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Revision Memo

- 12/00 The highlights of this revision are:**
- Deleted reference to **IP 5-2-1** regarding seal welding in the downcomer floor area.
 - Reverted to common industry nomenclature regarding side, center and off-center downcomers. Also reverted to downcomer width instead of rise. (The older terms are still in parentheses.)
 - Added discussion on the potential problem with hydraulic hammer at reflux inlets and design considerations to avoid problems.
 - Added criteria to ensure all feed and drawoff tray assemblies do not limit tower section.
 - Added references to **Section III-G** for additional recommendations on vapor distributors in packed towers.
 - Added an alternative configuration for vapor inlets between trays (new **Figure 4B**). Showed alternative locations for distributor vent and drain holes (revised **Figure 7C**).
 - Included a discussion on designing/rating flashbox inlets and added new **Figures 5B, 5C, and 5D**.
 - Added the preferred distributor arrangement for four-pass trays (new **Figure 6B**).
 - Added that internal piping for drawoffs is not the preferred design and made same notation on **Figure 11**. Added a note to check the vendor design of seal pan weirs to avoid possible interference from horizontal stiffening flanges. Removed option of total drawoff with no downstream distributor from notes for **Figures 12, 13, 14, 15**. Showed drawoff box sloped sides as an option in **Figure 16** to minimize interference at downcomer inlets.
 - Changed discussion regarding when an extended downcomer design is permissible for tower bottoms. Also included a discussion on the various types of tower bottom configurations for thermosiphon reboiler circuits, forced circulation arrangements, kettle reboiler arrangements, and internal reboiler arrangements. Included a discussion on evaluating the impact of entrainment from the reboiler return nozzle/distributor and options to reduce/handle entrainment. Included an alternative reboiler drawoff and return configuration with a flashbox return (new **Figure 20B**). Added notes to **Figures 21 and 22**.
 - Added chimney tray design notes. Revised chimney tray lower open area from 10% to 15%. Changed reasonable range for chimney tray open area from 10 to 25% to 15 to 30%. Added comment regarding higher open area for vacuum tower chimney trays. Included the V-hat design for rectangular chimney hats as the preferred design (new **Figure 29B**).
 - Added comment regarding use of conical hat chimney trays below tangential inlet to improve vortex action and stripping tray performance.
 - Added notes for **Eq. 10** and added **Eq. 13**. Added note stating that an orifice coefficient of 0.7 for perforated plates is adequate for rough estimates only and not suitable for detailed head calculations for liquid distributors.
 - Added conceptual design of coker strainer for severe fouling services (new **Figure 17B**).



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SCOPE

This section covers the techniques for specifying the process design features of tower internals other than the basic contacting devices. Detailed mechanical design is normally handled by the fabricator. This section covers distributors, drawoffs, tray supports, nozzle arrangements for feed and products, reboiler circuitry, coke strainers and entrainment screens. See [Section III-G](#) for packed or grid tower internals that are not covered here, such as liquid distributors and spray nozzles.

REFERENCES

DESIGN PRACTICES

- [Section V](#) Drums
- [Section IX](#) Heat Exchange Equipment
- [Section XII](#) Instrumentation
- [Section XIV](#) Fluid Flow

INTERNATIONAL PRACTICE

[IP 5-2-1](#) Internals for Towers and Drums

OTHER REFERENCES

1. *Atmospheric Pipestill Guide*, EMRE Manual No. EEPE 006
2. *Fractionating Tower Troubleshooting Guide*, EMRE Manual No. TMEE 021
3. *Fuels Vacuum Pipestill Guide*, EMRE Manual No. EETD 076
4. *Mobil Technology Company Process Design Practices*, Practices No. II, Volume No. 2, Trayed Tower Internals
5. Sideropoulos, T., *Tower Reboiler Return Arrangements - Test Program Results and Tentative Recommendations for Design Practices Changes*, 99CET 018, January 28, 1999

BACKGROUND

For trouble-free startup and normal operation of fractionating towers, it is imperative that all auxiliary equipment (i.e., drawoffs, return distributors, entrainment screens, etc.) be properly designed. The design techniques presented herein have been developed over a number of years and will generally assure economical, trouble-free operation.

TRAY SUPPORTS

The method by which trays are supported is set by the fabricator during the detailed design. The supports must meet or exceed the minimum standards of [IP 5-2-1](#). The number, size, and thickness of the support members depend on several factors, including tower diameter, the load to be supported, the need for accessibility for maintenance, and the corrosion allowance required.

Typically, in towers with diameters less than about 10 ft (3000 mm), the entire load of the tray is transmitted to the shell via the tray support ring which is 0.25 - 0.50 in. (6 - 13 mm) thick. In towers greater than 10 ft (3000 mm), the load is carried by one or more trusses attached to the shell as well as by the support ring. These items are discussed in more detail below.

SUPPORT RINGS

The required width of support rings ([Figure 1](#)) is generally between 2 and 3 in. (50 - 75 mm) and increases with increasing tower diameter. The tray panels and the minor trusses are attached to the support ring by bolts or clips.

For maintaining tray efficiency at low liquid loadings in critical services, consider continuously seal welding the downcomer floor to the support ring to prevent leakage. Also consider seal welding whenever the downcomer floor panels are oriented parallel to the direction of liquid flow (perpendicular to the edge of the downcomer) and the seams extend under the downcomer.

TRUSSES

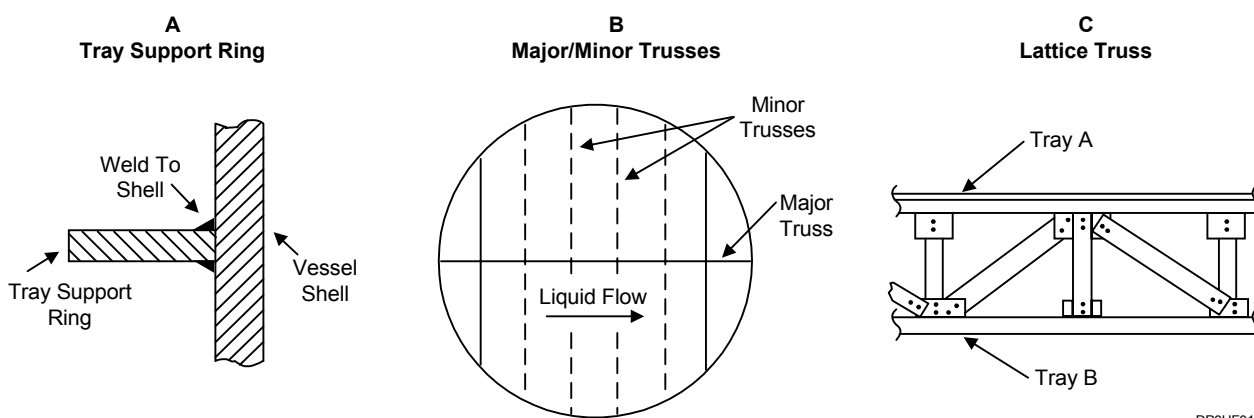
The minor trusses on trays are frequently formed as an integral part of the tray panel (i.e., integral truss). This reduces overall cost and permits faster installation. For tower diameters greater than about 10 ft (3000 mm) major trusses are usually needed in addition to minor trusses and support rings (see [Figure 1B](#) and [Table 1](#)). For tower diameters up to about 20 ft (6000 mm), these trusses usually consist of I-beams or channels. Where the tower diameter is greater than about 20 ft (6000 mm), built-up "lattice" type trusses are normally used and two trays are usually supported from each set of trusses ([Figure 1C](#)). Enough open area is built into "lattice" trusses to insure good lateral vapor distribution and to provide access to tray sections on both sides of the truss.

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TRAY SUPPORTS (Cont)

To prevent poor distribution of liquid and vapor on a tray, the major trusses must be parallel to the direction of liquid flow, unless they are part of the center (inboard) or off-center downcomers on multipass trays. Support beams exceeding 20% of the tray spacing in depth should not be placed perpendicular to the liquid flow under side (outboard) downcomers. Support beams should not be placed under drawoff boxes perpendicular to liquid flow as they may restrict the flow of liquid into the downcomer of the tray below and thus limit the capacity of that tray.

FIGURE 1
TRAY SUPPORTS



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TABLE 1
MAJOR TRUSS INFORMATION

TOWER DIAMETER				Number	APPROXIMATE HEIGHT	
Feet		Millimeters			Inches	Millimeters
≤ 10		≤ 3000		0	0	0
> 10	≤ 12.5	> 3000	≤ 3750	1	10	250
> 12.5	≤ 14.5	> 3750	≤ 4350	1	12	300
> 14.5	≤ 18.5	> 4350	≤ 5550	1	14	350
> 18.5	≤ 20	> 5550	≤ 6000	1	16	400
> 20	—	> 6000		2 or more	Lattice	Lattice

INLETS

Proper introduction of a vapor, liquid or vapor-liquid stream onto a tray is essential for reaching the hydraulic capacity potential of the internals. This section contains guidelines for selection and design of a) liquid inlets to top tray, b) liquid inlets between trays, c) vapor inlets, including kettle reboiler returns, and d) vapor-liquid inlets, excluding reboiler returns. It also includes guidelines for the design of perforated pipe distributors. Vapor-liquid reboiler returns are discussed under **REBOILER DRAWOFFS AND RETURNS** and tangential inlets are discussed under **FLASH ZONES AND TANGENTIAL (ANNULAR RING) INLETS**.

