WHITE PAPER

DEBOTTLENECK DISTILLATION COLUMNS USING DWC PRIME

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Background

Each refinery has its own unique arrangement which is determined by the refinery location, desired products and economic considerations.Refineries still use distillation as the main unit operation for separating various fractions. Distillation columns are one of the most expensive units in operations because they consume large amount of energy. Energy reduction in the distillation process can be very effective in improving the refinery margins significantly and in the current scenario wherein an increasing trend is seen in energy prices refineries look forward to such revamps.

When taking about debottlenecking and optimizing the distillation columns dividing wall columns have lot to offer. The technology of dividing wall columns comes with the benefits of energy savings along with improvement in product specifications and capacity augmentation .The retrofits are simpler and robust hence once the benefits of this technology in any area of operation is justified, time and budget constraint should not hold back the revamps. Dividing wall columns are great retrofits when its comes to debottlenecking any downstream columns such as Naphtha splitters or reformate splitters. Depending on their areas of applications and the feed handled they are broadly classified as top, middle or bottom dividing wall columns.

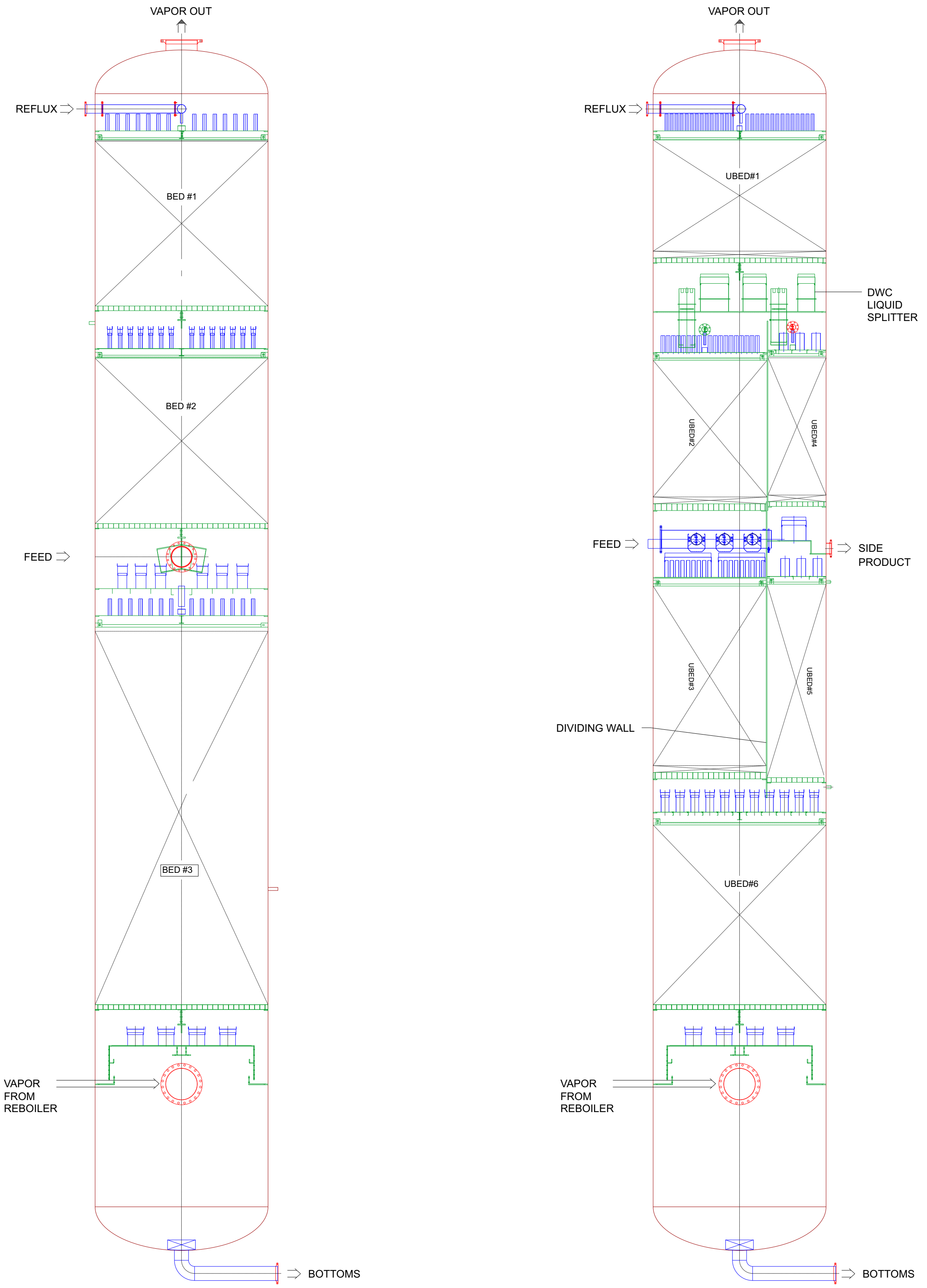
Insight into the dividing wall column Technology

