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Revision Memo

- 12/01** This update represents a major revision effort. Highlights of this revision are:
- (1) Major updates to discussions and figures throughout the entire section, to reflect the merging of ExxonMobil fractionation technologies.
 - (2) Updated Figure 4, "Some High Capacity Tray Designs", to include Provalve deck, UOP Multiple Downcomer Sieve Trays, and the Sulzer HiFi Tray.
 - (3) Updated the definition of waste area to account for three different types of wasted tower area.
 - (4) Included discussion and sketches of picket fence and swept back weirs.
 - (5) Major modifications to Vapor Handling Limitations section include:
updated hierarchy of design considerations,
included emulsion regime in discussion of flow regimes.
 - (6) Major modifications to Liquid Handling Limitations section include:
updated hierarchy of primary and secondary design considerations,
expanded and updated discussions of all design considerations.
 - (7) Major modifications to Other Process Considerations section include:
updated hierarchy of design considerations,
included discussion of fouling.
 - (8) Inserted Table 3D, "Relative Fouling Resistance of Common Fractionation Devices".
 - (9) Major modifications to Tables 1, 2, 3, 4A, 7, 8 to include newer fractionation devices and debottlenecking strategies.
 - (10) Inserted NOMENCLATURE section.



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SCOPE

This section presents guidelines which are useful for selecting the optimum contacting device for a given service. Also included are discussions on the various process limitations which restrict the operating range of a given device. The detailed design procedures for the various fractionating devices are covered in subsequent sections. A detailed Tower Design Checklist is included as **Table 7** (for trays) and **Table 8** (for packing). They are intended for use after the design has been completed. For information on mechanical requirements see **GP 5-2-1**. For fractionator process information, refer to the Separations Guide (TMEE 058).

REFERENCES

DESIGN PRACTICES

All Other Sections of [Section III](#)

GLOBAL PRACTICE

GP 5-2-1 Internals for Towers and Drums

OTHER REFERENCES

1. *Atmospheric Pipestill Guide*, ExxonMobil Engineering Technical Manual, EEPE-0006.
2. *Fractionating Tower Troubleshooting Guide*, ExxonMobil Engineering Technical Manual, TMEE 021.
3. *Fuels Vacuum Pipestill Guide*, ExxonMobil Engineering Technical Manual, EETD 076 (EE.20E.96).
4. Maloney, D.P., *Fuels Vacuum Pipestill Wash Zone Reliability*, New Section of the Fuels Vacuum Pipestill Guide, Technical Manual Update, EE.53E.98.
5. *Mobil Tower Internals Program (MoTIP) User's Manual*, Mobil Research and Development Corporation.
6. *Refinery Distillation Practices*, Mobil Technology Company, May, 1996.
7. *Separations Guide*, ExxonMobil Engineering Technical Manual, TMEE 058.
8. *Trayed Tower Internals*, MTC Process Design Practices, Mobil Technology Company, Practice No. II, Volume No
9. Attached to the Table of Contents for [Section III](#) - Fractionating Towers, is a list of ExxonMobil FRACTIONATION SPECIALISTS who can provide help on a broad range of fractionation issues.

BACKGROUND

KEY STEPS INVOLVED IN TOWER DESIGN - AN OVERVIEW

The purpose of this Subsection is to define the Basic Concepts needed to understand how the various contacting devices work and to help select the best internal for a given service. Once the contacting device has been selected, the designer should then read the particular Subsection that covers that device. Before beginning, however, it is important to look at **all** the steps that must be taken in order to achieve an optimum tower design. To do this, the eight key steps in designing a distillation tower are briefly reviewed below.

1. **Define the key separations.** In many cases, where individual components can be identified, the amount of impurity permitted in the products is given. This is needed in order to set the yield and purity level of the products being produced.
2. **Obtain the appropriate vapor-liquid equilibrium (VLE) and enthalpy data method.** This can be done by referring to the ExxonMobil Data Library Manual or by contacting your FRACTIONATION SPECIALIST. The use of an inappropriate data method could lead to off-spec products or an inoperable design.
3. **Calculate the theoretical trays required at different reflux rates.** By running parametric cases on a plate to plate computer program with differing numbers of trays and reflux rates, the shape of the theoretical trays vs. reflux ratio curve can be determined. This curve will assist in determining the most economical tower height and diameter combination.

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BACKGROUND (Cont)

4. **Estimate the tray efficiency.** This step assumes that the contacting internal will be sieve or valve trays; however, a similar process should be followed with other internals, such as packing. For most services, towers similar to the one being designed have been built in the past and operating efficiencies have been determined. These are tabulated in [Section III-I, Tray Efficiency](#), and are suitable for preliminary scoping purposes. For truly new systems, and for checking the efficiency during the tower design, the efficiency should be calculated via [Section III-I](#) (or the appropriate computer program), since the final efficiency is also influenced by the tray hardware design. The liquid flow path length (l_{fp}) is the most important hardware parameter with respect to tray efficiency, provided normal hydraulics (that is, weeping and entrainment below allowable limits, and A_o/A_b and weir heights within allowable ranges). The flow path length determines the number of mixing pools on the tray, which in turn has a direct influence on the tray efficiency. Tray efficiency increases rapidly from the minimum allowable flow path length (16 in [400 mm] for conventional trays) up to about 30 in (760 mm). For flow path lengths greater than 30 in. (760 mm), liquid flow on the tray is essentially plug flow, and efficiency is independent of flow path length. However, for flow path lengths greater than about 70 in. (1780 mm), tray efficiency starts to decrease due to the presence of stagnant regions on the tray, depending on tray geometry.
5. **Define the maximum and minimum feed rates that the tower must handle.** In general, a turndown ratio of 2/1 is adequate for most services. If greater turndown than this is needed, the turndown ratio itself becomes one of the key items in selecting both the tray type and how it should be designed. Another term commonly used is "flexibility", which is the ability of a device to operate efficiently over a range of vapor and liquid loadings.
6. **Selecting the best tower internal.** Subsequent discussions plus [Tables 1-3](#) will facilitate internals selection. For most trayed columns, sieve or valve trays will be the first choice whereas for packed towers a dumped packing of the 2 in. (50 mm) size will normally suffice. Of course, such items as fouling tendency, allowable pressure drop, turndown requirements, and in the case of revamps, required capacity and/or efficiency will have an important influence on the internal finally selected. As a design technique, zoning the tower into different sections can increase flexibility and reduce tower height. However, most new tower designs should not be divided into more than two sections (with the feed zone being the line of demarcation the two sections), due to diminishing returns on overly complex design. Contact a FRACTIONATION SPECIALIST if a design with more than two sections is being considered for a simple tower.
7. **Tower sizing and tray hydraulic calculations.** The key parameters to consider in the sizing and hydraulics areas are discussed in subsequent pages of this Subsection for the various devices available. Various computer programs are available in PEGASYS to facilitate calculations and permit rapid optimization via parametric cases.
It is strongly recommended, however, that the engineer's first internals design be done with the close guidance of a FRACTIONATION SPECIALIST, following the steps in the detailed design procedure, in order to develop the necessary feel for how the many variables interrelate. Subsequent designs can then be done via computer with confidence.
8. **Process Control.** In order to get optimal performance from any distillation tower, it must be controlled properly. As the tower diameter and number of trays increases, the lag time in the system can become quite large. The designer should see [Section XII - Instrumentation](#) and consult with the appropriate SYSTEMS ENGINEERING SPECIALIST to ensure that the correct process control system has been specified.

