

***HIGH-PERFORMANCE ANTI-FOULING TRAY TECHNOLOGY and  
ITS APPLICATION IN THE CHEMICAL INDUSTRY***

Presenter: ***Liem V. Pham***  
Glitsch, Inc.

***Mike Binkley, P.E.***  
Glitsch, Inc.  
Dallas, TX

***J. Y. Jang***  
Sunkyong E&C Ltd.  
Seoul, Korea

***Timothy M. Zygula***  
Westlake Styrene Corp.  
Sulphur, LA

***Robert M. Garner***  
Borden Chemicals & Plastics  
Geismar, LA

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## ***ABSTRACT***

Plugging of column internals in fouling services reduces column performance. More importantly, plant production will be interrupted due to frequent column downtime for cleaning of the internals. Trays, rather than packings, are the preferred column internals for these dirty services. Conventional trays, however, often have inactive areas, uneven and insufficient liquid cross-flows, stagnant liquid pools due to poor vapor/liquid distribution, and long liquid residence times in downcomers. All of these poor tray designs increase the tendency of polymerization, or solids settling on the tray.

Glitsch's High Performance anti-fouling SUPERFLUX® Tray, which features directional contact devices and a unique downcomer design, offers advanced anti-fouling tray technology to enhance tray performance. The advantages of the SUPERFLUX Tray include self-cleaning, vapor-driven liquid cross-flow, uniform liquid flow distribution, optimum vapor/liquid contact, minimum liquid residence time in the downcomer, and good liquid initial distribution to the active area.

The authors will present two (2) case studies detailing how the Glitsch SUPERFLUX Tray has increased capacity, efficiency, and extended run-time in petrochemical services.

The first case study will detail the revamp of a Butadiene column. Data before and after the revamp will be presented. The second case study will detail the revamp of an EDC Heavy Ends column. The case study will show that after this column was revamped with Glitsch's SUPERFLUX® Tray, there was a capacity increase of 24% as well as an efficiency increase. Plant data, before and after revamp, of this column will be presented.

## ***INTRODUCTION***

For fouling services, trays rather than packings are preferred as the contacting device in distillation columns. Trays offer the advantage of longer column operation, ease of cleaning, and lower cost. For a typical distillation tray, the liquid flows from the tray inlet area, across the bubbling area, into the downcomer and down to the tray below. Vapor ascends the column through holes in the active area bubbles and disengages from the liquid on each tray, and flows up to the tray above. Tray capacity and efficiency are generally a function of vapor/liquid distribution and bubbling activity on the tray. Conventional trays can create a situation of uneven and insufficient liquid cross flow velocity, poor vapor/liquid distribution, and long liquid residence time in the downcomer that lower tray efficiency and capacity, and creates stagnant liquid pools on trays. In fouling services, stagnant liquid pools can increase the tendency of polymerization, and solids settlement on trays. This type of material accumulation can reduce a columns performance and shorten the operation time of the column.

Through pilot plant studies and many successful commercial applications, Glitsch's High-Performance anti-fouling, SUPERFLUX Tray, was specially developed for use in fouling services. This high performance tray has the following advantages:

1. *Vapor-driven liquid cross flow, uniform liquid flow distribution.*
2. *Optimum vapor/liquid contact, self-cleaning.*
3. *Maximum tray active area, higher tray capacity.*
4. *Applies the latest downcomer technology to increase downcomer performance.*
5. *Minimum column modification.*

