2020

revamps

ptq

MODELLING **FCC REVAMPS**

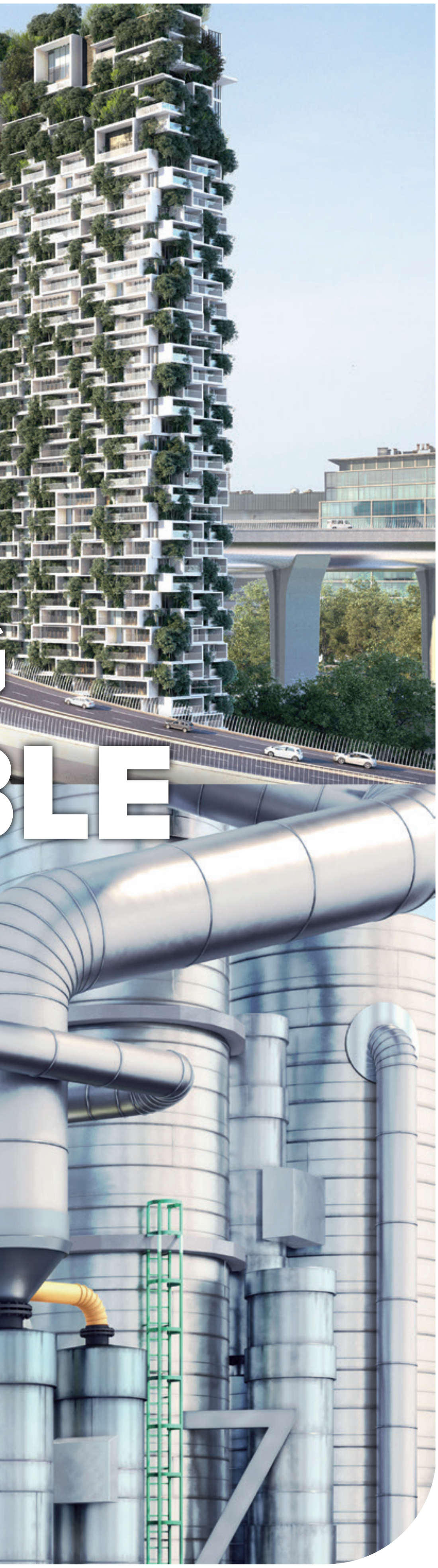
BOOSTING **RESID CONVERSION**

INTERNALS UPGRADES RAISE OUTPUT

TURNAROUNDS FIT FOR PURPOSE

Supplement to PTQ

POWERING A SUSTAINAB FUTURE



Through multi-specialist integrated offers, we deliver ever more inventive and sustainable solutions to our industrial clients, always aiming at preserving the planet.

www.axens.net

Axens
Powering integrated solutions

EMERGE STRONGER FROM GLOBAL MARKET CHALLENGES

Shell Catalysts & Technologies collaborates closely with our customers to create value through innovative solutions that leverage our expertise in catalyst, technology licensing and technical services. As a part of the Shell group of companies that also own and operate plants and refineries, we are uniquely positioned to tackle the complex global market challenges we face today. Our solutions are built on collaboration and innovation – enabling us to power progress together by providing more and cleaner energy solutions for the accelerating energy transition. Our objective is to maximise value for our customers by tailoring services to their unique challenges through proven, reliable solutions.

That's the promise of Shell Catalyst & Technologies, learn more at Shell.com/CT

SHELL CATALYSTS & TECHNOLOGIES
TRANSFORMING ENERGY TOGETHER

ptq
PETROLEUM TECHNOLOGY QUARTERLY

revamps

ptq

Editor
Chris Cunningham
editor@petroleumtechnology.com

Production Editor
Rachel Storry
production@petroleumtechnology.com

Graphics
Peter Harper
graphics@petroleumtechnology.com

Editorial
tel +44 844 5888 773
fax +44 844 5888 667

Business Development Director
Paul Mason
sales@petroleumtechnology.com

Advertising Sales Office
tel +44 844 5888 771
fax +44 844 5888 662

Managing Director
Richard Watts
richard.watts@emap.com

Circulation
Fran Havard
circulation@petroleumtechnology.com

EMAP, 10th Floor, Southern House,
Wellesley Grove, Croydon CR0 1XG
tel +44 208 253 8695

Register to receive your regular copy of *PTQ* at www.eptq.com/register

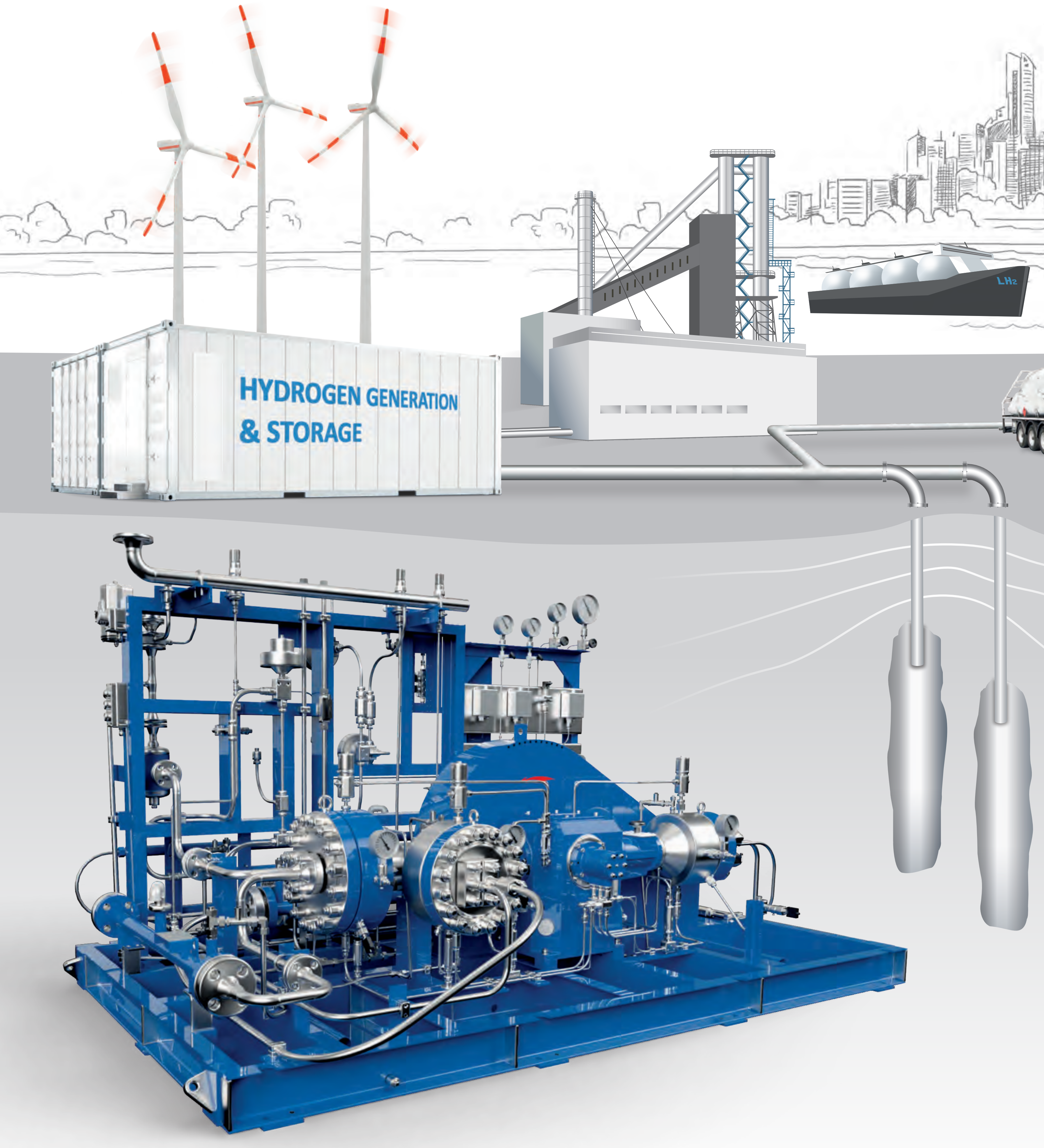
Cover
The Saudi Aramco Total Refining and Petrochemical refinery in Jubail is to carry out a $5 billion project to build a new petrochemical plant.

Photo: TechnipFMC

emap

©2020 The entire content of this publication is protected by copyright full details of which are available from the publishers. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, mechanical, photocopying, recording or otherwise – without the prior permission of the copyright owner.
The opinions and views expressed by the authors in this publication are not necessarily those of the editor or publisher and while every care has been taken in the preparation of all material included in *Petroleum Technology Quarterly* the publisher cannot be held responsible for any statements, opinions or views or for any inaccuracies.

COMPRESSORS ENERGI
THE TRANSITION TO TH



ZING
E H_2 ECONOMY

NEA COMPRESSORS
The H_2 Experts

Energy transition with compressors

For 80+ years NEUMAN & ESSER has been serving processes in refineries, the petrochemical and chemical industries according to API 618. This is why NEA has a profound know-how in the compression of all technical gases, especially of hydrogen and hydrogen mix gases. NEA GROUP has broadened its portfolio of applications by accompanying the transformation of the fossil fuel based oil & gas sector to an H_2 Economy with green hydrogen from renewable energy. This is where the proven compressor technologies from NEA and HOFER come into play. The conversion of the energy system with Power to Gas needs energy-efficient piston and diaphragm compressors. They are the perfect match to ensure both the flexibility of demand and energy security with green gases.

NEUMAN & ESSER: Agile. Solution. Experts.

Read the NEUMAN & ESSER blogs
with in-depth information
neuman-esser.com

Reactor LPG must be recovered

Be Smart about FCC Olefin Recovery

Whether the driver is propylene as a chemicals feedstock or propylene and butylene as alky feed, FCC units worldwide are being pushed to maximize olefin production. Increased hydrotreating to meet Tier 3 gasoline requirements is reducing gasoline pool octane at a time of high premium-to-regular gasoline price differentials. Maximizing FCC olefins to produce high octane alkylate barrels is attractive – if they can be recovered in the FCC gas plant LPG stream.

Higher reactor LPG yields increase wet gas compressor loading. So, in a unit that is already limited by wet gas compressor capacity, revamp modifications must be made to accommodate higher reactor LPG yields. Replacing the compressor entirely or installing a new parallel compressor are expensive options.

Instead, the keys to a practical offgas compressor revamp lie in the polytropic head equation (bottom right). Look to minimize main column inlet to wet gas compressor inlet pressure drop and overhead receiver temperature. Next, compressor speed and rotor modifications may afford additional capacity. On a mass basis, FCC wet gas rates have been increased by over 40% without installing a parallel compressor.

After compression to gas plant pressure of around 220 psig, the LPG must be condensed in the high pressure receiver or the absorber. Increasing reactor LPG yield stresses gas plant cooling systems and increases absorber and stripper column loads. Furthermore, high LPG yield often comes at the expense of naphtha yield, meaning that there is more vapor and less liquid in the absorber – this must be addressed to maintain high propylene recovery.

There is a strong incentive to maximize FCC olefin production with reactor temperature and catalyst formulation. Executing the correct revamp can economically address main column, wet gas compressor, and gas plant constraints so that theoretical reactor yields become actual barrels of valuable product.

Polytropic Head Equation

$$H_p = \frac{1{,}545}{MW} Z_{AVG} T_1 \left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\left(\frac{n-1}{n}\right)} - 1\right]$$

PROCESS CONSULTING SERVICES, INC.
3400 Bissonnet St.
Suite 130
Houston, TX 77005, USA
+1 (713) 665-7046
info@revamps.com
www.revamps.com

Effective preparation for turnarounds

Defining the objectives, planning thoroughly, and ensuring operator readiness will increase the likelihood of a successful turnaround

LEE WILLIAMSON
T.A. Cook Consultants

When preparation and execution of shutdown, turnaround, and outage (STO) becomes second nature, the scales will tip in your favour. For operations, a shift of focus from production to STO preparation does not happen overnight, however. For every hour when production is offline, there is a major impact on business performance due to lost revenue. If not thoroughly planned, the transition from operating the plant to clearing the plant in preparation for a turnaround will lead to prominent failure.

Resource requirements not being identified, operator experience levels being below expectations, key roles and responsibilities not being clearly defined, and the shutdown and start-up timeline not communicated to the STO team are just a few issues that will negatively impact the schedule. It is essential that operations managers are committed to implementing best practices for STO preparation as well as production. With the guidance of an effective milestone planning process, efficiency can be maintained when the time comes to take the unit down for an STO. Adhering to the milestone process helps ensure that operations is in alignment with the STO team and delivers an efficient and optimised event. Following this approach, your organisation will yield many benefits:

- Standardisation of processes will be implemented across all areas within an organisation.
- Well defined resource requirements will deliver an effective utilisation of staff.
- Operators are more prepared to execute tasks during shutdown and start-up of the plant.
- The enhanced quality of work will lead to increased productivity.
- The STO schedule will be more viable regarding equipment availability.
- Progress reporting will be clear and accurate.

We all can agree that, in some cases, preparing for a unit shutdown is widely viewed as an ad hoc process, with preparation and training as needed and when necessary. Understandably, operations typically focuses on meeting production targets at the proper run rates and within strict quality and regulatory guidelines. Thus, when an STO comes around every four or five years, preparedness is not necessarily on the 'high priority' list. In order to change this ad hoc way of doing business, operations should start preparing for the next STO as soon as the most recent one has completed. The first step would be to review the lessons learned, implement the recommendations, and address what did not go so well. In order to do that, operations managers must commit to driving productivity and efficiency, whether the plant is running at full capacity or preparing and executing a procedure to shut the unit down and bring it back up after all mechanical work has been completed.

Operations is in the business of producing a quality product. The transition from production to shutdown and start-up must go more smoothly. And yes, there is a way to bring about this smooth transition. This all begins with a blueprint for a successful STO. A well defined milestone process outlines those deliverables for which operations is accountable for completing. I bring this up because I have experienced misalignment between the STO team and operations when it comes to planning for an event. It appears that there are silos that exist. Part of it has to do with area of focus and expertise. The key here is to engage operations early in this process and gain buy-in. Within that blueprint are guidelines, targets and deliverables that govern how to effectively strategise, plan, and execute an event regardless of complexity. This article will focus on highlighting those deliverables that are specific to operations during the preparation and execution stages of an STO. This, in turn, will boost the engagement of operations and ensure that accountability is maintained throughout the process.

There are four key phases for operations planning: define, plan, readiness, and execution:

1. **Define**: develop the SD/SU strategy and V-plan, organisation roles and responsibilities, section and system blinding programme for equipment isolation and the permit process
2. **Plan**: lock out tag out (LOTO) procedure, SD/SU procedure review and system packages, resource planning and equipment isolation documentation (blind list)
3. **Readiness**: operator training, procedure training, SD/SU schedule, ISO and P&ID mark-up, mobile equipment lists, checklists and permit preparation
4. **Execution**: progress reporting, modify staffing plan, permit issuing, system QA/QC and field support

Commitment and engagement

Preparedness is a way of life, not something that happens instantly. In the world of maintenance turnarounds, this statement is especially true. Developing a good strategy, planning, and organising ensures readiness and sets the stage for the successful execution of an STO. But what is essential is the commitment and engagement of the operations staff throughout all phases of the turnaround management process. As owners of the asset, operations personnel shift focus from day-to-day production to clearing and isolating the equipment in preparation for the turnaround work to begin. The plant is turned back over to operations once all planned maintenance activities and construction are finalised. The task for operations is to then resume routine production safely while ensuring that the unit is at full capacity within a short amount of time. Lost production, increased labour, and maintenance costs negatively impact a company's profitability. When turnarounds are managed effectively, the impact on the bottom line will be less detrimental. Operational readiness is key to keeping costs within a specified range.

Front-end loading (FEL) critical dimensions are scope, cost, and schedule. In this phase, establishing scope is key to accomplishing favourable cost results and schedule adherence. Operations management must provide input into the scope of work for the turnaround. Participation in scope meetings during the beginning of the FEL process is crucial. In order to avoid costly expenditures, every item in the scope work list must be challenged. Needs must take priority over wants. Operations personnel have the working knowledge, experience, and expertise to play an integral part in what goes into defining the scope.

A successful turnaround also depends on having an effective organisational structure prepared well before the event takes place. The overall STO schedule includes the time it takes to shut down and start up the unit as well as the window where all maintenance work is done. So, even if all the scheduled work is completed within the set timeframe, the event will still be unsuccessful if the SD/SU of the unit takes longer than planned. In many instances, the start of the maintenance window is delayed because the operations manager failed to have the equipment available on the first day. For this reason, it is very important to ensure that operations are staffed to effectively manage the SD/SU phases. In order to accomplish this, a thorough review of the current SD/SU procedures must take place.

Benjamin Franklin once said, "By failing to prepare, you are preparing to fail." There is no better example of this than the specific preparations needed for a successful turnaround. Turnarounds are periodic events wherein processing/production units are temporarily removed from service in order to revamp and make improvements. This pause in production has significant effects on output, thus making precise turnaround planning vital to the overall financial success of the company. Given the importance and critical nature of this event, operations personnel must be actively involved in all aspects of the turnaround.

Change in perspective

A common mistake found in turnarounds begins with the pre-planned procedures and checklists. Often, the activities mentioned in them lack details on duration and required staffing. Identifying the duration of each required task and how many operators are required to perform the activity are both key in effective planning. The review of these procedures should be done in a group setting and include managers, supervisors, coordinators, and operators. The operators involved should have varying levels of experience. A fresh perspective from less-tenured operators is just as important as input from senior level operators. More experienced operators tend to rely solely on what has been done in the past. The less you hear "We've always done it this way", the better off you will be.

While the overall objective of this exercise is to develop duration and staffing, it is also important to optimise steps in the process and eliminate obsolete and ambiguous instructions. If the review is facilitated correctly, it will allow for participants to have better focus on overall objectives. A facilitator from outside of the organisation will be more effective at this, as they will not make assumptions of the knowledge of any one participant, thus ensuring that no participant is left behind.

Success story

One of the most important elements to ensure operational readiness is to make sure that objectives are met. Achieving primary objectives determines the success of a turnaround. Two key primary objectives are the development of shutdown and start-up procedures. Typically, process engineers utilise operations personnel to develop these procedures. Again, relying upon experience and knowledge of the area is a very important part of a successful turnaround. Adherence to established timelines is critical as well. In cases where the shutdown procedure was not finalised before the start of the turnaround, delays and increased labour costs were the result. Having maintenance technicians and contractors on hold while the plant is still in the process of shutting down is extremely expensive. Having these procedures developed, approved and in place during the FEL stage can mitigate costly over-runs. Here is an actual scenario that exhibits what I just stated:

Plant A takes 21 days to shut down and seven days to start up. The mechanical window is 42 days. Plant A will be down for 70 days. Therefore, 40% of the offline time is directly related to operations. At $750 000 per day, the overall revenue loss will be $52 million during the event. Of that amount, $21 million is directly related to shutdown and start-up.

What makes this significant is that the mechanical start date depends on having the unit shut down, cleared, and isolated. If the unthinkable happened and the shutdown took longer than the scheduled 21 days, the entire STO schedule would be impacted. And we all know what happens when an event goes on longer than expected. The challenge was to thoroughly review the shutdown and start-up procedures with a cross-functional team (operations, STO, safety) to verify the duration and manpower for each step. As an added measure, I wanted to challenge the team to find steps that could be done simultaneously by dividing the plant into blocks. The objective here was to optimise the shutdown and start-up procedures and reduce the time from 28 days by 25%. The client team exceeded expectations by reducing the shutdown and start-up duration by over 30%. We accomplished this by challenging the established procedures.

These procedures had not been reviewed and revised regularly in order to account for new equipment, process changes, and obsolete safety guidelines. Further, there was no verification of actuals during the previous STO some five years earlier. Therefore, the 21-day shutdown and seven-day start-up were essentially an estimate based upon what they had always done. Combing through each procedure with the cross-functional team revealed that there are inconsistencies in how Plant A should be decommissioned and commissioned. As a team, we were able to optimise the schedule and implement the documentation of actuals. These actuals will be used to revise the durations for the next shutdown and start-up, if needed.

I consider this a success story and the client was excited to realise a positive outcome. When it came time to execute these procedures, the operations team was more than prepared, fully staffed, and well-trained. While most of the work is being done by maintenance and managed by the turnaround team, operations personnel have responsibility for making sure the equipment is properly prepared, isolated, and safe. Daily permit meetings with the turnaround team are essential in preventing schedule delays. Ensuring that the equipment is available and prepared the shift before scheduled work is to be done goes a long way in maintaining schedule adherence. Communication of any equipment availability by operations is also important for schedule adherence and resource utilisation.

Operations deliverables

Delegation and accountability are also key to bringing about the successful completion of primary objectives. The list of STO milestones can be extensive and complex. Operations and STO leaders can become overwhelmed if these associated tasks are not delegated appropriately. Consideration should be made to establish turnaround coordinators, or specialists, to oversee the planning and execution of maintenance activities for each operating unit. The operations coordinator plays an integral role in managing the flow of work for an upcoming turnaround. Most organisations realise that a turnaround is not a single occurrence. They are complex and require multiple team members to be responsible for planning. Holding these team members accountable for results is also critical. At any time during this planning process, responsible designees should be able to prove that they are on track to meet deliverables. The milestone plan identifies all operations deliverables in alignment with the STO project plan.

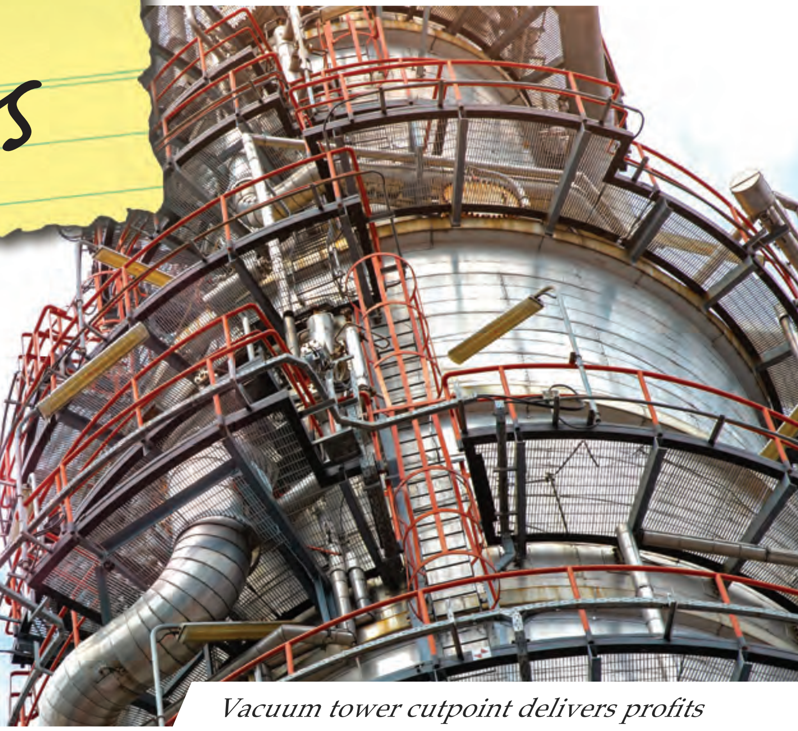
It is key to develop specific deliverables based upon the milestone. For example, Milestone 3.07: operations planning completed in common planning system (blinding, lock out/tag out, requirements for live systems, plans for vessel entry, rescue, decontamination). From this milestone, we can derive specific tasks relating to making the plant safe for the mechanical work to begin. With roles and responsibilities established during the define phase, key personnel have already been identified to complete these tasks within the timeframe allowed. In order to ensure accountability, a tracking tool is essential. A Gantt chart is very useful in tracking the completion of deliverables. This tool not only establishes accountability and target dates, it provides tangible evidence that the deliverables are progressing at an acceptable rate. The Gantt chart should be reviewed regularly during the STO FEL update meetings. This serves two purposes: tracking deliverables and ensuring operations is thoroughly engaged during the entire preparation process.

Conclusion

This article is based upon best practice methodologies for STOs. In many cases, I reflect on my own personal experience in working in the industry. Throughout my career, I have noticed that the STO team and operations are not always on the same page when it comes to preparing for an event. The operations team is the asset owner and their normal business demands producing a quality product within a specified rate that meets or exceeds the goals for the site. Having to shut down production every three to five years for an STO is not always an easy task because that is just out of the norm. However, defining the objectives, planning thoroughly and ensuring operator readiness through training will increase the likelihood of the successful execution of any STO. Organisations will standardise processes across all sites. What proves to be successful will be implemented by other asset owners with the objective of improving efficiency in activities that are outside the norm. The utilisation of staff will be more effective, and operators will be better prepared to support and execute. The quality of work being done will be enhanced along with increased productivity. Alignment of equipment availability with the STO schedule will be exemplary by focusing on preparedness. The reporting of operations progress during the shutdown and start-up of the plant will be more transparent, clear, and accurate. These are the steps that lead to effective STO preparedness for operations. Effective STO preparedness will result in productive execution during the event. Tip the scales to gain a more strategic advantage.

Lee Williamson is Senior Consultant with T.A. Cook Consultants North America. He has more than six years of experience providing strategic and operational advice to clients in asset-intensive industries. His consulting experience encompasses implementing best practices in scope optimization, turnaround front end loading and execution, maintenance efficiency and leadership coaching. As an asset management and turnaround practice leader, he provides consulting services with a focus on the petrochemical, oil, gas, and refining sectors.

