



DESIGN PRACTICES

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Revision Memo

12/01	Highlights of this revision are: Specified a minimum tray deck thickness of 0.104 in. (2.8 mm). Included table of operating experience under APPLICATION.
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SCOPE

This section covers the techniques for specifying the process design features of jet trays. Detailed mechanical design and tab arrangement are normally handled by the tray fabricator. A calculation form showing the step-by-step calculation procedure is given in the **APPENDIX** for both customary and metric units. [Section III-A](#) should also be consulted since it contains key definitions and figures that explain many of the basic concepts used when designing trays. For the design of tray-related tower internals, such as nozzles, drawoff boxes and reboiler connections, refer to [Section III-H](#). For jet trays in heat transfer service, the method given in [Section III-F](#) should be used to calculate the required number of trays.

REFERENCES

Some of the following literature has been used in the preparation of this section. The rest is listed for convenient reference.

GLOBAL PRACTICE

GP 5-2-1 Internals for Towers and Drums

OTHER LITERATURE

O'Bara, J. T., *Heat Transfer Coefficients for Jet Tray Pumparounds*, ER&E Report No. EE.14ER.70, May 1, 1970.

Colwell, C. J., *New Direct Contact Heat Transfer Correlations for Towers*, ER&E Report No. EE.98E.76, September, 1976.

Niedzwiecki, J.L., Computer Program Update, *Jet Tray Design Program #3019*, CPEE-7, December, 1989.

Pagendarm, S.M., *PEGASYS Jet Tray Program Validation Cases*, 97CET 073, May 20, 1997.

BACKGROUND

Jet trays have been used in the petroleum and chemical process industries since the early 1950's. Because of their high vapor and liquid handling capacity and low cost, they replaced bubble cap trays in many services. Since the mid-1960's, however, jet trays have been superseded by sieve trays and packing, which are more cost effective and have wider flexibility for most services. Nevertheless, jet trays are still important where very high liquid handling capacity is required, such as in the pumparound sections of various heavy hydrocarbon fractionators operating near atmospheric pressure.

DEFINITIONS

See [Section III-A](#) for an in-depth discussion of many of the basic concepts used when designing trays. Also see the **NOMENCLATURE** part of this section for the definition of specific terms.

APPLICATION

For most new distillation towers, sieve trays or packing are usually the best choice (see [Section III-A](#)). However, jet trays are recommended for heat transfer services, especially where high liquid loadings might require 3 or 4-pass sieve trays and hence complex transitions. For those cases, single or double-pass jet trays may be better. These services include pumparounds in atmospheric pipestills; cat, coker and steam cracker primary fractionators; and visbreaker fractionators.

Jet trays should not be used in the following cases:

- Where the liquid rate is below 4 gpm/inch of **diameter** per pass (10 dm³/s/m of **diameter**/pass). Liquid rates below this value may result in spray regime operation with a consequent loss in tray efficiency.
- In towers less than 7 ft (2100 mm) in diameter. In these towers, the tray bubble area will become relatively small because of the downcomer area required. This narrow bubble area, in turn, can result in high localized vapor velocities, which may increase entrainment and cause premature flooding.
- In vacuum towers because of their inherently high pressure drop and poor efficiency due to the low liquid rates usually encountered in these units.



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APPLICATION (Cont)

- The table below, which is based on operating experience, lists the lower and upper operating limits for most jet tray designs. If your case does not fall within these limits, contact your FRACTIONATION SPECIALIST to see what, if any, problems may exist.

