



DESIGN PRACTICES

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Revision Memo

- 12/99** Highlights of this revision are:
1. Revised title to include **SHEDS**.
 2. Included literature references.
 3. Included operating limits for baffles and sheds.
 4. Revised discussion on calculating bulge temperature loadings.
 5. Clarified the discussion on determining the maximum permissible shed gap.
 6. Included a discussion on mass transfer efficiency.
 7. Included design considerations for perforated pipe distributors in slurry service.
 8. Included a discussion on the use of spray nozzle liquid distributors.
 9. Included a discussion on the use of vapor distributors.
 10. Included a summary of design considerations for typical shed section services.
 11. Included additional design details for sheds.
 12. Included typical shed section layouts for coker scrubber and FCCU slurry pumparounds including recommended locations of thermowell connections.
 13. Included design details for thermowell placement and shielding.
 14. Included a section on the shed rating computer program and limitations.
 15. Revised the graphical form of the Surface Tension Viscosity Parameter correlation.



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SCOPE

- ▶ This section presents the design procedures for baffle sections (sheds and disc-and-donut baffles). To determine the heat transfer characteristics for these devices, see [Section III-F](#).

REFERENCE

INTERNATIONAL PRACTICE

[IP 5-2-1](#), Internals for Towers, Drums and Fixed Bed Reactors

OTHER LITERATURE

1. Colwell, C. J., *Shed and Jet Tray Capacity Guidelines*, 83CET814, July 19, 1983.
2. ER&E Fluid Coker Design Notes, 83HOP51, March 14, 1983.
3. *FCCU Operations Guide Update*, EEPS-004, EE.120E.98, November, 1998.
4. Holmes, P., *Port Jerome FCCU Reactor Overhead Line Coking - Review of Fractionator Survey*, EEEL Memorandum, June 13, 1995.
5. Marut, T. P., *Improved Monitoring/Control/Performance of Baytown Refinery's FCCU 3 BPA Circuit*, 95GCD023, May 3, 1995.
6. O'Bara, J. T., *OLA-3 Quench Tower Capacity Study*, Interoffice Memo No. 54821, June 18, 1975.
7. Peruyero, J. M. A. and Shin, S., *Fluid Coking / FLEXICOKING Fractionator Fouling Mitigation*, EE.123E.99, September, 1999.
8. Sideropoulos, T., *FCCU Fractionator Slurry Pumparound Improvements*, Marathon Oil Co., 96CET145, August 23, 1996.

BACKGROUND

In large towers, such as steam cracker primary fractionators and FCCU and coker fractionators, wash zones or slurry pumparounds are often provided to remove entrained bottoms, tar, catalyst fines, dirt, coke particles, or dark-colored high-boiling components from the material being distilled. These sections are characterized by a high degree of vapor "scrubbing," low-pressure drop, and a low degree of "fractionation" and heat transfer. Since trays are subject to plugging, baffle sections are often used instead. The low liquid residence time (holdup) characteristic of these devices tends to minimize coking, and the large open area prevents plugging.

- ▶ Grids can also be considered instead of sheds in FCCU fractionator slurry pumparounds. See [Section III-G](#) for details on grids. Before designing such a grid section, however, the designer should contact a FRACTIONATION SPECIALIST for relevant commercial experience.

DEFINITIONS

- ▶ **Baffle sections** contain tower internals designed to cause liquid to cascade down the tower in a series of "curtains," through which the vapor must pass as it rises through the tower. Two common types of baffle sections are **sheds** and **disc-and-donuts** as shown in [Figure 1](#). Also see definitions of horizontal free flow area, curtain area, effective baffle spacing, and truss height in [Figure 1](#). For chord heights, lengths and areas see [Section III-K](#).

APPLICATIONS

- ▶ **Baffle sections** are generally used in the desuperheating zone of FCCU and coker primary fractionators, coker scrubbers and in other severely fouling services such as slurry strippers.

