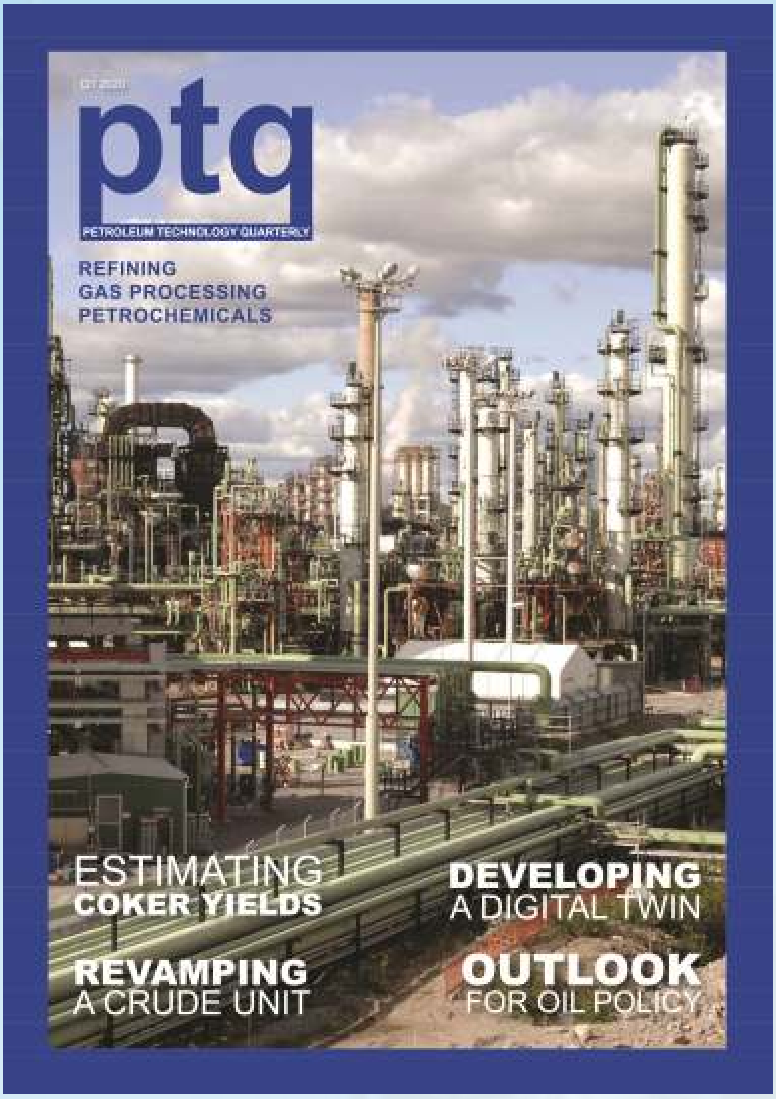
Dividing wall technology in distillation columns



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Dividing wall technology in distillation columns

Increased throughput required the revamp of a gasoline unit. Space constraints and strict product requirements led to dividing wall column technology as the most effective option

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Each refinery has a unique arrangement which is determined by 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 amounts of energy. Energy reduction in the distillation process can be very effective in improving refinery margins significantly and in the current climate, wherein an increasing trend is seen in energy prices, refineries look for such revamps.

When considering debottlenecking and optimising distillation columns, dividing wall columns have a 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. Retrofits are simpler and robust hence, once the benefits of this technology in any area of operation are justified, time and budget constraint should not hold back revamps. Dividing wall columns are great retrofits when it comes to debottlenecking downstream columns such as naphtha splitters or reformate splitters. Depending on their areas of application and the feed handled, they are broadly classified as top, middle or bottom dividing wall columns.

Versatile technology of dividing wall columns

Dividing wall columns have gained popularity over the last two decades in the distillation world. The technology works on the refurbishing of conventional distillation