Process Notes



Vacuum tower cutpoint delivers profits

Cutpoint Concerns

Crude unit vacuum tower performance is often critical to a refiner's bottom line. The vacuum tower bottoms stream is valued far below the gas oil cuts, so most refineries look to minimize it. Many vacuum columns are also designed or revamped to produce a diesel cut, recovering diesel slipped from the atmospheric column that would otherwise be downgraded to VGO product.

Good vacuum column performance can maximize the profitability of downstream units by removing distillate hydrotreater feed (diesel) from FCCU or hydrocracker feed (VGO) and removing VGO from coker feed (resid).

One important measure of vacuum column performance is VGO/resid cutpoint. The cutpoint is the temperature on the crude TBP curve that corresponds to the vacuum tower resid yield.

Vacuum column cutpoint depends on three variables:

1. Flash zone temperature
2. Flash zone pressure
3. Stripping section performance (if present)

Flash zone temperature is driven by vacuum heater coil outlet temperature (COT). Increasing COT increases cutpoint. Vacuum heater outlet temperature is typically maximized against firing or coking limits. When processing relatively stable crudes, vacuum heaters with better designs and optimized coil steam can avoid coking even at very high COT (800°F+, 425°C), but poorly designed heaters may experience coking with COT below 700°F (370°C).

Flash zone pressure is set by vacuum system performance and column pressure drop. Lower flash zone pressure increases cutpoint until the tower shell C-factor limit is reached, at which point the packed beds begin to flood. Vacuum producing systems are mysterious to many in the industry, so a large number of refiners unnecessarily accept poor vacuum system performance. With technical understanding and a good field survey, the root causes of high tower operating pressure can be identified and remedied.

In columns with stripping trays, stripping steam rate and tray performance are important. Stripping steam rate is limited by vacuum column diameter (C-factor) and vacuum system capacity. Any steam injected into the bottom of the tower will act as load to the vacuum system, so vacuum system size, tower operating pressure, and stripping steam rate must be optimized together. Depending on the design, a stripping section with 6 stripping trays can provide between zero and two theoretical stages of fractionation, which can drive a big improvement in VGO yield.

Although the variables for maximizing vacuum tower cutpoint are simple, manipulating them to maximize cutpoint without sacrificing unit reliability is not. Contact Process Consulting Services, Inc. to learn how to maximize the performance of your vacuum unit.

PROCESS CONSULTING SERVICES, INC.

3400 Bissonnet St.
Suite 130
Houston, TX 77005, USA

+1 (713) 665-7046
info@revamps.com
www.revamps.com

Hydrocracker revamp lifts product flexibility

How a new moving bed technology enabled a major refinery to improve residue conversion and crude flexibility

JOHN BARIC and COEN HODES
Shell Catalysts & Technologies

The refining sector is once again in a transition period. The International Maritime Organization's 2020 fuel sulphur mandate has introduced a need for significant changes in a refinery's management of its fuel oil pool; demand for gasoline and diesel continues to decline in some regions; and there is continuous pressure to sustain margins, especially as new capacity comes on-stream in Asia and the Middle East.

Consequently, two key objectives have emerged: the need to reduce fuel oil production and to increase margins.

To reduce fuel oil production, refiners with an abundance of capital could consider investing in the technologies that provide the highest conversion levels, such as slurry hydrocracking or ebullated bed residue hydrocracking, but these will be out of reach for most.

The combination of solvent deasphalting (SDA) and deasphalted oil (DAO) hydrocracking offers one of the lowest capital cost options for residue conversion, especially compared with slurry hydrocracking. The depth of extraction depends on the crude and the technology, which needs to handle high contaminant feedstocks.

Although this combination is considered a relatively new option, it has been applied at several sites over the last decade. Traditionally, DAO had to be processed in a fluidised catalytic cracking (FCC) unit because of its high metals and Conradson carbon residue (CCR) content, but can now be processed in a hydrocracking unit (HCU) with a modern, well-designed catalyst system featuring a demetallisation catalyst followed by pretreat and cracking catalysts.

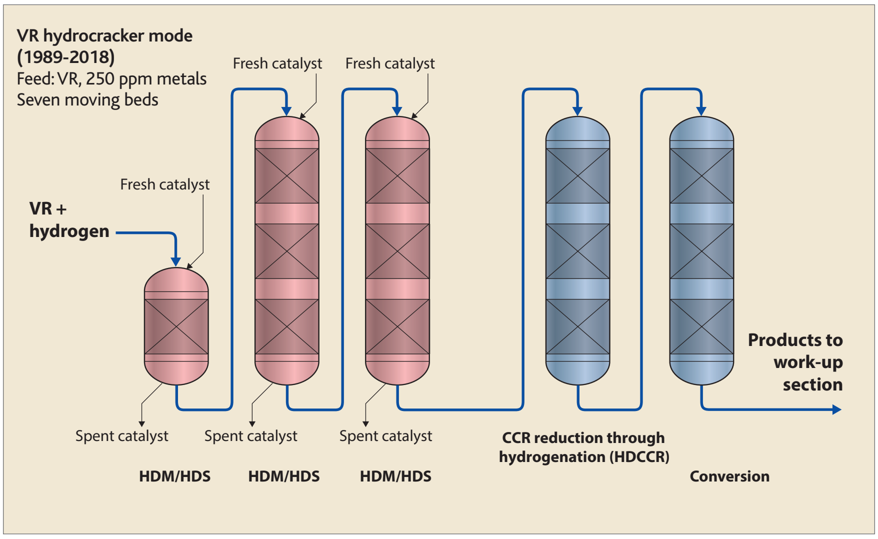


Figure 1 When it operated in VR hydrocracking mode, the Pernis Hycon unit had three moving bed reactors followed by fixed bed hydroconversion reactors

To increase margins, many refiners are shifting away from the traditional Middle Eastern crude mix to incorporate lower-priced heavy crudes from Mexico, Canada, or Venezuela.

Refiners with full flexibility to take crudes of differing qualities from several supply regions can capture margin benefits of up to $0.5/bbl

However, compared with traditional grades, such crudes can present substantial challenges because they typically have a high total acid number and high aromatics, metals, and nitrogen contents.

A high sulphur content is relatively easy to manage with today's high activity catalyst systems; however, metals such as nickel and vanadium are extremely difficult to remove. The amount of lower-priced crude that can be processed is often limited by the performance of the refinery hydrocracker or residue hydroprocessing unit.

Other refiners want to take advantage of their hub location and invest in revamps to enable increased flexibility for their bulk crude diet. This enables the refinery to take advantage of short-term fluctuations in crude pricing, and increases the refinery's economic robustness against longer term market disruption and trends.

Studies by Shell Catalysts & Technologies have shown that refiners with full flexibility to take crudes of differing qualities from several supply regions can also capture margin benefits of up to $0.5/bbl compared with those that have a restricted feed diet. This could unlock a total value of up to $31.5

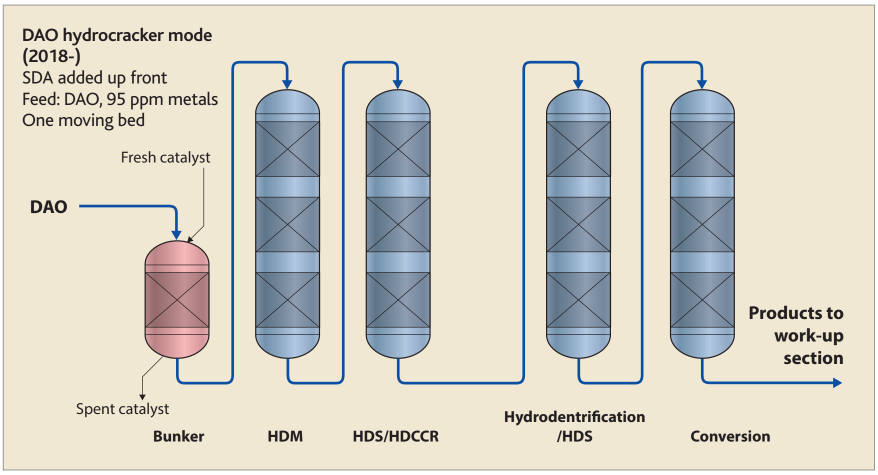


Figure 2 Now operating in DAO hydrocracking mode, only the single moving bed lead reactor is necessary for demetallisation because the feed contains fewer metals. Two reactors were converted to fixed bed mode

million if applied to 90% of the core diet of a typical 200 000 b/d refinery.

Shell Hycon MB technology can be used as a revamp option to remove constraints in the downstream hydrocrackers and residue hydroprocessing units, and enable the desired crude flexibility.

About the unit being revamped

Pernis's Hycon unit started up in 1989 and was designed to enable the processing of high metals vacuum residue (VR) feeds from crudes such as Maya. This produced vacuum gasoil (VGO) for a high conversion FCC unit and a modest, but low sulphur residue stream for low sulphur fuel oil.

Key to its operation were the three moving bed reactors in which the hydrodemetallisation catalysts were continuously replenished to maintain a consistent activity level without deactivation over time (see **Figure 1**). The unit consistently achieved two-year cycles, whilst processing 100% VR feeds.

Fast forward to 2018 and the market had changed. The site's management needed to reduce exposure to the forthcoming changes in bunker fuel specifications and also saw value in increasing crude flexibility.

Pernis's response was to install a new SDA unit, to revamp the gasification unit, and to repurpose the Hycon unit by changing its mode of operation from VR hydrocracking to DAO hydrocracking. The unit now predominantly produces on-specification Euro 5 diesel.

As the new feed to the unit had lower levels of contaminants, especially metals, only the single moving bed lead reactor was necessary for demetallisation. Consequently, two of the moving bed reactors were converted to fixed bed mode (see **Figure 2**).

The key to the project has been the ability of Shell Hycon MB technology to remove metals from heavy DAO feed, which can severely limit the performance of an HCU.

About the technology

With high metals feedstocks, even HDM catalysts have a relatively short life, so frequent catalyst replenishment is necessary.

In the Shell Hycon MB technology, fresh catalyst is semi-continuously added at the top of the reactor while spent catalyst is withdrawn from the bottom. In this way, the catalysts are constantly replenished and have a consistent, high activity level with no real deactivation over time. Thereby, the technology allows full decoupling of bulk metals removal from valuable fixed-bed hydroconversion duty.

Furthermore, this enables a relatively large volume of demetallisation catalyst to be used; essentially, Shell Hycon MB technology enables the catalyst activity of a large array of fixed bed HDM reactors to be achieved in one or two moving bed reactors, but without the resultant large pressure drop and consequent penalties on reactor hydraulics and hydrogen partial pressure.

The rate of catalyst replenishment is controlled in accordance with the rate of metal deposition. Special screens separate the catalysts from the process fluids before they leave the reactor.

The reactors operate in trickle flow to ensure the highest flow stability and the best reaction and temperature control. This also maximises the temperature operating window.

Each moving bed reactor is equipped with proprietary inter-

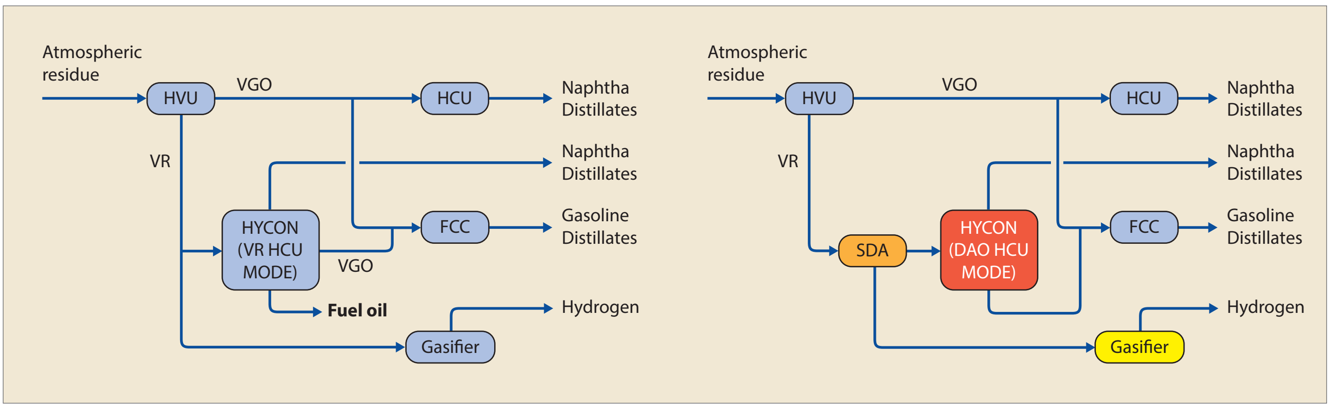


Figure 3 Block flow scheme of Pernis refinery's residue upgrading before and after the revamp

nals that optimise the distribution of fluid throughout the reactor while also allowing catalyst flow during replenishment. Under-utilised spent catalyst can be recycled back into the system so that the costs of catalyst fill can be optimised and the overall catalyst activity remains at a constant level.

Particular attention must be given to the reactor mechanics, hydraulics, and proprietary internals. However, as the Hycon unit has operated for more than 30 years, valuable operating experience has been developed which has also been used to further develop and improve the technology.

About the Shell Pernis revamp

With a capacity of 404 000 b/d, Pernis refinery is the largest integrated refinery-petrochemicals manufacturing site in Europe and, with hydrocracking, FCC, and gasification units in its configuration, it has a high Nelson complexity index.

The project involved not only revamping the Hycon unit but also adding a relatively low cost SDA unit upstream of that, and integrating these units with the downstream existing gasification and FCC units (see **Figure 3**).

The SDA unit (a residuum oil supercritical extraction, or ROSE, unit licensed by KBR) prepares high quality DAO that is suitable as a fixed bed HCU feedstock.

This feeds the Hycon unit, which was revamped from VR hydrocracking to DAO hydrocracking mode. Shell Hycon MB technology is key here; it sits upstream of the fixed bed reactors to enable the processing of 100% DAO.

In addition, as the SDA pitch is sent to the gasification plant, this required relatively small changes to enable it to handle a heavier stream, chiefly improving the feed preheat and tracing to enable the required burner feed viscosity to be met.

The project helped the site to reduce fuel oil production by 35%, increase middle distillate yield, and also process heavier, cheaper crudes that contain high concentrations of nickel and vanadium. The increase in crude flexibility has the potential to add substantially to the site's economics, given its strategic location in a major trading hub.

Revamping existing units and tight integration with the rest of the refinery meant that the project could achieve a return on investment above 15%, a factor of two higher than the prediction for the industry standard solution, a delayed coker.

The unit is designed to process crude from Russia, the Arabian Gulf, and West Africa and South America, depending on the economic value. The design DAO feed quality is shown in **Table 1**.

DAO feed quality			
	Design case Urals	Check case I Arab Light	Check case II WAF
Specific gravity	0.960	0.973	0.953
Sulphur, wt%	2.48	3.45	1.67
Nitrogen, ppm wt	4000	2709	4273
Vanadium, ppm wt	32	13	19
Nickel, ppm wt	10	5	10
Metals (Ni+V), ppm wt	42	18	29
CCR, wt%	7.4	8.7	6.5

Table 1

Shifting the feed from VR to DAO reduced the levels of all the feed contaminants, especially metals. This enabled changes in the design and operation of the Hycon unit. The lower metals level resulted in only the single moving bed lead reactor being necessary for demetallisation. This enabled conversion of the next two three-bed reactors from moving to fixed mode. Overall, optimisation of the entire catalyst system has resulted in higher conversion (up to 75%) for the same two-year catalyst cycle length while producing on-specification, ultra low sulphur diesel. The site is now evaluating minor changes to the Hycon unit which would help to increase future cycle lengths to three years.

In DAO hydrocracking mode, the unit has achieved the targeted higher conversion and an increased yield of high value products. In addition to improved refinery yields, the DAO hydrocracker generates high quality finished products (see **Table 2**).

DAO hydrocracking product qualities				
	Naphtha (C_5-160°C)	Kerosene (160-225°C)	Gasoil (225-360°C)	DAO hydrowax (360°C +)
Sulphur, mg/kg	3-10	3	5	20
Cetane number			58	
Cetane index			60	
Smoke point, mm		20		
Cold flow pour point, °C			−10	

Table 2

The opportunity for other refiners

Having demonstrated the technology's relevance to today's mar-

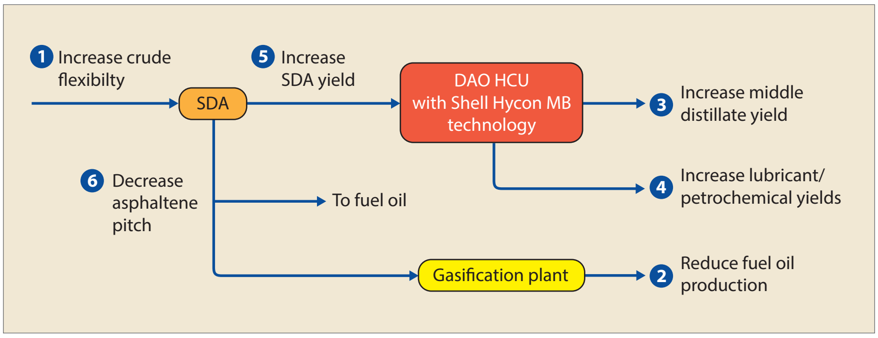


Figure 4 A typical DAO hydrocracking configuration with Shell Hycon MB technology and optional gasification of asphaltene pitch

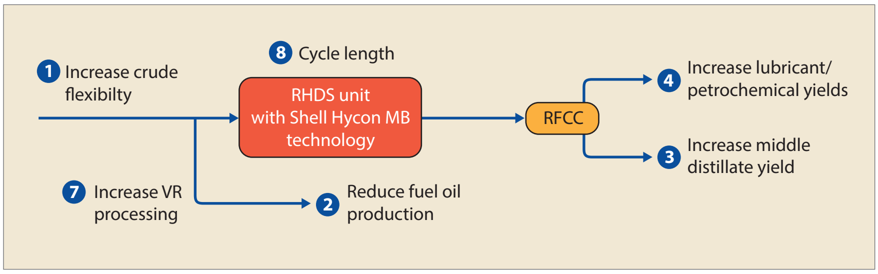


Figure 5 A typical RHDS configuration with Shell Hycon MB technology

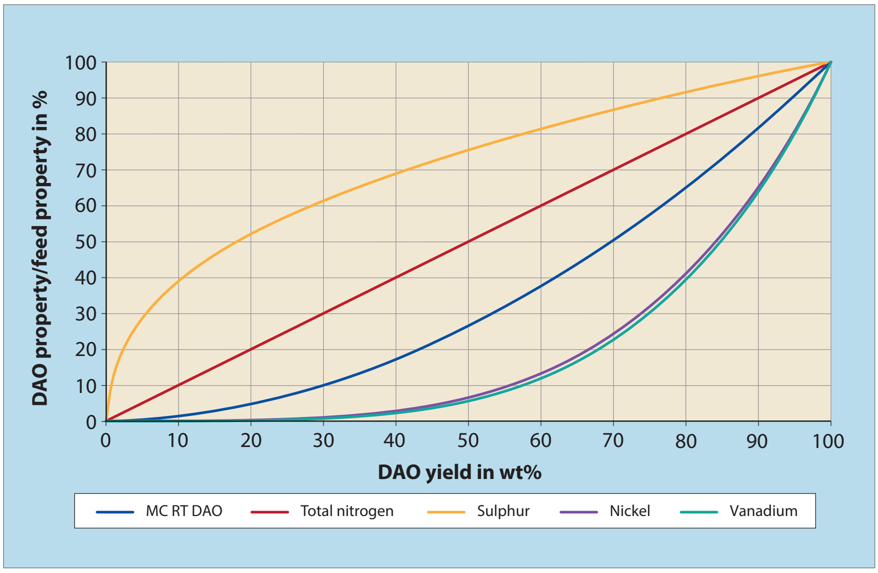


Figure 6 General curve for DAO contaminant levels

ket dynamics, Shell Catalysts & Technologies has made it and its associated intellectual property available for licensing. This could unlock major value if the technology is placed in front of a DAO HCU, a fixed bed HCU processing high metals VGO, or fixed bed RHDS reactors.

Figure 4 shows the benefits of installing the technology in an existing HCU or RHDS unit with an SDA unit. As an SDA unit has a relatively low investment cost, the economics of such a solution can be compelling. The technology can also be retrofitted to a DAO hydroprocessing unit, where it can create more value by increasing the depth of SDA extraction.

For lower sulphur crudes, asphaltene pitch can be routed to fuel oil. Furthermore, Shell Hycon MB technology enables a reduction of the fuel oil pool by increasing the DAO yield from the SDA.

Figure 5 shows how the technology can be used to debottleneck an RHDS residue FCC (RFCC) line-up:

❶ Increase crude flexibility

The technology reduces the reactor volume that is required for demetallisation and fully decouples metals removal, thereby maximising the reactor volume that is available for value generating catalysts for sulphur or CCR removal or hydrocracking. So, whereas a fixed bed DAO HCU is typically limited to about 30-35 ppm nickel plus vanadium, a DAO HCU with Shell Hycon MB technology can handle up to 100 ppm nickel plus vanadium. plus vanadium, such that nitrogen or CCR content become determining for crude selection and feed heaviness. Consequently, the technology unlocks the use of high metals crudes such as Maya and high metals feeds such as DAO, with high extraction depths.

Similar benefits, including consequent allowable higher metals contents, apply to residue feedstocks for RHDS units (see **Figure 5**). Typically, a fixed bed RHDS unit is limited to 120 ppm metals in atmospheric residue feed, if a one-year cycle is required. Shell Hycon MB technology increases the metals limit and allows additional (up to 100%) VR to be processed.

❷ Reduce fuel oil production

The scheme shown in **Figure 4** increases DAO yield and reduces SDA pitch. Furthermore, fuel oil production is reduced by routing the SDA pitch, which contains most of the residue's metals (nickel and vanadium), asphaltene, and CCR contaminants, to the gasifier. Consequently, it helps to reduce the site's yield of fuel oil; at Pernis refinery, this yield fell from 12% to 8%.

Similar benefits apply for RHDS unit schemes and the increased ability to process VR feedstock that otherwise would be routed to the fuel oil pool (see **Figure 5**).

❸ Increase middle distillate yield

Because the technology decouples contaminant removal, mainly metals such as vanadium and nickel, from high value hydroprocessing catalyst systems, it enables optimisation of the catalyst system in the existing reactor volume. More pretreatment and cracking catalysts can be loaded, which results in the successful processing of more difficult feeds for higher conversion and/or a longer catalyst cycle length.

A larger proportion of the crude barrel can be upgraded to middle distillates, ultimately at Euro 5 product specifications. Thus, with low to medium capital expenditure, the refinery's crude margin can be increased.

❹ Increase lubricant/petrochemical yields

Shell Catalysts & Technologies has developed various hydrocracking process line-ups designed to maximise naphtha yield (light naphtha as a direct feed for ethylene crackers and heavy naphtha to CCR and aromatics, so-called crude-to-chemicals) or to produce hydrowax from VGO, DAO, or heavy DAO feedstocks, which is an excellent feedstock for Group II or III base oils. These line-ups, used in combination with Shell Hycon MB technology, mean that more crudes and a larger portion of the crude barrel become eligible for petrochemical and base oil or lubricant production.

For RHDS schemes, increased upgrading of crude barrels to naphtha for petrochemicals is possible, thereby supporting crude-to-chemicals targets.

❺ Increase SDA yield

With conventional fixed bed hydroprocessing technology, the economic lift of DAO is typically constrained by the catalyst cycle length owing to the contaminants (metals) in the DAO. Shell Hycon MB technology can process DAO with a much higher metals content to enable a higher SDA lift (more DAO) while keeping the metals content to the fixed bed part of the unit at economic levels.

Figure 6 shows a general curve indicating selectivity for different contaminants in the feed and how this depends on extraction depth. The nickel and vanadium content of DAO has a strongly exponential relationship to DAO yield.

Figure 7 shows how the extraction depth can be increased for a typical heavy Arab Gulf crude if a Shell Hycon MB reactor is installed upstream of a DAO HCU.

❻ Decrease asphaltene pitch

Disposal of SDA pitch is typically a key economic variable in these projects. The lower pitch yield resulting from using the technology improves project economics significantly. This is valid regardless of the final routing or disposal of the pitch.

❼ Increase vacuum processing

Any atmospheric residue desulphurisation unit currently processing 100% atmospheric residue can benefit from using the technology as it enables co-processing of lower value VR feed while still maintaining an economic cycle length and meeting the target product quality. A larger portion of the crude barrel can be upgraded to valuable products without jeopardising product yields or qualities.

❽ Extend cycle length

The technology helps to extend cycle length by reducing the contaminants load (total metals deposition) on the catalyst in the downstream fixed bed reactors.

Further, the fixed bed reactors rely less on their HDM catalyst volume. Consequently, the available fixed bed catalyst volume can have a catalyst package optimised for more pretreatment and cracking to achieve increased hydrodesulphurisation and HDCCR.

