OPTIMIZE NAPHTHA BLOCK USING DWC

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Background

Full range naphtha is a complex mixture of hydrocarbon molecules from 5 to 12 carbon atoms. This fraction of hydrocarbons has a boiling point range between 30°C and 200°C. It typically constitutes 15-30% of crude oil, by weight. As the focus of refineries shifted towards minimizing the carbon foot print and lower emissions, focus on fuel with higher RON and low emissions became the gold marked products which any facility targeted to produce. Naphtha processing facilities surged ahead in refurbishing so as to make more of high-end fuel along with incorporating technologies on improving the RON of the gasoline fuel. Meanwhile the focus was also on finding out ways on how to minimize the dump of the low value streams in full range naphtha.

Many refineries processing naphtha eventually evolved towards producing fuel which was more sustainable and in demand and for this they have gone through various transformations in their original operations. Few of these changes were enforcement driven like the compliance on content of benzene in the gasoline while the impetus for others were maximization of RON of the fuel. The Isomerization and the Reforming unit became an integral part of the naphtha block to the level that it is difficult to locate a single facility in operation across the globe which does not have a Reforming unit.

Importance of Isomerization and Reforming in processing full range naphtha

Improvement in RON of full range naphtha is possible either by converting straight chain paraffins into their branched chain isomers through the process of isomerization or through the process of catalytic reforming. The process of isomerization isomerizes light naphtha (C5/C6)feed, thus enhancing the octane by converting the n-paraffins to iso-paraffins. The process cannot tolerate sulfur in the feed and, therefore hydrotreating the feed prior with makeup hydrogen is essential. The feed must be tightly controlled to minimize C7 materials apart from benzene in the feed because it cokes and poisons the catalyst. Typically, refineries may have once through or recycle process, but processes which incorporates recycle have advantages in terms of yields.

Similarly, the process of reforming also enhances the RON of the heavy naphtha stream rich in paraffins and naphthene's and to much higher numbers. In the process the stream is contacted with a platinum-containing acidic catalyst at elevated temperatures and pressures converting it into reformate which is rich in aromatic hydrocarbons. The conditions employed in the process of reforming is primarily governed by the end use of the naphtha stock i.e. in case the objective is to create motor fuels, low octane naphtha feed is reformed to a high-octane liquid gasoline used in blending and when the objective is to create aromatics as a feedstock for the petrochemical industry more severe conditions are employed to increase the conversion of the naphtha feed to maximize the production of aromatics.

Importance of Naphtha feed stocks preparation

Feed preparation of full range naphtha for isomerization and reforming is an essential and important part of the process for getting the final product. Full range naphtha from CDU is stabilized in naphtha stabilizer then goes as feed to the naphtha splitter. Light Naphtha is the top product of naphtha splitter and becomes the feed for the isomerization unit. It typically contains straight chain paraffins mainly C5's and C6's along with the typical constraints on benzene <4%wt,Naphthenes <2%wt and C7<3% wt. The Isom feed cannot take any amount more than that of C7 mentioned above as it tends to coke the catalyst.

Similarly, heavy naphtha is the bottom product from the Naphtha Splitter is send for reforming which contains mainly of carbon molecules of numbers higher than seven in form of paraffins, naphthenes, aromatics and in some cases very small amount of olefins. In case the outlet of reforming unit is send to the gasoline pool then the benzene content to the reforming unit is also kept low or else a benzene saturation unit or benzene extraction unit is installed post reforming unit. This is because in the process of reforming, benzene precursors in the feed eventually raise the level of benzene beyond the acceptable limit as this reaction has tendency to make more benzene out of its precursors.

It is worth noting that for all naphtha processing facilities optimizing the feed to the isomerization and reforming unit face challenges on benzene management depending upon the facilities available downstream after reforming unit and the end use of the products. Also, the feed has to be optimized in terms of the type of carbon atoms present in the top and the bottom product which eventually decides the compositions of the streams which will be discussed in the case studies to follow.