TYPES OF CONTACTING DEVICES AVAILABLE

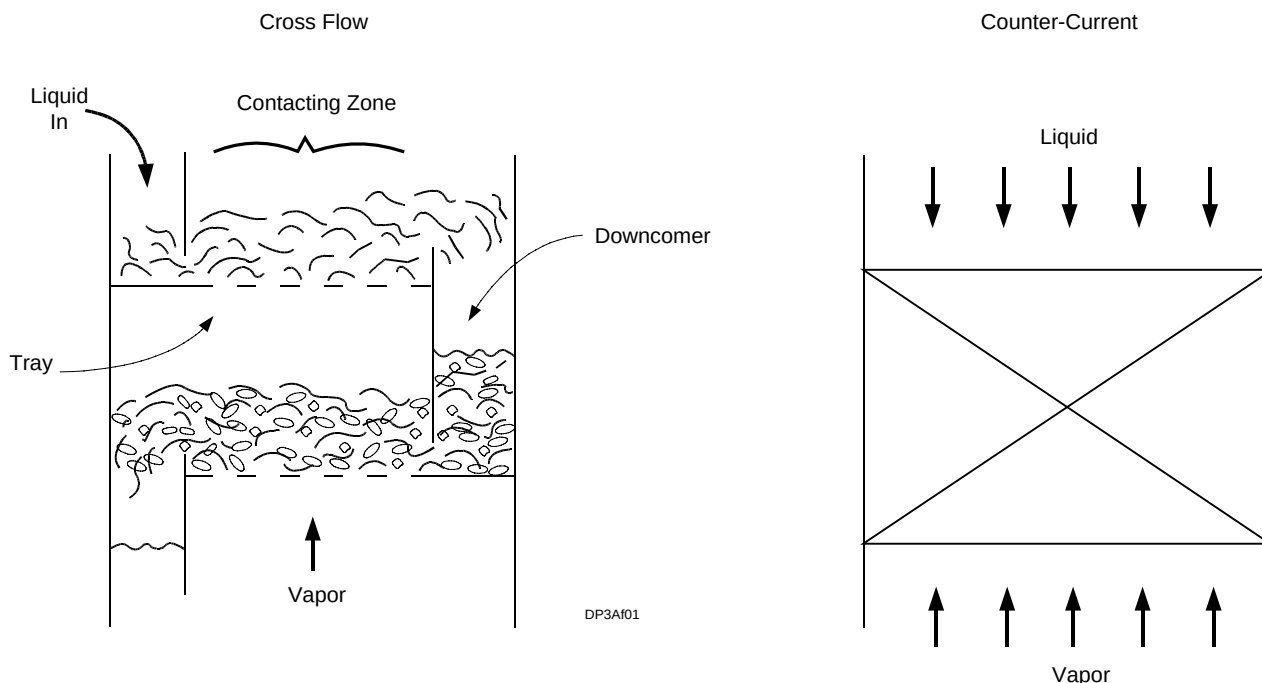
A contacting device must have good liquid and vapor handling capacities, good contacting efficiency, reasonable pressure drop, predictable turndown characteristics and be economical. The devices available fall into two broad categories - **cross flow** and **counter-current**. They are shown conceptually on [Figure 1](#). Subsequent paragraphs will discuss how each device works.



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BACKGROUND (Cont)

FIGURE 1
CROSS FLOW VS. COUNTER-CURRENT
DEVICE OPERATION



Cross Flow Devices (Trays). The liquid flows horizontally across a flat, level plate (called the tray) that contains a contacting device selected by the designer that intimately disperses the vapor into the liquid. In addition, the dispersion process must produce sufficient interfacial area and maintain the phases in contact with each other long enough to promote adequate mass transfer between the phases.

As the liquid flows across the tray, it is contacted by the ascending vapor. At the far side of the tray, the liquid enters a downcomer which carries it to the tray below where the contacting process is repeated. Obviously, the contacting area must be large enough to handle the required liquid and vapor rates while promoting the desired mass transfer. Likewise, the downcomer must be large enough to handle the liquid being processed. The various process limitations that define the operating constraints for the contacting area and the downcomer will be discussed later under **CROSS FLOW DEVICES - PROCESS DEFINITIONS**.

Counter-Current Devices (Packing, Grids, Baffle Sections, and Dualflow Trays). With these devices, the liquid flow is counter-current to the vapor flow. The efficiency of contact is again dependent on the area available for mass transfer. In trays, this is provided by bubbling vapor through the liquid, thereby producing sufficient interfacial area for mass transfer. With such counter-current devices as packing and baffle trays, however, the interfacial area needed for mass transfer is provided by the surface area of the device, or by forcing the vapor to flow through descending curtains of liquid (thereby breaking them up into droplets).

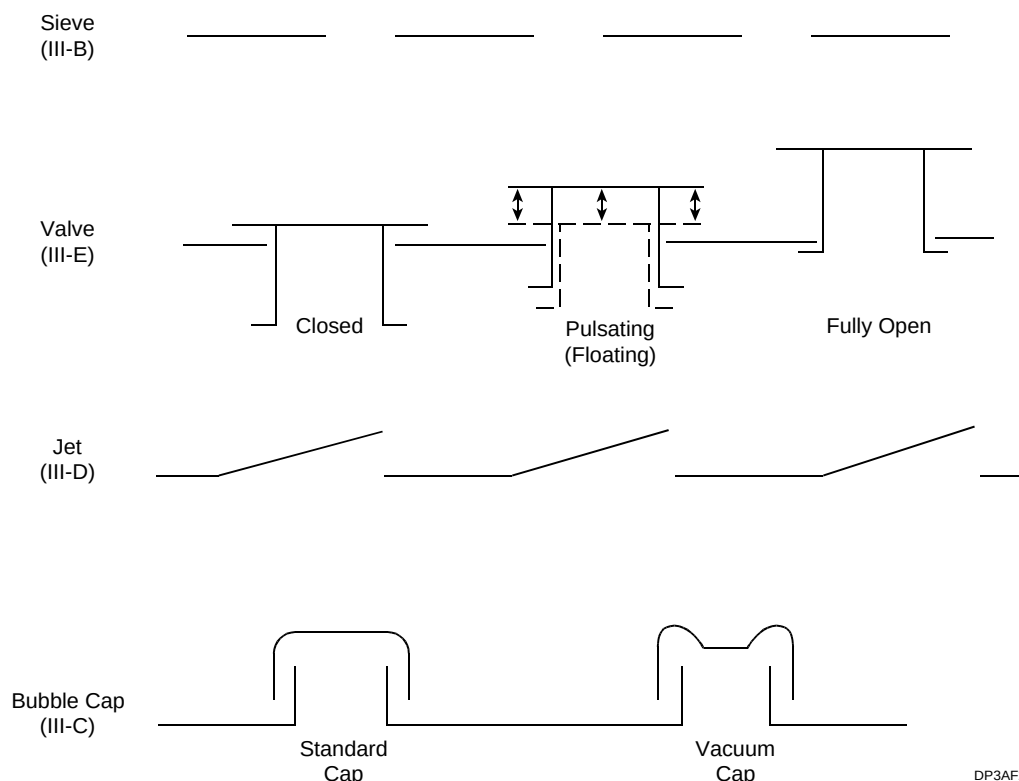
Generally speaking, as the surface area of the device goes up, the efficiency goes up. However, as the surface area increases, the capacity falls while its cost rises. Thus, the final choice involves optimizing the capacity, efficiency, cost, and other process considerations of the various internals available. Subsequent paragraphs will discuss how this is done.

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CROSS FLOW DEVICES - TYPES OF TRAYS AVAILABLE

Some trays used widely within the ExxonMobil circuit are sketched in **Figure 2** and discussed briefly in subsequent paragraphs. The pertinent Subsection for designing each device is also noted next to the figure in parentheses.

