Raschig High Capacity Mini Fixed Valves

FRI tested

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For mass transfer trays standard sized round and rectangular valves have been proven their industrial advantages many times. For typical applications the deck hole diameter of a standard moveable or fixed round valve is approx. 38 mm. For fouling services even larger valves in rectangular shape have been designed. Over the past years a new trend is pushing into the market: mini moveable or fixed valves. They are getting more and more popular especially for mass transfer columns were operators are looking for high capacities.

Raschig has recently tested its Mini Fixed Valve in the Fractionation Research Inc. (FRI) test column to provide more information about capacity, pressure drop and efficiency to the industry. This article discusses the FRI test results and shows typical applications were Raschig's high capacity Mini Fixed Valve was successfully applied. An industrial example for a grass root design and another example for a revamp case will be presented.

Introduction

The mini valve technology is based on the principles that small deck openings on a tray results in smaller gas flow streams pushing the liquid to a smaller extend to the mass transfer tray above. As the total open area is comparable to standard large valves the deck is equipped with a large population of mini valves. Fig. 1 shows the Raschig Mini Fixed Valve deck layout that was tested at FRI. Fig. 2 shows the Raschig Mini Fixed Valve in comparison to the regular fixed V0-valve. Beside the number of valves the shape of the Mini Fixed Valve is advanced compared to standard designs, see Fig. 2. The umbrella shape of the mini valve hat pushes the gas flow into a more horizontal direction what reduces the liquid entrainment to the tray above. The umbrella shape is designed just smooth enough to allow a low pressure drop. The V-shape of Raschig's Mini Fixed Valve pushes the liquid over the deck towards the downcomer. In 2014 Raschig's Mini Fixed Valves had been tested at FRI.

Fig. 1: Raschig's high capacity Mini Fixed Valve as tested at FRI

FRI testing of Raschig's Mini Fixed Valves

The Mini Fixed Valves had been tested in the low pressure column at FRI. The tests were performed with the system cyclohexane/n-heptane at 1.62 bar (24 psia) and 0.31 bar (4.5 psia). The operation included various total reflux run conditions to verify the tray efficiency over a wide capacity range, as well as non-total reflux run conditions to verify the capacity limits for a wide loading range. In this paper the total reflux runs will be discussed. For these tests FRI has used a liquid collector tray below the bottom tray for the first time. With this collector tray the weepage could be measured at the various operation modes.

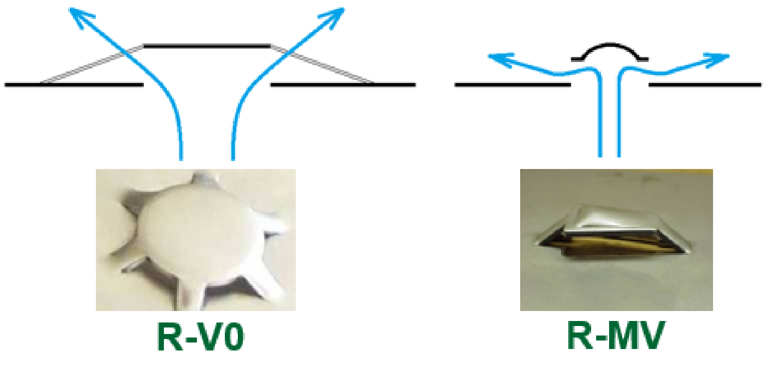

Fig. 2: Gas flow stream via a standard round fixed R-V0 valve and a high capacity R-MV Mini Fixed Valve by Raschig

The FRI column can be used for testing random packings, structured packings and mass transfer trays.This requires a very flexible column setup - therefore the column is not equipped with welded support rings. Instead, expansion rings get installed where required for the specific test. For the tray testing clips get welded to the column wall and expansion rings and support rings rest on the clips and get expanded towards the column shell. PTFE gasketing is applied to seal the expanded support ring as good as possible towards the column wall during tray installation. Using PTFE-sealed expansion rings is an industrial standard procedure if for example a tower revamp project is processed and new trays have to be positioned inside the tower without welding to the column shell.