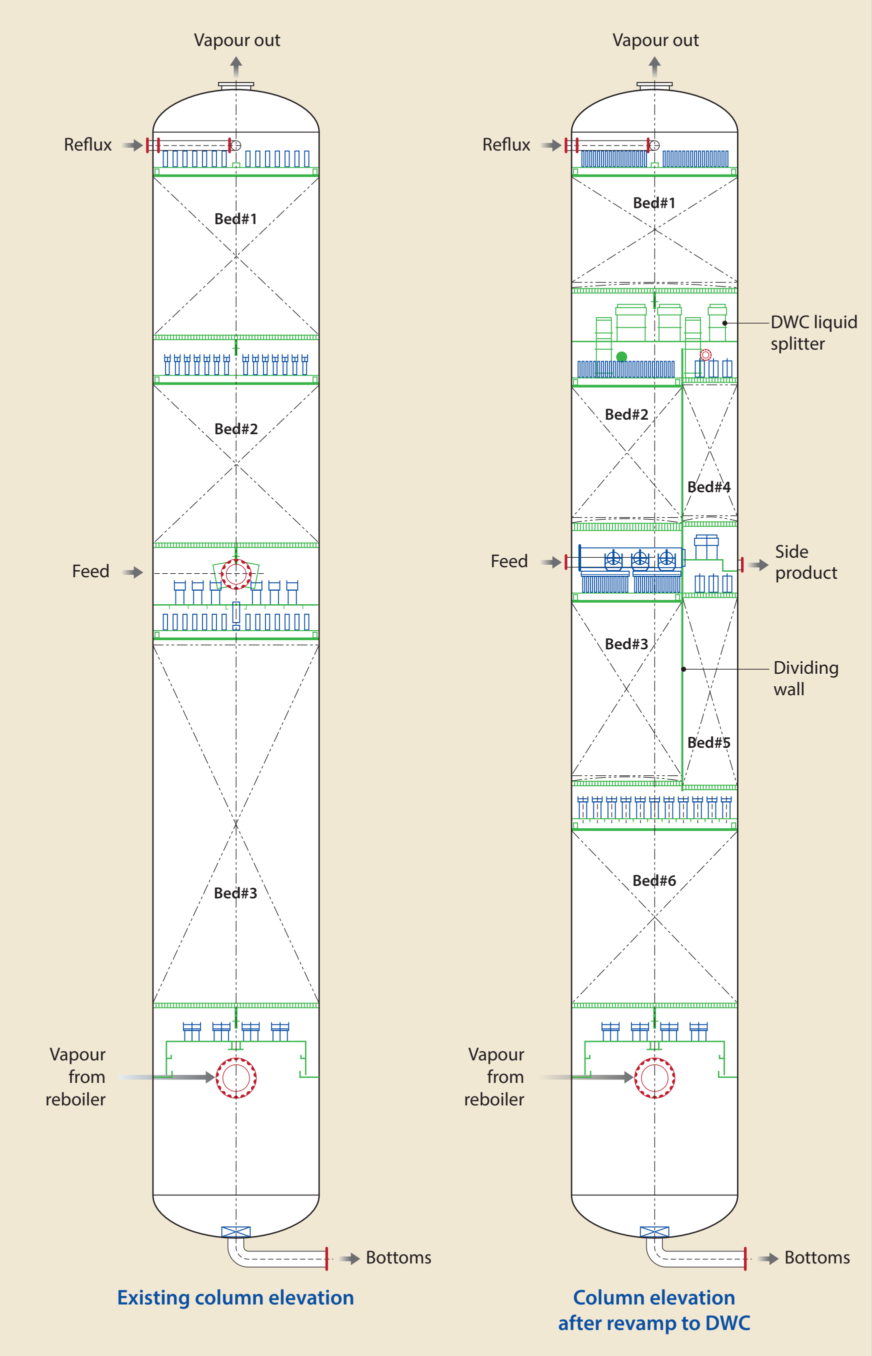

Figure 1 Elevation of a conventional side cut packed column (left) and a dividing wall column (right). A dividing wall column is equipped with a distinct wall inside the column which eliminates mixing between feed and side cut and also provides a prefractionation zone on the feed side