FIGURE 2
TYPES OF TRAYS
(SCHEMATIC)

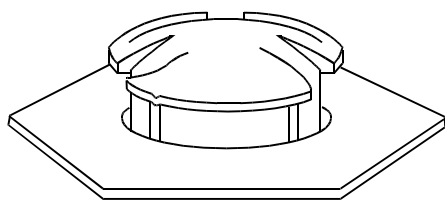


1. **Sieve Trays.** For most fractionation services in refining and petrochemicals, sieve trays will be the first choice. The contacting area consists of flat plates containing perforations, usually 1/2 in. (13 mm) in diameter. They are the simplest trays to fabricate and are therefore the cheapest. They also exhibit good capacity, efficiency, and turndown characteristics (about 2/1 to 3/1). Their flat surface facilitates maintenance; thus, they may be used in fouling services provided the hole size is increased to 3/4 - 1 in. (19-25 mm).
2. **Valve Trays.** The valve size, shape weight and other parameters vary from vendor to vendor (**Figure 3**). Valve trays should be used in lieu of sieve trays when the turndown ratio exceeds 3/1. These trays contain proprietary devices manufactured by Koch-Glitsch Inc. (formerly two companies, Koch and Glitsch), Saint-Gobain NorPro Corporation (formerly Norton), Sulzer Chemtech (formerly Nutter Engineering and Sulzer), and other vendors. Valve trays should be used in lieu of sieve trays when the turndown ratio exceeds 3/1; in the upstream sector, valve trays are the preferred choice due to this high turndown capability. For design purposes their capacity and efficiency are assumed to be about equal to that of a sieve tray, but their cost is roughly 10% higher. Floating (pulsating) valve trays are not recommended for fouling service; however, there are cases where fixed valve trays would be recommended for fouling service (see number 6 below). All else being equal (cost / delivery time, etc.), rectangular valves are preferred due to lack of rotation. Rotation eventually erodes the holes and legs, causing the valves to pop out. This occurs even if dual rotation stops are included in the valve specification.

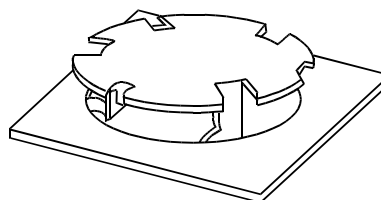
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CROSS FLOW DEVICES - TYPES OF TRAYS AVAILABLE (Cont)

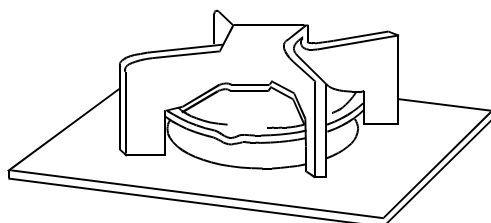
FIGURE 3
TYPES OF MOVEABLE VALVES



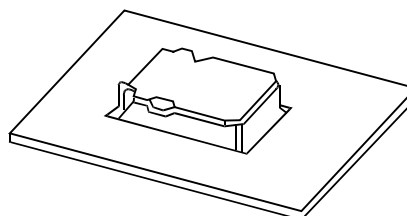
Koch-Glitsch Type A



Koch-Glitsch V-1



Koch-Glitsch Type T



Sulzer (Nutter) BDH

DP3AF3

3. **Jet Trays.** Jet trays, an Exxon development in the 1950's, are now used primarily in heavy hydrocarbon services that handle high liquid rates. The directional effect of the vapor as it leaves the inclined tabs helps push the liquid across the tray, thereby increasing its capacity. Unfortunately, this directional effect also reduces liquid residence time on the tray such that efficiency becomes low for most light ends and other towers with low to moderate liquid loads. For higher liquid rates typical of pumparounds, the efficiency in heat transfer service is comparable to other cross flow devices.
4. **Bubble Cap Trays.** These trays are used infrequently within ExxonMobil today because they cost about 100% more, and have a higher pressure drop, than a sieve trays. They should be considered when flexibility needs exceed 3/1 and valve trays cannot be used because fouling is a problem. While even bubble caps will foul over time their large physical clearances (compared to valve trays) provide a longer run length. For applications that require low pressure drop, vacuum caps should be considered instead of standard caps.
5. **Cartridge Trays.** These trays derive their name from the fact that they are really a collection of trays, held together by rods, to form bundles or "cartridges." These cartridges are then lowered into a top-flanged vessel. For convenient installation each cartridge usually contains 10-15 trays. The contacting device is usually a sieve or valve tray. They are used in small diameter columns (i.e., < 3 ft or 900 mm) where inaccessibility prevents the use of standard trays. Most cartridge trays in use by ExxonMobil were made by Sulzer Chemtech, since Sulzer's tray has the only commercially proven peripheral sealing device.
6. **Fixed Valve Trays.** These devices can best be described as valve trays whose valve units are fixed in the fully open position. Sulzer Chemtech's Nutter Small V-Grid (**SVG**) trays on triangular pitch are considered to be an alternative to sieve trays and generally have somewhat better turndown ratio (20% higher). Larger fixed valve units such as the Nutter SVG or the NorPro Provalve may be useful for extending run lengths in some fouling services (but not where sticky material is entrained from below). Nutter Large V-Grid (**LVG**) and fixed valve trays on square pitch have lower capacity and should only be used upon consultation with a FRACTIONATION SPECIALIST.
- Mini Fixed Valve Trays:** Sulzer Mini V-Grid (**MVG**), **Figure 4**, and Koch-Glitsch **VG-0**. At pressures under 50 psia (345 kPa) a tray with mini valves has an estimated 10-15% jet flood capacity advantage when compared to a conventional (0.5 in. [13 mm] hole) sieve tray with approximately the same efficiency. The capacity gain is similar to what is expected with a small hole sieve tray in low liquid rate services. V-Grid trays have the same directional effect as the NorPro Provalve tray. Koch-Glitsch's **Bi-FRAC** should not be considered for application. Contact your FRACTIONATION SPECIALIST for more details should an application of fixed mini valve trays exist.

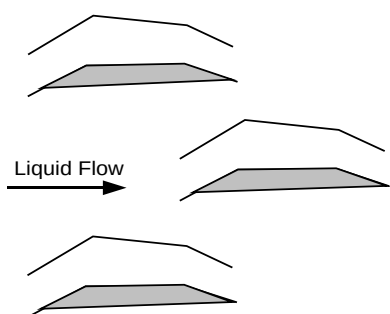


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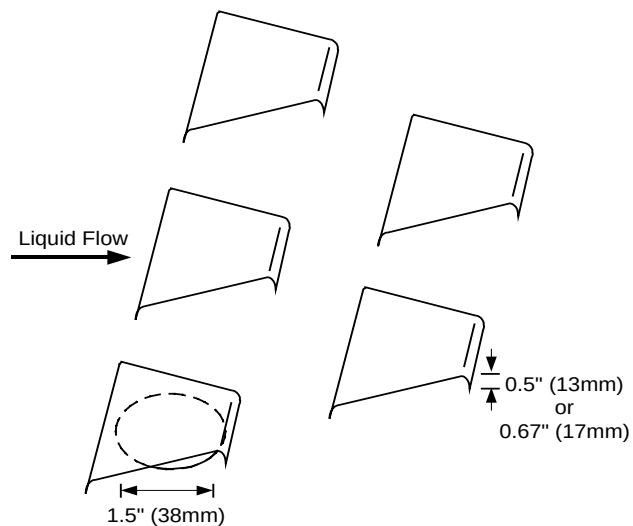
CROSS FLOW DEVICES - TYPES OF TRAYS AVAILABLE (Cont)

