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Process Developments

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# Ask more from vendors when revamping your distillation column

**Common-sense approach uncovers potential problems when upgrading tower internals**

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Distillation towers are generally considered the lead separation technology in refinery and chemical operations. Sophistication of tower internals, which are the heart of distillation towers, has increased exponentially — starting from bubble cap, sieve and valve trays, through 1st generation random packing to structure and mesh packing. All give a variety of operating ranges suitable for the grass-root design and revamp of distillation towers.

At the present time, engineering and operating companies lean towards revamping existing operating units to meet expansion objectives. Exceptions are emerging markets like China, which tolerate expensive grass-roots projects due to the lack of existing facilities and the desire to substantially increase production. They are eager to use newly discovered resources and compete internationally. On the other hand, traditional markets focus on retrofitting existing units due to ample availability of existing processing facilities and the desire to maximize return-on-asset with minimum capital and operating costs. Often, this requires increasing throughput to existing towers and replacing internals to avoid replacing the tower vessel, a major cost item.

Working with tower internal vendors to bring about the optimum retrofitting design is then one of the major activities that the process engineer should consider. For a successful revamp of distillation towers, the ability to work with vendors and handle diverse options of tower internals and technologies becomes vital. Solely relying on vendor's recommendations to serve the operating company's goals is not a satisfactory approach. After all, vendors are trying to sell their products. It is the process engineer's job to ensure that the project's objectives are met with a robust design that meets specifications. This article explores issues and tasks that a process engineer has to tackle while dealing with tower internal vendors. The goal is to bring about a philosophy on engineering-vendor interaction when specifying tower internals, especially for revamps projects where higher risk of troublesome design is present.

**Tower Internals Vendors Market.** In recent years, several acquisitions took place that involved major tower internals players such as Koch, Glitsch, Nutter, Norton and Sulzer. Koch and Glitsch products are currently marketed by Koch-Glitsch while Sulzer supplies Nutter's and Norton's technologies. This reduced the competition and diversity of the market and the ability to select competitive vendors.

Due to acquisitions, some technologies that are relevant are not showcased because of marketing agendas. The process engineer needs to persist to explore all technologies. For example, recent Sulzer's catalogues market Mellagrid packing while Nutter snapgrid is not showcased. When available tower spacing is a concern, Nutter snapgrid is advantageous over Mellagrid because it can be thru-rodded in-place. Thus, the use of large beams above the hold-down grid could be avoided, saving space in the tower.

To guard against the above disadvantages, the process engineer should have adequate knowledge of available technologies and their applicability to the design in question. Also, the engineering company should maintain a library containing catalogues and references of recent and old technologies. A worldwide database of typical tower internals used in actual processes would be of great benefit. Certainly, membership to fractionation associations such as FRI (Fractionation Research, Inc) will bring a wide source of data for the process engineer.

**Select Tower Internal Vendors.** The process engineer should identify vendors with a good track record in supplying tower internals for the specified distillation service. The selection may also include demanding a specific vendor engineer to handle the design work as qualifications and experience of personnel working within the vendor's organization may vary. Vendors with previous experience in a specific distillation service have a stronger background in the applicability of tower internal technologies.

For example, an experienced vendor in refinery vacuum distillation may recommend increasing the assumed 1/2 theoretical stage for the wash section to 1 theoretical stage to improve metals removal. He may also warn the process engineer against increasing the number of theoretical stages to 2 if adequate wash oil is not available as that would lead to packing dry out and coking. Experienced vendors would also provide insight on the minimum distance between the charge nozzle and bottom wash section for better vapour distribution. Clearly, vendors or engineers with no relevant background or experience would not provide the process engineer with such useful insight.

**Scope of Work.** Defining the scope of work is critical to ensure smooth evaluation of vendor's recommendations at a later stage. In some cases, process engineers failed to clearly spell out the scope of work for vendors, which resulted in widely different recommendations. In other cases, process engineers set a tight scope of work, where tower internals were specified and the vendors' role was limited to calculating the hydraulic capacity. In such cases, higher reliability rested on the process engineers' shoulders to come up with the optimum design. In addition, useful input from the vendors, the experts in this field, was missed.