Dividing Wall Column technology for Naphtha feed stock preparation

DWC's look like convectional columns from outside. But from inside they have a distinguishing dividing wall arrangement. The dividing wall segregates the column into a prefractionation side and the product side. Feed is introduced on the prefractionation side of DWC and the product is withdrawn on the opposite side.

Dividing wall columns are suitable for separating multi component mixture into three or more high purity product streams in a single column and are ideal alternative for revamp of side cut columns when high purity is required from the three product streams. They are popular over their peers because of lower foot print, lower turnaround time and lower capital expenditure. The operational and capital expenditure are reduced by approximately 20-50% with the use of this technology.

Refiners are accepting DWC technology as an attractive option for debottlenecking existing distillation columns. Dividing wall columns are extensively used in separating naphtha cuts. The subsequent case studies will highlight the importance of DWC columns in Naphtha block. Figure 1 below shows an inside view of a dividing wall column.

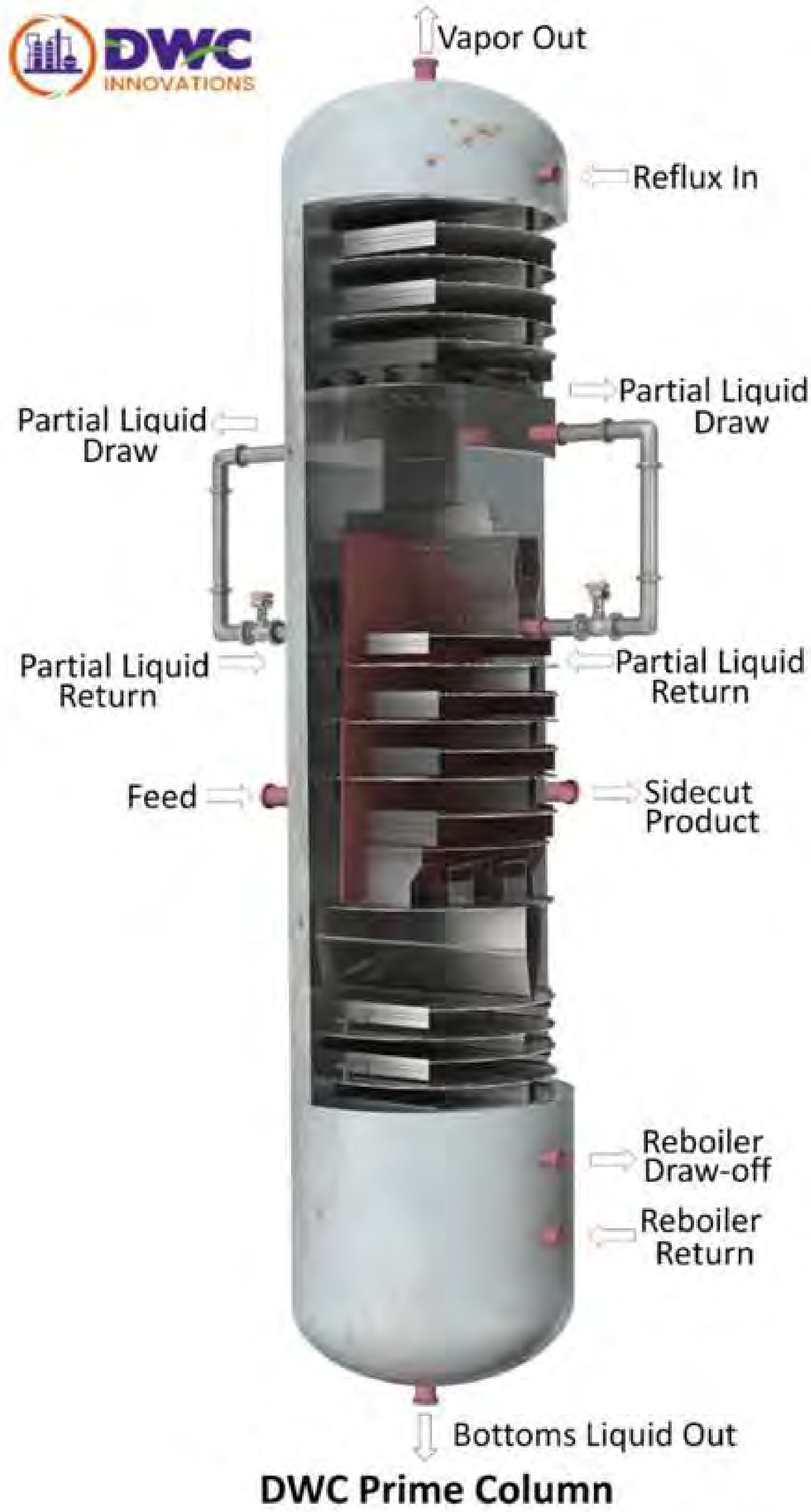

Figure 1: Inside view of Dividing wall column

Case study 1: Naphtha block with Light Isomerization and CCR Units

This case study focuses on the naphtha complex in a South East Asian refinery. The top and the bottom products from the Naphtha splitter cater to Isomerization and CCR unit respectively had a processing capacity of 4300 TPD. The naphtha complex configuration is provided in figure 2.

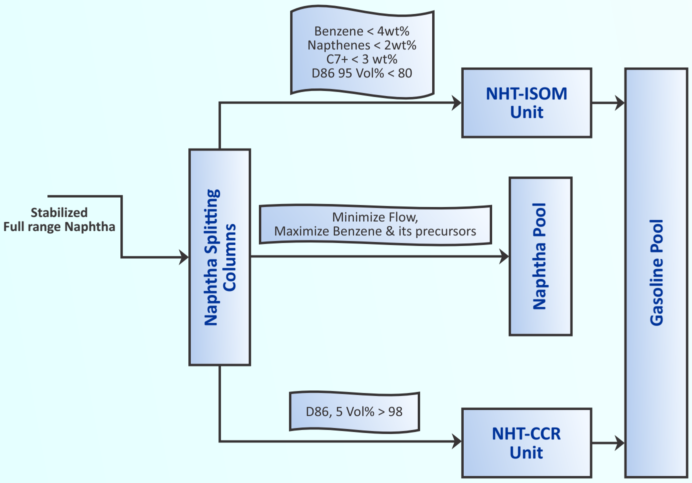

Figure 2 : Naphtha complex configuration with Isomerization and CCR Units

Full range naphtha splitting was done in a series of columns such that the top product of the first column was routed to the Isom while its bottom was sent to the second column. The bottoms of the second column was send to the CCR unit while the top was routed to the naphtha pool. Figure 3 provides the existing naphtha splitting sequence with two columns in series. The columns have already been through multiple revamps and were using high capacity structured packing for internals

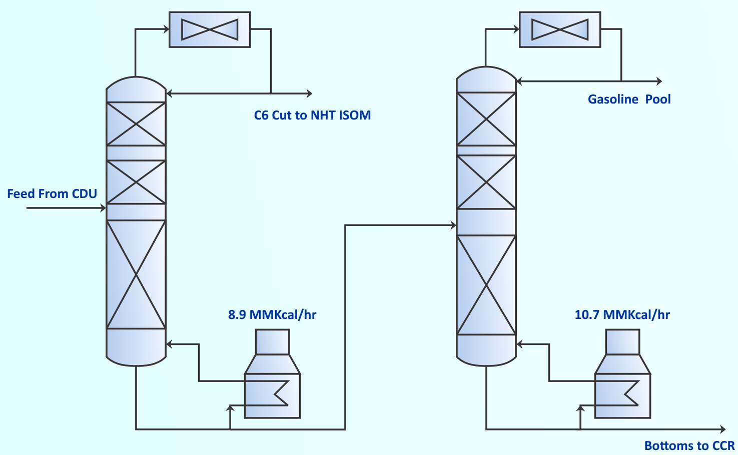

Figure 3 : Existing Naphtha splitting configuration. Two naphtha splitters using high capacity structured packing are operating in series.