VARIABLE	LOWER LIMIT	UPPER LIMIT
Pressure, psia (kPa)	15 (104)	100 (690)
Temperature, °F (°C)	65 (18)	800 (430)
Diameter, ft (mm)	7 (2100)	46 (14,020)
Physical properties		
surface tension, dyne/cm (mN/m)	2.4 (2.4)	72 (72)
liquid viscosity, cP (mPa·s)	0.07 (0.07)	1 (1)
vapor density, lb/ft ³ (kg/m ³)	0.077 (1.2)	2.3 (37)
liquid density, lb/ft ³ (kg/m ³)	28 (450)	62 (1000)
Tray Spacing, in. (mm)	18 (460)	48 (1220)
Open Area as % of A_b	5%	30%
DC Clearance, in. (mm)	1 (25)	3.5 (90)
DC inlet area as % of A_s	6.8%	*
Number of passes	1	2
Outlet weir height, in. (mm)	0 (0)	0 (0)
Tab size, in. (mm)	2 (50) **	2 (50)
Flow path length, in. (mm)	16 (410) *	209 (5310) *

* Jet trays should be designed so that the sum of the downcomer inlet area (A_{di}) and outlet area (A_{do}) is less than 45% of the superficial tower area (A_s). Remember that the tower diameter must be within the allowable range specified in the table.

** 1 in. (25 mm) jet tabs have been used in at least one service. This tab size is not recommended for designs since there is an increased fouling risk with small tabs.

BASIC DESIGN CONSIDERATIONS

The procedure outlined in this section for designing new towers involves calculating a trial diameter, tray spacing, and downcomer area, and then checking and revising (if necessary) this trial design for ultimate capacity, jet flooding and downcomer filling. This procedure results in a tray design which should not be subject to excessive entrainment, weeping, dumping or operation in the spray regime. The same criteria can be used for rating existing jet trays. For a discussion of the various types of tray limitations, see [Section III-A](#). The equation numbers shown in the text correspond to their location on the **JET TRAY CALCULATION FORM** presented in the **APPENDIX**.

TRAY SPACING

The optimum combination of tray spacing and tower diameter is the one which minimizes total tower investment, subject to the condition that tray spacing must be high enough to permit access for maintenance.

Minimum tray spacings, which are based on maintenance considerations, are tabulated under **DETAILED DESIGN PROCEDURE**, as a function of tower diameter and service. No vapor capacity credit is allowed for tray spacings above 36 inches (900 mm) except for steam cracker primary fractionators. See also the discussion of downcomer filling under TRAY HYDRAULICS, and [Table 1](#) in the **APPENDIX**.

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BASIC DESIGN CONSIDERATIONS (Cont)

TOWER DIAMETER

In addition to the criteria discussed below under DOWNCOMER SIZING, DOWNCOMER CLEARANCE and DOWNCOMER SEALING, the tower must provide enough cross-sectional area to avoid entrainment per the following jet flood equation.

$$\left[\frac{(V_L / A_b)_{\text{actual}}}{(V_L / A_b)_{\text{allowable}}} \right] \times 100 \leq 90\%$$

$$\left[\frac{V_L}{A_b} \right]_{\text{allow}} = K_{HL} K_{\sigma\mu} \quad (\text{Customary or Metric}) \quad \text{Eq. (3a5)}$$

where: V_L = Vapor load, ft³/s (m³/s)

A_b = Bubble area, ft² (m²)

K_{HL} = Tray spacing - liquid rate factor, **Figure 1A** or **1B**

$K_{\sigma\mu}$ = Surface tension - viscosity factor, **Figure 3**

K_{HL} , the tray spacing-liquid rate factor, has been developed from commercial data. It can be read directly from **Figure 1A** or **1B** or calculated from **Eq. (3a2)** or **(3a3)** found on the **JET TRAY CALCULATION FORM**.

Note: Because of the unique physical properties of the materials being handled, **steam cracker primary fractionators** should be designed using a special K_{HL} factor. This factor is shown as **Eq. (3a4)** on the **JET TRAY CALCULATION FORM**. In addition, for tray spacings between 36 and 48 in. (914-1220 mm) the K_{HL} factor at 36 in. (914 mm) should be corrected upward by multiplying by $(H/36)^{0.5}$ or $(H/914)^{0.5}$ (metric). No capacity credit should be taken for tray spacings greater than 48 in. (1220 mm). These two comments are specific to steam cracker primary fractionators ONLY and are not applicable to other services.

The system property factor, $K_{\sigma\mu}$, is plotted on **Figure 3**. This correlation is based on data from a number of hydrocarbon towers.

