



DESIGN PRACTICES

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Revision Memo

12/01 Modified **Table 1B** to reflect most recent Kock-Glitsch data available for **FLEXGRID #2** and **FLEXIGRID #3** style grids.

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SCOPE

This section discusses the techniques for designing towers containing grid or packing for use in vapor-liquid operations. Topics covered herein are the choice of grid and packing type and size, the determination of tower diameter and packed height, and the selection of tower internals. A step-by-step procedure for calculating packed height as well as design guidelines for spray nozzles is also provided.

For the design of vapor distributors and chimney trays, see [Section III-H](#). The methods given in [Section III-F](#) should be used for sizing a packed bed in direct contact heat transfer service. [Section IV-C](#) should be used to design packed towers for liquid-liquid extraction / treating applications.

REFERENCES

DESIGN PRACTICES

- [Section III-H](#) Tower Internals
- [Section III-I](#) Tray Efficiency
- [Section IV](#) Extraction Towers

♦ OTHER LITERATURE

- Colwell, C. J., *Recent Developments Improve Packed Tower Performance*, ER&E Report No. EE.21E.86 (February, 1986).
- Colwell, C. J., *New Pall Ring Packing Efficiency (HETP) Correlation*, ER&E Report No. EE.52E.77 (April, 1977).
- Colwell, C. J., *Design Methods for Modern Tower Packings*, ER&E Report No. EE.13E.89 (February, 1989).
- Iyengar, J. N., *Performance Evaluation of New Deentrainment Grids for Towers*, ER&E Report No. EE.24E.88 (March, 1988).
- Melin, G. A., *New Packed Tower Flooding Correlation*, ER&E Report No. EE.8ER.71 (May, 1971).
- FRI reports on structured packing / random packing maldistribution effects.
- EMRE PEGASYS Users Manual, Chapter 4.
- Niedzwiecki, J. L., *Computer Information Memorandum, Packed Tower Design Program #3454*, ER&E Report No. EE.36E.89 (June, 1989).
- Mobil Tower Internal Program (MoTIP) User Manual, A&A NO: 003-42 (December, 1993).

♦ BACKGROUND

Packing has been recommended for many of the same applications as trays in various process units. Designers should be aware, however, that packed tower designs (primarily the liquid distributors) are far more sensitive to fouling than trays. Therefore, it usually pays to thoroughly explore all tray options for debottlenecking before resorting to packing. This is especially true if the tower has experienced fouling in the past by solids imported from the feed, distillate drum, or from corrosion products spalling off the vessel wall, support beams, etc. For applications where packing is recommended, see the discussion under **PACKING AND GRID APPLICATIONS**. If after investigating trays, packing still appears to be the only option to meet the required capacity and the tower has a fouling history, special measures should be taken to prevent liquid distributor fouling, as detailed further in **APPENDIX A**.

In addition, the recent development of the Koch-Glitsch NYE tray, the Sulzer MVG tray, NorPro Triton tray and other new tray technology may offer more effective ways to debottleneck trayed towers. Also, since packing usually costs more than trays, the use of a "trayed" solution is normally more economical. However, structured packing offers the highest capacity debottleneck for most vacuum and atmospheric to moderate pressure towers, exceeding what is possible with even high capacity trays in these towers by 15+%.

The equations given in this section for predicting packing capacity, efficiency (HETP), and hydraulics have been derived largely from Fractionation Research, Inc., (FRI) data, supplemented by data from simulator and commercial tests. These equations represent the data far more accurately than do the correlations prepared by FRI, various vendors, or those available in the literature.

- ♦ Equations in the text of this section are numbered in the same way as they appear in the **PACKING / GRID CALCULATION FORMS** located in **APPENDICES C** (Customary) and **D** (Metric). Those equations not discussed in the text are shown in the appropriate section of these calculation forms. Wherever possible both the customary and the metric equations are shown in the text, the latter shown with an "M". However, if the equation is complex, the metric version has been omitted in the text for clarity but can be found on **PACKING / GRID CALCULATION FORM (METRIC), APPENDIX D**.



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DEFINITIONS

Dumped or Random Packing - These packings are dumped into the tower and orient themselves randomly. They are manufactured in various sizes and shapes [Pall rings, (various vendors), Ballast rings (Koch-Glitsch), Flexirings (Koch-Glitsch), Nutter rings (Sulzer), Intalox Metal Tower Packing (IMTP by Norton), etc.]. The capacity, efficiency and pressure drop characteristics vary with packing size and type. The comparative performance characteristics of the various packings are given in **Figure 3** where the nominal 2 in. (50 mm) sized packings are used as the base. See **Figure 23, Section III-A** for typical photos. Random packing generally has more risk than structured packing, due to possible packing problems (non-randomness due to installation procedures) and less ability to handle maldistributed liquid.

Structured Packing - This packing is fabricated from long sheets of metal with the pieces held together by bands or tie rods. Typically, each bundle is about 8 to 12 in. high, 15 in. wide, and up to 6 ft long (200 - 300 x 375 x 1800 mm). It is installed in layers and each layer is oriented at 70° to 90° to the layer below. Different "sizes" are available by varying the crimp height. See **Figure 24, Section III-A** for typical photos. Please note under **PACKING AND GRID APPLICATIONS** that structured packing has a more limited range of applicability than random packing, but is often the preferred packing option within that range of applicability.

Structured packing offers capacities up to 30% higher than Pall rings for equal efficiency or efficiencies up to 50% higher at the same capacity. In addition, pressure drop is as low as one half that of Pall rings. Prices of structured packing have come down recently, due to increased competition among the suppliers and higher fabrication capacity. After accounting for the reduced volume of packing often required due to its higher efficiency, it has about the same cost of dumped packing of the same capacity and material of construction.

Structured Packings are supplied by Koch-Glitsch (**FLEXIPAC**), Norton (**INTALOX STRUCTURED**), Montz (**MONTZ**) and Sulzer (**MELLAPAK**).

Another form of structured packing is fabricated from wire gauze and has very high efficiency. Because of its very high cost, however, its use has been limited to a few specialty applications. Your FRACTIONATION SPECIALIST should be consulted for any application of gauze packings.

Grid - This device is composed of panels that contain vertical, sloped, and horizontal surfaces that promote mass transfer and enhance entrainment removal. See **Section III-A, Figure 25** for grid photos as well as the discussion of grids in that section. They have high open area, resulting in high capacity, low pressure drop (about 1/10 that of trays), and a high tolerance to fouling. However, the amount of surface area per unit volume is much less than that of a dumped packing and thus the grid's efficiency is only about 1/2 that of 2 in. (50 mm) Pall rings. The same design and rating calculations for packing are also applicable for grid, with specific design parameters provided in **Table 1**.

PACKING AND GRID APPLICATIONS

For most new towers, trays are usually cheaper than packing (or grid). In grass roots vacuum towers, however, the low pressure drop provided by packing usually will generate process credits that outweigh the incremental cost of packing.

For **debottlenecking**, conventional tray modifications as well as new, high capacity tray types should be considered first. A packed tower design will require a fouling resistant liquid distributor, as well as strainers on most liquid streams that enter the tower. One of the primary drawbacks of both random and structured packing, is that because of ancillary internals required between beds, it is not feasible in most cases to have the flexibility of multiple feed or draw locations without significant loss of packed height. These ancillary internals also reduce the effective straight side of actual packing in revamp towers, and must be taken into account in the design or debottleneck phase.

Some of the key areas where packing and grid are still recommended are listed below. In each case, successful operating experience justifies their continued use:

PACKING

Recommended Applications

- **Vacuum Pipestill Fractionation Sections** - Lower pressure drop will provide an increased cut point or energy savings due to lower flash zone pressure. In addition, structured packing is especially useful to debottleneck lube vacuum pipestills. It has the lowest pressure drop per theoretical stage.
- **Heat Transfer Service** - Vacuum pipestills or other non-fouling services where a low pressure drop is required.
- **Small-Diameter Towers** - For diameters up to about 3 ft (900 mm), both random packing and Sulzer cartridge trays should be considered.
- **FCC Main Fractionators** - Had good success debottlenecking restricted parts of these towers with structured packings, with the added advantage that wet gas compressor capacity (or main air blower capacity) was also achieved due to the lower pressure drop. Use of structured packing in sections where frequent salt deposition is expected should be evaluated closely from a risk and mechanical / materials design standpoint.

