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# Improving the Performance of Towers with Random Packing

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Random packing is generally the preferred mass transfer device in towers operating at elevated pressure and/or high liquid rates. The performance of these towers can be improved by using modern random packing with increased capacity or efficiency. INTALOX ULTRA random packing can be used to achieve efficiency or capacity benefits compared to IMTP and other random packing types. In the demethanizer and gas absorber applications discussed in this paper the operating companies were able to significantly increase the capacity of their units without sacrificing separation performance. This allowed operating companies to increase the capacity of their towers by replacing IMTP random packing with INTALOX ULTRA random packing.

## 1. Introduction

About 5 centuries ago scientists began using distillation devices in ethanol/water separations that increased the concentration of ethanol in the distillate by unknowingly generating extended surface area and internal reflux. In the early 1800's distillation trays were invented to harness these advances (Forbes 1948). Later in the 1800's scientists started using elements in the towers that could be described as the forerunners of modern random packing. These packing elements were characterized by a low surface area per unit volume and low void fractions. This limited the performance of towers equipped with random packing. With the advent of metal random packing about 100 years ago this changed, since the thin-walled metal pieces yielded higher void fractions and higher surface area per unit volume. This packing still had fundamental deficiencies which limited the capacity and efficiency. The quest in the last 100 years has been to get the highest rate of mass transfer and the highest hydraulic capacity with the least amount of material. Hundreds of different random packing styles have been introduced, with all purported to address these challenges to some degree. In an attempt to group these packings the terms 1st, 2nd, 3rd and 4th generation were created. These groupings do not do complete justice to the performance of the different packings since experience has shown that that the performance of a packing cannot be based solely on the generation it is assigned. The IMTP random packing, even though not classified as a latest generation packing, is still very popular and has a large installed base due to its good performance.

Random packing is the preferred mass transfer device in applications that have high specific liquid rates, the system pressure is high, good separation performance is required, and the system calls for significant operating flexibility in liquid and vapor rates. Structured packing does not give good performance at high pressure and at high liquid rates. Trays can handle high liquid rates and high system pressures, but the operating window is relatively small.

About a decade ago Koch-Glitsch embarked on a systematic study of the performance of random packing. Through extensive, novel computational and experimental studies the key items that drive random packing performance were identified. During this project more than 100 novel random packing shapes were studied. The mass transfer performance of a few of the better performing prototypes are compared to 3rd and 4th generation random packing in Table 1. From this table it is evident that the performance of the prototypes significantly exceeded that of the commercial random packing available at that time. This extensive study culminated in the development of the INTALOX ULTRA random packing, which exhibits improved performance compared to the prototypes and commercially available packing. (Nieuwoudt et al., 2010; Nieuwoudt et al., 2010, Nieuwoudt et al., 2014).

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*Table 1: Mass transfer performance of commercial random packing versus prototypes*

| Packing type | Commercial | Commercial | Prototype | Prototype | Prototype | Prototype |
|---|---|---|---|---|---|---|
| Features | 3rd Gen Saddle shape | 4th Gen Non-saddle shape | Ball with multiple loops | Multiple loops; No saddle shape; No split fingers | Multiple loops; Saddle shape | Multiple loops; Split fingers; Saddle shape |
| | | |  |  |  |  |
| Relative mass transfer coefficient | 103% | 100% | 126% | 130% | 136% | 137% |

The performance of random packing is driven by the effective area and the mass transfer coefficients. The surface of random packing provides some of the area across which mass transfer can occur. There are also droplets that fall from the packing elements that provide additional surface area. In this way, a well-designed random packing can have an effective surface area greater than that of the packing itself. The effective surface area of a random packing can be measured by absorption with a fast first order chemical reaction. In this case, the mass transfer coefficient is largely dependent on the rate of reaction and independent of the hydrodynamics of the liquid and vapor phases. The effective area can be calculated from the measured mass transfer coefficient. The effective surface area of several nominal 50 mm [2 in] packings was measured by absorption of $CO_2$ into a dilute solution of NaOH. Dividing the effective surface area, $a_e$, by the actual packing surface area, $a_p$, and plotting that value (fractional area) as a function of liquid rate, allows a comparison of the effectiveness of packings with different surfaces areas. Such a plot for the packings tested is shown in Figure 1. The results indicate that compared to other random packings of the same nominal size, INTALOX ULTRA random packing generates more effective surface area per unit area of packing through surface renewal and droplet creation mechanisms.