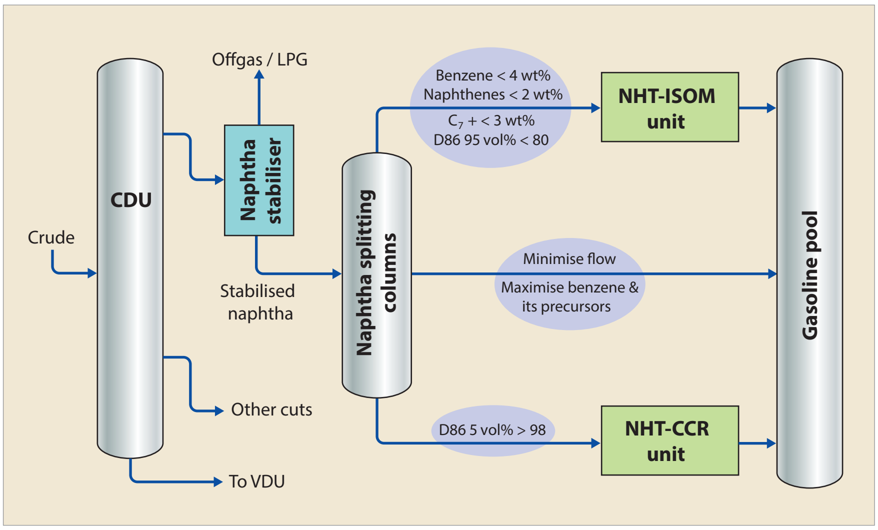

Figure 2 Crude distillation units separate crude oil into fractions. The top cut from the CDU is naphtha, which is again split into light and heavy fractions. The light fraction is fed to the isomerisation unit and the heavy cut is fed to the catalytic reforming (CCR) unit. The purpose of both units 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 limit on benzene and its precursors in the catalytic reforming and isomerisation units

columns which are the most energy intensive areas of the refining and chemical industries. A lot of literature is available on how and where this technology can reap maximum benefit.

Ideally, retrofitting any conventional column to a dividing wall column brings benefits because it overcomes the limitations of conventional columns in terms of overlap between cuts, as a result of which the desired product purity is not achieved. It is suitable for separating multi-component mixtures into three or more high purity product streams in a single column. Its benefits can be summarised as:

- Ideal alternative for the revamp of side cut columns when high purity is required from the three product streams
- Smaller footprint since the equipment count is reduced by half
- Equipment turnaround time and other miscellaneous expenditures are reduced
- Operational and capital expenditures are reduced by 20-50%

Structurally speaking, from the outside a dividing wall column looks like a conventional distillation column, but inside it has a dividing wall 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 feed is introduced works effectively to separate the heaviest and the lightest components. 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. Since this wall removes intrinsic mixing which takes place in the conventional column by creating different separation zones, these columns are thermodynamically more efficient in comparison to their counterparts, hence they provide benefit in terms of operating costs.

Figure 1 is a representation of a middle dividing wall column. A dividing wall can be a bottom, middle or top wall depending upon the nature of the feed it is processing. A middle dividing wall column is an ideal replacement for two columns in series. A top dividing wall column conveniently replaces the need for side strippers in distillation columns and comes 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 wherever columns are in indirect sequence.

These columns have been used in a variety of applications including gas plants, naphtha splitters, and reformate splitters, amongst others.

Characteristics of stabilised naphtha feed to the naphtha splitter column

Property	Value
Density @ 15°C, kg/m³	706.0
ASTM D86 distillation	
IBP, °C	37.3
5 vol%, °C	46.5
10 vol% °C	52.2
30 vol%, °C	69.5
50 vol%,°C	80.8
70 vol% °C	93.4
80 vol%, °C	95.9
90 vol%, °C	107.1
95 vol%, °C	111.8
FBP, °C	119.0
RVP, max. psia	8.0
Component analysis	
Paraffins, wt%	66.48
Naphthenes, wt%	24.81
Aromatics, wt%	8.71

Table 1

History and conceptualising of a revamp

This article highlights the revamp of a gasoline unit at a major refinery in South East Asia using dividing wall column technology. **Figure 2** shows the gasoline unit's configuration at the refinery.

The revamp aimed to optimise the naphtha splitters which process stabilised naphtha from the CDU and send it for further processing. The CDU is the first unit in this facility and distils incoming crude oil into various fractions with different boiling ranges. The top product from the CDU is unstablised naphtha which goes to the naphtha stabiliser. Stabilised naphtha is sent to a naphtha splitter to deliver top and bottom products for the isomerisation and catalytic reforming units respectively. The mid-cut is drawn and diverted to the gasoline pool, carrying benzene and its precursors with it. **Table 1** shows the characteristics of stabilised naphtha feed to the naphtha splitter.

Naphtha splitting at this facility is carried out in two units in series (see **Figure 3**).