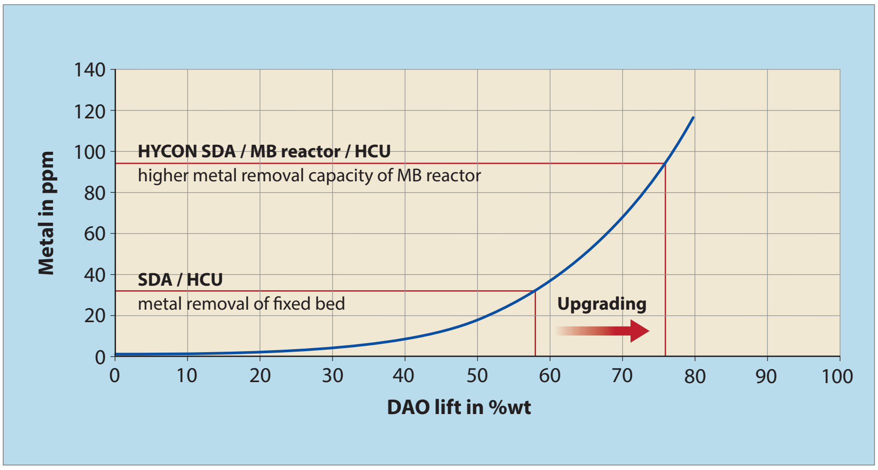


Figure 7 Impact of a Shell Hycon MB reactor on allowable feed extraction depth for a DAO hydrocracker

Tight integration with the rest of the refinery meant that the project could achieve a return on investment above 15%

Revamp options

The technology can either be incorporated into an existing HCU or RHDS unit or, if plot space in an existing unit is an issue, a small demetallisation unit can be built ahead of the existing unit.

In the former case, the moving bed reactors would be installed inside the existing plot, between the charge furnace and the lead fixed bed reactor, and the catalyst handling system could be installed on an additional, optimised plot.

In the latter case, the new unit would contain the moving bed reactors, the catalyst handling system, a furnace, a separator, and a recycle gas compressor. This new unit would feed the existing one.

Conclusions

By revamping its Hycon unit to a DAO HCU, Shell's Pernis refinery has improved its competitiveness by being better able to respond to changing market dynamics. Crucially, it did this cost-effectively; tight integration with the rest of the refinery meant that the project could achieve a return on investment above 15%.

Key to this project was Shell Hycon MB technology, which provides high metals removal capability for VR and DAO.

Now available for licensing, it offers opportunities for other refiners facing similar challenges. Placed in front of a DAO HCU, a fixed bed HCU processing high metals VGO, or fixed bed RHDS reactors, it could provide a relatively low cost way of reducing fuel oil production while also enabling processing of a wider range of lower-priced crude oils.

John Baric is Technology Licensing Manager with Shell Catalysts & Technologies, Amsterdam, The Netherlands.
Email: john.baric@shell.com

Coen Hodes is Team Lead Hydroconversion with Shell Catalysts & Technologies, Amsterdam, The Netherlands.
Email: coen.hodes@shell.com

ITW

Innovative Technologies Worldwide

WILLING TO AVOID OR SPEED UP A TURNAROUND ?

SELECT THE BEST PICTURES: BEAT THE BUDGET WITH NO STRESS!!!

Patented ITW Online Cleaning can remove any type of fouling from equipment, including polymers, without the need to open or enter hazardous process equipment.
An entire Process Unit can be cleaned by utilizing ITW Online Cleaning in as little as 24 hours on a feed-out/feed-in basis.
Online Cleaning can be applied at any time during the run of the Unit in order to solve the problems when they start appearing rather than when they are no longer sustainable.
This will in turn increase run length and avoid throughput reduction, giveaway and energy loss associated with fouling.
The application of ITW Online Cleaning will be therefore driven by performance recovery and Opex improvement rather than the economics for placing a turnaround.

ITW Online Cleaning can be applied to all Refinery/Petrochemical/Gas Field/Oil Field production Units to avoid a cleaning turnaround.
This will in turn avoid production losses and budget will be beaten...with no effort and stress...typical of any turnaround planning and execution.

Regular application of ITW Online Cleaning will target an increased run length under *clean* conditions with related value.

For turnaround applications, ITW Online Cleaning can eliminate/dramatically reduce the need for mechanical cleaning, thereby reducing downtime and improving operational HS&E.
In a turnaround, ITW can create additional value by applying proprietary ITW Improved Degassing/Decontamination to achieve quick and effective safe entry conditions.
Our patented chemistry does not create any emulsion, and fluids can be easily handled by Waste Water Treatment Plant.

EVALUATE ITW ONLINE CLEANING AND ITW IMPROVED DEGASSING/ DECONTAMINATION TODAY TO IMPROVE YOUR PLANT'S PROFITABILITY!

For more information contact:

ITW S.r.l.- C.da S.Cusumano - 96011 Augusta - Italy
Tel. +39 (0931) 766011
E-mail: info@itwtechnologies.com
www.itwtechnologies.com

Now hiring Professionals Worldwide

Join ITW Team worldwide and send your Curriculum Vitae to : jobs@itwtechnologies.com

High performance internals in severe service

Application of a severe service grid achieved 10% higher throughput with improved reliability in a vacuum tower revamp

MICHAEL KRELA and MERAJ SHAH *Koch-Glitsch*
PHILLIPPE WEISS *Consumers Co-operative Refinery Limited*

While the recent shale energy revolution and supply infrastructure issues from heavy oil producing countries have steered the majority of US refineries towards being set up for processing light, sweet crude oils, the situation in Western Canada is starkly different.[1] Refineries there were originally designed to process light sweet crude oils, but over time have had to make the necessary adjustments to process heavier crude oils due to growing oil sands production.[2]

As the operator of Canada's first heavy oil upgrader, the Consumers Co-operative Refinery Limited (CCRL) refinery has pioneered its way through the ever-changing Canadian energy landscape. Founded by eight enterprising farmers amid the great depression to reduce their reliance on major oil companies, the refinery has since gone through numerous upgrades and expansions.[3] CCRL is a wholly owned subsidiary of Federated Co-operatives Limited (FCL) and owns and operates the refinery and upgrader facilities.

While major capital projects are one way to increase value to refinery operations, opportunities such as end of life vessel replacement or five-year maintenance shutdowns should not be overlooked with a replacement in kind (RIK) scope. This is an opportune time to improve unit performance without incurring significant costs, and often can be done without incurring any incremental cost when compared to a RIK scope.

This article goes on to discuss the changes made during a vacuum tower replacement project, where new technology was incorporated instead of taking the RIK approach.

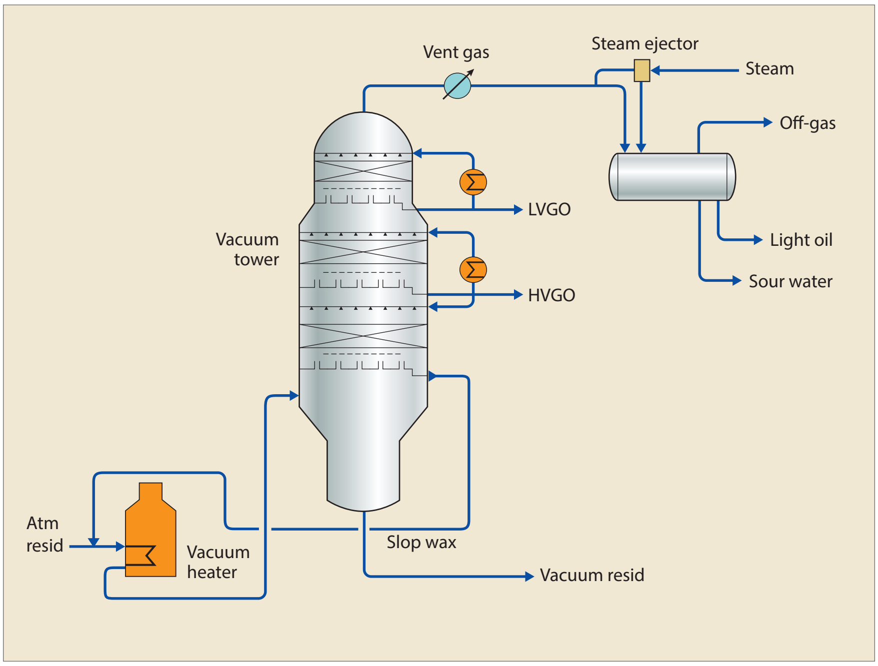


Figure 1 Schematic of a typical dry vacuum crude unit

The changes made increased throughput by 10% while reducing pressure drop, resulting in significant savings in operating costs as well as a more reliable operation for a typically severe service. CCRL became the first refinery in the world to use Proflux severe service grid in a vacuum column wash bed, and the article will discuss the reliable operation achieved and performance benefits realised since start-up in 2013.

Project overview

Crude vacuum distillation units are responsible for maximising gasoil recovery from atmospheric residue. While this service is generally severe due to the origin of the feedstock, the importance and severity are further underscored in the Western Canada region where the front-end feed to the refinery is already a low quality, heavy crude.[4]

The feed to the vacuum column is heated to temperatures in the range 700-760°F which can result in cracking and subsequent carbon residue formation, known as coking. The transfer line is sized so that the two-phase stream enters the column at close to critical velocity through a feed device designed for severe service applications. A well designed wash bed should reduce and withstand fouling in order to increase column run life, as well as protect the quality of the HVGO product from entrainment from the flash zone. The low operating pressure is instrumental to extracting gasoils from the atmospheric residue.

As part of the company's initial RIK equipment inquiry, CCRL communicated a desire to increase the column throughput. This opened discussions to look for higher performance tower internals within the framework of an RIK vessel

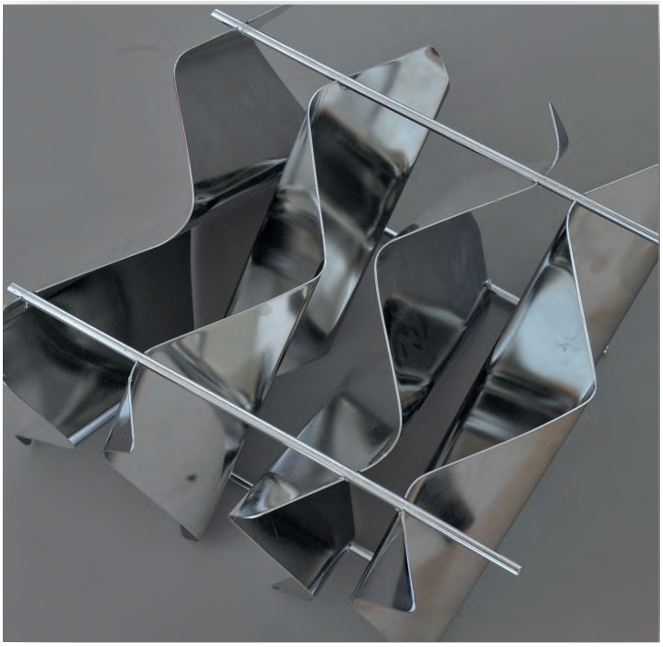


Figure 2 Proflux severe service grid

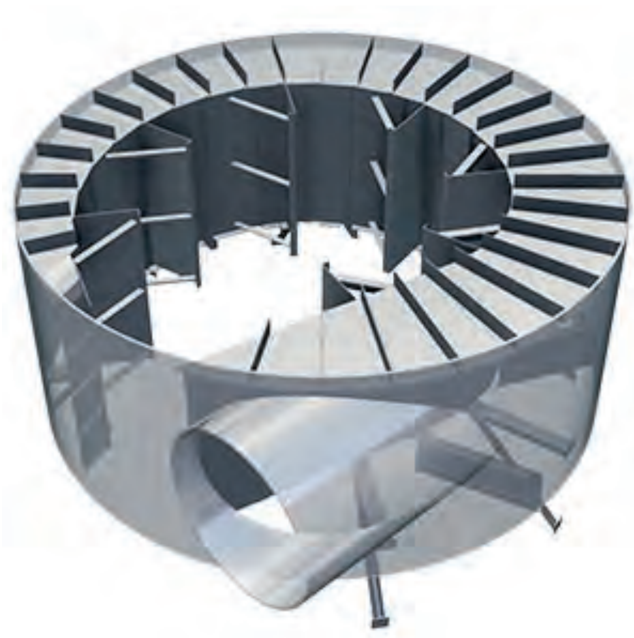


Figure 3 Enhanced Vapor Horn

project so that throughput could be increased while maintaining product quality. The column operates as a dry vacuum column (see **Figure 1**).

Enhanced process technology

Utilising new technology to increase capacity, reliability, efficiency and minimise pressure drop across the tower provides benefits that can be realised in a variety of ways. These include:

- Reduced operating costs from the auxiliary equipment
- Increased product recovery
- Stable operating conditions
- Reduced equipment replacement cycle

While this article specifically talks about the enhancements added in this vessel replacement project, it is important to realise that typical five-year maintenance outages are an opportune time to replace old technology with new designs – and reap some of the benefits mentioned above. Many design enhancements can be explored for vacuum column operation, however focus here is on three areas: high performance packing – grid and structured – and a high performance inlet feed device.

The wash bed, along with the flash zone, is the most critical section of the vacuum column and the optimal design approach can be a source of rigorous debate within the industry.

Wash bed – Proflux severe service grid

The function of the wash bed is to eliminate entrainment of residue in the feed to the HVGO product, and to provide some fractionation to improve the HVGO end point. The main entrainment concern to be addressed is minimising the amount of micro Concarbon residue (MCR) and heavy metals that end up in the HVGO. The results section of this article will discuss the impact of high performance tower internals on the MCR found in the HVGO product – a lower MCR was obtained at higher throughput for similar feedstocks.

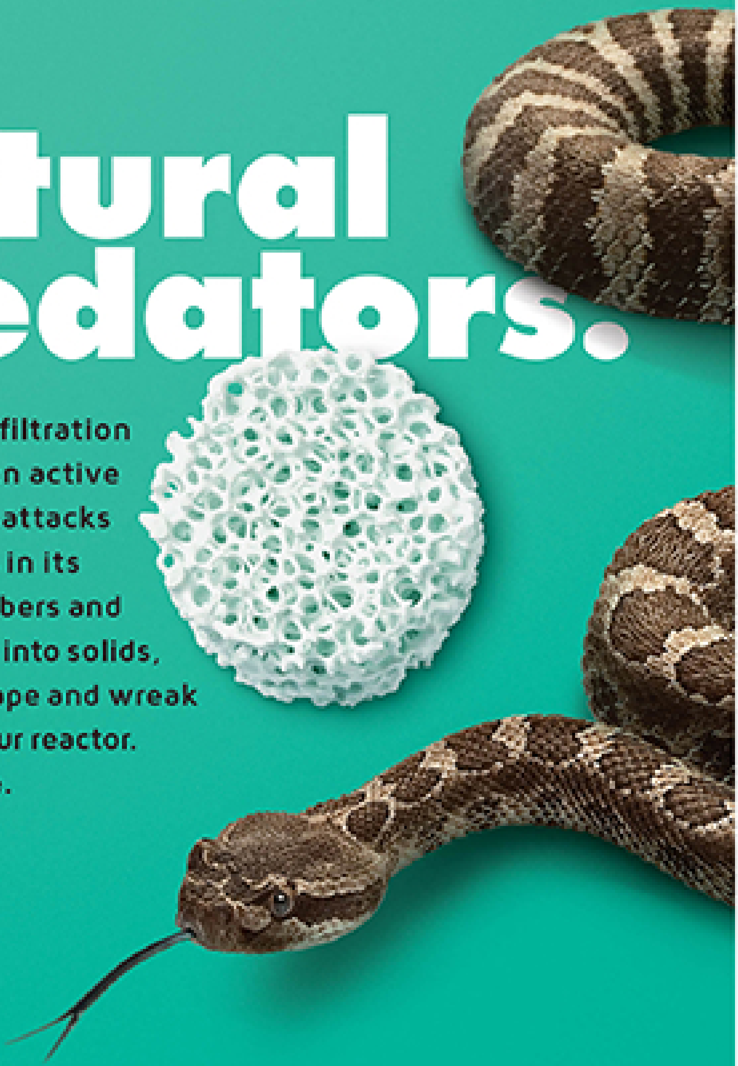
There are many competing interests in the design of the wash bed and the packing types traditionally used in this application; first generation grid packing and structured packing have limitations. Maximising gasoil product can potentially come at the expense of insufficient wash oil to maintain adequate packing wetting, a key requirement of preventing coke formation. The use of an open, low surface area, first generation grid packing for severe service offers good fouling resistance but does not provide adequate de-entrainment in vessels that are pushed past a moderate operating point (Cs > 0.35 ft/s). The use of a medium crimp structured packing offers high de-entrainment properties and provides good fractionation, but it comes at the expense of less reliability – it is susceptible to fouling, and too much fractionation can cause the bed to dry out the wash oil and promote coke formation. A deep bed provides more efficiency than a short bed does, but it also increases residence time which can lead to increased fouling. The ideal approach is to balance the de-entrainment and fractionation requirements while maintaining reliability and maximising gasoil yield.

In 2009, Koch-Glitsch set out to provide the industry with a better packing product for fouling applications. With hundreds of existing vacuum column installations to draw from, the company looked to provide a packing that offered the de-entrainment characteristics of structured packing while improving upon the reliability of a traditional grid packing. De-entrainment tests that emulated vacuum column wash bed operating conditions were performed in the Koch-Glitsch pilot plant. The results confirmed what operating engineers have experienced in vacuum column wash beds around the world:

- Structured packing provides better de-entrainment than traditional grid packing at moderate and high gas velocities (Cs > 0.35 ft/s).
- For a given packing style, the amount of fouling is proportional to the surface area – higher surface area increases the fouling tendency.

Crystaphase

Natural predators.



Only ActiPhase® filtration technology has an active component that attacks soluble foulants in its reticulated chambers and transforms them into solids, so they can't escape and wreak havoc deep in your reactor. **Foulants, beware.**

Optimize *protection* crystaphase.com

Crystaphase tech

Vergel Lantaco
Technical Service Lead

Meet the people behind our solutions.

Growing up in a military family, Vergel learned how to be a "cultural chameleon." He puts that cultural daptability to work at Crystaphase as the point person for every client outside of the continental United States, answering their questions and explaining our technology.

MANTRA

Don't be nervous. Be prepared.

PHILOSOPHY

"When you get the football, take it all the way to the end zone."

INTERESTS

Being the best family man possible.
Traveling home to the Philippines.
My coconut planation.


Crystaphase
We never stop thinking about what comes next.
No one can predict the future, so let's create the one we want.
Optimize
our expertise
crystaphase.com

• For the same surface area, the shape of the packing will influence the pressure drop and amount of fouling.

With respect to the last point, testing also confirmed that the structured packing geometry itself contributes to the fouling tendency. Contact points between sheets provide locations for solids to bridge and propagate. Experiments showed a novel structure that employs sheets that are shaped to prevent material from building up, and spacing these sheets apart would minimise the fouling potential.[5]

The Proflux severe service grid was developed to address the shortcomings of traditional grid and structured packing that have been observed in operating columns and through our pilot testing.[6] As **Figure 2** shows, the following design features differentiate the construction compared to traditional structured and grid packings:

• Corrugated sheet structure provides better efficiency, pressure drop, and de-entrainment compared to conventional grid packing.

• Spacing between the sheets eliminates contact points where solids can potentially collect.

• Welded rod construction provides greater durability compared to conventional structured packing.

Flash zone – Enhanced Vapor Horn

Properly feeding the vacuum tower is crucial to overall performance. The feed entering the tower is typically near the critical velocity and enters the column as a high momentum two-phase feed. The velocity of the feed is such that entrainment will be generated; the degree to which it occurs is a function of the device chosen and the gas velocity in the column.

A well designed feed device will perform the following functions:

• Dissipate high inlet momentum and provide uniform vapour distribution while taking minimal pressure drop.

• Provide bulk phase separation between the vapour and liquid in the feed, thereby minimising entrainment.

A uniform vapour velocity is critical as localised vapour superficial velocities can be detrimental to good wash bed performance, resulting in localised flooding and coke formation. This can consequently lead to inadequate gasoil quality and yield, along with propagation of coke over the run length of the unit. Furthermore, the ability of the feed device to provide good vapour distribution and minimise feed entrainment is paramount to maximising vacuum column capacity. The majority of vacuum columns have throughput constrained by entrainment into the HVGO product, not by the hydraulic capacity of the packing. The operating improvements obtained with the use of a vapour horn have been discussed previously[7,8], with the higher performance of an Enhanced Vapor Horn relative to other feed devices documented at high column gas velocities.[9,10]

The ability of the feed device to provide good vapour distribution and minimise feed entrainment is paramount to maximising vacuum column capacity

Phase separation is also critical to not overload the wash bed with material that is high in metal and MCR. While some overflash is inevitable and can help with maintaining wetting of the bottom layer of packing, minimising entrainment is critical to ensuring that good wash bed performance is achieved and gasoil product yield is maximised (operating with minimum wash oil). The combination of the Koch-Glitsch Enhanced Vapor Horn feed device and Proflux severe service grid in the wash bed was selected to handle the increased gas velocities the column would operate at post vessel replacement.

Figure 3 shows an Enhanced Vapor Horn similar to the one used in the CCRL vacuum column. It utilises:

• Turning vanes, in a proprietary arrangement break the high feed inlet velocity for improved vapour distribution and de-entrainment.

• Anti-swirl baffles, positioned on the outside of the horn, eliminate the cyclonic motion of the vapour as it leaves the flash zone.

• Tapered profile to reduce device footprint, thereby reducing gas velocity through the core area within the vapour horn, resulting in lower entrainment leaving the flash zone.

LVGO pumparound – Flexipac HC structured packing

With many refineries designed with old technologies, it is quite common to find conventional structured packing inside the tower. Conventional structured packing's capacity limitations stem from the liquid that is held at the interface between layers. This results in a higher pressure drop across the bed.

Flexipac HC structured packing combines improved capacity and efficiency characteristics, resulting in lower pressure drop per theoretical stage. The construction is like its predecessor, however the HC packing has a modification in the geometry of the corrugation at the top and bottom of each packing layer. This change in geometry:

• Eliminates the abrupt change in flow direction of the liquid and vapour phases at the packing layer interface

• Eliminates the premature build-up of liquid

• Helps maintain the low pressure drop characteristics of structured packing throughout the efficient operating range of the packing

From the operator's perspective, upgrading to high capacity structured packing during a RIK maintenance turnaround can be considered found money as the performance benefits realised outweigh any minimal cost impact incurred. The HC version provides the same surface area (and thus the same heat transfer coefficient in the pumparound) while reducing pressure drop.

In addition to the changes in the LVGO pumparound, a larger crimp packing was used in the HVGO

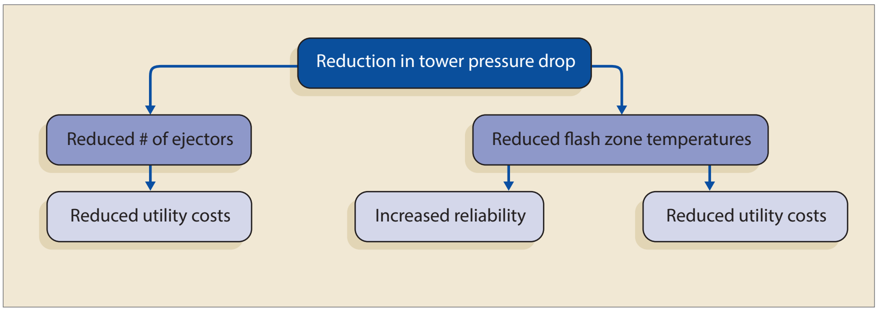


Figure 4 Operating cost savings realised with new tower configuration

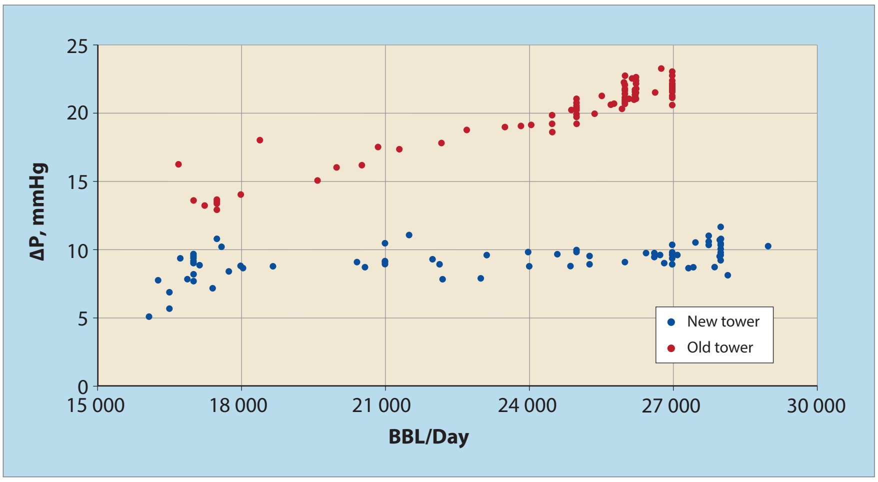


Figure 5 Column pressure drop vs feed rate, all feedstocks

pumparound to increase capacity and consequently reduce tower pressure drop. An additional layer of packing was added to the HVGO pumparound without increasing the vessel height as the spacing between the bottom of the bed and the chimney collector tray was reduced.

In order to project the benefits of offering an equipment enhancement over an RIK scope, operating data were collected from the existing operation and modelled in a simulator to obtain the vapour/liquid traffic in the column, as well as the velocity through the feed device. From this, a second simulation was done that modelled the effects of the change in mass transfer equipment in the column.