These two columns were processing full range naphtha feed as shown in table 1

Property	Units	Value
Density @ 15 °C	kg/m3	706.0
ASTM D86 Distillation		
IBP	°C	37.3
5% volume	°C	46.5
10% volume	°C	52.2
30% volume	°C	96.5
50% volume	°C	80.8
70% volume	°C	93.4
80% volume	°C	95.9
90% volume	°C	107.1
95% volume	°C	111.8
FBP	°C	119.0

Table 1 : Full range naphtha feed

Off late when the need arose for further expansion to process 6000 TPD of FRN feed, these columns became bottleneck and the only option to move ahead was to install two new columns in parallel with existing system. As the facility is located in a populous area with restrictions on available plot area clubbed with the additional expenditure of the new column forced this revamp to take a back seat.

The technology of Dividing wall column was explored by the technocrats at the facility and this resurging technology offered solution keeping the following constraints in place.

- No new column.
- Existing Column dimensions shall not be changed.
- Minimum modifications to column tray support rings.
- New column internals to be installed in 20 man in to man out days.
- No Change in fired heater reboilers and its absorbed duties.
- No change in existing condensers.

The modifications were done in such a way that the first column was kept as conventional column with some change in packings while the second column was converted into divided wall column. The arrangement of the streams was done in such a way the that the quality and the quantity of the desirable stream i.e. light and the heavy isomerate were optimized.

The quantity of low value midcut decreased as the overlap between the cuts reduced which brought in huge benefits. This capacity augmentation for pushing 6000 TPD through the existing Naphtha splitters was meticulously managed with this technology minimizing the quantum of modifications.

The figure 4 below shows the configuration after the DWC revamp of the facility in concern.

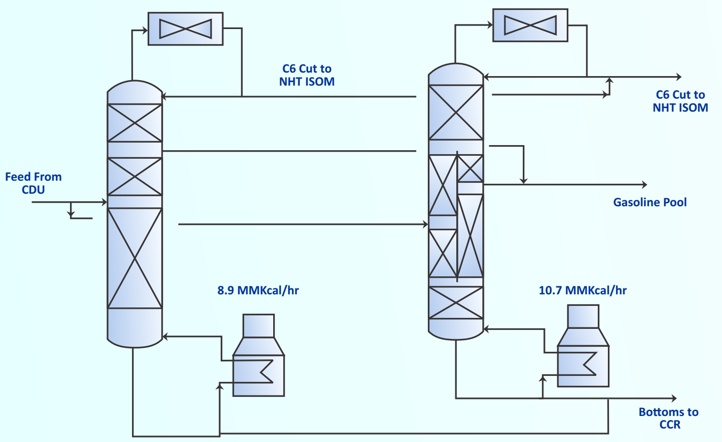

Figure 4 : New configuration after Revamp to DWC

The table 2 below is comparison between the product specification before and DWC revamp in order to increase the capacity of the Naphtha Splitters.

Parameter	Desired Product Specs	Existing Configuration	Revamp to DWC
Column Internals		Structured Packing	Structured Packing
Feed rates, MTPD		4300	6000
Top Cut			
Benzene, wt%	<4.0 %	2.6%	3.12%
C6 Naphthenes, wt%	<10.0 %	6.5%	8.08%
C7+, wt%	<3.0 %	2.2%	1.9%
D86 95%V, °C	<80	68.7	74.0
Yield, wt% of Feed	Max.	34.1%	46.15%
Mid Cut			
Benzene, wt%	Max.	7.8%	5.3%
Toluene, wt%	<2.0 %	1.78%	1.8%
Yield, wt% of Feed	Min	24.0%	12.4%
Bottom Cut			
D86 5%V, °C	98	98	98
Yield, wt% of Feed	Max.	41.8%	41.3%

Table 2 : Performance of Naphtha splitters before and after revamp to DWC

The benefits of the revamp can be summarized as below:

- 40% increase in capacity.
- Improved Product specifications. Isom unit feed specification were improved with low C7+ components.
- Improved revenue by maximizing feed rates to Isom and CCR units.
- Reduction in low value mid cut stream to naphtha pool.
- No requirement of additional plot area.
- Revamp capex decreased to 3.0 MMUSD against 15.0 MMUSD.