LIQUID INLETS TO TOP TRAY

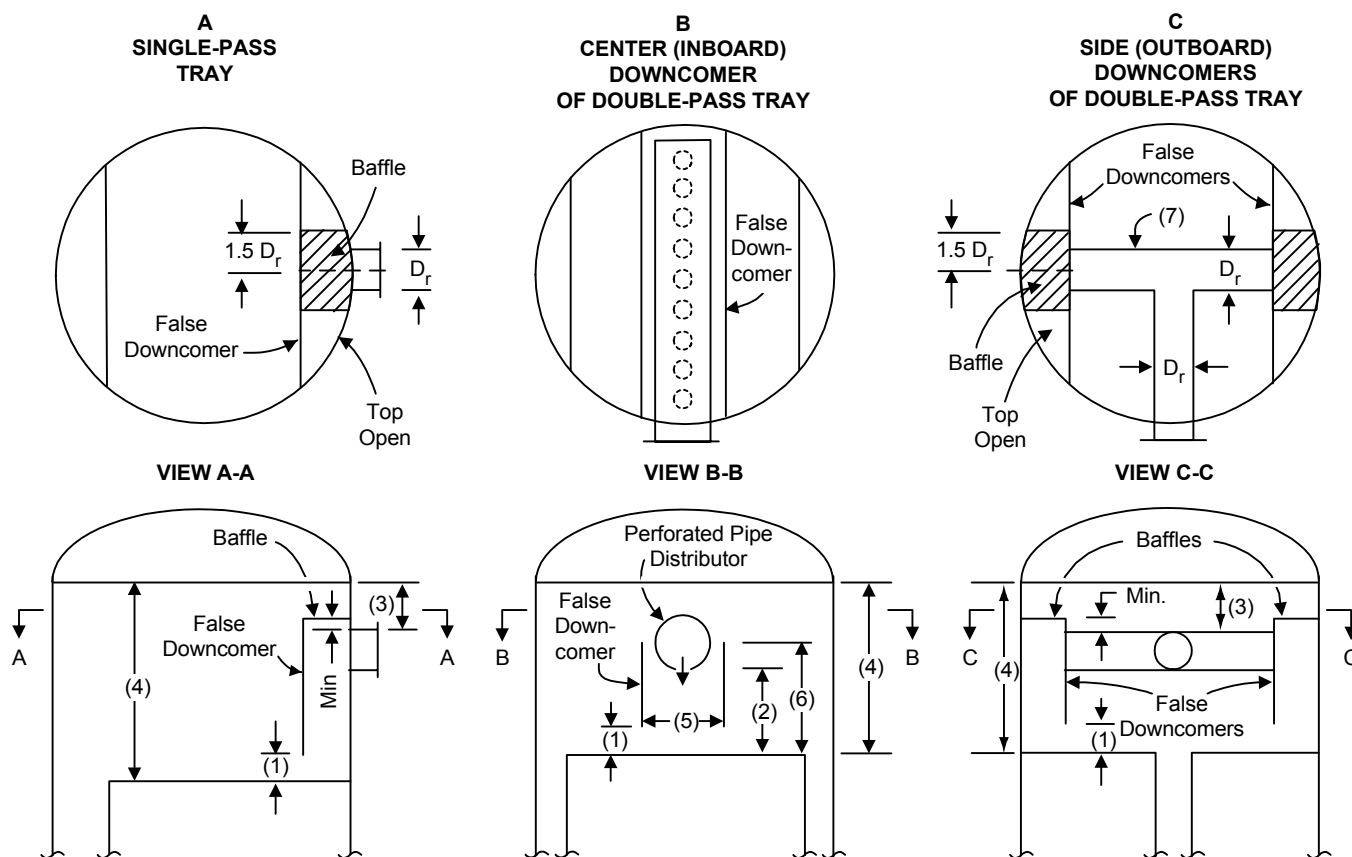
For single pass trays, the inlet is normally a flush, radial nozzle, installed behind a false downcomer apron, with a baffle placed above it to prevent liquid from splashing over the top of the downcomer apron and being entrained out the top of the tower; **Figure 2A**. The nozzle is usually line size. For two pass trays, use a perforated pipe distributor (see **DESIGN OF PERFORATED PIPE DISTRIBUTORS**) or a tee-shaped inlet as shown in **Figures 2B** and **2C**, respectively. These three inlets are intended only for all-liquid streams. If a mixed phase is present, refer to **VAPOR-LIQUID INLETS**.

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INLETS (Cont)

Reflux inlets must be carefully designed for configurations in which the tower vapor can flow into the reflux line at low reflux rates and the vapor can suddenly collapse by mixing with the colder reflux stream, resulting in hydraulic hammer and vibration. Long horizontal piping runs at the reflux inlet nozzle elevation should be avoided. A FRACTIONATION SPECIALIST should be consulted when evaluating options for sealing a reflux inlet nozzle or distributor with a sub-cooled reflux stream to avoid hydraulic hammer. Although seldom used in trayed towers, reflux distributors with downtubes should be avoided. This is because of potential problems with liquid maldistribution caused by siphoning effects. Please consult with a FRACTIONATION SPECIALIST if you are rating a tower with this configuration.

FIGURE 2
LIQUID INLETS TO TOP TRAY



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Notes for Figure 2:

1. Clearance under a false downcomer(s) should be 1 in. (25 mm) or sized for a head loss of 2 in. (50 mm) of hot liquid, whichever is greater. Use of a shaped lip is not required since there is no downcomer seal or filling issue.
2. Distance between the bottom of the perforated pipe distributor and the tray below should be about 9 in. (225 mm).
3. Minimum but not less than 4 in. (100 mm).
4. Normal tray spacing or if a manway is present, the greater of (a) normal tray spacing (if vessel head is flat plate use normal tray spacing + $D_t/4$) or (b) $1.5 \times$ (manway diameter) plus 4 in. (100 mm). If there is a demister, this is the distance to the demister. For towers with side drawoffs, see VAPOR DRAWOFFS.
5. False center (inboard) downcomer outlet width at the bottom should be equal to the outlet width of the normal downcomers. Minimum distance from the downcomer apron to the perforated pipe distributor is 1 in. (25 mm). Straight false downcomers are preferred but if the distributor diameter is large, the downcomer width at the top can be increased to satisfy the minimum distance to the distributor.
6. The false center (inboard) downcomer top should be approximately at the elevation of the perforated pipe distributor center.
7. The top tray capacity should be calculated using the distributor area as waste area.

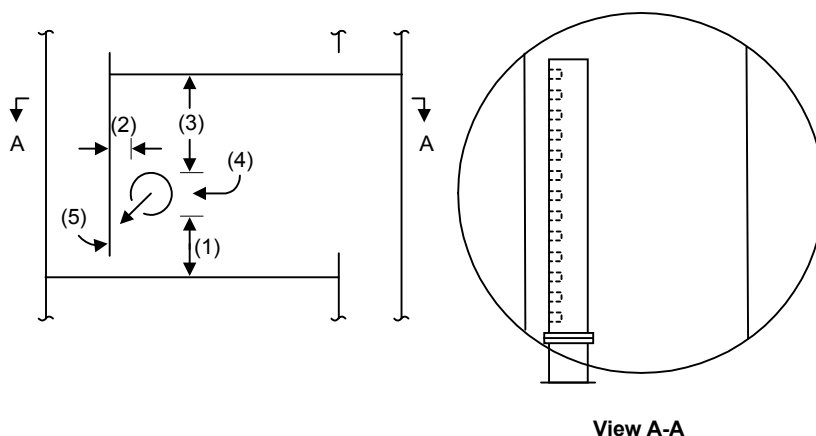
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INLETS (Cont)

LIQUID INLETS BETWEEN TRAYS

A perforated pipe distributor is typically used for liquid inlets between trays (**Figure 3**). For distributor design information see DESIGN OF PERFORATED PIPE DISTRIBUTORS in this section.

FIGURE 3
LIQUID INLETS BETWEEN TRAYS



Notes:

- (1) The distance between the bottom of the distributor and the tray below should be about 9 in. (225 mm). Revamps or designs with large downcomer clearances should ensure that the distributor liquid impinges a minimum of 2 in. (50 mm) above the clearance. An impingement point can be determined by drawing a straight line from the center of the distributor through the center of the distributor holes or slots.
- (2) The distance between the distributor and the downcomer or insulating baffle (**Figure 8**) should be about 3 in. (75 mm).
- (3) The minimum distance between the top of the distributor and the tray above is 8 in. (200 mm).
- (4) For flooding calculations, treat the projected area of the distributor and insulating baffle (if used) as waste area.

The distributor holes or slots should discharge downward at a 45° angle for vertical downcomers and at a lesser angle from the horizontal for sloped downcomers. The distributor holes should be designed according to the method outlined under **Design of Perforated Pipe Distributors** in this subsection. Stepped downcomers should be avoided at tower inlet locations. For trays with modified arc downcomers and for distributors on trays without downcomers from above (e.g., one side of a one-to-two pass transition tray) see **Design of Perforated Pipe Distributors** and **Figure 7(B)**.

- (5) To prevent vaporization in the downcomer of the tray above the feed, an insulating baffle should be provided when the feed temperature exceeds the temperature of the downcomer liquid (**Figure 8**). The impingement surfaces for feed inlets should be smooth (**Figure 9**).

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VAPOR INLETS (INCLUDING KETTLE REBOILER RETURNS)

Vapor inlets are typically attached to the bottom of towers with kettle reboiler circuits. Vapor inlets can be introduced into the vessel with a flush nozzle or with a distributor. This will depend on the tray hardware being specified, inlet velocities and pressure drop limitations.

Good quality inlet vapor distribution to a trayed column is not as critical as in a packed tower. Vapor will tend to distribute adequately across the bubble area of the first tray. This is due to the relatively high pressure drop across a tray [about 5 in. (125 mm) of water] compared to a packed tower [about 0.1 to 0.2 in. (2.5 to 5 mm) of water per ft (0.3 m) of packing]. In a packed tower, the vapor flow does not have sufficient resistance to obtain a constant profile across the tower. Therefore, good vapor distribution to a packed tower is critical. See **Section III-G, VAPOR DISTRIBUTORS** for guidance and design requirements.

Vapor maldistribution at high velocities can be a problem. To limit disturbances caused by the incoming vapor, an inlet distributor is typically used to dissipate the kinetic energy. The vapor inlet nozzle should be sized based on the pressure drop criteria in **Sections XIV-B** and **XIV-C**. When a chimney tray is located above a vapor inlet, such as in a kettle reboiler circuit, a flush nozzle is sufficient. However, if the velocity exceeds 100 ft/s (30 m/s), a distributor should be used to break up the inlet velocity head.

Flush nozzle vs. distributor. A flush nozzle can be used below the bottom tray or between trays when the vapor added is less than 6% of the tray's vapor load and good distribution is not critical. For all other cases, a distributor should be used; see the various categories below and DESIGN OF PERFORATED PIPE DISTRIBUTORS.

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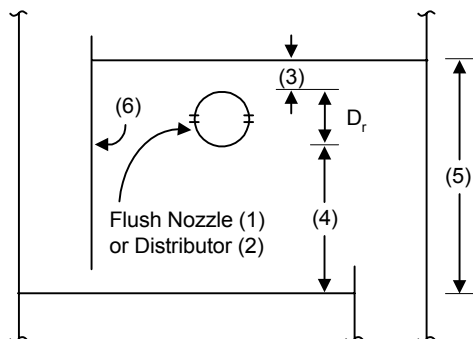
Distributors Below the Bottom Tray should avoid interference between the vapor and the bottoms liquid or the liquid leaving the seal pan(s). They should direct the vapor downward and toward the vessel wall, employing one or two rows of holes or slots, each at about 45° angle from the horizontal. The distance between the top of the distributor (or flush nozzle) and the tray above should be minimum, but not less than 8 in. (200 mm). The minimum distance between the bottom of the perforated pipe distributor and the high (or the emergency) liquid level is the greater of 24 in. (600 mm) or one pipe diameter. See DESIGN OF PERFORATED PIPE DISTRIBUTORS.