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PACKING AND GRID APPLICATIONS (Cont)

- **Aromatics Separation** - The use of structured packing to debottleneck BTX towers has been successful at providing capacity increases over what is possible with high capacity trays.
- **Corrosive But Non-Fouling Services** - Typically, for absorption or stripping operations, especially in the gas treating area.
- **Sidestream Strippers** - Packing, because of its higher efficiency, may provide significant steam savings in towers with a large steam usage. Packing should be considered as an alternative to trays in both new and existing strippers.

Applications NOT Recommended

- **Vacuum Pipestill Bottoms Strippers** - These applications are no longer recommended because of operating problems caused by imported solids.
- **Debottlenecking of Some Light Ends Towers** - Imported as well as internally generated solids have created problems in some of these towers over the past 3 years. Evaluate new "trayed debottlenecking devices" (NYE, MVG tray, Triton tray, and others) before considering packing. If packing is the only viable option, discuss your case with the FRACTIONATION SPECIALIST to evaluate the risks involved. Past inspection reports on the tower shell, support beams, feed drum, and reflux drum would be helpful in assessing the severity of any potential fouling problem.
- Structured packing is not normally recommended for distillation applications above 100 psia (670 kPa) or when the liquid rate is greater than 20 gpm/ft² (13.6 dm³/s•m²). However, recent FRI data on Intalox 4T packing showed excellent performance with the iC4/nC4 system at 165 psia (1100 kPa). Also an application of Intalox 4T at 24 gpm/ft² (16.3 dm³/s•m²) in a dehexanizer met design conditions. If your distillation debottleneck application is above 100 psia (670 kPa) or has a liquid rate greater than 20 gpm/ft² (13.6 dm³/s•m²), please consult with a FRACTIONATION SPECIALIST regarding the best internal based on current data for high capacity devices.
- **Lower and Upper Operating Limits** - The table below, which is based on over 30 years of operating experience, lists the lower and upper operating limits for most packed towers. If your case does not fall within these limits, contact your FRACTIONATION SPECIALIST to see what, if any, problems may exist.

TABLE A
PACKED TOWER OPERATING LIMITS

VARIABLE	LOWER LIMIT	UPPER LIMIT
Pressure	0.5 psia (3.45 kPa)	Random: 350 psia (2400 kPa) Structured: 100 psia (670 kPa)
Temperature	32°F (0°C)	750°F (400°C)
Physical Properties		
Surface Tension	2 dynes/cm or (mN/m)	75 dynes/cm (mN/m)
Liquid Viscosity	0.05 cP or (mPa•s)	2 cP or (mPa•s)
Vapor Density	0.005 lb/ft ³ (0.08 kg/m ³)	5 lb/ft ³ (80 kg/m ³)
Liquid Density	20 lb/ft ³ (320 kg/m ³)	80 lb/ft ³ (1280 kg/m ³)
Bed Height	3 ft (900 mm)	35 ft (10,700 mm) or 12 theoretical plates, whichever is less.
Packing Type	Must be in Table 1A or 1B	Must be in Table 1A or 1B
Liquid Loading	Random: 0.25 gpm/ft ² (0.17 dm ³ /s•m ²) Structured: 0.1 gpm/ft ² (0.068 dm ³ /s•m ²) Grid: 0.05 gpm /ft ² (0.034 dm ³ /s•m ²)	70 (48 dm ³ /s•m ²) 20 (in distillation) (13.6 dm ³ /s•m ²) 50 (34 dm ³ /s•m ²)
Liquid Distributor Design	Per APPENDIX A of this Design Practice. Vendor test requirements listed in APPENDIX B.	Per APPENDIX A of this Design Practice. Vendor test requirements listed in APPENDIX B.
Vapor Distributor	Per text in this Design Practice Section.	Per text in this Design Practice Section.

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PACKING AND GRID APPLICATIONS (Cont)

GRID

Grid should be used primarily in the wash section of heavy hydrocarbon towers (vacuum pipestills, cat fractionators, fluid coker and FLEXICOKER scrubbers, etc.) for entrainment removal. A secondary use is to debottleneck pumparound sections of heavy hydrocarbon towers. Split beds of grids on the bottom and structured packing on top are recommended for cases where high entrainment removal and some fractionation is required.

Grid has also been used in Venturi Scrubber Separator drums for deentrainment applications.

SELECTION OF PACKING AND GRID TYPE

PACKING

Properties such as capacity, efficiency, turndown ratio, corrosion, fouling resistance, and cost must be considered when choosing a packing or tray for a tower design which will minimize investment and/or operating costs and provide reliable operation. Any tower debottlenecking or design job, whether packing or trays, should begin with a simulation of the tower operation, determining if the stage count and feed location is optimal for the new design basis conditions. Often this becomes an iterative process, where the tower feed rate / product specifications and internals are varied until an acceptable design condition is achieved. There may be more than one solution, especially if more than one type of internal is being considered. To help designers evaluating packing options when doing this work, **Figure 3** was developed. Designers can quickly determine the relative capacity and efficiency of various packing types and sizes by using **Figure 3**. Remember, however, that **Figure 3** is for screening purposes only. This figure uses the 2 in. (50 mm) Pall ring as the base point.

Remember, this figure can only be used to narrow the range of potential packing selections for specific applications. The final choice of internals would depend on more detailed design calculations carried out using PEGASYS or the **PACKING / GRID CALCULATION FORM (APPENDICES C and D)**.

The packing types included in **Table 1** are supported by a large amount of independent as well as vendor supplied performance data, and are recommended for commercial use. Several other types of packing are also available commercially but are not included due to the small amount of independent data available. See your FRACTIONATION SPECIALIST for design information if the need arises. However, there is generally no advantage to use these packings over the ones listed.

For **new designs**, dumped packing should be evaluated based on using Nutter Rings, IMTP, or CMR. Use **Table 2** and previous experience in a specific service for guidance in selecting packing size. For towers operating at high vacuum structured packings should be the first choice. For structured packing, previous experience with the specific service and **Table 2** should also be used to select packing size. A specific surface area of around 65-76 ft²/ft³ (210-250 m²/m³) is a common starting point for large diameter towers (for example, MELLAPAK 250Y, Flexipac 2Y or Intalox 2T).

For **revamps**, the selection of packing size will favor the larger sizes: 2 in. (50 mm) or larger for increasing capacity. For increasing efficiency, the smaller sizes [2 in. (50 mm) or smaller] are usually considered. Packing sizes less than 1 in. (25 mm) are usually not recommended in commercial towers. Structured packing should be considered if within the ranges shown in **Table 2** and earlier in **Table A**.

PACKING MATERIALS SELECTION CONSIDERATIONS

Most Applications Will Use Stainless Steel Packing - The corrosion rate for carbon steel is too high to consider its use in most, if not all, packing applications. Therefore, stainless steel or other alloys are typically required. The packing's thickness has been reduced as much as possible to reduce costs. Therefore, for random packing the thickness is 0.012 to 0.028 in. (0.3 to 0.7 mm) and for structured packing 0.006 to 0.008 in. (0.15 to 0.20 mm). These thicknesses are adequate mechanically, providing crushing is avoided during installation by using boards to distribute the installer's weight. However, there is no tolerance for corrosion. Therefore, a MATERIALS SPECIALIST should approve the selection of all packing materials. It is also important that all ancillary internals, including liquid distributors, internal feed piping, feed flashboxes, chimney trays, etc. be stainless steel in packed tower applications. This minimizes the risk of fouling of liquid distributors due to corrosion products from carbon steel internals. This is especially important in wet H₂S services.

In addition, the corrosion products from carbon steel packing can foul the packed bed, the liquid distributor located below, and the downstream heat exchange equipment. The use of stainless steel packing and ancillary internals will help eliminate these problems.

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SELECTION OF PACKING AND GRID TYPE (Cont)

Plastic Pall rings or other equivalent plastic packings should be considered for aqueous systems when corrosion is a problem, since they have good corrosion resistance, high capacity and high efficiency. The use of polypropylene, the standard plastic material, is limited to temperatures less than 260°F (125°C) and to services where condensed hydrocarbons are not present. Selection of one of the plastic packings for use in non-aqueous systems should be made carefully, since softening or even dissolution in various solvents has been observed. The polypropylene Pall ring is normally the standard choice for plastic packing, and design parameters are included in **Table 1A** for this type. Intalox saddles above 200°F (93°C) have demonstrated a tendency to “nest” (lock together) and therefore limit capacity after long operating periods. If vendors recommend newer, high-performance plastic packings consult your FRACTIONATION SPECIALIST for guidance.

