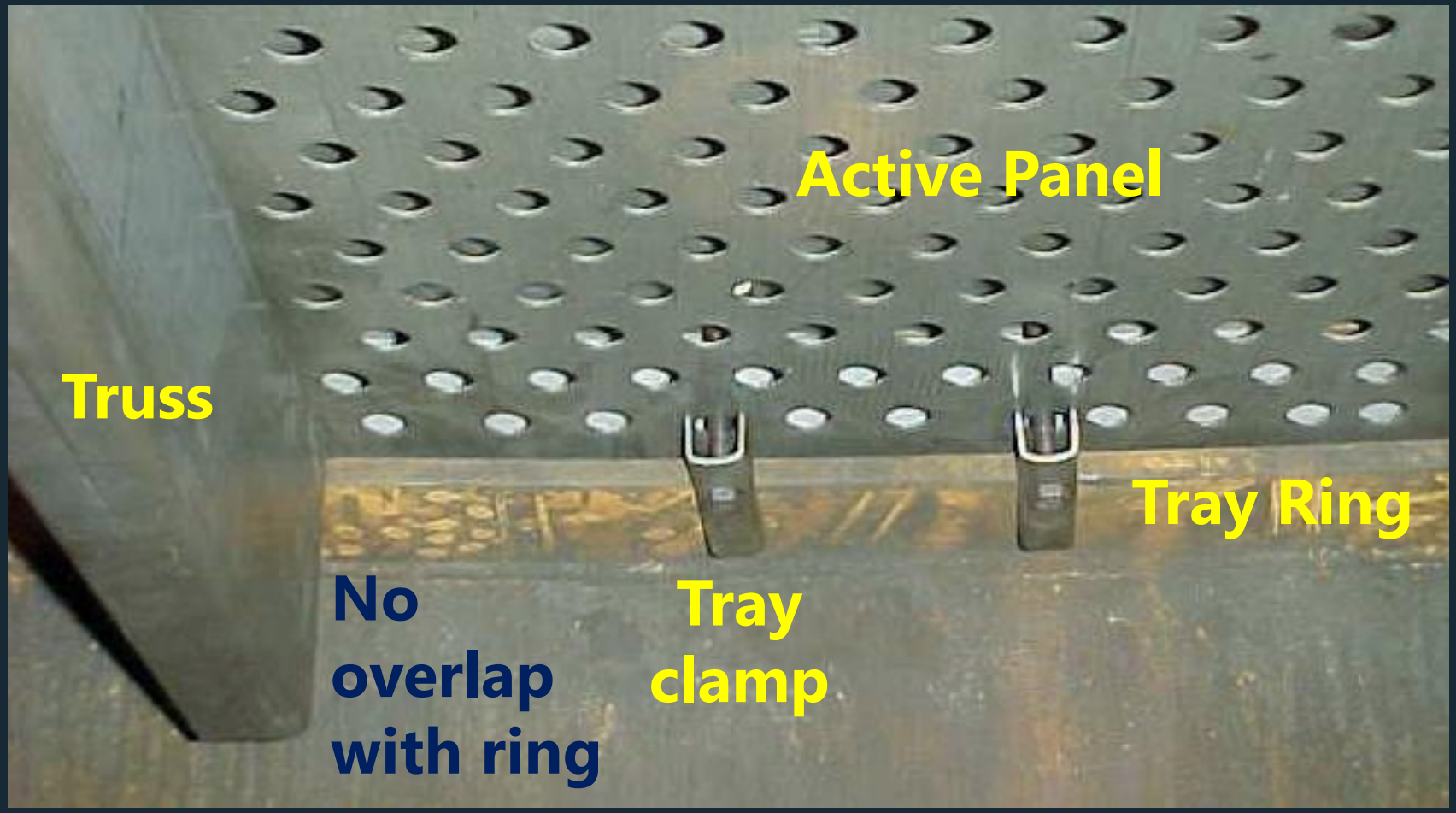
Bolts, clamps, and washers hold tray in place: friction fit