Distributors Below the Bottom Packed Bed should be as symmetrical as possible to minimize vapor maldistribution. They should have 2 or more legs (i.e., be "T" or "H" shaped) and should direct the vapor downward, employing two rows of holes or slots on each leg, each discharging at about 45° angle from the horizontal. There should be 12 in. (300 mm) between the top of the distributor and the packed bed above. The minimum distance between the bottom of the perforated pipe distributor and the high (or the emergency) liquid level is the greater of 24 in. (600 mm) or one pipe diameter. See DESIGN OF PERFORATED PIPE DISTRIBUTORS and [Section III-G](#), VAPOR DISTRIBUTORS for additional requirements.

Distributors Between Packed Beds or Distributors Between a Tray and a Packed Bed. For these less common cases see [Section III-G](#) and consult your FRACTIONATION SPECIALIST.

Distributors or Flush Nozzles Between Trays. See **Figure 4A** and **Figure 4B**.

FIGURE 4A
VAPOR INLETS BETWEEN TRAYS



Notes:

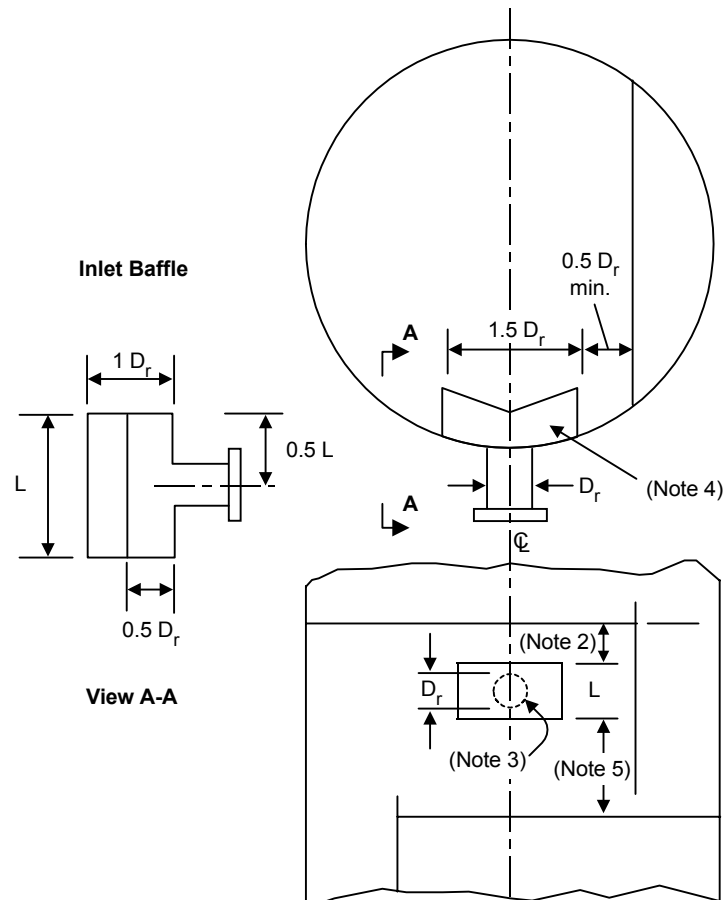
- (1) Flush nozzles should be used only if the vapor added is less than 6% of the tray's vapor load and good distribution is not critical. They should be radial, line-size, and discharge across the tray perpendicular to the liquid flow. **Figure 4B** shows an alternative configuration with an inlet baffle.
- (2) Perforated pipe distributors between trays should have two rows of holes discharging horizontally in opposite directions. They should be perpendicular to the liquid flow and centered under the bubble area of the tray above. See **Design of Perforated Pipe Distributors** in this subsection.
- (3) The distance between the top of the distributor or flush nozzle and the tray above should be minimum, but not less than 8 in. (200 mm).
- (4) Provide at least 2/3 of the normal tray spacing (the higher of the tray below or above) between the bottom of the distributor or flush nozzle and the tray below.
- (5) The feed tray should be designed such that it is not the limiting tray in a section. The tray spacing should be the higher of:
 - (a) the spacing of the tray below or above, (b) the sum of the dimensions (3), (4) and D_r or (c) the tray spacing that satisfies the tray hydraulic calculations described below.
 Two sets of calculations should be made for the feed tray:
 - (A) For all criteria other than jet flood and ultimate capacity: Follow the standard calculation procedure (it uses the vapor entering the tray from below and the total liquid leaving the feed tray).
 - (B) For jet flood and the ultimate capacity: Repeat calculation for item (A) using a waste area that includes the projected areas of the feed distributor and the insulating baffle (if present); also, the vapor rate and density should be those of the total vapor entering the tray above.
- (6) To prevent vaporization in the downcomer of the tray above the feed, an insulating baffle should be provided when the feed is directed against the downcomer and its temperature exceeds the temperature of the downcomer liquid (**Figure 8**).

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FIGURE 4B
VAPOR INLETS BETWEEN TRAYS
ALTERNATIVE CONFIGURATION WITH NOZZLE INLET Baffle ⁽⁶⁾

**Notes:**

- (1) For existing nozzles, D_r is the nozzle diameter. For new nozzles, D_r and L are sized to meet a max F-factor of 20 (24), where $F\text{-factor} = V_n \sqrt{\rho_v}$.
- (2) Minimum spacing is measured from the top of the nozzle to the tray above. This spacing applies from the top of the baffle to the tray above. It is 6 in. (150 mm) for tower diameters < 10 ft. (3 m) and 9 in. (225 mm) for larger towers.
- (3) Inlet nozzle must be parallel with downcomer panel and located on the vessel centerline.
- (4) For existing nozzles, baffle is required when F-factor > 20 (24). L is sized to limit discharge F-factor to < 20 (24) with a minimum of $1.5 D_r$. The baffle is closed on the top and the bottom and open on the sides for vapor flow.
- (5) Minimum spacing is from the bottom of the nozzle to the tray below. This spacing applies from the bottom of the baffle to the tray below. This spacing is $3/4$ of the tray spacing or 18 in. (450 mm) minimum.
- (6) Design Criteria from Reference 4.

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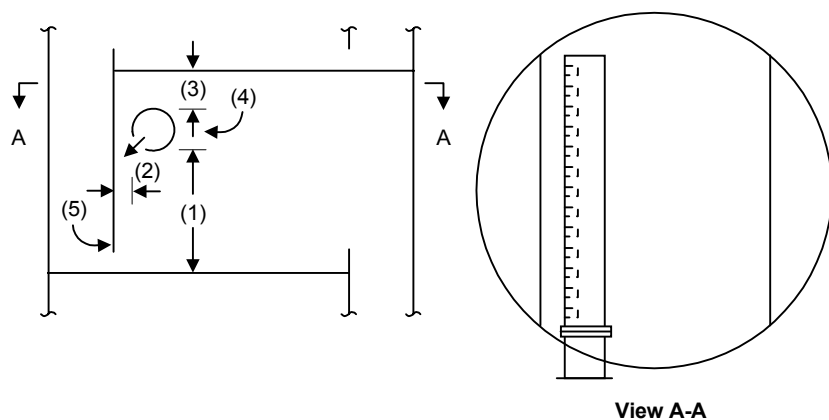
VAPOR-LIQUID INLETS (EXCLUDING REBOILER RETURNS)

Inlet Arrangement Options. Perforated pipe distributors are used where pressure drop is not critical and some entrainment is acceptable. They require the least tower height and should be used even when the amount of vaporization is small. For feeds below the bottom tray use the recommendations for reboiler returns. Annular rings with tangential inlet nozzles are used where entrainment must be minimized, such as in Pipestill flash zones (see **FLASH ZONES AND TANGENTIAL INLETS**). Chimney trays with perforated pipe distributors should be used above all packed beds (see **CHIMNEY TRAYS**). Chimney trays should also be considered for trayed towers where vapor/liquid disengaging may be poor, where foaming may occur (i.e., flashing into Catacarb regenerators, multi-feed demethanizers), where the feed vapor exceeds 50% of the total vapor, and for complex feed arrangements, such as, tower diameter (swages) transitions and tray-pass transitions.

Tangential Inlets (Annular Ring). See **FLASH ZONES AND TANGENTIAL INLETS**.

Distributors Between Trays of New Towers. See Figure 5A.

FIGURE 5A
VAPOR-LIQUID FEED DISTRIBUTOR BETWEEN TRAYS OF NEW TOWERS

**Notes:**

- (1) The distance between the bottom of the distributor and the tray below should be at least the normal tray spacing (the higher of the tray above or below). For evaluating existing towers see the text.
- (2) The distance between the distributor and the downcomer or insulating baffle should be about 3 in. (75 mm).
- (3) The minimum distance between the top of the distributor and the tray above is 8 in. (200 mm).
- (4) The distributor holes or slots should discharge downward at a 45° angle for vertical downcomers and at a lesser angle from the horizontal for sloped downcomers. The distributor holes should be designed according to the method outlined under **Design of Perforated Distributors** in this subsection. To ensure equal vapor/liquid distribution between the two

passes of a two-pass tray, the feed piping arrangement should be symmetrical. For trays with modified arc downcomers and for distributors on trays without downcomers from above (e.g., one side of a one-to-two pass transition tray) see **Design of Perforated Pipe Distributors** and Figure 7(B).

- (5) To prevent vaporization in the downcomer of the tray above the feed, an insulating baffle should be provided when the feed temperature exceeds the temperature of the downcomer liquid (Figure 8). Downcomer apron panels at feed inlet locations should provide a smooth surface for vapor/liquid impingement (Figure 9).

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♦ **Rating and Modifying Existing Vapor-Liquid Distributors Between Trays.** The inlet arrangement should be evaluated by a FRACTIONATION SPECIALIST if any of the following criteria are not met:

1. The distance between the bottom of the distributor and the tray below should be at least 2/3 of the normal tray spacing (the higher of the tray above or below).
2. The feed impingement point on the downcomer should be a minimum of 12 in. (300 mm) above the tray deck. An impingement point should be determined by drawing a straight line from the center of the distributor through the center of the distributor holes or slots.
3. Criteria of Notes (2), (3), (4), or (5) in Figure 5A are not satisfied.