Ceramic packings (with Intalox saddles being preferred) are sometimes economically attractive in corrosive services. Although their expected life is not as long as that of plastic packing, successful operation of 10 years or more may be obtained if the tower is run properly. Tower upsets from either vapor surges or severe temperature changes may cause breakage and plugging and require packing replacement. Also, some attrition may occur after startup with new packing, thereby producing fine ceramic particles. Ceramic packings are generally resistant to acids, alkalis, and solvents, with the exception of hot caustic and hydrofluoric acid. In hot caustic solutions, life on the order of 1 year can be expected either for operation with 10% caustic up to 125°F (50°C) or for 1% caustic up to 200°F (95°C). Ceramic packings should be wet packed to avoid damage and breakage caused by dumping the packing elements dry.

SELECTION OF GRID TYPE

For a given service, grid selection is a function of the capacity required and the fouling tendency of the service. The various grids available include:

Koch-Glitsch GRID - Has good capacity and pressure drop characteristics, and the EF25A style is the basis for comparisons with other grid types.

Koch-Glitsch FLEXIGRID is available in two styles.

- Style 2 - Is the most “open” of the grids. It has 28% more capacity than Koch-Glitsch EF25A and is also the most resistant grid to fouling. Its efficiency, however, is lower and 40% more grid height is required for equal mass transfer, heat transfer, or entrainment removal.
- Style 3 - Is equivalent to Koch-Glitsch EF25A.

Sulzer #3 SNAPGRID - has 14% more capacity than Koch-Glitsch EF25A, but because of its poorer efficiency, requires 20% more height.

For most applications the designer should note in the Design Specification that Koch-Glitsch EF25A or Koch-Glitsch FLEXIGRID Style 3 are equally acceptable. The final choice should be made during detailed engineering based on vendor's bids. If the special characteristics of Koch-Glitsch FLEXIGRID Style 2 or Sulzer #3 SNAPGRID are required, the designer should recognize that the cost may be greater than the other grids, since there is no other demonstrated competitive grid currently available.

BASIC DESIGN CONSIDERATIONS COMMON TO PACKING AND GRID

PACKING CAPACITY

An evaluation of the heritage Exxon and heritage Mobil correlations for efficiency and capacity of packing has been carried out. It was determined that the correlations for random packing are very similar and yield statistically similar results. Therefore no change in the design correlations for random packing is being proposed. The evaluation of the structured packing correlations shows that the heritage Mobil correlations are more accurate for hydrocarbon distillation and also predict higher capacities than the heritage Exxon correlations. It is recommended at this time to use the Exxon structured packing correlations (given in this section of Design Practices) for grass roots and major revamp designs. The Mobil correlations should be used (for hydrocarbon distillation only) as a second check on the maximum capacity possible with structured packing for the purposes of economic evaluation and tower auxiliary equipment sizing. A brief report documenting this work and the Mobil capacity correlation with parameters for structured packing is being prepared for FRACTIONATION SPECIALISTS. Please consult your FRACTIONATION SPECIALIST if you are evaluating the debottlenecking of a hydrocarbon distillation tower with structured packing. Further work in this area is planned to finalize which set of correlations to use for structured packing performance estimation (Exxon, Mobil, Fractionation Research, Inc. or other). This section of the Design Practices will be updated again when that work is complete.

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BASIC DESIGN CONSIDERATIONS COMMON TO PACKING AND GRID (Cont)

The tower diameter should be chosen to minimize total investment while insuring operation under satisfactory hydraulic conditions. Generally, packed towers should be operated between 25 and 85% of flood. Tight designs run the risk of having excessive liquid entrainment or even flooding. On the other hand, operation at very small percents of flood is unwise, both economically and because of reduced efficiency due to insufficient vapor / liquid contacting, usually caused by liquid distributor turndown problems.

Base the design on the maximum loaded stage. If loadings change significantly, however, consider splitting the bed into two or more sections (i.e., by using different packing sizes). Split beds of random packing or random / grid should incorporate separator screens to prevent packing element nesting, which may reduce packing capacity. The screen should have at least 90% open area and is usually made of wire cloth with openings 25% smaller than the smallest packing dimension. Significant loading changes are most likely to occur in strippers and pumparounds of heavy hydrocarbon towers. In vacuum towers this practice can help reduce the pressure drop. If the loading change is large, the designer should determine whether swaging the tower is justified. For packed beds in condensing pumparound service, capacities of up to 100% of flood have been demonstrated as long as the average flood did not exceed 85%. These packed beds did not result in a capacity problem and had high heat transfer coefficients, but also demonstrated high pressure drop. High floods can be tolerated at the bottom of highly condensing regions because the vapor load drops so rapidly that the top of the bed is not flooded.

The percent of flood for an **existing tower** can be calculated from the following equation. For the metric equations and their respective units, refer to **APPENDIX D**.

$$\% F_c = 100 \frac{C_s}{C_{SF}} \quad \text{from Eq. (2b3)}$$

- where:**
- A_s = Tower cross-sectional area, ft²
 - C_s = V_L / A_s , actual C-factor, ft/s
 - C_{SF} = $K_L K_{\sigma\mu}$, C-factor at flood, ft/s
 - $\% F_c$ = Calculated percent of flood
 - K_L = Liquid rate parameter, ft/s
 $= (S_2) (S_3)^{(Q_L / A_s)}$
 - $K_{\sigma\mu}$ = Surface tension - viscosity parameter, dimensionless see (**Figure 1**)
(Limit $K_{\sigma\mu}$ to 1.2)
 - Q_L = Liquid rate, gpm at conditions
 - S_2 = Parameter for packing/grid flooding correlation (from **Table 1**)
 - S_3 = Parameter for packing/grid flooding correlation (from **Table 1**)
 - V_L = Vapor load, ft³/s = $q_v \left[\frac{\rho_v}{\rho_L - \rho_v} \right]^{0.5}$
 - q_v = Actual vapor rate, ft³/s
 - ρ_v = Vapor density, lb/ft³ @ conditions
 - ρ_L = Liquid density, lb/ft³ @ conditions

Selecting a diameter for a **new tower** involves choosing a design percent of flood and solving **Eq. (2b3)** for the area necessary to give that value. The details of the calculation are outlined in **APPENDICES C** and **D**. **Table 3** lists the recommended values of design percent of flood for various services.

GRID CAPACITY

Grid capacity can be determined from the procedure outlined above [**Eq. (2b3)**] for all services. However, since most grids are used in heavy hydrocarbon towers, the simplified flooding curves presented on **Figure 2A** or **2B** should be used. Design for 85% of the value read from this figure or from **Eq. (2b3)**. Also see Step 2(b) of the **PACKING / GRID CALCULATION FORM**.

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BASIC DESIGN CONSIDERATIONS COMMON TO PACKING AND GRID (Cont)

♦ LIMITATIONS OF THE EXXONMOBIL CAPACITY CORRELATION

The flooding correlation [Eq. (2b3)] will not predict capacity if foaming occurs. Although 60% of the flooding loadings without foaming has been suggested as the design criterion (Table 3), higher values can be used if justified by past operating experience. There is good evidence (FRI PR Sept 1976) that packing handles foaming services much better than trays, because no high velocity jets of vapor exist to regenerate foam. However, flashing feeds over packed beds in foaming services will still cause capacity problems if not properly designed. The use of anti-foaming agents to eliminate the problem should also be considered although this choice is frequently a high cost option and may have adverse product quality issues.

ULTIMATE CAPACITY

The tower diameter calculated from the preceding flooding correlation [Eq. (2b3)] should be checked for an ultimate capacity limitation by Eq. (2c1) in the **PACKING / GRID CALCULATION FORM**. If the ultimate capacity vapor load is exceeded, the liquid will be broken up into such fine droplets that the available tower area will be insufficient to prevent entrainment. The ratio of design vapor load, V_L , to the ultimate capacity vapor load, $V_{L(Ult)}$, must be kept below 85%. If necessary, the tower diameter must be increased since increasing packing size does not increase the ultimate capacity limit.

♦ PRESSURE DROP

Knowledge of the pressure drop is important for performing process calculations, especially for systems under vacuum. Vacuum tower designs require an iteration on pressure drop and vapor load until a converged design case is reached. The equations for calculating pressure drop are outlined in Step 4 of the **PACKING / GRID CALCULATION FORM** and are discussed below. Constants for these equations are provided in Table 1A or 1B.