Dividing Wall Columns (DWCs) have gained popularity since last two decades in the distillation world. The technology works to replace a sequence conventional distillation columns, which are the most energy intensive areas of refining and chemical industries. A lot of literature is available on how and where the use of this technology so as to reap maximum benefits and lot of literature is also available on the same.

Ideally retrofitting any conventional columns to DWC may bring the following benefits because they overcome the limitations of conventional columns in terms of overlap between the cuts due to which the desired product purity is not achieved.It is suitable for separating multicomponent mixtures into three or more high purity product streams in a single column. Its benefits can be summarized as:

- Ideal alternative for revamp of sidecut columns when high purity is required from the three product streams.
- Lower foot print as equipment count is reduced by half.
- Equipment turnaround time and other miscellaneous expenditure are reduced.
- The operational and capital expenditure are reduced by approximately 20-50%.

Structurally from outside a dividing wall column looks like a conventional distillation column but inside they have a defining wall in the column to separate the tower into two sections. Different fractionation zones are created in the column due to this wall. The zone in the column where the feed is introduced works to effectively separate the heaviest and the lightest key. A rectifying zone exists on the other side of the column, where the side stream is withdrawn. The mid-cut from the other side of the column is rich in middle boiling components. Because this wall removes the intrinsic mixing which takes place in the conventional column by creating different separation zones, hence these columns are thermodynamically more efficient in comparison to their counterparts hence benefit in terms of operating cost.



Existing column elevation

Column elevation after revamp to DWC PRIME

Figure 1 :Elevation of a conventional sidecut packed column vs dividing wall column. A DWC is equipped with a distinct wall inside the column which eliminates mixing between feed and sidecut and also provides a prefractionation zone on the feed side.

The figure above is a representation of a middle dividing wall column. A dividing wall column can be a bottom, middle or top wall depending upon the nature of feed it is processing. A middle dividing wall columns is ideal replacement of two columns in series. The top dividing wall columns conviniently replaces the need of side strippers in distillation columns and come with an added advantage of heat integration as it has two overhead condensing systems operating at different temperatures. Similarly bottom dividing wall columns are useful where ever the columns are in indirect sequence.

Dividing wall columns can be further clubbed with advantages of heat integration. In the nutshell this is state of art technology and every column stands as a masterpiece of what has been chiseled by simulations and years of experience of working in the field of dividing wall columns. These columns have been used in a variety of applications including gas plants, naphtha splitters, reformate splitters amongst others.

History and conceptualizing revamp:

This article highlights the revamp of a gasoline unit at a major refinery in South East Asia using dividing wall column technology. The figure below shows the gasoline unit configuration at this refining facility.

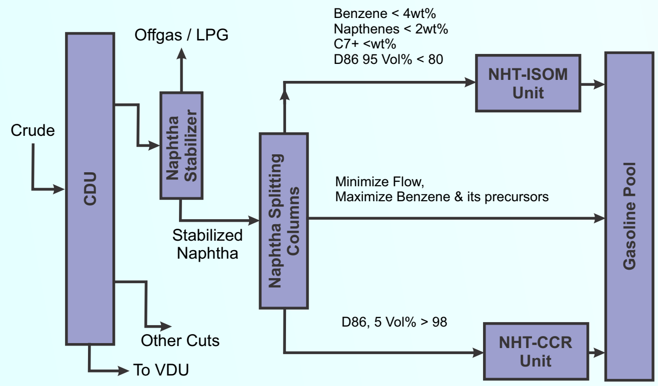


Figure 2 : Crude distillation units separate crude oil into use fractions. The top cut from CDU is Naphtha, which is again split into light and heavy fraction. The light fraction is feed to Isomerization unit and heavy cut is feed to CCR unit. The purpose of both the units is to increase the overall octane value of the gasoline pool by converting straight chain hydrocarbons to branched chain hydrocarbons. A mid-cut is taken to meet the benzene and its precursors limit in CCR and Isomerization unit.

