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ResidHydroTreat 2017
International Symposium on Residue Hydrotreating

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KNPC

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Editor’s Note

Khuloud Al-Mutairi
Corporate Communication Manager

We dedicate the second issue of KNPC TECH for the ResidHydroTreat 2017 Symposium. This is the first time such an international level event was held in Kuwait that deals with a very important aspect of refining.

KNPC, in cooperation with Kuwait Integrated Petrochemical Industries Company (KIPIC), organized the Symposium.

The event came at a critical time for the refining industry. The more stringent environmental conditions being applied all over the world, combined with the oil market fluctuations, are pushing down the profit margins. Refiners are forced to find new solutions, and one major option is to move to full conversion of residues and heavy crude. This part was the main concern of the Symposium.

We are moving ahead with our Clean Fuel Project as well as KIPIC’s Al-Zour Refinery Project. The two projects will boost Kuwait capability to produce cleaner fuel and process heavy crude. This comes in line with KPC strategy to increase Kuwait production capacity of heavy crude. At a later stage, we are moving to maximize our capacity to full conversion of low-value heavy oil into high-value products.

The presentations, work-papers and discussions were prominent enough to push us to publish excerpts of what has been covered at the Symposium in order to disseminate the contents as wide as possible.

Due to limited space, we only published abstracts of the presentations. The full versions can be seen at the site indicated in the previous page.

The KNPC TECH will continue to be a source of important technical knowledge and refining information.

Atmospheric Residue Desulfurization Unit at MAA

Kuwait's First ResidHydroTreat 2017 Symposium

Kuwait played host to ResiHydroTreat 2017 Symposium. Sponsored by the Minister of Oil and Minister of Electricity & Water, the event took place on November 6th, 2017 to signify an important milestone in the long history of Kuwait refining industry.

It could not have been a better time to hold this first of its type Symposium in Kuwait. CEOs, top experts and officials from the world's oil majors spoke in the Symposium about the new refining technologies, how to produce cleaner fuel and how to be financially efficient.

During the 3-day event, various topics were covered. Trends in hydro treating, catalyst improvements, advances in residue processing technologies, best practices in operation and unit monitoring, feedstock and catalyst management.

Changing lanscape

"The refining industry is witnessing yet another paradigm shift in the markets with the recommendations of the Prevention of Pollution from Ships Convention (MARPOL) on bunker sulfur content and changes in energy demand, economic growth and new challenges like electric vehicles", KPC CEO Nizar Al-Adsani said to inaugurate the Symposium. His speech was titled "Paradigm shift in refining industry and refiners need to act fast".

"The marine fuel landscape is changing dramatically with the decision of the International Maritime Organization (IMO) to reduce the sulfur content in marine fuel used on the open seas from 3.5% to 0.5% by weight, which is likely to be in effect by 2020. These limits will present a challenge for refiners to decide what to do with the high-sulfur residual oil that can no longer be blended into bunker fuel".

Al-Adsani said that the Refineries need to act fast and make investment decisions on residue treating to cope with ever tightening legislative-environmental regulations for the industry.

"I am sure you will all agree, there is an urgent need to make residue processing technologically robust, economical and more environment-friendly," he concluded.

Future uncertainty

With the increasing inconsistencies in the world oil industry changing oil prices, fierce competition, low refining margins and tougher environmental stipulations, new concepts are emerging to cope with ever-escalating challenges.

The IMO mandate to limit the bunker fuel sulfur content will have drastic impact on the refining industry and mounting pressure on refiners plans and budgets.

With higher rate of cleaner products, better profit margin and flexibility in treating heavy and low-quality cheap crude oil to more valuable products, hydro-processing is being resorted to as the most suitable response for the hard challenges.

As well, metals and other contaminants will be removed, allowing a maximum production of various products which can be used as a feed stock for downstream conversion processing.

KNPC ARDS experience

Since the 1970s, KNPC has resorted to Atmospheric Residue Desulfurization (ARDs). With further expansion with ARD capability through the Clean Fuel Project (CFP), the conversion rate will be higher. The-state-of-the-art technologies in ARDS, catalysts and other performance-enhancing processes will be used. The conversion rate will also be even greater with Al-Zour (ZOR) Refinery project which will have the world's largest ARDs complex with total capacity of 330,000 bpd. In line with KPC strategy in increasing Kuwait heavy crude oil (KHC) production capacity, the ZOR Refinery will be able to process KHC, and residue even as low as 10.5 API, hence better benefit for Kuwait. With the problems of high sulfur content in Kuwait crudes solved ZOR Refinery will supply Kuwait power plants with LSFO, with much less environment impact.

The new clean petroleum products will also be used as a feedstock for petrochemical industry as part of the integration with refining.

At the Symposium final day, guests had the chance to have a closer look at CFP, Kuwait's largest project ever. They toured the Green Field at Mina Abdullah Refinery, and had a fair idea about capabilities, technical specifications and technologies used.

The project is expected to catapult Kuwait refining industry into a new international level with its clean product and international environment requirements. It will open new markets in Europe, USA and other strict countries.

Following the outstanding success of the Symposium, it was decided to hold Kuwait "Second ResidHydroTreat Symposium." We expect a similar success.

Message from the CEO Mohammad G. Al-Mutairi

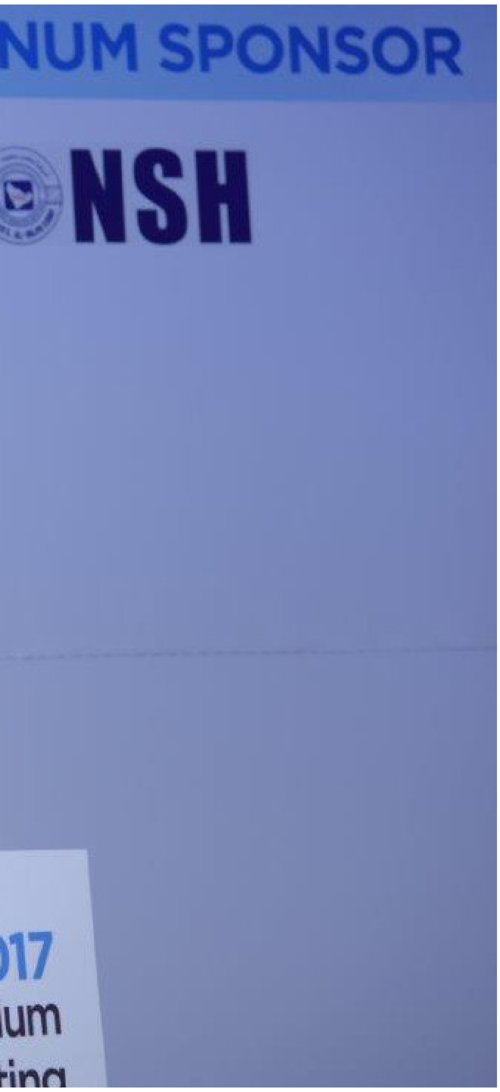
Kuwait to become one of the world's biggest hubs of Residue-Hydrotreating

The "ResidHydroTreat 2017," has been the first ever international Residue Hydrotreating Symposium being held in Kuwait. It was hosted by KNPC, with support from KIPIC.

KNPC has been operating Atmospheric Residue Hydrotreating in its Refineries for more than 30 years. With the completion of KNPC's CFP Project and KIPIC's ZOR Refinery Project, Kuwait Atmospheric Residue Desulfurization (ARD) capacity will reach an impressive 758,000 bpd from current 228,000 bpd. Thus, Kuwait is on its way to become one of the world's biggest hubs of Residue Hydrotreating. This will enable us to produce cleaner fuel that observe the world's stiffening specifications.

Though Residue Hydrotreating has been in use for several decades, the technology has been slow to adapt, with only incremental advances in catalyst cycle lengths and product qualities.

There is an increasing need of building capabilities for quicker and reliable catalyst evaluation techniques to identify the right recipes of the catalyst systems particularly beneficial to the ARD units, which in the future are likely to treat more



difficult residues from the heavier crudes.

Refiners need to boost capabilities for full conversion and extract all available value from the whole barrel. Those who are able to convert very heavy and high-sulfur crude to light products face prosperous years and will be the biggest winners.

ARDS process plays an important role in upgrading the cheap heavy petroleum oil and residues to cleaner and more valuable environment friendly transportation fuel, and to partially convert the residues to produce low-sulfur fuel oil and hydrotreated feedstocks. Kuwait's refining sector has extensive experience in operating ARDS units for over 30 years; and with completion of ongoing projects, will be the largest user of ARDS process in the world. ARDS has a key role in achieving our Vision & Mission.

The refiners are facing increasing challenges. The fluctuating crude oil prices, low profit margins and growing competition force the refiners to find better solutions.

As well, the marine fuel landscape has changed dramatically. The recent decision of the International Maritime Organization (IMO) to reduce the sulfur content in marine fuel used in the open seas from 3.5% by weight to 0.5% will be in effect by 2020. These limits will push the refiners to decide what to do with the high-sulfur residual oil that can no longer be blended into bunker fuel and Refineries need to act fast and make investment decisions.

The Symposium gave us a chance to discuss:

- How the industry is geared up for adding new capacities in residue hydrotreating,
- Challenges faced with current technologies,
- Catalyst and technology breakthroughs for cost effective residue treating,
- Best practices in operations and troubleshooting, and future trends

Collaborative efforts with Refineries are encouraged with support from licensors / catalyst vendors.

ResidHydroTreat-2017 facilitated the coming together of end-users, licensors, catalyst suppliers and contractors to discuss and share best practices, latest developments and provided a platform to address future trends in residue processing.

Our thanks go to the sponsors of ResidHydroTreat 2017:

- Kuwait Petroleum Corporation
- Honeywell UOP
- ART and CLG
- Kuwait Catalyst Company
- Criterion and Shell Global Solutions
- Nasser S. Al Hajri Corporation
- Axens
- ExxonMobil

Kuwait's Residue Hydrotreating Journey

Nadia Al-Hajji
DCEO Petrochemicals & Liquefied Gas
KIPIC

Heavier crudes have more Atmospheric Residue (sulfur, metals, asphaltene) compared to lighter crudes, making them difficult candidates for handling/processing; hence, the need for different refinery configurations. Residue Hydrotreating is used to prepare feed to FCC/RFCC/Coker, and produce better quality fuel oil.

Background

KNPC is responsible for domestic refining & gas processing as well as integrating refining with petrochemicals and LNG Import. The objective is to satisfy the local fuel demands for power generation and transportation, feed to petrochemical plants and supply products for International markets.

Crudes Classification / Characterization

The crude oil is mainly classified to: Light (API > 34), Medium (API 22-34) and Heavy (API <22). Kuwait Export Crude (KEC) has API 30.5.
Heavier crudes have more Atmospheric Residue / Sulfur / Metals / Asphaltenes compared to lighter crudes, making them difficult candidates for handling/processing; hence, the need for different Refinery configurations.

Residue Hydrotreating is used to prepare feed to FCC/RFCC/Coker and to produce better quality fuel oil. The Residue Hydrotreating is becoming more popular due to competition for crude oil supplies, heavier and higher sulfur crudes, declining demand on high sulfur residual fuel oil, demand for low-sulfur fuels/Coke and strong growth in the demand for distillate.

Role of ARDS

ARDS functions include hydrodesulfurization (HDS), Hydrodemetallization (HDM), hydrodenitrogenation (HDN) and CCR removal through hydrogenation (HDCCR). It can be advantageous to operate Residue Hydrotreater for maximum conversion.

Need of ARDS in Kuwait's refining configuration scheme

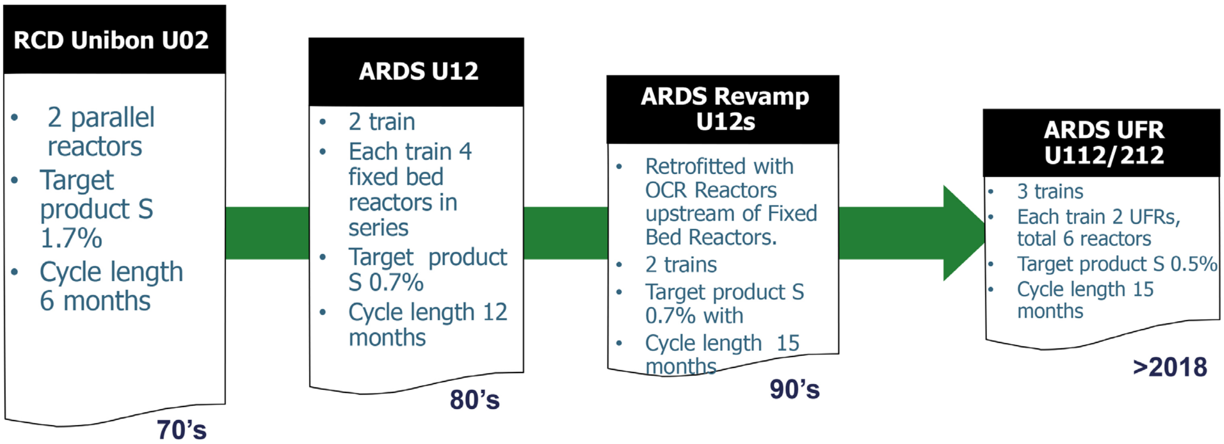
KNPC processing scheme

KNPC processing scheme of ARDS in between crude and vacuum distillation for production of desired feed stock for downstream conversion units:
1. VGO 'S': 0.35 wt%, 'N': 1000 ppm max
2. Target Green Coke Sulfur is 3.0 wt% max
3. ARDS process selected with configuration of 2 ARDS Trains each with 4 Fixed Bed Reactor system

KIPIC processing scheme

KIPIC processing scheme of ARDS downstream of CDUs for production of low sulfur fuel oil for power generation and desired feed stock for future upgrade project.

KNPC Mina Abdulla (MAB) ARDS evolution



RCD main features table

Salient Features	
Feed	HSAR
Feed Filtration	25 Microns
Cycle length	6 months
Reaction Section	2 parallel Rxs
Water injection	U/S and D/S of Rx section

Feed Quality	Typical values
API Gravity	13.0
Sulfur, wt%	4.5
CCR, wt%	10.5
Metals (Ni+ V), ppm	75
Nitrogen, ppm	2500

LSFO Quality	Typical values
Sulfur, wt%	1.6
CCR, wt%	7-9
Metals (Ni+ V), ppm	53
Nitrogen, ppm	1900

Improved business performance

The Company strategy seeks to have processing capacity enhancement with low cost/ minor revamp and debottlenecking upstream & downstream units (CDU/VRU/Coker/HCR). In order to avoid producing excess atmospheric residue fuel oil, major revamp was implemented for ARDS Units at MAB Refinery. The revamp resulted in higher capacity 66 to 84 KBPD (28% increase), longer catalyst run length 11 to 15 months (36% increase), higher distillate yield 5 wt% with LSFO with 0.7% sulfur.

The ARDS revamp was implemented as it plays a vital role for upstream units' onstream efficiency and downstream units' capacity utilization.

Challenges & achievement post ARDS revamp with OCR technology

The challenges included achieving target run length of 30 months for OCR Reactor and target product sulfur of 0.7 wt% throughout the cycle. Depending upon the individual catalyst loaded in ARDS units, metal and sulfur distribution between VGO and VR are changing, resulting in coke quality Issues.

The mitigation was done through the inclusion of sulfur and metal limits in VGO & VR as part of catalyst tender specification, modification of OCR internals and the diversification of catalyst source for ARDS fixed beds. The latter resulted in optimized catalyst selection process, price competitiveness/competitive bidding and improved yields & performance. The diversification of OCR catalyst has only recently been achieved.