The dry pressure drop (ΔP_{dry}) is calculated as if no liquid were flowing through the packed bed from Eq. (4a1) below. Then, the "dynamic" pressure drop (ΔP_{dy}), which is the pressure drop attributed to frictional and holdup effects within the packing, is calculated from Eq. (4a2). As shown in Eq. (4a2), the first term corrects the dry pressure drop via the factor e^b for holdup of liquid flowing as a film along the packing surface and the rise in velocity due to some of the tower volume now being occupied by liquid. The second term "c" empirically accounts for additional liquid holdup other than that along the packing surface. This additional holdup is characteristic of the "loading" region in a packed bed and occurs only at rates above 70% of flood. Eq. (4a5) adds the static head of vapor to obtain the total pressure drop, ΔP_{tot} .

The difference between the total and dynamic pressure drop is small in vacuum to moderate pressure towers, but can be significant when the vapor density exceeds 0.5 lb/ft³ (8 kg/m³). In practice, the right form of the pressure drop depends on the end use. For example, use the dynamic pressure drop (ΔP_{dy}) when only the pressure drop added by the presence of packing is being evaluated. Also, when comparing measured pressure drops in high pressure packed towers, the dynamic pressure drop (ΔP_{dy}) is measured when the external lines leading to a ΔP cell or manometer contain vapor with the **same** density as the internal vapor. On the other hand, if the lines are continually purged with a relatively light vapor, the measured pressure drop may be closer to the total pressure drop.

The total pressure drop of the packed bed (ΔP_{PB}) is found by multiplying the packing pressure drop per unit of height times the packed bed height [see Eq. (4b1) below]. In very high vacuum services where ΔP_{PB} is critical, the designer should also add to (ΔP_{PB}) the pressure drop caused by the liquid distributor and chimney tray (if present). See Section III-H, Table 1 for the chimney tray pressure drop equation.



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BASIC DESIGN CONSIDERATIONS COMMON TO PACKING AND GRID (Cont)

Only the Customary form of each equation is shown below. The metric form of these equations can be found in Step 4 of the **PACKING / GRID CALCULATION FORM (METRIC)**.

$$\Delta P_{\text{dry}} = K_{\text{DP}} V_s^2 \rho_v \quad \text{from Eq. (4a1)}$$

$$\Delta P_{\text{dy}} = \Delta P_{\text{dry}} e^b + c \quad \text{from Eq. (4a2)}$$

$$\Delta P_{\text{tot}} = \Delta P_{\text{dy}} + 12 \rho_v / \rho_w \quad \text{from Eq. (4a5)}$$

$$\text{where: } b = 0.15 \left[\frac{Q_L}{A_s} \right] \left[1 - \frac{7}{a_p} \right] [1 - 0.0106 \rho_L] [1 - 0.002 Q_L / A_s]$$

$$c = 0.000211 [\% \text{ flood} - 70]^{2.5} \text{ for } \% \text{ flood} > 70$$

or

$$= 0 \text{ if } \% \text{ flood} \leq 70$$

and

where:

- a_p = Packing specific area ft²/ft³
- K_{DP} = Dry pressure drop coefficient, from **Table 1A** or **1B**
- Q_L = Liquid rate, gpm
- V_s = Vapor velocity based on tower cross-sectional area, (A_s), ft/s
- ΔP_{dry} = "Dry" pressure drop per height of packing, in. of H₂O/ft of packing
- ΔP_{dy} = "Dynamic" pressure drop per height of packing in. of H₂O/ft of packing
- ΔP_{tot} = Total pressure drop per height of packing, in. of H₂O/ft of packing
- ρ_w = Density of water, 62.4 lb/ft³

$$\Delta P_{\text{PB}} = \Delta P_{\text{tot}} (Z) \quad \text{from Eq. (4b1)}$$

where: ΔP_{PB} = Total packed bed pressure drop, in. of water

EFFICIENCY (HETP)

To determine the required packed height for any given separation, two basic quantities must be known: first, a packing efficiency (i.e., the height of packing required to achieve some unit of separation), and second, a measure of the degree of separation required (in units consistent with the packing efficiency). Three approaches to predicting the required packed height have been developed: the height equivalent to a theoretical plate (HETP) method, the height of a transfer unit (HTU) method, and the overall mass transfer coefficient (K_{OGa}) method. In theory, any problem may be solved using any one of these methods. However, in practice one of the methods may be preferred over the others in a particular design situation (due mainly to the relative ease of the calculations). A detailed discussion of these methods and the calculation procedures associated with them is presented in **METHODS FOR CALCULATING PACKING HEIGHT**.

At liquid rates below 0.2 gpm/ft² (0.15 dm³/s/m²) for hydrocarbon systems and 0.5 gpm/ft² (0.35 dm³/s/m²) for aqueous systems, mass transfer efficiencies may be lower than predicted. This is due to erratic wetting of the packing surface and channeling of liquid through the packed bed. This behavior has not been correlated satisfactorily. For such cases, consult your FRACTIONATION SPECIALIST.

HEAT TRANSFER

- ▶ **Packing** - Along with mass transfer applications, tower packings are useful in various heat transfer services. The necessary design principles for calculating the required packed height are discussed in [Section III-F](#). Capacity limits are the same as for mass transfer applications discussed elsewhere in this section, with the exception that in condensing services, packing flood at the bottom of the bed (using vapor in / liquid leaving) can be 100%, provided the average flood does not exceed 85%.

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BASIC DESIGN CONSIDERATIONS COMMON TO PACKING AND GRID (Cont)

- ♦ **Grid** - Since grids have poor fractionation efficiency, their heat transfer efficiency is also low. Hence, a deeper, more expensive bed is required for accomplishing heat transfer with grids than with packings. Therefore, most new designs will contain one of the structured packings because of their better efficiency, high capacity, and low pressure drop (similar to grid). However, in some cases the use of grid in a given section of a tower might still be justified. In such a case, while the bed depth would be greater, the diameter would be smaller. This might permit using a straight-sided tower or one with a smaller overall diameter. The final decision should be based on economics.

Nevertheless, grid can be justified in some debottleneck cases, where their very high capacities are required. A split bed arrangement may also be considered for these cases, i.e., grid in the bottom portion of a given bed for maximum capacity and packing in the top portion for maximum heat transfer efficiency. (This can also be done with two different sizes packing.) When a split bed involving random packing is used, provide a screen on top of the grid to ensure that the packing will not migrate into the grid's openings. The screen should have at least 90% open area and is usually made of wire cloth and have openings 25% smaller than the smallest packing dimension. In addition, for many revamp cases, structured packing should be evaluated since it may be more cost-effective than grid.

The height of grid required for heat transfer applications can be calculated from [Section III-F](#).

LIQUID HOLDUP

The equation given below can be used to estimate h_L , the fraction of liquid held up in a packed bed. It is applicable to random and structured packings as well as grid. This value can then be used with the packed bed height to calculate the volume of liquid holdup, v_h . This volume is often needed for calculating packed bed support beam loadings as well as for determining how much liquid drains to the bottom of a tower when the vapor rate is stopped. For the metric equation, refer to **APPENDIX D**. Note that this equation applies only up to 100% of flood.

$$h_L = 0.0072 \left[\frac{Q_L}{A_s} \right]^{2/3} \frac{(a_p)}{\rho_L} + \frac{7.1}{\rho_L} e^{-0.0036 (109 - \% \text{flood})^2} \quad \text{from Eq. (5a1)}$$

where: h_L = Fraction of packed bed volume occupied by liquid, dimensionless

$\frac{Q_L}{A_s}$ = Liquid flow rate per unit of tower cross-sectional area, gpm/ft²

a_p = Packing specific area ft²/ft³ (from **Tables 1A and 1B**)

ρ_L = Liquid density, lb/ft³

$$v_h = (h_L) (Z) (A_s) \quad \text{from Eq. (5b1)}$$

where: v_h = Volume of liquid held up in a packed section, ft³

Z = Packed bed height, ft.

A_s = Tower cross-sectional area, ft²

SPECIAL DESIGN CONSIDERATIONS FOR PACKING

Good performance of a packed tower depends as much on the auxiliary internals as on the type of packing used. The choice of internals can affect both tower efficiency and capacity. Proper initial distribution of the liquid and vapor is essential to provide the vapor / liquid contacting needed to attain maximum packing efficiency. Although support plates or bed limiters cannot improve capacity, it is necessary to provide sufficient open area for these devices so that they do not reduce tower capacity. A typical arrangement of packing and internals is shown in **Figure 4**. Additional details / dimensions for the various internals needed to complete a packed tower design can be found in **Table 5**.