The revamp aimed to optimise the naphtha splitters which process stabilized naphtha from CDU and send it for further processing. The CDU is the first unit in this facility and distills the incoming crude oil into various fractions of different boiling ranges. The top product from CDU is unstablized Naphtha which is stabilized in Naphtha Stabilizer. Stabilized naphtha is sent to a Naphtha splitter to split into top and bottom products which cater to the Isomerization and the Catalytic reforming unit respectively. The mid-cut from one of the column is drawn and diverted to the gasoline pool and it mainly carries benzene and its precursors with it. Table 1 provides the feed characteristics of stabilized naphtha to Naphtha Splitter.

Property	Units	Value
Density @ 15 ^{0}C	kg/m3	706.0
ASTM D86 Distillation		
IBP	^{0}C	37.3
5% volume	^{0}C	46.5
10% volume	^{0}C	52.2
30% volume	^{0}C	69.5
50% volume	^{0}C	80.8
70% volume	^{0}C	93.4
80% volume	^{0}C	95.9
90% volume	^{0}C	107.1
95% volume	^{0}C	111.8
FBP	^{0}C	119.0
RVP	Max. psia	8.0
Component Analysis		
Paraffins	%wt	66.48%
Naphthenes	%wt	24.81%
Aromatics	%wt	8.71%

Table 1 : Feed characteristics of Stabilized Naphtha to Naphtha Splitter column

The naphtha splitting at this facility is done in a series of two Naphtha Splitters as shown in figure 3.

This article highlights the revamp of a gasoline unit at a major refinery in South East Asiausing dividing wall column technology. The figure below shows the gasoline unit configuration at this refining facility.

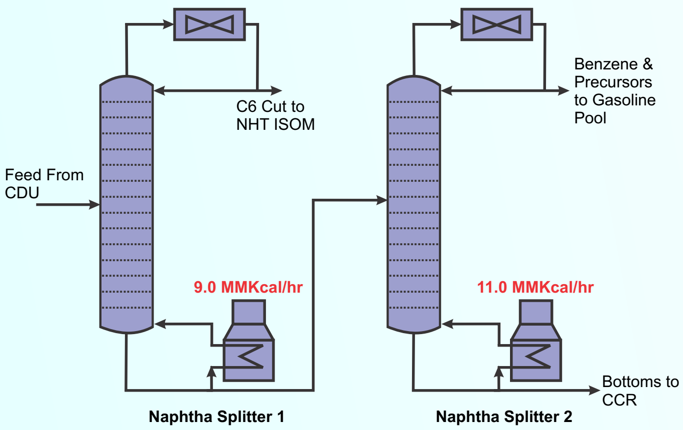


Figure 3: The original design of Naphtha splitter columns operating in series. The top product of the first column which is mainly the C6 cut is fed to ISOM while the bottom product of this column is the feed to the second column. From the second column the top product is send to the gasoline pool for blending while the bottoms is send to the CCR unit.The columns were initially designed to process a feed rate of 125T/hr of stabilized naphtha. The columns were trayed with conventional sieve trays.

Revamp of Naphtha splitters using structured packing

Later as the column through put was increased from 125T/hr to 185T/hr, capacity augmentation of Naphtha splitters was done by changing from trays to structured packing .Though it helped pushing more throughput through these splitters but problems were being faced on meeting the allowable benzene specs in the top product from the column going to the isomerization unit and this was a cause of concern .

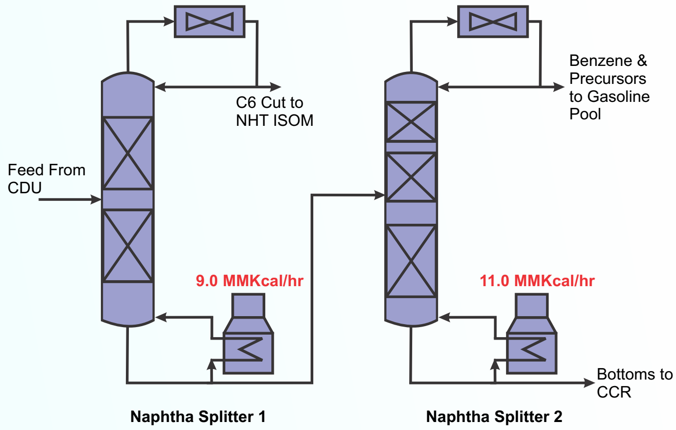


Figure 4 :Revamp 1 of The Naphtha Splitter columns. The columns were revamped from conventional sieve trays to structured packing when the feed rate was increased from 125T/hr to 185T/hr.