- Allows for fabrication, installation, out-of-round tolerances

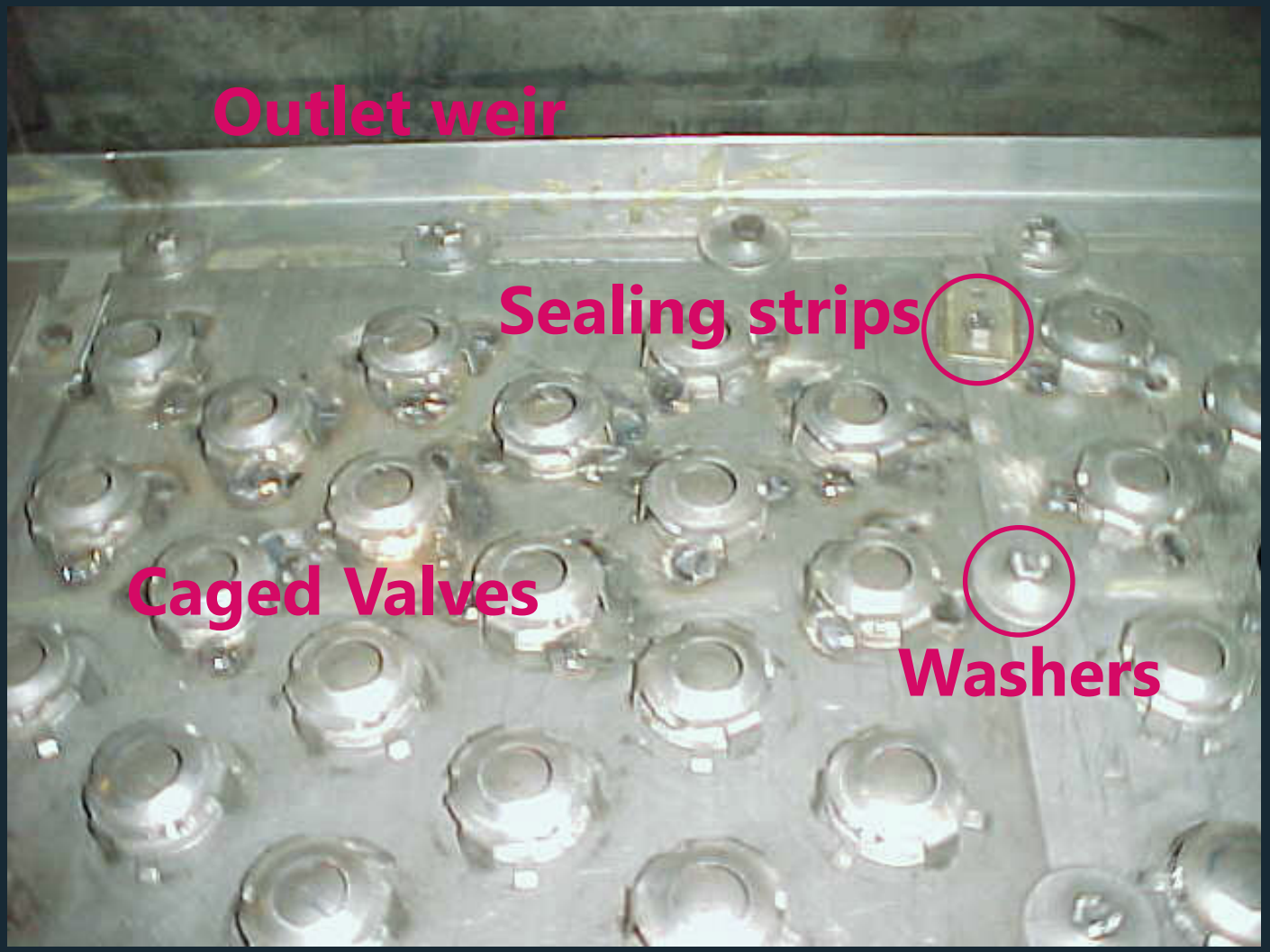
Component Schematic



Tray Clamps


Active Panel
Truss
Tray Ring
No overlap with ring
Tray clamp

Washers and Seals



Underside: Trusses Do Not Overlap or Connect

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Mechanical Specifications Often Assumed