♦ LIQUID DISTRIBUTOR SELECTION CRITERIA

The improved performance offered by packing can be easily lost without good liquid distribution. Although the need for good distribution has always been recognized, Fractionation Research, Inc. (FRI) test data have shown improvements in efficiency of 50% on average and up to 80% in many high pressure, light ends systems, with the use of new distributors. A limited number of recent distributor revamps within ExxonMobil's towers have also improved efficiency significantly. Thus, the choice of distributor is critical for achieving optimum packed tower performance.

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SPECIAL DESIGN CONSIDERATIONS FOR PACKING (Cont)

To ensure that the desired efficiency (HETP) is obtained commercially, the "quality" of the liquid distributor must be GOOD. The term "quality" refers to how close the actual distributor comes to an ideal distributor. While current technology does not permit a quantitative (numerical) rating for each type of distributor, if the guidelines outlined in **APPENDIX A** are followed, the distributor "quality" should be GOOD.

The type of distributor to use depends on the amount of fractionation needed, tower size, system fouling tendency, liquid rate and (occasionally) packing type. The best distributor for a given application depends on optimizing many design parameters as well as cost. These parameters include drip point density, uniformity of drip point distribution, distributor orifice size, distributor orifice elevation, and other design parameters discussed in **APPENDIX A**. GOOD quality distributors consist of the Narrow Channel and the Orifice Pan types. Spray nozzle distributors have POOR quality. **Figure 5** shows a picture of each of these distributors while the text below highlights their characteristics.

For most applications, the preferred distributor is a trough-style distributor. This is because the troughs are sealed elements, and will not leak. They are also easily removable, unlike seal welded orifice pans. Trough style distributors also offer higher vapor flow area than orifice pan distributors, without loss of pour point uniformity that normally results when high open area orifice pans are used. If the liquid rate is above 30 gpm/ft² (20 dm³/s/m²), a wide trough distributor or an Orifice Pan may be required. Trough distributors have been demonstrated with good liquid distribution performance up to about 40-45 gpm/ft² (27-31 dm³/s/m²) when designed following ExxonMobil guidelines. These guidelines include limiting the parting box (predistributor trough) liquid flux to 150 gpm/ft² (100 dm³/s/m²) and also limiting the maximum linear trough liquid velocity to less than 0.6 ft/s (0.2 m/s). Note from the listing below that the Orifice Pan is NOT recommended if the liquid rate at turndown is less than 10 gpm/ft² (6.7 dm³/s/m²). This is because the seams in the pan leak and cause maldistribution problems. Leakage can be eliminated by seal welding the orifice pan seams, but the vendor should compensate by using thicker deck material to avoid any warpage of orifices. Slight warpage of the pan elevation is not significant and does not affect overall performance.

If your case falls at the liquid rate borderline, consider specifying that either a Narrow Channel or an Orifice Pan can be used, with the choice being left to the vendor. If in doubt, consult your FRACTIONATION SPECIALIST.

If the liquid rate is very low [say less than 1.5 gpm/ft (1.0 dm³/s/m²)], a special distributor such as the Sulzer MTS 109 or the Sulzer VEP style narrow trough distributor may be required. Such unique cases should be discussed with your FRACTIONATION SPECIALIST.

To guarantee that the distributor meets or exceeds "quality" expectations, a number of guidelines have been provided in **APPENDIX A**. For those separations that require a GOOD quality distributor, it is recommended strongly that each distributor be flow tested in the vendor's shop. The criteria for such a test are outlined in **APPENDIX B**. Requests for vendor quotes should specify that the cost of water testing the distributor be included with the quotation. **APPENDICES A** and **B** should also be attached to the Vendor's Quotation Request package.

The distributor flow test procedure outlined in **APPENDIX B** should be included in all packed tower Design Specifications as well as purchase orders for replacement distributors. Furthermore, the designer should check with the FRACTIONATION SPECIALIST to be sure the latest technology is being used and to determine whether **APPENDIX B** has been further updated and should be modified for the case at hand.

Often the distributor flow test is the last item scheduled before hardware shipment. Under rush situations, this places pressure on the vendor and witnessing engineer to pass marginal distributors, due to the impending unit shutdown. Project planning should avoid this by scheduling distributor design and testing as the first item in the vendors supply schedule. Also a full review of the proposed distributor design by a qualified FRACTIONATION SPECIALIST will often find issues which will cause test non-performance and can be corrected prior to fabrication.

Fouling can destroy distributor quality very quickly. To minimize the likelihood of this being a problem, four things have been done. First, the liquid distributor (**APPENDIX A**) should provide for more fouling resistance, for example, by requiring raised orifices. Secondly, external strainers have been recommended for all liquid streams that enter the tower ABOVE the packed bed. This is done to collect solids generated externally during unit upsets. Thirdly, using side orifices with removable flow guides (such as the Koch-Glitsch TNT 727 model) allows cleaning of orifices and troughs during plant turnarounds. Plant turnaround planning may need to incorporate plans for inspection and possible cleaning of packed bed distributors on a regular basis, similar to other equipment. Measurement of the rate of solid accumulation for side orifice troughs vs. future desired run length should be used to make the cleaning decision. A fourth item is to provide screens over the distributor, if it is located below a vessel head or a carbon steel internal. This will prevent corrosion flakes from falling into the distributor and plugging the distributor holes.

Characteristics of the three most commonly used distributors are listed below.

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SPECIAL DESIGN CONSIDERATIONS FOR PACKING (Cont)

◆ TROUGH-STYLE DISTRIBUTOR (PREFERRED FOR MOST APPLICATIONS)

- Liquid distribution quality is GOOD.
- Turndown greater than 2/1, depending on design used. Higher turndown can often be achieved with a second distribution hole. Designer should be aware that performance may suffer at liquid rates which place the level just above the second hole.
- Cost: High.
- Manufactured with raised orifices or drip tubes to resist fouling (see **APPENDIX A** and its **Figure A-1**). A specialized version using lower pour point densities and strike baffles or flow multipliers has been used in low liquid rate lube vacuum tower fractionation sections with success.
- Recommended for towers with diameters greater than 3 ft (900 mm).
- Requires accurate leveling for good operation.
- Design details - by vendor, but must meet **APPENDIX A** distributor guidelines.
- **Applications:** Various light ends towers, gas treating columns, cat fractionators, atmospheric pipestills, lube VPS fractionation zones, oxo alcohols.

◆ ORIFICE PAN (ACCEPTABLE, BUT HAS SERIOUS DRAWBACKS)

- Liquid distribution quality is GOOD.
- Turndown is 2/1.
- Cost: Moderate.
- Must contain drip tubes to resist fouling (see **APPENDIX A** and its **Figure A-1** as well as **Figure 5**).
- Design details - by vendor, but must meet **APPENDIX A** distributor guidelines.
- 1st Major drawback - seams between adjacent sections leak and cause maldistribution. Seal welding can be used if pan material is 12 gage or thicker. Therefore: Can use at all liquid rates if diameter is less than 3 ft (900 mm). Can use in towers greater than 3 ft (900 mm) only if the liquid rate at turndown is greater than 10 gpm/ft² (6.7 dm³/s/m²).
- 2nd Major drawback – limited vapor flow area or possible non-uniform liquid distribution pattern.
- Specialized proprietary devices (such as the Sulzer MTS109 distributor). These contain slotted drip tubes, sectionalized multi-pan designs, etc., and:
 - Provide good operation at low liquid rates [say < 5 gpm/ft² (3.3 dm³/s/m²)].
 - Have high turndown ratios (up to 10/1).
 - Not recommended as first choice for large diameter columns (25 - 30 ft (7.5 - 9 m)) due to complexity of construction and difficulty leveling. Consider the Sulzer VEP instead.
 - Cost: high.
- **Applications:** Sidestream strippers, various gas treating columns.

◆ SPRAY NOZZLES

- Liquid distribution quality is generally POOR.
- Turndown is only 2/1.
- Cost: Low.
- Upstream strainers required if nozzle “free passage” is less than 0.40 in. (10 mm).
- Can be used in both small and large diameter towers.
- For design details, see GRID SPRAY NOZZLE CONSIDERATIONS.
- Demisting device occasionally required above the nozzles.
- Wide range of nozzle sizes permits designing for low, moderate, or high liquid rate applications.
- **Applications:** Wash zones of heavy hydrocarbon towers, pumparounds, some quench towers. Do not use in critical fractionation services.



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SPECIAL DESIGN CONSIDERATIONS FOR PACKING (Cont)

Narrow channel and orifice pan distributors should generally be located 6 in. (150 mm) above the packing in order to provide sufficient free vapor space in the tower for gas disengaging. The distributor material of construction must be a material with a very low rate of corrosion in the intended service. Stainless steels are almost always preferred.