KNPC'S Clean Fuel Project (CFP) & Al-Zour Refinery Project (ZOR)

The schemes for the two projects were selected after reviewing 32 refining schemes, ARDS/Coker/HCR conversion for bottom of barrel upgrade.

The main objective of CFP is to upgrade/expand on KNPC's MAB and MAA Refineries into an integrated merchant refining complex that meets the future diversified market requirements while maintaining high Safety and Environmental standards.

Whereas the major objective of ZOR is to produce LSFO with 1% sulfur content in the 1st stage and provide feedstock to conversion units in the 2nd stage. The Hydro-treated residue of FCC is being considered for the twin objectives of propylene feed stock for upcoming petrochemical projects and MOGAS production. Both projects are under implementation with target commissioning dates are 2018 for CFP and 2020 for ZOR.

ARDS Main Features Comparison (FB,OCR,UFR units):

Features	FB	OCR	UFR
Online Catalyst Replacement	NA	Available	NA
No. of Beds	one bed	one bed No bed distributor trays	Three beds Two inter-bed distributor trays
Catalyst Quantity, M3	818 m^3/ train	Total: 1187 m^3/ train OCR: 369 m^3/ reactor (Without weekly replacement)	Total: 1668 m^3/ train UFR: 364 m^3/ reactor
System Pressure, psig	1750	1640	2200

Need of ARDS in Kuwait refining configuration scheme

Without such ARDS scheme, Kuwait Refineries will produce high sulfur fuel oil product, the vacuum rerun units feed stock will be with high sulfur ~ 5 wt% and the Coker units feed stock with 9-10 % sulfur.

Moreover, the associated metallurgical concerns will appear in the downstream units due to high sulfur and temperature. As well, issue of disposal of very high sulfur green coke will also appear.

Without ARDS in Kuwait Refining Configuration Scheme…	➢ High Sulphur product fuel oil ➢ Vacuum rerun units feed stock with high sulfur ~ 5 wt%. ➢ Coker units feed stock with ~9-10 % sulfur. ➢ Associated metallurgical concerns in the downstream units due to high sulphur and temperature ➢ Issue of disposal of very high sulphur green coke

What's next?

With the increasing sulfur in crude and, at the same time, fuel oil sulfur specifications are tightening, then ARDS is key.

ARDS allows processing more difficult cheaper feeds and produce more valuable lower sulfur products. ARDS also prepares feeds for downstream conversion units.

For KNPC MAB Refinery, the ARDS journey continues: The startup of CFP and ZOR ARDS is the next major milestone.

Installation of Reactors at ZOR Project

The Role of Pumparound Contactor in Enhancing the Recycle Gas Purity

Abdullah Mandani – Senior Process Engineer - MAA
Kuwait National Petroleum Company

In order to achieve and maintain the ARDs units' operation efficiently, several best practices are being followed in the day to day unit monitoring activities at MAA ARDs. One of the best practices observed in MAA ARDs is discussed in this article.

Pumparound Contactor (PAC)

Among the KNPC ARDs, the unique Pumparound Contactor (PAC) system is available only at MAA Refinery.

The purpose of Pumparound Contractor is to dissolve methane and other impurities from the recycle gas so that a high hydrogen content recycle gas is available for the reactor system.

Pumparound Contactor system

The Pumparound Contactor is an absorption column with 7 Trays. The Recycle Gas from the High Pressure Cold Separator (V-016) enters from the bottom of the column below Tray #1. The hydrocarbon liquid from the Low Pressure Cold Separator (V-017) enters on the top 7th tray.

The purity of the recycle gas with respect to its H2 content is greatly enhanced in this absorption process.

Process parameters of the Pumparound Contactor

The recycle gas flow to PAC is around 140 Knm3/hr. The liquid hydrocarbon flow is around 110 to 120 m3/hr. The pressure is 120 kg/cm2 and temperature is 45 °C.

The process of the Pumparound Contactor

The working principle of the PAC system will be highlighted with a real-time case study. The effect on the below given major process parameters will be highlighted with trends.

a- Establishment of Pumparound oil flow

The Pumparound oil flow of about 120 m3/hr. is established (Fig. – 2)

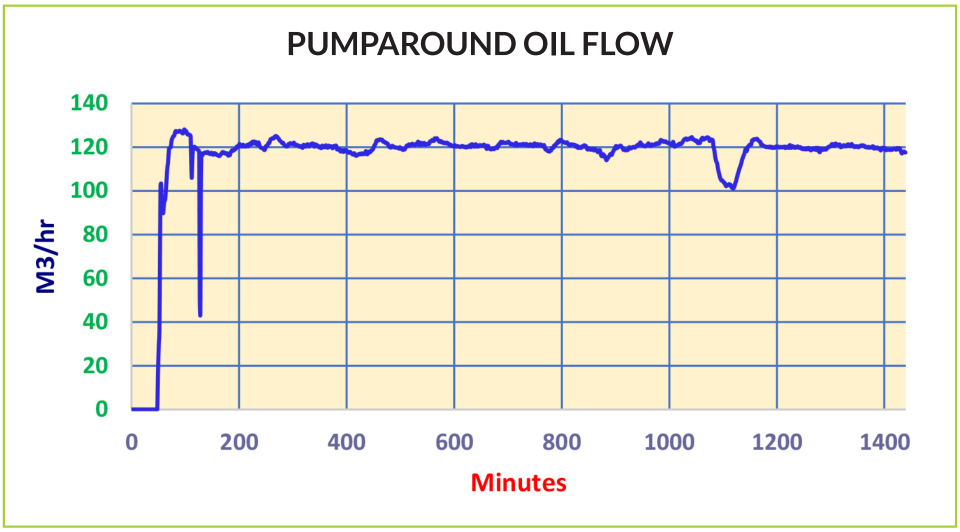


Fig. – 2 Pumparound Flow Established

b- Recycle gas molecular weight

As soon as the Pumparound flow is established the recycle gas molecular weight reduces from about 5.0 to about 4.0. The indicates that the recycle gas has become lighter or that its H2 content has improved (Fig. – 3).

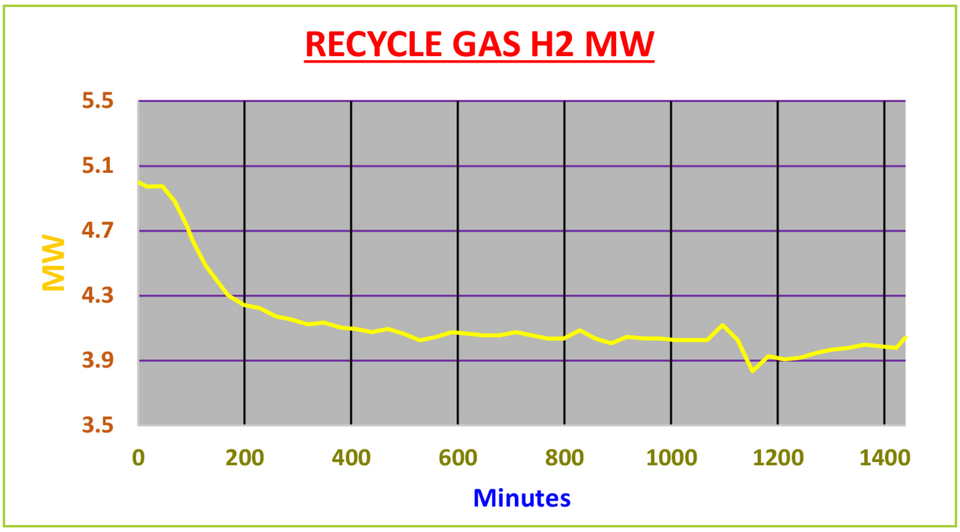


Fig. – 3 Reduction of Recycle Gas Molecular weight

c- Recycle gas H2 purity

A sharp rise in the recycle gas H2 purity is noted. The H2 content of the recycle gas increases from about 80% to about 85% (Fig. - 4) .

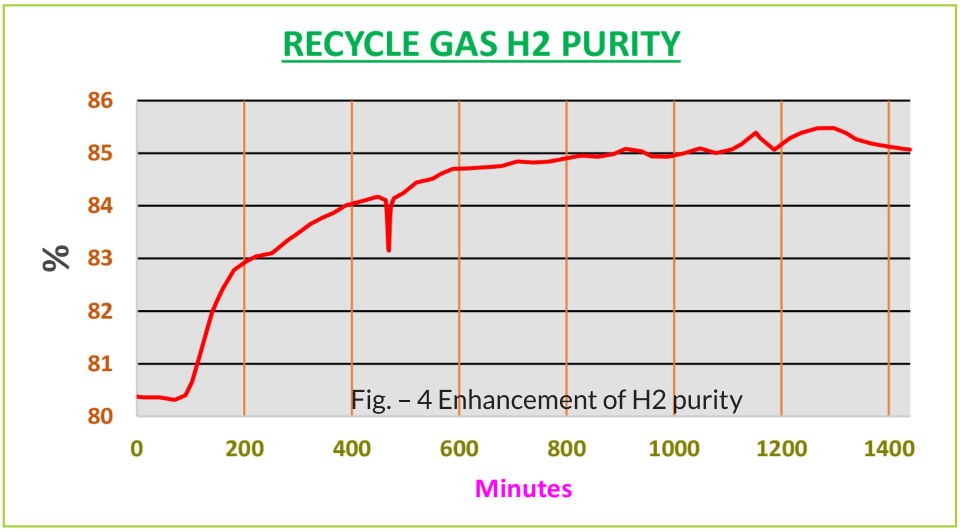


Fig. – 4 Reduction of Recycle Gas Molecular weight

d- Recycle gas flow

The corrected RG flow of about 150 Knm3/hr drops initially and then finally settles slightly above the original flow (Fig. – 5 the yellow trend line). Basically, the RG flow remains same but with a much higher purity.

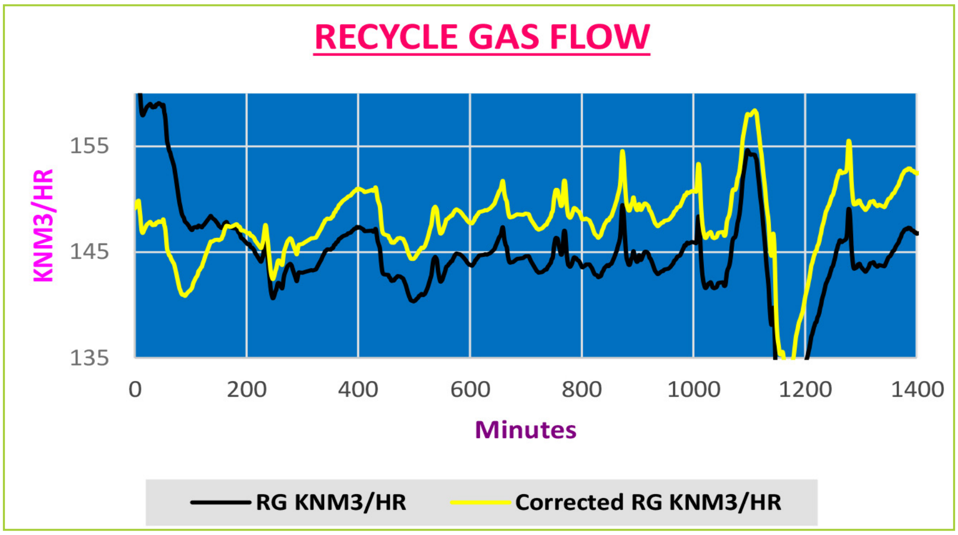


Fig. – 5 The actual and corrected recycle gas flow

e- Off gas flow

As methane and heavier hydrocarbons are removed from the recycle gas, these are absorbed in the off gas from the low pressure cold separator (LPCS-1 V-017). The below trend shows the increase in off gas generation from 18 to 21 Knm3/hr. (Fig – 6). This means that the recycle gas was having about 3 Knm3/hr of hydrocarbons heavier than H2. The PAC effectively removes them.

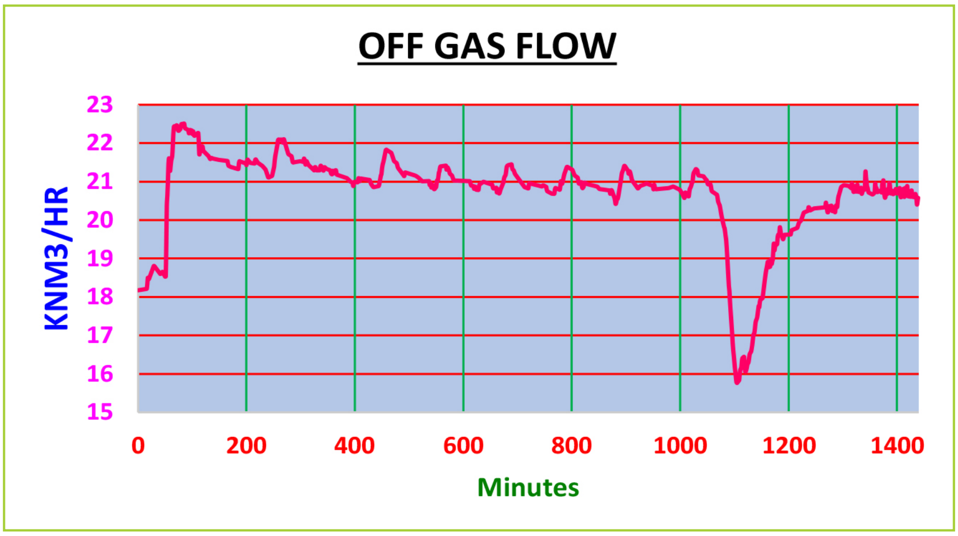


Fig. – 6 Increase in off gas flow

The Pumparound Contactor's design material balance is given below in Table – 2. This clearly shows that the Pumparound oil absorbs about 2 Knm3/hr. of hydrocarbon gases from the recycle gas

Component	PA oil in	PA oil out
	Nm3/hr	Nm3/hr
H2S	1042.8	1356.1
Hydrogen	71.4	1113.5
Methane	308.4	903.4
Ethane	137.3	201.7
Propane	253.8	209.5
I Butane	153.7	162.5
N Butane	347.8	362.2
Total	2315.3	4308.9

Table – 2 PA liquid design material balance

f- Purge gas flow

In order to maintain the H2 purity of the recycle gas, a purge gas flow of about 3 Knm3/hr is usually maintained. Once PAC system is available, this purge is no more required. The Pumparound Contactor has a role in enhancing the recycle gas H2 purity.

Water Injection In ARDS Unit

J.V. Parthiban
Process Engineer - MAA Refinery
Kuwait National Petroleum Company

J.V. Parthiban (right) with DCEO Support Services Nasser Al-Shamaa

Water injection to the ARDs reactor system is another exceptional facility that is available only in MAB and MAA ARDs. Over the past many cycles of operation, it has been observed that water injection to the reactor system increases the activity and stability of the catalyst. Also, the injected water serves another purpose of preventing deposition of solid ammonium salts in the effluent heat exchangers downstream of the reactor.

Whenever water injection is stopped, there is a gradual loss of catalyst activity and these will be highlighted in this article suitably with reactor snapshots taken over a period. Similarly, mitigation of corrosion on the system is elaborated with actual plant data by showing the reduction of pressure drop across the recycle gas compressor through the dissolution of salts with water injection in the downstream exchangers.

The above-mentioned water injection to the reactor system is one among the many best practices.