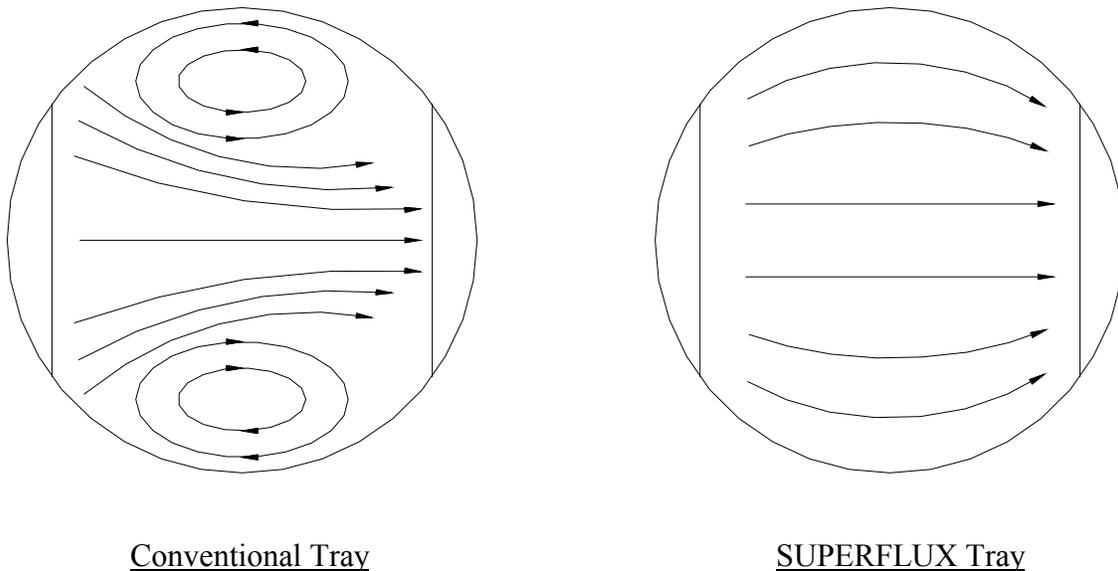
### ***Uniform Liquid Flow Distribution***

The bottom of a conventional sloped side downcomer tray always has a shorter exit length than weir length at the top of the downcomer. When liquid flows out of a conventional side downcomer, it usually flows through the tray in an area at the middle of the tray. The length of this area is almost the same as the downcomer's exit length. The liquid flow velocity is higher in the center area of the tray. Meanwhile, at the periphery of the tray the liquid just swirls with a very small net flow in the direction of the flow path, creating stagnant liquid pools.

Normally, the clear liquid head is higher at the tray inlet area, and little or no aeration occurs in the first few inches of a conventional tray. The high liquid flow velocity out of the downcomer bottom, together with a high clear liquid head at the inlet area, suppress the vapor flow at this location. Maldistribution of vapor and liquid can result. Movable devices on conventional trays in fouling services, i.e., movable valves, can plug. A plugged or fouled movable device can reduce the effectiveness of that device, and hamper the performance of the tray.

To improve liquid distribution and avoid liquid stagnant pools on trays, the SUPERFLUX® Tray uses a specially designed section at the bottom of the downcomer instead of a straight exit length as in conventional trays. With this improvement, the downcomer bottom exit length is actually longer than the chord length at the top downcomer. The liquid exiting the downcomer can be distributed in a wider area than in conventional trays. Once out of the downcomer, the liquid is driven evenly across the tray by vapor flow through specially-designed directional contact devices on the tray. Liquid flow distribution on the tray is improved dramatically. **Figure 1** shows a comparison of the liquid flow distribution between a conventional tray and the SUPERFLUX Tray.

**Figure 1.** *Liquid Flow Distribution Comparison*



### ***Optimum Vapor/Liquid Contact***

Uniform bubbling activity on a tray is another key achievement of the SUPERFLUX® Tray. In fouling services, stagnant liquid pools on conventional trays not only reduce tray performance but also cause plugging on trays due to solids settlement and polymerization. In addition to good liquid distribution, the SUPERFLUX Tray also uses bubble promoters to promote even vapor/liquid bubbling activity on the tray. The bubble promoters, which are placed along and in front of downcomer bottom chordal length, immediately convert clear liquid out of the downcomer into froth, as opposed to high clear liquid head as normally seen on the first few inches of the inlet area of the conventional tray. High liquid gradient is eliminated, and the bubbling activity on the tray in the direction of liquid flow is also evened.

In a conventional tray, the area under each downcomer is a dead area. Glitsch's SUPERFLUX trays use an advanced technology to minimize this inactive area. The maximized active area lowers the velocity of the rising vapor so that at a given vapor rate, less liquid entrainment and lower tray pressure drop is achieved. Consequently, the trays can handle a higher vapor-liquid loading for extra capacity.