Revamp of naphtha splitters using structured packing

Later, as the column throughput increased from 125 t/h to 185 t/h, capacity augmentation of the naphtha splitters was achieved by changing from trays to structured packing (see **Figure 4**). Although this helped to achieve more throughput for these splitters, there were problems meeting allowable benzene specifications in the top product from the column fed to the isomerisation unit and this was a cause for concern.

At a 185 t/h feed rate, the benzene content in the top product, the feed to the isomerisation unit, was higher than the acceptable limit. To control the level of benzene in this stream, provision was made to draw a mid-cut from the first column primarily to meet the benzene specification of the top product, as the mid-cut carried about 12% of benzene and this in turn could maintain the benzene content in the top product to below the allowable limit of 4% (see **Figure 5**).

Table 2 compares product specifications achieved in the revamps.

Revamp of naphtha splitter to dividing wall column

Lately, with the availability of 255 t/h of stabilised naphtha feed, these columns became a bottleneck. Capacity augmentation in terms of pushing more feed through the columns was not possible with the current arrangement, so other options were sought and the overlap between the draws from the column had to be taken care of.

To increase the throughput of these splitters to 255 t/h, the easiest option would be to install a series of two new columns in parallel to the existing ones. The refinery was already facing constraints of plot space due to its location in a populous area, so installing a new column for more feed throughput was the least practical option. This option would also invite huge expenditure, so the benefits of capacity augmentation were definitely going to be outweighed.

The other matter of concern was the mid-cut of the first column. Although this mid-cut brought benefits in terms of keeping the benzene specification in the top product of the column below the allowable limit, there was considerable slippage of C_5 in this stream. Since

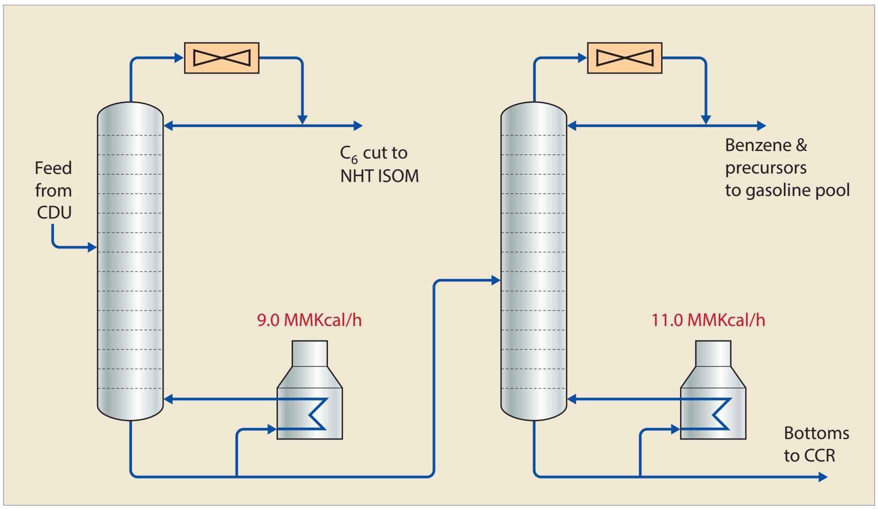

Figure 3 The original arrangement of naphtha splitter columns operating in series. The top product of the first column, mainly the C_6 cut, is fed to the isomerisation unit (ISOM) while the bottom product of this column is the feed to the second column. From the second column, the top product is sent to the gasoline pool for blending while the bottoms are sent to the CCR unit. The columns were initially designed to process a feed rate of 125 t/h of stabilised naphtha. The columns were fitted with conventional sieve trays

Product comparison of the revamps

	Desired product specs	Original design	Revamp 1	Revamp 2 (with side cut)	Notes
Column internals		Sieve trays	Structured packing	Structured packing	
Feed rate, t/h		125	185	255	
Top cut					
Benzene, wt%	<4.0	3.36	2.97	2.6	
C_6 naphthenes, wt%	<10.0	8.41	7.95	6.5	
C_7+, wt%	<3.0	1.2	11.1	2.2	On-spec feed
D86 95%V, °C	<80	80.4	89.3	68.7	to ISOM unit
Yield, wt% of feed	Max.	42.9	46.9	34.1	Reduced feed
Mid-cut					to ISOM unit
Benzene, wt%	Max.	10.2	11.7	7.8	Increased side
Toluene, wt%	<2.0	0.01	0.01	1.78	cut rate with
Yield, wt% of feed	Min.	12.3	11.2	24.0	low octane value
Bottom cut					
D86 5%V, °C	98	98	98	98	
Yield, wt% of feed	Max.	44.8	41.9	41.9	