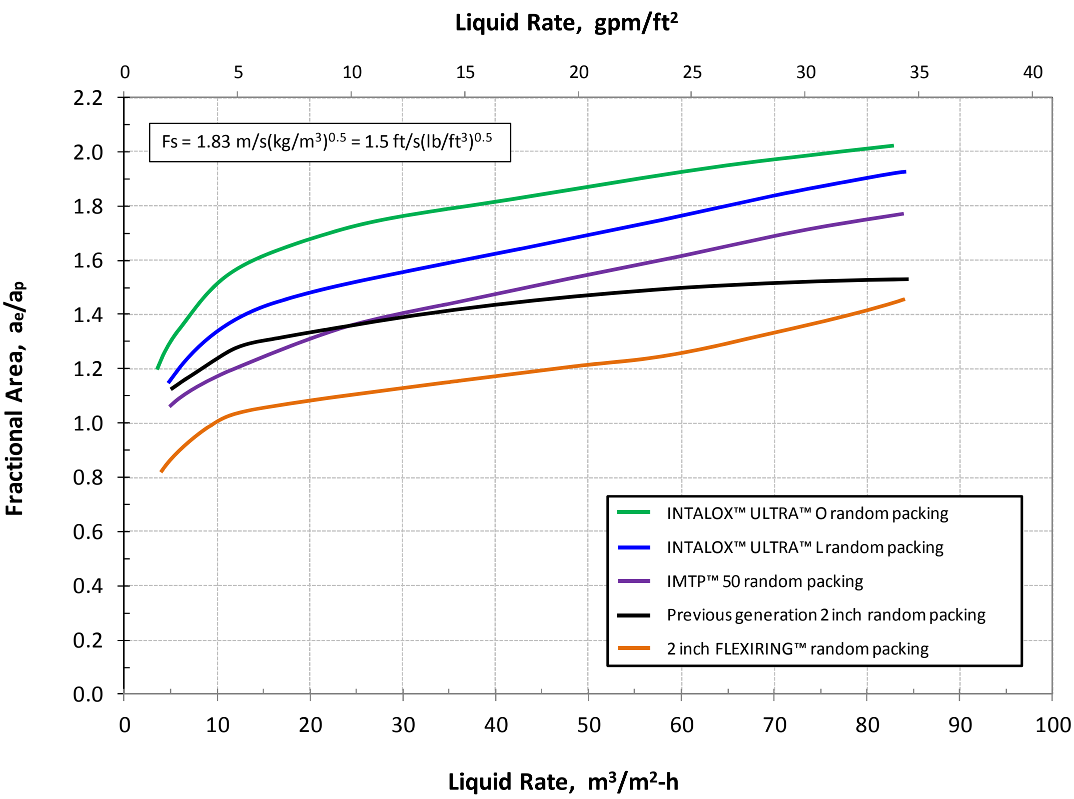


*Figure 1: Fractional area of INTALOX ULTRA packing and various random packings*

Another useful parameter to compare random packing is the gas phase mass transfer co-efficient $k_g$. Since rectification is a gas film controlled operation, HETP data can be used to calculate kg

The following equation relates HETP to $k_g$:

$$HETP = \frac{u_s}{k_g a_e} \cdot \frac{ln\lambda}{\lambda - 1}$$

where $u_s$ is the vapor superficial velocity and $\lambda$ is the ratio of the slopes of the equilibrium and operating lines. Rearranging the equation gives us a more useful expression:

$$k_g a_e = \frac{u_s}{HETP} \cdot \frac{ln\lambda}{\lambda - 1}$$

The effective area ($a_e$) for the test system is not known, but the parameters $\psi = a_e/a_p$ and $k'_g$ can be defined to help analyse the experimental data:

$$k_g a_e = k_g(\psi a_p) \text{ and } k'_g = k_g \psi$$

The packing surface area ($a_p$) is known, which means that $k'_g$ can be calculated from the experimental data. $k'_g$ shows the magnitude of gas phase mass transfer coefficient and the degree to which the packing can create effective mass transfer area. $k'_g$ is plotted as a function of the vapor rate in Figure 2. The packings were tested with the same system under identical conditions. The $k'_g$ values have been normalized for this comparison. The INTALOX ULTRA random packing is again showing the highest gas phase mass transfer coefficient of any nominal 50 mm [2 in] packing.