60 psf (lb/ft^2) distributed load (at operating conditions) [0.030 kg/cm^2]

or

30 psf (lb/ft^2) distributed load for light duty [0.015 kg/cm^2]

250-300 lb point load (at operating conditions) [0.122-0.146 kg/cm^2]

1 % vessel out of roundness maximum (ASME BPC VIII-1 UG-80)

Bolting not to be critical-slip

Install with vessel in vertical position

Manway opening from top only

Beams and trusses all underneath active area

Hole punch direction down

Mechanical to Specify, Common

Components

- Metal thickness for tray decks, panels, and devices
- Beam thicknesses (minimums)
- Average thickness or minimum thickness

Load requirements

Materials of construction

Size of manhole to pass pieces through

Manway opening from top and bottom

If out-of-roundness needs to be worse than 1%

Hardware extra pieces (5 to 10%)

Include tower attachments (weld-in components) or not

Common Specifications: Components

	Gage	Inch*	mm*
Major support beams	7	0.1793	4.5
Minor support beam			
Alloy and non-ferrous	12	0.1046	2.5
Carbon steel	10	0.1345	3.5
General components			
Alloy and non-ferrous	14	0.0747	2.0
Carbon steel	10	0.1345	3.5

* Approximate equivalents

Mechanical to Specify, Less Common

Deflection under load, often not specified, should be 1/8” or 3 mm

Uplift resistance, often not specified

Supported from ring only or split support (from above)

If to be installed while vessel horizontal

Leak rates

Leak tests

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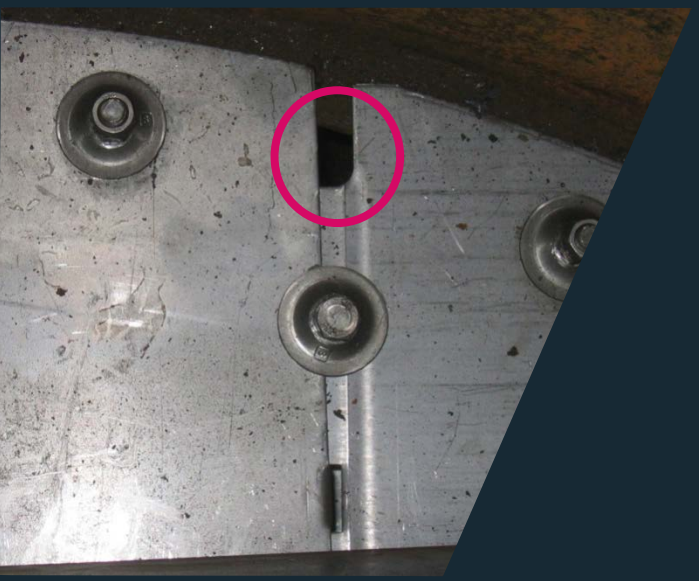
Trays Leak



Always some leaks (unless fully seal welded)

Seal plates used to close gaps in tray

Gaps in downcomer seal area more of a problem than in the tray deck

- Head of liquid in downcomer increase leak
- Liquid bypasses tray completely
- Vapor flow on tray reduces active area leaks

Major Damage, Trays Fail…

Corrosion, pick the right materials

Installation, understand and follow procedures

The “Big 4”

Pressure surges, water entering hot systems (or other sudden vaporization)

Level upsets in tower bottoms

Vibration (rare)