Water Injection System

Pressurized Boiler Feed Water (BFW ~ 154 kg/cm2) is preheated (~315 °C) and then injected in to each of the four passes of the charge heater. Water injection is about 3.3 wt.% of the feed or about 2 X 4 = 8 M3/hr.

Enhancing Catalyst activity with Water Injection

The next reactor snap shots (Fig. – 2 & 3) show the temperature profile across the reactors on 28th June with full water injection and on 6th July 2017 without water injection.

On 28th June the Guard Chamber (GC, V001) exotherm is 11.2 °C and the overall exotherm is 61.7 °C.

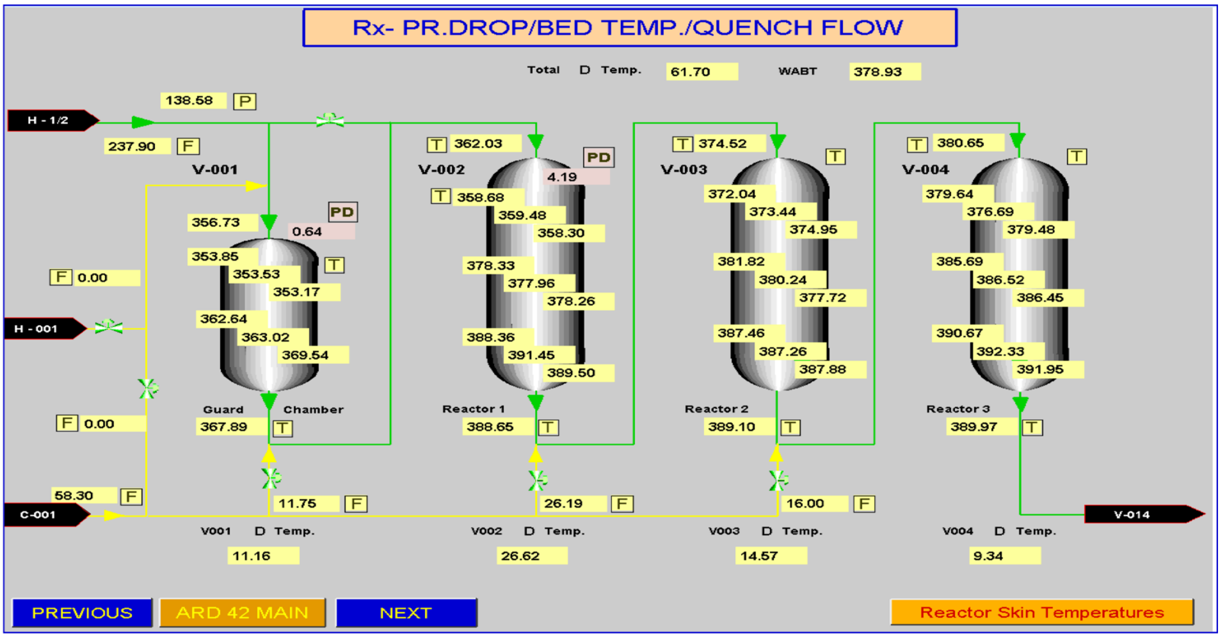


Fig-2 The GC Exotherm is 11.2 °C, V002 Exotherm is 26.6 °C & Overall Exotherm is 61.7 °C (28th June '17)

However, when water injection was stopped on 6th July, the GC exotherm drops to 5.7 °C and the overall exotherm remains close at 59.6 °C.

The reactor V002 exotherm also drops from 26.6 °C to 22.9 °C. The above change in exotherm indicates that the catalyst activity in GC and V002 reactors are lost. This loss in activity is partly compensated by the next two reactors V003 and V004.

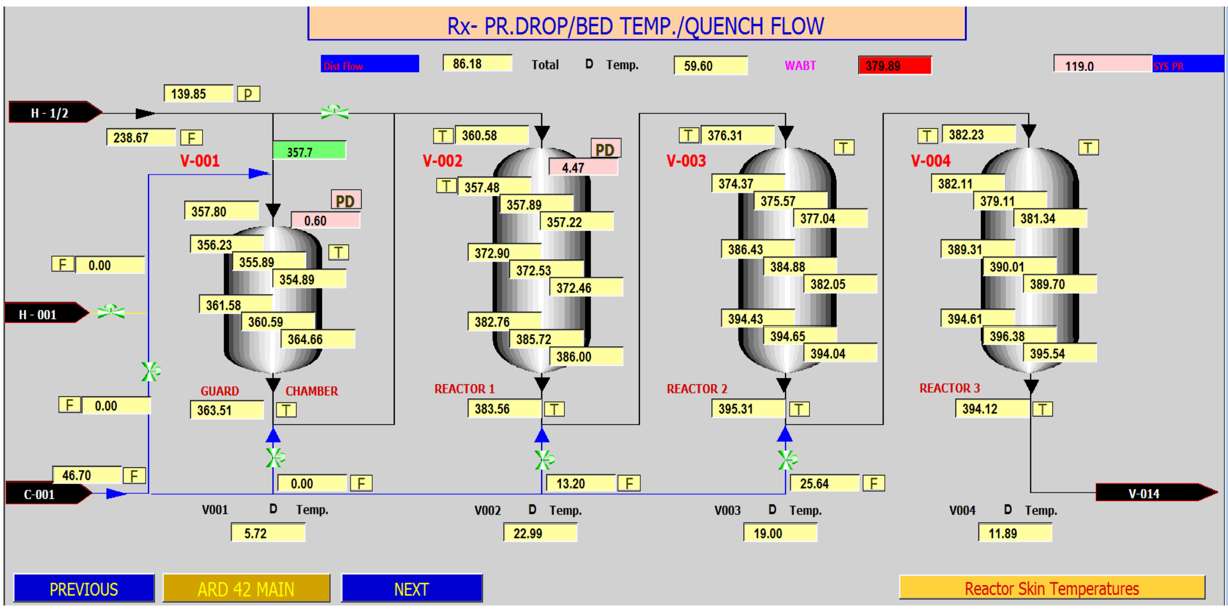


Fig. – 3 The GC Exotherm is 5.7 °C, V002 Exotherm is 22.9 °C & Overall Exotherm is 59.6 °C (6th July 2017)

Water injection was resumed on 12th July at 4.5 m3/hr. Immediately the GC and V002 exotherm increases thus indicating a gain in the catalyst activity.

Finally, when water injection was fully restored on 16th July, the original catalyst activity prior to stopping water injection was restored.

		DT °C			
Date	Water M3/hr	GC	V002	V003	V004
28-Jun-17	8.0	11.2	26.6	14.6	9.3
6-Jul-17	0.0	5.7	23.0	19.0	11.9
9-Jul-17	0.0	3.9	24.0	20.3	12.4
12-Jul-17	4.5	7.9	26.1	15.2	9.9
13-Jul-17	8.0	8.9	26.0	14.1	9.3
16-Jul-17	8.0	10.5	26.2	13.7	9.0

Table - 1 Comparison of the Reactor Exotherms

(Table – 2) below shows that the severity of operation is lost when water injection is stopped as indicated by the LPHS Sulphur results.

07/07/2017 12:00:00 PM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.73	% mass	W/O Water
07/08/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.74	% mass	
07/10/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.72	% mass	
07/12/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.77	% mass	
07/15/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.76	% mass	With Water
07/17/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.69	% mass	
07/19/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.70	% mass	
07/22/2017 6:00:00 AM	LOW PRESSURE HOT SEPARATOR OIL / OUTLET V-42-023	Sulfur	0.69	% mass	

Table – 2 LPHS Sulphur Results

Effect of water Injection on mitigation of corrosion

This part of the article will explain how water injection to the reactor effluent exchanger (E-004 AB) mitigates corrosion and improves the pressure drop across the Recycle Gas compressor.

Toward the end of run operation, tube side fouling is experienced in the exchanger (E-004 A/B) due to build-up of Ammonium Bisulphide salts. This is indicated by the gradual pressure drop across the Recycle Gas compressor from 27 to 37 kg/cm2.

Water injection is usually started when the Recycle Gas compressor pressure drop increases to about 33 kg/cm2 (469 psi). This operation is done by reducing the water injection to the reactors and diverting the water to E-4 A/B tube inlet.

The effect is immediate. The pressure drop across the Recycle Gas compressor drops back to about 27 kg/cm2 as shown in the below trend (Fig. – 4).

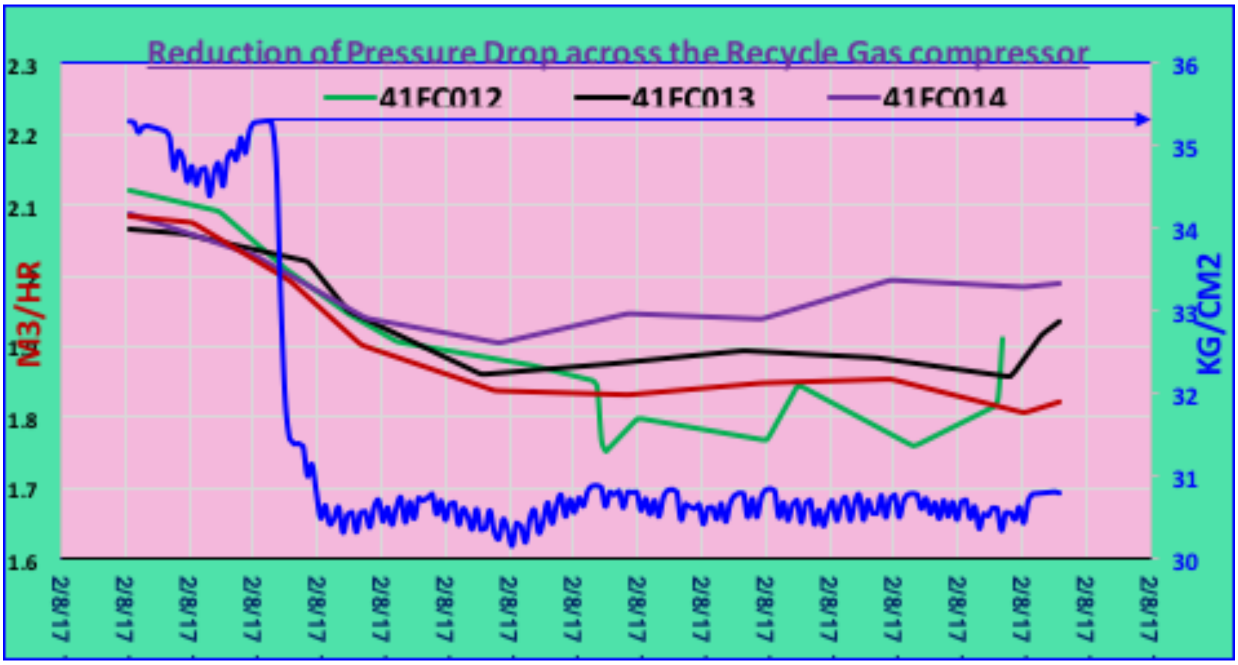


Fig – 4 WATER INJECTION TO E-4A/B (HPWS EXCHANGER), brings down the DP across RG compressor.

The above highlighted reactor snap shots and trends undoubtedly bring out the effect of water injection in enhancing the activity of the catalyst and as well mitigation of corrosion.

Corrosion Problems & Lessons Learnt in ARD Unit

***Sunil V. Vipat**, Specialist - TPL (Inspection)*
***Ali Al Shatti**, Engineer Inspection*
KNPC

The presentation tackles the corrosion problems in the ARDs units, reasons, lessons-learned and recommendations.
Atmospheric Residue Desulphurization is an established Hydrotreating process for desulphurizing atmospheric residue from crude units. The process removes metals, sulfur and nitrogen from the atmospheric residue under high pressure and temperature in presence of catalyst and hydrogen. Corrosion / degradation problems occurred after the unit revamp, due to inadequate review of materials at the time revamp.

Case history 1

Due to high temperature H2S/H2, corrosion of fractionator feed pre-heat exchanger tube sheet and components were seen.

Inspections exposed heavy fouling / scaling and deposits on shell side, shell side of floating head (CS) corroded severely and lost about 0.33 inch (8.3 mm) thickness, tube bundle re-tubed with SS 405 materials and floating head shell side was strip lined with available 316L SS plate. As well, loss of thickness of 0.6 inch noticed in corroded section of fixed tube sheet. The tube bundle was partially re-tubed.

Photos and Sketches showing extent and locations of corrosion are in next two slides

Reasons for corrosion

Corrosion of the CS tube sheet, baffles, tie rods, bypass strips and floating head was attributed to an increase in the operating temperatures and H2S levels.

Case history 2

Corrosion of impingement plates & inlet nozzle internal pipe in high pressure cold separator vessel

Inspections showed severe corrosion, with perforations in the 16" diameter inlet nozzle N1 elbow and the impingement opposite plate. The impingement plate was found bulged also thinning was detected along the flow direction. The fillet weld between impingement plate and the South head (dished end) was corroded / eroded on one vertical and bottom side.

The corroded / perforated impingement plate and inlet nozzle elbow were replaced with higher thickness.

Corroded impingement plate fillet weld

Severe Corrosion / Thinning & Perforation in 90 Internal Elbow on Inlet Nozzle "N1

Ali Al Shatti

Sunil V. Vipat

Reasons for corrosion

Corrosion was due to increase in the velocity of the vessel inlet stream after the revamp. The space between the inlet nozzle internal elbow exit point and the impingement plate were not changed during revamp, and this might have contributed to erosion of the impingement plate and the inlet elbow in the flow direction. High NH4HS concentration (though slightly decreased in general, occasional spikes of up to 4 wt% have been observed during operational upsets).

Other reasons include turbulent flow at inlet and increased liquid quantity (%) as compared to gas, between pre and post revamp (3% post revamp as compared to 1.6% pre revamp),

Case history 3

High Temperature H2S/H2 corrosion of pump around piping in diesel stripper section of fractionator

The Pumparound (P/A) piping were installed and commissioned as part of original ARDS Unit in 1988. A small quantity of high temperature fractionator P/A stream was added to the diesel stripper section in 1993. Operating temperature of P/A stream was originally 581°F.

The P/A stream to diesel stripper piping is of C.S. material. A negligible corrosion observed in the piping prior to revamp.

The operating temperature of P/A stream post revamp since 2004 became 636°F, and the material of construction of main P/A piping is 5Cr - ½ Mo material. The corrosion rate observed since revamp is 0.6 mm / year.

The corrosion and thickness reduction was observed in liquid inlet nozzle "N7" of diesel stripper tower. The SS 316 internal sleeve was installed in year 2010 shutdown to mitigate corrosion in the nozzle.

Reasons for corrosion

As the CS piping section connected to diesel stripper was originally designed for 631°F with operating temperature of 581°F, it resulted in accelerated high temperature H2S/H2 corrosion of CS section during the last run of the fractionator section post revamp while operating at 636°F.

High temperature H2S/H2 corrosion is a function of the material of construction, temperature, and the concentration of H2S.

Lessons learnt

Revamp of any unit for increasing capacity, run length, improving yields, increasing severity of operations etc., should include thorough review

Internal corrosion of liquid inlet nozzle of process conditions, materials and degradation expected in hardware due to process / operating changes.

Failures and degradations occurred due to inadequacy of equipment design and material selection at revamp design stage should be given full attention.

Sleeve installed on the nozzle ID

Recommendations (all completed)

Fractionator Bottoms / Feed Heat Exchanger: New tube bundle is being procured with improved materials for the shell side surfaces.