Table 2

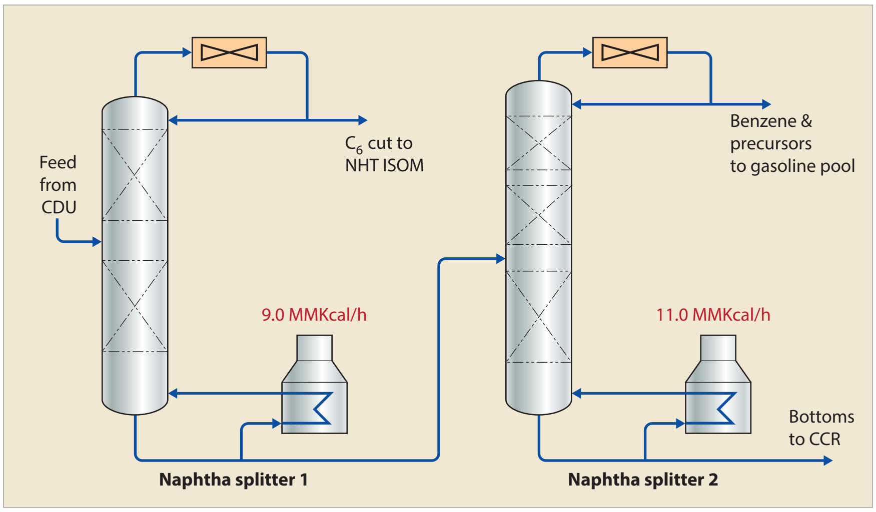

Figure 4 Revamp 1 of the naphtha splitter columns. The columns were revamped from conventional sieve trays to structured packing when the feed rate was increased from 125 t/h to 185 t/h

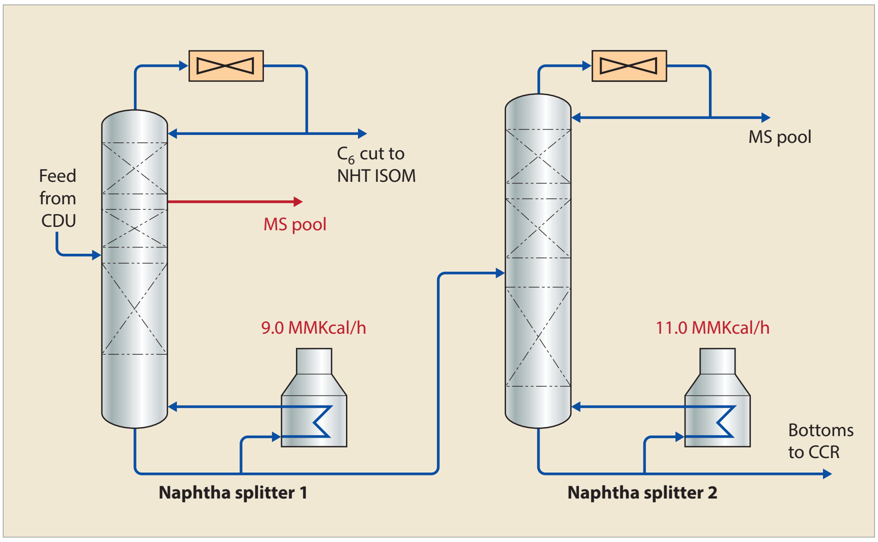

Figure 5 Revamp 2 involved introducing a side cut stream in naphtha splitter 1 to meet the benzene and C_7+ product specifications for the top cut stream fed to the isomerisation unit

this was being diverted to the gasoline pool, the refinery was losing a lot of value to a low octane stream.

Brainstorming sessions reached a consensus that for a further capacity increase an effective solution was to make these naphtha splitters operate in parallel. This option could be combined with other options so that the least amount of change could be envisaged. Eventually it was recognised that revamping the existing column using dividing wall column technology was the best option. With this option, augmentation of capacity was possible by revamping the existing columns while the retrofitted wall would also help in achieving product streams with the desired quality. A further benefit would be minimisation of the draw of mid-cut which in turn would increase revenue from the top or bottom product instead of dumping this cut to the gasoline pool.