Results

While this project started as a RIK scope, based on the technical proposal offered by Koch-Glitsch, CCRL showed a willingness to entertain the most current mass transfer equipment technology. The objective of the modifications was to increase throughput without sacrificing product quality or reliability. Not only was an increase in throughput obtained, there was a marked improvement in product quality, reduction in operating cost, and improved reliability over the subsequent five-year run length. The new tower operated with the same wash oil rate as the old tower configuration. A by-product of this upgrade was a lower overall column pressure drop which had resulted in downstream benefits to the overall operation of the tower. The pressure drop savings resulted from a combination of more advanced structured packing and severe service grid being utilised instead of conventional structured packing and grid, more uniform distribution from the Enhanced Vapor Horn, and less fouling over the run length of the column. This is illustrated in **Figure 4** and further characterised by the plant process data in the subsequent graphs.

Pressure drop

The following data represent the plant's operations for crude feeds with an API gravity of 16-17. The upgrade in structured packing and severe service grid, as well as a modified design to the chimney tray internals, resulted in a pressure drop reduction over 10 mm Hg while operating at higher throughput. **Figure 5** compares the overall pressure drop pre- and post-revamp.

This significant decrease in pressure drop allowed the refinery to move from utilising six ejectors to four. The decrease in ejector usage resulted in a cost saving of C$20 000/month.

Feed temperature

The reduction in pressure drop enables reducing the temperature of the feed to the vacuum tower while not compromising vacuum gasoil (VGO) recovery. A comparison of VGO recoveries is shown in **Figure 6**. The average temperature for API 16-17 feeds for the old design was approximately 755°F, while after column replacement this temperature decreased to approximately

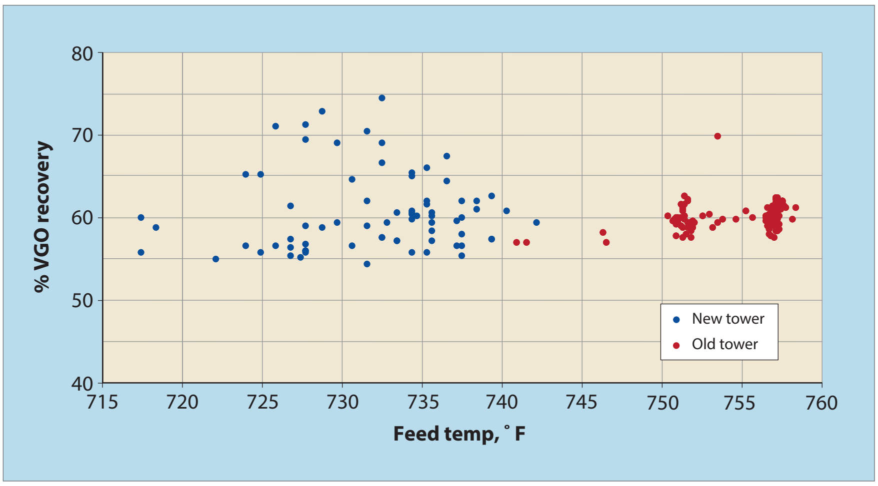


Figure 6 Gas oil recovery comparison for API 16-17 feedstock

THERE'S GOOD.
THERE'S BETTER.
THEN THERE'S BECHT.

Becht has maintained its reputation as an industry leader for more than fifty-five years by delivering a complete range of solutions and resources that overcome the entire spectrum of revamp, shutdown and maintenance challenges.

Today, that reputation continues to grow thanks to our never-ending innovation, proprietary services and programs, and trusted partnerships throughout the energy, process and power industries.

Achieve your goals with the best. The experienced team of SMEs from Becht.

BECHT
Good. Better. Becht.™

Bring us your challenges.

solutions@becht.com

908-580-1119 **becht.com**

ENGINEERING SOLUTIONS | PLANT SERVICES | SOFTWARE TOOLS | LEARNING & DEVELOPMENT

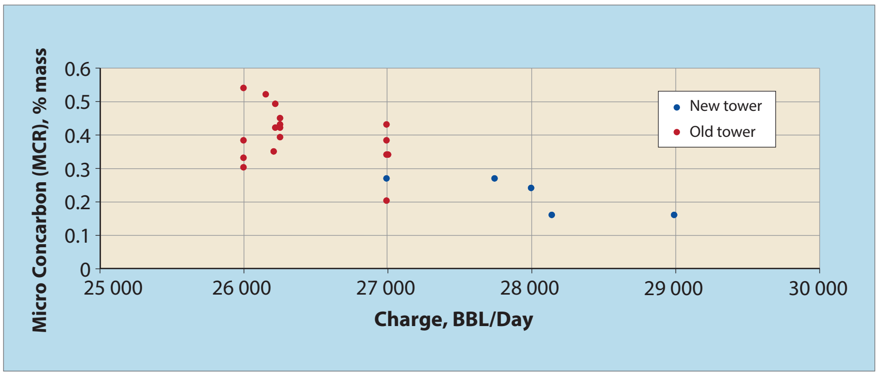


Figure 7 Micro Concarbon (MCR) in HVGO comparison for API 16-17 feedstock

Operating performance comparison normalised for API 16-17 feedstock		
Parameter	**Old tower**	**New tower**
Max feed rate	27 000-28 000 b/d	30 000-31 000 b/d
Pressure drop	20.0-23.0 mmHg	10.0-11.5 mmHg
Feed temperature	750-760°F	725-740°F
HVGO quality (MCR)	0.5-0.55 wt%	0.25-0.27 wt%
Wash oil rate	← Unchanged →	
# of runs	1 (4 years)	2 and going (7 years+)

Table 1

730°F. This equates to a reduction in duty of 8.5 MM BTU/h (12.5%). This saving in energy can be valued at approximately C$15 000/month considering a C$2.50/MM BTU cost (similar to natural gas in the region).

Product quality and wash bed reliability

Product quality and wash bed reliability often go hand in hand. When wash bed performance begins to suffer, the results are generally witnessed in the HVGO bed above, where entrained contaminants produce off-spec product. Product contaminants such as MCR and heavy metals can be minimised through adjustments made in the operating conditions as well as with the technology used in the flash zone and wash bed.

Increased feed temperatures have a direct influence on contaminants in the HVGO. As feed temperatures increase, thermal cracking increases, generating harmful products such as carbon residue and corrosive non-condensable gases, translating to lost crude product yield.[11] Reducing pressure drop across the tower allows operations the flexibility to reduce feed temperatures without compromising product recoveries.

Reducing pressure drop across the tower allows operations the flexibility to reduce feed temperatures without compromising product recoveries

With both the operational and equipment upgrades, the wash bed performance improved significantly, and is substantiated through analysis of the HVGO product draw. These improvements were not made at the expense of increasing wash oil, as this was held constant between each tower configuration, even though the new tower was handling up to 10% additional throughput. As a result of the reduction in feed temperature, the installation of the Enhanced Vapor Horn, and the use of new severe service grid packing, the MCR values in the HVGO reduced significantly (see **Figure 7**). Also, the HVGO ASTM D1160 95% cut point and final boiling point (FBP) alludes to wash bed performance issues in the old tower, as these were in the range of 1040-1050°F and 1070-1080°F. In the new tower design, there is a 10°F drop for both HVGO 95% cut point and FBP ranges – a sign that heavier components were being entrained in the old tower configuration.

A summary of operating conditions and performance characteristics is shown in **Table 1**. The old tower design had undergone one turnaround, in which the wash bed packing had to be replaced. The new tower is approaching the midpoint of its second five-year run with the same internals. The user does not have any concerns with the wash bed performance so far and, if everything goes smoothly, will be leaving the wash bed as it is for its third five-year run.

Conclusion

Different strategies can be employed when operating a wash bed. One extreme would be to push the tower as hard as possible and minimise the wash oil usage to the point that it is approaching failure just in time for a turnaround. Treating the wash bed packing as a consumable can be challenging as it requires a detailed approach to monitoring the condition of the wash bed and its coking rate. However, if done successfully, the rewards would be in maximising VGO product.[12] At the other end of the spectrum, a more comfortable operating approach allows for the re-use of wash bed internals through multiple turnarounds. The industry norm is typically somewhere in the middle – however, having a well designed wash bed is a plus regardless of the operator's risk tolerance.

This project demonstrated the benefits an operating company can obtain when taking advantage of a maintenance turnaround as an opportunity to use modern grid and structured packings. In vacuum crude oil distillation specifically, the potential for performance gains is possible due to the role that Proflux severe service grid plays in maintaining a low column pressure drop and de-entraining feed contaminants in the wash bed. The annual cost savings realised from the reduced feed temperature and lower overall pressure drop are nearly C$0.5 million, in addition to the improvement in operating margin obtained with a 10% increase in throughput.

PROFLUX, FLEXIPAC and Enhanced Vapor Horn are marks of Koch-Glitsch.

Acknowledgement
We would like to thank Phillippe Weiss and Jonathan Kushneriuk of CCRL and Darius Remesat who was at Koch-Glitsch during the project. They played a key role in assessing the potential for an operating improvement with high performance mass transfer equipment.

References
1 U.S. Energy Information Administration, The United States Tends To Produce Lighter Crude Oil And Import Heavier Crude Oil, Washington, 2019.

2 Natural Resources Canada, Refinery Economics, Government of Canada, 2018.

3 Our Story, Fcl.crs. www.fcl.crs/about-us/our-story, published 2020, accessed 10 Jul 2020.

4 Golden S, Canadian crude processing challenges, *PTQ*, Q1 2008.

5 Nieuwoudt I, Quotson, P, Ferrari A, PROFLUX® severe service grid – Dealing with Challenging Applications, Distillation & Absorption 2014, 10th International Conference.

6 US8298412B, US Patent, Structured packing module for mass transfer column and process involving same.

7 Hanson D, Martin M, Low-capital crude unit revamp increases product yield, *Oil and Gas Journal*, Mar 2002.

8 Hanson D, Lieberman N, Lieberman E T, De-entrainment and washing of flash zone vapours in heavy oil fractionators, *Hydrocarbon Processing*, Jul 1999.

9 Remesat D, Consider the 'inside-out' approach to optimize distillation operations, *Hydrocarbon Processing*, Aug 2006.

10 Remesat D, Improving crude vacuum unit performance, *PTQ*, Q3 2008.

11 Elayane, Jaouad & Bchitou, Rahma & Bouhaouss, Ahmed, Study of the thermal cracking during the vacuum distillation of atmospheric residue of crude oil, *Scientific Study and Research: Chemistry and Chemical Engineering, Biotechnology, Food Industry*, 18, 61-71, 2017.

12 Cantley G, Pless L, Managing wash beds, *Hydrocarbon Engineering*, Apr 2017.

Michael Krela is Process Design Manager with Koch-Glitsch Canada and has over 15 years' experience providing solutions for mass transfer and separations designs in refining and petrochemical plants. He has also been a Sessional Instructor for the Separation Processes course in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto. He holds a BASc in chemical engineering from the University of Waterloo, Canada, and is a member of the Koch-Glitsch Global Refining Team.
Email: Michael.Krela@KochGlitsch.com

Meraj Shah is Western Canada Technical Sales Manager with Koch-Glitsch Canada and has over seven years' experience in providing mass transfer and separation solutions in a technical and commercial capacity. Prior to joining the sales team, he worked in the process design group, providing sizing and troubleshooting support for mass transfer and separation equipment designs. He graduated from the University of Toronto with a BASc in chemical engineering and is an industry guest speaker on mass transfer equipment at the University of Alberta.
Email: Meraj.Shah@KochGlitsch.com

Phillippe Weiss is a Lead Process Engineer, Process Technology with Consumers Cooperative Refineries Ltd and has over 40 years of process design and operational experience. He is currently responsible for process design, process optimisation, and troubleshooting, and also assists in catalyst selection and monitoring. He has a BaSc in chemical engineering from the National University of Engineering, Peru and a MaSC in chemical engineering from the University of British Colmbia. He is a registered Professional Engineer in Alberta and Saskatchewan, Canada.
Email: Phillippe.Weiss@fcl.crs

www.grabner-instruments.com
DO YOU HAVE A VISION?
We can help you with our latest 'VISION SERIES' of analytical instrumentation.

VAPOR PRESSURE
● Pressure Range: 0 - 2000 kPa
● Highest Precision and Accuracy

FLASHPOINT
● ASTM D6450 and D7094
● Continuously Closed Cup

FTIR FUEL ANALYSIS
● Measures 100+ Preconfigured Fuel Parameters
● Gasoline, Diesel, Biodiesel, Jet Fuels

Ask about the MINIDIS ADXPERT for Distillation Testing

Monitor your processes through Cockpit Software...
24/7 access to multiple analyzers!

GRABNER INSTRUMENTS®
Phone: +43-1-282 16 27-0
Email: info.grabner-instruments@ametek.at
AMETEK®

SULZER
Because life is fluid

NeXRing™ Reshaping the future of separation efficiency

When it comes to boosting separation performance, even small innovations can make a major difference. With NeXRing packing, separation towers across a wide range of applications can benefit from up to 50 percent higher capacity, decreased pressure drop and reduced fouling. All thanks to a breakthrough design that maximizes surface area availability and reduces foaming. Find out how our industry-leading separation column internals can make a difference for your operations at sulzer.com.

Learn how NeXRing can give you up to 50% higher separation capacity.

Start-up and shutdown issues in sulphur processing

Knowing the limitations of the sulphur unit and what may occur during start-ups and shutdowns helps to prevent damage

MATHEW D BAILEY, G SIMON A WEILAND and NATHAN A HATCHER
Optimized Gas Treating, Inc.

Part 1: The SRU at turndown

The transient nature of start-ups and shutdowns arguably causes the most damage to an SRU through thermal cycling of the process equipment. Start-ups and shutdowns can be more devastating to equipment than years of steady, normal operation, and these are the very conditions often overlooked or given little thought. Thermal cycling affects the reliability of the waste heat boiler (WHB), most notably by degrading the tube sheet system, which includes the refractory, ferrules, the tube sheet itself, the fragile tube-to-tube sheet joints, and the tubes.

From an initial set of parameters such as feed flow rates, composition, temperatures, and pressure, a sulphur recovery unit (SRU) is designed to meet a specific set of targets. During design, attention is given to different operating scenarios such as varying feed quality, feed rate (turndown), equipment fouling, and catalyst aging to help ensure the design is robust. Amine treating units and sulphur plants usually work well when equipment is operated at design conditions; however, equipment and instrumentation behave differently under turndown conditions, and not always in desirable ways.

It is normal for an SRU to operate below design flow rates and for operating conditions to change after construction and commissioning, and every so often during operation of the unit. Ensuring adequate performance under off-design conditions is crucial to successful operation. Through proper design, operating practices, and maintenance procedures, the reaction furnace and WHB system can have a life expectancy in excess of 20 years. However, with an inadequate design, poor operating practices, frequent cycling, or poor maintenance, it can be as short as two or three years.[1] Being able to model accurately the effect of variations in feed quality, feed rate, exchanger fouling, and catalyst ageing can provide invaluable understanding of the effects of these parameters, and reveal operating conditions that will expose various SRU components to premature failure.

Feed conditions for AAG and SWAG		
	AAG, mol%	SWAG, mol%
H_2O	5.28	22.19
H_2S	87.14	35.01
CO_2	6.63	0
NH_3	0	42.79
CH_4	0.95	0

Table 1

Case studies: turndown and operating an SRU during shutdown and start-up

A series of case studies was performed to analyse the effects of turndown on a Claus SRU. The unit studied is a typical two-stage SRU in a refinery processing both sour water acid gas (SWAG) and amine acid gas (AAG) at a combined total acid gas (CAG) design flow rate of 125 long tons per day (lt/d) (see **Figure 1** and **Table 1**). The heat exchange units, such as the WHB and condensers, were simulated in rating mode to assess accurately the effects of operating at off-design rates. All cases were simulated using SulphurPro, a kinetic rate and heat transfer rate based sulphur recovery simulator, with the AAG to SWAG ratio fixed at 5.6 to 1.

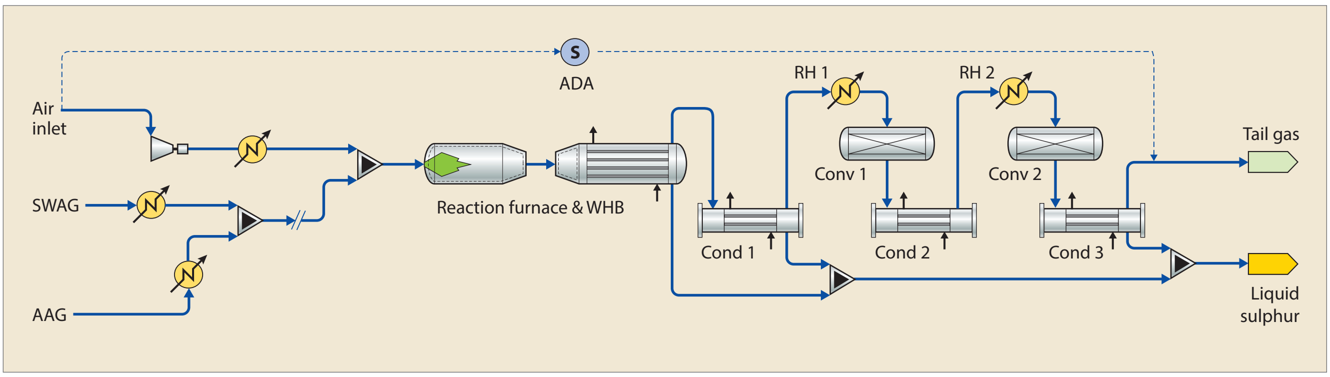


Figure 1 SulphurPro PFD for two-stage Claus unit processing AAG and SWAG

Parametric results from turndown, Case A			
	100% of design 125 lt/d (base case)	60% of design 75 lt/d (A-1)	30% of design 40 lt/d (A-2)
Sulphur throughput, lt/d	125	75	40
Air flow, lb.mol/h	928	560	302
Reaction furnace temperature,°F [i]	2390	2400	2410
WHB peak tube wall temperature, °F	545	530	517
WHB peak heat flux, Btu/h.ft^2.°F	36,000	26,200	18,200
WHB mass flux, lb/s.ft^2	3.0	1.8	0.97
WHB sulphidation corrosion, mils/y[ii]	8.6	7.5	6.6
Sulphur conversion, %	96.95	96.85	96.75
Sulphur recovery, %	96.46	96.43	96.33
Hydrogen in tail gas, mol%	1.9	1.5	1.18
COS in tail gas, ppmv	319	374	455
CS_2 in tail gas, ppmv	0.6	0.55	0.5

i Simulations ignore heat loss
ii Using correlation derived from ASRL lab data

Table 2

Two cases are considered: Case A is a unit simulation in two turndown scenarios: one is at 75lt/d (60% of design) of CAG, the other at 40 lt/d (30% of design). The performance of the unit, and specifically the exchangers, is assessed at each turndown step.

Case B assesses the unit at a point during the start-up/shutdown procedure halfway between 30% turned down and hot standby (natural gas only). To achieve this condition, half the CAG at 30% load is replaced with natural gas. In other words, the overall hydraulic load is kept at 30% of design but the feed is 50:50 natural gas and CAG with CAG now at 15% of the design rate.

Results

Table 2 shows that as the unit is turned down from 100% (base case) to 60%, and then to 30% of design rates (Case A), the most noticeable changes are in the WHB operating conditions. At 30% turndown, the peak heat flux is reduced to nearly half of the base case. The cause is the severely reduced mass flux through the unit. Reduced heat flux and WHB tube wall temperatures are beneficial in reducing corrosion. However, if the rate of change from design to turndown is fast, mechanical stress from the rapid temperature changes can create differential thermal expansion and thermal shock. Without simulation, these potential hazards can be neither identified nor engineered around.

The overall Claus sulphur conversion, sulphur recovery, and CS_2 in the tail gas do not seem to be highly affected by turndown. Although not directly calculated in the version of SulphurPro used in this study, pressure drop decreases rapidly with turndown.

Hydrogen in the Claus tail gas drops quite markedly from the base case design as turndown progresses. This can have a significant effect on the performance and reliability of a reduction-quench-amine type tail gas treating unit (TGTU) downstream. Per unit volume of feed gas, the reducing gas demand increases with turndown, so either more external hydrogen or more natural gas must be combusted sub-stoichiometrically in the TGTU reducing gas generator (RGG). Insufficient hydrogen increases the risk of SO_2 breakthrough during turndown operations. Additionally, if the TGTU hydrogenation catalyst is not fully active, COS and CO conversion will tend to fall off first.[2]

Increased turndown results in considerably higher COS in the Claus tail gas. Even though rates are reduced so that more residence time is available in the hydrogenation reactor catalyst, if the TGTU catalyst is sick or there is flow maldistribution, then unconverted COS will slip through the TGTU amine system to the incinerator. If there is not a TGTU downstream of the Claus unit, stack emissions increase in direct proportion to the unconverted sulphur. Regardless of the presence of a downstream TGTU, incineration systems that are legally permitted on the basis of SO_2 concentration in the stack will see an increase in SO_2 at turndown; this should be considered at the design stage.

In addition to these points, there are two further complications with turndown operations. The first is the formation of sulphur fog in the sulphur condensers. The second concerns heat loss. In the case of sulphur fog, conversion to elemental sulphur is not directly affected; rather, the recovery of sulphur in the condensers suffers. At low mass velocities (< 1 lb/s·ft^2), fine droplets of elemental sulphur mist evade capture by conventional mist elimination equipment, leading to reduced sulphur recover efficiency.[3,4] The risk of reaching the sulphur dew point in a downstream sulphur converter also increases, and this is compounded

Parametric results from 50% start-up/shutdown, Case B			
	Base	30% of design	
		Acid gas only Case A-2	50:50 AG:NG Case B
Sulphur throughput, t/d	125	40	20
Air flow, lb.mol/h	928	302	341
Reaction furnace temperature, °F [i]	2390	2410	2815
WHB peak tube wall temperature, °F	545	517	530
WHB peak heat flux, Btu/h·ft^2·°F	36,000	18,200	26,200
WHB mass flux, lb/s·ft^2	3	0.97	0.865
Conversion, %	96.95	96.75	91.29
Recovery, %	96.46	96.33	89.65
Hydrogen in tail gas, mol%	1.9	1.18	4.6
COS in tail gas, ppmv	319	455	720
CS_2 in tail gas, ppmv	0.6	0.5	0.4

i Simulations ignore heat loss

Table 3

by increased heat loss. Besides concern for reaching the sulphur dew point in the catalyst beds, heat loss reduces the temperature in the reaction furnace and is also exacerbated at turndown. Blais *et al.* provided a methodology to estimate heat losses in the reaction furnace.[5]

Because both heat loss and sulphur fogging concerns are highly specific to plant configuration and design capacity, we will not explore these facets further here. Suffice it to say, their relative influences are blunted somewhat by choosing to limit the turndown in the sulphur plant to 30% of design. In the case of a well-designed sulphur condenser, the risk of fogging losses is minimal at 30% hydraulic load.

Table 3 compares the unit operating at 30% turndown on acid gas only versus operating at 30% hydraulic turndown on a mixture of 50% AG and 50% NG (Case B). This case is illustrative of an operating point halfway through pulling the acid gas out during a shutdown. The reaction furnace temperature is a significant concern (+400°F) for the mixed firing case. Here, we limited the temperature by adding tempering steam in the simulation. Plant operators who do not avail themselves of simulation to anticipate reaction furnace temperatures are at the mercy of the accuracy and reliability of the installed temperature measurement devices. In the case of ceramic thermocouples, the measured temperature is going to be near the refractory wall temperature at the point where the thermowell is inserted. An optical pyrometer is subject to changes in the gas emissivity caused by differing concentrations at turndown and start-up/shutdown. Additionally, pyrometers tend to average the temperature along the line of sight.

It is noteworthy (see **Table 3**) that significant changes occur in the WHB and downstream tail gas when natural gas makes up a sizeable part of the feed. For acid gas firing alone, the peak heat flux shows a large reduction compared to full-rate operations, as might be expected. However, when operating on the mixture of acid gas and natural gas, the peak heat flux is much less affected by turndown simply because the reaction furnace is so much hotter when natural gas is part of the fuel. Tempering steam is necessary when combusting large amounts of hydrocarbons, not just to keep the temperature moderated, but also to mitigate soot formation.

Under start-up/shutdown operations with natural gas in the feed mixture, overall sulphur conversion and recovery are considerably reduced compared to both the full rate, and even 30% turndown on AG alone. If the operators are mandated to meet a certain percent recovery or SO_2 concentration in the incinerator stack, using natural gas could plausibly prevent the plant from meeting permitting requirements. There could be further complications from increased CO destruction that would be problematic in some environmental jurisdictions. A simulation that is not based on reaction kinetics and heat transfer rates will be unable to capture these differences.

Part 2: The amine unit at turndown

Amine treating units and sulphur plants usually work well when equipment is operated at design conditions; however, equipment and instrumentation behave differently under turndown conditions, and not always positively. During design, attention is given to different operating scenarios such as varying feed quality, feed rate (turndown), equipment fouling, and catalyst aging to help ensure the design is robust.