Currently, no specific recommendation has been made regarding HPCS Vessels. Performance of the enlarged impingement plate will be evaluated in next shutdown and further recommendation will be made.

Pump Around Piping in Diesel Stripper Section of Fractionator: CS section of this line has been recommended for upgrade to alloy steel to mitigate high temperature H_2S/H_2 corrosion. Commit

Al-Adsani and Al-Mutairi touring the Exhibition

Kuwait Heavy Crude Residue Desulfurization

ZOR ARDS Project Features & Challenges
Ahmad Al-Majed
Team Leader, Process Engineering – ZOR
KIPIC

Kuwait tendancy to produce more heavy oil, and Al-Zour Refinery capabilities to process this kind of oil are tackled below.

Kuwait Heavy Oil production

Heavy Crude oil production is in an increasing trend in Kuwait resulting in increasing atmospheric residue. For a typical light Kuwait Export Crude (KEC), the residue is about 45-50%, whilst for a heavy Eocene/ Lower Fars crude, it is in the range of 65-70%.

Al-Zour Refinery is designed to process a wide range of crude; KEC crude (29.9 API) to as heavy as Lower Fars (13.9 API). The high-sulfur, metals (Ni, V) & CCR content in heavy crude poses challenges to Refinery.

Al-Zour Refinery – overview

Al-Zour is the world's largest grass-root Refinery with crude processing capacity of 615,000 BPD. It consists of three mini Refineries. The main objective is to provide a steady supply of 225,000 BPD of LSFO to Power Plants and produce high quality products (340,000 BPSD) as per international specifications for export. The Refinery complies with the environmental objectives of State of Kuwait with respect to improvement in air quality by reducing emission.

Reducing emissions

In principle, Al-Zour is a hydro-skimming Refinery and can be upgraded to full conversion Refinery (in Phase-II).

Designed for Two modes of crude processing:

	Light Crude Mode (BPD)	Heavy Crude Mode (BPD)
CDU -01	205,000 KEC	205,000 KEC
CDU - 11	205,000 KEC	210,000 KHC
CDU - 21	205,000 KEC	120,000 Eocene/ Lower Fars

Al-Zour Refinery – features

Al-Zour Refinery has the World's largest Atmospheric Residue Desulfurization (ARDs) Complex. The heat integrated complex utilizes hot process streams to maximize energy efficiency.

The slops reprocessing flexibilities is available, and has a maximized hydrogen recovery from all H2 rich off gas streams. Its Sulfur Recovery Units are highly efficient (99.9%). As well, it has a maximized condensate recovery for reuse as BFW makeup.

It has waste water treatment facilities with Zero Liquid Discharge; reuse treated effluent as cooling water makeup.

With a Flare Gas Recovery system of zero-flaring design philosophy during normal operation. The multipoint ground flares is designed for smokeless and low noise operation.

Refinery products

Products	Destination	Rate
Low Sulfur Fuel Oil	Kuwait Power Plants – via U/G pipelines	225,000 BPSD
ULS Diesel	Marine Terminal – Export product	147,000 BPSD
ULS Kerosene	Marine Terminal – Export product	99,000 BPSD
Petrochemical Naphtha	Marine Terminal – Export product	86,000 BPSD
Sulfur	Marine Terminal – Export product	2,500 TPD
LPG	Transfer to MAA Refinery	9,800 BPSD

ARDS Unit – features

The "ARDS" unit is the heart of Al-Zour Refinery. Each of the three identical ARDS units is with a capacity of 110,000 BPD (Total 330,000 BPD). With 36 reactors in the three units, the ARDS is a Fixed-Bed Reactor process with design based on extensive hydro-processing experience of CLG. The Atmospheric Residue processing capability is up to 10.5 API; whereas, the desulfurization is up to 92% and demetallization of 85%.

There is a membrane unit for recovery of H2 from purge gas (95% recovery). The multiple reactor trains provide operating flexibility and overall availability of the unit. The units are efficiently heat-integrated to optimize energy consumption.

ARDS feed properties

Feed A – Light Crude
Feed B – Mixed Heavy Crude

Specifications	Unit	Feed A	Feed B
Gravity	API	13.1	10.5
Total Sulfur	Wt%	4.5	5.06
Total Nitrogen	ppmw	2600	3000
CCR	Wt%	11.5	13.72
Vanadium	ppmw	60	70
Nickel	ppmw	20	29
Total V+Ni	ppmw	80	99
Hot C7 Asphaltenes	Wt%	4.7	7.4
Viscosity	cSt@100C	59.4	105

ARDS product specifications

Low Sulfur Fuel Oil Specification	LSFO (Feed-A EOR)	LSFO (Feed-B EOR)
Gravity, degrees API	20.8	20.5
Sulfur, Wt %	0.5	0.5
Nitrogen, Wt %	0.14	0.15
Hydrogen, Wt %	12.1	12.2
Viscosity, cSt @ 50°C	175	175
Nickel, ppmw	6.9	7.1
Vanadium, ppmw	8.1	7.9
Asphaltenes, Wt %	2.3	3.65
Carbon Residue, Wt %	4.9	5.2

ARDS challenges

- ARDS Membrane unit:
  - High H2S content in Membrane Tail gas (150 ppm) impacts HPU, with potential catalyst poisoning.
  - Naphtha to compensate tail gas as feed to HPU due to high H2S.
  - Routing of tail gas to SGU resulting in more fuel gas generation.
- ARDS H2S Absorber sizing to determine a right size H2S Absorber to meet H2S specification in downstream unit.
- RDS Relief load with increased relief loads to HP and LP flare higher than envisaged in FEED stage.

- Safety concern in operation due to very high pressure operation.
- Frequent catalyst change-over due to short life cycle of catalyst; one year for heavy crude operation. The catalyst change-over every two months for each of six trains increases the spent catalyst handling activities.
- Complex and long procedure for catalyst activation, and spent catalyst handling.
- Highly corrosive and fouling service - posing challenges for future inspection and monitoring.

Other project challenges

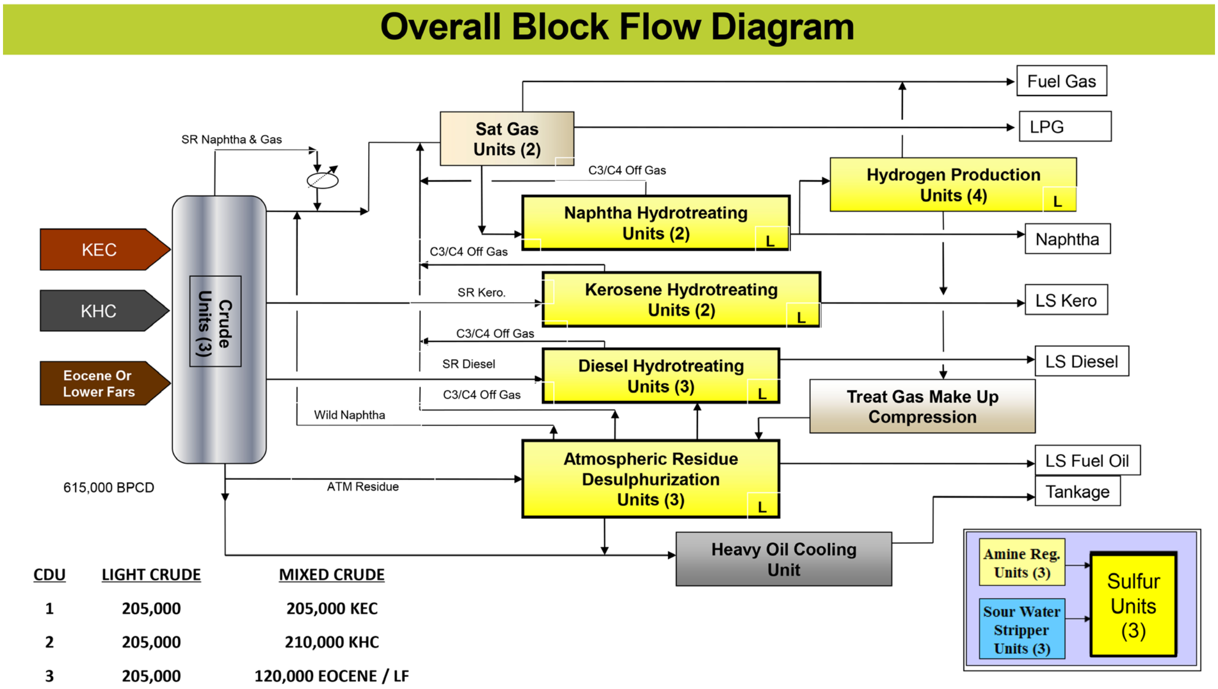
The crude desalter design is with high density of crude/oil-water separation with varying salt content.

The compatibility of crudes. The blend of Eocene with other crudes has a potential fouling of equipment. As well, the unstable sulfur compounds in crude have impact in metallurgy of column overhead.

Closing remarks

ARDS will play a key role in achieving the Vision and Mission of KIPIC and contributing to the overall economy.
Other expansion projects include RFCC, Petrochemicals, and Full Conversion Refinery (in Phase-II).

Al-Zour Refinery



CDU	LIGHT CRUDE	MIXED CRUDE
1	205,000	205,000 KEC
2	205,000	210,000 KHC
3	205,000	120,000 EOCENE / LF


Kuwait ARDS capacity will reach an impressive 758,000 BPD

Developments in Residue Technologies

Ashok Krishna
Vice President
Chevron

The presentation speaks about Chevron integrated hydroprocessing approach, process technology (RDS/VRDS), Upflow Reactor (UFR), Onstream Catalyst Replacement (OCR) and catalyst technology (RDS/VRDS).

ARDS/VRDS: A key process for the future

Considerably more than just a process to remove sulfur, residue hydrotreating provides both impurity removal and hydrocarbon upgrading:

- Resid conversion levels of 30-40% can be achieved
- Cracking and volume expansion result in 2-4 vol% naphtha and 16-28 vol% diesel
- Viscosity reduction and carbon residue reduction
- RDS upgrades residual materials in the crude to feed RFCCs and hydrocrackers and to maximize petrochemical feedstock
- Integration of RDS into configurations with other process technologies – a key focus for R&D and optimization studies.

ARDS/VRDS will become more important with the advent of the new IMO regulations and the bias towards petrochemicals integration in our refineries of RDS/VRDS.

What are upflow reactors?

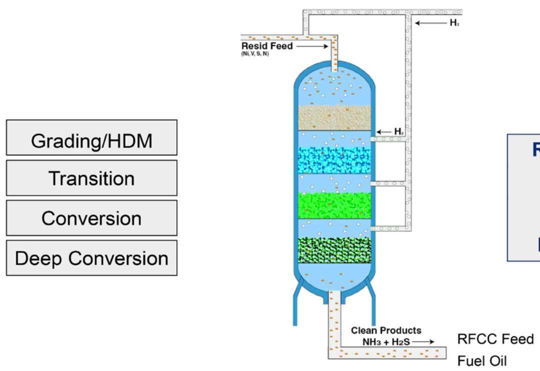
Part of the CLG RDS/VRDS portfolio:

- Upflow guard reactor used to hydrotreat AR/VR feedstocks upstream of fixed bed RDS units
- The reactor leverages spherical catalyst technology
- Two options available:
  - With Onstream Catalyst Replacement (OCR)
  - Without Catalyst Replacement: Upflow Reactor (UFR)

ART Resid Hydroprocessing catalysts

- Trusted global leading supplier of hydroprocessing catalysts for 16 years since launched in March 2001 as JV between Chevron and WR Grace.
- Complete portfolio of hydroprocessing catalysts.
- Leader in Fixed Bed Resid and Ebullating Bed Resid.
- Currently supplies >50% of all RDS catalyst worldwide.
- ART RDS catalysts are currently in use in CLG-designed RDS units and also in units designed over the years by other licensors.
- Eleven new CLG-licensed units to come onstream in the next 5 years.
- R&D expertise to develop unique products for specific refinery requirements.
- Strong global manufacturing base and production flexibility.
- Outstanding technical service and sales support.

RDS Catalyst System Design



Reaction	Conversion
HDS	85-95%
HDM	70-98%
HDMCR	30-65%

- Allows flexibility to tailor catalyst systems for specific customer feed and product objectives

Summary

- ARDS/VRDS is a key process for the future of hydrocarbon upgrading.
- Impending regulations and petrochemicals focus provide opportunities for RDS integration.
- Chevron has a history of commitment to RDS technology.
- CLG: Industry leading licensor with breadth of experience.
- ART: Industry leading catalyst supplier.
- Benefits from CLG/Chevron's continuing research in heavy oil processing.
- Benefits from ART's ongoing new catalyst development program and outstanding technical service.
- Integrated approach allows JVs to work together to address future customer needs resulting from market shifts in demand and regulations.

Bringing Clarity to Complexity

Süleyman Özmen
Vice President, Refining and Chemical Licensing
Shell Global Solutions

The presentation outlines the chalnges facing the residue upgrading projects, the implications, response and what solutions to adopt.

Drivers for residue upgrading projects

Resorting to residue upgrading projects aim to increase margins, respond to IMO 2020, produce clean fuel for power plants and reduce fuel oil production.

The implications of IMO 2020 marine fuels specifications

The International Maritime Organization (IMO) will tighten the global cap on the maximum sulfur content of marine fuel oil from 3.5 to 0.5% in 2020. There are three options for the shipping industry:

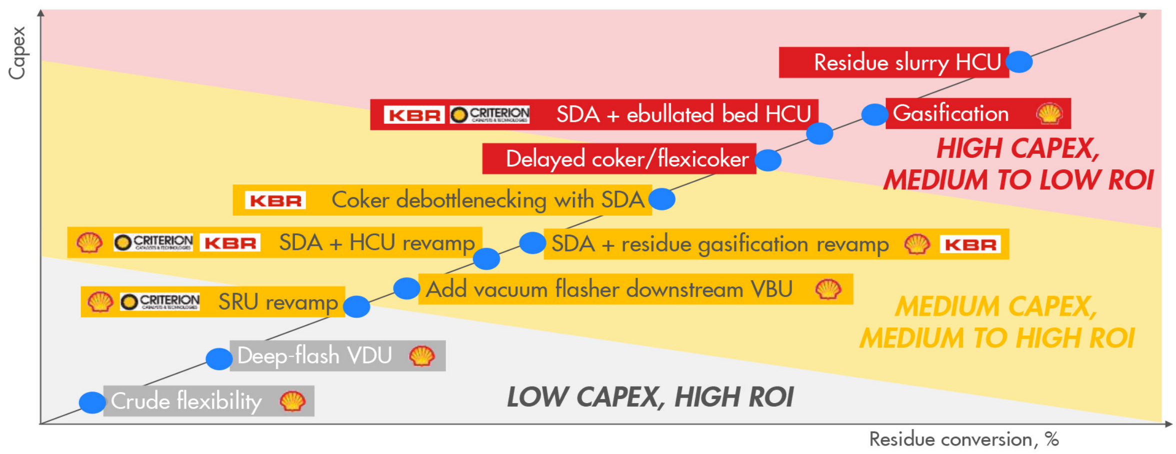
- Scrubbers.
- Liquefied natural Gas.
- Low-sulphur fuel.

Responding to IMO 2020 will be highly complex and expensive for most refiners. The key factors that will influence individual refiners' investment decisions regarding the current Refinery configuration are the amount of capital expenditure they can afford and how discounted they believe HSFO will be and for how long.