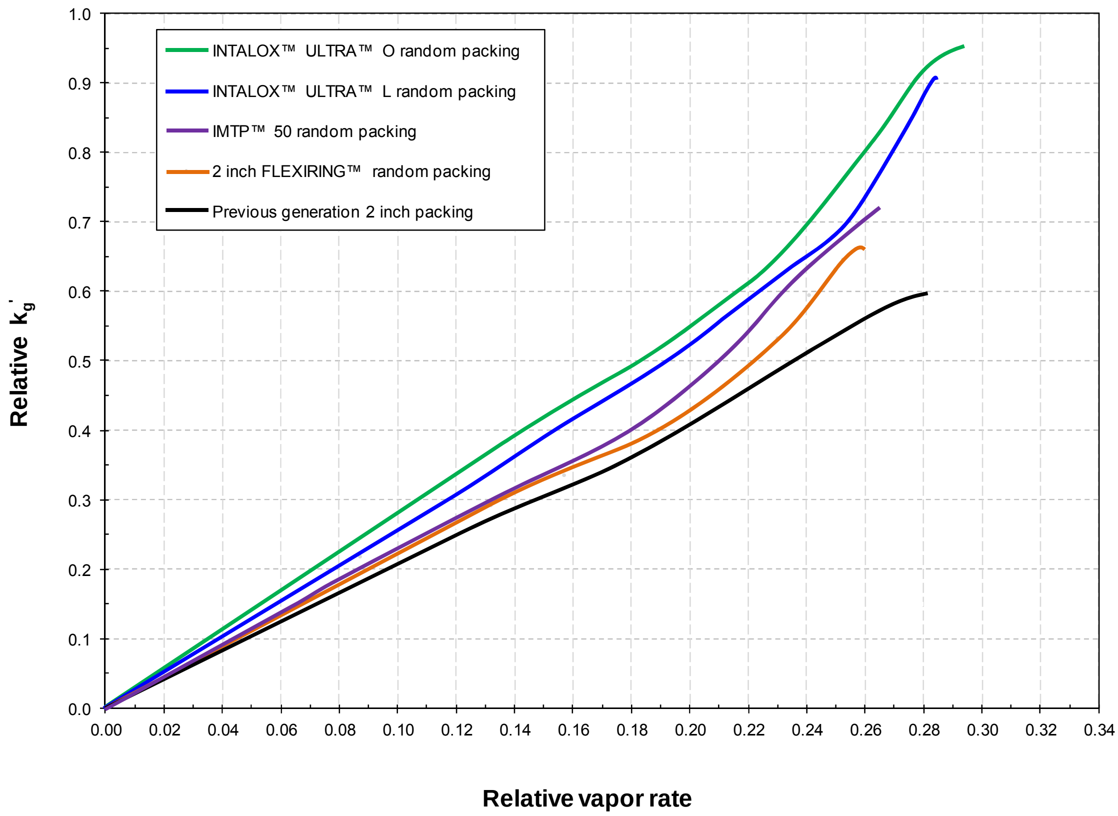


*Figure 2: Relative gas phase mass transfer coefficient of INTALOX ULTRA packing and various random packings*

The performance of the INTALOX ULTRA random packing is illustrated in Figure 3. From this figure it is evident that the INTALOX ULTRA random packing give the same or better efficiency as the next smaller size

IMTP random packing, but the capacity of the next larger size IMTP random packing. This opened up exciting possibilities for revamps or new installations. From a capacity perspective, the user can either get more capacity or build a tower with a smaller diameter. From a separations perspective, the user can get better separation or build a shorter tower. These benefits are highlighted in the case studies in this paper. At the time of writing this abstract INTALOX ULTRA random packing has been installed in more than 1000 towers worldwide.