Operating an upstream amine unit at below design rates can cause sizeable variations in the hydrocarbon content of the AAG, resulting in unforeseen consequences for the SRU. This part of the article takes a detailed look at a refinery amine system treating a typical gasoil hydrotreater feed gas at steady state under turndown scenarios to gain a better understanding of how these

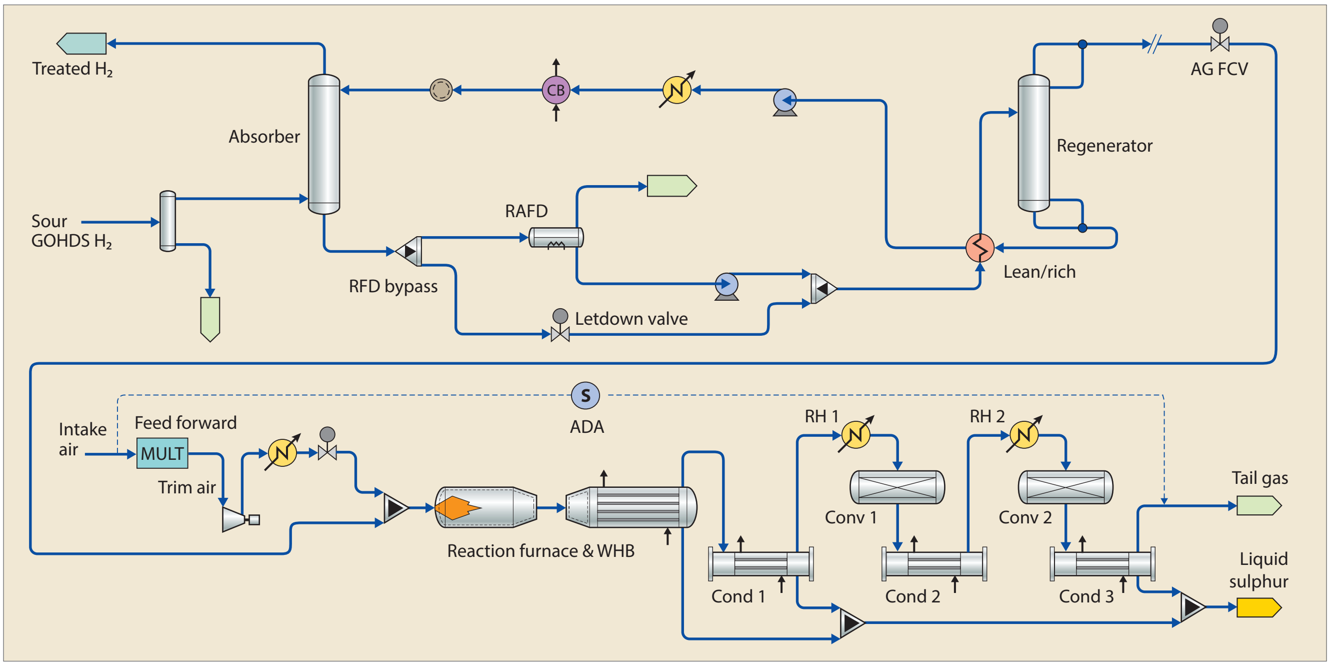


Figure 2 SulphurPro and ProTreat integrated flowsheet for a refinery sulphur processing train treating HDS gas (see Part 2 case study)

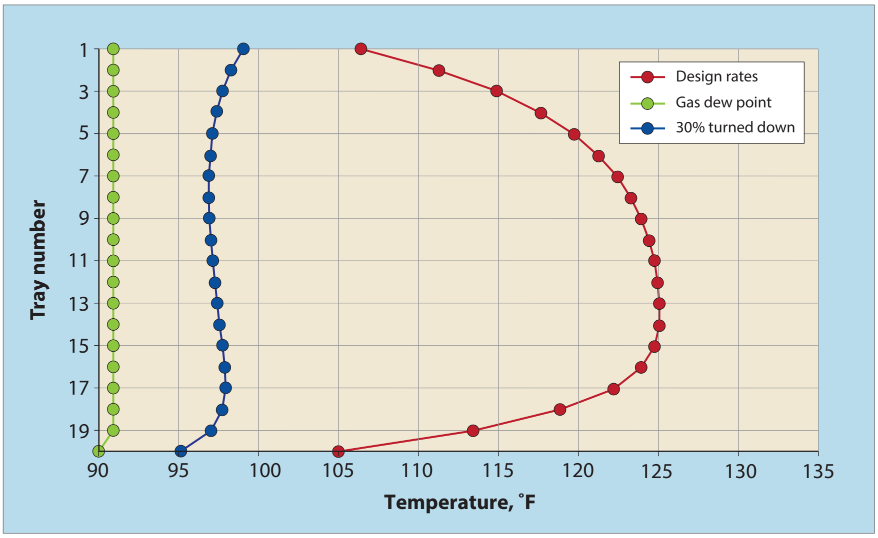


Figure 3 Amine contactor temperature profiles; the turned down case includes heat loss

operational deviations can directly affect the downstream SRU. At turndown, common practice is to leave the amine circulation rate at design. This can cause numerous problems that can adversely affect the SRU. An important part of confidently operating at turndown is knowing that the plant is operating safely and reliably. Here, we give an example of how process simulation can complement plant operations by predicting the unexpected.

Case study: effect of amine unit turndown on the SRU

This case relates to a refinery sulphur processing train treating mainly HDS gas (see **Figure 2**). The system used 45 wt% MDEA to treat 200 MMSCFD of recycle hydrogen containing nominally 1.2% H_2S from a gasoil hydrodesulphurisation system (HDS). A multi-discipline root cause analysis (RCA) team was commissioned to investigate repetitive hydrocarbon upsets to the SRU. Within this plant, upsets historically occurred with every HDS start-up. A sister refinery experienced the same problems with worse consequences because there was no rich amine flash drum (RAFD) installed. This study assesses the impacts and ramifications of both scenarios for an upstream amine unit with and without a RAFD.

Results

For the plant in question, as well as for a sister plant without an installed flash drum, the RCA team noted that HDS start-ups used considerably sweeter and lighter oil feedstock (distillate). This, combined with lower pressure start-up operations in the HDS, was found by simulation to produce a significantly larger heavy hydrocarbon tail in the feed to the amine contactor. The separation equipment upstream of the amine absorber was designed for HDS recycle flow at higher operating pressure (900+ psig vs 550-600 psig start-up operation). The RCA team found from separator calculations that the inlet separation system was inadequate at the lower operating pressure. These factors were the root causes for liquid hydrocarbon slugs entering the amine system.

A more subtle factor was that considerably less H_2S was present in the amine contactor feed at start-up with processing distillate versus the normal gasoil feedstock. The RCA team found that the amine contactor actually could be bypassed for a major portion of the start-up. The systems were modelled post-mortem using ProTreat and SulphurPro simulation at 30% turndown operation on HDS oil to mimic the actual start-up on lighter distillate feedstock.

With only 30% of design H_2S in the feed, ProTreat identified that absorber internal temperatures were much colder at turndown and dangerously close to the dry-gas dew point (see **Figure 3**). Heat loss from the turndown lowered the dew-point approach temperature by another degree. The original 13°F dewpoint approach at design drops to only 3-4°F at turndown. With this dewpoint approach, even minor hydrocarbon inlet liquid entrainment can be expected to result in major problems in the amine unit and SRU.

In addition to analysing the operations themselves, the economics and several performance metrics related to lost hydrocarbon product were also evaluated. **Table 4** shows that hydrocarbon content in the acid gas increases nearly eightfold at turndown vs design rates. The ramifications here are:

- Feed forward air ratio control in the SRU is off 1-5% at turndown versus design. While this is not a very large amount, it is enough to affect TGTU reliability because of the potential for SO_2 breakthroughs should there be a problem with feedback air demand analyser.[6]

Parametric results from turndown, Case A

Parameter	Design rates		30% Turndown	
	With RAFD	Without RAFD	With RAFD	Without RAFD
%Hydrocarbon as C_1 in AG	0.12	1.07	0.60	4.60
Air demand, mol/mol AG	2.16	2.18	2.18	2.27
MMBtu/y of HC lost				
Acid gas	768	6,180	1,140	8,390
Flash gas	5,410	5,410	7,250	7,250
Total	6,180	6,180	8,390	8,390
Value of HC lost, $/y				
Acid gas	2,303	18,531	3,433	25,160
Flash gas	16,225	0	21,735	0
Total	18,529	18,531	25,168	25,160
SRU recovery, %	94.43	94.28	96.68	96.18
H_2 in tail gas, % dry	1.95	1.98	2.09	2.24
COS in tail gas, ppmv dry	9.5	48.9	2.4	17.1

Table 4

There is definite value to having an RAFD installed.

- There is an economic penalty to burning hydrocarbon in the SRU versus leaving it in the money-making hydrocarbon units. The larger penalty that cannot be as easily quantified is the lost SRU capacity from reliability-related downtime.

Table 4 also shows improved SRU sulphur recovery at turndown conditions. This results from longer residence time in the Claus catalyst at lower throughput. Regarding the approach to equilibrium in the second converter, the design case is at 59.5% while at turndown the equilibrium approach is 95.5%. As developers of the kinetic rate based Claus Converter model in SulphurPro, we questioned whether this data was valid or a bug in the software. After comparing reactor conditions versus plant performance test data for similar applications, the effect was concluded to be real. However, the observations are not universal to all situations, as the dependence on rates, temperature, and degree of catalyst aging can be quite touchy. In fact, in this case the second converter operates cooler than many plants in the very area where Claus reaction equilibrium is more favourable, but reaction rates are slower.

Conclusions

While start-up and shutdown operations are short term, there can be very serious long-term implications that must be considered if damage to the SRU or reliability driven economic penalties are to be avoided.

There should be ample consideration given to up-front design for start-up, shutdown, and turndown operations. Knowing the limitations of the unit and what may occur during such operations helps to prevent damage. One should also consider whether leaving an amine system on hot standby is appropriate during a shutdown and whether means for keeping a higher ΔT margin in the amine unit's absorber for turndown scenarios should be considered.

Turndown was found to reduce dewpoint margin inside a refinery HDS contactor and degrade the quality of the acid gas. To our knowledge, this finding has not gained the industry's attention. The means are available to allow this condition to be carefully monitored through rate based process simulation. An important learning is that in addition to being more susceptible to upsets, amine units without rich amine flash drums can have more serious potential consequences.

The rate based sulphur recovery and amine unit engines within the SulphurPro and ProTreat simulators can provide valuable tools to identify the factors important to properly considering off-design operating scenarios, and help to set better operating guidelines. Considering these scenarios as part of the design effort will provide industry with more flexible and intelligent designs.

References

1 Nasato E, Misale-Lyttle D, Barrow D, Huffmaster M, Examining the impact of waste heat boiler design and operation on WHB reliability, Sulphur 2015.

2 Krueger K, Maldonado F, Huffmaster M, Low temperature tail gas kinetic functions – what they are – really, Brimstone Conference Proceedings, Vail, CO, 2016.

3 Knight W P, Evaluate waste heat steam generators, *Hydrocarbon Processing*, 1978.

4 Goar B G, Design considerations for modified Claus sulphur recovery plants, Proceedings of the Comprimo/Western Research Seminar on Gas Sweetening and Sulphur Recovery, Nov 1985, Amsterdam, The Netherlands.

5 Blais D, Marshall C, Wissbaum D, How hot is your reaction furnace – really?, Proceedings of the Laurance Reid Gas Conditioning Conference, Feb 2012, Norman, OK.

6 Hatcher N, Jones C, Weiland S, SO_2 breakthrough under the microscope, *PTQ Gas*, 2017.

Matt Bailey provides sales and marketing support with Optimized Gas Treating, Inc. He holds a BS in chemical engineering from Texas A&M University and an MBA from the University of Houston.

Simon Weiland is a Technical Applications Engineer with OGT, responsible for key accounts, employee and customer training, and workshops. He holds a BS in chemical Engineering with a minor in German from the University of Oklahoma.

Nate Hatcher is an Engineering Consultant with OGT following several years as Director of Technical Development. He leads the development of a new Consulting Group to leverage OGT's substantial breadth and depth in gas treating and sulphur recovery. He holds a BS in chemical engineering from the University of Kansas, is a registered professional engineer in the state of Kansas, and is currently a member of the industry Amine Best Practices Group. *Email: Nathan.Hatcher@ogtrt.com*

PROFLUX® severe service grid packing

Engineered for maximum fouling resistance

"Since installing the PROFLUX SEVERE SERVICE Grid in our wash bed we have seen a marked improvement in our Vacuum Gas Oil product quality and have been able to push the tower much harder than before. With multiple runs using the same grid packing – we consider the performance of the PROFLUX exceptional!"

– Lead Process Engineer, Process Technology at Consumers Co-operative Refining Limited (CCRL) with over 40 years experience of process design and operational experience

With over **300 installations**, PROFLUX has become the first choice for operators looking to increase reliability in their severe service applications.

- Atmospheric Crude Tower
- Vacuum Crude Tower
- FCC Main Fractionator
- Ethylene Fractionator & Water Quench

PROFLUX® 40X | PROFLUX® 45 | PROFLUX® 64

Scan to learn more.
koch.link/PTQR20

United States 316-828-5110 | Canada 905-852-3381 | Italy +39-039-638-6010
Singapore +65-6831-6500 | India +91 (0) 2667-244-344 | Japan 81-3-4332-5560

KOCH-GLITSCH

YOU CAN RELY ON US.

A KOCH ENGINEERED SOLUTIONS COMPANY

Modelling ensures a successful revamp

Pre-turnaround computational modelling built confidence in the benefits of introducing design changes to a FCC regenerator revamp

RAJ SINGH, PAUL MARCHANT and STEVE SHIMODA *TechnipFMC Process Technology*
MARC A SECRETAN *Suncor Energy*

For FCC operation, regenerator performance is a key factor in maximising unit economics. Regenerator performance is generally evaluated by uniformity of combustion, seen in the temperature profile, and strongly depends on good distribution of both air and spent catalyst. Both operating conditions and hardware configuration influence the air catalyst mixing and flow patterns within the regenerator.[1]

Understanding the impact of hardware configuration on regenerator fluidised bed hydrodynamics is important for any potential design modification, optimisation, and troubleshooting. It is important to pre-evaluate the performance of the unit with planned design modifications to reduce any unforeseen risks before the implementation. TechnipFMC actively uses computational fluid dynamics (CFD) tools for design validation and troubleshooting.

This article discusses an FCC regenerator revamp at the Suncor Edmonton refinery, aimed to incorporate advanced design features to mitigate operational challenges and improve the mechanical reliability of the internals. This article describes how CFD modelling tools were used to confirm the adequacy of the proposed hardware changes, fine-tune the design, and evaluate the performance to minimise risks on start-up. Post-turnaround performance of the unit confirms the benefit of the implemented design.

Suncor's Edmonton refinery is one of four refineries which Suncor operates in North America. The refinery was built in the 1950s, can process 142 000 b/d of crude, with FCC throughput of roughly 45 000 b/d. The FCC unit is a 'side by side' reactor/regenerator configuration which includes a close coupled riser termination device in the reactor and a regenerator with a fast burn zone. The layout of the FCC unit with its latest design features is shown in **Figure 1**. The unit has been revamped with multiple FCC Alliance (TechnipFMC, Axens, IFPEN, and Total) technology features in the last 20 years.

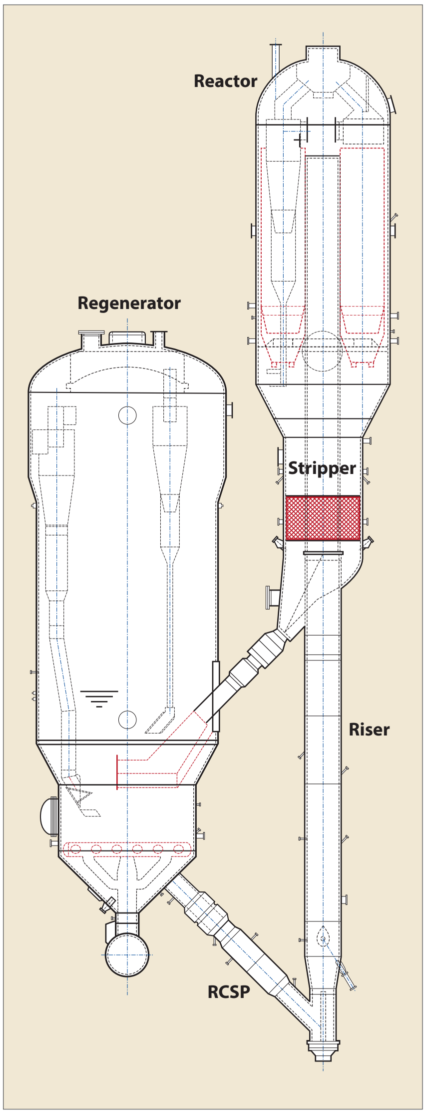


Figure 1 Suncor Edmonton refinery's FCC unit with key technology features

In 2001, FCC Alliance proprietary feed injectors and Suncor and TechnipFMC's jointly developed riser termination device were installed in the riser reactor section. Post-revamp, the unit performance was significantly enhanced due to improved feed atomisation and reduced post riser residence time. Even though the regenerator operation was switched from partial combustion to complete combustion, the unit managed to achieve higher catalyst to oil ratio and lower delta coke. The unit experienced improved yields; gasoline increased by approximately 5 vol% and coke decreased by 1 wt%.

In 2004, FCC Alliance's proprietary structured packing was installed in the FCC stripper. It was deemed a successful revamp as the unit was able to reduce the stripping steam consumption from 4lb to 2lb/1000lb catalyst circulation at a constant regenerator temperature. Since 2004, Suncor has inspected the packing during scheduled turnarounds and found no significant damage or erosion. It continues to perform effectively. Inspection pictures after 5, 10 and 14 years of service (see **Figure 2**) confirm that the packing is in good condition and continues to be reused.

Suncor's FCC regenerator is a single stage, full burn regenerator with a fast burn zone in the lower section of the regenerator. It operates at higher superficial velocities than typical regenerators. The original internals consisted of a single horizontal arm spent catalyst distributor, 'cross type' air grid distributor, and an internal hopper feeding the regenerated catalyst

Figure 2 Stripper packing inspection images

standpipe (RCSP). The regenerator was experiencing an afterburn of 40°F (22°C) which infringed on the turbo expander inlet temperature limit. Additionally, high gas entrainment into the RCSP led to poor head build-up and low regenerated catalyst slide valve (RCSV) pressure drop.

For the 2018 turnaround, as the regenerator was determined to be at end of life, Suncor decided to replace the entire vessel and internals such as the air grid, cyclones, spent catalyst distributor, and so on. The original objective was to be a replacement-in-kind revamp. However, Suncor took the opportunity to incorporate some design improvements to the regenerator internals to mitigate the known operational problems and improve the mechanical reliability of the internals. The regenerator shell design was kept unchanged to minimise impact on the foundation, structure, piping, and external work required during the turnaround. The existing top hemispherical head was replaced with an elliptical head to raise cyclone inlet elevation, while keeping the total regenerator height constant.

Technology and design development

During the planning stage, technology enhancements focused primarily on spent catalyst distribution and RCSP operation. A self-aerated, submerged compound angle spent catalyst distributor was designed to improve spent catalyst mixing in the bed, promote uniform bed combustion, and reduce afterburn. The RCSP inlet was modified to reduce gas entrainment, increase catalyst density, and improve head build-up above the RCSV. A comparison of the original regenerator configuration with the new/modified configuration, with changes highlighted in red, is shown in **Figure 3**.

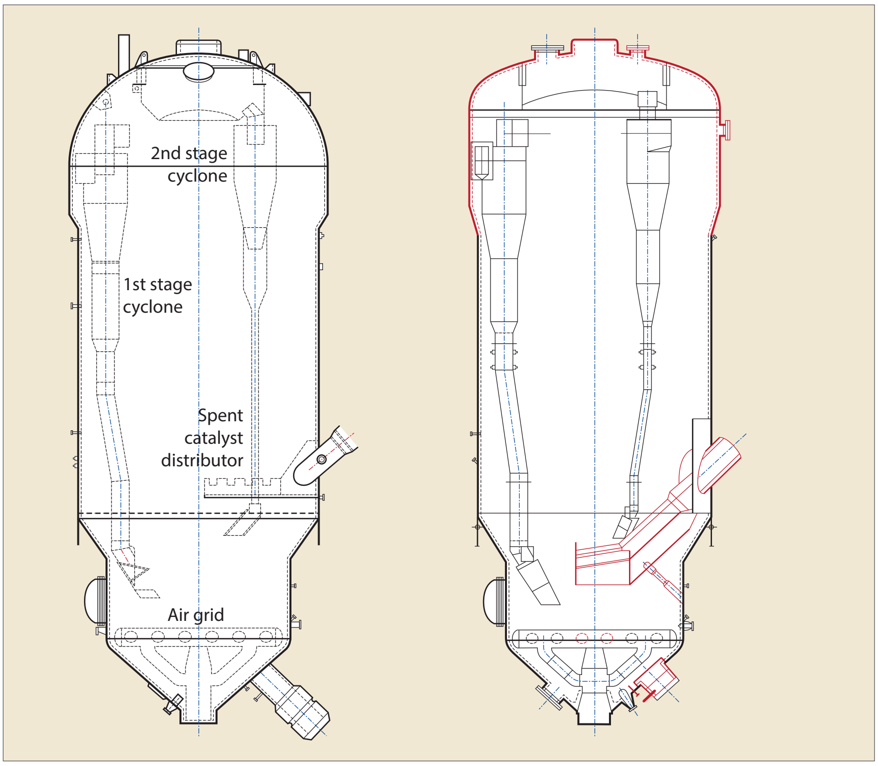


Figure 3 FCC regenerator: original (left) and modified (right)

The modified configuration in **Figure 3** shows an improved version of FCC Alliance's standard compound angle wye bathtub distributor design, where a major portion of the distributor arm is submerged in the catalyst bed. Considering the regenerator diameter was small and the standpipe inlet was tangential to the vessel, a one-arm bathtub instead of wye arms was designed for this application. The initial angle of the bathtub is optimised to ensure incoming spent catalyst has sufficient momentum to flow down the arm, without aeration, into the fluidised catalyst bed. The latter portion of the bathtub is designed to self-aerate, utilising the gas from the bed underneath, and distribute catalyst preferentially to the centre and sides of the vessel. The design provides self-fluidisation and eliminates the need for a sparger system to fluidise the catalyst in the distributor. The design allows the catalyst to discharge in the high velocity lower section of the regenerator, in close proximity to the primary cyclone dipleg discharge. This promotes spent catalyst interaction with hot catalyst returning from the primary diplegs and overall mixing in the bed, which is essential to enhance bed combustion uniformity and reduce afterburn.

Since the revamp was originally intended to replace the regenerator and its internals in kind, there was concern that the proposed hardware

Precious Metals

Edelmetale
Metale te cmuar
Qiymətli Metallar
Metal preziatuak
Dragoceni metali
Metalls preciosos
Bililhon nga Mga Metals
Zitsulo Zamtengo Wapatali
贵金属
Metalli Preziosi
Dragocjeni metali
Drahé kovy
Værdifulde metaller
Kostbare metalen
Altvaloraj Metaloj
Väärismetallid
Mahalagang Metals
Jalometallit
Métaux Précieux
Edelmetalen
Metais preciosos
Edelmetalle
Metali presye
Karfe mai daraja
Nā Metala kūpono
Lub Neej Zoo Nkauj
Nemesfémek
Dýrmæt málm
Alsdị ọla dị oké ọnụ ahịa
Logam Berharga
Metalli preziosi
貴金属
Metals Logam
귀금속
Metayên hêja
nobilis metalli
Dārgmetāli
Taurieji metalai
Metaly sarobidy
Logam Berharga
Metalli prezzjużi
Metara Raraemi
Edelmetaller
Drogocenne metale
Metais preciosos
Metale prețioase
O Metotia Taua
Meatailtean luachmhor
Metali ea Bohlokoa
Metals anokosha
Drahé kovy
Plemenite kovine
Birta Qaaliga ah
Metales preciosos
Logam lumayan
Vyuma vya Thamani
Ädelmetaller
Değerli Metaller
Qimmatbaho metallar
Kim loại quý
Metelau Gwerthfawr
Iintsimbi ezixabisekileyo
Awọn irin Iyebiye

sabin METAL CORPORATION
Refining • Precious Metals • Recycling

It doesn't matter what you know, until you know what matters.

Sustainability

Platinum Group Metals (PGMs) remain at the forefront, the absolute cutting edge, of Conservation, Energy Production and World Health, and demand for PGMs is expected to increase for decades to come.

Sabin Metal Corp. is dedicated to recycling and refining these valuable metals from industrial by-products and wastes efficiently and sustainably, returning the maximum amount of these assets to our clients for industrial re-use.

If you'd like to learn more about sustainability at Sabin, or any Precious Metal matters, please visit our PM 101 section at sabinmetal.com.

SABIN METAL CORPORATION 75TH ANNIVERSARY 1945-2020

VEREINIGTE
FÜLLKÖRPER-FABRIKEN
GMBH & CO. KG

TÜVRheinland®
CERT
ISO 9001

Your expert for tower packings, catalyst support material and column equipment

Please give us a call
+ 49 (0) 26 23 / 895 - 10

VFF has no shortage of supply because of its own resources and the biggest stock in Europe.

- Europe's largest producer of catalyst support material and random packings
- All relevant sizes and materials
- 100% Made in Germany
- Short time delivery
- Highest available safety
- More than 30 agencies worldwide

For further information please visit **www.vff.com**

P. O. Box 552, D - 56225 Ransbach-Baumbach Phone +49 26 23 / 895 - 0, info@vff.com changes may adversely impact the performance of the unit. To gain confidence in the likelihood of success and moreover to reduce any unforeseen risks, it was decided to evaluate and optimise the proposed design using computational fluid dynamics (CFD).