Since the jet flood **Eq. (3a5)** is empirical, capacity data for the type of tower being designed should be used whenever possible. This is especially true when revamping towers that are heavily loaded.

ULTIMATE CAPACITY

Eq. (2c1) (below) gives the limiting vapor load for ultimate capacity. See the **NOMENCLATURE** section for the definition of the variables. The ratio of design vapor load, V_L , to the vapor load for ultimate capacity $V_{L(Ult)}$ must be kept below 90%. If necessary, the tower diameter must be increased, even though **Eq. (3a5)** on jet flood has already been satisfied. However, the diameter calculated from **Eq. (3a5)** usually provides sufficient free area to satisfy the ultimate capacity limitation.

$$V_{L(Ult)} = C_1 A_f \left[\frac{\beta}{1 + \beta} \right] \left[\frac{\sigma_L}{\rho_L - \rho_V} \right]^{-0.25} \quad \text{Eq. (2c1)}$$

$$\text{where: } \beta = 1.4 \left[\frac{\rho_L - \rho_V}{\rho_V} \right]^{0.5}$$

$C_1 = 0.62$ for Customary units (0.378 for Metric units)

NUMBER OF LIQUID PASSES

Multiple-pass jet trays are less likely to be needed than is the case with other types of trays, because jet trays have an inherently high liquid handling capacity. This characteristic results from the horizontal component of the vapor velocity, as the vapor leaves the tab openings. This vapor jet action helps to propel the liquid across the tray. Therefore, when two-pass jet trays are required in a tower, it is because other types of trays in the adjacent sections of the tower are multiple-pass trays, not because single-pass jet trays would have been overloaded. When two-pass jet trays are used, no credit should be taken for extra vapor handling capacity. If the liquid rate exceeds 24 gpm/inch of diameter/pass (60 dm³/s/meter of diameter/pass) or if 3 or 4 pass jet trays are proposed, contact your FRACTIONATION SPECIALIST for advice.

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BASIC DESIGN CONSIDERATIONS (Cont)

DOWNCOMER SIZING

The required downcomer inlet area is set by froth disengaging limitations. If insufficient area is provided, downcomer choking may back up froth onto the tray and cause premature flooding. The downcomer entrance velocity should be limited to a maximum of 0.35 ft/s (0.105 m/s), based on vapor-free liquid at operating conditions. For foaming or high-pressure systems (300 psig; 2070 kPa gauge or higher), this value should be reduced to 0.2 ft/s (0.06 m/s). For a straight downcomer, these values automatically apply to the outlet as well. For the sloped or stepped downcomer, the outlet velocity should not exceed 0.6 ft/s (0.18 m/s) for non-foaming systems and 0.4 ft/s (0.12 m/s) for foaming systems.

To prevent choking of the downcomer inlet by the rapidly moving froth, an anti-jump baffle should be provided for center (inboard) downcomers. To insure good liquid distribution, the length of the downcomer apron must be at least 65% of the tower diameter. This means that the downcomer outlet area (hence, the tray inlet area) must be at least 6.8% of the tower superficial area, A_s . If the downcomer inlet area required to satisfy the velocity criteria exceeds 12% of A_s , then the outlet of a straight downcomer would be oversized and a sloped or stepped downcomer should be considered. For revamps, consider specifying modified arc downcomers in order to maximize tray bubble area and vapor handling capacity. The above stated downcomer inlet velocities for straight downcomers must be satisfied with modified arc downcomers. The minimum rise criteria must also be satisfied. Center and off-center downcomers for 2 pass and multipass trays should maintain a minimum inlet width of 8 in. (200 mm). Sloped or stepped center (and off-center) downcomers should have a minimum outlet width of 6 in. (150 mm).

At high liquid loadings, the required downcomer areas can become a large percentage of the tower area. Hence, there may not be enough bubble area to provide a good tab layout. If the sum of the required downcomer inlet and outlet areas is greater than 45% of A_s , the tower diameter should be increased.