FIGURE 4
SOME HIGH CAPACITY TRAY DESIGNS

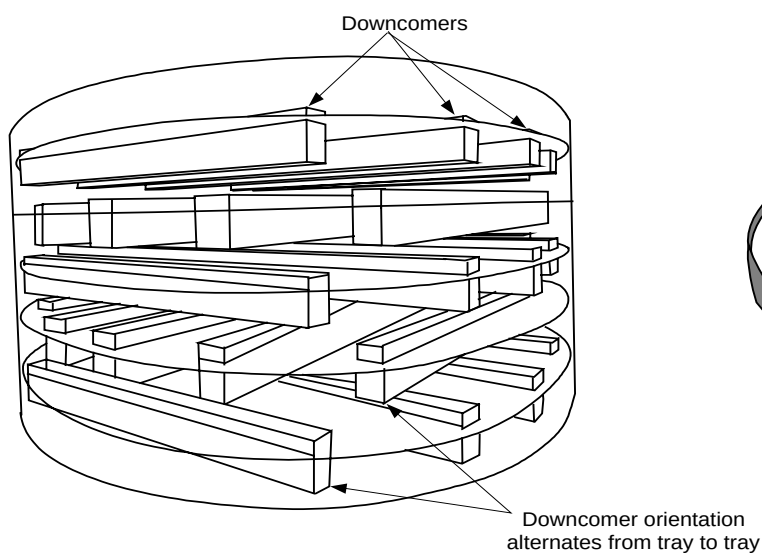
SULZER CHEMTECH'S NUTTER MVG TRAY



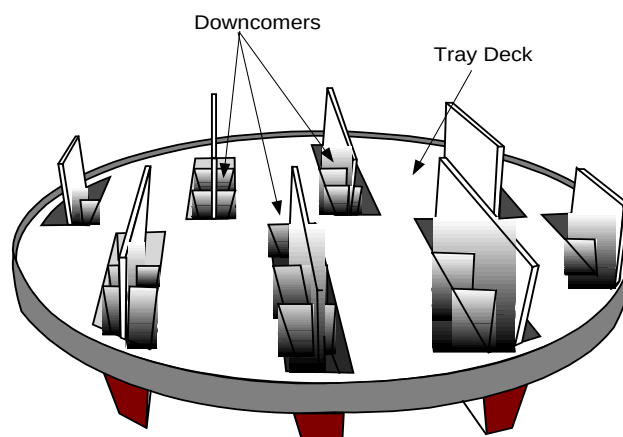
NORPRO PROVALVE DECK



UOP MULTIPLE DOWNCOMER SIEVE TRAYS



SULZER HI-FI TRAY



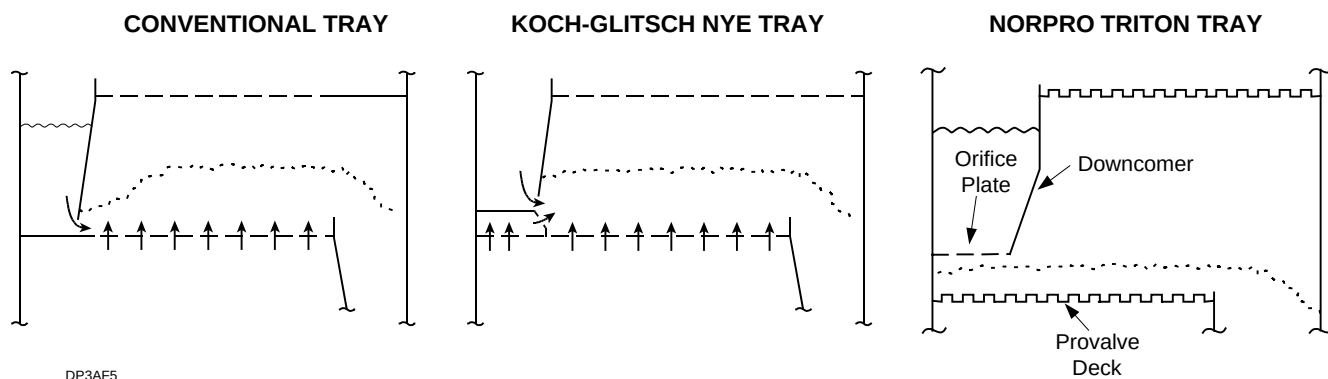
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CROSS FLOW DEVICES - TYPES OF TRAYS AVAILABLE (Cont)

7. **Enhanced Downcomer Trays.** Enhanced downcomer trays currently available include Koch-Glitsch's **Nye Trays** and **MaxFrac** trays, Saint-Gobain NorPro's **Triton** trays (see 8d below) and the Sulzer **MVGT** Tray. By utilizing the area under the downcomer for additional vapor flow, an increase in the vapor handling capacity is achievable (**Figure 5**). Nye trays and recently, to a more limited extent, Triton trays have successfully been applied in tower revamps. An estimated 10-15% additional jet flood capacity can be expected with similar efficiency when compared to a conventional sieve tray. It should be noted that the increase in capacity is approximately proportional to the ratio of the downcomer outlet area (downcomer bottom area) to the tower cross-sectional area. Contact your FRACTIONATION SPECIALIST should an application of an enhanced downcomer tray exist.

FIGURE 5
ENHANCED DOWNCOMER TRAYS



8. Other Trays.

- a. **Multiple Downcomer Trays:** UOP **MD** (Multiple Downcomer) and **ECMD** (Enhanced Capacity Multiple Downcomer) Trays, Sulzer **Hi-fi** Tray. These proprietary trays are particularly useful for fractionation services handling high liquid rates. Although they have about 20% higher capacity than a conventional sieve tray, their efficiency is less than that of sieve trays while their cost is greater. These characteristics make them unattractive for new tower designs of less than 15 ft (4570 mm) diameter. For high pressure, light ends towers greater than 15 ft (4570 mm) diameter, MD, ECMD or Hi-Fi trays should be considered in the scoping phase, with total tower cost (internals plus shell plus installation) compared to the conventional 4-pass design cost. In revamp situations, these trays can be installed at low tray spacings, and may therefore provide more theoretical stages for a given tower height. Because of the many downcomers used in these trays, tray to tray access is limited. Thus, the entire tray may have to be removed if full access to lower trays is required. This may be a significant maintenance debit for some applications. These trays are not recommended in fouling services because of the inability to fully inspect and clean the trays in a reasonable amount of time. The small hole size typically used, 3/16 in. (4.76 mm), is a further concern in fouling services. Capacity increases of 10% relative to the standard MD tray are achievable with the ECMD tray. The ECMD tray is the highest capacity tray used by ExxonMobil. The first installation of ECMD trays within ExxonMobil occurred in 1996. The Sulzer Hi-fi Tray is an alternate multiple downcomer tray with similar performance. Contact your FRACTIONATION SPECIALIST if an application of multiple downcomer trays is being considered.
- b. **Koch-Glitsch SuperFrac Tray.** Koch-Glitsch uses the brand name **SuperFrac** to describe a variety of tray technologies developed to improve the maximum vapor handling capacity of trays relative to standard sieve, valve, and bubble cap trays. The technologies incorporated into a SuperFrac tray may include any of the following: (1) small (mini-) valves, either fixed or movable depending on turndown requirements, (2) a patented downcomer design to minimize its size which maximizes the space for vapor flow, (3) an inlet weir to seal the downcomer and/or distribute liquid to the tray, (4) special aerated washers, used to fasten tray panels, that distribute vapor to relatively unaerated areas of the tray deck, (5) bubble promoters to provide rapid aeration of the liquid flowing from the inlet downcomers, (6) directional orientation of some valves to distribute liquid uniformly over the tray deck, and (7) a calming box with orifices at the bottom (also called a relief downcomer) upstream of each downcomer to unload the downcomer.

There are a few applications of SuperFrac trays within ExxonMobil. EMRE has evaluated limited commercial data on this technology, including a high pressure C3 splitter. Based upon the sparse data available to EMRE, the SuperFrac tray has features that can allow 15% to 25% increased jet flood capacity versus standard sieve, valve or bubble cap

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trays, when the system is non-fouling and non-foaming. Contact your FRACTIONATION SPECIALIST if a Koch-Glitsch SuperFrac application is being considered.