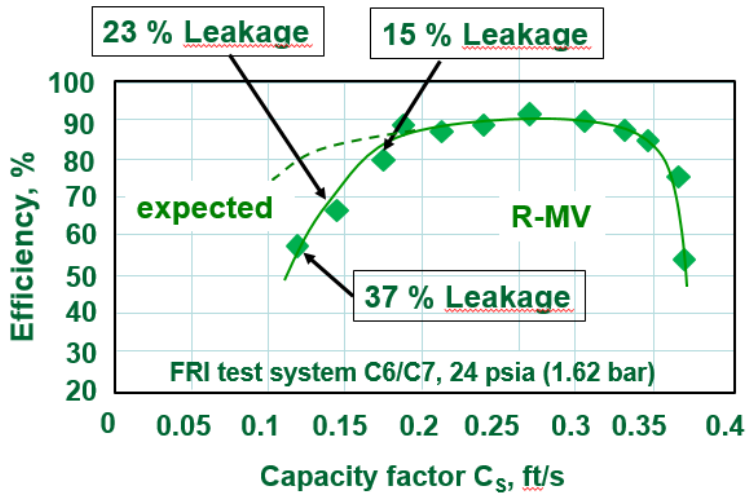

Fig. 3: Tray efficiency, capacity and tray support ring leaking fraction over column cross section area related Cs-factor of Raschig Mini Fixed Valves tested at FRI with cyclohexene/n-heptane at 1.62 bar (24 psia)

Six trays have been installed into the FRI low pressure column and an additional collector tray below. The tray spacing was 600 mm (24 inches) as a typical industrial standard. A standard sloped downcomer was used to enlarge the tray deck, providing a downcomer area of 6.7 % of the column cross section at the downcomer top and a 5 % downcomer area at the downcomer bottom. The tray active area was 87 % of the column cross section and the valve hole area was 12.4 % of the bubbling area. 549 Mini Fixed Valves were placed on each deck. A 51 mm (2 inches) outlet weir was incorporated in the tray design.

Fig. 3 shows the efficiency and capacity plot of Raschig's high capacity Mini Fixed Valve with the test system cyclohexane/n-heptane at 1.62 bar (24 psia). As described above the support ring expansion and PTFE sealing was controlled carefully. A liquid collector below the bottom tray was installed to read tray weepage.