At 185 T/hr of feed rate, the benzene content in the top product which was the feed to the ISOM unit was higher than acceptable limit. In preview of maintaining the levels of benzene in this stream a provision was made to draw a mid-cut from the first column primarily to meet the benzene specs of the top product, as the mid-cut carried about 12% of benzene with it and this in turn could maintain the benzene content in the top product to ISOM below the allowable limit of 4%.

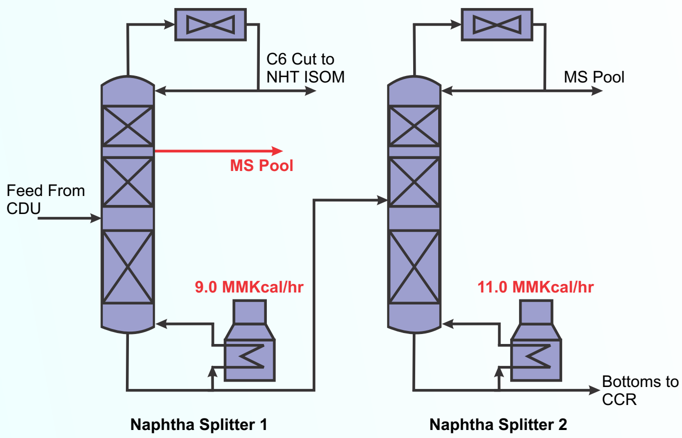


Figure 5: Revamp 2 involved introducing a side cutstream in Naphtha Splitter 1 so as to meet the benzene and C7+ product specs for the top cut stream going to Isomerization unit.

The following table shows the comparison of product specifications achieved in the revamps.

Parameter	Desired Product Specs	Original Design	Revamp 1	Revamp 2 (with sidecut)	
Column Internals		Seive Trays	Structured Packing	Structured Packing	
Feed rate, T/hr		125	185	255	
Top Cut					
Benzene, wt%	<4.0%	3.36%	2.97%	2.6%	
C6 Naphthenes, wt%	<10.0%	8.41	7.95%	6.5%	
C7+, wt%	<3.0%	1.2%	11.1%	2.2%	OnSpec Feed to Isom Unit
D86 95%V, °C	<80	80.4	89.3	68.7	
Yield, wt% of Feed	Max.	42.9%	46.9%	34.1%	Reduced Feed to Isom Unit
Mid Cut					
Benzene, wt%	Max.	10.2%	11.7%	7.8%	Increased Sidecut rate with low Octane Value
Toluene, wt%	<2.0%	0.01%	0.01%	1.78%	
Yield, wt% of Feed	Min.	12.3%	11.2%	24.0%	
Bottom Cut					
D86 5%V, °C	98	98	98	98	
Yield, wt% Feed	Max.	44.8%	41.4%	41.9%	

Table 2 : Product spec comparison between the three revamps.

Revamp of Naphtha splitter to DWC

Lately with availability of 255 T/hr of stabilized Naphtha these columns became bottleneck. Capacity augmentation in terms of pushing more feed through these columns was not possible with the current arrangement so other options were to be looked out for along with this the overlap between the draws from the column had to be taken care of.
Aset of thoughts provided impetus to take up the revamp of the Naphtha Splitters in concern.

To increase the throughput of these splitters to 255 T/hr the easiest option one could see was installing a series of two new columns in parallel to the existing ones. The refinery was already facing the constraint of plot space due to its location in a populous area so installing a new column for more feed throughput was the last option. This option would also invite a huge capex so the benefits of capacity augmentation were definitely going to be outweighed.

The other matter of concern was the midcut of the first column because though this midcut bought benefits in terms of keeping the benzene spec in the top product of column below the allowable limit , there was considerable slippage of C5 in this stream and as this was being diverted to the gasoline pool the refinery was losing lot of valuables to a low octane stream.

Brainstorming sessions forth way to arrive to consensus that for further capacity increase one effective way is to make these Naphtha splitters operate in parallel This option could be further clubbed with other lucrative options so that least amount of changes could be envisaged. Eventually it was recognized that revamping the existing column with the use of dividing wall columns technology was the best option. With this technology capacity augmentation was possible by revamping the existing columns and there trofitted wall would also help in attaining the product streams with desired quality. One more added benefit will be the minimization of the draw of the midcut which in turn would increase the revenue in terms of getting more of top or bottom product as against dumping this cut to the gasoline pool.