Pressure surges, PSV releases

Pressure Surge Tray Damage

Best Approach

Reduce the number and size of upsets

Pressure Surges

Keep violently flashing streams out of the system

Keep level controllers working

Avoid PSV releases

Vibration

Inherent in operating conditions

Mechanical solution required

Make tray stiffer and change mechanical layout

Specifications to Add

Higher distributed load

Specify an uplift resistance

Make components thicker

Additional features

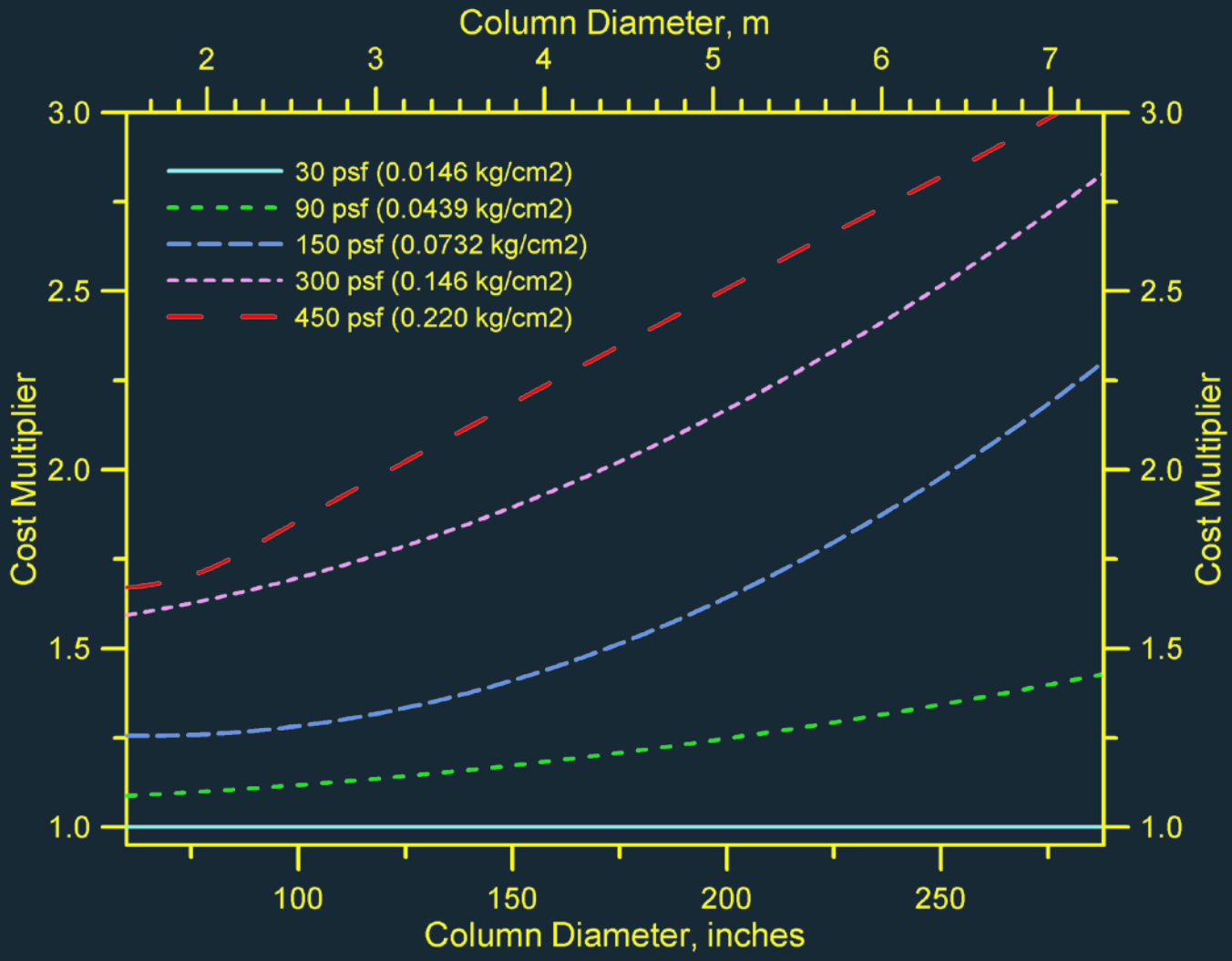
- Truss lugs, to prevent trays from being pushed down
- Shear clips, to prevent trays from being pushed up
- Through bolting, requires field fit and drilling