Computational modelling plays an increasingly important role in understanding gas particle flow dynamics in the FCC process, enabling designers to offer low risk, high value improvements. The latest generation of CFD modelling tools enables rapid exploration of different configurations to optimise the design. Compared to cold flow testing, CFD allows a deeper understanding of what is happening at all points in the system. It provides the qualitative information needed to visualise processes difficult to see in physical models, along with the quantitative results that enable realistic comparisons of equipment configurations. Combining these results provides an understanding of how hardware and operational changes impact gas catalyst flow dynamics in the fluidised bed. Conducting CFD 'virtual testing' of new devices, combined with experience, increases confidence in proposed changes.

Computational modelling

A CFD model was developed for the regenerator configuration with proposed internal modifications to study the impact on the fluidised bed hydrodynamics. Barracuda VR, CFD software developed exclusively to model gas solids fluidised bed reactors, was used for the study. The software was selected because of its capability to accurately handle dense gas solid flows. The algorithms and models incorporated into the Barracuda VR software have been validated against cold flow experimental data and commercial operating reactors.[2,3]

A portion of the regenerator section (see **Figure 4**) was selected as the modelling domain for the hydrodynamic study. It incorporates all the essential features of the regenerator which can influence the prediction of the regenerator bed's hydrodynamic behaviour, such as: primary and secondary diplegs returning entrained catalyst back to the bed to maintain bed level and temperatures; actual nozzle count and gas momentum through the air grid distributor; details of the new spent catalyst distributor, and others. The inlet and outlet flows are defined by pressure, flow, and injection boundary conditions. There were essentially two modelling cases: one with the regenerator configuration with the proposed spent catalyst distributor design and original RCSP hopper, and a follow-up case with no RCSP internal hopper.

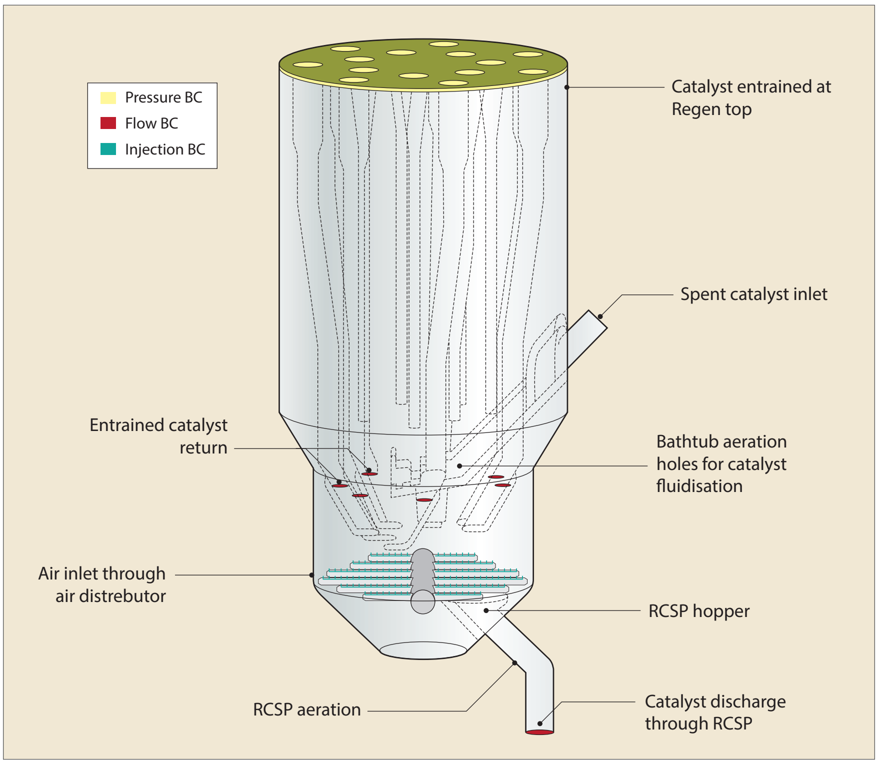


Figure 4 Regenerator modelling domain

Self-aerated submerged spent catalyst distributor

The modelling results from the base case regenerator configuration with the new spent catalyst distributor is shown in **Figure 5**. The gas catalyst flow pattern and mixing are represented by both instantaneous and time average catalyst volume fraction profiles at the centre line of the X and Y planes of the model, along with the radial contours of the catalyst density profile at selected elevations. Both the radial and axial plots indicate that the fluid and catalyst are well mixed in the bed, resulting in uniform catalyst density. No gas by-passing is observed in the results. The instantaneous plot of catalyst density signifies that the bed is highly active above the air distributor. This is primarily due to high superficial velocity in the regenerator lower section. Terminating the primary diplegs in the regenerator lower section tends to bring all the entrained hot catalyst back to the lower section of the regenerator and helps to maintain the bed densities as well as desired temperatures for combustion.

The performance of the new spent catalyst distributor was evaluated both qualitatively and quantitatively. A qualitative representation of the modelling results in terms of overall catalyst mixing, spent catalyst coverage, and catalyst species across the bed is shown in **Figure 6**. The presence of spent catalyst all over the regenerator clearly indicates that spent catalyst is completely distributed across the bed.

The quantitative results shown in **Table 1** confirm even distribution of spent catalyst from the distributor sides as per the proposed design. The CFD results also indicated that the flow from the distributor slots towards the wall is in very close proximity to one of the primary cyclone diplegs, which may cause erosion of the dipleg and

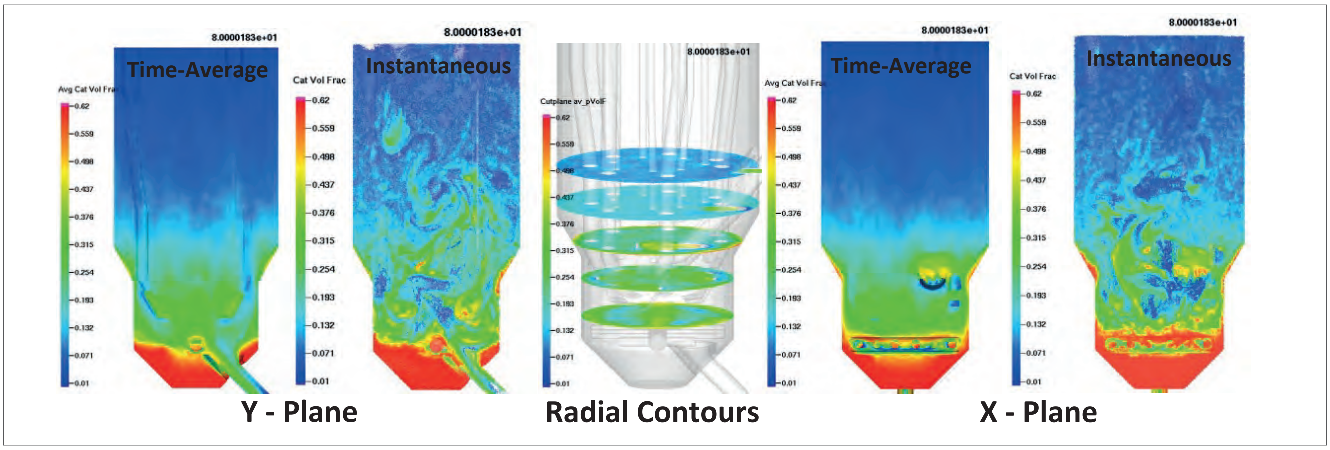


Figure 5 CFD prediction: catalyst density profile

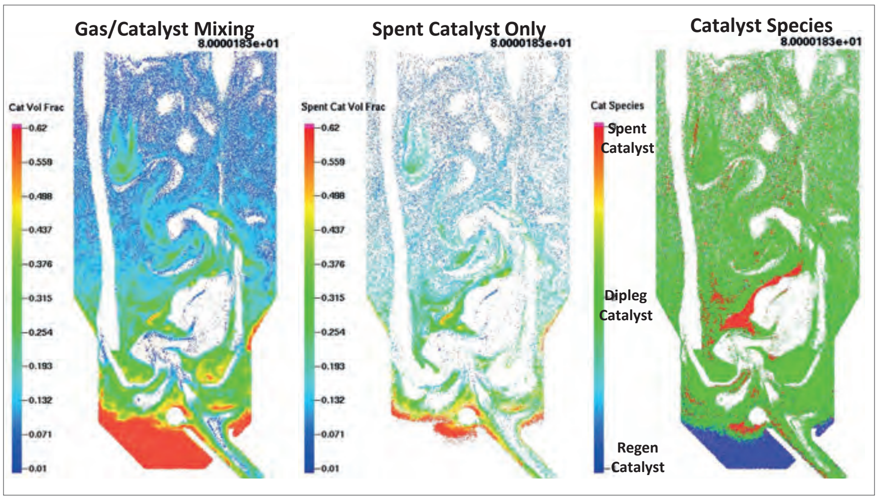


Figure 6 Regenerator centre line cut-plain: catalyst density and species plot

Spent catalyst distribution

	Proposed design, %	Optimised design, %
Towards centre	43	62
Towards wall	43	23
From distributor end	14	12

Table 1

disrupt valve opening and closing. Thus, the distributor slots towards the wall region were removed to increase catalyst flow towards the regenerator centre and reduce the potential for catalyst impingement on the cyclone dipleg valve concerned. Biased flow towards the centre further promotes spent catalyst coverage across the regenerator.

RCSP internal hopper

The original regenerator configuration had an eccentric internal catalyst hopper connected to the RCSP inlet nozzle (see **Figure 3**). The hopper was located a minimum distance below the air distributor and tended to withdraw catalyst directly from the active zone above the air grid distributor. The catalyst flux at the hopper inlet was approximately 60 $lb/ft^2/s$ which increases to 225 $lb/ft^2/s$ at the RCSP inlet in less than three seconds' residence time. The fact that the distributor was too close to the hopper, and the hopper was quite small, resulted in a lack of sufficient residence time for gas to disengage from downflowing catalyst into the RCSP. This resulted in high gas entrainment, which further caused low catalyst density and low head build-up in the standpipe. This analysis was supported by both plant data as well as findings from CFD modelling results.

The regenerator operating data versus pressure drop along the RCSP is plotted in **Figure 7** as a function of regenerator superficial velocity at constant catalyst circulation. The plot shows a decrease in head gain with an increase in superficial velocity, which is generally due to increased gas entrainment down the standpipe.

CFD predictions of regenerator configuration with and without an internal RCSP hopper are compared in **Figure 8**. Both the configurations are modelled with the new spent cat-

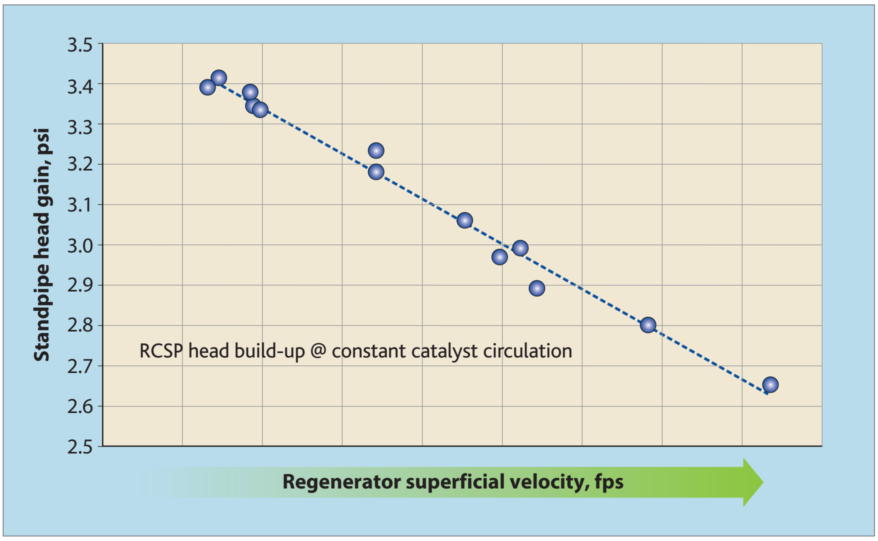


Figure 7 RCSP pressure build-up vs regenerator superficial velocity with internal hopper

alyst distributor, and the RCSP hopper is removed to evaluate its impact on spent catalyst flow and gas entrainment into the RCSP. **Figure 8** shows the time average axial distribution of catalyst volume fraction along the regenerator centre line and represents catalyst density distribution in the bed as well as in the RCSP inlet. The bed is uniformly mixed with and without the RCSP hopper and there is no significant change in gas catalyst flow pattern above the air distributor. The hopper mainly withdraws catalyst from the active zone above the air grid and draws an excess amount of gas into the RCSP. The results clearly show high gas entrainment and low catalyst density with the RCSP hopper.

With no RCSP hopper, CFD predicts the catalyst flow to the RCSP will be 40% denser, which indicates directionally less gas entrainment and improved RCSP head build-up. Additionally, Barracuda VR has a useful feature in that catalyst 'in the bed' and incoming spent catalyst can be tracked separately. The RCSP hopper draws catalyst from above the air grid and increases the chances of 'bypassing' spent catalyst into the RCSP, estimated at about 11% of spent catalyst short-circuiting into the RCSP with a residence time of less than 60 seconds in the system. Removing the hopper and drawing catalyst preferentially from below the air grid reduces the amount of bypass to around 5%. Based on the CFD findings, the following modifications were made to the RCSP inlet:

- Removed the RCSP hopper and increased the RCSP inlet nozzle size to reduce catalyst flux at nozzle inlet
  - Increased residence time for gas to disengage from downflowing catalyst into the RCSP
  - Reduced gas entrainment, increased catalyst density, and improved standpipe pressure head
- Provided fluidisation nozzles close to the RCSP inlet to keep the RCSP inlet region fluidised to aid smooth transfer of catalyst from regenerator to RCSP
- Provided debris guard

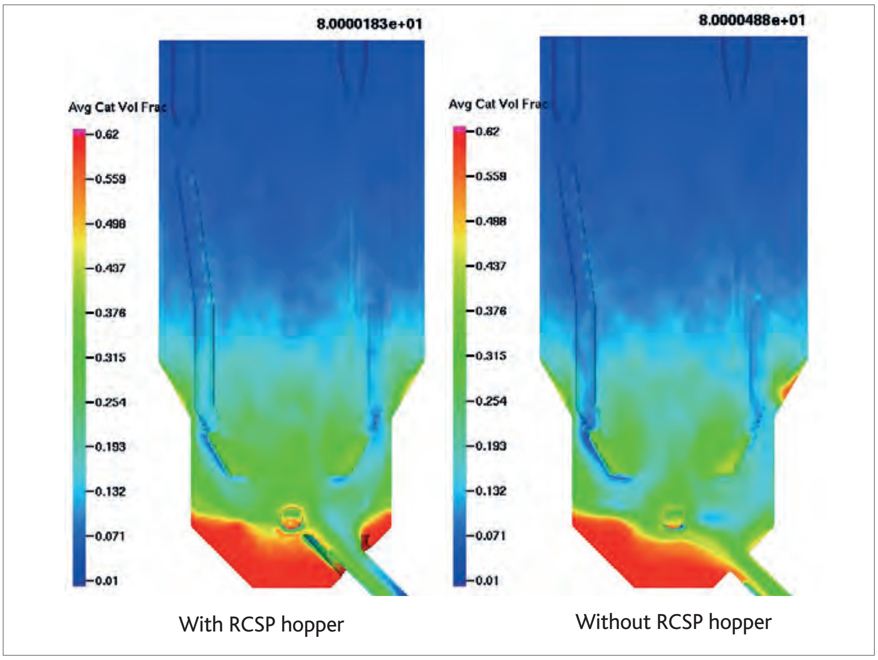


Figure 8 Density plot comparison: with and without RCSP hopper

Figure 9 Installation of spent catalyst distributor

Unit operation

After fabrication of the regenerator vessel along with its internals, the vessel was placed on a temporary structure on-site before it was swapped with the original vessel during the turnaround. The installation of the spent catalyst distributor in the regenerator vessel is shown in **Figure 9**. The unit has been in operation for more than two years since turnaround, showing significant improvement in unit performance.

The performance of the regenerator before and after the turnaround is shown in **Figures 10** and **11**. More than a 50% reduction in dense and dilute phase temperature variation (see **Figure 10**) after turnaround clearly represents the benefit of the newly implemented spent catalyst distributor in achieving uniform combustion and temperature profile within the catalyst bed.

Figure 11 shows the afterburn data with respect to both dilute phase and overhead flue gas temperature. The afterburn, with respect to dilute phase temperatures, dropped by roughly 15°F (8°C) whereas the overhead flue gas temperature showed a 35°F (19.5°C) drop in temperature, resulting in minimal afterburn with the submerged compound angle bathtub distributor.

The pre- and post-turnaround operating conditions and yields, compared in **Table 2**, clearly indicate the benefit of incorporating advanced regenerator internals into the operation. High levels of

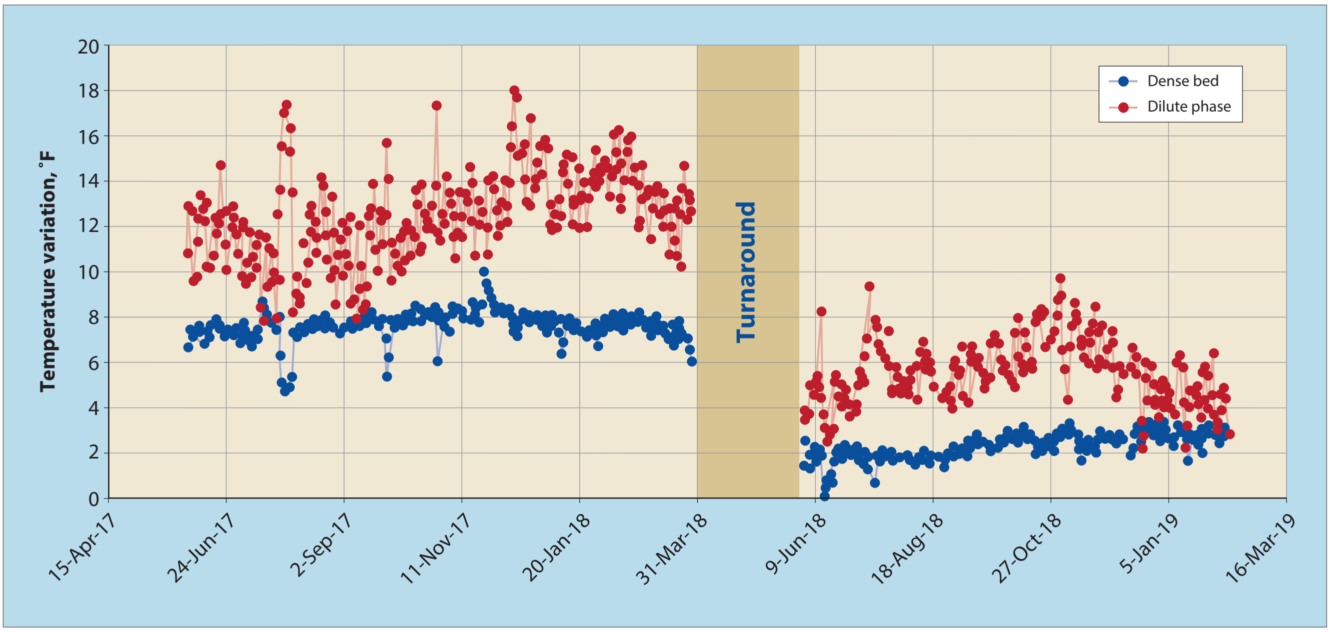


Figure 10 Pre/post-operating data: dense and dilute phase temperature variation

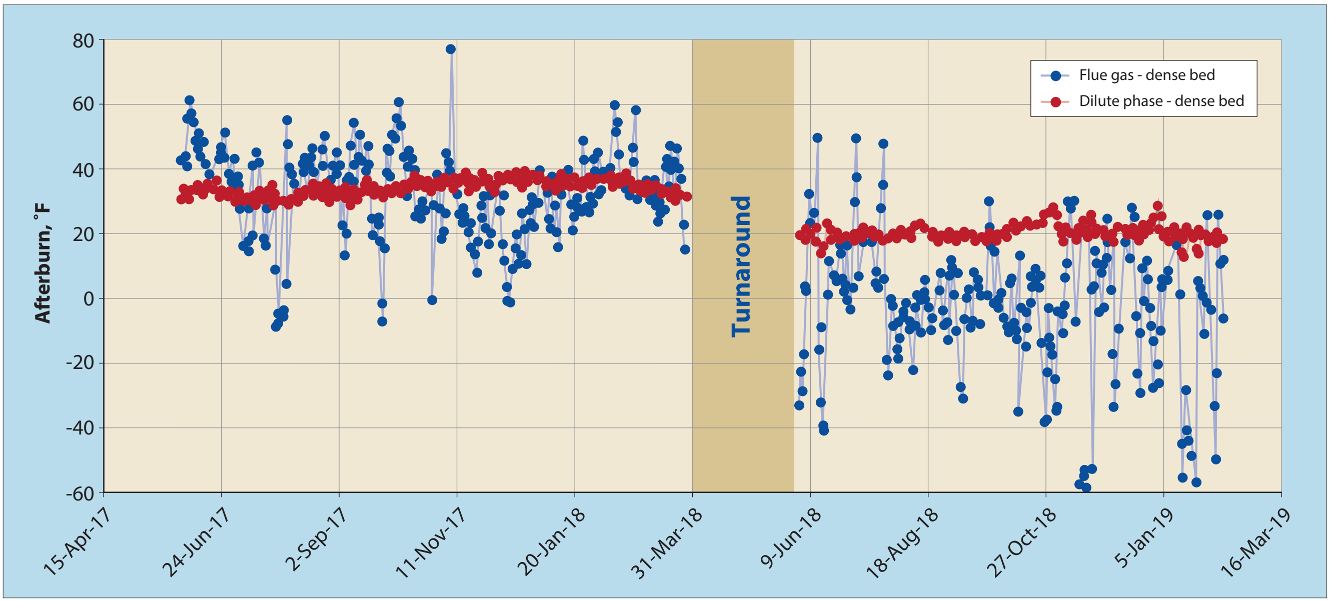


Figure 11 Pre/post-operating data: afterburn

throughput, catalyst circulation, and conversion have been achieved without encountering flue gas temperature limits. Modifications to the RCSP inlet proved to be beneficial in reducing gas entrainment into the RCSP and increasing standpipe head gain by 1.3 psi.

Conclusion

Implementing any new technology or design brings with it attendant risks as the real-world performance is not known. Success depends on properly planning all phases of the project including conception, process design, mechanical design, fabrication, installation and finally start-up. All stakeholders must understand the design intent and have a high degree of trust in each other. For the Suncor revamp, the original intent was to replace in kind. However new design concepts were considered and implemented to realise improved process performance and mechanical reliability.

To increase confidence in the design, TechnipFMC prepared a CFD model of the design to demonstrate that improved process performance would be achieved. The purpose of modelling was to indicate improved spent catalyst distribution as well as improved standpipe pressure build-up. Accurate system modelling allowed proper design evaluation. The CFD tools helped all stakeholders to develop confidence in the proposed changes.

Collaboration between process and mechanical designers continued throughout detailed engineering, fabrication, and installation phases. Following the turnaround, unit start-up was trouble free, and once the unit stabilised the process data indicated that the distributor was working as intended. Variation in the dense bed temperature and reduced afterburn were a clear indication of improved distribution. Catalyst circulation was smooth and RCSP pressure build-up was improved, indicating better performance at the inlet.

Barracuda VR is a registered trademark of CPFD Software.

References

1 Singh R, Marchant P, Shimoda S, Improved distribution of spent catalyst, *Revamps 2019, PTQ*.

2 Adkins B D, Kapur N, Dudley T, Webb S, Blaser P, Experimental validation of CFD hydrodynamic models for catalytic fast pyrolysis, *Powder Technology*, 316, 2017, 725-739.

3 Singh R, Gbordzoe E, Modelling FCC spent catalyst regeneration with computational fluid dynamics, *Powder Technology*, 316, 2017, 560-568.