See [Section III-K](#) for geometrical relationships of chords and circles to help calculate downcomer area, weir length, etc. In addition, the PEGASYS Geometry, Segments of Circles option can be used to determine geometric relationships.

DOWNCOMER CLEARANCE

The downcomer clearance is the vertical distance between the bottom edge of the downcomer apron and the tray deck. This clearance is based on a normal head loss (pressure drop) of 0.5 to 1.5 in. (13 to 38 mm) of hot liquid, according to the submerged weir formula [Eq. (4d1)] shown on the **JET TRAY CALCULATION FORM**. The clearance should be no smaller than 1 in. (25 mm). In those cases where high liquid rates would require use of either a large downcomer clearance (over 3 in. [75 mm]) or a deep recessed inlet box, a shaped downcomer lip (see [Section III-A](#)) may be used instead. For a 2 in. (50 mm) shaped lip downcomer, the coefficient in the submerged weir formula [Eq. (4d1)] is reduced from 0.06 to 0.02 (customary); 160 to 53 (metric). However, a shaped downcomer lip must not be used when either a recessed inlet box or an inlet weir has been specified. This is because the obstruction presented by the vertical face of the recessed inlet box, or by the inlet weir, would cause turbulence and defeat the purpose of the shaped downcomer lip.

DOWNCOMER SEALING

To prevent some of the vapor from bypassing a tray by traveling up the downcomer, the downcomer must be sealed to within 0.25 in. (6 mm) by the liquid on the tray below. Therefore, it is necessary to check the sum of the clear liquid height (h_c) at the inlet to the tray and the head loss (h_{ud}), under the downcomer at the minimum liquid flow rate. This sum plus 0.25 in. (6 mm) should at least equal the downcomer clearance. If sealing is not obtained, consider one of the following steps to seal the downcomer: adding an inlet weir, using a recessed inlet box, using a smaller clearance with a shaped lip, or decreasing the downcomer clearance [down to a minimum of 1 in. (25 mm)]. The designer must check that the downcomer filling does not become excessive at design rates.

The maximum depth for a recessed box is 6 in. (150 mm). However, recessed inlet boxes should be avoided at liquid rates greater than 11 gpm per inch of diameter per pass (28 dm³/s/m of diameter/pass). At such high liquid rates, the reversal in direction of flow under the bottom edge of the downcomer causes a high liquid buildup just downstream of the recessed box. This high inlet head, in turn, promotes dumping through the inlet rows of tabs. Under these conditions, a better solution is to use a shaped downcomer lip.

The use of a shaped downcomer lip should be considered if a very wide range of liquid rates must be handled. The shaped downcomer lip provides a lower head loss for a given clearance than does the standard sharp-edged downcomer. As mentioned earlier, however, it should not be used if either a recessed box or an inlet weir has been specified.

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BASIC DESIGN CONSIDERATIONS (Cont)

TRAY LAYOUT, TAB AREA, AND OUTLET WEIR HEIGHT

Important features of the tray layout are the bubble area A_b (Section III-A, Figure 12, Bubble Area Definitions) and the free area A_f (Section III-A, Figure 13, Free Area Definitions). These, in turn, depend on the liquid handling areas (downcomers) and waste area, A_w . The waste area, A_w , is defined as any unperforated area farther than 3 in. (75 mm) away from the nearest tab. Normally, there is no waste area on a jet tray, unless a very low tab area is required (part of the tray is left unperforated).

The bubble area, A_b , and the vapor velocity V_o through the tabs have been shown to strongly influence plate efficiency and heat transfer. High velocities through the tabs and low ratios of tab area to bubble area lead to improved tray performance. This optimum can best be achieved if the tray is designed for a dry tray pressure drop (h_{ed}) between 3 and 6 in. of hot liquid (75 to 150 mm) if permitted by the tray hydraulics. However, the tab area should not be less than 5% of the bubble area, A_b . The 2 in. (50 mm) nominal size tab should be used for all new jet tray designs. The tab area in ft^2 (m^2) can be calculated for revamps by multiplying the number of tabs by 0.0248 (0.0023). For tab details see Figure 7.