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INLETS (Cont)

- The adjusted jet flood and ultimate capacity should not cause the feed tray to be the limiting tray in the section. Increase the tray spacing as required to insure this. In a revamp situation, one or 2 trays may need to be removed. Another possible solution is to segregate the feed vapor from the feed tray rating by means of a flashbox. Please contact a FRACTIONATION SPECIALIST for assistance with this type of design. To calculate the adjusted jet flood and ultimate capacity: a) use a waste area that includes the projected areas of the feed distributor and any insulating baffle, b) use the rate of the liquid leaving the trays, c) use the vapor rate and density to the tray above (except in the unusual case where the vapor load, V_L , to the feed tray is greater).

DESIGN OF PERFORATED PIPE DISTRIBUTORS

Is a Perforated Pipe Distributor Required? See the applicable **Inlets** or **Reboiler Returns** section.

Type. Four common types of distributors are shown in **Figure 6A**. The "Straight" distributor is typically used for inlets between trays. It is shown in **Figure 6A** discharging against a downcomer. A single "straight" distributors should be used only for trayed towers under 10 ft (3000 mm) diameter and packed towers up to 4 ft (1200 mm) diameter. "T", "U", "H" and other multiple leg distributors are used for large diameter towers or when good distribution is critical. The pipe distributor arrangement for four-pass trays are shown in **Figure 6B**. More options for the orientation of the feed nozzle are available if the feed nozzle and the distributor are placed at different elevations (**Figure 7A**).

Location of the Distributor and Tray Spacing Requirements. See the applicable **INLETS** section.

Distributors Directed Against Downcomers. The downcomer surface must be smooth (**Figure 9**). An insulating baffle may be required (**Figure 8**). Distributors against modified arc downcomers should conform to the shape of the downcomer (**Figure 7B**).

Distributors on Trays Without Downcomers. In cases where there are not any downcomers, for example, on one side of one-to-two-pass tray transitions, the feed can be directed against a false downcomer. Alternatively, a segmented distributor, similar to the one illustrated in **Figure 7B**, can direct the feed against the vessel wall. The latter option results in higher tray free area and lower % of jet flood.

Holes vs. Slots. Round holes tend to give a more uniform distribution than slots, and are preferred. However, slots are often specified because they give a larger total discharge area than holes of the same width.

Hole or Slot Area. The total hole or slot area should give a pressure drop of at least 0.25 psi (1.7 kPa) but not more than 0.5 psi (3.4 kPa) at design rates. The pressure drop calculation should be based on the use of a discharge coefficient of 0.6 (see **FLUID FLOW EQUATIONS, Eq. 5 to Eq. 8**). Depending on the conditions and flow rates, this procedure for determining the hole or slot area may result in non-uniform distribution. See also **Distribution Quality** below.

Hole or Slot Size and Direction. Use round holes or narrow rectangular slots with a minimum diameter or width of 0.5 in. (13 mm). Larger hole diameters and slot widths should be used for fouling services. For the required hole or slot direction see the appropriate **INLETS** or **REBOILER RETURNS** section. For 2 phase feeds between trays, the opening angle "a" (**Figure 7C**) should not exceed 60°. A wear plate may be required when the feed impinges against the vessel wall.

Hole or Slot Layout. Since a "straight" distributor is usually flanged inside the tower close to the vessel wall, it cannot be perforated along its entire length. Therefore, for design purposes, assume that 10% of the distributor's length or 1 ft (300 mm) (whichever is less) is not available for perforating. For mechanical strength, the minimum permissible distance between holes or slots is equal to the thickness of the pipe. Provide a 0.5 in. (13 mm) drain hole at the downstream end of each distributor if the process fluid does not discharge vertically downward.

Distributor Diameter. Accepted practice is to make the nozzle and distributor line-size. However, there are exceptions, e.g. where flow is split, or where swaging is required to maintain velocity at the far end of distributor in slurry services.

Distribution Quality. The criteria presented here provide acceptable distribution for practically all cases. Higher pressure drop through the holes improves distribution, however, pressure drop should not exceed 0.5 psi (3.4 kPa) as it may cause premature flooding. If the quality of distribution is critical, contact a FRACTIONATION SPECIALIST.



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► DESIGN / RATING OF FLASHBOX INLETS

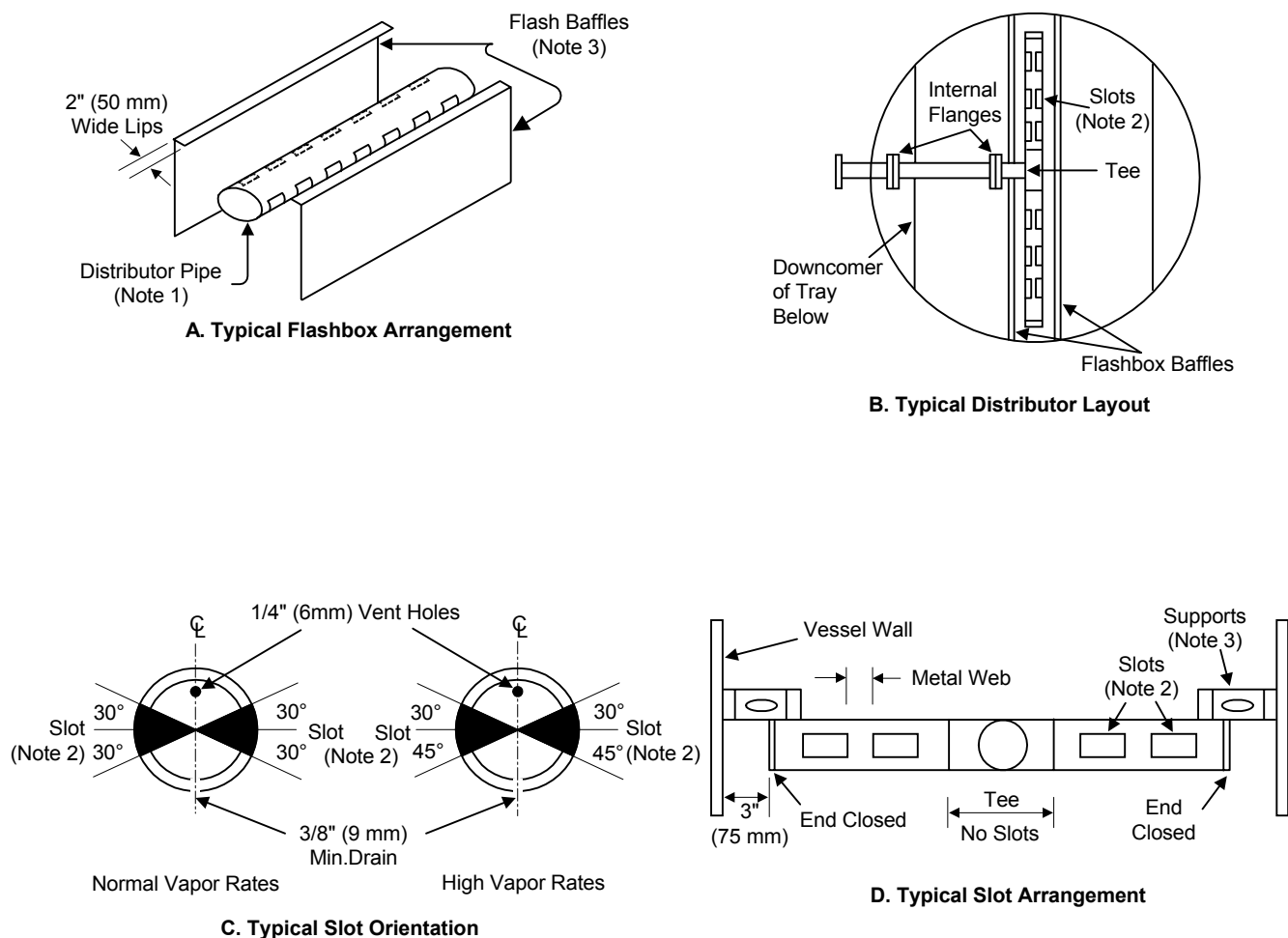
Flashbox inlets have been used in heritage Mobil fractionators for two-phase feeds. Typical flashbox details for a center inlet arrangement are shown in **Figure 5B**. Similar details for a typical side flashbox arrangement are shown in **Figure 5C**. For multi-pass tray arrangements, the details for typical center and off-center flashbox arrangements are shown in **Figure 5D**. It is important to note that flashbox arrangements typically require more tower height than heritage Exxon perforated pipe distributor designs. Flashboxes should be considered an alternate design option for high vapor rate flashing feeds or reflux streams at the top of towers and for reboiler returns. Important considerations for designing and rating flashbox internals are listed below:

- Flashbox arrangements are typically used for flashing feed inlet nozzle velocities below 100 ft/s (30 m/s).
- The discharge velocity of the two-phase mixture through the slots should be less than 6 ft/s (2 m/s).
- The minimum width of the flashbox is twice the outside diameter of the pipe distributor or the pipe diameter plus 8 in. (200 mm), whichever is greater. The net open area must be sized to avoid entrainment by designing for a capacity factor (C_s) of 0.3 ft/s (0.1 m/s) or for 85% of ultimate capacity, whichever is less. The open area at the flashbox top excludes the area occupied by the 2 in. (50 mm) lips on both sides of the baffles. The lips help to prevent vapor from entraining liquid off the top of the baffle walls and also act as stiffeners to add rigidity to the flashbox side baffles.
- A minimum distance of 18 in. (450 mm) or 3/4 of the tray spacing in the section above, whichever is greater, must be provided between the top of the flashbox and the tray above.
- The straight side of the baffles must be high enough to ensure that all the fluid being discharged from the distributor impinges on the baffle and does not splash outside the box.
- The distributor support and side baffles must be rigid enough to withstand the impact force of the fluid and vibration effects. The minimum thickness for the flashbox baffles is 10 gauge (0.134 in.) (3.5 mm).
- The free area adjacent to the flashbox for vapor flow from the tray below must be sized for 85% of ultimate capacity or less.
- The side flashbox bottom width should be sized to limit the downward liquid velocity to 0.6 ft/s (0.18 m/s) for non-foaming systems and 0.4 ft/s (0.12 m/s) for foaming systems. The minimum allowable width is 3 in. (75 mm).
- The minimum clearance between the side flashbox baffle bottom edge and the tray deck is the downcomer clearance plus 2 in. (50 mm). Radius tips on the flashbox baffle edges should not be used.
- A minimum 2 in. (50 mm) spacing between the side flashbox baffle and the downcomer panel is required. This 2 in. (50 mm) clearance prevents the flashing feed vapor/liquid from heating the liquid in the downcomer and avoids interference with downcomer stiffeners.
- Valves or sieve holes should not be positioned directly under a side flashbox arrangement. A minimum 2 in. (50 mm) clearance between the flashbox baffle and the first row of valves or holes is recommended.
- Center and off-center flashboxes can be designed with or without inlet weirs. Inlet weirs can improve liquid distribution for the tray below the feed. Inlet weirs also may be required to seal the flashbox. The maximum horizontal liquid velocity leaving the bottom of a flashbox is 1 ft/s (0.3 m/s) for designs without inlet weirs and 1.5 ft/s (0.5 m/s) for designs with inlet weirs. A minimum clearance of 1 in. (25 mm) between the tray deck and the bottom of a flashbox is required.
- The flashbox bottom width for center and off-center flashbox arrangements (with inlet weirs) should be sized to limit the downward liquid velocity to 0.6 ft/s (0.18 m/s) for non-foaming systems and 0.4 ft/s (0.12 m/s) for foaming systems. The flashbox bottom width for center and off-center flashbox arrangements (without inlet weirs) should be sized to limit the downward liquid velocity based on the downcomer design below the feed.
- A rating of the feed tray should be done to insure it is not the limiting tray in the section. Please contact a FRACTIONATION SPECIALIST on how to perform this rating.
- A FRACTIONATION SPECIALIST should be consulted when designing or rating a flashbox. Note that downpipes or troughs may be required when there is a seal pan above the feed inlet or when there is a change in tray geometry in the feed zone.