To achieve the above improvement, i.e., maximized active area, and longer exit length at downcomer bottom for better liquid distribution requires some improvement in downcomer and a good understanding of downcomer behavior.

### ***Downcomer Improvement***

As the high froth flux flows into the downcomer, the downcomer top needs to be large enough for vapor/liquid disengagement. The liquid at the bottom downcomer is almost clear that the downcomer bottom can be much smaller without great effect in downcomer performance. The SUPERFLUX Tray uses a regular segmental chord at the downcomer top. However, the downcomer bottom is made into a multi-chordal lengths. The longer exit chordal length together with plural downcomer sidewall, and fully opened downcomer bottom help liquid easily flow out of downcomer, lowering downcomer head loss & consequently reduce the clear liquid head in the downcomer. Also, as the tray pressure drop of the SUPERFLUX Tray is lowered, the difference in density of vapor and liquid increases. This helps vapor and liquid to disengage easier in downcomer. Liquid residence time in the downcomer is shortened, thus providing less of a chance for solids to settle in the downcomer. The longer downcomer bottom exit length is also responsible for good initial liquid distribution onto the tray below.

Another advantage of using the SUPERFLUX Tray rather than packing in revamps is that minimum column modifications are required. In most cases, a one-to-one tray replacement is possible. With the use of downcomer adaptors, most of the existing tower attachments, i.e., tray support ring, downcomer bars, etc., can be retained for reuse with slight modifications. In many cases, no welding is required to modify the tower attachments. Also column downtime is minimized.

The benefits of the SUPERFLUX Tray, i.e. anti fouling, higher capacity (approximately 10%-30%) while at the same or better efficiency than conventional trays, better column operation and longer run time, have been confirmed by many successful revamps in commercial columns. Summaries of two (2) successful revamps, one in a Butadiene plant, and the other one in a Vinyl Chloride Monomer plant, are present in Cases Studies 1, and 2 below.

### **CASE STUDY 1: SUPERFLUX Trays In a Far East Butadiene Plant**

Due to the high demand in Butadiene supply, a Butadiene plant in the Far East was revamped to increase plant production. Existing conventional valve trays in a distillation column were replaced with Glitsch's high-performance SUPERFLUX Trays to debottleneck this column.

#### **Revamp Objectives:**

- Increase column capacity by 15%
- Eliminate fouling on the tray caused by Butadiene polymerization
- No welding to column shell allowed, due to short turnaround

#### **Solution:**

To meet the revamp objectives, (101) SUPERFLUX Tray were offered for this column to replace the existing conventional valve trays. Due to the short turnaround, new SUPERFLUX Trays were to be installed inside the column without welding. This was done with the use of downcomer adaptors. Existing tower attachments were mostly reused with minimum modification. Table 1 summarizes the column modifications.

**Table 1**

	Existing	Revamp
Column Diameter, mm	2,150	2,150
Tray Type	1-pass valve tray	SUPERFLUX tray
No. Of Trays	101	101
Tray Spacing, mm	380	380

**Results:**

Before the revamp, polymers were filtered out of the column through dual-strainer filters at top and bottom of column. Frequent switching of the filters was necessary with one strainer in service, the other one being cleaned. This necessity was no longer required after the revamp with the SUPERFLUX Trays. During a plant shutdown for maintenance, this column was inspected and found clean with no polymers on the trays. Comparison photos of fouled conventional tray before revamp, and clean SUPERFLUX tray, after one (1) year in operation, are shown in Figure 2.

With no polymers on the trays and good SUPERFLUX Trays performance, the overall column pressure drop was reduced from 1.26 kg/cm<sup>2</sup> to 0.7 kg/cm<sup>2</sup> after the revamp. Reflux ratio was reduced from 4.8 before the revamp to 4.2 after the revamp, at the same product purities. Energy savings were achieved with the reboiler duty reduction of approximately 9%.

Not only was the targeted revamp capacity met, but the revamped column has also been able to achieve an overall capacity increase of approximately 132%. Comparison of the column performance before and after revamp is summarized in Table 2.