Key takeaways

Many refiners will continue evaluating options to reduce or eliminate their residue exposure, but this

The optimum Refinery investment option may not result in full residue conversion



is challenging due to:

- There is no one-size-fits-all solutions.
- The highest residue conversion technologies may not be the preferred investments; integrated solutions may provide better returns.
- Shell and its partners have accumulated vast experience on how refiners can integrate their technology blocks for cost-effective solutions.

Commonly encountered implementation challenges

- Mitigate business risk to avoid regret investments
- Lack of sufficient reference units
- High capital expenditure
- Achieve adequate return on investment
- Secure preferable terms for finance and insurance
- Integration with existing refinery configurations

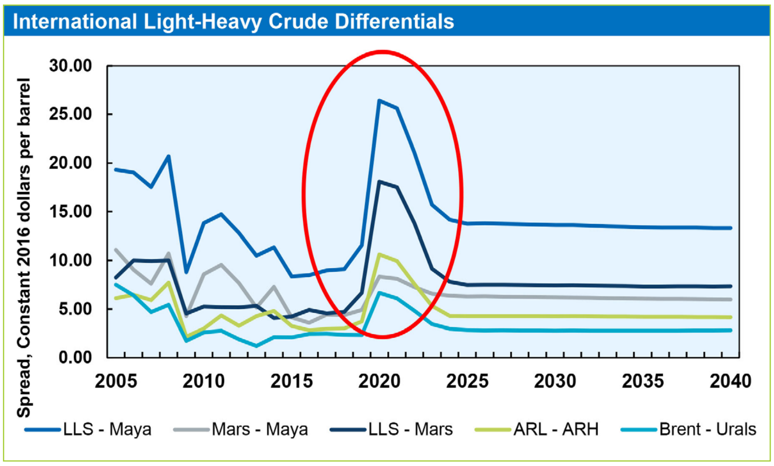
Managing the Uncertain Seas of Residue Processing

Jim Rekoske
Vice President & CTO
Honeywell UOP

The Speaker talks about the dilemma facing the refineries to meet MARPOL stipulations, and the available options for Refineries.

MARPOL Annex will have worldwide effects on HSFO demand and price

MARPOL will significantly reduce HSFO use for bunkering, a surplus residue is expected after residue conversion and power generation usage, and the HSFO is expected to be priced at severe discount (~40% lower).



Refinery decision dilemma

It is unprofitable to make High Sulfur fuel oil or export residue and exports to HS bunkers market after 2020 is curtailed.

The Refineries should convert HS fuel to LS Bunkers (0.5% S), and convert HS Bunkers to distillates / gasoline.

Refinery options with HS bunkers

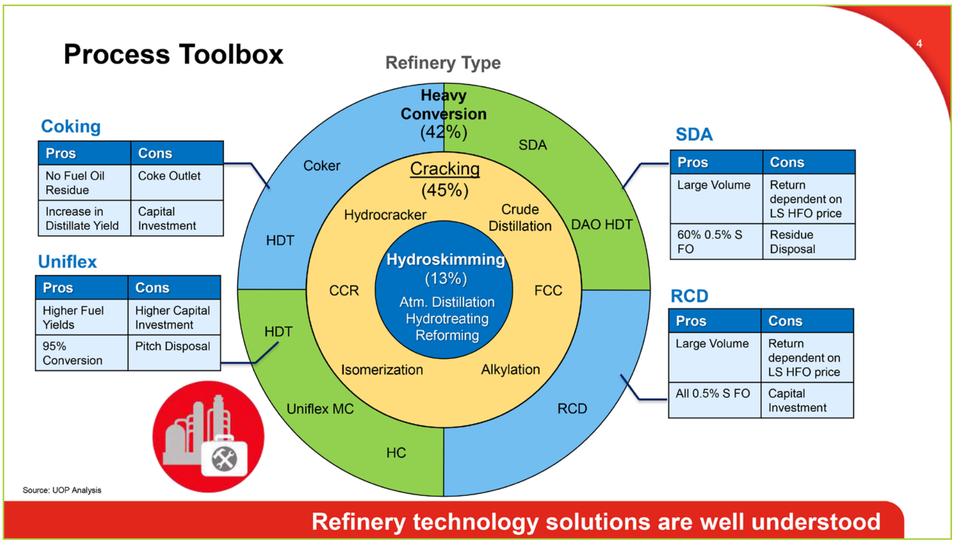
As the search for a phased capex approach is a no regret route, the choice is either convert to distillates or gasoline:

- Slurry bed process such as Uniflex MCTM
- Coking process such as AMEC FW DCU process

- RCD Unionfining and RFCC process.

Or, Make LS Bunkers:
- Desulphurise HS bunkers with process such as RCD UnionfiningTM.
- Ebullated bed process.
- Process VR in new SDA and desulphurise DAO.

Refiner response options



Case study for phased approach

Base case: Typical Refinery

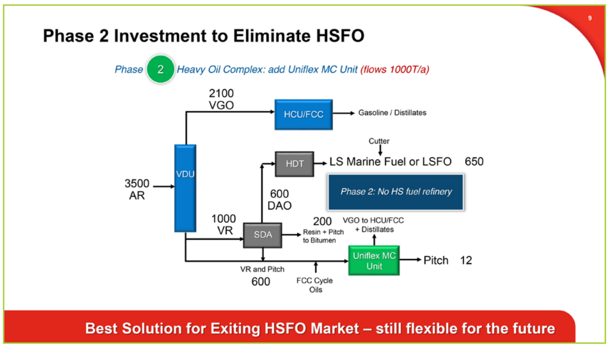
Crude Distillation / Vacuum Distillation, Hydrocracker or FCC unit, Visbreaker

Phase 1 investment

Add Solvent Deasphalting and Hydrotreater units

Phase 2 investment

Add Uniflex MC



Uniflex MC process

Comprehensive development program
- New catalyst innovations
- Process enhancements

Responding to customer and market needs includes:
- High conversion to valued products
- Process design for sustained operability and reliability
- Economically efficient catalyst systems, and manufacturing capability
- Economically advantaged disposition for all products
- Robust feed and product characterization

Research, Operation & Revamping Experience in Residue Hydrotreating

Jérôme Picou
ARDS/VRDS Lead Process Engineer
Manufacturing & Project Division
TOTAL

The petrochemical experience of Total is outlined in the following paragraphs

The volume of its Refining and Petrochemical activities places TOTAL as the largest refiner in Europe and among the top 10 integrated chemical producers in the world.

TOTAL Refining & Petrochemical activities include operation of 9 assets (Europe, USA), shares in 10 others (Saudi Arabia, Africa, Asia...) and crude treatment capacity of around 2.0 Mb/d.

TOTAL's last grass-root Refinery in 2014 was SATORP (JV ARAMCO/Total – Jubaïl, KSA).

TOTAL Residue Hydrotreating experience

Experience started in 1980's through ambitious research programs:

- ASVAHL project launched in 1979 between ELF, TOTAL and IFP and having led to the construction of a "mini refinery" to maximise residues / heavy crudes upgrading
- Dedicated Pilot plants built in the 2 Technical and Research Centers (FR, BE)
- Construction in 1994 of a 2-trains ARDS unit in Total Antwerpen Refinery (Belgium) – 100% owned by TOTAL. CLG license.
- Technical assistance to NATREF (South Africa, 36% equity, VRDS)
- Wide and strong expertise, supported by Technical and Research Centers, to improve unit performance in troubleshooting (short-term), optimisation (short- and mid-term) and revamping studies (long-term).

In the frame of unit integrity follow-up, loss of thickness was identified at main fractionator inner shell (feed exit). The CFD by Koch to mimic hydrodynamics at feed distributor exit, was done with internal expertise to identify root causes. The distributor was modified to re-equilibrate flow patterns and mitigate corrosion / erosion.

Impact of feedstock quality

- Unexpected quicker loss in HDS activity and higher pressure drop in reactor
- Rapid identification that one crude in cocktail was likely to be the root cause
- Use of pilot testing facilities confirming this hypothesis. Difficulties to unload pilot reactor, as process unit: Switch to other cocktail to avoid the issue
- Characterization with sophisticated analytics to identify nature / concentration of responsible components: Aim is to enhance comprehension, contributing to the selection of "opportunity" crudes

Optimisation

Catalyst selection

Objectives:

- Evaluate catalyst Start-Of-Run activity, as well as stability.
- Get the maximum value from pilot through modeling.
- Enhance unit profitability by proposing best catalyst loading (activity Vs. run length Vs. cost).

Increase of VR/AR ratio

Objectives:

- Increase VacRes / AtRes ratio in feed as much as possible, from original 70% VacRes - 30% AtRes (@constant flow) – Natref asset
- Improve unit profitability by processing heavier feedstocks.

Vulnerability study

Improve unit profitability by maximizing its availability rate.

Conclusion

TOTAL benefits from its more than 30 years of expertise in Residue Hydrotreating to adjust its R&D programs, troubleshoot and optimize existing units and to revamp Residue Hydrotreating Units.

The tools available are numerous, including its 2 technical centers, knowledgeable Engineers working in a multi-disciplinary team, dedicated pilot plants/sophisticated and analytical methods / modeling tools.

This allowed developing a large spectrum of competencies to support units in operation, process/ process safety/catalyst selection and modeling.

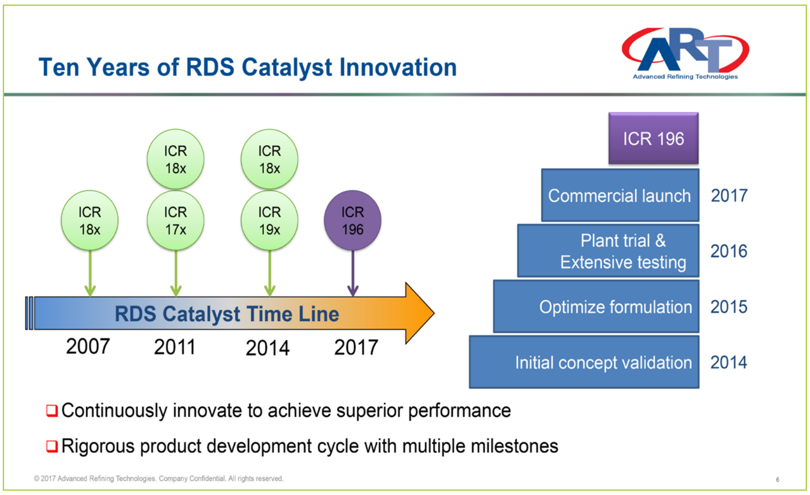
Advances in ART Resid Hydrotreating Catalyst Technology

Rong He
Product Line R&D Manager, Fixed Bed Resid
Advanced Refining Technolgy

The residue hydrotreating catalyst demand is growing at 7% rate annually, and ART catalysts are in use in CLG-designed RDS units and also in units designed by other licensors. The RDS technology tackles the challenges in residue hydrotreating by developing superior catalysts and design to enhance catalyst systems.

RDS catalyst system design

Typically produces low sulfur fuel oil, residue FCC feed and coker feed. It also allows for flexibility to tailor catalyst systems for specific customer objectives.



High HDS & HDMCR stability

The new catalyst ICR 196 has extraordinarily stable HDS and HDMCR activity. As well, it is beneficial for middle to end of run operation.

It Features High metal removal function

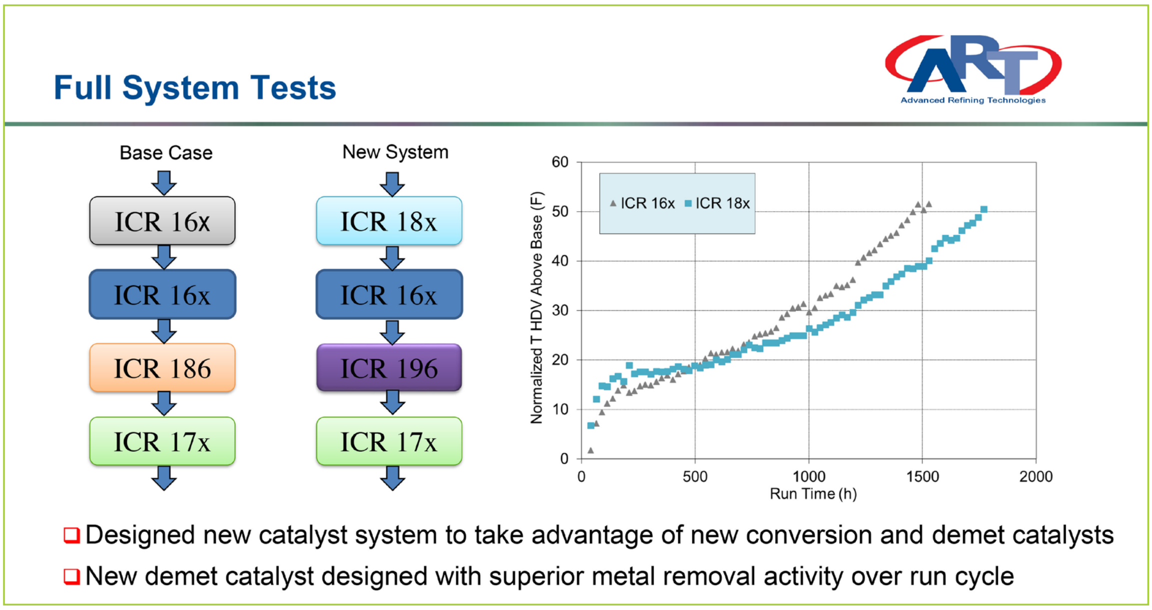
The New Catalyst ICR 196 has better HDV activity and higher metals tolerance. It offers better protection for deep conversion catalyst (~5 ppm less vanadium passed on).

ART RDS catalyst generations delivering

With continuous performance improvements, the ART new conversion catalyst ICR 196 offers:

- Highly stable HDS/HDMCR activity
- Enhanced metals removal function
- High metals tolerance suitable for challenging operations

Full system tests



Better activities and better quality product

- New system reduced product sulfur to allow more flexibility in making BFO.
- RFCC application would benefit from lower levels of MCR and metals.

Summary

- ART Residue HydroTreating catalysts serves in a wide range of client applications.
- ART continuously innovates superior catalysts to strengthen RDS catalyst portfolio and deliver enhanced performance.
- High metals tolerance conversion catalyst ICR196 offers highly stable HDS and HDMCR activities with enhanced metal removal function.
- The optimized catalyst system with new demet and conversion catalysts delivers better HDS, HDMCR, and HDM activity.
- The optimized catalyst system can benefit clients in both bunker fuel oil and RFCC applications.

Robust Integrated Solutions & Best Practices

Meeting the Challenge of Heavier Residue Processing

Dr. David Mc Namara
Criterion Residue Upgrading R&D, Houston, USA

Opening "Food for Thought" message

- Crude oil is the number 1 exported item in the world
- Are all opportunity crudes really just that?
- Bottom of the barrel means different things to different refiners
- Is gas the new oil?