Specified number and type of major beams

Welding installation (allow for thermal expansion)

Pressure relief options

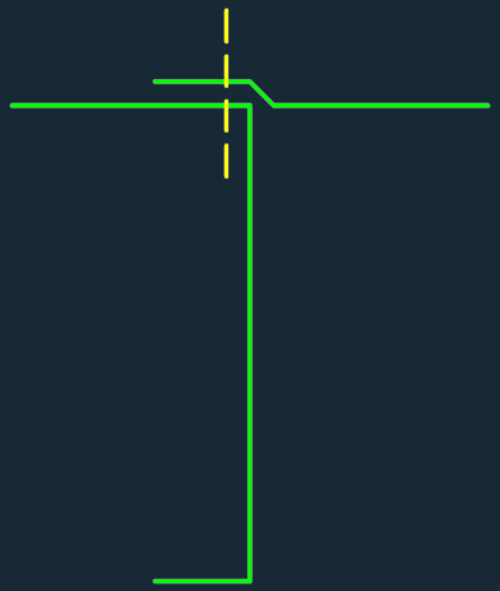
Relative Cost: Making Trays Stronger



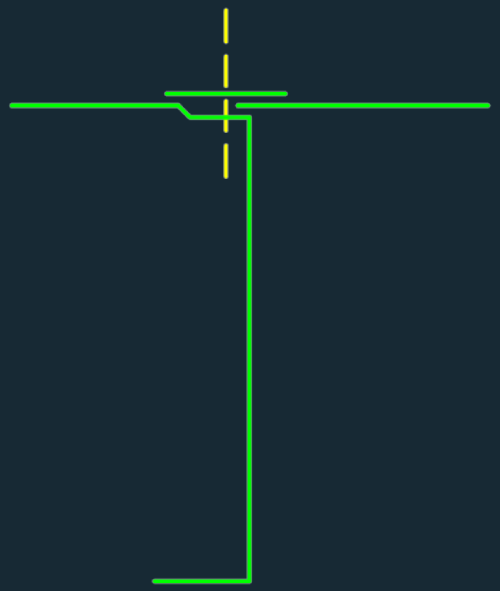
Based on G. H. Shiveler, 'Use Heavy-Duty Trays for Severe Services', *Chemical Engineering Progress*, 91.8 (1995), 72–81.