▶ VAPOR DISTRIBUTORS

A perforated pipe is recommended for vapor distribution. Depending on tower size, the distributor may be constructed in a T [< 4 ft (1.2 m) diameter], X [4 to 8 ft (1.2 to 2.4 m) diameter] or an H [> 8 ft (2.4 m) diameter] configuration. The design criteria for perforated pipe distributors are discussed in [Section III-H](#). Vapor orifice orientations should be adjusted to uniformly feed all sections of the tower as explained below. Good vapor distribution is especially critical in large diameter lube vacuum towers where low pressure drop, low aspect ratio beds of structured packing are employed. The technique for determining if uniform vapor distribution is achieved involves evaluating the vapor release area on both a concentric circle basis and a quadrant basis. For the concentric circle basis, the tower is divided by a circle which splits the area equally between the inner circle and the outer annulus. Then the vapor release area (number of orifices or vapor riser area) in each area is calculated. The two areas should not deviate from each other by more than 10%. Vapor riser area may be adjusted using chokes to achieve this on an existing chimney tray. The quadrant analysis is similar but divides the tower into quadrants, using lines at 45 degrees to the main axis of symmetry of the chimney tray or vapor distributor. Then as before the vapor release areas are compared between these quadrants and should be within 10% of each other. Again risers can be choked to accomplish both this and the above criteria. A FRACTIONATION SPECIALIST can assist with this design.

▶ VAPOR-LIQUID INLETS

When the feed is a mixture of vapor and liquid, the tower internals design must provide for both adequate disengaging of the mixed phase as well as proper distribution of the disengaged vapor and liquid. A typical design to achieve this purpose is shown in [Figure 4](#), View A-A. This figure shows an H-shaped perforated pipe distributor discharging onto a chimney tray to promote vapor-liquid disengagement. This design is useful in the case of foaming flashing feeds and is preferred for such services. It also has the advantage of allowing corrosion products carried into the tower to accumulate on the chimney tray, prior to the liquid reaching a distribution orifice which could plug. If the vendor proposes a non-chimney tray option (such as a flashing gallery distributor, baffled parting box with sparger, etc.) or a non-ExxonMobil design is being rated, the designs should be reviewed by a FRACTIONATION SPECIALIST.

▶ PACKING SUPPORT PLATES

Support plates for random packings should have a high percent open area (i.e., at least 100% of A_g) to accommodate the simultaneous passage of vapor and liquid. See [Figure 6](#). Support plates should be uniformly perforated. Some vendors supply packing support plates which are not perforated at the top ridges, effectively blocking 5% of the tower area. These devices should be avoided. Also the orientation and configuration of the packing support should be coordinated with the chimney tray or distributor below, to avoid interaction between the liquid leaving the valleys and the vapor leaving the chimneys on the distributor. Support plates made from flat, perforated plates are NOT acceptable since they have small open areas and may limit tower capacity. Support plates for structured packing are usually made of subway grating or other high open area grid-type devices and have an open area of at least 90%. See [Figure 6](#). All support plates should rest on a 360° circumferential support ring.

LIMITATIONS ON PACKED BED HEIGHT

The maximum allowable packed bed height depends on the number of theoretical trays in a given section of the tower, on the type and the material of construction of the packing, and on the operating temperature. Grid bed depth limitations are discussed under **SPECIAL DESIGN CONSIDERATIONS FOR GRIDS**. The following considerations may limit packing height:

For Liquid Redistribution - The liquid must be collected and redistributed when the bed depth reaches that equivalent to 12 theoretical plates. However, mechanical limitations restrict bed height to 35 ft (10,500 mm). Therefore, the designer should use the smaller of these two values.

To promote liquid mixing and thus a more uniform liquid composition to the bed below, a chimney tray should be provided below each packed bed. By providing a central downcomer(s), the liquid will be mixed better than had it simply "rained down" on the packing below. To further promote mixing, the downcomer(s) on adjacent chimney trays should be rotated 90° with respect to each other. Structured packing may be used in the downcomer to act as a static mixer to help achieve total mixing.

For Ceramic Packing - This packing can generally be used in depths up to the 20 ft (6000 mm) maximum. However, towers operating at pressure drops greater than 1.0 in. of H₂O per ft of packing (0.8 kPa/m of packing) and towers subject to operating surges should be designed with shorter beds.

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SPECIAL DESIGN CONSIDERATIONS FOR PACKING (Cont)

For Aluminum Ring-Type Packing - The maximum allowable bed depth for aluminum rings is a function of the operating temperature. Laboratory studies indicate that the maximum depth should be 4 ft (1200 mm) for operation at 700°F (370°C) with 18-gauge aluminum Pall rings and 3 ft (900 mm) for 20 gage at the same temperature. The packing vendors recommend a maximum bed depth of 10 ft (3000 mm) for aluminum rings at 400°F (200°C).

For specific recommendations, refer to the *Chemicals or Refinery Construction Materials Manual* or consult your MATERIALS SPECIALIST.

◆ BED LIMITERS AND HOLDDOWN PLATES

Bed limiters are fastened to the tower wall by clips and serve to restrain the packing during upsets, keeping the packing in the bed and out of draw nozzles or other critical areas. They are a recommended part of packed bed design. Horizontal full circumference support rings for bed limiters are not acceptable as they will limit bed capacity. Holddown plates are a special type of bed limiter, and not recommended for most packings. Bed limiters should have sufficient open area so as to not limit bed capacity in any way. Typically this is 90% open. A mesh screen on their lower side is required to prevent carryover of small sized packings. Holddown plates are much heavier, and have less open area. Typically holddown plates are heavy enough to prevent uplift up to 35-40 lb/ft² (1.7-1.9 kPa).

For metal and plastic random packings, a supported bed limiter is usually provided, clipped to the vessel wall. It prevents expansion of the bed during high pressure drop operation and contains the packing during minor operating surges.

For ceramic and other breakable packings, a holddown plate, also known as an unsupported bed limiter, should be provided. A holddown plate is used so as the packing settles, the holddown plate would lower with the top layer of packing. Once the packing begins to fluidize, the holddown plate would then raise with the packing. If a fixed bed limiter was used the packing would settle below the limiter and upon fluidization would smash into the bed limiter thus plugging the bed, thereby reducing tower capacity.

For **structured packing**, provide a grid of hold-down bars with the majority of hold-down bars rotated 90 degrees to the top packing elements. Hold-downs should be attached to the vessel wall, through clips. Full circumference rings for structured packing holddowns are not acceptable. At least one grating bar should cover each element of packing.

For **grids**, the top three layers are normally bolted together with "J" bolts. In high uplift services use through bolting to tie the grid hold-down to the grid support for added uplift resistance.

SPECIFYING PACKING ORDERS BY VOLUME

- **Random Packing** - Due to settling and wall effects, the volume of random packing shipped in crates or bags may not exactly match the volume calculated via the diameter and height of the bed. A design specification should therefore require the vendor to supply a volume of packing sufficient to fill the packed bed to its design level. In addition, an excess of 5% is recommended to compensate for losses in handling and/or to fill up a bed during a future turnaround if any settling has occurred.

- **Structured Packing** - If the tower is known to be out-of-round in excess of typical tolerances, the vendor should be told what the actual dimensions are so the structured packing "elements" will fit in the tower. Since each tier is rotated 90° with respect to the tier below, this means some elements will have to be custom made.

The vendor should be asked to provide filler sheets equal to 1.5% of the tower diameter of structured packing per tier so they can be installed between elements or around the circumference should the tower be slightly out-of-round. Wall wipers are required for each layer due to structured packing tendency to promote wall flow.

The vendor should also be told exactly what packed height is desired, since the thickness of each "element" can vary by about 1/8 in. (3 mm). Thus, if say 16 elements were to be installed, the actual height could be too high by nearly 2 in. (50 mm). In some cases this has forced the removal of an entire tier to meet fit-up requirements for the bed limiters and liquid distributor.

DEMISTING

Elimination of entrained liquid may be necessary in services handling corrosive or expensive liquids or when spray nozzles are used. Droplets entrained from spray nozzles to the next higher bed can be expected to be 3-5% of the nozzle flow. Therefore, a crinkled wire mesh entrainment screen (CWMS) may be required if this level of entrainment is unacceptable. The design criteria for choosing and sizing a CWMS are discussed in [Section III-H](#).

◆ LIQUID SIDESTREAM DRAWOFF

Use a chimney tray / liquid distributor combination, similar to a redistributor when withdrawing a sidestream. This typically will require 48 to 60 in. (1200 to 1500 mm) vessel straight side. See [Section III-H](#), for design criteria for chimney trays.