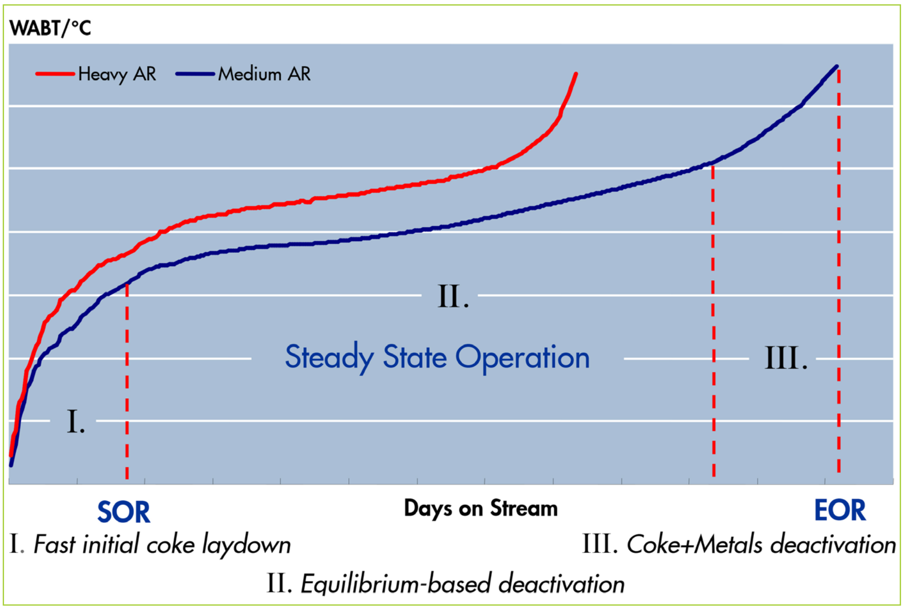
Overview

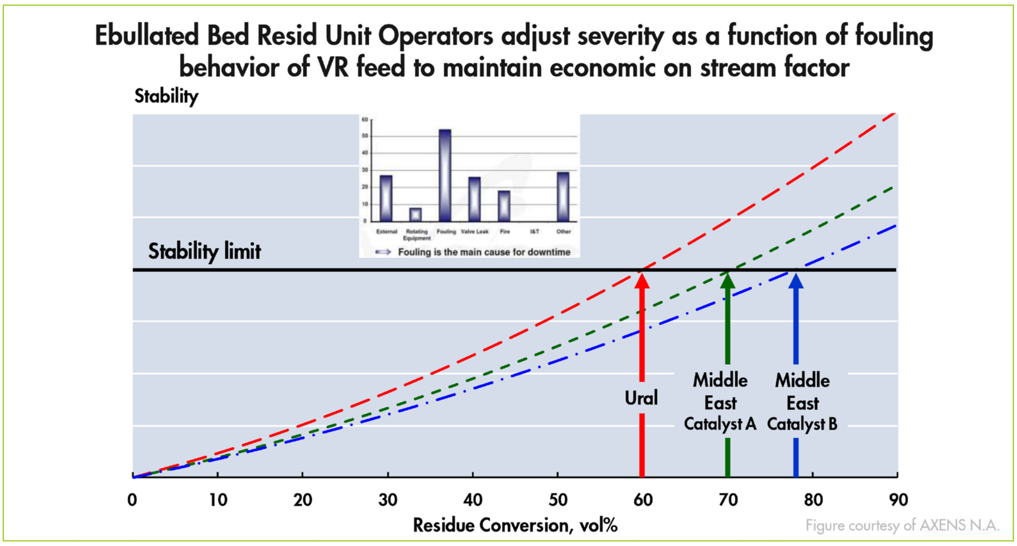
Sustainable future economic heavier oil processing in fixed bed resid units (ARDS/RHDS/VRDS) requires an effective pro-active mitigation program of measures to be applied.

Heavy oil upgrading challenges

The need to exploit heavy oil is driven by increasing demand for energy, the end of easy oil era and constrains on CO2 emissions. As well, the reduction of marine fuel oil sulfur to 0.5 wt.% per 1/1/2020. Hence, the ultra-low sulfur diesel "ULSD" wave for RESIDUE UPGRADING has arrived.

The right chemistry to meet the heavy oil upgrading challenge





Key takeaway messages

Sustainable economic fixed bed resid (ARDS/RHDS/VRDS) unit operation in the era of intensifying heavy oil upgrading challenge requires pro-active mitigation measures to be applied.

Robust, commercially proven process + catalyst integrated technology drop-in solutions exist which can help refiners not only rise to this challenge but also transform it into profit-making opportunities. These integrated solutions feature the synergy of customized catalysts and state-of-the-art reactor internals leading to balanced process and chemistry across the unit cycle.

The Extensive Effort Behind 75 ZOR & CFP Projects Reactors

Les Antalffy
Assisted in the development of this presentation by:
Anil Rajguru and Shankar Vaidyanathan
FLUOR

Ahmad Al-Jemaz (left) with Les Antalffy

This presentation centered around the 36 Reactors and 6 High Pressure Separators in the Al-Zour Refinery Project (ZOR) and the 27 Reactors and 6 Separators in the Clean Fuel Project (CFP) which are considered long lead equipment items, which needed to be purchased in the Front End Engineering Design (FEED) in order to meet the existing project schedules.

The two world-class projects are taxing the combined global capabilities of the strategic material suppliers and reactor fabricators. The basic reactor supply strategy was developed by Fluor and presented to KNPC's Management for consideration in February 2005.

Historical background

In 2004, Fluor was awarded the FEED contract for KNPC's New Refinery Project later renamed the Al-Zour Refinery Project. This was a 615,000 bpd Ultra Low Sulfur Fuel Oil Refinery to provide ultra-low sulfur fuel oil for power generation. The Refinery consisted of the following major units: Crude Unit, 330,000 bpd ARDS Unit, Diesel Hydrotreater, Kerosene Hydrotreater, Naphtha Hydrotreater, Hydrogen Plant, Sulfur Plant, Utilities & Offsites.

The CFP long-lead reactor equipment consisted of 27 reactors and 6 separators, mainly for 3 ARDS and 1 UOP Licensed Hydrocracker unit at MAB. Whereas, MAA vessels were designated for 1 ARDS Train reactors and 1 Separators.

Selected licensors

Chevron Lummus Global (CLG) was the licensor selected to provide technology for ARDS Units of Al-Zour Refinery. Originally, the ARDS Unit concept proposed consisted of 3 units, with 8 Reactors and 2 High Pressure Separators per unit, for a total of 24 Reactors and 6 Separators. This concept was then revised because the reactors were so large, that on a global basis, the only reactor fabricators who could fabricate such thick, large and heavy wall reactors were very limited in number.

Pressure Vessel Code allowable stresses and thinner, lighter reactors facilitating fabrication, transportation and erection.

Summary of projects

ZOR Project

- Total weight of 36 Reactors & 6 Separators 37,029 metric tons
- Thickest Reactor 305 mm
- Heaviest Reactor 1,077 MT

CFP

- Total Weight of 27 reactors and 6 separators 29,218 metric tons
- Thickest reactor 308 mm
- Heaviest reactor 1,540 MT

The total combined weight of 75 vessels was 66,247 metric tons. The largest order ever placed for vessels to a single supplier was to Larsen & Toubro for US$ 421 million for 22 vessels with 19,000 MT total of weight.

The revised ARDS concept then changed to 3 Units, each with 2 Trains. In order to have the flexibility of interchanging reactors, the ARDS reactors for the ZOR and CFP Refineries were made identical, even though the throughput of the ARDS trains at different locations was slightly different.

There was a significant concern that with such massive projects and with such a limited number of material suppliers and reactor fabricators, the project schedule that existed then could not be met.

Reactor material selection

Fluor proposed that the reactors and separators be fabricated out of the newer 2¼Cr-1Mo-¼V alloy. The Vanadium modified alloy offered better resistance to hydrogen attack, higher ASME

Hammer forging and descaling a reactor shell at SFAR Steel

FCCU: Leveraging Advances for Maximum Heavy Oil Processing & Profitability

Ebrahim Talib
Deputy Chief Executive
Bapco Bahrain

The presentation covers BAPCO experience in FCC, the technology adopted and FCC catalyst management.

Bapco's Fluid Catalytic Cracking Unit (FCCU) used UOP original Model II. It startup in 1945 - second ever Model II unit outside USA.

The unit's unique design used 2 reactors and 1 elevated regenerator, longest regenerated catalyst standpipe (RCSP) in the world - 125 ft.

The original feed was 18 mbpd, increased to 43 mbpd - mainly VGO, CCR 0.9 wt%. The current feed is 13 mbpd, CCR 6-7 wt%, 65 vol% heavy oil. Continuous improvement over 72 years, in technology and catalyst.

One of Bapco's main strategies has been to reduce fuel oil make by upgrading heavy oil components to maximise conversion of low value heavy oil into high value products and increase Refinery revenue.

First Step: Minimise Refinery Fuel Oil yield:

1. New VGO Hydrocracker (HCU)
2. FCCU Resid Processing
3. Maximise HCU-FCCU synergy

Next Step: a new Resid Hydrocracker - future project

1. New hydrocracking unit

The Low Sulfur Diesel Production (LSDP) Project is based on 60 mbpd VGO Hydrocracking Unit (HCU).

Most of VGO to be processed in the new HCU.

The HCU bottoms routed to FCCU for clean feedstock; hence significantly lower VGO feed to FCCU.

The opportunity was created to process heavy oil in FCCU. The HCU would make Unconverted Oil (UCO) - good quality FCCU feed, but flow rate lower than traditional VGO feed. The lower FCCU feed plus better quality would allow heavy oil processing and reduce overall fuel oil make.

2. FCCU residue processing project

Included installing a new state-of-the-art reactor packed stripper, and Mix zone Temperature Control (MTC) - riser quench - technology by Stone & Webster.

The reactor packed stripper

The structured packing was developed by Koch-Glitsch. Bapco was one of the first users.

The reactor allows processing of more heavy oil. The feed Conradson Carbon Residue (CCR) is significantly increased from 0.9 to 2.5 wt%. The packed stripper alone paid for the whole project even before commissioning of MTC.

3. Hydrocracker-FCCU synergy

The new VGO Hydrocracker reduced VGO feed availability to FCCU, and created good quality FCCU feed (UCO). Feed CCR further increased from 2.5 wt% to 4.0 wt%.

In 2012, a new Lube Base Oil Unit (LBOU) was commissioned. The HCU UCO was processed in LBOU. The combined feed CCR 6-7 wt% - one of the highest FCC feed CCR in the world.

The making of full use of HCU-FCCU synergy achieved a substantial reduction in fuel oil make. (Was 22 vol%, and now 15-16 vol%). The next step requires massive capital investment.

FCC Catalyst Management

It is based on ongoing catalyst optimization. It requires search for and finding the best catalyst for the feed and process objectives development.

Bapco worked with catalyst vendor to formulate a catalyst for heavy oil processing:

- Higher metals tolerance: Ni+V 10,000 wppm.
- Better hydrothermal stability of matrix and zeolite.
- High Light Cycle Oil (LCO) selectivity.
- Heavy ends cracking capability: lower Heavy Cycle Oil (HCO) yield means lower fuel oil make.

Remarks

- Bapco's adopted a stepwise process to investment and implementation.
- FCCU revamped with modest investment to process heavy oil.
- When modernizing, do not forget the old units - Look for and create opportunities.
- Hydrocracker - FCCU synergy minimizes Refinery fuel oil make and maximizes profitability.

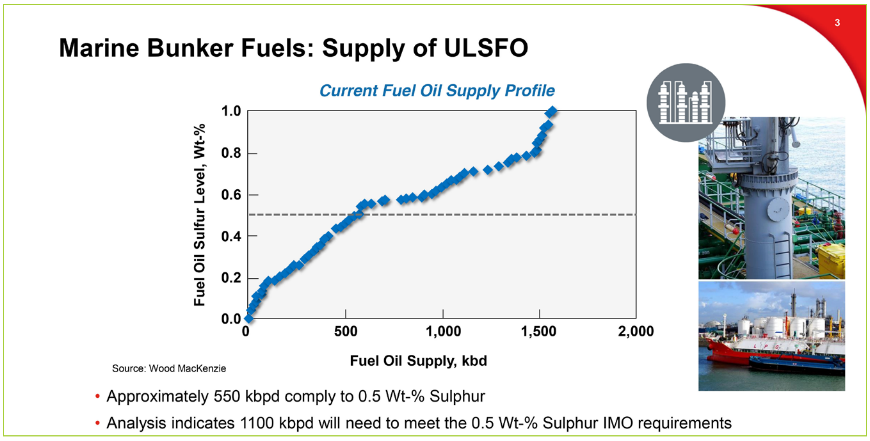
Advancements in UOP RCD Unionfining™ Process

Alexander Jimenez
Honeywell UOP

UOP's heavy oil processing technolgies to tackle the new marine bunker ultra low sulfur oil are outlined in the following two pages.

Marine bunker fuels: supply of ULSFO

Current fuel oil supply profile



Propylene and gasoline demands

The gobal propylene demand is expected to increase by 40% approximately by 2026, whereas the global gasoline demand is expected to increase 12% approximately by 2030.

RCD unionfining commercial experience

- 30 commercial licensed units (total capacity > 1 million bpsd)
  - Commercially proven technology developed by UOP and Unocal
  - Uses commercially proven catalyst system
  - Designs include single and parallel reactor trains, and stripper or full fractionation configurations
  - Includes proprietary reactor internals – UOP Uniflow™ internals
- Feedstock qualities of commercial RCD Unionfining process units have ranged from:
  - °API: 9-18
  - Sulfur: 3 - 5 Wt-%
  - Conradson Carbon: 5 - 15 Wt-%
  - Organometallics (Ni+V): 10 - 200 wppm
  - Viscosity: 25 - ~1000 cSt @100°C

- Operating conditions of commercial RCD Unionfining process units have ranged from:
  - Throughput: 5600 - 75,000 BPSD
  - Pressure: 1200 - 3000 psig
  - LHSV: 0.10 - 1.2 hr-1
  - Operating cycles: 6-24 months
- Performance is typically up to 95% desulphurization, metals removal up to 90%, denitrification and asphaltene removal 65% .

Two-stage RCD unionfining with water injection

- Inter-stage separation avoids inhibiting effect from H2S.
- Water injection improves HDS activity for HDM catalyst .

Key benefits

Increase cycle length

- Cycle length increased by approximately 30% over base.
- Potential $US 5 -10 MM + catalyst costs OpEx savings due to fewer catalyst reloads.
- Potential additional revenue $US 100 MM due to longer on-stream production (RCD-RFCC).

Higher quality feedstock to RFCC

- Improves RFCC Performance.
- Higher conversion, higher yields.
- Lower OpEx.

UOP heavy oil development center

- Expanded capabilities to support bottom of barrel technology development.
- New facility for pilot plant expansion at UOP:
  - High throughput feed preparation / fractionation
  - Uniflex MC pilot plant: high capacity operation with multiple reactors.
  - Solvent de-asphalting (SDA) pilot plant: Multi solvent capability: Propane, butane, pentane
  - Flexible heavy oil Hydroprocessing pilot plant: Heavy oil technologies fully integrated with UOP Unicracking™ and RCD and Distillate Unionfining™ pilot plants.

Summary

- UOP's extensive heavy oil technology portfolio allows UOP to develop the optimum residue upgrading solution.
  - Separation and hydrotreating: Crude/ Vacuum, SDA and RCD unionfining.
  - Conversion: Visbreaking, delayed coking, Uniflex MC, Post-treatment/conversion: Distillate unionfining, Unicracking, RFCC Processes.
- RCD Unionfining process is commercially proven for treating highly contaminated feeds for conversion units or producing LS fuel oil.
- RCD-RFCC complex can be designed for either maximum gasoline or maximum propylene production.
- Enhanced RCD unionfining flow schemes improve performance.
- Low cost water injection revamp for existing fixed bed residue hydrotreating units.
- Next generation Uniflex MC offers solution for zero HSFO production.
- High conversion of residue to middle distillates will improve Refinery profitability.