Case Study 2 : Naphtha block with Light Isomerization, Para Xylene and CCR Units

This case study focuses on another widely used configuration of the naphtha complex in which the top and the bottom products from the Naphtha splitter cater to Isomerization and Para Xylene Unit respectively

The FRN feedto the Naphtha Complex is defined in table 3 below:

Feed Rate	Tons/Hr	180
ASTM D86 (Vol %)		
IBP	°C	40.0
5%	°C	54.7
10%	°C	53.3
50%	°C	92.3
90%	°C	127.4
95%	°C	138.2
FBP	°C	164.2

Table 3: Full range naphtha feed

The Naphtha splitter produces three cuts

- Top to Isomerization Unit
- Mid cut to Naphtha pool
- Bottoms to PX complex

In the existing operation, Mid cut is taken and diverted to the Naphtha pool pertaining to the reason that the C7 content in the feed going to the PX complex should be <10%wt. In the attempt to keep the C7 content in the heavy naphtha below the above-mentioned limit the C7 content in the top increases to about 22%wt which is undesirable as it will coke the Isom catalyst. Therefore, to maintain the constraints of C7 in the top product going to Isom and bottom to PX unit, a side draw is taken which has about 22%wt of C7 and is dumped into the Naphtha pool. Because there is also substantial loss of C6 components in this mid cut due to overlap this stream is unfit to be used in the CCR unit and hence becomes a low value dump. This results in lesser heavy naphtha generation due to C7 loss to side cut and also reduces CCRU feed availability. Figure below provides the schematic of existing Naphtha block

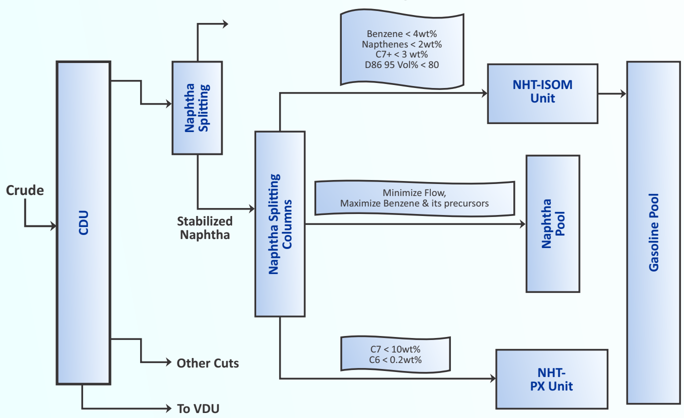

Figure 5 : Existing Naphtha Complex configuration with bottoms to Para Xylene Units. The naphtha splitter has a side cut as product specifications of C7+ to Isom and C7 to PX unit were off spec.

With the off-spec feed compositions to Isom and PX units, client decided to explore dividing wall column revamp with the following objectives.

Feed & Products	Current Destination	New Objectives
Feed	Full Range Naphtha	Full Range Naphtha
Top Product	Isomerization Unit	-Maximize Top Product -Minimize C7 Content. -Maximum allowable C7+ is 3%
Side cut	Naphtha Pool	-Disposal os sidecut in Naphtha pool is a problem. -Minimize C6 Content & concentrate in C7's. -Makes it suitable for CCR feed.
Bottoms Product	CCR	-Maximize Bottom. Quantity to be maximized. -C7 should not exceed more than 10 wt% -Minimize C6 less than 0.2wt%

Table 4 : Objectives for revamp to DWC

After revamp to the dividing wall column the Splitter could produce the top and the bottom product as per the specification of the feed to the Isom and PX complex respectively along with minimizing the C6 content in the midcut to the level that this stream could now be diverted to the CCR unit.Thus, a stream of low value which was dumped in Naphtha pool could now be used as feed to NHT-CCR which improved the overall octane barrel for the unit.The Figure 6 below shows the configuration post revamp.