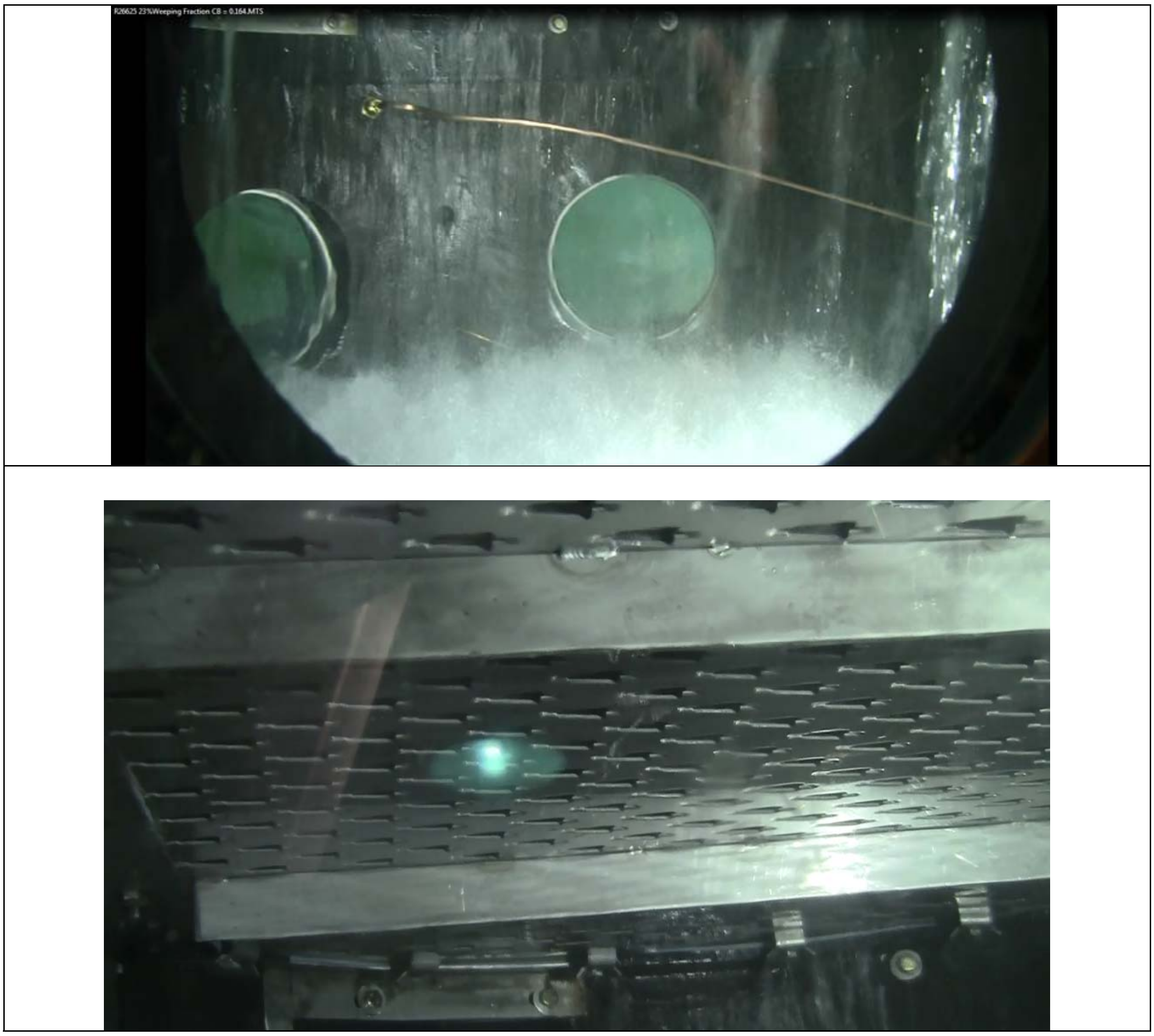

Fig. 4: Videotaped tray support ring leakage; top: column wall view between tray 3 and 4; bottom: view to tray 4 from below

Fig. 4 shows a snapshot during column operations between tray 3 and tray 4 during operation at a low column capacity. During operation of the trays noticeable support ring leakage was recognized at low loadings. The trays themselves were weepage free. Fig. 5 shows the pressure drop of the tray deck. One can see that the efficiency in Fig. 3 starts to drop when the ring leakage exceeded 15 % of the reflux rate. In the mid and upper capacity range the pressure drop of the trays were high enough to hold the liquid on the tray without leakage. In Fig. 3 the dotted line shows Raschig's expected efficiency curve assuming no support ring leakage.

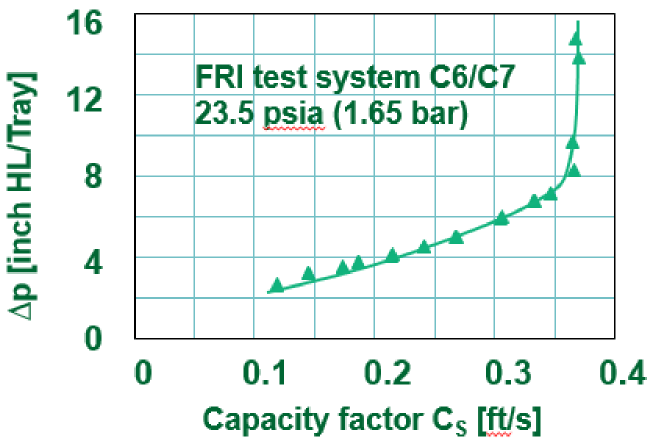

Fig. 5: Pressure drop and capacity over column cross section area related Cs-factor of Raschig Mini Fixed Valves tested at FRI with cyclohexene/n-heptane at 1.62 bar (24 psia)

Fig. 6 and Fig. 7 shows the equivalent test results for cyclohexane/n-heptane at 0.31 bar (4.5 psia) and provides corresponding information about support ring leakage and pressure drop. The dotted line shows again Raschig's expected efficiency curve without ring leakage. The turn-up and turn-down ratio for the Mini Fixed Valve is in the typical range for fixed valves. But Raschig's high capacity Mini Fixed Valve provides noticeable capacity and pressure drop advantages.