New design objectives

The design objectives can be summarised as follows:

- Feed rate to increase from 185 t/h to 255 t/h keeping in mind the optimisation of feed distribution to minimise the number of modifications and maximise yield and product quality
- Flow rate of the top product being fed to the isomerisation unit to be maximised, with minimisation of benzene, C_6 and C_7+
- Flow rate of the mid-cut diverted to naphtha storage should be minimised, as should its overlap with the top cut and bottom cut
- Flow rate and the toluene content of the bottom stream fed to the NHT-CCR unit should be maximised
- Feed and bottom preheating to be considered for heat optimisation
- Combined reboiler heat duty and combined condenser heat duty for both the columns to be minimised

The space and time constraints with this revamp were to pose a few more challenges because the existing columns were to be retrofitted so that their dimensions could not be altered and no changes could be made in the operating conditions of the top, bottom and mid-cuts to suit the available equipment.

With the shutdown approaching, the refiner had to decide on going ahead with the revamp as soon as they were convinced of the solution offered by the proposed technology. This is the kind of project in which the design and availability of the column internals, lines, and valves relating to changes outside the column should be on site in the least possible time after approval of the project. The shutdown window for the revamp was small and the allowance of a total of 20 man-in, man-out days was one more critical consideration to be kept in mind.

The revamp of the splitters is based on an optimised technical solution to maximise product yields by operating both splitters in parallel. It was decided to keep splitter 1 as a conventional column and revamp splitter 2 as a dividing wall column (see **Figure 6**).

The second column would be revamped to a middle dividing wall column. All the packings in this column would be replaced with high efficiency packing to sustain the desired vapour-liquid loadings.

The wall reduces the overlap considerably; as a result, the desired product purity is achieved. With this revamp, the specifications of the top and bottom products going to the isomerisation and catalytic reforming units improve and the flow rate of the mid-cut reduces significantly. **Table 3** summarises the comparative specifications of the top, middle and bottom products.

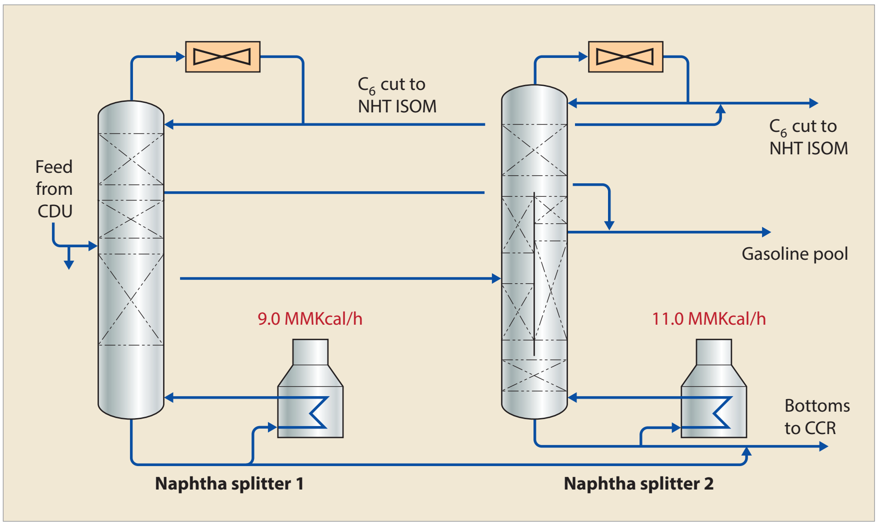

Figure 6 Revamp using dividing wall technology to process 6000 t/d

Introducing dividing wall technology to this revamp brings the following benefits:
- 38% increase in capacity
- Improved product specifications
- Improved revenue by maximising feed rates to the isomerisation and catalytic reforming units
- No requirement for additional space
- Revamp capex of $3 million against $15 million for installation of a new column.

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Product comparison for the three revamps

Parameter	Desired product specs	Case 1 Original design	Revamp 1	Revamp 2 (with side cut)	Revamp 3 (DWC)
Column internals		Sieve trays	Structured packing	Structured packing	Structured packing
Feed rate, t/h		125	185	185	255
Top cut					
Benzene, wt%	<4.0	3.36	2.97	2.6	3.12
C_6 naphthenes, wt%	<10.0	8.41	7.95	6.5	8.08
C_7+, 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% of feed	Max.	44.8	41.8	41.8	41.4

Table 3

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