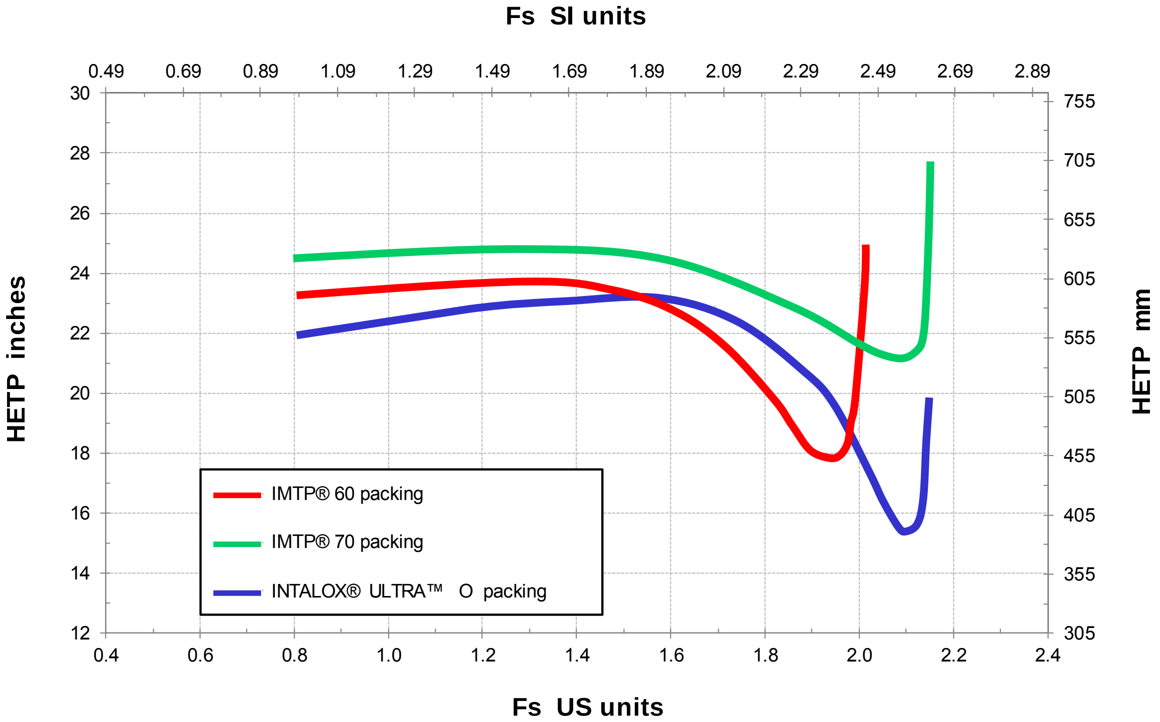


*Figure 3: Performance of INTALOX ULTRA random packing versus IMTP random packing*

## 2. Case Studies

### 2.1 Grass-roots demethanizer

A Middle Eastern gas producer developed a project to recover very large amounts of ethane and other NGL (natural gas liquids) from natural gas. The amount of gas processed required one of the largest demethanizers in the world. Demethanizers run at high pressures to facilitate the condensation of liquid hydrocarbons at reasonable temperatures and therefore the vessel walls are very thick. The shell thickness increases with diameter as well, which has a significant impact on the cost of the demethanizer unit. The subject demethanizer was designed with a previous generation random packing, so there was opportunity for optimization and diameter reduction. By substituting the specified packing with INTALOX ULTRA random packing, a reduction in tower cross sectional area of 7.5% was possible. The reduced diameter and thickness resulted in significant cost savings for the vessel, packing and internals.

The demethanizer was required to operate with lean and rich feeds during winter and summer conditions. The operating flexibility required the use of liquid distributors designed for a high turndown ratio. Multiple levels of orifices can be used to achieve this; however it is important to make sure the liquid level above the upper orifices is sufficient to allow for a reasonable amount of out of levelness to ensure good liquid distribution. With so many operating cases this can be challenging. In the upper part of the tower where the liquid rates are lower, a trough distributor with side-wall orifices was installed, whereas in the lower section with smaller diameter and higher liquid fluxes, deck distributor with elevated orifices in drip tubes were employed.

Multiple feeds and three reboiler returns entered the tower as two phases. The liquid and vapor phases must be separated before the liquid is fed to the liquid distributor to prevent surface turbulence and liquid maldistribution. Flash galleries with V-baffles fitted to the inlets are very efficient and robust devices used to accomplish this task. Care must be taken when setting the height of the gallery to account for the frothiness of the low surface tension, low viscosity liquid. The actual height of the frothy liquid in the gallery can be almost double the calculated clear liquid head.

Even with the reduced tower size and complex design, the tower continues to produce on specification product after many months of operation owing to the benefits of INTALOX® ULTRA random packing and proper design of the associated internals.

### 2.2 Increasing the capacity of demethanizers

The shale gas revolution has transformed the energy landscape in the United States, bringing with it abundant supplies of natural gas and natural gas liquids (NGL) for heating, power generation and petrochemical production. Increased production required a rapid build out of cryogenic processing facilities and fractionation plants. The demand was so great that several companies decided to design and build off the shelf plants that could be ready for installation as soon as the gas was available. This situation has opened some interesting opportunities for the use of random packing in processing towers.