APPLICATIONS (Cont)

- The table below, which is based on operating experience, lists the lower and upper operating limits for most baffle and shed section 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)	4 (28)	450 (3100)
Temperature, °F (°C)	123 (51)	788 (420)
Diameter, ft (mm)	2.5 (762)	33 (10060)
Physical Properties		
Surface tension, dyne/cm (mN/m)	1 (1)	75 (75)
Liquid viscosity, cP (mPa•s)	0.05 (0.05)	200 (200)
Vapor density, lb/ft ³ (kg/m ³)	0.04 (0.64)	5 (80)
Liquid density, lb/ft ³ (kg/m ³)	22 (352)	80 (1300)
Baffle/shed spacing, in. (mm)	12 (300)	36 (900)
Free area as % of A _s	30	60
Curtain area as % of A _s	32	101
Gap as % of shed spacing	– 50 (overlap)	59
Number of liquid passes	1	18
Liquid rate, gpm/in. (dm ³ /s/m) of shed edge	1 (2.5)	16 (40)
gpm/ft ² (dm ³ /s/m ²) of A _s	3.8 (2.5)	59 (40)
Distribution weir height, in. (mm)	0 (0)	4 (100)
Distribution hole size for notched weirs, in. (mm)	0.1875 (5)	0.5 (13)

BAFFLE SECTION DESIGN

Tower Diameter and Jet Flooding - If trays are to be installed above the baffle section, the tower diameter calculated for the trays will usually set the baffle section diameter as well. Otherwise, the tower diameter can be obtained (or checked) by setting the design vapor load per unit of superficial area (V_L / A_s) equal to 90% of the allowable as calculated from **Eq. (1a)** or **(1b)** below. Since $(K_{\sigma\mu})_B$ is essentially fixed for a given system, the only way to increase capacity is by increasing the effective baffle spacing (H), by decreasing baffle area (i.e., by increasing A_f / A_s) or by decreasing liquid rate (Q_L / A_s). Limitations on A_f / A_s are discussed in a subsequent paragraph under **BAFFLE SECTION DESIGN - Horizontal Layout**.

$$\left[\frac{V_L}{A_s} \right]_{\text{allow}} = 0.228 (H)^{0.4} (K_{\sigma\mu})_B \left[\frac{A_f}{A_s} \right]^{0.45} (e)^{-0.014 Q_L / A_s} \quad (\text{Customary}) \quad \text{Eq. (1a)}$$

$$\left[\frac{V_L}{A_s} \right]_{\text{allow}} = 0.01893 (H)^{0.4} (K_{\sigma\mu})_B \left[\frac{A_f}{A_s} \right]^{0.45} (e)^{-0.0206 Q_L / A_s} \quad (\text{Metric}) \quad \text{Eq. (1b)}$$

where: $V_L = q_v \left[\frac{\rho_v}{\rho_L - \rho_v} \right]^{0.5}, \text{ ft}^3/\text{s} \text{ (m}^3/\text{s)}$

q_v = Volumetric vapor rate, ft³/s (m³/s)

ρ_L = Liquid density at conditions, lb/ft³ (kg/m³)

ρ_v = Vapor density at conditions, lb/ft³ (kg/m³)

H = "Effective" baffle spacing, in. (mm). See **Figure 1**.

Note: Baffles are usually supported by trusses that are formed integrally with the baffle. Since these trusses reduce the curtain area by their depth [which is assumed to be 4 in. (100 mm) for new designs], the "effective" baffle spacing H equals the vertical baffle spacing minus 4 in. (100 mm). The baffle spacing should also be debitted further if weirs are used. See **Figure 1** for details.

A_f = Horizontal free flow or open area, (i.e., superficial area minus the baffle area in a given horizontal plane). See **Figure 1, Section A-A**.

Note: If curtain area $A_c < 1.3 A_f$, see discussion entitled **Curtain Area and Vertical Spacing**.