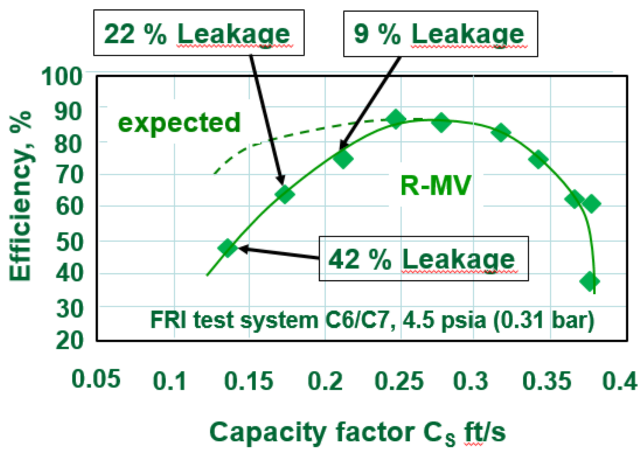

Fig. 6: Tray efficiency, capacity and tray support ring leaking fraction over column cross section area related Cs-factor of Raschig Mini Fixed Valves tested at FRI with cyclohexene/n-heptane at 0.31 bar (4.5 psia)

Fig. 8 shows the efficiency and capacity comparison to a standard movable V1 valve deck layout tested at FRI. Fig. 9 shows the comparison to a standard sieve tray deck layout and Fig. 10 shows the comparison to a standard fixed V0 valve deck layout, both also tested at FRI. These comparisons demonstrate the noticeable capacity and pressure drop advantage of Raschig's Mini Fixed Valve. A typical capacity advantage over standard fixed V0 valves is in the range of 10 % by using Raschig's high capacity Mini Fixed Valves.

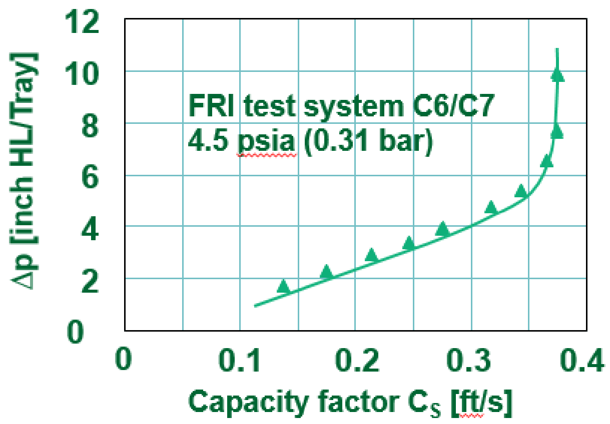

Fig. 7: Pressure drop and capacity over column cross section area related Cs-factor of Raschig Mini Fixed Valves tested at FRI with cyclohexene/n-heptane at 0.31 bar (4.5 psia)