Global Market Overview & IMO Regulations

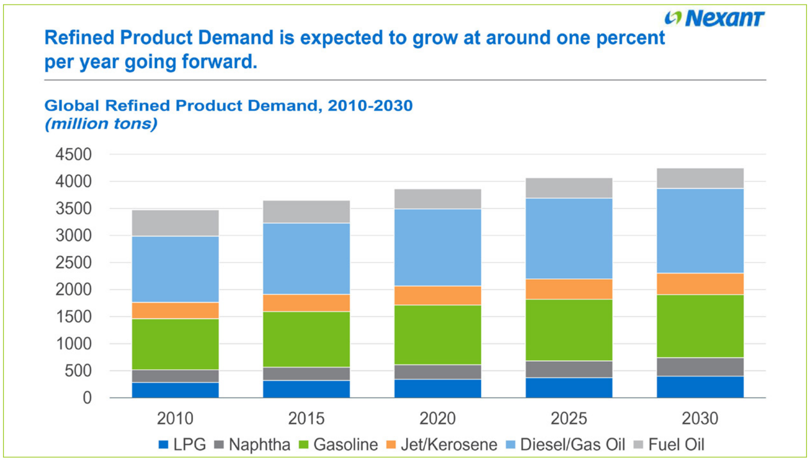
Andrew Inglis
Managing Consultant
Nexant

Speaker focuses on the development of world main regions supply and demand of the oil products, MARPOL impact and options for the refining industry.

Global demand and supply

North America and Asia will remain to be the two largest customers by 2030 with the biggest growth expected in Africa, Middle East (ME) and Asia. Refined product demand is expected to grow at around 1% per year going forward.

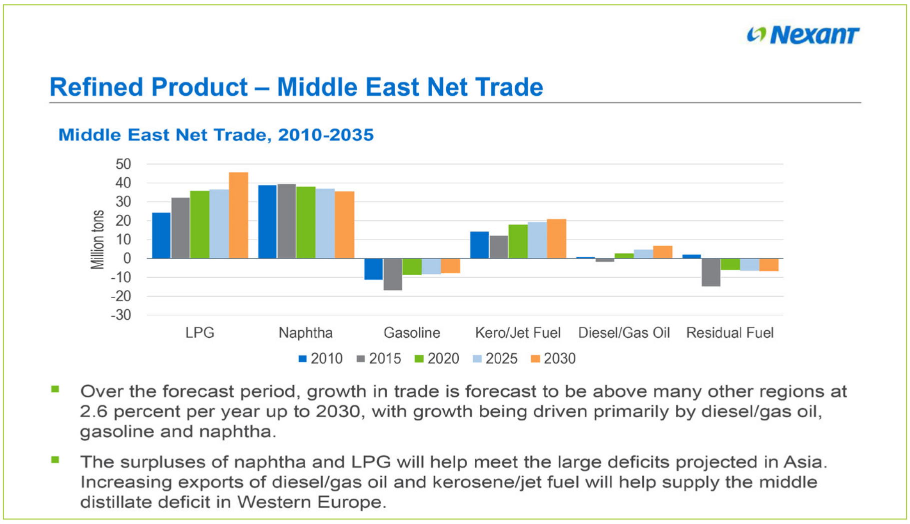
Supply from Asia will continue to grow over the coming decades at



1.3% per year with highest growth in Africa and ME.

The Middle East

The Middle East (ME) will dominate crude oil production increases between 2015 and 2030, with approximately 43 % of total production, increasing its global overall share from 31 % to 36 %. The export Refinery projects are proceeding/completed with upwards of 1.5 mmbpd of refined products. Wheras, the new Refineries are conversion primarily focused on distillate. More projects are still being announced and Iran is now showing signs for growth in refining. We see the regional demand also increasing and is growing at the highest rate after Asia.



ME residual fuel oil requirements will grow by 19 million tons per year by 2035, driven by increasing use in power generation and increase in bunker demand.

MARPOL impact

Marine bunker fuel quality is governed by the International Maritime Organisation's International Convention for the Prevention of Pollution from Ships (MARPOL). Bunker standards have tightened, under the IMO framework. Limits have tightened on emissions of sulphur oxides, particularly in Emission Control Areas (ECAs). Such a global product shift on this scale being required from refiners over such a short space of time, has never been seen.

Major development will be the introduction of global 0.5 % limit in 2020 with HSFO (3.5 % sulfur) nominally unsuitable for use, and LSFO (1 %) also pushed out, although refiners are more likely to be able to produce LSFO. The changing pattern will result in diesel being used as bunker fuel which is accounted for 29% of bunker fuel consumption in 2000 due to new ECAs. It is expected to rise to 60 % by 2020.

Options for the refining industry – Residue Hydroprocessing

Three schemes offered by licensors: Fixed bed hydrotreating, ebullated/moving bed hydrocracking and slurry phase hydrocracking. Forecasts include increase in gas oil/diesel prices during the mid-2019 to 2023 period, depressed HSFO prices, increase in the gas oil/diesel crack spread versus crude oil, associated with the increased price differentials between gas oil/diesel as well as HSFO, and a decrease in the HSFO crack spread versus crude oil, associated with the trend in price differentials between gas oil/diesel and HSFO.

IMO

- Spreads of LSFO to HSFO likely to be significant in the short term.
- Investment in Residue Hyrdoprocessing will be critical for refiners to gain from this transition. The choice of technology is critical.
- Economic options for shippers are not clear and modelling scenarios are essential.
- Politics continues to play a massive role.
- EVs will have an impact but not in the short term and unlikely to impact investment decisions.

Vietnam Refinery Project RHDS Challenges Faced

Nguyen Kim Manh Hoang
Technical Service Manager
Nghi Son Refinery & Petrochemical

The speaker covers the Refinery project, RHDS's KOP, challenges faced and risks involved.

Several parties are involved in the Nghi Son Refinery and Petrochemical Complex, namely: Vietnam Oil and Gas Group (PVN) of Vietnam 25.1%, Kuwait Petroleum International (KPI) of Kuwait 35.1%, Idemitsu Kosan Co., Ltd. (IKC) of Japan 35.1% and Mitsui Chemicals, Inc. (MCI) of Japan 4.7%.

The Refinery capacity is 10 million tons/year (200K barrels per stream day) of Kuwait crude oil (KEC) feedstock. The Refinery produces LPG, Gasoline 92 &95, Diesel, Jet fuel, PP, Para-xylene, Benzene and Sulfur. The total investment US$ 9.2 Billion (EPC: US$ 5.2 Billion).

It is located in Nghi Son Economic Zone, Thanh Hoa Province.

RHDS design basis

Licensor: Chevron Lummus Global (CLG) with 105,000 BPSD Capacity. Catalyst Life is 348 days.

Product properties	Target	Conversion
Sulfur	0.4 %wt.	91 %
Nitrogen	1200 ppm	57 %
Ni + V	15 ppm	83%
CCR	5 %wt.	58 %

Challenges faced and risks

Hot Hydrogen Integrity Test (HHIT)

During SU sequence review, CLG recommended to perform HHIT to check the mechanical integrity before catalyst loading. However, it is not feasible for NSRP to implement this advice due to the limitation of Hydrogen source in Vietnam market or causes long- delayed in overall Refinery start up schedule (by using CCR H2).

In addition, sponsors have no experience about HHIT. The RHDS in IKC Hokkaido has never applied HHIT because it was commissioned before CLG developed HHIT. Meanwhile, KPI has 2 trains of ARDS and 1 under developing project (UFRARDS). The application of HHIT to KPI's project is currently being discussed between KPI and CLG.

NSRP mitigation plan

NSRP discussed with CLG and secured an agreement that hot circuit operation will be carried out with Nitrogen instead of Hydrogen and heated up to Operating Temperature (350 degC) and then inspect internal condition before catalyst loading.

Reactor cooling down rate too slow

After the completion of system dry out, NSRP carried out cool down reactor to ambient temperature in order to prepare for catalyst loading. The recycle gas compressor (RGC) was put out of service since the reactor skin temperature was equal to RGC discharge temperature (@138 deg.C).

Since then, NSRP installed two fans to introduce air to the reactors. However, it took about 12 days to cool the reactor skin temperature down to 40 deg. C. The cooling rate was very low at around 0.5 deg C/h due to the reactor vaerylarge wall thickness (230mm) and internal heavy traffic.

Sharing

The commissioning schedule was delayed due to this matter. Air conditioning unit or mobile chiller should be prepared in advance to cool introduced air in order to speed up the cooling rate.

Hydro-drilling with pie plate

In the origin reactor internal dump pipe design, there are one pie plate inside this pipe.

The dump pipe purpose is to transfer spent catalyst from top bed to bottom during unloading process. However, licensor requested NSRP to install the Pie plate to prevent mal-distribution for future operation but they did not recommend to use Hydro-drilling as a catalyst unloading method.

Concern: Since NSRP had selected Hydro-drilling as a catalyst unloading method, we have a big concern whether the pie plate will have adverse effect to unloading process or not.

UFR Guard Bed Benefits and Optimizing an Existing RDS Unit

Claudio Albanese
Vice President
Technical Services eni

The presentation talks about eni's Taranto Refinery , RHU, UFR project, UFR & RHU design and unit performance.

eni Taranto Refinery: Resid Hydroconversion Unit

The Residue Hydroconversion Unit (RHU) was designed by Shell for the desulfurization, demetallization and conversion of long residue feedstock, also to produce low sulfur fuel oil (1%wt). Now the main product is the CAT FEED for FCC unit. For the future (2020), with the new legislation for the fuel oil quality, eni is studying the possibility to produce fuel oil 0,5%wt of Sulfur.

The UFR contains a high activity demetallation catalyst with high metals tolerance. The UFR consists of catalyst bed which is slightly expanded by the gas bubbles and feed liquid travelling upward in the reactor.

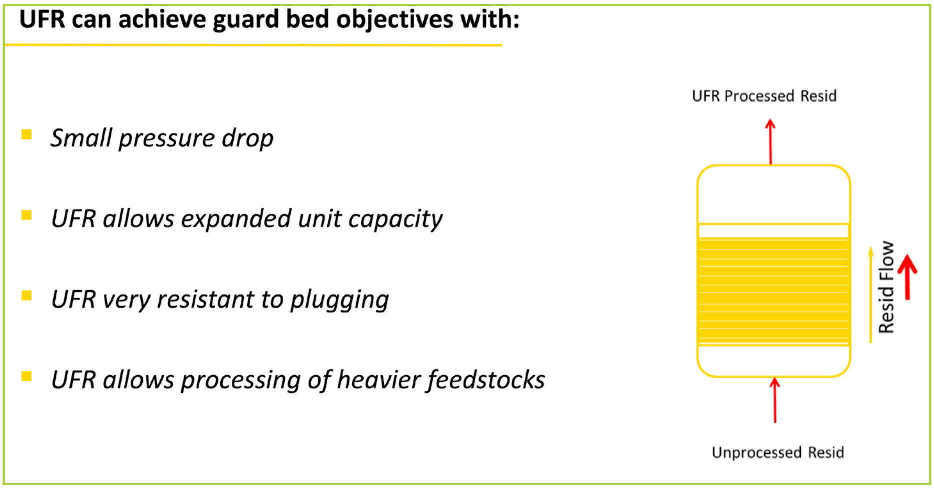
We see increase of metals content in the feed (Ni+V) from 75ppm to 108 ppm in concentration. The Metals loading increased from 300 kg/g to 430 kg/g.

UFR can achieve guard bed objectives with:

- Small pressure drop.
- UFR allows expanded unit capacity.
- UFR very resistant to plugging.
- UFR allows processing of heavier feedstocks.

RHU design data and performance

The RHU capacity is 167 tons/hr (4,000 tons/day) of feed, and the feed type of 50/50 Monte Alpi/Belaym (high feed metals 108 ppmw Ni + V).



Design catalyst life

Total 18 months for fixed bed (includes one UFR catalyst change-out, with 8 months for UFR (R-4120). The UFR has block valves and bypass line to allow for UFR catalyst change while the RHU continues to operate.

Performance (4 fixed bed configuration):

- 520°C+ Conversion: 30,8 (SOR) – 52,6 (EOR) .
- HDM: 91,86 (SOR) – 86,94 (EOR) .
- HDS: 88,07 (SOR) – 90,51 (EOR) .
- HDCCR: 62,16 (SOR) – 64,09 (EOR).
- HDN: 55,16 (SOR) – 57,63 (EOR).

Benefits of UFR

The higher metals pick-up, longer cycle length, low DP, and Intermediate change-out, all allowed eni to integrate an ISOCRACKING unit into the existing RHU high pressure loop by sacrificing 4° fixed bed reactor.

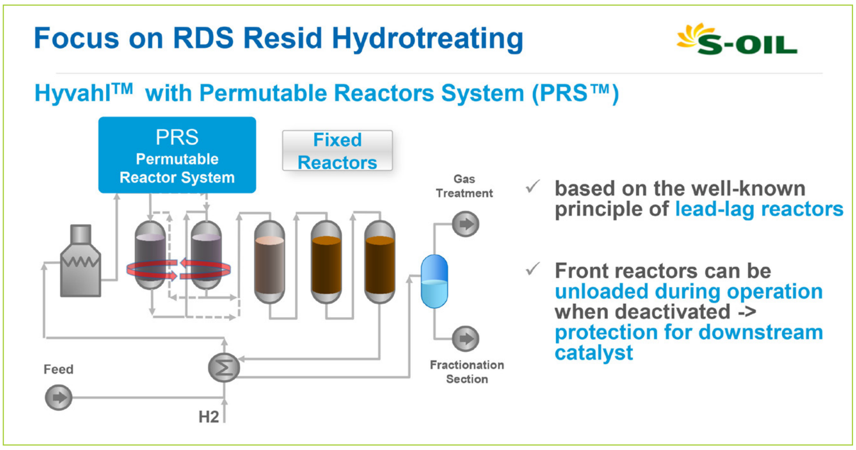
Residue Upgrading Options Towards Petrochemical Integration

Cécile Plain
Technology Team Manager - Performance Programs
Axens

Speaker focuses on HyvahlTM Technology, solutions developed by Axens Consulting Services and economic evaluation.

Focus on RDS Resid Hydrotreating

HyvahlTM with permutable reactors system (PRS™)



The system is based on the well-known principle of lead-lag reactors. The front reactors can be unloaded during operation when deactivated, It also provides protection for downstream catalyst.

PRS™ system main features

Profitable

The system has longer cycle lengths than conventional RDS, it has a higher on-stream factor and eliminates risk of pressure drop.

The conventional RDS requires full shutdown to replace the catalyst of any reactor of the loop. The PRS™ technology is an on-line front reactors catalyst change-out, without interrupting production.