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SPECIAL DESIGN CONSIDERATIONS FOR PACKING (Cont)

EXTERNAL STRAINERS

- **For Spray Nozzle Distributors** - To minimize nozzle plugging due to scale or coke particles, when the nozzle minimum free passage is less than 0.40 in. (10 mm), a strainer must be provided and the following steps taken:
 - A fixed basket type strainer should be selected whose openings are 1/4 or less of the free passage diameter of the nozzle.
 - The strainers should be mounted as close to the tower as possible.
 - Strainer bodies, elements, and all downstream piping including the distributor must be alloy, so as to minimize plugging of the spray nozzles with corrosion products.
 - Strainers should be of the "tandem" variety, so that one can be cleaned while the other is in operation.
 - Necessary instrumentation should be provided, so that the pressure drop across the strainer basket can be checked and the cleaning frequency established.
 - Strainer basket size must be adequate so that extremely frequent cleaning (more than once per day) is not required during normal operation.
- **For All Other Types of Liquid Distributors** - Install external strainers (fixed basket type) in all liquid lines that enter the tower **ABOVE** the packed bed to protect against slugs of solids entering the tower during unit upsets. Locate such strainers at grade, but as close to the tower as possible. The basket openings should be 1/4 of the minimum opening of the distributor or 1 mm, whichever is larger. The strainers should be of the "tandem" variety, allowing cleaning of one while the other is in operation. Necessary instrumentation should be provided so that pressure drop across the strainer basket can be checked and the cleaning frequency established.

For moderate and high pressure towers, appropriate backflush and blowdown facilities should be provided. Be sure to review such cases with the SAFETY SPECIALIST.

LOCATION OF MANHEADS

Access to all packed beds is recommended at the following locations:

1. Above the top of the **top** bed.
2. At every liquid distributor.
3. Between every chimney tray and the support plate **of each bed**. If a chimney tray is located immediately above a liquid distributor, only one vessel manhole is required, with access to the chimney tray through a removable chimney hat.
4. Below the support plate of the bottom bed.
5. Immediately above the support plate of each packed bed that contains random packing **IF** frequent loading and unloading is expected (i.e., especially for ceramic packing where breakage may occur). If no manway is provided, consider a 10 in. (250 mm) handhole. Not required, however, for structured packing or grid.
6. Any other existing vessel manholes internal to packed beds and certain process nozzles require internal plugs to prevent vapor and liquid channeling caused by the manhole. This should be called out in the design package.

SPECIAL DESIGN CONSIDERATIONS FOR GRIDS

The entrainment removal efficiency of grid is good, provided that the C_s factor (see **Figure 2A** or **2B**) is in the recommended range of 0.1 ft/s (0.03 m/s) to 85% of the flooding value given by the curves for the various grids. If the C_s factor falls below 0.1 ft/s (0.03 m/s), entrainment removal will be poor.

GRID WASH SECTIONS

1. Since the various grids have higher capacities than those of conventional trays or dumped packings, the tower diameter is usually set by the capacity of trays or packing above and/or below the grid bed. While unlikely [unless the grid is in a smaller diameter, swaged section] the grid capacity should be checked to ensure that flooding in the wash zone is not encountered. (**Note:** If the application is non-fouling, consider whether one of the dumped packings should be used instead of grid.)
2. In potentially coking services, the wash rate **leaving** the grid section should be at least 0.05 gpm/ft² (0.034 dm³/s/m²). However, for coker scrubber wash sections, the rate **to** the grid should be 1.0 gpm/ft² (0.68 dm³/s/m²).
3. Use 5 ft (1500 mm) of Koch-Glitsch GRID EF25A or Koch-Glitsch FLEXIGRID Style 3 to provide adequate deentrainment.
4. Use 6 ft (1800 mm) of Sulzer #3 SNAPGRID or Koch-Glitsch GRID EF 300A or 7 ft (2100 mm) of Koch-Glitsch FLEXIGRID Style 2 to provide adequate deentrainment.

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SPECIAL DESIGN CONSIDERATIONS FOR GRIDS (Cont)

- If good fractionation in addition to deentrainment can be justified economically in the wash zone, consider changing the wash zone to a split bed of grid and structured packing. A 50/50 split by height of grid followed by structured packing is recommended. The structured packing does not require additional support beams, support plates, etc. but will require a hold-down grid as described earlier. A FRACTIONATION SPECIALIST can assist with the best trade-off of deentrainment, fractionation, and fouling resistance for the split bed design.
- For higher capacity, an existing grid can be replaced with a deeper bed of #3 SNAPGRID or FLEXIGRID Style 2 if ultimate capacity limits have not been reached. Where vertical space is limited and a deeper bed cannot be provided, more entrainment of bottoms material into the zone above the grid may occur. The FRACTIONATION SPECIALIST should be consulted for these cases.
- For chronic fouling problems, consider grid replacement with FLEXIGRID Style 2. As stated above, a deeper bed is needed to do the same job as Koch-Glitsch GRID EF25A, FLEXIGRID Style 3, or Sulzer #3 SNAPGRID.
- A low flow alarm must be provided on the fresh wash, in order to ensure that header coking does not occur at low flow rates. Low-pressure cut-ins should be avoided, since they will not trip under all low flow situations, such as a plugged strainer.
- An alternate supply of wash oil, such as the next higher sidestream, should be provided to minimize coking of the header. The design should ensure that a change in wash oil supply can be made safely and quickly with a minimum of manual valve operations. Neither vacuum bottoms nor overflash should be used as an alternate source of wash oil. **Additionally, steam can no longer be recommended for displacing wash oil.**
- Mechanical design of grid wash sections should take into account the fouled weight of the grid / packing in services where coking is expected.

GRID BED DEPTH LIMITATIONS

If bed depths greater than 10 ft (3000 mm) are used, additional tower straight side may be needed for intermediate bed supports. Contact the vendor for their latest recommendation since this varies from grid to grid.

GRID SPRAY NOZZLE CONSIDERATIONS

Grids are presently used primarily in wash zones and some pumparounds. In the wash zone, sprays must be used because the low liquid rate available falls outside the range of other types of liquid distributors. In the case of pumparounds, sprays are used because they are cheaper and less prone to fouling than more conventional liquid distributors. Sprays are also desirable because they don't need careful leveling and are less vulnerable to upsets. To ensure good spray header operation, the following criteria should be met:

- Determining the Number of Spray Nozzles Required** - To maximize run length, experience has shown that a small number of large nozzles is better than a large number of small nozzles. This is true because large nozzles can pass larger particles and are thus less susceptible to plugging. Process factors dictate that the spray header be located 16 to 30 in. (400 - 750 mm) above the top of the grid (or packing in some cases). Therefore, since the spray angle for a given type of nozzle is essentially constant, the number of nozzles can be calculated readily. The nozzle size and complete spray header design should be specified by the designer and should **not** be left to the contractor.

As a **first approximation**, the number of nozzles required may be set equal to the tower area in square ft (m²) divided by 14 (1.3) for fractionation services and 20 (1.9) for pumparounds. There is no analogous rule-of-thumb for wash sections since a larger spray diameter is needed to keep within the nozzle size limit stated later on. Then, a scale drawing (see **Figures 8A - 8D**) should be made, to show what the final coverage will be. This drawing can be produced quickly by using PEGASYS and selecting Fractionation Towers; Spray Header Layout from the main menu. The most common designs utilize 7, 19, 37 or 61 nozzles, depending on tower diameter and are shown in **Figures 8A - 8D**.

The coverage is adequate when about 95% of the top of the bed is wetted and less than 3% of the liquid runs down the wall (wall flow). However, the overlapping areas should be less than 25% of the tower's cross-sectional area. The spray nozzle height can be raised or lowered to optimize the coverage, overlap, and number of nozzles required. As a starting point, 18 in. (450 mm) can be assumed for the nozzle height above the bed. The height of the spray nozzle above the bed is measured from the top of the bed to the bottom of the spray nozzle orifice. All spray nozzle orifices for a given distributor must be at the same elevation.

Since PEGASYS forces the nozzles to be laid out on an equilateral triangular pitch, some of the nozzles closest to the wall may create too much wall flow. This can be easily corrected by moving these nozzles away from the wall and manually estimating the change in wall flow, overlap, and bed coverage graphically on the PEGASYS drawing. If the coverage criteria outlined in the paragraph above cannot be met, consult a FRACTIONATION SPECIALIST.