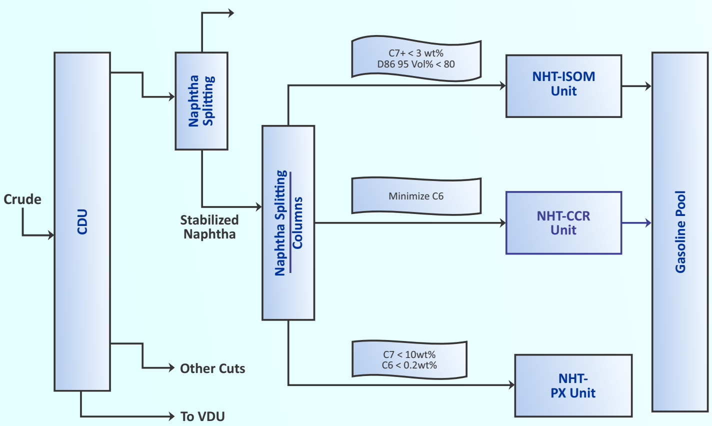

Figure 6 : Configuration after revamp with sidecut routed to CCRU

It is worth mentioning that dividing wall technology is the most suitable and cost effective alternative when it comes to improving purity of products from a conventional sidecut column. Table below summarizes the column performance before and after the DWC revamp.

Parameter	Unit	Existing Operating	Revamp to DWC
Feed	Tons/hr	180	180
Top product to Isom Unit			
Flow rate	Tone/Hr	86.0	77.2
IBP (ASTM D86)	C	44.2	44.2
FBP (ASTM D86)	C	95.1	80.0
Total C7+	wt%	20	3
SideCut			
Flow rate	Tons/hr	27.7	48.2
IBP (ASTM D86)	C	60.1	93.3
FBP (ASTM D86)	C	114.8	116.1
Total C6	wt%	22.9	1.4
Bottom Product to PX			
Flow rate	Tons/Hr	66.3	54.6
IBP (ASTM D86)	C	110.3	116.5
FBP (ASTM D86)	C	164.1	164.2
Total C6	wt%	0.1	0.2
Total C7	wt%	15.4	4.1
Duty			
Heating Duty	MMKcal/hr	19.0	19.0

Table 5 : Product specifications before and after revamp to DWC. The DWC revamp eliminated the side cut overlap with the C6 components of the top product. DWC revamp resulted in producing a more valuable side cut draw which is now an acceptable feed to Isom unit.

Case Study 3: Naphtha complex with two cut Naphtha splitter, Isomerization Unit and CCR Unit

This case study targets those facilities where the Naphtha Splitter separates FRN into the top product to the Isom unit while the bottoms is routed to the CCR unit. The top cut to isom unit has strident C7 (less than 3wt%) specifications. In order to maintain C7 spec to isom unit, the benzene and its precursors are diverted to the Reforming unit. There is an additional benzene management system downstream of CCR Unit. The most common arrangement would be a two-cut reformate splitter feeding the top C5/C6 components to benzene extraction unit. The bottoms product goes to the gasoline pool. The Figure 7 below shows the flow in the concerned unit