New design objective with availability of excess feed:

Retrofitting came with its own do and don't and how these objectives will be taken care by this versatile technology of dividing wall column is worth mentioning. The design objectives can be summarized in the following points:

- Feed rate is to increase from 185T/hr to 255 T/hr keeping in mind the optimization of feed distribution so as to minimize the quantum of modifications and maximize the yield and product quality
- The flowrate of the top product being fed to the isomerization unit is maximized with minimization of Benzene, C6 Naphthene's & C7+in it.
- The flowrate of the midcut which is diverted to Naphtha storage will be minimized along with minimization its overlap with top cut & bottom cut.
- The flowrate and the toluene concentration of bottom stream which was fed to NHT-CCR unit will be maximized
- Feed and bottom preheating will be considered for heat optimization.
- The combined reboiler heat duty and combined condenser heat duty for both the columns is to be minimized

The space and time constraint with this revamp were to pose few more challenges because the existing columns were to be retrofitted so their dimensions in no case could be altered and moreover no changes could be made in the operating conditions of the top, bottom, midcut design operating conditions as these were to suit the equipment available .

With the shutdown approaching the facility had to decide on going for the revamp as soon as they were convinced with the solution offered by the technology. This is one of its kind projects in which the designing and the availability of the column internals, lines and valves pertaining to changes outside the column will be at site in minimum possible time after the allotment of the project. The shutdown window for the revamp is small and allowance of a total of twenty man in man out days was one more critical consideration to be kept in mind.

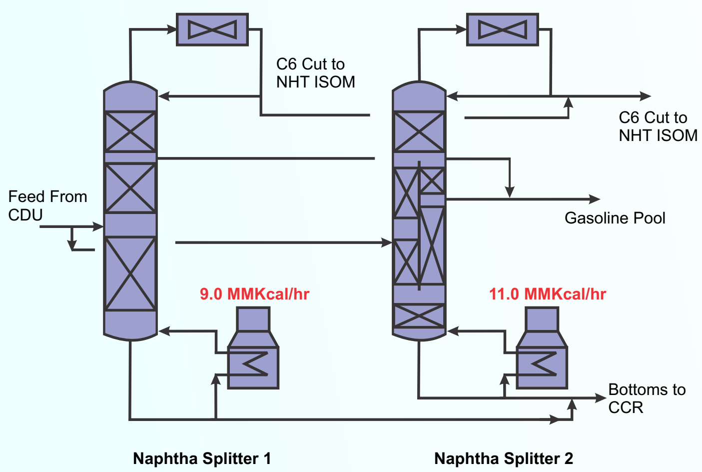


Figure 4 : Revamp using Dividing wall technology to process 255T/hr feed rate

The revamp of Splitters is based on an optimized technical solution which will maximize the product yields by operating both the splitters in parallel. It is decided to keep Splitter 1 as a conventional column and revamp Splitter 2 to a dividing wall column.

The second column will be revamped to a middle dividing wall column. All the packings in this column will be replaced with high efficiency packing so as to sustain the desired vapor liquid loadings.

The wall reduces the overlap considerably as a result of which the desired product purity is achieved. Due to this revamp the specifications of the top and the bottom product going to the ISOM and the CCR will improveand also the flow rate of the midcut reduced drastically. The table below summarizes the comparative specifications of the top, middle and the bottom products.

Parameter	Desired Product Specs	Original Design	Revamp 1	Revamp 2 (with sidecut)	Revamp 2 (with sidecut)
Column Internals		Seive Trays	Structured Packing	Structured Packing	Structured Packing
Feed rate, T/hr		125	185	185	255
Top Cut					
Benzene, wt%	<4.0%	3.36%	2.97%	2.6%	3.12%
C6 Naphthenes, wt%	<10.0%	8.41	7.95%	6.5%	8.08%
C7+, wt%	<3.0%	1.2%	11.1%	2.2%	1.93%
D86 95%V, °C	<80	80.4	89.3	68.7	74.0
Yield, wt% of Feed	Max.	42.9%	46.9%	34.1%	46.2%
Mid Cut					
Benzene, wt%	Max.	10.2%	11.7%	7.8%	5.3%
Toluene, wt%	<2.0%	0.01%	0.01%	1.78%	1.8%
Yield, wt% of Feed	Min.	12.3%	11.2%	24.0%	12.4%
Bottom Cut					
D86 5%V, °C	98	98	98	98	98
Yield, wt% Feed	Max.	44.8%	41.8%	41.8%	41.4%

Table 3 : The table shows the product spec comparison between the three revamps.

The benefits of introducing dividing wall technology to this revamp brings in the following benefits::

- 38% increase in capacity.
- Improved product specifications
- Improved revenue by maximizing feed rates to Isomerization and CCR Units
- No requirement of additional place
- Revamp Capex $3 million as against $15 million for installation of new column