**Table 2**

	Before Revamp	After Revamp
Capacity	100%	132%
Product Purities		same
Column Bottom Temp., °C	59	54
Total ΔP, kg/cm <sup>2</sup>	1.26	0.7
Reflux Ratio	4.8	4.2
Reboiler Duty		~9% reduction

## **CASE STUDY 2: SUPERFLUX Trays In A Vinyl Chloride Monomer Plant**

In recent years Borden Chemicals & Plastics was looking to debottleneck their EDC Heavy Ends column. This column separates the EDC product and lighter components from 1,1,2 Trichloroethane and heavier components. Borden was looking to increase the capacity of the column by 25%. Sieve trays are widely used in this type of application. This column has a history of fouling in the section of the column below the feed. The goal was to achieve a 25% increase in capacity with extended run time. The column was revamped with High Performance Anti-Fouling Trays (SUPERFLUX® Trays), **Figure 3**.

### **Analysis Of The EDC Heavy Ends Tower**

The vapor and liquid loadings throughout the column were generated by using the PRO/II Simulator and matching it to the plant data. The generated results were used to evaluate the existing sieve tray hydraulics. At the original design feed rate of 327 gpm the calculated hydraulic parameters indicated that the existing trays were at their capacity limits. A gamma scan test further confirmed that the tower is at or very near its operating limit. The single-pass trays above the feed in the column showed a lack of good clear vapor space between the trays. Spray heights above the one-pass trays were high, but less than the tray spacing. The two-pass trays below the feed were very near flooding conditions. Spray heights above the two-pass trays extended into the higher trays. A revamp proposal was developed to replace all of the existing sieve trays in the column with Glitsch's High Performance SUPERFLUX Trays. Details of the existing trays and the new SUPERFLUX® Trays are shown in Table 3.

**Table 3**

Section	Before Revamp		After Revamp	
	Rectifying	Stripping	Rectifying	Stripping
Tower Diameter, in.	108	108	108	108
Tray Type	1-pass Sieve	2-pass Sieve	1-pass SUPERFLUX	2-pass SUPERFLUX
Tray No.	15-60	1-14	14-58	1-12
Total Number of Trays	46	14	45	12
Tray Spacing, in.	15	15	15	18

The column's arrangement before and after the revamp are shown in Figure 3. The one-pass trays above the feed were replaced with one-pass SUPERFLUX® Trays. A tray spacing of 15 in. was maintained. The spacing of the trays below the feed was increased from 15 in. to 18 in.. In addition, the tray immediately below feed was removed and replaced with a transition tray. The function of the transition tray was to mix the liquid coming from the one-pass trays above and the incoming liquid feed. The transition, in turn, would then distribute the mixed liquid to the two-pass trays in the bottom of the column. Expansion tray rings and special downcomer adapters were used to support the new SUPERFLUX Trays to eliminate field-welding to the vessel wall.

## Results

After the revamp, the column was started up and lined out. A test run was performed to evaluate the effectiveness of the SUPERFLUX Trays. The objective of the test run was to operate the Heavy Ends column at 110% of design rates for a two-day test period. At the midpoint of the first day of the test the 110% rate was achieved with acceptable EDC quality. The target purity of 99.6% EDC in the overhead product stream was achieved. The amount of 1,1,2 Trichloroethane impurity in the overhead was at an acceptable level.

Due to downstream limitations, this column has not yet reached the targeted revamp throughput of 125% of design rates . However, it has operated at 124% of original capacity over a two-year period without any problems. The column has not had any lost operation time due to tray fouling. This is considered a major success compared to frequent shutdowns before the revamp because of tray fouling. The original sieve tray design of this column operated with three (3) additional trays. Even through three (3) trays were eliminated in the new design, the required product purities were achieved at the same reflux ratio. This indicated that the SUPERFLUX® Trays provided higher tray efficiency than the existing conventional trays. A comparison of the column's performance before and after the revamp is shown in Table 4.