Through-Bolting Adds Strength

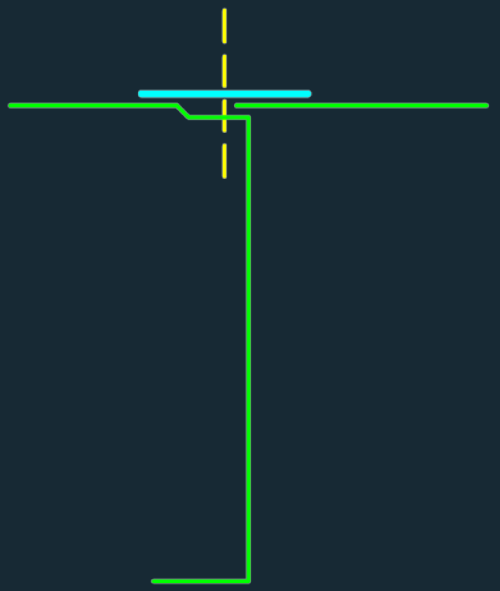
Through-Bolted on Truss



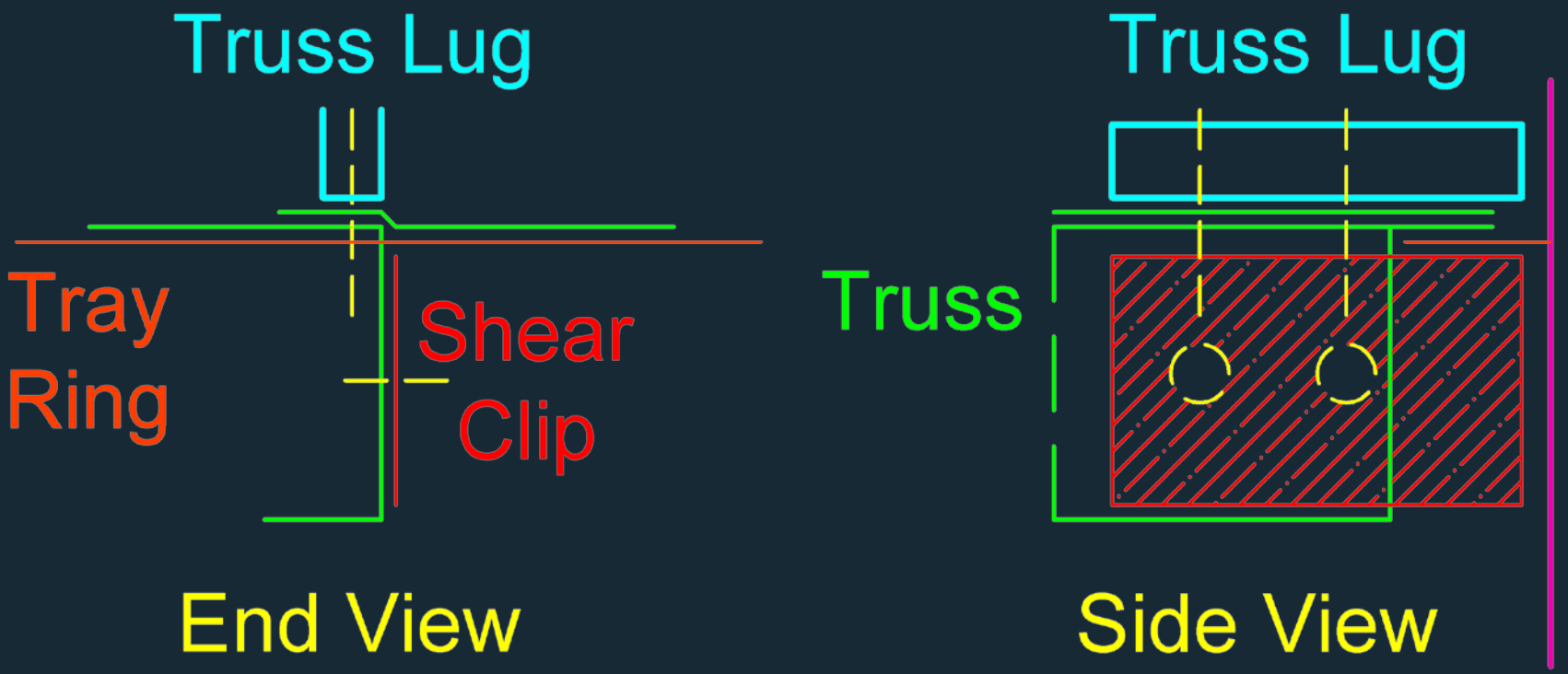
Friction-Fastened on Truss (Standard Washer)



Friction-Fastened on Truss (Heavy Washer)