Outlet weirs are not specified for new jet trays although they may exist on a few towers. Visual observations in an air/water simulator indicate that an outlet weir has almost no effect on jet tray hydraulics. The liquid is lifted off the tray deck and thrown over the weir by the horizontally entering vapor (see Figure 6). Thus, the outlet weir does little to maintain liquid on the tray for holdup or downcomer sealing purposes. However, a term has been included in Eq. (4a1) on the **JET TRAY CALCULATION FORM**, to give a conservative value for downcomer filling calculations in the rare event an outlet weir has been provided.

TAB LAYOUT AND BLANKING

A detailed tab layout is not shown in ExxonMobil Design Specifications since this is handled by the vendor. The vendor will also set the number and location of major and minor trusses when the detailed mechanical design of the tray is performed.

However, the vendor should be told the tab area required along with the open area per tab [0.0248 ft^2/tab (0.0023 m^2/tab)] and should be given a sketch similar to the one in Figure 6B, Section III-A (Typical Tray Layout) showing the general tray dimensions.

It is sometimes necessary to blank tabs to maintain high efficiency in sections of towers where the vapor loadings change markedly. For **new designs**, the vendor should be told to preferentially blank tab rows downstream of the minor trusses since these rows tend to weep first. For **revamps**, the designer should also blank these rows first. The blanking should be placed on the underside of the tray deck. Do not blank more than half the tabs on a tray without consulting your FRACTIONATION SPECIALIST for assistance.

WEEPING, DUMPING AND SPRAY REGIME OPERATION

Spray regime operation should not occur if the liquid rate is kept above 4 gpm per inch of diameter per pass (10 $\text{dm}^3/\text{s/m}$ of diameter/pass) and the dry tray pressure drop is kept below 6 in. (150 mm) of hot liquid. To minimize weeping and dumping, the dry tray pressure drop at minimum vapor rates must equal or exceed 1.0 in. (25 mm) of hot liquid.

TRAY HYDRAULICS

The optimum dry tray pressure drop will generally fall in the range of 3 to 6 in. (75 to 150 mm) of hot liquid. The effect on tray hydraulics and downcomer filling of increasing dry tray pressure drop (decreasing tab area) can be calculated from Step 3b on the calculation form.

Downcomer filling, as a percent of tray spacing, should not exceed the values given in Figure 4a or 4b as a function of pressure. Otherwise, the tray spacing and/or the tower diameter should be increased.

If two-pass trays are used, anti-jump baffles must be provided on all inboard downcomers, to prevent liquid from jumping across (choking) the inboard downcomer, with consequent premature flooding. (See Figure 6 of this section and Figure 14 of Section III-A.)

OVERALL EFFICIENCY AND HEAT TRANSFER

For most new designs, jet trays will only be used in the heat transfer sections of heavy hydrocarbon towers. For these cases, the number of trays should be determined by the methods in Section III-F.

For revamps, the vapor-liquid mixing energy factor, F_e , given below should be equal or close to 70 (85 in metric units) in order to optimize tray efficiency. Under these conditions, the efficiency will be roughly 20 percentage points less than that of a sieve tray in the same service. Figures 5a and 5b give jet tray efficiencies as a function of F_e and the fluidity of the tray liquid. Whenever possible, however, past experience should be used as a guide for determining efficiency.

$$F_e = \frac{V_o [\rho_v]^{0.5}}{A_o / A_b} \quad \text{(Customary or Metric)} \quad \text{Eq. (3c1)}$$

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BASIC DESIGN CONSIDERATIONS (Cont)

START-UP CONSIDERATIONS

At very low vapor velocities (such as during start-up), jet trays normally dump, with the result that no liquid level is maintained on the tray. Hence, when revamping jet tray towers that contain thermosyphon reboilers, special provisions must be made so that the reboiler will have liquid feed during start-up. This can be done by:

- Providing a chimney tray as the drawoff tray (see [Section III-H](#)).
- Installing a jumper line from the tower bottoms drawoff line to the reboiler inlet. This jumper must have a valve, so that it can be closed when the reboiler is generating enough vapor to support the liquid on the drawoff tray.
- For design of drawoffs and towers internals, see [Section III-H](#).