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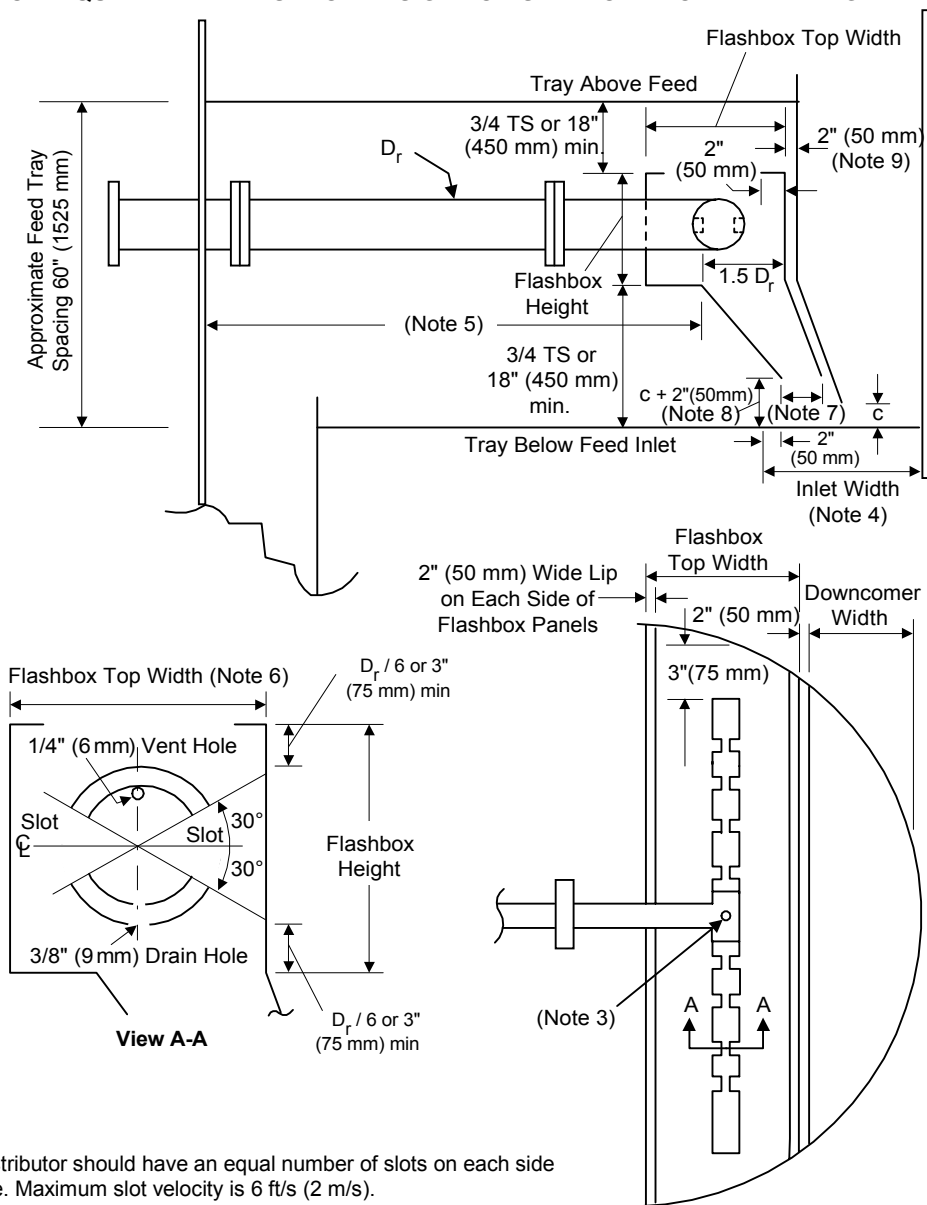
FIGURE 5B
VAPOR-LIQUID FEED DISTRIBUTOR FOR TYPICAL FLASHBOX LAYOUT (5)

**Notes:**

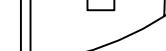
- (1) Flashbox arrangements are appropriate for flashing feed inlet nozzle at velocities below 100 ft/s (30 m/s).
- (2) The discharge velocity of the two-phase mixture through the slots should be less than 6 ft/s (2 m/s).
- (3) The distributor support and side baffles must be rigid enough to withstand the impact force of the fluid and vibration effects. The minimum thickness for the flashbox baffles is 10 gage (0.134 in.) (3.5 mm).
- (4) A FRACTIONATION SPECIALIST should be consulted when designing or rating a flashbox.
- (5) Design Criteria from Reference 4.

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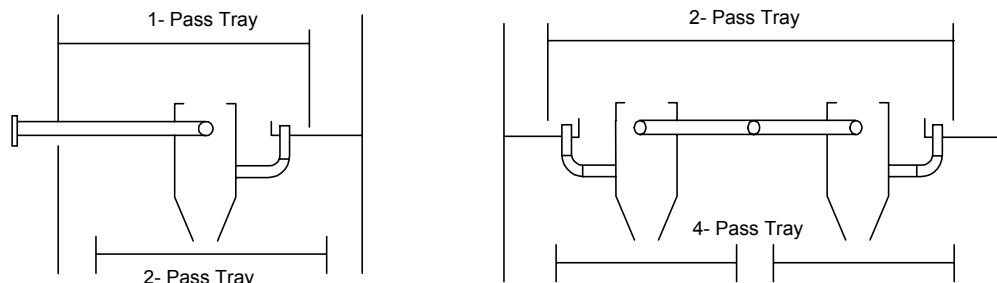
Notes:

1. Flashing feed distributor should have an equal number of slots on each side of distributor pipe. Maximum slot velocity is 6 ft/s (2 m/s).
 2. No shaped lips are permitted on downcomer panels or flashbox baffles.
 3. No slots are permitted on tee, except a 3/8" (9 mm) drain hole located on the bottom centerline of the tee.
 4. Valves or sieve holes are to be omitted from the designated inlet width.
 5. The free area adjacent to the flashbox for the vapor from the tray below must be sized for 85% of ultimate capacity or less.
 6. The minimum width of the flashbox is twice the outside diameter of the pipe distributor or the pipe diameter plus 8 in. (200 mm), whichever is greater. The net open area must be sized to minimize entrainment by designing for a capacity factor (C_S) of 0.3 ft/s (0.1 m/s) or for 85% of ultimate capacity, whichever is less. The open area at the flashbox top excludes the area occupied by the 2 in. (50 mm) lips on both sides of the baffles. The lips help to prevent vapor from entraining liquid off the top of the baffle walls and also act as stiffeners to add rigidity to the flashbox side baffles.
 7. The flashbox bottom width for side flashbox arrangements should be sized to limit the downward liquid velocity to 0.6 ft/s (0.18 m/s) for non-foaming systems and 0.4 ft/s (0.12 m/s) for foaming systems. The minimum allowable width is 3 in. (75 mm).
 8. The minimum side flashbox clearance from the tray deck is the downcomer clearance plus 2 in. (50mm).
 9. A minimum 2 in. (50 mm) spacing between the side flashbox baffle and the downcomer panel is required. This 2 in. (50 mm) clearance prevents the flashing feed vapor/liquid from heating the liquid in the downcomer and avoids interference with downcomer stiffeners.
 10. A **FRACTIONATION SPECIALIST** should be consulted when designing or rating a flashbox.
 11. Design Criteria from Reference 4.
- 
- DP03HF05c

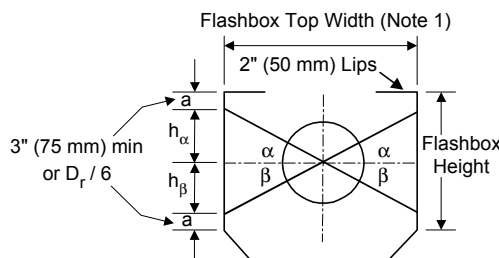
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FIGURE 5D
VAPOR-LIQUID FEED: FLASHBOX DESIGN FOR
CENTER / OFF-CENTER DOWNCOMER ARRANGEMENTS (4) (5)



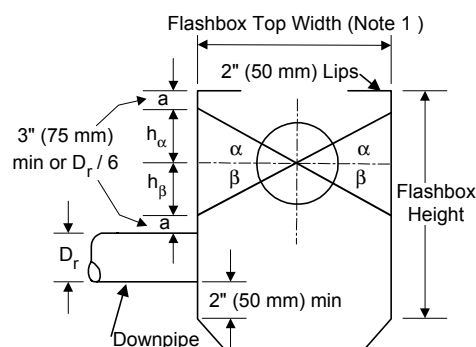
A. Typical Center and Off-Center Flashboxes



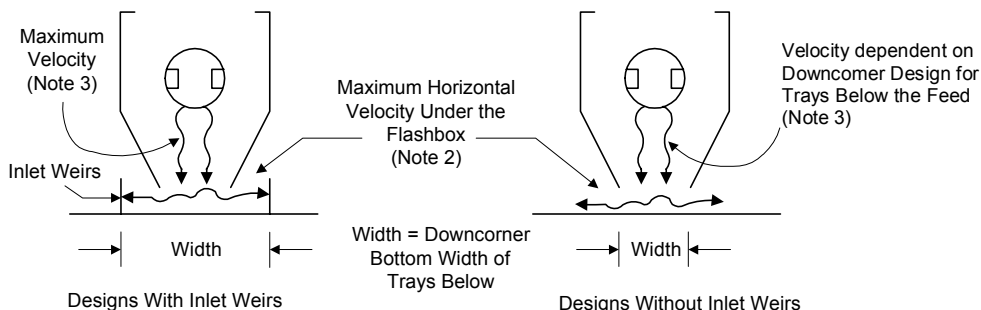
B. Flashbox without Downpipe

Where:

- a = greater of 3" (75 mm) or $D_r / 6$, in.(mm)
- D_r = diameter of downpipe, in.(mm)
- α = angle above the distributor centerline (30° max.)
- β = angle below the distributor centerline (45° max.)
- h_α = impact height above the distributor centerline, in.(mm)
- h_β = impact height below the distributor centerline, in.(mm)



C. Flashbox with Downpipe



D. Flashbox Designs With & Without Inlet Weirs

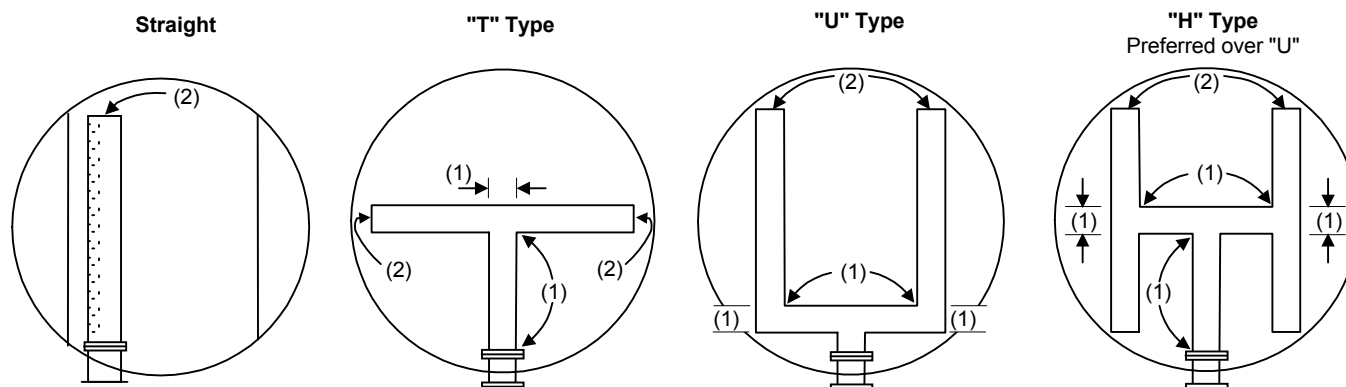
Notes:

- The minimum width of the flashbox is twice the outside diameter of the pipe distributor or the pipe diameter plus 8 in. (200 mm), whichever is greater. The net open area must be sized to avoid entrainment by designing for a capacity factor (C_d) of 0.3 ft/s (0.1 m/s) or for 85% of ultimate capacity, whichever is less. The open area at the flashbox top excludes the area occupied by the 2 in. (50 mm) lips on both sides of the baffles. The lips help to prevent vapor from entraining liquid off the top of the baffle walls and also act as stiffeners to add rigidity to the flashbox side baffles.
- Center and off-center flashboxes can be designed with or without inlet weirs. Inlet weirs can improve liquid distribution for the tray below the feed. Inlet weirs are also required to seal the flashbox. The maximum horizontal liquid velocity leaving the bottom of the flashbox is 1 ft/s (0.3 m/s) for designs without inlet weirs and 1.5 ft/s (0.5 m/s) for designs with inlet weirs. A minimum clearance of 1 in. (25 mm) between the tray deck to the bottom of the flashbox is required.
- The flashbox bottom width for center and off-center flashbox arrangements (with inlet weirs) should be sized to limit the downward liquid velocity to 0.6 ft/s (0.18 m/s) for non-foaming systems and 0.4 ft/s (0.12 m/s) for foaming systems. The flashbox bottom width for center and off-center flashbox arrangements (without inlet weirs) should be sized to limit the downward liquid velocity based on the downcomer design below the feed.
- A FRACTIONATION SPECIALIST should be consulted when designing or rating a flashbox. Note that downpipes or troughs may be required when there is a seal pan above the feed inlet or when there is a change in tray geometry in the feed zone.
- Design Criteria from Reference 4.



FRACTIONATING TOWERS
TOWER INTERNALS

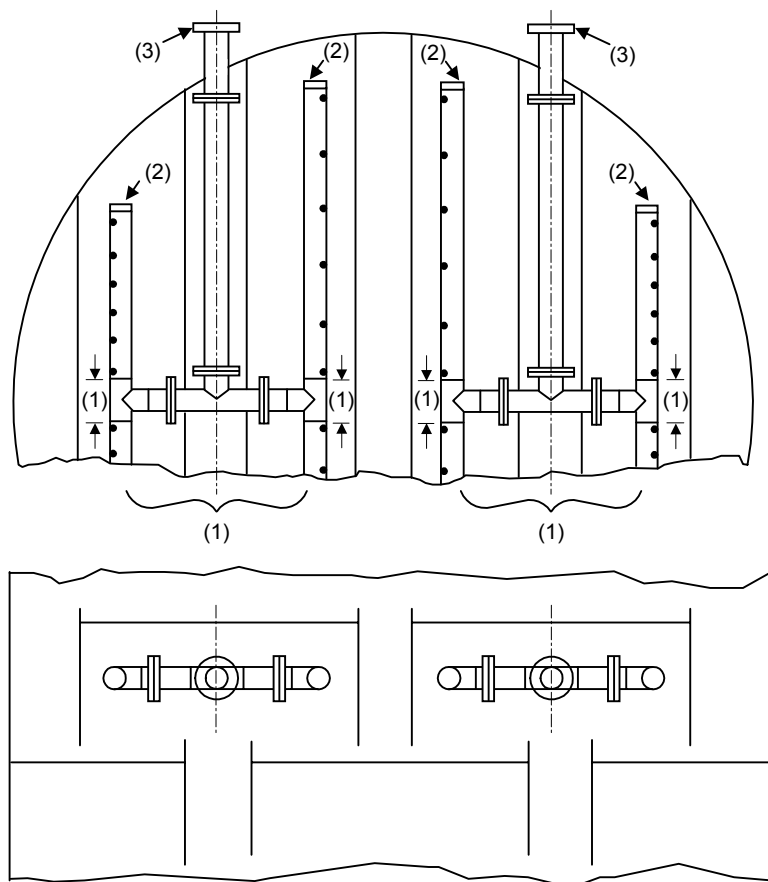
INLETS (Cont)

FIGURE 6A
PERFORATED PIPE DISTRIBUTORS

Notes:

- (1) Do not perforate this section of the pipe.
- (2) Capped end.

DP03Hf06a

FIGURE 6B
PIPE DISTRIBUTOR ARRANGEMENT FOR FOUR-PASS TRAYS

Notes:

- (1) Do not perforate this section of the pipe.
- (2) Capped end.
- (3) External piping to be symmetrical.

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INLETS (Cont)

FIGURE 7
DISTRIBUTOR ARRANGEMENTS

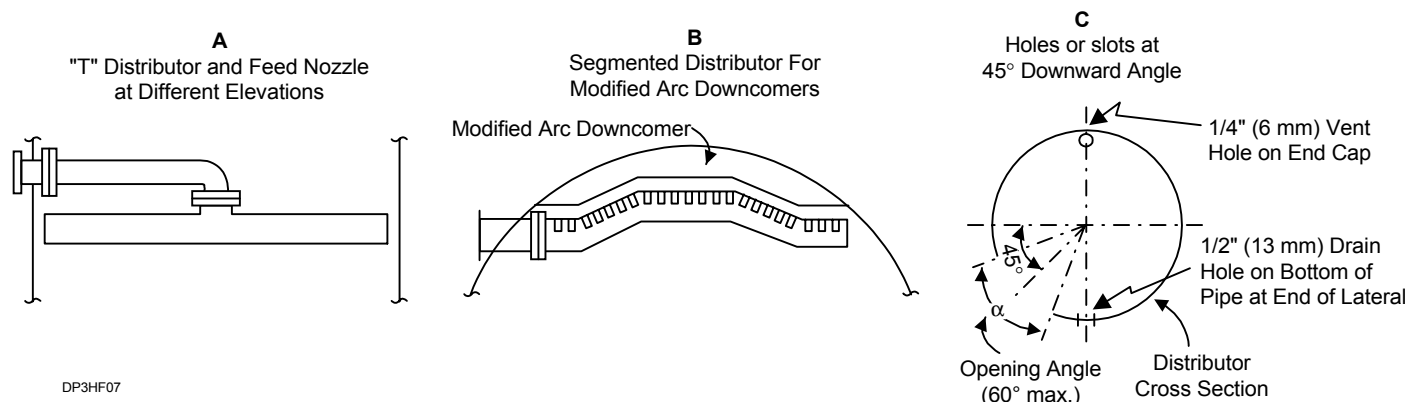
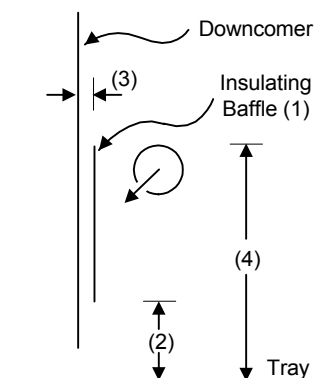


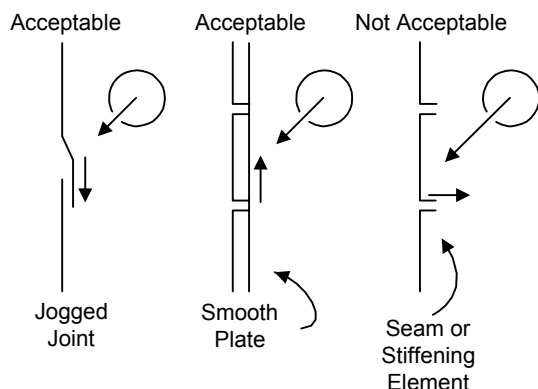
FIGURE 8
INSULATING BAFFLES FOR DOWNCOMERS

**Notes:**

- (1) To prevent vaporization in the downcomer of the tray above the feed, an insulating baffle should be provided when the feed temperature exceeds the temperature of the downcomer liquid.
- (2) The distance between the bottom of the insulating baffle and the tray should be the greater of 4 in. (100 mm) or the downcomer clearance plus 2 in. (50 mm).
- (3) The horizontal distance between the insulating baffle and the downcomer should be 1/2 to 1 in. (12 to 25 mm). The space between the baffle and the downcomer should be open at both the bottom and top for drainage and ventilation.
- (4) The top of the insulating baffle should be flush with the top of the distributor.