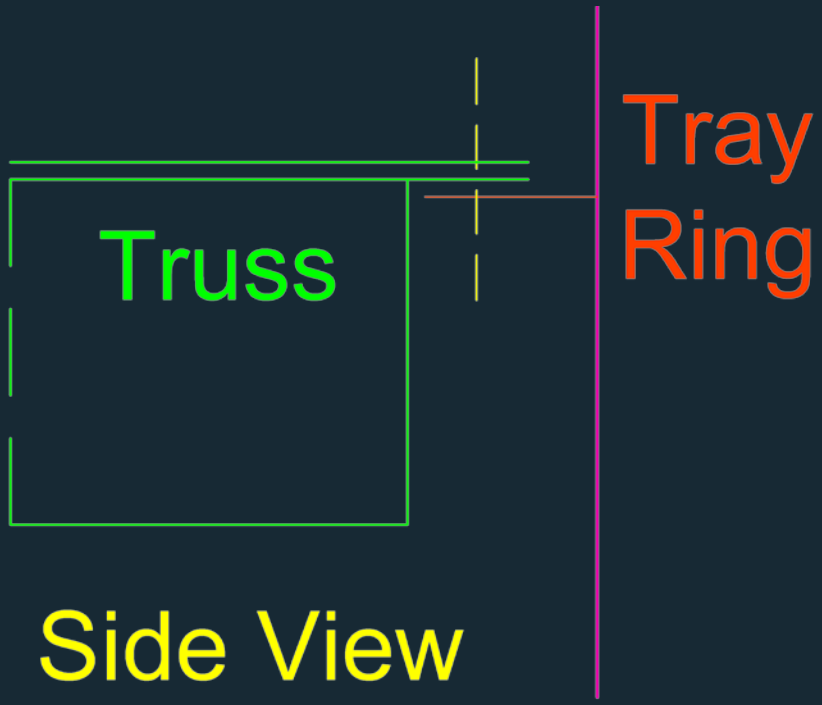


Lugs and Clips: Panel-to-Ring



Through-Bolted Rings

Through-bolting requires field fit and drilled holes



Rings are thick

Alternative: Pressure Relief

Add a trap-door to handle pressure relief

Deals with pressure surges, not with level induced damage or vibration damage

Trap-Door Tray

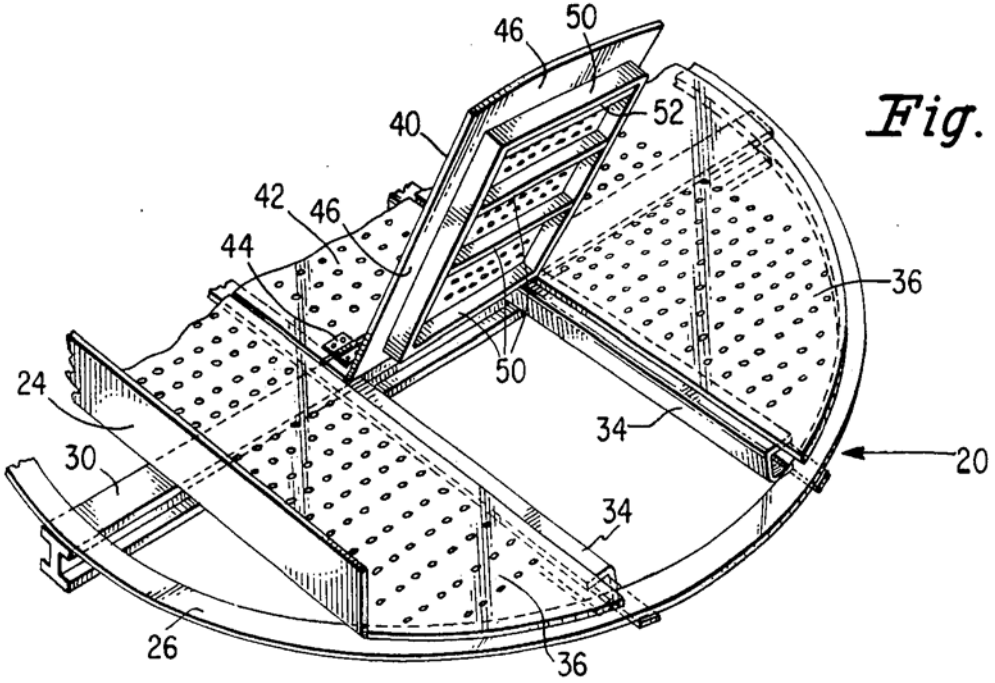


Fig. 3.

From USA Patent 4,133,852

Trap-Door Tray

One Final Caution

Don’t make the trays stronger than the vessel.

Conclusions

Today's Take-Away

Mechanical requirements add to process requirements

Understand cost, delivery time, installation time consequences of requirements

Basic requirements outlined

Many complex trays with special features

Further Reading

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Rules for Construction of Pressure Vessels. (2010, July 1). ASME International.

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