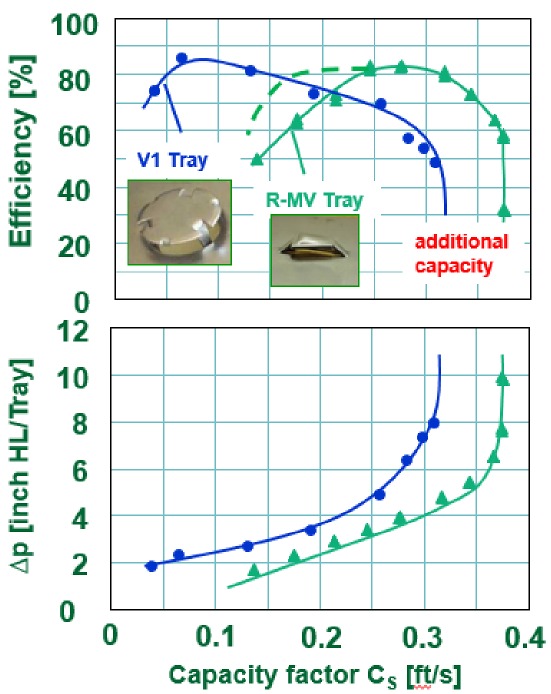

Fig. 8: Efficiency, pressure drop and capacity over column cross section area related Cs-factor of Raschig Mini Fixed Valves and movable V1 valves tested at FRI with cyclohexene/n-heptane at 0.31 bar (4.5 psia)

It has to be noticed that comparisons of tray efficiencies, capacities and pressure drop of different trays are very difficult to make as the whole tray design concept is determining its performance. For example the downcomer can be arranged straight, sloped, multi-chordal and truncated, the inlet and outlet weirs often have different heights, the orifice areas and bubbling areas can be different as well as the tray spacing - to name only a few parameters. Two, three and four pass designs have their own characteristics and are difficult to compare with one pass designs. But this is also typical for industrial practice. In a grass root design mini valves will have a different tray and downcomer layout than standard valve trays. In revamp cases for example the tower is performing with a given tray design at its capacity limit. Revamps often require an optimized downcomer, deck and valve design.

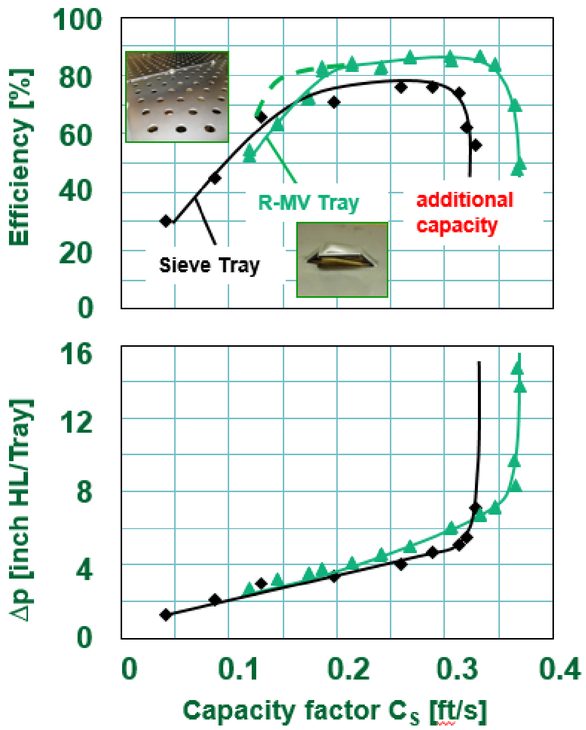

Fig. 9 Efficiency, pressure drop and capacity over column cross section area related Cs-factor of Raschig Mini Fixed Valves and sieve trays tested at FRI with cyclohexene/n-heptane at 1.62 bar (24 psia)

Application of Raschig's high capacity Mini Fixed Valve for a revamp case

An organic distillation column in Europe was equipped with movable round V1 valves. Tray spacing was 460 mm (18 inch) only and the column was operating at 2.2 bar (32 psia). The column was limited by its downcomer capacity. Consequently for increasing the capacity of the column the downcomer area had to be enlarged with the penalty that the active area had to be reduced, see Fig. 11. With the existing movable round V1 valve a jet flood value of 103 % was expected. No welding to the column shell was allowed in this revamp project.