Unit operation comparison

	Pre T/A	Post T/A	Delta
Key operating conditions			
Throughput, b/d	Base	+	2.60%
ROT, °F	975	968	-7
C/O	6.7	7.3	9%
Catalyst circulation, t/m	31.3	35.3	12%
Regen dense bed temp, °F	1260	1246	-14
Regen dilute phase temp, °F	1283	1261	-22
Regen flue gas, °F	1278	1246	-32
Yields, wt% FF			
Dry gas	1.8	1.7	-5.6%
LPG	18.7	18.5	-1.1%
Gasoline	56.5	57.1	1.1%
LCO	14.2	14.2	0.0%
Slurry	4.7	4.3	-8.5%
Coke	4	4.2	5.0%
Conversion, wt%	81.1	81.5	0.5%

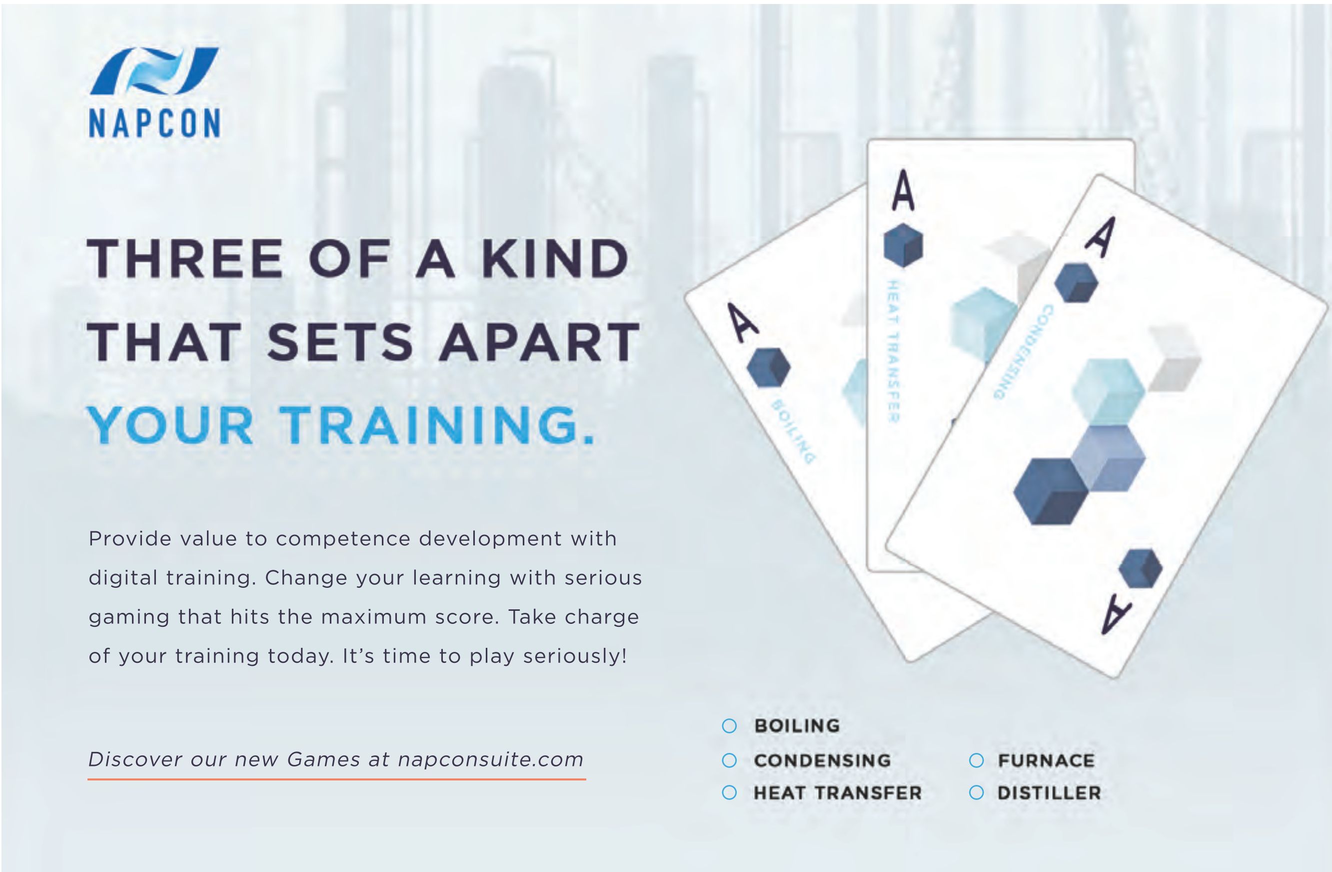
Table 2

Raj Singh is Senior Technologist, FCC Refining with TechnipFMC. With over 15 years of experience in FCC equipment design, technology development and troubleshooting, he has contributed to a wide range of projects, including revamps, grassroots designs, process studies, CFD studies, and FCC proposals. He holds a MS in chemical engineering from Illinois Institute of Technology, Chicago.
Email: raj.singh@technipfmc.com

Paul Marchant is the Process Manager, Refining with TechnipFMC in Houston Texas. He has worked on all aspects of FCC technology programmes and projects for over 20 years. He has been awarded several patents, and holds a BEng from the University of Bradford, UK.
Email: paul.marchant@technipfmc.com

Steve Shimoda is Director of the FCC programme with TechnipFMC. He has over 20 years of process technology experience with refining units. His current responsibilities include project development, technical marketing, and technology licensing. He holds a PhD in chemical engineering from the University of Houston and a BS in chemical engineering from the University of Oklahoma.
Email: steve.shimoda@technipfmc.com

Marc Secretan is FCC Engineering Specialist with Suncor in Calgary, Alberta. With over 20 years of experience in refining, his work has primarily focused on process improvement and optimisation, troubleshooting operational problems, unit start-ups, turnaround inspections, incident investigations, component design, risk assessment, and automation of FCC units. He holds a BSc degree in chemical engineering from the University of Alberta.
Email: msecretan@suncor.com



THE WORLD'S PREMIERE DELAYED COKING CONFERENCE

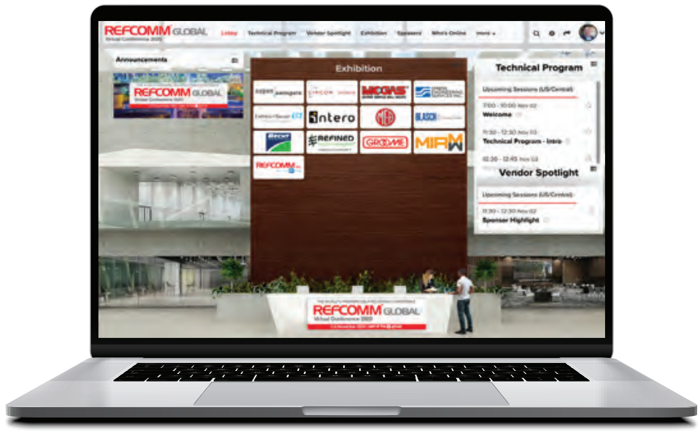
REFCOMM® GLOBAL

Virtual Conference 2020

2-6 November 2020 | part of the CRU group

An interactive and immersive experience awaits YOU!

RefComm Global: a Virtual Delayed Coking Conference and Exhibition will be a fully immersive online environment where you can attend technical presentations by industry experts with live Q&A; interact with exhibitors, and network with fellow attendees.



Agenda

The timings and mix of live and on-demand programs will mean that whatever time zone you're in, you can watch the presentations you want, when you want. No need to choose between attending a meeting or attending a presentation - you can now do both!

Networking Opportunities

Here you can search the delegate list, request private meetings, chat in a group, or schedule a video chat.

> *"I picked up a lot of good information. I would definitely encourage those that are interested to participate and not to miss this conference."*
>
> *Gregg Lorimor, Sr. Engineering Specialist, HollyFrontier Tulsa*

Exhibit Hall

Visit a booth, chat to the exhibitors, watch their videos and download brochures of interest. Booths will be manned by industry focused vendors during the event dates.

More Time for Everything

The virtual event will be open before the event start date and will remain open after - allowing you more time to schedule meetings, watch conference sessions and browse the exhibit hall.

Sponsors

CIRCOR | DeltaValve

STRESS ENGINEERING SERVICES INC.

Endress+Hauser People for Process Automation

BLASCH PRECISION CERAMICS

AMPO POYAM VALVES

Intero

MOGAS® SEVERE SERVICE BALL VALVES

BECHT Good. Better. Becht.

MEA

Inspectioneering®

OILMAN THE MAGAZINE FOR LEADERS IN AMERICAN ENERGY

BIC MAGAZINE

ptq

DIGITAL REFINING

For more information and to register, visit **www.refcommglobal.com**

Planning a turnaround that fits

A risk based work selection process screens worklist items to ensure they are justified for risk reduction or financial benefit as part of a turnaround

EILEEN CHANT and **ABBY KING**
Becht Engineering

In today's process industries, sustained long-term reliability of facilities is a key to profitability and competitiveness. The cost of unreliability, which includes health, safety and environmental (HSE) incidents, is difficult for even healthy companies to endure and with investment in the right proactive measures can be avoided. Risk based work selection (RBWS) is a work process that prioritises and optimises turnaround and maintenance work without sacrificing reliability. RBWS uses risk to screen individual worklist items to ensure they are justified by either HSE risk reduction or financial benefit to cost analysis. Significant reductions in turnaround work scope typically result from this structured work process. At the same time, the nature of the process is such that there are numerous additional benefits such as 'sleeper' risks not previously considered, minimising discovery work, and helping with alignment of the cross-functional teams.

Inconsistent methods for screening turnaround and maintenance work can lead to missed opportunities for risk reduction and a poor return on investment (ROI). Becht's RBWS method is a systematic and consistent approach to screen turnaround work lists using historical and industry performance data. The company's turnaround and reliability specialists have reviewed turnaround work scopes for over 20 years. The average work list optimisation is $3 million in reduced turnaround spending per review with a reduction of 24% of low ROI work list items.

The RBWS process is data driven, ensures consistency of decision making and results in a risk-optimised worklist. The process includes consideration of risk management, reliability and conservation of financial resources. The results are fully documented for leadership review and future turnaround planning. **Figure 1** shows the RBWS work process.

Questions that drive the RBWS justification process include (but are not limited to):
- Can the work be done cost effectively on-stream rather than during the turnaround?
- Does the risk of deferral meet the HSE threshold?
- Is there a clear justification for the work?
- Is the scope and cost well-defined?
- Does the cost of doing the work meet the client's benefit-to-cost ratio threshold (this consideration only applies when HSE risk is below threshold)?
- Will the work eliminate a bad actor?

It is a process which is not limited to fixed equipment but covers all equipment classes.

The software tool

Use of the right software tool saves time and improves the

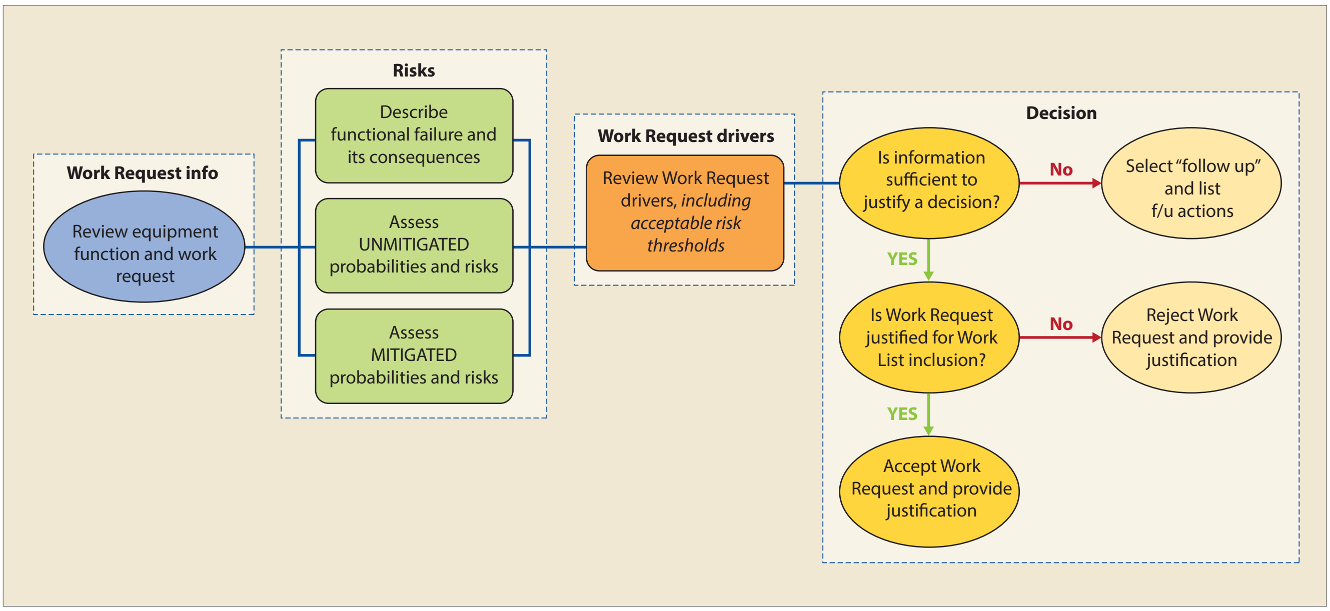


Figure 1 RBWS work process

results of the RBWS review. The process uses the web based software tool, BechtRBWS, to achieve consistent and efficient facilitation of cross-functional meetings, store the worklist data, and document decision making and results. Documentation of the rationale allows the leadership team to understand the 'whys' of the outcome, develops consistency between disciplines and sites, and provides a roadmap for future turnaround planning.

The information necessary to conduct an RBWS should already exist. The challenge is digging the information out of desk drawers, databases, and Excel spreadsheets, and organising it for review. Assessments are for a specific timeframe; one turnaround cycle, usually 4-7 years. The software will have this timeframe built into it.

What characteristics should the software tool have?

Documentation
An RBWS session is only as good as the documentation. Being transparent about the team's thought process and recommendations enables leadership to make informed decisions on what is 'in' or 'out of a turnaround and why. Proper documentation helps eliminate recycle before and during the turnaround and can also be used as the starting point for future turnarounds. A dedicated tool preserves the data and results of the session.

Data gathering
A dedicated software tool should lessen the burden of data gathering for RBWS. Well-defined data fields, along with examples, help guide teams during the data acquisition phase. We recommend that teams new to the process should have training on the process and the data that they are required to gather. Setting clear expectorations for the data to include in workscope submittals will help minimise rework and help communicate the expectation that work items will be scrutinised and require justification.

Facilitation
RBWS requires input from the entire turnaround team with several members participating in a session at any given time. Therefore being efficient is critical to a successful session. The tool should ease the data entry, facilitation, and risk calculations done during a session, minimising the downtime. Toggling between screens and scrolling back and forth takes time and can be distracting and confusing. An ideal tool will have a single screen that is the focus during the session. That screen will present the data that was pre-loaded along with fields that capture the discussion during the session and show the risk assessment results.

Accessibility
Sharing information across a site or from site to site can add a lot of value for improved workflow, lessons learned, benchmarking, and to leverage work products from a past turnaround for a future turnaround. A tool should enable this by being accessible. Web based tools that can be logged into from anywhere have a distinct advantage over tools that are loaded onto a single computer.

Reporting
A software tool should have reporting capability built in so it can roll up results that show the items reviewed, deferred, or recommended to be in or out of the turnaround. Most software has standard report templates but having the capability for customised reports is a beneficial feature. An example of a report that our clients like to see is the Benefit to cost graph, which plots each discretionary item in terms of cost versus financial risk mitigated (benefit).

Preparation
The cross-functional team consists of an expert facilitator leading a group of refinery operations, maintenance, technical supervisors, and subject matter experts. As a team of plant personnel participates in the review, developing an efficient process is critical, to minimise meeting time. Preparation steps are recommended so that the team can hit the ground running when starting the review.

Worklist data
During the review, the drivers (process or equipment integrity) for the turnaround work items are evaluated. The risk-based process is structured to challenge the work list items and determine whether the turnaround work is justifiable, or whether deferments are permissible. Effective evaluation of the drivers requires the right information. Thus the data should support the evaluation of the benefits of performing the tasks versus deferring the item until the next turnaround.

In addition to work scope, item description, hours to complete, cost estimate (±30% is recommended), a description of "What will happen if this worklist item is not performed?" is required. Also for each common type of turnaround task, Becht provides specific direction on the information required. For example, in order to justify a heat exchanger cleaning, the following information and data are requested:

- Past history
- Service (clean/dirty)
- Monitoring/data such as pressure drop over time
- Percent slowdown or shutdown and time to clean
- U-values or the ratio of ΔTemperature to ΔTemperature at design

The RBWS input workbook is reviewed by the Becht team and there is typically a back-and-forth finalisation of the data prior to the review session. For a site which does not have experience with the process, it typically takes two weeks after the first worklist is provided to fully prepare for the review. The worklist, when complete, is imported into the web based application.

Training and preparation
For sites that have not been through the process, an on-site or webinar based series of meetings is recommended prior to the review (see **Table 1**). The training should educate the participants so that expectations for the meeting are understood. The site's goals for the turnaround and reliability considerations are reviewed with the leadership team.

Preparation and training meetings

Topic	Personnel
Kick-off	TA Manager
Discussion of equipment worklists for equipment types with SMEs	Lead Fixed Equipment Inspector Machinery Supervisor Electrical Supervisor Instrumentation Supervisor
Discussion of reliability considerations	Reliability Manager
Training on the RBWS work process and examples	Key Stakeholders and Contributors to work list Complex Managers, Process People, Operations, Reliability, Inspection, HSE Specialist
Discussion of corrosion rate prediction and NDE inspections	Metallurgist
Prescreening work prior to TA Mgr meeting	N/A
Close-out meeting to review follow-up items	TA Manager

Table 1

Pre-screening is also one of the preparatory steps where items that are deemed essential to the turnaround are taken out of the review process and automatically accepted into the finalised turnaround worklist. Becht develops the list of pre-screening criteria with the user and culls the list of items that will be covered during the review. Example criteria include: low cost items that do not warrant review; items required by a risk based inspection programme; and items required for regulatory compliance. This reduces the scope of the review and meeting time, while maintaining the full value of the review.

Risk basics

Risk concepts should be well understood by the cross-functional team. It is formally defined as probability x consequence, with respect to an adverse event (see **Figure 2**).

Development of risks during a risk based work process requires definition of some of the following:

- What can happen? Consider the initiating and cascading events, contributing factors, and outcomes
- What are the consequences? Quantify the HSE and economic consequences
- What is the likelihood, or probability of failure?

A risk matrix is required to provide structure to the evaluation. BechtRBWS software imports any conventionally designed risk matrix (see **Figure 3**).

BechtRBWS includes a risk calculator, which is based on the site's risk matrix and risk definitions, so that the cross-functional team can estimate business and HSE risk levels. In calculating risk, the probability and consequence categories are combined and unmitigated and mitigated risk levels are displayed. Both economic and HSE risks are used.

The benefit to cost ratio (BCR) is the benefit of mitigation (reduction in business risk) divided by the cost of the task. The cross-functional team uses the BCR along with other considerations (unmitigated HSE risk, cost of action item, bad actor resolution, and so on) to decide whether the task is within scope based on previously developed task acceptance criteria. The group should clearly document a justification for the decision. Ultimately the important considerations from a risk perspective are:

- HSE risks are mitigated to achieve acceptable risk levels
- Business risks are mitigated based on ROI, or BCR

Consequence evaluation

Becht has an in-house methodology to determine consequence for loss of containment incidents. An automated tool which considers fluid properties (flammability, toxicity and vapour cloud potential), pressure, and size of expected leak are taken into account to determine the consequence category in accordance with the user's consequence category definitions.

Economic consequences are used in calculating the BCR for discretionary work list items. The possibility of lost profit resulting from a slowdown or shutdown is provided for this calculation.

When determining the number of days for a shutdown or slowdown, it is important to consider how much time is needed for operations to isolate and decontaminate the equipment for maintenance, inspection to determine repair scope, days of maintenance to conduct repairs, any special considerations for the equipment such as post-weld heat treatment of weld repairs, and the time it takes to return the equipment to service. As an example, depending on geographical location, complexity of the unit, and equipment considerations, a typical outage duration for a drum is 7-10 days, whereas a tower could need 14-21 days, depending on size.

Outcomes and case studies

An RBWS assessment for a major turnaround (>500 000 man-hours) is likely to take as much as two weeks, provided the front end planning

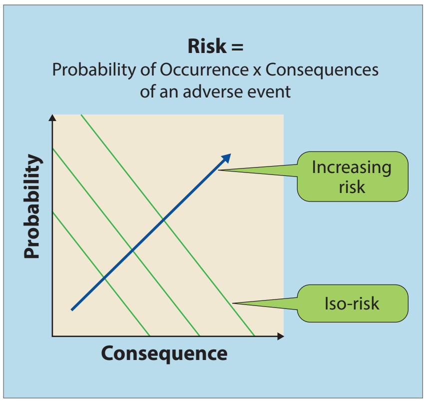


Figure 2 Risk basics

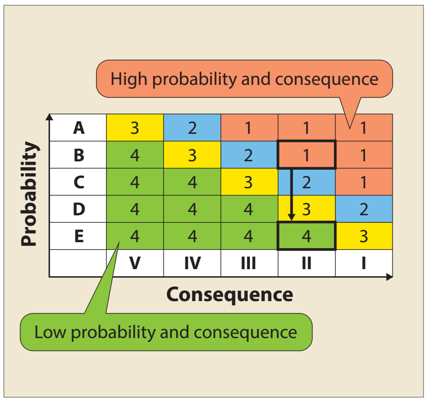
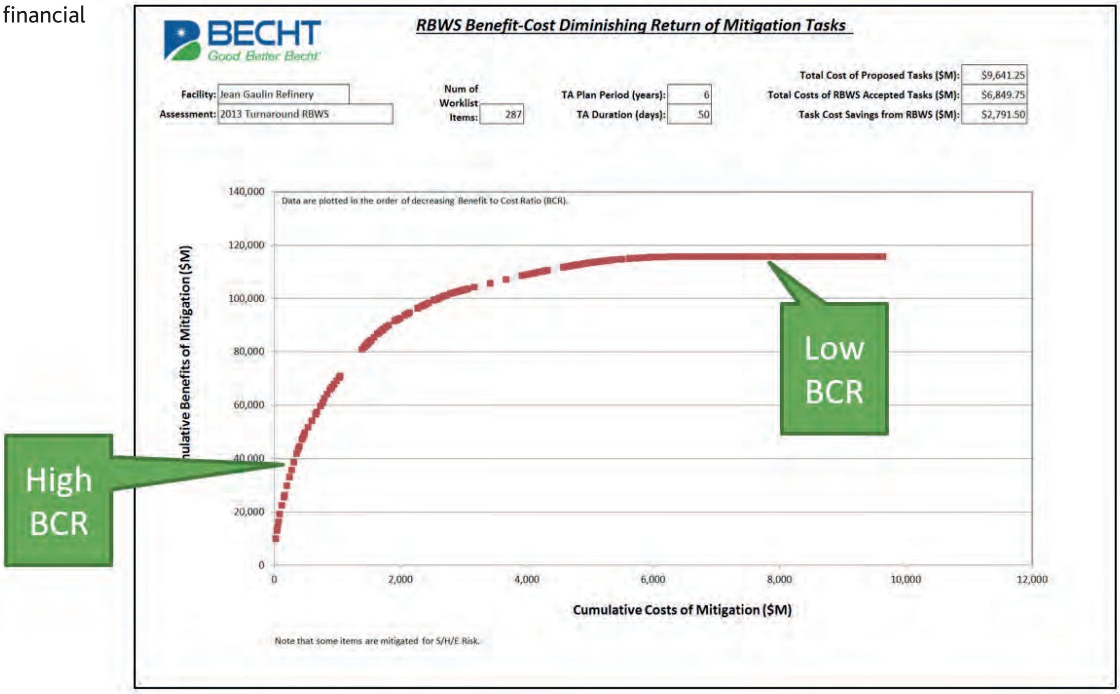


Figure 3 Sample conventional risk matrix

Figure 4 Cumulative financial benefit-cost curve



Sample RBWS results		
	# Items	$ Value
In-scope	156	12 086 000
Out of scope	158	12 715 000
Pending	13	1 541 000
Total reviewed	327	26 342 000

Table 2

and prescreening are effectively completed and the items on the work list are of the required quality. **Table 2** shows sample results from a recent RBWS.

The results in **Table 2** are from a one-week RBWS where the list was pre-screened by the site. The first step is determining if the work can be executed on the run with little or no impact to production. Items that can be executed on the run can then be prioritised by routine maintenance for execution. One of the main drivers to execute work outside the turnaround is reduced cost. Experience in industry indicates that routine maintenance work is at least half the cost of turnaround work and, depending on site specifics, can be as high as four times the cost.

At this particular site, frequent inspections had been done in the past, providing the opportunity to reduce turnaround activities without accepting substantial risks. We also identified that there was significant potential for discovery work in one of the units due to several process upsets over the last run.

At the same time, the RBWS process allows the team, guided by the facilitator, to consider lower cost actions if the proposed task is not justified but risk mitigation is warranted. Sleeper risks can be identified as an organic outcome of the discussion process.

Figure 4 plots the work list tasks in order of decreasing BCR and illustrates the diminishing return nature of risk mitigation. This automated output from the RBWS work process allows plant managers to conserve maintenance resources and minimise risk by targeting the high return work list items (corresponding to the left side of the figure).

Note: this figure does not consider HSE risk drivers, which are considered independently

Conclusion

Becht's RBWS method is a systematic approach to screen turnaround work lists. The process is facilitated by turnaround and reliability specialists who have decades of experience in execution of RBWS and turnaround planning.

RBWS uses risk to screen individual worklist items to ensure that they are justified by either HSE risk reduction or financial benefit to cost analysis. Significant reductions in turnaround workscope typically result from this structured work process. At the same time, additional benefits such as identification of 'sleeper' risks, minimisation of discovery work, and alignment of the cross-functional teams on a consistent approach for turnaround worklist development are realised through the BechtRBWS process.

Eileen Chant is a Mechanical Engineer with over 20 years' experience in the energy industry. She has been with Becht Engineering for 13 years and manages execution of projects in the area of ASME design code compliance, fitness for service and risk based processes, and serves on the Materials Technology Institute's board of directors. She holds a BS from Rensselaer Polytechnic Institute, and MS and PhD degrees from Georgia Institute of Technology.

Abby King is Manager of Becht Reliability Services, focusing on turnarounds and reliability initiatives. He has developed risk based work processes and tools and has led teams in the development of tens of thousands of risk based reliability plans. He graduated from Carnegie Mellon University with a mechanical engineering degree.

Revamping an integrated hydrocracker and lube base oil unit

Process and catalytic advances enabled large-scale expansion of an integrated unit to increase fuels and base oil production

SANJEEV GANGURDE and SUBHASIS BHATTACHARYA
Chevron Lummus Global and Advanced Refining Technologies

A refinery located in South East Asia embarked on a challenging expansion plan in early 2019. This comparatively complex refinery processes local crude along with a large diet of Middle Eastern crudes. After the crude is fractionated into various boiling cut points, a network of complex process units is employed to make valuable fuels, chemicals, and lubricant base oil products.