Natural gas is refrigerated in the cryogenic plant to recovery NGL and lower the heating value to pipeline specifications. This is done in the demethanizer column which is usually designed as a packed tower. There are several reasons for using random packing in the demethanizer, the most important being that packed towers have a much wider range of operation compared to trays. This flexibility is important when considering changing markets and demand for NGL. Random packing is chosen over structured packing because it can handle the higher liquid rates encountered in high pressure distillation. High liquid rate operation with structured packing has resulted in reduced efficiency. (Rukovena, et al, 1989)

A North American provider of cryogenic plants experienced capacity issues in the bottom section of the demethanizer in one of their standard plants that used a third generation nominal 40mm random packing. The gas turned out to be slightly richer than anticipated, so more heat input to the reboilers was required. This caused the internal loadings to increase beyond the capacity of the existing packing. It has been shown that replacing IMTP random packing or other previous generation packings with the same nominal size INTALOX ULTRA random packing provides the capacity and pressure drop of the next larger size without a reduction in efficiency (Nieuwoudt, et al, 2010). Koch-Glitsch was able to offer INTALOX ULTRA A random packing to relieve the bottlenecked section of the demethanizer. Subsequently the base design was changed to include INTALOX ULTRA random packing in all sections of the demethanizer.

On another occasion, a gas processor asked a provider of standardized modular cryogenic plants for an increase in the nameplate capacity after construction of the plant had been started. The demethanizer vessel had already been built, which meant that the diameter was fixed. Based on the standard design using IMTP® random packing, the desired capacity increase could not be achieved. Using INTALOX ULTRA random packing instead allowed an additional 10% increase in throughput.

A number of fractionation towers in gas processing units were supplied with IMTP random packing. The IMTP random packing was replaced with INTALOX ULTRA random packing resulting in increased capacity while maintaining product quality. This allowed subsequent units to be designed with a higher nameplate capacity without changing the dimensions of the vessels, resulting in significant savings.

### 2.3 Increasing the capacity of a large-scale gas treating unit

This case study summarizes the debottlenecking of natural gas absorption columns at the ExxonMobil Shute Creek Facility in Wyoming US. ExxonMobil's natural gas production operations in Wyoming includes a gathering system, dehydration, gas purification, and sales. The facility was originally designed in the 1980s to process 480 MMSCFD, and continuous debottlenecking efforts over the years increased the plant capacity to 720 MMSCFD in 2004. The feed gas for this field contains approximately 65% $CO_2$ and 5% $H_2S$ (Grave, 2016). The front-end of the gas purification system relies on two absorption trains to remove Hydrogen Sulfide ($H_2S$) from the feed gas using a physical solvent system. The $H_2S$ absorbers, which operate at high pressure and at a high specific liquid rate, were originally equipped with IMTP random packing and pan-type liquid distributors. After being operated successfully for several years, potential internals modifications were evaluated for incremental capacity opportunities while maintaining mass transfer efficiency. Process modelling, hydraulic calculations, and detailed reviews of available test data were completed in order to confirm that the increase in capacity was achievable. INTALOX ULTRA random packing was identified as a way to increase the capacity while maintaining the quality of the gas. In addition, all pan-type liquid distributors were removed and replaced with trough type liquid distributors with more open area for the gas flow. Collaboration between ExxonMobil and Koch-Glitsch ensured that a good revamp plan was drawn up and that technical risks were mitigated. The revamp was successfully completed by a multidisciplinary team including a specialized contractor during a planned maintenance activity in 2016. Before other constraints were reached in the system, the gas absorption column capacity was increased approximately 5% without compromising product quality. The capacity increase was consistent with the design basis and justified the project economics.

## 3. Conclusions

Random packing is generally the preferred mass transfer device in towers operating at elevated pressure and/or high liquid rates. The performance of these towers can be improved by using modern random packing with increased capacity or efficiency. INTALOX ULTRA random packing can be used to achieve efficiency and/or capacity benefits compared to IMTP and other random packing types. In the demethanizer and gas absorber applications discussed in this paper the operating companies were able to significantly increase the capacity of their units without sacrificing separation performance. This allowed operating companies to increase the capacity of their towers by replacing IMTP random packing with INTALOX ULTRA random packing.

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