Robust

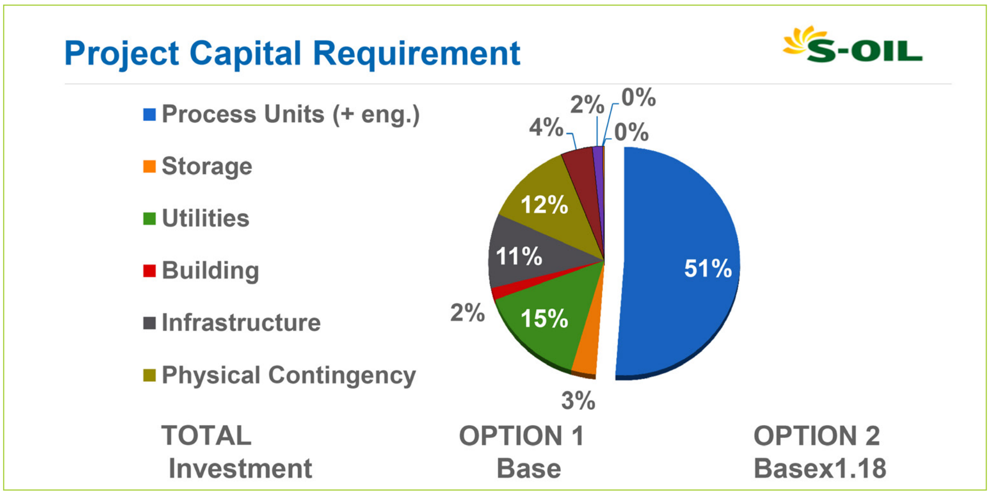
- >20 years of PRS™ industrial operation with Zero safety issues. It is proven with difficult feeds. The PRS™ has an unmatched Safety Record.
- The S-OIL has more than 20 years of experience with a wide range of feedstock quality. Several 12-month cycles at 100% VR can be applied.
- The 2 units in operation already have 90+ successful PRSTM catalyst change-outs over about 20-year period without any safety issue.
- Sustainable with high flexibility for evolving feedstock.
- Solutions Developed by Axens Consulting Services .
- Maximization of Petrochemical Production.

In 2013, Axens has been consulted to carry out a study for optimizing the residue conversion towards maximum propylene production keeping the same total crude capacity and crude origin in an existing Refinery. The main objective of this upgrading project is to minimize remaining HSFO (3.5%S) production, integrate new necessary units within existing Refinery assets, maximize propylene production, keep processing same crude oil and no Refinery capacity increase.

Maximization of petrochemical production

Axens carried out studies for optimizing the residue conversion towards maximum propylene production while keeping the same total crude capacity and crude origin in an existing Refinery. It was done successfully and minimized the remaining HSFO (3.5%) production.

Economic evaluation



Conclusion

This project has shown that additions of conversion units, even in existing complex Refinery, makes sense and has a good profitability especially for petrochemical production.

Thanks to Axens unique conversion portfolio, deep and accurate analysis of Refinery scheme is optimized, leading to the right direction for decision making.

Synthesis of Large Pore Hydrometallization Catalyst for Heavy Crude and Residual Oils

Mohan S. Rana & Faisal Al-Humaidan
Petroleum Research Center
Kuwait Institute for Scientific Research (KISR) - Kuwait

The presentation mainly covers the catalysts, support & catalyst synthesis, catalyst composition & mechanical properties, catalysts in Lower Fars-AR (HDM), effect of active metals on HDM (KU Crude), Asphaltene & Micro Residue Conversion, and catalyst selectivities (Feed KU-Crude).

Need for residue hydroprocessing

The global production of heavy oil is increasing. Heavy oil has large amounts of metals which are associated with asphaltene that required to be diffused to catalytic sites. In Kuwait, the production of heavy crude oil (i.e., LF; API=10-15°) is being started.

Hydroprocessing is the most flexible process to treat poor quality feed and produce selective yield of products with superior fuel specifications, if catalyst is designed adequately.

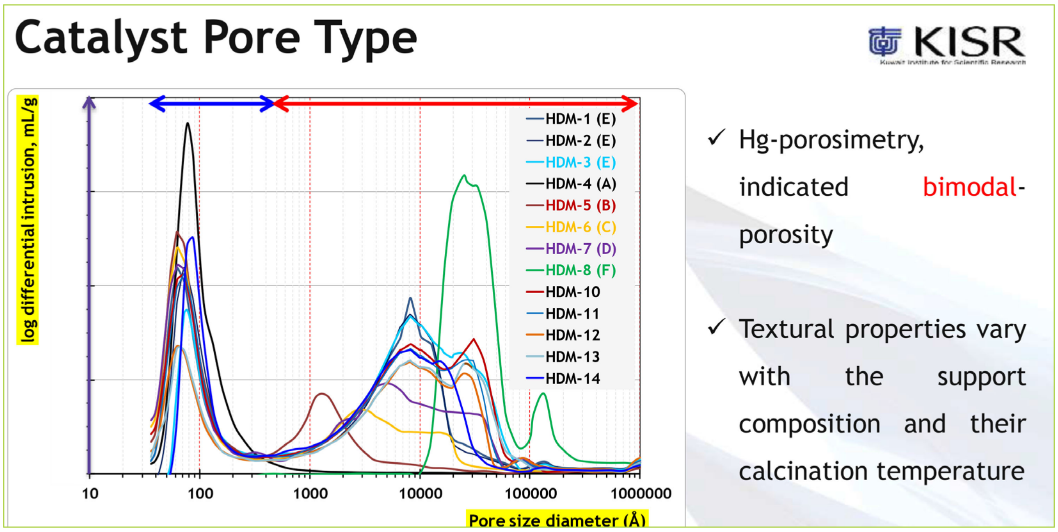
Optimization of Petroleum Refining Processes (OPRP)

Petroleum Research Center (PRC) has a world-class facility for distillation and residue testing units (Micro to Pilot Plants: 16 units; at different scales up to 500 gram catalyst loading) using single &/or double trains. It also has an excellent Petroleum Evaluation Facility (PEF); bulk analysis to possible molecular analysis; gas molecules to vacuum residue. This includes elemental analysis laboratory and basic research facility for catalyst synthesis, characterization (mechanical to bulk properties), and surface to in-situ characterization.

Effect of feed properties: process selection

Hydroprocessing can be used, if catalyst and process parameters are well designed. Asphaltene presence elevates instability in feed, product and reactor. The asphaltenes are sources of metals accretion and root cause of sediments/coke formations.

Hypothetical catalyst design



Feed properties

Feedstock Properties	Ku Crude (Mexican crude)	LF-AR
Sulfur, wt%	5.52	6.5
Total metals (Ni+V+Fe+Na)	578.84	212.3
Asphaltenes, wt%	13.4	11.2
Conradson Carbon Residue, wt%	13.2	16.3
Viscosity at 40°C, CSt	5760	6916
Density @ 65° C, g/cc	0.9543	1.02
API gravity °	16.7	7.3
Water content, wt ppm	550.8	-------
Trace analysis (SEM-EDX)		
Al, ppm	0.0	4.7
Si, ppm	12.0	7.2
Ca, ppm	15.2	27.2

Conclusion

- Through the design of support, it is possible to increase the HDM, HDS and other HDT functionalities of catalysts.
- HDM catalysts are synthesized which have bimodal type pore size distribution (i.e., meso- and macro-pore).
- The large pore catalyst typically has a high metal retention capacity, and allow to process heavier, higher-metal & asphaltene feedstocks.
- Feedstock composition significantly affects catalytic activity, catalyst stability and its deactivation.

Increase Value from Residue Hydro Processing Units

Santosh Viswakarma
Alessandro Riva
Jonnie Verwoert
Albemarle Corporation

The presentation speaks about the challenges in RDS performance management, performance optimization, and Albemarle's experience in increasing Refinery profit.

Alessandro Riva

Santosh Viswakarma

RDS performance management

Challenges in RDS are seen in pressure drop control (Fe, Ca), contaminant metals management (Ni, V), heteroatoms management (CCR, N, S) and cycle management.

The modeling for Performance Optimization can be advanced by:

- *RDS STAX® kinetic modeling, multi-variable process and loading optimization.*
- *RFCC kinetic modeling.*

Performance indicators and fine-tune RDS operation (e.g. crude selection, operation conditions) to be validated to meet the desired cycle and to maximize Refinery profitability.

Pressure drop control

(Fe) cannot penetrate the pores of normal Hydrotreating catalysts and deposits in the inter particle void. The Iron Sulfide (FeS) causes coking, catalyst agglomeration, pressure drop build up and leads to maldistribution.

Albemarle's FBR STAX® Zone Concept

HDM zone performance

The Nickel and Vanadium are mainly inside the asphaltene structure. Also, the front end demetallization catalysts are designed to have superior accessibility and tuned activity, allowing maximum hydrogenation of asphaltenes, giving deep Ni & V removal.

The latest generation demet catalyst have extreme high capacity to trap Ni&V, allowing less demet catalyst and more finishing catalyst, giving better product properties.

Transition zone performance

The transition catalysts have a sophisticated design with bi-functionality:

- Still having a high accessibility and higher hydrogenation activity, allowing asphaltene hydrogenation and Ni&V deposition inside the macro-pores.

- This is especially important during MOR and EOR operation when the front end demet catalyst accessibility is largely reduced due to metal and coke depositions.
- The higher surface activity (than HDM) allows hetero-atom impurity removal (especially HDS HDCCR in the resins).

Finishing zone performance

- Superior pore architecture and ultra high activity reaction sites for high HDS/HDCCR/HDN in resins

Summary & conclusions

Four steps to increase value in RDS

Catalyst	System State of the art catalysts combined with a deep understanding of different reactions and reaction zones, taking into account the desired reaction paths
Multi Variable RDS Process	Temperature strategy, feed quality (crude selection), product yields, product qualities and cycle length
Multi Units approach in the Refinery	Identify routing of the RDS products and determine influence on downstream processes and final products
Economic Optimization	Overall value assessment by assigning feed and product prices and calculating the benefit of the combined product streams (e.g. RDS/ RFCC, typically most value is created in the RFCC and not in the RDS)

Performance Comparison (Hot High Pressure Separator Bottoms)

	Cycle	
	Competition	Albemarle
Cycle, months	12	12
Ni+V, mg/kg	**15**	16
SG, kg/m3	930	930
CCR	5.5	**5.3**
Sulfur	0.55	**0.50**
	Consecutive Cycle	
	Competition	Albemarle
Cycle, months	15	15
Ni+V, mg/kg	15	15
SG, kg/m3	930	**927**
CCR	5.5	**5.3**
Sulfur	0.55	**0.50**

The value the RDS brings is mainly achieved in the units handling the downstream products from the RDS (RFCC or Coker).

When optimizing the RDS performance, the operation constraints and the impact on the downstream units must be taken into account.

Albemarle's multi-variable optimization tools, based on the FBR STAX® kinetic model is a valuable tool to increase Refinery profitability and it has proven to increase value.

Albemarle's Residue Hydroprocessing KFR catalyst have proven to increase Refinery profit.


Jonnie Verwoert

Improving Residue Bottoms Upgrading Utilizing Up Flow Reactor Technology

Eng. Robert Wade
CHEVRON AND CB&I JOINT VENTURE

The speaker covers the Refinery project, RHDS's KOP, challenges faced and risks involved.

CLG residue Hydrotreating technology (RDS) success

CHEVRON LUMMOS GLOBAL (CLG) has licensed 80% of Residue Hydrotreaters worldwide in the past 20 years, 19 new CLG RDS Units started up in the past 20 years. Of the 24 RDS's feeding RFCC, 18 were licensed by CLG (75%). Many repeat customers include KNPC, SK, ENI, & FPCC.

ARDS/VRDS Hydrotreating

ARDS (Atmospheric Residue DeSulfurization) or VRDS (Vacuum Resid DeSulfurization) is a high pressure catalytic Hydrotreating process.

Possible feeds for the ARDS/VRDS include: Atmospheric and Vacuum Residue, Vacuum Gas Oil, Heavy Coker Gas Oil/FCC Cycle Oils and De-asphalted Oil.

The residual product is used for IMO Low Sulfur Fuel Oil (0.5 wt% sulfur), RFCC feedstock either for gasoline market or to produce propylene for petrochemicals feedstock, and as a feedstock to Hydrocrackers and Cokers.

Typical ARDS Feed Properties and Product Properties

CLG
Chevron Lummus Global
a joint venture between Chevron and CB&I

Feed properties	
API	10-18 (S.G:1.0-0.946)
Sulfur, wt%	3.5-5.0
CCR, wt%	11-16
Ni + V, ppm	60-120
Nitrogen, ppm	2000-3500
Iron, ppm	10
Typical Target Product Properties	
Sulfur, wt%	<0.5
CCR, wt%	<7
Ni + V, ppm	<20
Nitrogen, ppm	<1750
Iron, ppm	<10

- Cycle length is typically 12 months

UFR Technology

- Fixed Bed Characteristics.
- RDS/VRDS is a high pressure catalytic hydrotreating process.
- Utilizes downflow trickle bed reactors at high pressures and low space velocities.
- Impurities are removed as hydrogen sulfide and ammonia into gas phase.
- Metals such as nickel and vanadium are catalytically removed, but they stay and deactivate catalysts.
- Catalyst systems are complex consisting of multiple catalysts.
- Grading materials to mitigate pressure drop build up.
- HDM, Transitional, and HDS catalysts.
- High gas to oil ratios are critical to achieving target DP/length and maximizing H2 PP from inlet to outlet.

UFR Characteristics

The UFR is positioned upstream of the RDS/VRDS downflow reactors. It utilizes liquid packed up flow and can be designed with 1, 2 or 3 catalyst beds. It can also be designed with isolation to enable MOR UFR change with no processing loss (demonstrated).

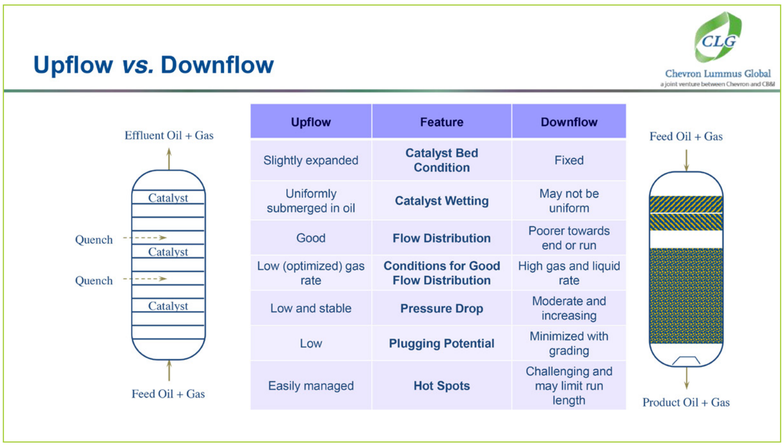
UFR primary function is metals removal – hydrodemetalation (HDM). The gas rates are less than half of FB reactors. It has low DP and remains stable from SOR to EOR.

Objective of upflow reactors: Guard Bed

If the unit operating at maximum rate, it will be difficult to increase rate/severity, and feed options are limited.

The upflow reactors are popular for retrofits due to low DP for incorporation in existing loop, the RGC compressor modification is unnecessary and additional HDM capacity is needed for tougher feeds (VR).

An Upflow reactor upstream of Fixed Bed RDS train is added to help mitigate FB guard DP due to soluble metal impurities. The high feed metals and difficult feeds benefit from UFR guard reactor.



Upflow	Feature	Downflow
Slightly expanded	Catalyst Bed Condition	Fixed
Uniformly submerged in oil	Catalyst Wetting	May not be uniform
Good	Flow Distribution	Poorer towards end or run
Low (optimized) gas rate	Conditions for Good Flow Distribution	High gas and liquid rate
Low and stable	Pressure Drop	Moderate and increasing
Low	Plugging Potential	Minimized with grading
Easily managed	Hot Spots	Challenging and may limit run length

Only CLG has long term history with high metals in RDS Feed, with feed metals ranged from 300ppm to 400ppm. The Reactor Module Run Life was limited to 6 Months due to down flow Guard Reactor metal sulfide plugging and coking.

البترول الوطنية

KNPC

إحدى شركات مؤسسة البترول الكويتية

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