CROSS FLOW DEVICES - TYPES OF TRAYS AVAILABLE (Cont)

- c. **NorPro Provalve Tray.** This tray uses large valves that are wider on the upstream end of the valve than on the downstream end, thereby deflecting vapor and directing liquid. This directional effect promotes uniform vapor distribution throughout the bubbling area of the tray, resulting in better performance than conventional valve trays. In addition, the large size and unique shape of the fixed Provalve valves make them highly resistant to fouling. ExxonMobil has used Provalve trays in such services as debutanizers, coker fractionators, amine regenerators, and C8/C9 splitters. Contact your FRACTIONATION SPECIALIST for assistance regarding potential application of this technology.
- d. **NorPro Triton Tray.** This tray uses proprietary **Provalve** valves, with truncated downcomers to increase tray bubbling area. FRI has verified NorPro claims of significantly higher capacity (about 20% higher) compared to conventional valve trays, with comparable mass transfer efficiency. The results of FRI tests also suggest about 10% higher capacity compared to the Nutter MVG tray. Triton trays also exhibit lower pressure drop than conventional fixed valve and MVG trays. Contact your FRACTIONATION SPECIALIST for assistance regarding potential application of this technology.
- e. **Other Devices.** For trays not mentioned in this Subsection please contact your FRACTIONATION SPECIALIST for guidance.

CROSS FLOW DEVICES - HARDWARE DEFINITIONS

In order to understand how a tray functions, it is important to define various hardware and process parameters. The hardware parameters will be described first. **Figure 6A** shows a typical sieve tray tower. The particular tower in **Figure 6A** has six single-pass sieve trays, with the sieve holes on a triangular pitch. Inlets include a reflux inlet nozzle to the top tray, a reboiler return distributor below the bottom tray, and a liquid distributor to the third tray (from the top). There is a total drawoff following the second tray (from the top), a reboiler drawoff after the bottom tray, and a third liquid outlet at the bottom of the tower (not shown) for the bottom product. The arrows in the figure depict the direction of liquid flow. The hardware parameters in **Figure 6B** are common to all the cross flow trays.

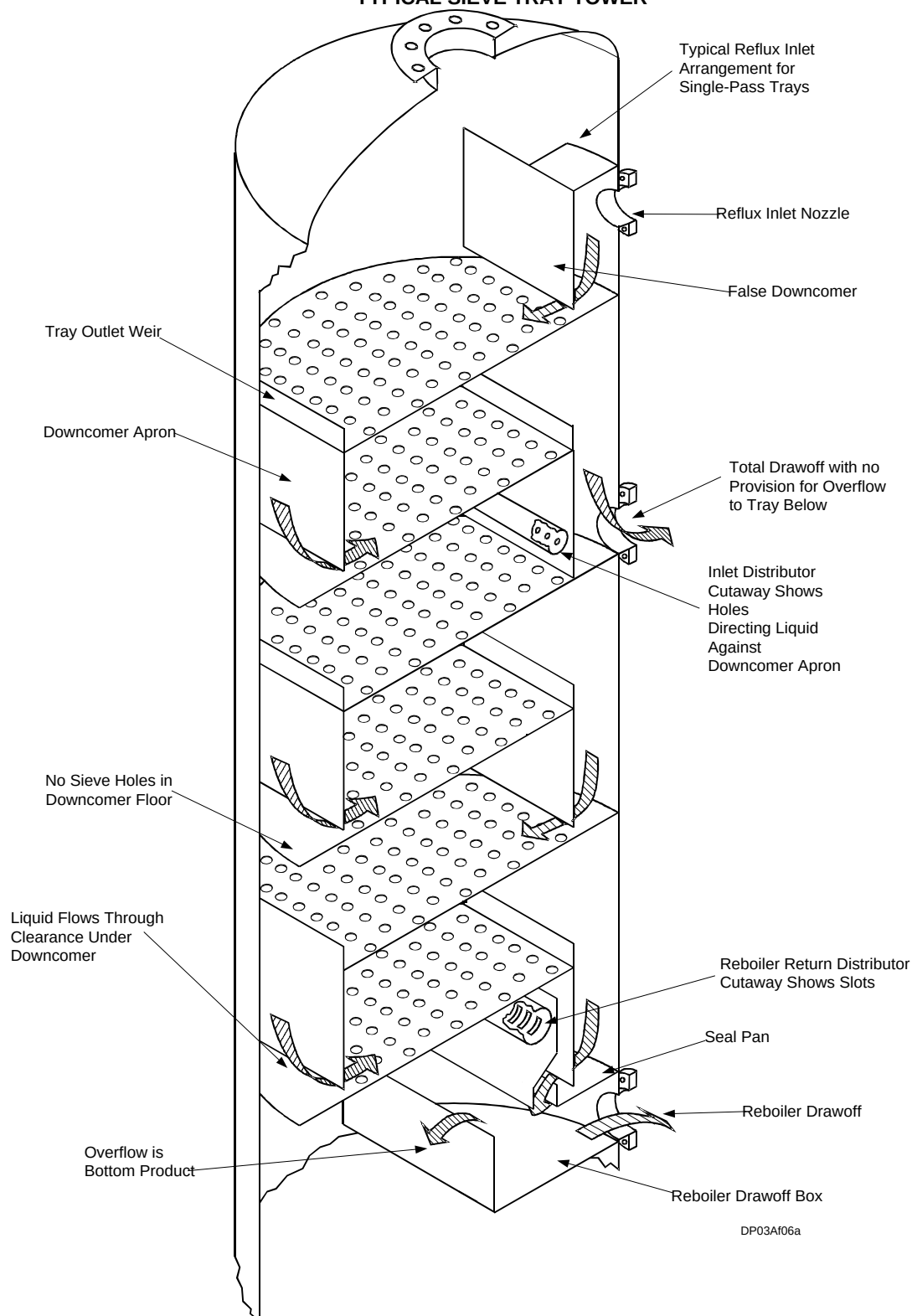


FRACTIONATING TOWERS

DEVICE SELECTION AND BASIC CONCEPTS

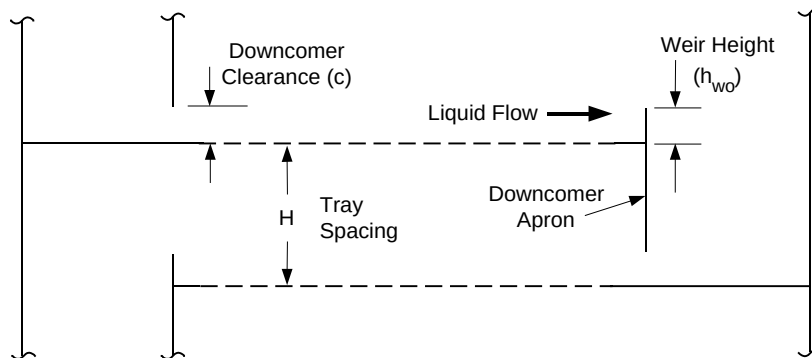
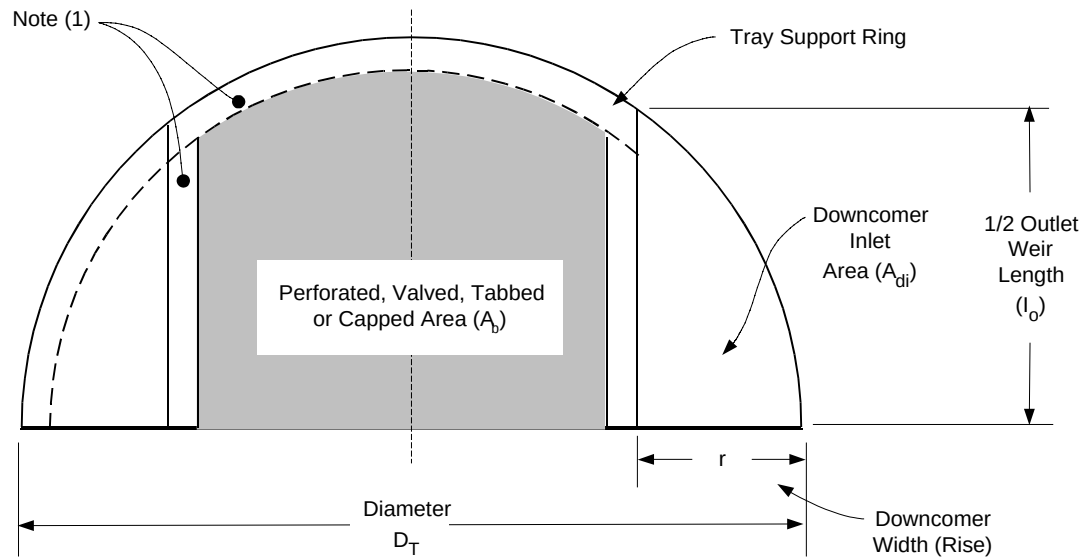
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FIGURE 6A
TYPICAL SIEVE TRAY TOWER



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FIGURE 6B
TYPICAL TRAY LAYOUT



Note:

- (1) Any portion of these areas within 3 in. (75 mm) of a hole is included in the tray's bubble area (A_b).