At the heart of its relatively large capacity, the refinery operates a high conversion hydrocracker integrated with a lubricant base oil unit utilising Isocracking, Isodewaxing, and Isofinishing technologies from Chevron Lummus Global (CLG). The hydrocracking unit operates in two stage recycle (TSREC) configuration to achieve upwards of 80% conversion of straight-run vacuum gasoil to produce Euro-VI quality distillate products. The unconverted oil (UCO) mainly feeds the base oil unit to produce API Group II and III lubricant oil base stocks (LOBS), and the balance is used as feed to the FCC unit.

Over its 15 years of operation, the hydrocracking unit has seen minor modifications, mainly to accommodate feed blend changes. In 2019, the mandate from the refinery was to revamp the integrated HCU-LOBS unit to process 150% fresh VGO feed to enhance lube base oil throughput, along with additional UCO production to be used as a petrochemical feedstock. CLG carried out a revamp design to achieve this objective with minimum changes to the existing assets, keeping in mind to implement the modification recommendations within a regular plant turnaround period.

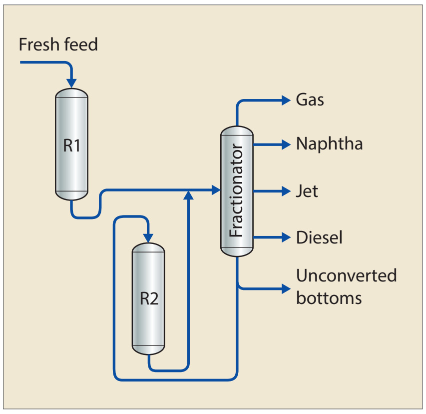


Figure 1 Schematic of TSREC process

The continued safety and reliability of the unit guided this revamp design. An extensive audit was carried out to evaluate the suitability of materials of construction for the unit under revamp conditions by materials experts from the owner and technology provider. The capacity of the LOBS unit increased to 170% of the original design. This revamp project design included a new food grade white oil unit. An innovative process and latest generation catalyst technology were employed to achieve the revamp discussed in this article.

Background

Over the years, the refinery's capacity has been augmented to process about 250 000 b/d of crude oil through progressive revamps. Notable among these was the implementation of the hydrocracking project at the turn of this century to further boost the versatility of the refinery to process a wide range of crude oils while making high quality fuel products. After a rigorous technology evaluation process, the TSREC process licensed by Chevron Lummus Global was selected for a 40 000 b/d hydrocracking unit. **Figure 1** shows a simple schematic of the process.

The first stage reactor is designed for deep hydrotreating to eliminate most of the heteroatomic contaminants and to achieve an optimum level of conversion with some aromatic saturation. The first stage products are distilled off in intermediate distillation, and a certain fraction of the unconverted oil is recycled to a clean second stage for further conversion to desired high quality distillate products. This process separates catalyst functions in the first stage and the second stage for maximum effectiveness. The clean second stage operates in recycle mode at a much lower temperature to achieve target per-pass conversion. As a result, the TSREC process requires an overall lower reactor or catalyst volume, resulting in the lowest cost hydrocracker for relatively high capacity plants (see **Figure 2**).

During the detailed engineering phase of project implementation of the hydrocracking unit, the refiner decided to build a LOBS manufacturing unit utilising Isodewaxing and Isofinishing technology. This integrated unit was designed to process unconverted oil from the hydrocracking unit as feedstock to produce premium base oil grades.

CLG has licensed both grassroots designs and revamps of several commercial integrated hydrocracking and Isodewaxing/Isofinishing units. In these integrated units, the services of some of

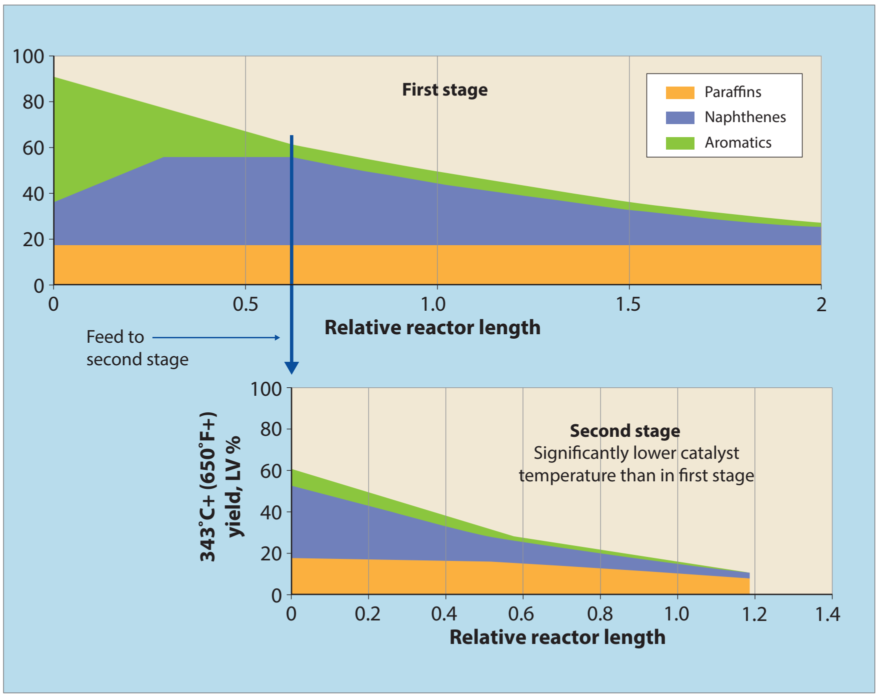


Figure 2 The TSREC process requires overall lower reactor/catalyst volume

the high pressure equipment, like the make-up hydrogen compressor, recycle gas compressor, and associated equipment in the hydrocracking unit, are combined with those required in the Isodewaxing/Isofinishing unit. As a result, the overall investment cost of the integrated unit is reduced, with lower combined energy consumption when compared to two standalone units.

Figure 3 shows a schematic of such an integrated unit. The unconverted oil is fractionated in the feed preparation unit (FPU) into various waxy cuts based on the desired viscosity grades of final base oil products, namely API group II 65N, 100N, 150N, and 500N. These waxy cuts are stored and then processed in the LOBS unit in block mode of operation. This unit has the capability to produce API Group III 250N base oil products as well.

The latest revamp

One factor that remained constant for this refinery, especially with the integrated hydroprocessing unit at the centre, was change, be it with optimum utilisation of hydraulic capacity by processing incremental quantities of straight-run distillates, or routing several secondary streams from the refinery through this unit. However, the innate strength of this TSREC hydrocracking configuration was sustained with the production of premium middle distillate and lube base oil grades. A few significant revamps were undertaken when, as a result of compliance projects to build dedicated distillate hydrotreating units, additional VGO processing potential emerged in the hydrocracking unit. Current operational best practices from the refiner and CLG were applied, but none of these improvements over the years would compare to the magnitude of the next revamp project.

Salient features of the latest revamp project were:
- Debottleneck the hydrocracking unit to process 50% additional fresh VGO feed
- Generate more UCO while maintaining the distillate production at last revamp level
- 170% expansion of the LOBS unit's UCO processing capability
- 20 000 b/d of additional UCO generated as feedstock for a new petrochemical complex while continuing to cater to the FCC unit's feed requirement
- A new 4500 b/d nominal capacity white oil unit

Hydrocracking unit revamp design was carried out for a total of 64 000 b/d of fresh VGO feed that was 50% higher than the design fresh feed rate to the hydrocracker in TSREC mode. As **Figure 4** shows, CLG's catalyst system and process technology were employed in this revamp design to process fresh VGO feed in both the first stage and second stage of the hydrocracker. The hydraulic capacities of the reactor stages were fully utilised at an optimum overall conversion to continue to make Euro-VI quality distillate fuel products and upgraded UCO as premium base oil feedstock. The refiner decided to revamp the FPU and the LOBS unit to process additional UCO. Most of the medium and higher viscosity draws from the FPU are utilised as feedstock for the desired base oil grades at the revamped 170% feed capacity of the LOBS unit, and the balance is split between FCC unit feed and feedstock for a new petrochemical complex.

After collecting the required waxy lube base oil cuts, a blend of various waxy side-cuts that are lighter than waxy 500N draw but heavier than diesel is prepared. Based on the specific gravity, distillation, and other characteristics, this blended stream is considered an excellent feedstock for the steam cracker. A quick estimate using the SRT-VII heater from Lummus Technology indicates an ethylene yield of 32 wt% and a propylene yield of 14 wt% for this feed, with less than 9 wt% pyrolysis fuel

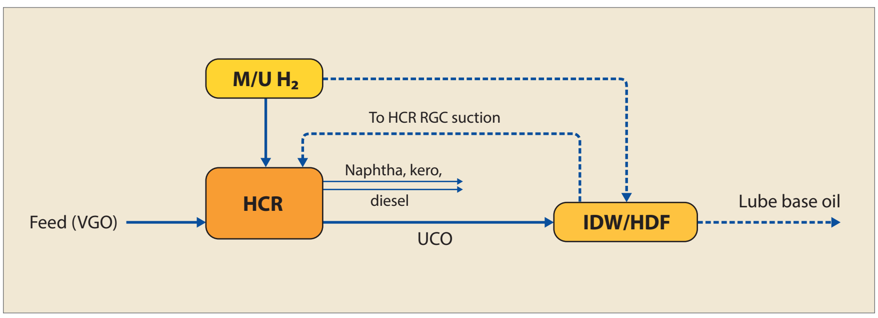


Figure 3 Schematic of an integrated HCU-LOBS unit

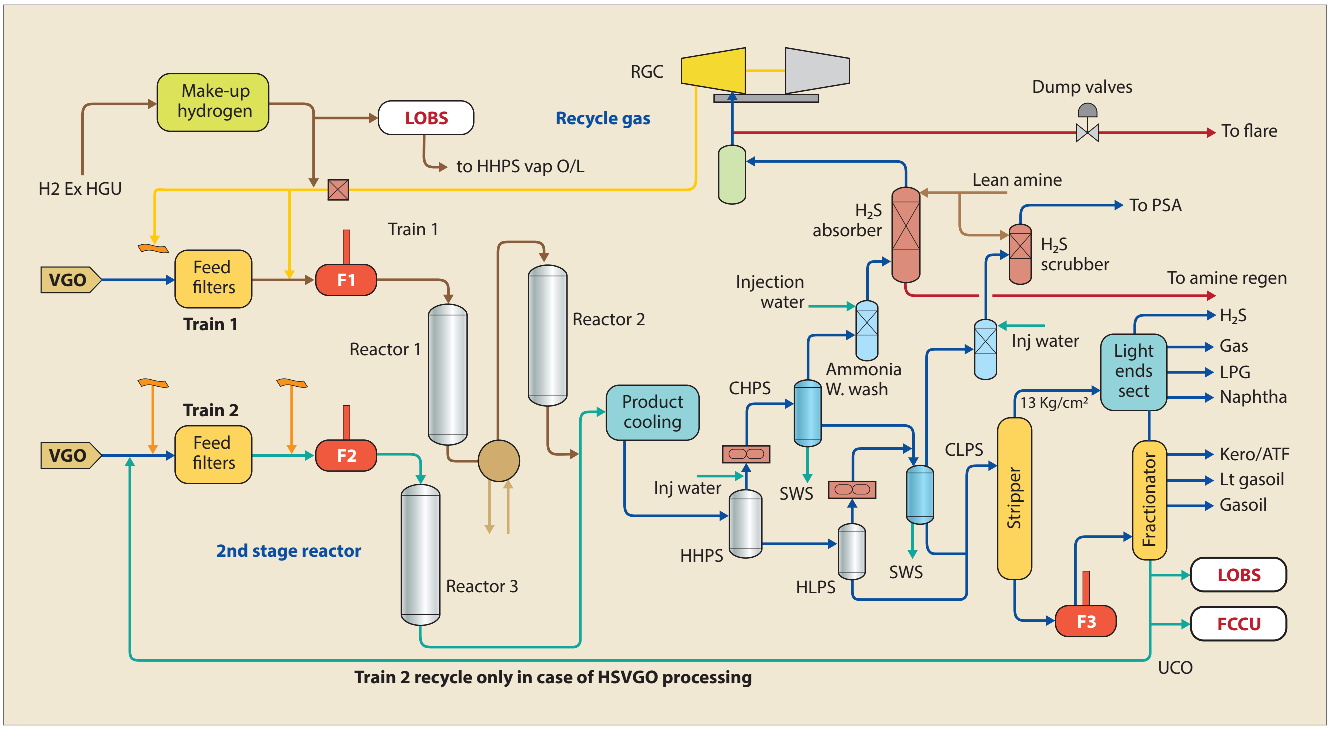


Figure 4 CLG's Process Technology 150% hydrocracker revamp design

oil. The balance UCO fulfills the FCC unit's feed requirement.

The main challenge in processing fresh, high sulphur VGO feed in the second stage reactor was managing higher exotherm from more reactive feed components compared to processing clean UCO in TSREC mode. A combination of appropriate activity grading of the catalyst system and liquid quench mechanism was applied to maintain a healthy temperature profile in the second stage reactor while operating in once-through mode.

Sour service in the repurposed second stage reactor system warranted a thorough review and adequacy checks for the material of construction in the hydrocracker. A team from the refiner and CLG studied the maintenance and inspection records of the hydrocracker. Based on this, CLG prepared a material recommendation for the revamp. Three factors formed the backbone to these recommendations:

- Changes arising as a result of new sour service in the second stage under the revamp conditions
- Application of latest API guidelines
- Implications from existing corrosion rates in the unit

Individual piping loops and equipment in each section were reviewed to check the safety and reliability of the unit. All aspects, including and not limited to the resistance to high temperature hydrogen attack, H_2-H_2S corrosion, wet H_2S cracking/sulphide stress cracking, ammonium bisulphide corrosion, and so on, were evaluated. Modifications were mainly found to be needed in the second stage reactor effluent section, where the metallurgy needed upgrading.

The LOBS unit was initially designed for a nominal capacity of 6200 b/d using CLG's Isodewaxing and Isofinishing process scheme to produce premium lubricating base oils in a single, once-through operation with two reactors in series. The first reactor isomerises most of the normal paraffins (waxes) in the waxy UCO feed cut to iso-paraffins and lowers the pour point. Others are cracked to highly saturated lighter products such as high smoke point jet and high cetane index diesel. The second reactor saturates the remaining mono- and polyaromatics, and increases the oxidation stability, thermal stability, UV stability, and colour stability of the base oil product. The unit was designed to process waxy UCO cuts based on the desired viscosity grades, in block mode operation to maximise base oil yields and to avoid over-dewaxing the lighter product to achieve the heavier lube base oil pour point.

With incremental UCO availability from hydrocracker capacity expansion, the refiner decided to enhance the LOBS unit capacity and widen the product portfolio to include high quality specialty solvents and white oils. CLG carried out extensive process study and pilot plant testing. It was concluded that the feed capacity of the LOBS unit could be revamped to 170% of the original nominal capacity by employing CLG's latest Isodewaxing and Isofinishing catalyst system under a newly designed, optimum reactor operating condition. Further testing demonstrated the stability of the catalyst system under new and challenging conditions with a projected catalyst life of more than five years at 170% feed capacity of the LOBS unit. The entire range of API Group II base oils, including 65N, 100N, 150N, and 500N, will be produced at the revamped capacity. This unit has the capability to produce API Group III 150N and 250N base oil products as well.

CLG was awarded a contract for the licence and design of the hydrocracker and the LOBS unit for

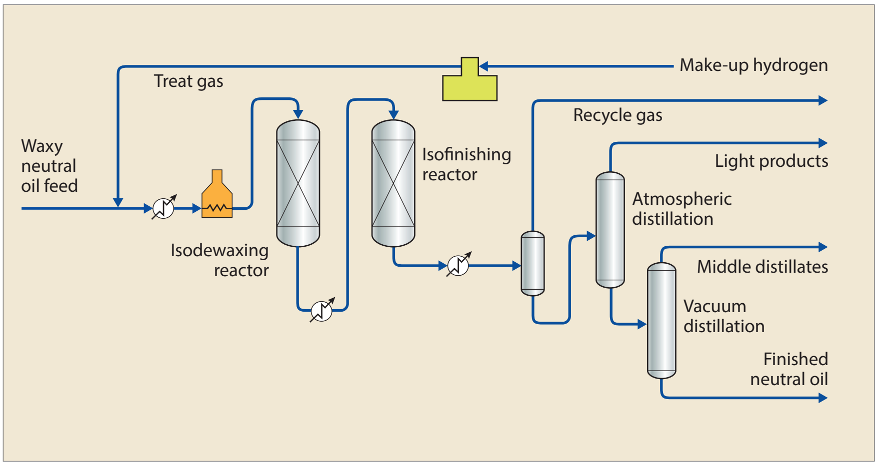


Figure 5 CLG's Isodewaxing and Isofinishing process scheme with once-through hydrogen from the hydrocracker

enhanced capacities. The new white oil plant will use CLG's Isofinishing technology to produce high quality specialty solvents and food grade white oils. The scope of work also included the supply of catalysts and Isomix-e reactor internals. The basic engineering design of the LOBS unit revamp has been completed, and the project is in the advanced detail engineering phase.

Dearomatised solvent and white oil production

The refiner has been making certain grades of dearomatised solvent (DAS) and white oil in the LOBS unit by adjusting reactor operating parameters with continued technical service provided by CLG. Certain specialty white oil grades with stringent aromatic specifications were also produced by reprocessing some of the low viscosity base oil grades. The LOBS unit has also produced drilling fluid in response to market demand.

The refiner recognised the potential market for white oils and dearomatised solvents in the region and their price margins over regular base oils. White oil units are smaller in capacity and more commonly range from 30-50% of the upstream LBO unit capacity. Accordingly, the refiner decided to build a dedicated white oil unit with the objective of running the LOBS unit at full revamp capacity to maximise lube base oil production. Some of the requirements for white oil quality, like good fluidity at low temperatures and water white colour, are achieved in the LOBS unit at revamp capacity.

A new white oil unit was designed using Isofinishing technology to produce food grade white oils corresponding to the entire base oil viscosity range from the LOBS unit. This food grade white oils unit will process LOBS unit products from tankage in a block mode of operation. Almost 100% of the feed to the unit is converted into food grade white oils product with near-complete aromatic saturation at selective hydrogen consumption. The key properties of the products from the unit are shown in **Table 1**. Depending on the viscosity grade application, the products from this unit will meet United States Food and Drug Administration regulations for white mineral oil and lubricants for machinery in the food industry. These products will also comply with United States Department of Agriculture requirements and United States Pharmacopoeia Standards.

Notwithstanding the prospect of significant value addition with the new white oil project, the challenge was to locate a suitable plot to build this unit adjacent to the hydroprocessing complex

The food grade white oils unit will also produce D series dearomatised solvent using superior light distillate products from the hydrocracker. Carefully designed blends of distillate products from the hydrocracker fractionator form the feedstock for these specialty products that have strict initial boiling point, final boiling point, and flash point specifications. Other key properties are shown in **Table 2**.

Notwithstanding the prospect of significant value addition with the new white oil project, the challenge

Key food grade white oil specification for different viscosity ranges		
Viscosity, cSt @ 100°C	ASTM D445	2.5-12.0
SUS @ 100°F	ASTM D2161	60-550
Pour point, °C	ASTM D5950	<-15
Colour, Saybolt	ASTM D156	+30
Readily carbonisable substance test	ASTM D565	Pass
UV absorbance on DMSO extract in 260-420 nm	ASTM D2269	<0.1

Table 1

Key D series dearomatised solvent specification		
Bromine index (mg Br/100 g)	ASTM D1492	<5
Sulphur, wtppm	ASTM D4045	<2
Aromatic hydrocarbons, %	HPLC	<0.1

Table 2

was to locate a suitable plot space to build this unit adjacent to the compact layout of the hydroprocessing complex. However, CLG was able to design the new white oil unit without adding a new furnace. This was made possible by employing the latest Isofinishing catalyst that allowed optimum performance at a lower temperature. As a result, the process enabled the use of high pressure steam as a heating medium to provide the required reactor inlet temperature for the entire cycle length of the catalyst. Without the constraints of positioning a new furnace at a specific location, the simplified white oil unit could be located within the plot space of the LOBS unit. Much of the equipment that needed to be replaced in the LOBS unit revamp design was utilised in the new white oil unit. The total estimated cost of the new white oil unit was substantially reduced.

Conclusion

Technical services over a decade helped a refiner in South East Asia to upgrade a hydrocracker-LOBS complex with the latest process and catalytic advances from CLG that culminated in a 150% expansion of the hydrocracker and 170% expansion of the LOBS unit to enhance fuels and premier base oil production.

A new white oil unit design was also prepared that would complete the whole spectrum of fuels, base oil, and white oil products from the hydroprocessing complex. The revamped design is currently at the EPC phase. The estimated cost of implementation of this revamp is $130 million with payback in less than 30 months. During the turnaround early in 2020, CLG's latest Isodewaxing and Isofinishing catalyst system was loaded into the LOBS unit. Since then, the unit has operated close to the revamp capacity with on-specification lubricant base oil yields exceeding all previous records.

ISOCRACKING, ISODEWAXING, ISOFINISHING, and ISOMIX-e are marks of Chevron Lummus Global.

References

1 Bridge A, Cash D, Mayer J, COGELS – Unique Family of ISOCRACKING Catalysts, 1993 NPRA Annual Meeting.

2 Rogers J, Bhattacharya S, Lei G, Krishna K, Catalysts for better base oils, Lubes 'n' Greases (Europe - Middle East - Africa), July/Aug 2010.

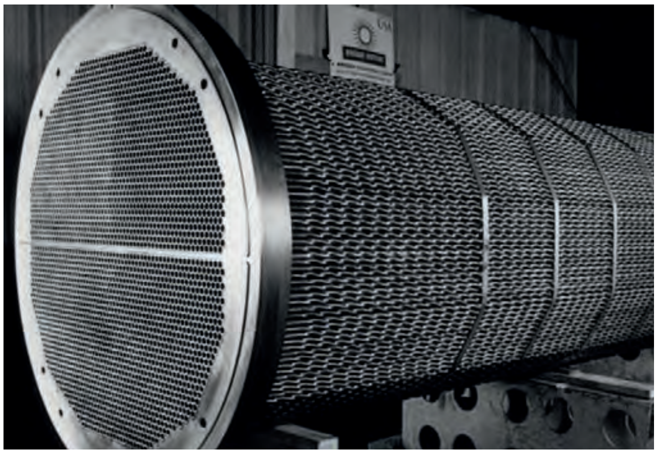
3 Parekh J, Repurposing existing hydro-processing assets to maximize refinery gross.

4 Margin, AFPM, Spring 2017.

5 Bhattacharya S, Lei G, Shiflett W, Maximising crude value in base oil production, *PTQ*, 2019.

Subhasis Bhattacharya is Global Technology Manager – Base Oils with ART & CLG, Richmond, California. With 31 years' experience in process design and technology development, he holds an MSChE from Indian Institute of Technology, Kanpur. *Email: SBhattacharya@chevron.com*

Sanjeev Gangurde is Technical Service Manager – Hydrocrackers and Base Oils with ART & CLG, Mumbai, India. With 30 years' experience in technical services and operations for hydroprocessing units, he holds a BChem from the University Department of Chemical Technology, Mumbai. *Email: sanjeev@chevron.com*



Feeling a pinch in your process?

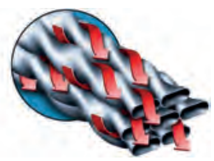
Open it up with
TWISTED TUBE®
Heat Exchanger Technology!

Common applications include:
- Crude preheat exchangers
- Overhead condensers
- Reboilers
- Feed / Effluent exchangers in:
  - Hydrocracking
  - Hydrotreating (diesel or naptha)
  - Reforming

The drop-in solution for increased flows, greater heat recovery and reduced pressure drops. **TWISTED TUBE® Heat Exchanger Technology** is your solution for enhancing the performance of your shell & tube heat exchangers.

Tube-side flow

Shell-side flow



BROWN FINTUBE® INNOVATORS IN HEAT TRANSFER

KOCH™ HEAT TRANSFER

kochheattransfer.com

For related trademark information, visit kochheattransfer.com/trademarks.
© 2020 Koch Heat Transfer Company. All rights reserved.

A KOCH ENGINEERED SOLUTIONS COMPANY

Alphabetical list of advertisers

Register to receive your regular copy of *PTQ* at www.eptq.com/register

NOW FULLY RESPONSIVE

digitalrefining.com is the most extensive source of freely available information on all aspects of the refining, gas and petrochemical processing industries.

It provides a constantly growing database of technical articles, company literature, videos, industry news and events.

ENGINEERING EXCELLENCE FOR THE HIGHEST AVAILABILITY

Burckhardt Compression offers a complete portfolio of Process Gas Compressors ranging from bare shaft compressors to turnkey solutions. Our dedicated refinery expert team is able to give excellent FEED engineering support and offers outstanding project management and engineering expertise. In addition, we offer comprehensive in-house electrical engineering services, including instrumentation, control & monitoring.
Learn more: burckhardtcompression.com/refinery

Compressors for a Lifetime™

Burckhardt Compression

Through multi-specialist integrated offers, we deliver ever more inventive and sustainable solutions to our industrial clients, always aiming at preserving the planet. www.axens.net

Axens
Powering integrated solutions