DRAWING NOTES

The following notes should be considered for inclusion on the tray drawing or specification.

1. **GP 5-2-1** shall be followed.
2. The tab area per tray shall be _____. The jet tabs shall be constructed to the details shown in **GP 5-2-1** with a tab area per tab equal to 0.0248 ft²/tab (0.0023 m²/tab).
3. A minimum tray deck thickness of 0.104 in. (2.8 mm) should be specified.
4. Details of blanking pattern, if required (see TAB LAYOUT AND BLANKING).

DETAILED DESIGN PROCEDURE

The step-by-step procedure for designing a jet tray is given on the **JET TRAY CALCULATION FORM** (Customary or Metric) in the **APPENDIX**. Basically, the procedure involves assuming a trial design with the help of the principles given above, checking it against various potential operating limitations, and then modifying it as required to arrive at the optimum tray design. Deciding how to modify the trial design (changing diameter, spacing, downcomer size, etc.) will require judgment and application of the basic design considerations already discussed. The calculation step numbers and equation numbers referred to below are the same as those used on the calculation forms.

VAPOR AND LIQUID LOADINGS (STEP 1)

This information is normally calculated as part of the heat and material balances for the tower and usually comes from a computer program like PRO/II. If minimum liquid and vapor loadings have not been specified, assume 70% of the design loadings. Vapor loadings to the tray in question along with liquid loadings from the tray should be used, since these are nearly always the maximum values.

TRIAL TRAY SPACING, SIZE AND LAYOUT (STEP 2)

Downcomer Areas. The velocity of the vapor-free liquid entering the downcomer should be limited to a maximum of 0.35 ft/s (0.105 m/s). For foaming or high pressure (greater than 300 psig; 2070 kPa gauge) systems, use 0.2 ft/s (0.06 m/s). This sets the downcomer area(s) to be used for the first trial. However, tower diameter considerations further on in the design procedure may require the downcomer area(s) to be increased.

Tray Spacing. A low tray spacing [between 18 and 24 in. (450 and 600 mm)] is often the most economical. For the first trial, a tray spacing of 24 in. (600 mm) or that shown below (whichever is larger) should be used. The values given below are the minimum, as determined by considerations of maintenance and depth of support beams. In special cases, smaller spacings [but not less than 18 in.; (450 mm)] can be used; but this makes maintenance very difficult and some chemical plants and refineries may not permit smaller spacings. Downcomer filling requirements may dictate the use of a tray spacing larger than the minimum. Also, tray spacings of 27 to 36 in. (675-900 mm) are commonly used in pumparounds to provide extra capacity. This is done so that the pumparound section does not increase tower diameter over that required by adjacent sieve tray sections. Spacings up to 36 in. (900 mm) may be used to permit a higher superficial vapor velocity.

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DETAILED DESIGN PROCEDURE (Cont)

MINIMUM TRAY SPACING

TOWER DIAMETER, ft (mm)		CLEAN SERVICE		FOULING SERVICE	
		in.	mm	in.	mm
Over 7 to 7.5	(Over 2100 to 2250)	18*	450	21*	525
Over 7.5 to 10	(Over 2250 to 3000)	18*	450	24	600
Over 10 to 16.5	(Over 3000 to 5000)	21*	525	27	675
Over 16.5	(Over 5000)**	24	600	30	750

* Minimum tray spacing with a manhead present is 24 in. (600 mm).

** For towers larger than about 20 ft (6000 mm) in diameter, "lattice" type trusses should be used to facilitate maintenance and promote good vapor distribution.