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As shown, a typical tray layout contains certain key items:

1. **Tower Diameter and Tray Spacing.** These are the two major parameters that set the capacity of the tower. As the distance between trays is increased (tray spacing, H), the tower capacity will increase. The most economic spacing usually falls between 18-24 in. (450-600 mm) for most services. Spacings above 36 in. (900 mm) provide little incremental capacity advantage and are therefore not usually recommended. Likewise, tray spacings as low as 12 in. (300 mm) can also be used, but this increases the tower diameter (D_T) required to handle a given set of vapor and liquid loadings. In addition, low spacings also make maintenance much more difficult. Each tray's [Section III \(B, C, D and E\)](#) contains a table of minimum acceptable tray spacings for maintenance as a function of tower diameter and service (i.e., whether it is clean or fouling).
2. **Contacting [bubble] area (A_b , shown shaded).** The bubble area is defined as the tray deck area where the liquid/vapor contacting occurs. It is calculated during the detailed design of the tray.
3. **Downcomer Area.** This is the area (A_d) that must be devoted to handling the liquid as it flows from a given tray to the tray below. A distinction is made between three different areas associated with a given downcomer geometry, because tray performance depends on each of these values. The downcomer inlet area (A_{di}) is the horizontal area available for liquid flow into the downcomer. The downcomer outlet area (A_{do}), also called the downcomer bottom area, represents the corresponding horizontal area at the bottom of the downcomer. The area under the downcomer (A_{ud}), also called the downcomer escape area, is the downcomer clearance (c) multiplied by the downcomer outlet chord length. The edge of the downcomer is usually chordal in shape and its maximum width is called the downcomer width or downcomer rise (r). The difference between the width at the top and the width at the bottom of a sloped downcomer is referred to as the "downcomer kick". [Section III-K](#) contains the necessary tables to calculate downcomer areas and other geometric parameters. Alternatively, the PEGASYS computer program's "Segment of Circles" program located within the Geometry Menu can also be used.
4. **Downcomer Clearance.** This is the vertical clearance (c) between the tray floor and the bottom edge of the downcomer apron. This clearance varies with liquid rate and is discussed in each tray's Subsection under **BASIC DESIGN CONSIDERATIONS**.
5. **Outlet Weir Height and Outlet Weir Length.** As the liquid leaves the contacting area, it flows over the outlet weir as it enters the downcomer. The height of the outlet weir (h_{wo}) is set by the designer to provide liquid holdup on the tray to promote efficient liquid/vapor contacting and to seal the downcomer upstream of the weir. The outlet weir length (l_o) is the same as the downcomer inlet chord length.

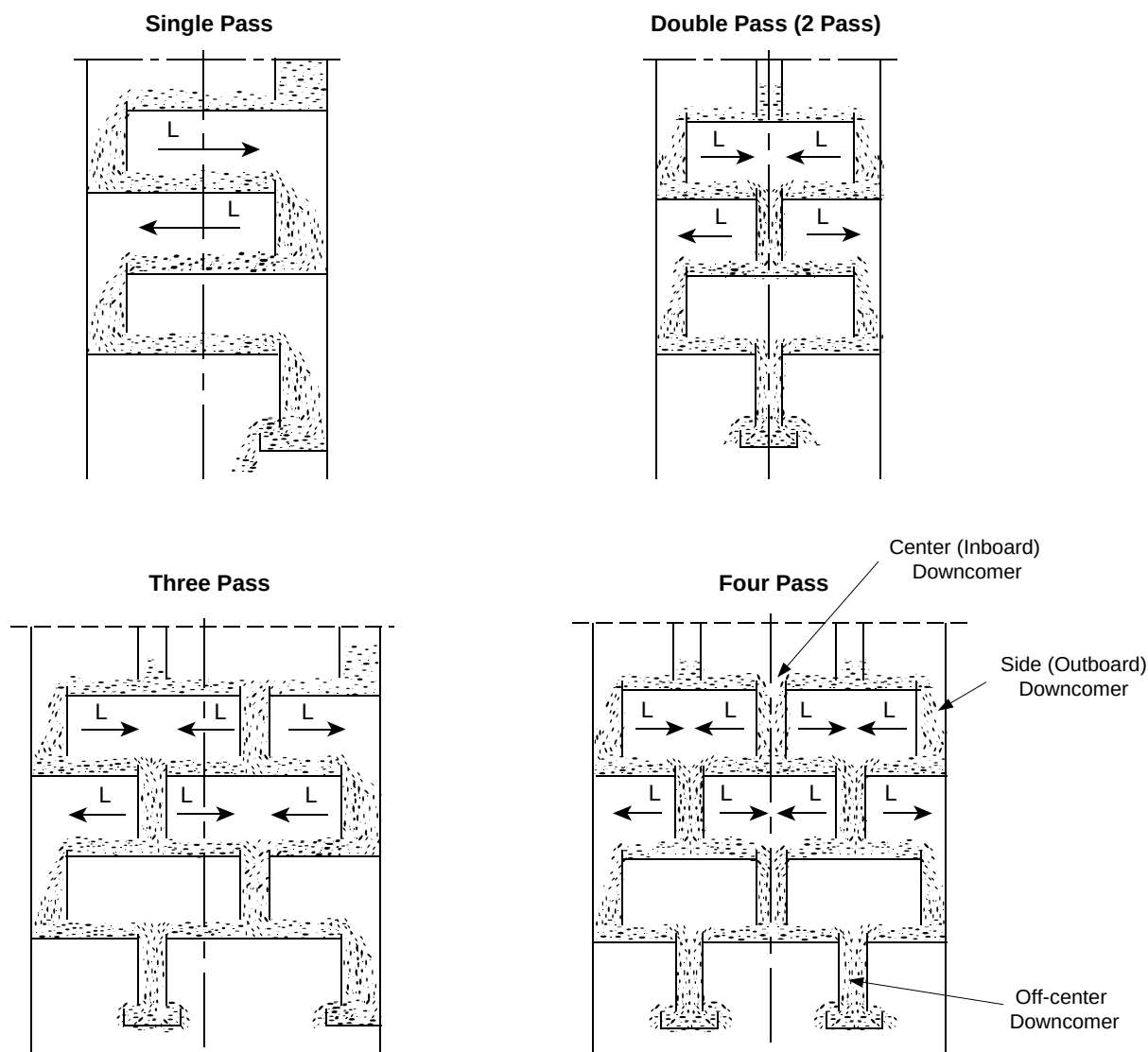
Note: The "inlet" and "outlet" terminology used for weirs and downcomers can be confusing. For weirs, "inlet" refers to the upstream weir on a given tray. For downcomers, "inlet" refers to the upstream (top) part of the downcomer. Therefore, the outlet weir is located on the downcomer inlet chord.
6. **Multi-pass Trays.** As the liquid rate on a tray increases, the capacity of the tower can usually be increased if the liquid flow is split into more than one path (see arrows labeled L on [Figure 7](#)). Such split-flow trays are called multi-pass trays. While single pass trays are the most common, double pass (2 pass) trays are frequently used. Three and four pass tray designs are also available, but their use comprises less than 5% of the total trays used in ExxonMobil towers, with four pass designs being more common than three pass. Since higher pressure towers have a higher volumetric ratio of liquid to gas, multi-pass trays with greater total downcomer area are common in these towers.