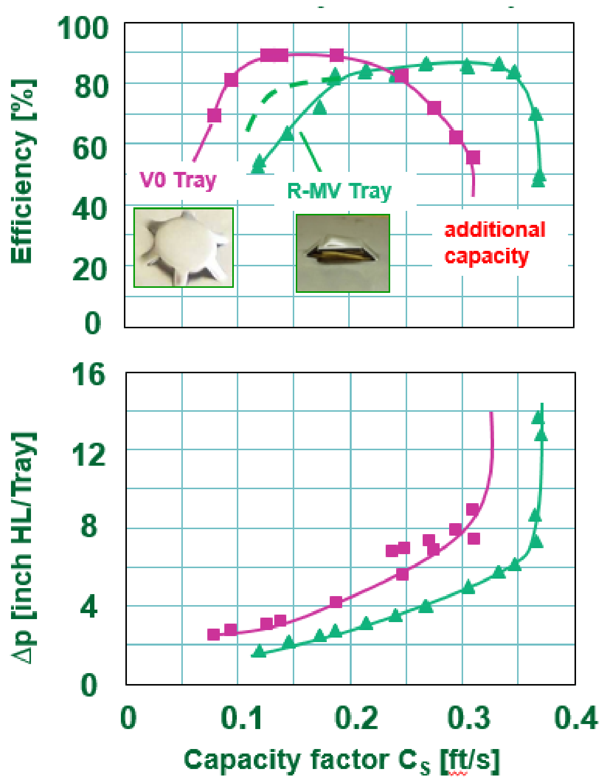

Fig. 10 Efficiency, pressure drop and capacity over column cross section area related Cs-factor of Raschig Mini Fixed Valves and fixed V0 valves tested at FRI with cyclohexene/n-heptane at 1.62 bar (24 psia)

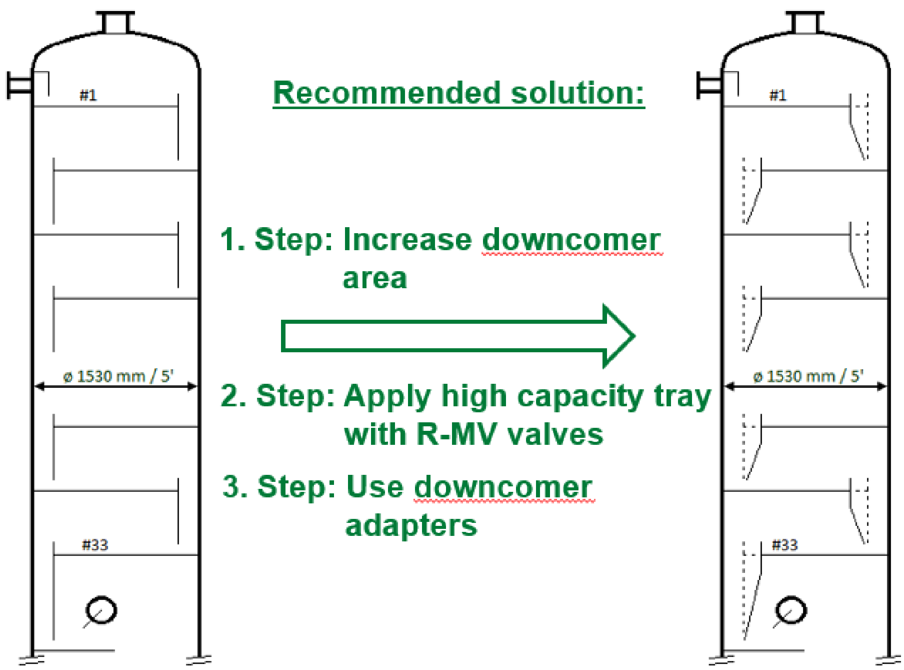

Fig. 11: Revamp of a distillation column from movable V1 valves to high capacity Raschig Mini Fixed Valves

The solution was as follows. First the downcomers were enlarged at their top end and received a sloped designed. Downcomer adapters were used, connected to the existing downcomer bars. Because of their high capacity Raschig's Mini Fixed Valves were applied on the tray deck. Fig. 12 shows the deck layout and the downcomer adapters. With this optimized design the capacity of the distillation tower was pushed by 13 % compared to its original design.