**Table 4**

	Before Revamp	After Revamp
Feed Rate, gpm	327	406
OVHD Product Rate, gpm	310	385
OVHD EDC Purity, wt%	99.60	99.61
OVHD Temperature, °F	221	236
Bottom Temperature, °F	250	252 - 257
Column Pressure Drop, psi	9.0	8 - 9.5
% Capacity Increase	100%	124%
Reflux Ratio (L/D)	0.48	0.45 - 0.52

# Butadiene Distillation



Fouled Valve Tray Before Revamp  
*"Pop-corn Polymer"*

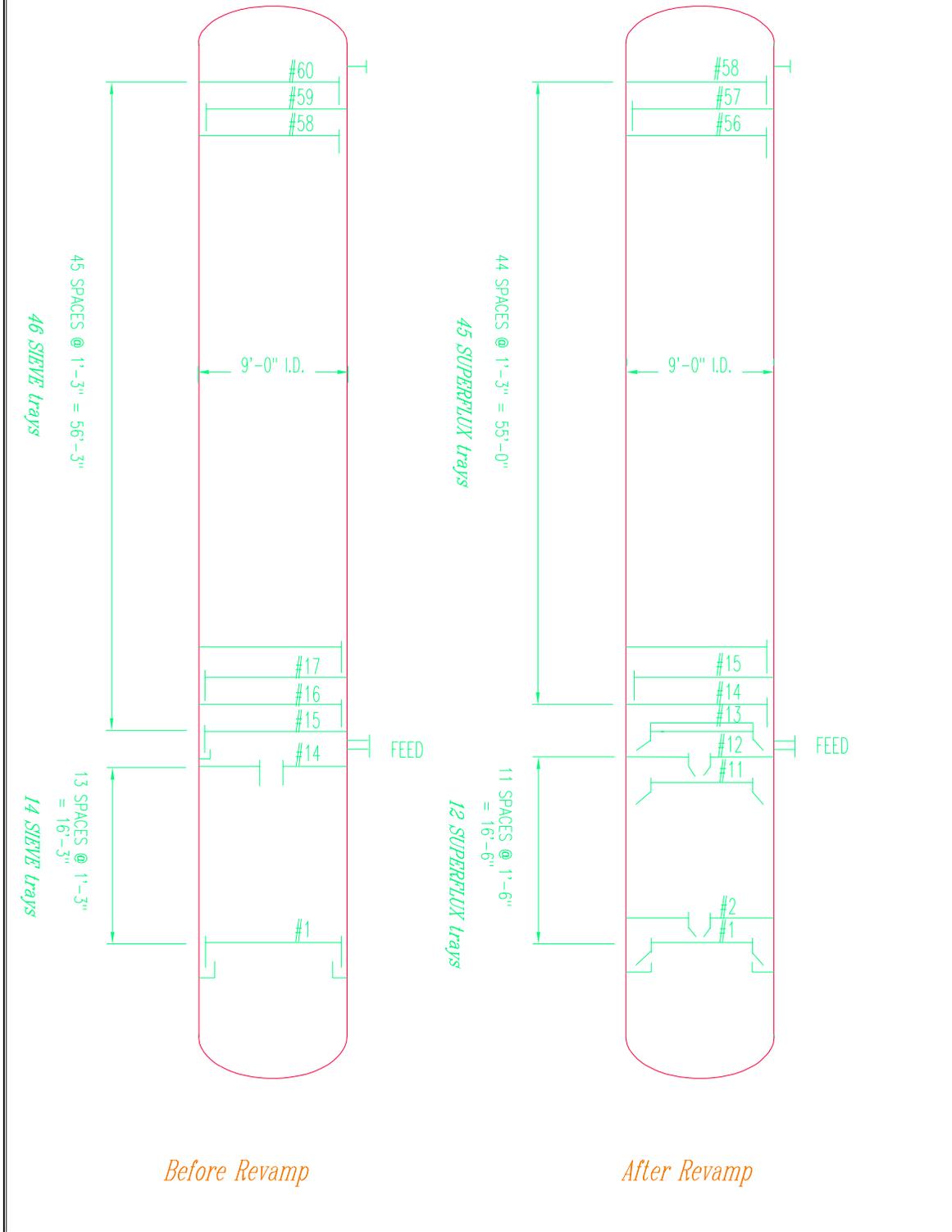


Glitsch High-Performance Anti-Fouling Tray, SUPERFLUX®  
*"After one year in operation"*

Figure 2



FIGURE 3. REVAMP OF EDC HEAVY ENDS COLUMN



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