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FIGURE 7
PASS ARRANGEMENT ON MULTI-PASS TRAYS



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On multi-pass trays, the downcomer(s) nearest the tower centerline are referred to as “inboard” or “center” downcomers, while those farthest away are called “outboard” or “side” downcomers.

- Sloped and Stepped Downcomers.** For a given tower diameter, a certain amount of the available cross-sectional area is needed for liquid handling (downcomer area) with the remainder available for vapor flow (bubble area). Therefore, any steps that can be taken to reduce the area consumed by the downcomer(s) will provide additional area for vapor flow. This goal can be achieved on heavily liquid loaded trays by using stepped or sloped downcomers as shown on **Figure 8**. Typical design for a downcomer “step” is for the step to be located at 33% of the tray spacing. Stepped downcomers are preferred in small diameter towers [$D_T < 48$ in. (1220 mm)] due to easier weld-in installation. Otherwise, sloped downcomers are preferred. When a sloped downcomer is specified, often suppliers offer a “semi-sloped” design. This design has better mechanical features, since the upper vertical portion is often used as a support beam. However, the associated reduction in average free area results in a slight loss in capacity.



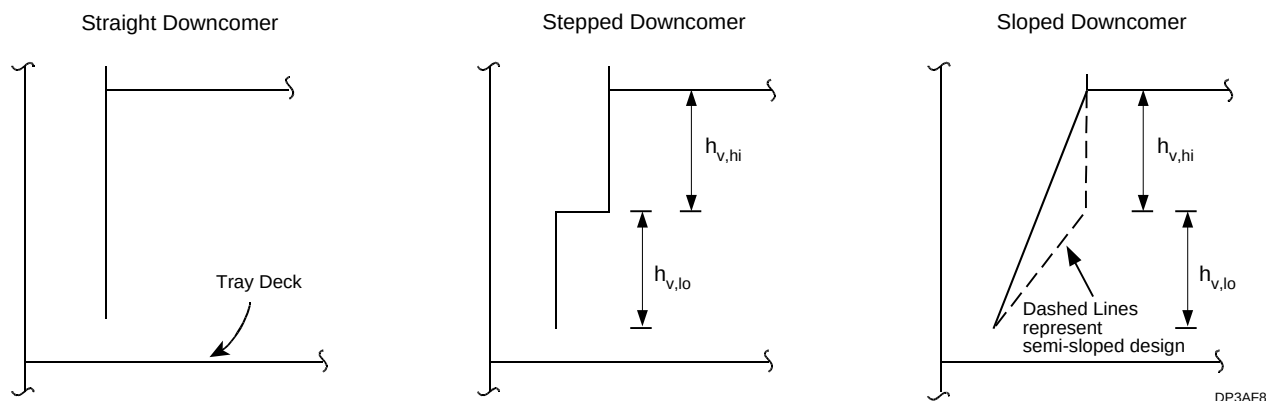
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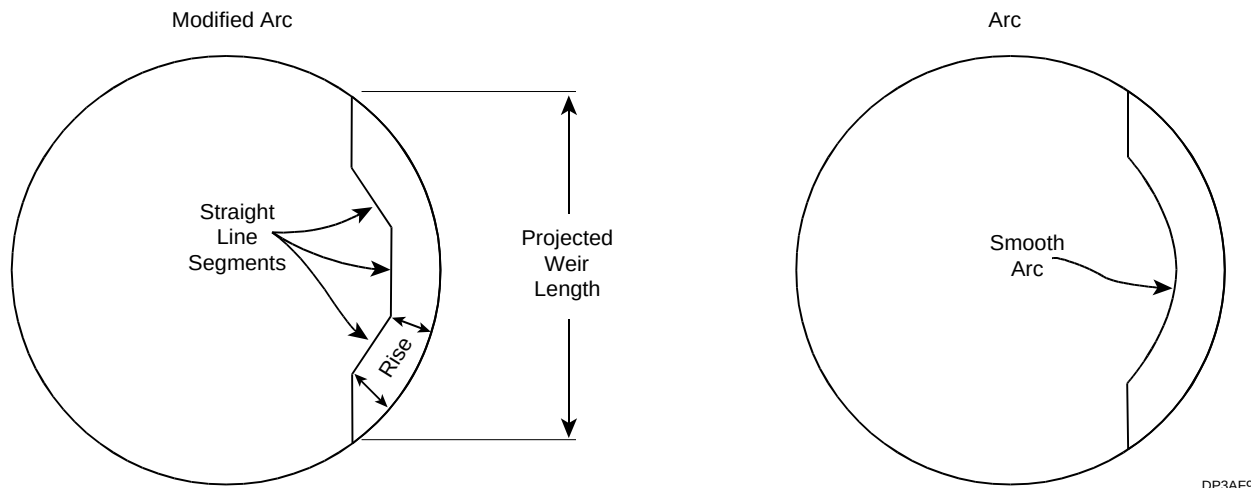
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FIGURE 8
STEPPED VS. SLOPED DOWNCOMERS



8. **Modified Arc and Envelope Downcomers.** The chord length at the bottom of a downcomer must be sufficient to provide uniform liquid flow distribution onto a tray, because uniform liquid distribution results in good tray efficiency. The appropriate Subsection in [Section III](#) provides the minimum suggested chord length for a specific type of tray. In some services where very low liquid rates must be handled, minimizing the downcomer area can result in a downcomer chord length that is smaller than that suggested in the appropriate Subsection. In these cases, a modified arc (also known as segmental, or swept back) downcomer can be specified (see [Figure 9](#)). A modified arc downcomer has a smaller area than a chordal downcomer, when the chord length of the chordal downcomer is equal to the "projected" weir length of the modified arc downcomer. The modified arc downcomer thereby enables a reduction in downcomer area without sacrificing uniform liquid flow distribution onto the tray below. Modified arc downcomers can also be used to help balance weir lengths for four-pass tray designs. Some pre-1960 towers may contain a full arc-type downcomer. This style downcomer functions in the same manner as a modified arc but can be more expensive to build; therefore, smooth arc-type downcomers are not specified in new designs. However, they can be retained if their area is sufficient for revamp conditions. [Section III-K](#) provides geometric data for chordal and modified arc downcomers.

FIGURE 9
MODIFIED ARC VS. ARC TYPE DOWNCOMERS

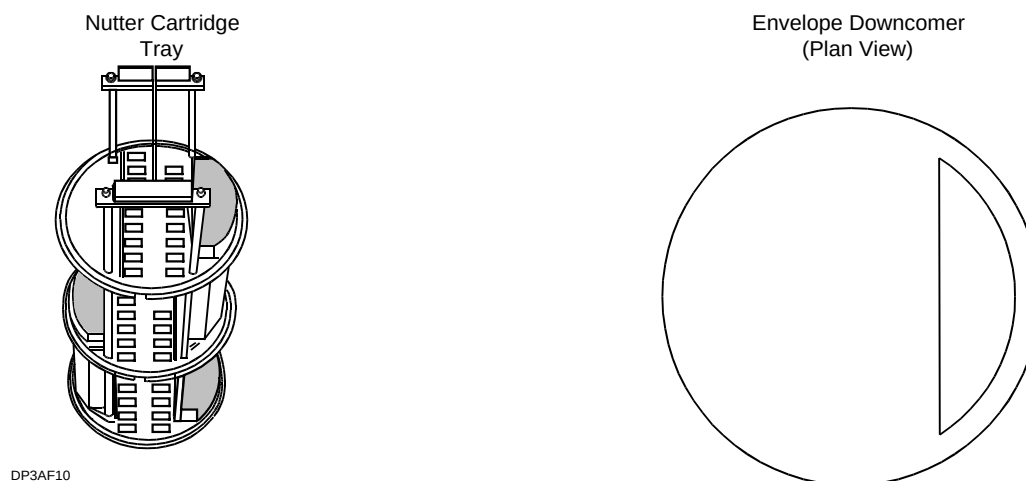


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For towers under 36 in. (900 mm) in diameter, cartridge or package trays are frequently used. These trays are installed in sets (or bundles) held together by rods, and can be lowered into a top-flanged vessel. Since the trays are removable the downcomer must be an integral part of the tray. These downcomers are called envelope type downcomers (See **Figure 10**). Standardized downcomer sizes for these trays can be found in **Section III-E, Table 4A** and **4B**. However, custom sizes can be provided if one of the standard sizes does not meet process requirements.