Trial Tray Size. The trial diameter (D_{tr}) is calculated from the superficial area, A_s , which is determined by [Eq. \(2b5\)](#). At this point, A_{di} and A_{do} (Step 2a) should be checked to make sure that $A_{do} \geq 0.068 A_s$. If $A_{di} > 0.12 A_s$, consider a sloped or stepped downcomer. If the sum of $A_{di} + A_{do}$ exceeds 45% of A_s , the tower diameter should be increased. If necessary, increase tower diameter and correct K_{HL} and D_{tr} . Also, D_{tr} should equal or exceed 7 ft (2100 mm) for new towers.

Number of Liquid Passes. Jet trays will normally be single-pass, unless adjacent trays in the tower are multipass. However, the calculation form has been set up to handle multipass trays, if needed.

Ultimate Capacity. The vapor load corresponding to ultimate capacity is calculated from [Eq. \(2c1\)](#). The ratio of design to ultimate capacity vapor load must be kept below 90%.

FINAL TRAY SPACING, SIZE AND LAYOUT (STEP 3)

Tower Areas. Use the last value of D_{tr} calculated in Step 2(b) or 3(a) for the final tower diameter.

Tab Details. For the first trial, the dry tray pressure drop, h_{ed} , is calculated from a value of the vapor velocity V_o , based on the tab area A_o calculated in Step 3(b). If this value of h_{ed} is acceptable (in the range of 3 to 6 in. [75 to 150 mm] of hot liquid), proceed directly to the next calculation step. However, if h_{ed} exceeds the recommended limit of 6 in. (150 mm) or if other considerations (e.g., limited pressure drop across the tower) require a smaller value of h_{ed} , it will be necessary to recalculate V_o , [\[Eq. \(3b2\)\]](#) and A_o , [\[Eq. \(3b3\)\]](#).

The dry tray pressure drop should also be checked at minimum vapor rates to insure that excessive weeping is not a problem. To minimize weeping, $h_{ed(min)}$ should be ≥ 1.0 in. (25 mm) of liquid at conditions. If it is not, reduce A_o and recalculate $h_{ed(min)}$ and h_{ed} . If both criteria cannot be met simultaneously [6 in. maximum at design rate, 1 inch minimum at minimum rate (150 mm and 25 mm respectively)] consult your FRACTIONATION SPECIALIST.

Downcomers and Weirs. The length of the downcomer apron at the bottom of the downcomer should be checked to be sure that it is at least 65% of the final tower diameter. Consider a sloped or stepped downcomer if $A_{di} > 0.12 A_s$. In addition, for two-pass trays, the width of the inboard downcomer must be at least 8 in. (200 mm). Sloped or stepped center (and off-center) downcomers should have a minimum outlet width of 6 in. (150 mm). For tray geometry relationships, see [Design Practice III Section K](#).

Mixing Energy. Check only when **revamping** existing distillation towers - ignore for pumparounds. If the mixing energy gives an undesirably low efficiency, h_{ed} should be increased (within the limitations discussed above) and the appropriate portions of Step 3(b) recalculated. If there is no room for a higher h_{ed} in the design at this point, a moderate efficiency debit may have to be accepted. (See [Figure 5A](#) or [5B](#)).

TRAY HYDRAULICS AND DOWNCOMER FILLING (STEP 4)

The sum of the clear liquid height (h_c) at the inlet to the tray and the head loss under the downcomer (h_{ud}) plus 0.25 in. (6 mm) must be checked at the minimum liquid flow rates to ensure that it equals or exceeds the downcomer clearance, thereby sealing the downcomer. If a seal is not obtained, consider the use of an inlet weir, a recessed inlet box, a smaller downcomer clearance, or a shaped downcomer lip. For tray geometry relationships, see [Section III-K](#) or use the PEGASYS Geometry, Segments of Circles option.

If the criteria for downcomer filling as a percent of the tray spacing is exceeded, it will probably be necessary to increase the tray spacing, rather than make other adjustments to decrease tray pressure drop.

OVERALL EFFICIENCY (STEP 5)

For new designs, jet trays are only recommended for heavy hydrocarbon heat transfer service. The number of trays in this service is set by heat transfer requirements (see [Section III-F](#)). If an old jet tray distillation tower is being revamped, then the