DP03HF08

FIGURE 9
SURFACES AT FEED INLET LOCATIONS

**Notes:**

- (1) Downcomer apron panels at feed inlet locations should have jogged overlapping seams to provide a smooth surface for vapor/liquid impingement. Otherwise, a smooth, flat plate must be installed to provide such a surface.
- (2) When an insulating baffle is used, it must also provide a smooth surface for vapor/liquid impingement.
- (3) Stepped downcomers should be avoided at tower inlet locations. Sloped downcomers should be used instead.

DP3HF09

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DRAWOFFS (EXCLUDING REBOILER DRAWOFFS)

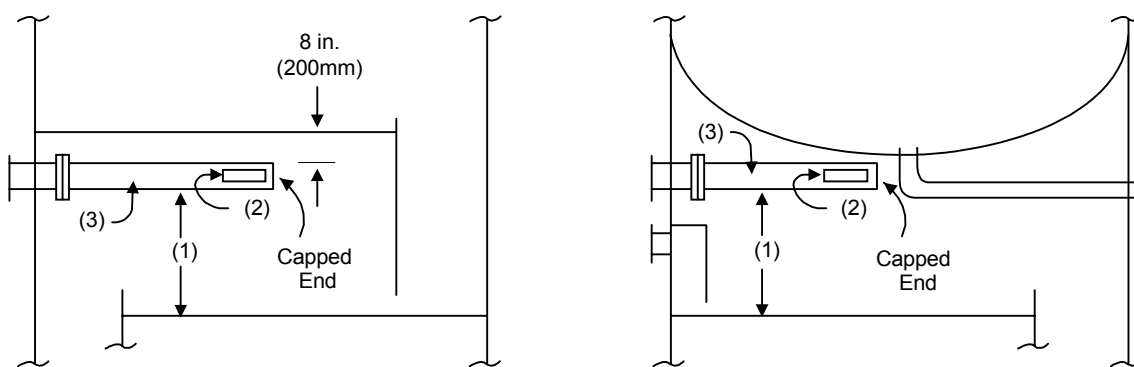
VAPOR DRAWOFFS

Vapor drawoffs typically use nozzles that are line size.

Deentrainment. If entrained liquid can cause product contamination, a deentrainment device, such as a crinkled wire mesh screen (CWMS) may be considered. For the design of deentrainment devices for vapor drawoffs using collector pipes consult your FRACTIONATION SPECIALIST.

Side Drawoffs. If not properly designed, a side drawoff can cause premature flooding due to high localized vapor velocities. The design of a side drawoff should reduce vapor maldistribution and make allowances for any maldistribution that is expected to occur. See **Figure 10**.

**FIGURE 10
VAPOR SIDE DRAWOFFS**



Notes:

- (1) The bottom of the collector pipe should be one normal tray spacing plus 12 in. (300 mm) above the tray.
- (2) The end of the collector pipe should have two side-facing slots located above the center of the bubbling area. The total slot area should be about 150% of the pipe cross-sectional area.
- (3) Small diameter collector pipes (say under 12 in. (300 mm) diameter) may have to be supported; consult a MECHANICAL SPECIALIST. For revamps with limited vertical height and for towers with diameters over 8 ft (2400 mm), a more complex collector may be required. For these cases and when there is a CWMS below the drawoff or when there is weeping from the tray above, consult a FRACTIONATION SPECIALIST.

DP3HF10

LIQUID DRAWOFF OPTIONS

Partial vs. Total Drawoff. Part or all of the liquid flowing down a tower may be withdrawn as a sidestream product or as a pumparound stream. The choice between a partial drawoff and a total drawoff normally depends on the anticipated effects on tower control and on flow stability of the internal reflux. As a general rule, the partial drawoff rate should not exceed 75% of the sum of the internal reflux plus product at the drawoff tray. In heat transfer sections, pumparound liquid which is pumped under flow control through heat exchangers and then back to the pumparound section should not be included in the above formula.

Downcomer vs. Chimney Tray Drawoffs. Withdrawal may be either from a drawoff box fed by the tray downcomer or from a chimney tray extending across the tower's cross-sectional area. Drawoffs from downcomers (drawoff box fed by downcomer) are the most common as they require lower investment. A chimney tray should be used when (a) appreciable liquid holdup is required, as for product surge or for water settling (see [Section XII](#) for holdup requirements), (b) when leakage cannot be tolerated for process reasons, such as, in water wash sections where leakage into amine or caustic solutions is unacceptable, or (c) when a drawoff box would occupy excessive tray cross-sectional area.

Total Liquid Drawoff (Drawoff Box Fed by Downcomer). The only recommended arrangements are the ones with a seal dam (**Figures 12 and 13**). Arrangements without a seal dam do not provide downcomer seal and may cause premature flooding. Occasionally, it is necessary to operate the total drawoff tray as a partial drawoff by allowing some of the liquid to pass over the overflow weir. To handle such an operation, the tray spacing should be high enough to permit flow of all the liquid over the overflow weir, without excessive downcomer filling. Total drawoffs designed according to the criteria in **Figures 12 and 13** will permit partial drawoff operation. Drawoff arrangements with a seal dam generally occupy more of the tray's area and thus they reduce the bubbling area and the capacity of the tray. To reduce this effect, a sloped downcomer can be used.

Partial Liquid Drawoff (Drawoff Box Fed by Downcomer). Two options are available: a) arrangements without a seal dam (**Figures 14 and 15**) and arrangements with a seal dam (**Figures 12 and 13**). Arrangements without a seal dam are not as effective in disengaging vapor from the liquid. They are not recommended for drawoffs where vapor in the liquid is not acceptable, such as, drawoffs that are pumped. They are satisfactory in services where vapor disengaging in the downcomer

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DRAWOFFS (EXCLUDING REBOILER DRAWOFFS) (Cont)

is rapid, or in services where some vapor entrainment with the liquid can be tolerated, such as, drawoffs sent to sidestream strippers or disengaging drums. For all other services the arrangements with a seal dam are recommended. Drawoff arrangements with a seal dam generally occupy more of the tray's area and thus they reduce the bubbling area and the capacity of the tray. A sloped downcomer can reduce this effect.

Vapor disengaging and drawoff box design are particularly important in high pressure light ends towers, where the surface tension is low and the liquid rate is usually large. These conditions produce small bubbles and make phase separation difficult.

Reboiler Drawoffs. See subsection on **REBOILER DRAWOFFS AND RETURNS**.

SPACING AND FREE AREA REQUIREMENTS FOR TRAYS WITH DRAWOFF BOXES

The concern with inadequate spacing is that the drawoff box may reduce the free area (A_f) or it may obstruct liquid flow into the downcomer of the tray below. Both effects may cause premature tray flooding. **Figure 16** provides spacing recommendations between the drawoff and the tray below.

♦ SIZING THE DRAWOFF BOX AND NOZZLES

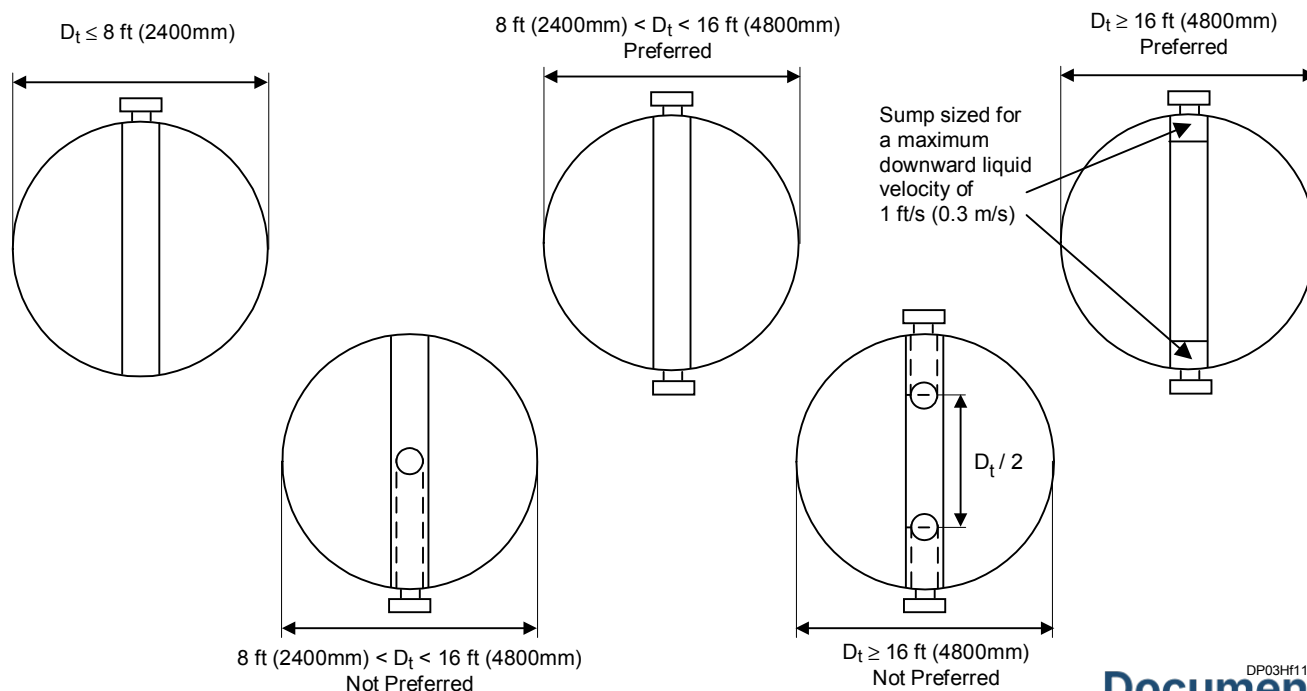
Box Size. The box should have a depth of at least 6 in. (150 mm) or 1.5 times the drawoff nozzle diameter, whichever is greater, to overcome nozzle contraction losses, which with insufficient liquid static head will result in liquid flashing in the nozzle. The box should extend across the full chord length of the overflow weir and cover the entire chordal area. Anti-vortex baffles(s) should be provided as indicated. For the design of anti-vortex baffles, see **IP 5-2-1**. The nozzle should be as close as possible to the bottom of the box to facilitate drainage.

Number of Nozzles. To ensure design flow through a partial drawoff nozzle from a center (inboard) downcomer of a two-pass tray, the distance along the downcomer to the nearest nozzle should be minimized. Five drawoff arrangement options are presented in **Figure 11**. The second and fourth use drawoff pipes below the box. These designs are not the preferred options, because of the risk of vaporization in these pipes caused by heat transfer from the vapor. Consult your FRACTIONATION SPECIALIST regarding use of these configurations.