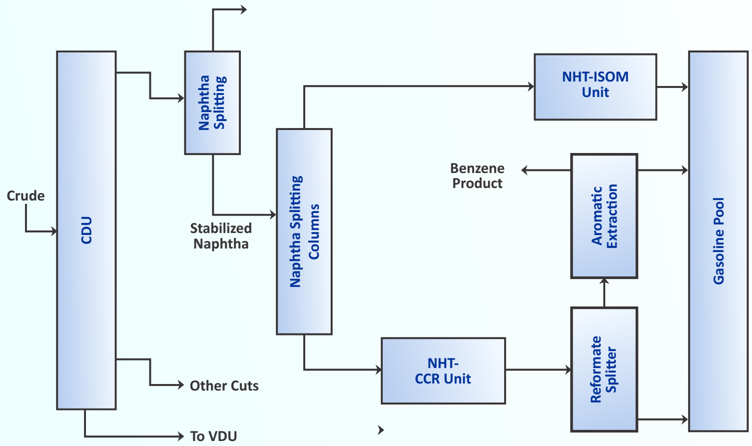

Figure 7: Schematic of two cut Naphtha Splitter, Isom & CCR Units with a benzene management system. The outlet from the CCR is routed to the Reformate splitter. This is typically a two-cut column splitting the reformate stream into a top product containing C5-C6's and the bottom product is C7+ which is send to the gasoline pool. The top product of Reformate Splitter is sent to aromatic extraction unit which splits the feed into a benzene product stream and non-aromatic raffinate. The raffinate is send to the gasoline pool. The table below provides the feed composition to the reformate splitter

Flow rate	Tons/hr	138.6
Composition		
C4	wt%	0.2
C5	wt%	3.6
C6	wt%	13.7
Benzene	wt%	6.5
C7	wt%	76.0

Table 6 : Feed to reformate splitter

There was a requirement of debottlenecking the Aromatic extraction unit. In the existing configuration the entire top product (C5 / C6) was feed to the ARU unit. Client decided to revamp the reformate splitter to a dividing wall column with three cuts. The top C5 cut and bottoms C7 cut was sent directly to blending. A concentrated C6 midcut was taken and sent to ARU unit. The figure below provides the existing and DWC revamp configurations of reformate splitter.

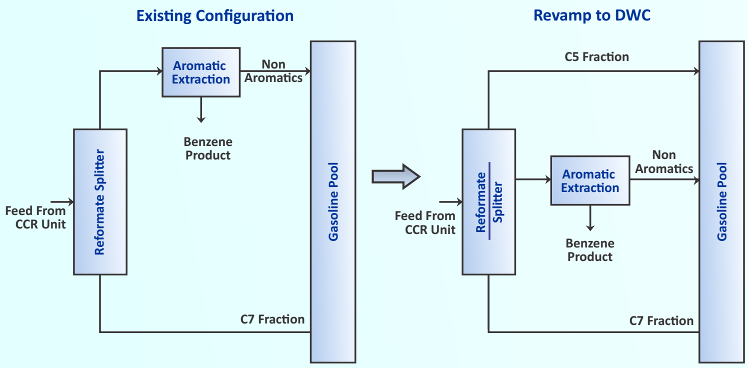

Figure 7: Existing vs DWC revamp configuration of reformate splitter. With DWC revamp feed rate to ARU unit was reduced by 27%.

As shown in table below, the DWC revamp resulted in 27% reduction in feed to ARU Unit. The feed now has 22.4% benzene as against 16.8% in the existing configuration.

Parameter	Unit	Existing Operating	Revamp to DWC
Feed	Tons/hr	138.6	138.6
Top product			
Flow rate	Tons/Hr	52.9	14.1
Benzene	Wt%	16.8	1.6
SideCut			
Flow rate	Tons/hr		38.8
Benzene	wt%		22.36
Bottom Prod. to Gasoline Blending			
Flow rate	Tons/hr	85.6	85.6
Benzene	Vol%	0.14	0.10
Duty			
Heating Duty	MMKcal/hr	10.1	10.1

Table 7: Reformate splitter performance before and after revamp to DWC

The dividing wall column revamp of reformate splitter is well known application. There were several DWC revamps of reformate splitter to meet the MSAT II requirements for benzene reduction. This facility realized the following benefits from the DWC revamp:

- Feed rate to extraction unit reduced by 27%.
- Modifications were limited to column internals only. No change in any equipment outside the column.
- No additional heating or cooling utility.

Conclusion

The use of Dividing wall columns is not restricted to a particular column but there are multiple units (including Naphtha complex) in the refinery which can be benefited by its use. Besides lower capex and opex the benefits of dividing wall columns include capacity expansion and improved product specifications. A smaller DWC revamp of a naphtha / reformate splitter saves substantial capex of debottlenecking downstream units of isomerization, CCR & ARU units by improving feed quality to these units. DWC improves revenue by upgrading low grade streams to high value product streams that can be blended directly into gasoline pool.