In general, the key to a successful scope definition is to provide clear guidance on design objectives and expectations while allowing the vendors to have adequate room to recommend the optimum design. The following are some of the scope definition points that should be communicated to the vendors (if applicable):

- Design and expansion objectives should be stated
- Listing product specs is an important reference
- Metallurgy, material selection and thickness are important design and cost parameters.
- The process engineer may ask the vendor to follow the specified number of theoretical stages, recommend changes to improve a specified product recovery or feel free to take the approach that the vendor see fit.
- The process engineer may ask the vendor to recommend changes to the operating conditions and number of theoretical stages that will avoid excessive entrainment, vapor/liquid maldistribution, coking, metals contamination, fouling and other operating issues that may affect product specifications and unit operation.
- Upset conditions may be stated for design purposes.
- Robustness may be specified to vendor by stating a +/- change in vapor/liquid traffic or an overdesign factor.

**Submit Adequate and Equal information.** While a list of tower internals vendors is being identified, the engineering company may select to work with one vendor in the development stage of the design. In most cases, this involves submitting simulation output rather than process data sheets. In addition, design considerations and clarification is discussed with the vendor. Since simulation output may contain greater details than that provided in process data sheets, this may put other vendors at a disadvantage as the first vendor may utilize the data to come-up with a more robust design. Also, discussions that accompany such efforts may give more insight to the first vendor on the process engineer design expectations.

Consider the following case where both unequal and inadequate data put one vendor at a disadvantage. Two vendors, A and B, were selected to bid on a vacuum tower internals revamp. Vendor A was sought for help in the front-end stage development where simulation output was used for communicating data. At the detailed engineering stage, a process data sheet was issued to both vendors. The simulation output showed stage-to-stage vapor/liquid traffic while the process data sheet showed the vapor/liquid data for stages of highest loads. Due to the high vapor/liquid traffic, vendor B recommended Grid Structured Packing, which would require extending the tower height by several feet. Vendor A utilized previous inter-stage data to recommend a combined packing bed, where high capacity Grid Structured Packing would be installed below high efficiency Corrugated Structure Packing. The optimized design reduced required bed height. See Figure 1 for illustration.

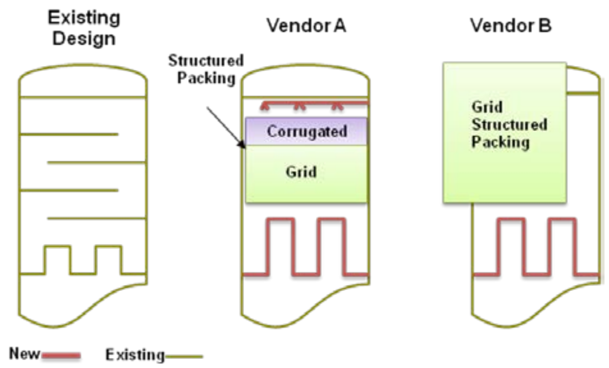


**Fig. 1** Existing tower modifications, where vendor A used inter-stages vapor/liquid traffic from simulation output to come up with an optimum design and vendor B was supplied with only highest loads data in the process data sheet.

**Evaluate Bids.** Do not blindly rely on vendors' recommendations. For a trouble free revamp, evaluation of the bids for technical feasibility is a must. The process engineer should have prior experience and knowledge of tower internals technology and issues in order to bring the design to the optimum point. Examples of issues that vendors may not always help identify are:

- Opportunity to improve fractionation for better yield
- Feasibility to fit existing towers with new internals
- Selection of optimum design for tower internals

- Actual mass transfer efficiency
- Resolving conflicting recommendations

Further discussion with supporting examples of the above issues will follow.

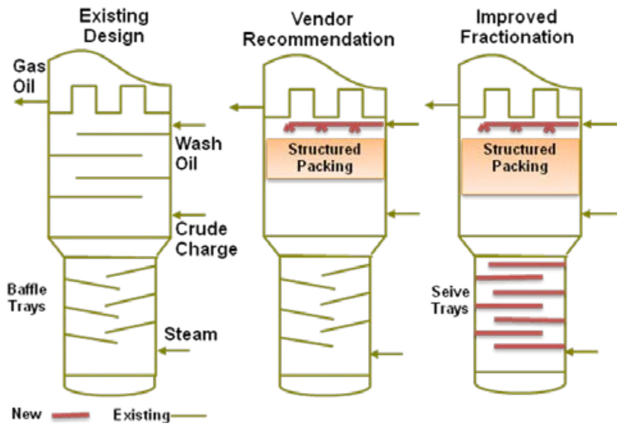


**Fig. 2** Existing tower modifications, where vendor recommended internals that matched simulated number of theoretical stages. Vendor did not point out that enough space is available to provide higher gas oil recovery.