Nozzle Size. The size of the drawoff nozzle(s) should be based on a flow area which gives a maximum liquid velocity of 3 ft/s (0.9 m/s) with the line full. See **FLUID FLOW EQUATIONS**, **Eq. 9**. However, the nozzle should be no smaller than line size.

Liquid Height Above Nozzle. Occasionally, the designer needs to know whether a drawoff nozzle is running partially full. This can be determined using **FLUID FLOW EQUATIONS**, **Eq. 10**.

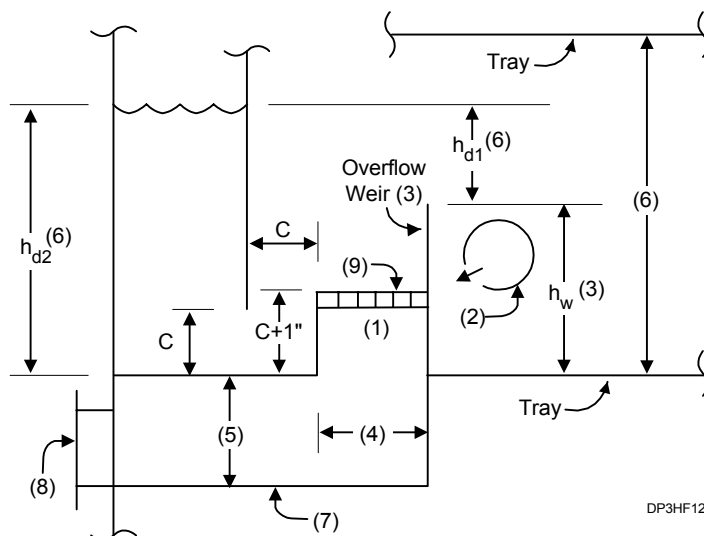
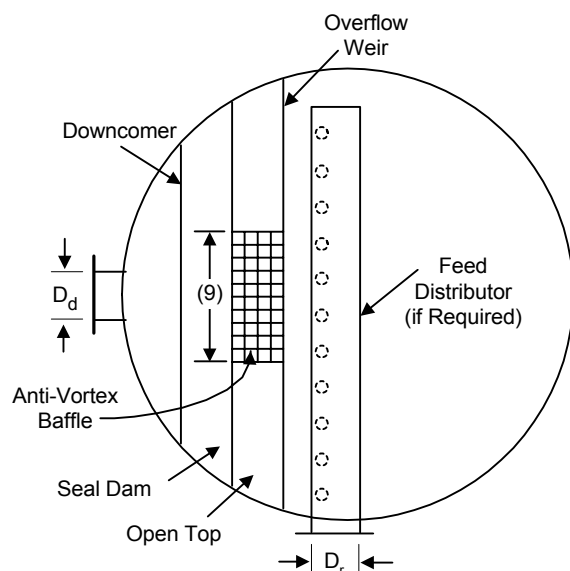
FIGURE 11
DRAWOFF NOZZLE LOCATION VS. DIAMETER



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DRAWOFFS (EXCLUDING REBOILER DRAWOFFS) (Cont)

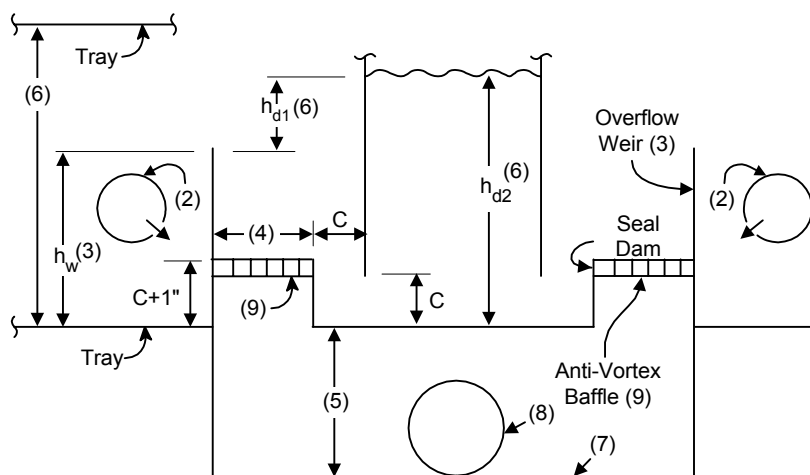
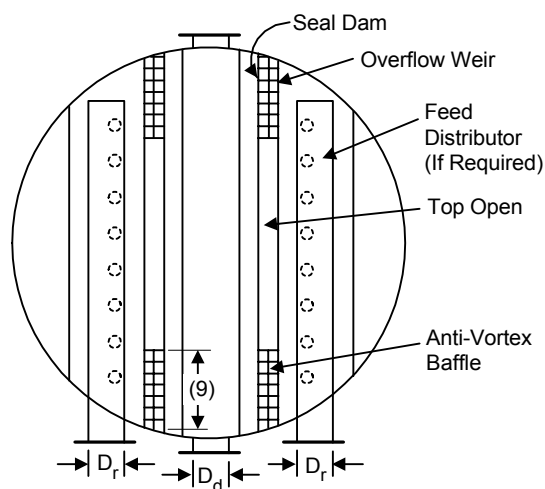
FIGURE 12
DRAWOFF WITH SEAL DAM – SIDE (OUTBOARD) DOWNCOMER, (1)



DP3HF12

See Applicable Notes After Figure 15

FIGURE 13
DRAWOFF WITH SEAL DAM – CENTER (INBOARD) DOWNCOMER, (1)

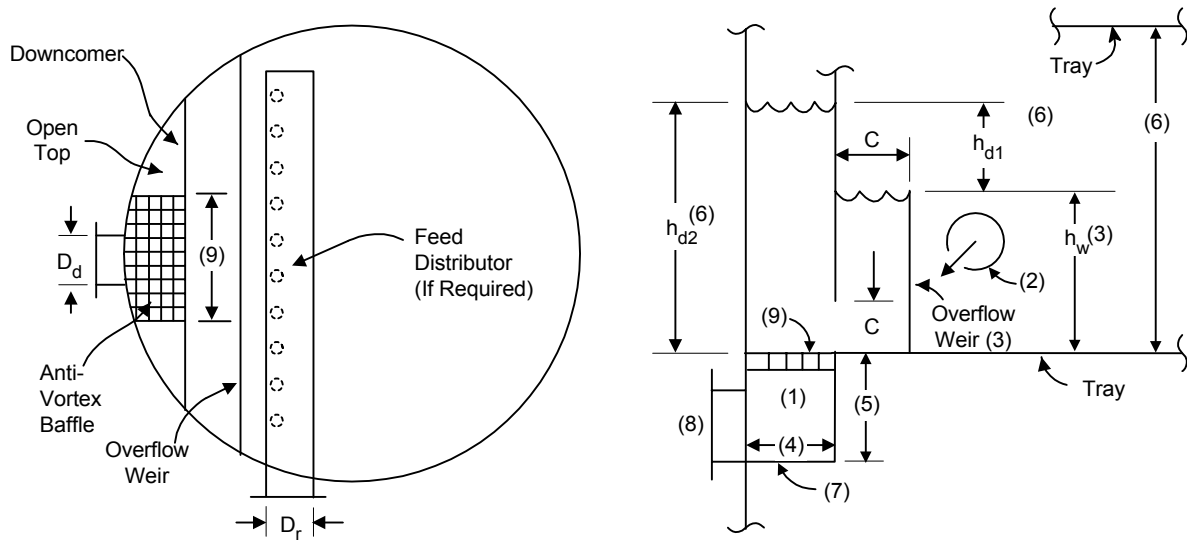


DP03HF13

See Applicable Notes After Figure 15

DRAWOFFS (EXCLUDING REBOILER DRAWOFFS) (Cont)

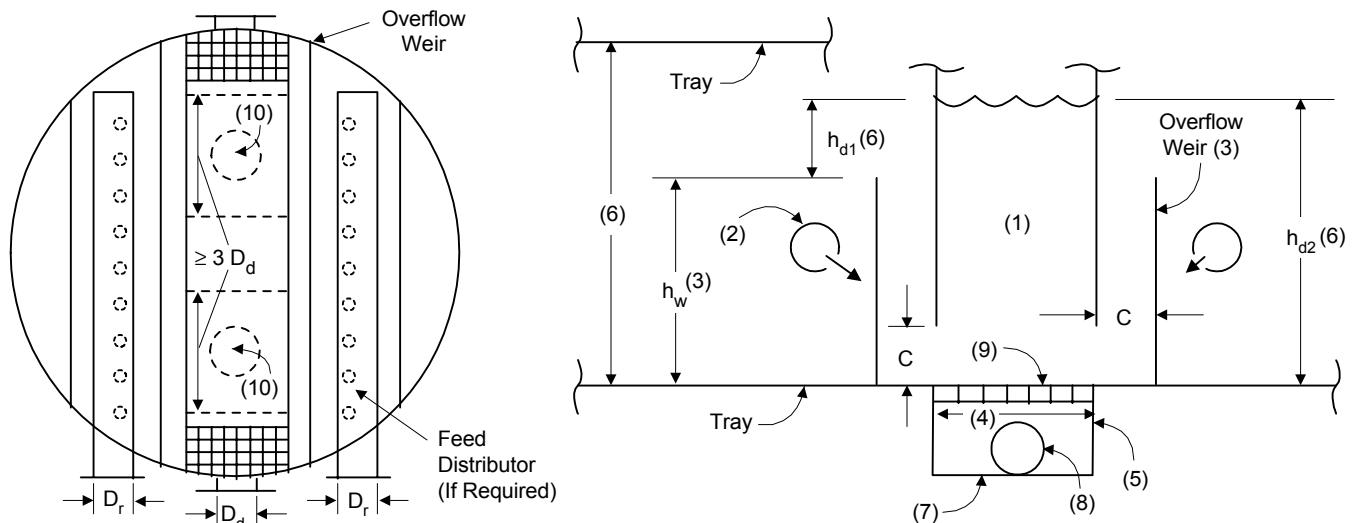
FIGURE 14
DRAWOFF WITHOUT SEAL DAM – SIDE (OUTBOARD) DOWNCOMER (1)



See Applicable Notes After Figure 15

DP03Hf14

FIGURE 15
DRAWOFF WITHOUT SEAL DAM – CENTER (INBOARD) DOWNCOMER (1)



See Applicable Notes After Figure 15

DP03Hf15