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SPECIAL DESIGN CONSIDERATIONS FOR GRIDS (Cont)

Once the number of nozzles has been chosen, the exact nozzle size should be determined. [Exception: For vacuum pipestill wash zones, the minimum allowable nozzle size is 3/4 in. (18 mm)]. The designer should select the largest diameter spray nozzle from **Tables 6A to 8B** that has the flow rate and pressure drop characteristics desired. For most cases, the nozzle pressure drop should normally fall between 3 and 20 psia (21 and 138 kPa). However, if the turndown ratio is 2/1 or less, a pressure drop of 10 - 15 psia (69 - 104 kPa) at design is preferred. High nozzle pressure drop [over 20 psia (138 kPa)] should be avoided, since finer atomization and probable entrainment of the liquid may occur. Conversely, pressure drops below 3 psia (21 kPa) are also undesirable, since the spray angle decreases and the spray cone collapses. Therefore, the final number and size of nozzles must be checked at minimum rates (as well as at design rates) to insure satisfactory spray nozzle performance.

For C-factors leaving the wash bed exceeding 0.17 ft/s (0.051 m/s) (regardless of spray nozzle pressure drop), entrainment of wash oil droplets starts to become a factor and should be considered when determining the wash oil pumpdown rate, to achieve a given irrigation rate of the top of the bed. Please contact a FRACTIONATION SPECIALIST for assistance with this determination. A deentrainment device may be required above the spray header if entrainment cannot be tolerated in the bed above.

Tables 6A and 6B contain data for Spraying Systems Company nozzles while **Tables 7A and 7B** contain data on Bete Fog Nozzle Inc. nozzles, and **Tables 8A and 8B** contain data on Lechler Tangential nozzles. For fouling services (vacuum pipestill wash zones, etc.), the recommended nozzle is made by Bete. The maximum pressure drop for Bete nozzles should be less than 17.5 psia (a good design point for Bete is 7.5 to 10 psi and settling for less than 2/1 turndown). This specific nozzle is recommended because it has a large free passage opening, is less prone to fouling, and has worked well. Data on the Lechler Tangential nozzle has been included in **Tables 8A and 8B** because the nozzle has an even larger maximum free passage diameter and looks promising for this service. However, due to lack of commercial feedback, use of the Lechler Tangential nozzle should be considered experimental. Since the Lechler Tangential nozzle has the liquid entering the SIDE of the nozzle, special care is required if one of the standard nozzle layouts is used. This occurs because the nipple from the header to the nozzle must be moved so that the nozzle can be installed in the "standard" position. Consult your FRACTIONATION SPECIALIST when considering Lechler nozzles. For all other services, either Bete or Spraying Systems nozzles can be used.

The pressure drops and spray angles given in **Tables 6A to 8B** for the different nozzle sizes are based on **WATER**. Therefore, a correction factor is required as follows:

$$\text{Flow rate (corrected)} = \text{Flow rate (from Tables 6A to 8B)} \left[\frac{1}{(\text{Spec. Gravity @ Cond})^{0.5}} \right]$$

This correction amounts to about 15% for heavy hydrocarbon wash oil systems. Unfortunately, there is no generalized correction factor for viscosity. Discussions with the vendors indicate that no correction is required for viscosities between 0.1 and 10.0 cP (mPa•s). Outside this range, viscosity affects both nozzle capacity and spray angle. While nearly all ExxonMobil designs should fall in the above viscosity range, your FRACTIONATION SPECIALIST should be consulted if the viscosity falls outside this range.

2. **Sizing the Spray Header Piping** - To minimize residence time and potential coking problems, the diameter of the header should be minimized. However, the header should be large enough to permit the attachment of the spray nozzle without unduly weakening the wall of the header. Reducers should be used where necessary to go to small pipe diameters. In addition, for uniform distribution, the spray header piping should be large enough so that the maximum friction pressure drop along its length (between the nozzle closest to the entrance and the nozzle furthest away) is less than 10% of the design nozzle pressure drop. See **Section XIV-B** for a calculation procedure to determine the amount of maldistribution expected for a given design.
 - a. Flanged connections in the spray header system are preferred in cases where coking is anticipated such as wash headers. In other headers which fouling /plugging is not expected, connections should be welded or screwed whenever feasible. Graphite-filled spiral-wound stainless steel gaskets should be specified for all flanged connections. Mechanical support of a flanged spray header must eliminate any bending moment on the flanges as this will cause flange leaks. All internal piping flanges must be standard ANSI class 150 lb, raised-face weldneck or slip on flanges.
 - b. Spray nozzles and headers shall be located symmetrically about the tower centerline and spaced in a triangular pattern. Irregular spacing to contour around the tower circumference is acceptable. See **Figures 8A-8D** for standard nozzle and header layout dimensions.
 - c. The ends of the spray header(s) and its laterals shall be capped.

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- d. The main spray header and its laterals shall be supported from the vessel shell to ensure that the nozzle axis remains perpendicular during operation (see **Figure 9**). Additional intermediate header support and/or guiding shall be provided as required. However, the header design shall not restrict thermal expansion of the spray header or its laterals.
- e. The contractor, during detailed engineering, should ensure that the other internals (i.e., support beams, bed limiters, etc.) do **not** interfere with the spray distribution to each bed. There should be no vertical projections above the bed higher than 3 in. (75 mm). The bed limiter (if used in the case of packing) must present a uniform surface to the spray.
3. **External Strainers** - To minimize nozzle plugging due to scale or coke particles when the nozzle maximum free passage diameter is less than 0.4 in. (10 mm), a strainer must be provided and the following steps taken:
 - a. A fixed basket type strainer should be selected whose openings are 1/4 or less of the free passage diameter of the nozzle.
 - b. The strainers should be mounted as close to the tower as possible.
 - c. Strainer bodies, elements, and all downstream piping including the tower nozzle and the distributor must be alloy, so as to minimize corrosion products and the potential for spray nozzle plugging and leaks in the distributor, tower nozzle, and spray nozzles.
 - d. Strainers should be of the "tandem" variety, so that one can be cleaned while the other is in operation.
 - e. Necessary instrumentation should be provided, so that the pressure drop across the strainer basket can be checked and the cleaning frequency established.
4. **Grid Spray Header Startup Considerations** - The headers and laterals should be flushed with water at rates as close to design as possible prior to installing the nozzles. Flushing will insure that all debris in the upstream piping is removed prior to nozzle installation. After the nozzles are installed, the system should be tested with water and observed visually to insure that all nozzles are "spraying" properly at design and minimum rates and that no flanges are leaking. The pressure upstream of the header should be noted. The water rates should be density-corrected to obtain the corresponding oil rates. The pressure drop across the nozzles should be close to those calculated for design and minimum rates. Defective nozzles should be replaced. At least 20% additional nozzles should be ordered as spares.

In heavy hydrocarbon services, liquid flow should be initiated in the wash section spray header before the vapor temperature is raised above 600°F (316°C).

♦ GRID VAPOR DISTRIBUTION

To assure good vapor distribution, a chimney tray is usually provided below the grid. This tray generally has from 20 to 30% open area for vapor flow. If the open area is too large, the pressure drop will be too low and poor vapor distribution will result. Too small an open area, on the other hand, results in excessive pressure drop. See **Section III-H** for design criteria for chimney trays. Heritage Mobil vacuum towers and some atmospheric towers contain a special chimney tray, called a deentrainment tray. The deentrainment tray is used above the flash zone to collect the overflash material. This tray is like a large bubble cap tray (but is not designed for vapor liquid contacting) and provides an added deentrainment step after the flash zone. It is effective in removing 30-40 micron droplets and larger. In vacuum towers it also aids vapor distribution to the wash bed. To accomplish this, it is normally designed with about 2-3 mm Hg pressure drop in vacuum service. Quadrant and concentric circle vapor distribution analysis should be applied to these trays and choke dimensions varied to obtain the required maximum deviations as explained under VAPOR DISTRIBUTORS above. Consult with a FRACTIONATION SPECIALIST if rating an existing deentrainment tray or designing a new one.

♦ GRID INSTALLATION AND HOLD-DOWN

As a further measure to insure good vapor and liquid distribution, each grid tier is rotated 45 degrees horizontally with respect to the preceding tier. This arrangement prevents vapor and liquid channeling and provides intimate contact between descending wash liquid and ascending vapor. The designer should call for the 45-degree alignment in the design specification. The grid may be held down with "J" bolts that fasten the top three tiers of grid together. Another option would be to use through bolting to tie the grid hold-down to the grid support which provides added uplift resistance. No other hold-down device, such as subway grating, is needed.