FIGURE 10
SULZER CARTRIDGE TRAYS AND THEIR
ENVELOPE DOWNCOMERS



9. **Downcomer Sealing Techniques.** In order to prevent some of the vapor from bypassing the contacting region by flowing upward through the liquid in the downcomer, the downcomer must be "sealed" by liquid. In most tray designs with an outlet weir, the liquid holdup (or clear liquid height) will sufficiently seal the downcomer clearance without additional hardware devices (See discussion on **Downcomer Seal** under **Liquid Handling Limitations**). When this is not possible, however, ways to provide a seal via hardware techniques are shown in **Figure 11**.

Both the recessed inlet box and the inlet weir seal use **mechanical** means to help seal the downcomer. In the case of the recessed box, the seal is obtained because the bottom of the downcomer apron and the tray below are at the same elevation. With an inlet weir, the weir height plus the liquid head over the inlet weir must be at least equal to the downcomer clearance. By using a shaped downcomer lip, the head loss under the downcomer is reduced, allowing a smaller downcomer clearance to be used. This reduced downcomer clearance can provide a **process** seal for the downcomer, although the corresponding increase in the velocity under the downcomer may cause it to exceed the specified limit (See **Downcomer Seal** and **Velocity under downcomer** in **CROSS FLOW DEVICES-PROCESS DEFINITIONS**).

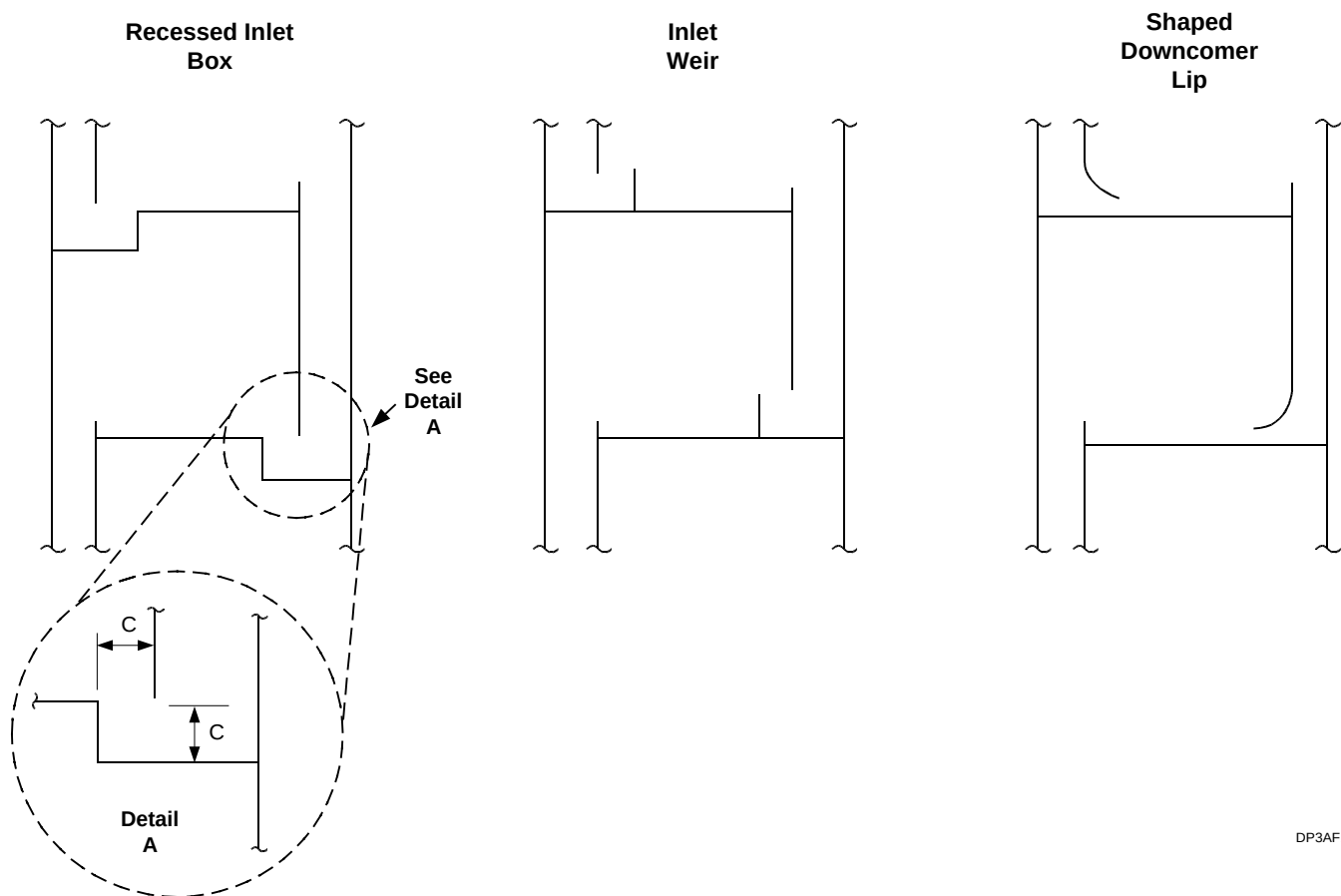
Recessed inlet boxes are susceptible to trapping solids, which may affect tray performance. If this is a problem in an existing tower, the boxes should be covered or removed and the edge of the downcomer panel will need to be modified in order to properly seal the downcomer. If the recessed inlet boxes are covered, then a side vent and bottom drain are required. Consult **GP 5-2-1** regarding drain hole specifications for recessed inlet boxes.

For shaped lip downcomers, the radius tip (shaped downcomer lip) may be in the range of 1 to 2 in. (25 or 50 mm), although 1 in. (25 mm) is typical. Remember to check the location of sieve holes, valves, or jet tabs relative to the edge of the shaped lip to avoid getting vapor into the downcomer. Do not use shaped downcomer lips on top reflux distributors (false downcomers), or with a recessed inlet box, an inlet weir, or a bubble cap tray. Most importantly, the presence of a radius tip in conjunction with a seal pan or inlet weir creates an undesirable restriction for the liquid flow. In addition, the presence of these downstream devices induces turbulence and defeats the purpose of streamlining the flow with a shaped downcomer lip.

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FIGURE 11
DOWNCOMER SEALING TECHNIQUES



10. **Contacting Area Definitions.** During the design of a given device, such terms as bubble area, free area, hole area, and waste area are used. They are explained below.

- a. **Bubble area (A_b).** This is the area between the downcomers where vapor/liquid contacting occurs. See **Figure 12**.
- b. **Hole/valve/cap/tab area (A_o).** This is the open area or hole area provided within the bubble area to permit vapor to enter, contact, and pass through the liquid on the tray. In the case of a sieve tray, it will be equal to the total area of all the holes on a given tray.

The hole area is usually expressed as a fraction or percentage of the bubble area (A_o/A_b). This ratio is determined by various correlations discussed in each tray's Subsection.