Fig 12: Tray deck layout applied for revamp project with Raschig Mini Fixed Valves and downcomer adapters

Application of Raschig's high capacity Mini Fixed Valve for a grass root design

A butane splitter had been designed to operate at 5.5 bar (80 psia), see Fig. 13. In the original design the column was specified with a 2-pass tray layout using fixed round V0 valves by applying a tray spacing of 400 mm (16 inches). During the detail engineering phase the customer has changed the column loadings to higher capacities. The specified V0 valves could not handle the new capacities as their capacity limit was 90 % of the new loadings. The limitation was jet flooding.

The solution was a change of valve type. Instead of using the standard V0 valves Raschig proposed its high capacity Mini Fixed Valves. This provided a capacity gain of 10 %. In addition Raschig proposed the application of NYE inserts at the downcomer outlets as shown in Fig. 14. The NYE inserts pushes the liquid out of the downcomer which helps the downcomer capacity. In addition the NYE inserts elevate the downcomer bottom area. Below the downcomer bottom area the NYE inserts are perforated. Also the front end area of the NYE inserts are perforated which provides more gas capacity. By applying the NYE insert technology a capacity gain of another 7 % was obtained.

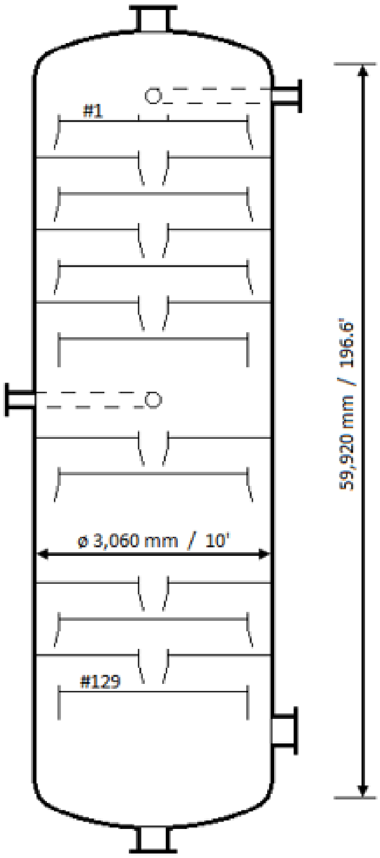

Fig. 13: Grass root design of a Butane Splitter with Raschig's to high capacity Mini Fixed Valves

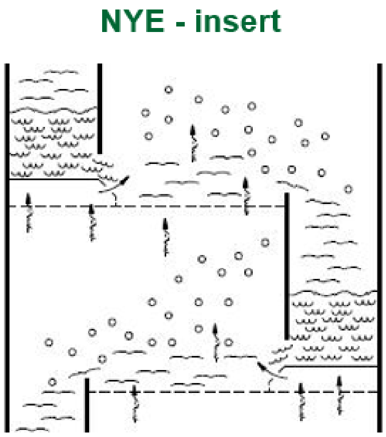

Fig. 14: Principle flow scheme of a NYE insert

Fig 15: Tray deck layout applied for a grass root butane splitter project with Raschig Mini Fixed Valves and NYE inserts

Conclusion

The high capacity Mini Fixed Valve technology designed by Raschig provides significant capacity and pressure drop advantages without any loss in efficiency compared to standard fixed valves. Typically a 10 % capacity gain can be expected changing from standard fixed valves to Raschig's high capacity Mini Fixed Valves. Modern downcomer designs can be applied to further bust capacities. The Mini Fixed Valve has widen Raschig's tray portfolio into high capacity devices. This technology helps our customers to increase their column capacities. Raschig has a long history in tray tower designs and has references available for several hundreds of trayed towers world-wide.

Nomenclature

Cs	ft/s, m/s	gas capacity factor: $u_V \sqrt{\frac{\rho_V}{\rho_L - \rho_V}}$
Δp	inchHL/tray	pressure drop in inch hot liquid per tray
u_V	ft/s, m/s	superficial gas velocity
ρ_V	kg/m^3	gas density

Literature

/1/ Fractionation Research, Inc.; February 1957 Progress Report Revision September 30, 1957

/2/ Fractionation Research, Inc.; Topical Report No. 41; December 15, 1967

/3/ Fractionation Research, Inc.; Topical Report No. 19; December 15, 1959