***Opportunity to Improve Fractionation.*** Tower internals vendors assume that identifying opportunities for better fractionation is the responsibility of the process engineer. Vendors normally assume that their scope of work is to meet the bare minimum that the process data sheet specify. Consequently, opportunities to improve fractionation and recover more valuable products are missed.

In one case, a distillation tower was sought to handle virgin light crude rather than heavy fouling crude as per the original design. Typical two theoretical stages were assumed for the wash section while one theoretical stage was used for existing low efficiency stripping baffle trays. Vendor recommendations were supplied to meet the assumed # of stages by replacing the wash section trays with structured packing while re-using the stripping baffle trays. Vendors did not point out that more space was available to recover higher distillate flow if improved washing and stripping efficiencies were provided. This could have been achieved by adding more packing layers in the wash section to obtain 4-5 theoretical stages and replacing the baffle trays with higher efficiency sieve or valve trays to obtain 2-3 theoretical stages as shown in Figure 2.

***Fitting Existing Tower.*** Usually tower internal vendors do the initial evaluation for free. The detailed look at the design and available spacing is delayed until after the award. This may result in recommending internals that will not fit the existing tower height and nozzle locations.

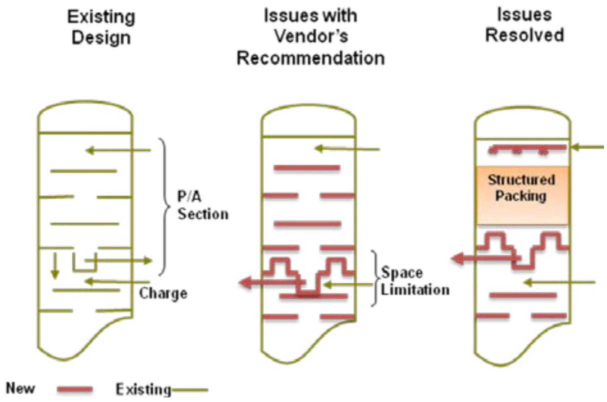


**Fig. 3** Existing tower modifications, where vendor recommended replacing existing four trays and partial draw box in the P/A section with four trays and a total draw chimney tray. Upon investigation by the process engineer, space limitation was identified.

The following case shows an example of tower limitations not identified by vendors. A top pumparound section was revamped to handle a higher circulation rate. It was also desired to replace the partial draw box with a total draw chimney. One vendor quoted to replace the existing trays with higher capacity trays and existing partial draw box with a chimney tray. The vendor did not identify that tower spacing was too limited to fit the recommended internals without major modifications, especially that the draw nozzle had to be enlarged to a diameter equal to 70% of tray spacing.

To accommodate a total draw chimney tray, it was necessary to install the chimney tray in place of a distillation tray in addition to the partial draw box. Removing a tray from the pumparound section was equivalent to losing some fractionation and heat transfer area. Thus, the remaining trays in the pumparound section were replaced with packing of adequate efficiency and heat transfer area. In this case, a spray or trough distributor was required above the packing bed. A spray distributor required 15-20 psi of pressure drop, which would have impacted the pumparound hydraulics. Alternately, a trough distributor required much less pressure drop but was more expensive and harder to troubleshoot. See Figure 3 for illustration.

Clearly, accepting the initial vendor recommendation without evaluation would have resulted in escalation of engineering and material costs at the detailed engineering or construction phase of the project. To avoid similar problems, the process engineer should always draw a schematic of the existing tower with existing internals and nozzles. Then the recommended internals should be drawn in an equivalent sketch. Conflicts with existing internals, nozzles and spacing can then be identified.

***Selection of Optimum Design for Tower Internals***. Due to the diversity of tower internals, vendors may recommend tower internals that do not provide the best design. The process engineer should utilize available resources and previous experience to judge vendors' proposals. The process engineer should compare tower internal recommendations to published standards and data. Several books have been published and many engineering firms possess tower internals design standards that can assess in this matter. In one case, a vendor provided a side stripper design with a jet flood below 30% and claimed that 50% efficiency was acceptable. The vendor failed to warn the process engineer that at jet flooding below 40-50%, efficiency tends to decrease exponentially, resulting in an qoperation that does not meet specifications. Also, 50% efficiency is an optimistic efficiency for side strippers even at suitable jet flooding.

In another example, in a vacuum tower revamp, one vendor recommended corrugated structured packing for one section of the tower, giving a jet flooding value of 85%. A second vendor suggested a combined bed of grid structure packing topped with corrugated structure packing, which reduced flooding to 80% across that section. This required extending the tower vessel height to fit the recommended packing. Obviously, the second recommendation would have been more expensive, but from an operating point of view, refinery operation where crude types and quality varies, a robust design that was insensitive to process variations was vital.