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BAFFLE SECTION DESIGN (Cont)

A_s = Tower superficial area, ft² (m²)

Q_L = Liquid rate, gpm (dm³/s)

$(K_{\sigma\mu})_B$ = From **Figure 2**, or calculated from:

$$f_{(\sigma,\mu)} = \frac{\sigma_L - \sigma_{STD}}{(\sigma_L \sigma_{STD})^{0.5}} \quad (K_{\sigma\mu})_B = 1.58^{f_{(\sigma,\mu)}} \quad \text{Eq. (1c)}$$

where: $\sigma_{STD} = 10^a$ where $a = 1.68 - [0.276 / \mu_L^{0.45}]$

Note: Truncate $(K_{\sigma\mu})_B$ to 1.0 if a value greater than 1.0 has been calculated.

σ_L = Liquid surface tension at conditions, dynes/cm (mN/m)

σ_{STD} = Standard surface tension, dynes/cm (mN/m)

μ_L = Liquid viscosity at conditions, cP (mPa•s)

- Bulge Loadings** - For services where superheated vapors must be cooled (such as in FCCU, coker and steam cracker primary fractionators), the designer should determine whether any of the reflux entering the baffle section or any of the recirculating pumparound will be vaporized and condensed within the heat transfer section. This can best be achieved by varying the number of theoretical stages to match the liquid drawoff temperature (2 or 3 stages are typical). The theoretical stage with the highest loadings should be used for design purposes. Such vaporization and condensation sets up an internal recycle which increases tower loading significantly (10-30%). This increase in loadings is referred to as the "bulge" loadings. These loadings usually set baffle section diameter.

Ultimate Capacity - The baffle section design calculated from **Eq. (1)** should be checked for an ultimate capacity limitation by the equation given below [**Eq. (2)**]. If the ultimate capacity vapor load is exceeded, the liquid will be broken up into such fine droplets that the available free area will be insufficient to prevent massive entrainment. The ratio of the design vapor load (V_L) to the ultimate capacity vapor load ($V_{L(Ult)}$) must be kept below 90%. If necessary, the tower diameter must be increased, even though the flooding limitation built into **Eq. (1)** has already been satisfied. In most cases, the diameter calculated from **Eq. (1)** will provide sufficient free area to satisfy the ultimate capacity limitation. However, some low-pressure towers that have been debottlenecked in the past may be close to their ultimate capacity.

$$V_{L(Ult)} = 0.73 A_s \left[\frac{\beta}{1 + \beta} \right] \left[\frac{\sigma_L}{\rho_L - \rho_v} \right]^{0.25} - 0.00312 Q_L \quad (\text{Customary}) \quad \text{Eq. (2a)}$$

$$V_{L(Ult)} = 0.4452 A_s \left[\frac{\beta}{1 + \beta} \right] \left[\frac{\sigma_L}{\rho_L - \rho_v} \right]^{0.25} - 0.0014 Q_L \quad (\text{Metric}) \quad \text{Eq. (2b)}$$

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

Other terms were defined previously for **Eq. (1)**.

- Horizontal Layout** - If two adjacent shed rows or a disc and its adjacent donut are superimposed on each other, there may be either a projected gap or a projected overlap (see **Figure 1**). A design with no gap, or even a slight overlap (~1-2 in.; 25-50 mm), is desirable; however, a gap is permissible if it doesn't exceed 40% of the sum of the "effective" vertical spacing of the baffles plus 4 in. (100 mm) or the existing truss height, whichever is greater. Therefore, the maximum permissible gap can be expressed as follows:

40% x ("effective" vertical spacing + 4 in. [100 mm]) or

40% x ("effective" vertical spacing + truss height), whichever is greater.

- The truss is the support member running underneath the length of the shed panel. It is important to note that as the shed gap is increased, the efficiency of the sheds will directionally decrease based on limited data from Fractionation Research Incorporated (FRI).

The number of sheds per row is influenced by the vertical spacing between rows as well as the desire to keep the shed width below 24-30 in. (600-750 mm). As a first approximation, the number of sheds in the top row can be calculated from $D_t / 4$ (Customary) or $D_t / 1200$ (Metric) where D_t is the tower diameter. The designer should also try to keep the width of all full-sized baffles the same, regardless of whether they are in an odd or an even numbered row. The width (or chord height) of the two smaller side baffles should be about 2/3 the width of the full-sized baffles.