***Mass Transfer Efficiency.*** Determining the mass transfer efficiency of packing involves some engineering judgement even though vendors publish efficiency data in their catalogues. This is because many factors other than the packing itself determine the actual efficiency. These factors include:

- Packing height
- Liquid distribution
- Vapor distribution
- Vapor/liquid physical properties
- Hydraulic capacity

In one case, the vendors supplied packing internals thought to match the assumed number of theoretical stages. This was verified by reviewing published efficiencies of the recommended tower internals in similar hydrocarbon systems. The hydraulic capacity of the tower was below the acceptable jet flooding value of 85%. Nevertheless, the vendor did not report that the C-factor (superficial velocity corrected for vapor and liquid densities) was high (~0.5 ft/s), which may have resulted in excessive liquid entrainment contaminating side products and reducing packing efficiency.

***Resolve Conflicting Recommendations***. Often one vendor recommends a certain technology and another recommends a different one. The process engineer should be aware if such recommendations come from a biased position. For example, a vendor may choose to recommend their technology rather than other more relevant third party technology. In addition, vendors quote advantages of the recommended technologies and disadvantages of other's technologies, and sometimes two or more vendors seem to disagree. The process engineer has a duty to review the recommendations and select the optimum design based on design objectives.

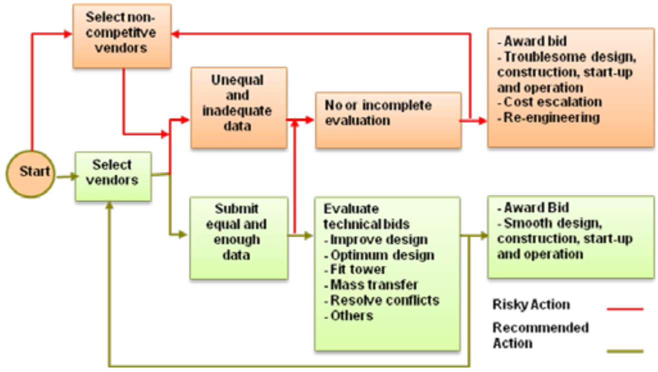


**Fig. 4** Process engineer – tower internals vendor interaction diagram. To be read from left to right.

Use the following points when coming across such an issue.

- Ask vendors to supply supporting documents of their claims such as published or internal papers.
- Ask vendors to supply supporting references to be contacted.
- Ask vendors to list advantages and disadvantages of their recommendations.
- Seek published papers in qualified engineering magazines.
- Some operating firms have previous and extensive experience in certain technologies already applied in their operation and other worldwide operations. Seek references and recommendations from these sources.
- When recommending tower internals, consider impact on tower operation, capacity and efficiency, ease of maintenance, options of testing and troubleshooting, and operators' familiarity with the technology.

In one case, evaluation of using trough or spray distributors was carried out according to the above points. Even though trough distributors had the advantage of exposing the tower to less liquid entrainment, spray distributors were recommended because of their ease of operation, testing and maintenance as well as operators' familiarity with the technology.

**Handling Guarantees.** Four types of process guarantees are usually considered when working with tower vendors.

- Hydraulic capacity
- Pressure drop
- Heat capacity efficiency
- Mass transfer efficiency
- Product specifications

The process engineer should ask the vendor to verify meeting the above guarantees. Hydraulic capacity is usually the one that all vendors guarantee. For pressure drop, vendors usually guarantee the pressure drop with a margin (120% of calculated pressure drop). For pump-around sections, vendors also guarantee heat capacity efficiency.

Mass transfer efficiency and product specifications are the two items that vendors resist to guarantee. Nevertheless, the process engineer often overlooks the difference between the two guarantees when negotiating with the vendors. Mass transfer efficiency is related to the type of internals selected as well as other factors mentioned earlier in the article. Vendors should be asked to guarantee the efficiency. On the other hand, product specification is a function of simulation and thus cannot be guaranteed by the vendor. Nevertheless, the vendor should be asked to guarantee that no operating conditions (such as the high C-factor mentioned earlier or liquid mal-distribution) would impact the efficiency of the internals or contaminate side products.

**Conclusion.** In revamping distillation towers, working with tower internals vendors become a vital skill that may bring about a successful and trouble free design. Figure 4 is a stepwise chart summarizing the issues and tasks reported in this article. The author believes that considering these items would help engineers bring about a successful execution for retrofitting existing towers.
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