KNPC TECH

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شركة البترول الوطنية الكويتية

KNPC

إحدى شركات مؤسسة البترول الكويتية

A Subsidiary of Kuwait Petroleum Corporation

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Editor's Note

On behalf of the Corporate Communication Department team and myself, I am pleased to resume the release of the KNPC TECH publication after a forced interruption due to the pandemic situation that has hit Kuwait and the entire world and has forced us as a Department to set certain priorities in place to support the overall business requirements.

As you are all aware, our KNPC TECH publication relies heavily on work papers submitted by our range of professional Employees at local and international Conferences. Unfortunately, such Events were dramatically placed on hold or cancelled due to the pandemic situation. None-the-less, we managed to maintain the same level of content despite the situation and since the featured articles are research in nature, the time lapse becomes irrelevant.

With the nearby closure on the Clean Fuels Project, our Company enters a new era with newly commissioned Units whereby new technologies are expected to drive us through new frontiers. We selected a number of articles to cover certain aspects of the new Units, mainly the Atmospheric Residue Desulphurization (ARD) that is expected to add sizeable value to Kuwait natural wealth. With our new ARD Units, in addition to those at Al-Zoor Refinery, Kuwait will now occupy the world's largest ARD capacity.

Other topics feature the Ultra-Low Sulfur Diesel currently produced in our Refineries, which is expected to provide us the competitive edge in the largest international markets. Featured articles will in parallel concentrate on certain issues and challenges encountered in our daily operations, ranging from detecting Corrosion and Cracks in the Refinery Plants, to Hydrocarbon Loss Measurement methodology, Gas Chromatography, Energy Efficiency, and many other technical related issues.

With the commissioning of our Mega Projects, I am very optimistic that we shall have more leading edge content and areas to dwell on to feature in our upcoming issues.

I urge you to spare few minutes of your time to browse through this issue of the KNPC TECH publication as we look forward to receive your input and feedback on how can we improve the content by sharing your innovative and creative ideas with my team.

Khuloud Saad Al-Mutairi
Manager Corporate Communication

Ultra-low Sulfur Diesel

Automotive Gasoil, commonly known as Diesel, is one of the most widely used transportation fuel. Its quality, particularly Sulfur content, has always been a prime concern in environment protection and pollution abatement.

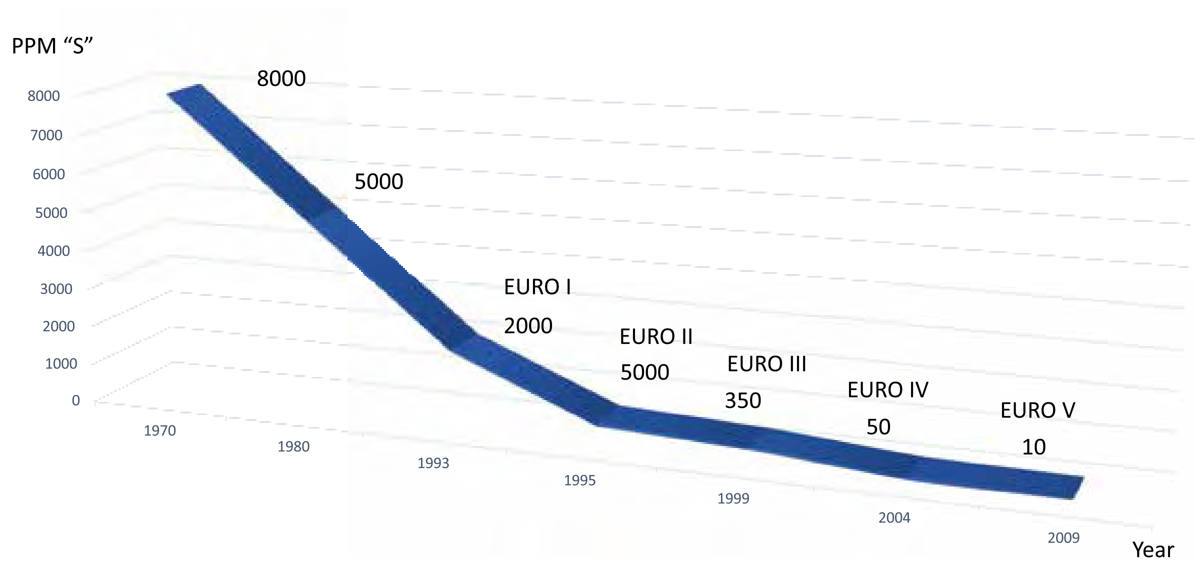
By Nawal Al-Badou
Team Leader Operational Planning – MAB

The sulfur in diesel causes particulates and soot, which are the main contributors to air pollution. In order to minimize the effect of these pollutants and improve the air quality, the specification limit of Diesel Sulfur is being reduced progressively up to 10 ppm (Ultra Low Sulfur Diesel - ULSD). Lower sulfur content in diesel substantially lowers the harmful emissions from diesel combustion engines, which in turn also reduces the release of greenhouse gases, harmful to Ozone, from the vehicle exhaust.

The standards for diesel have substantially changed since the introduction of Euro specifications in 1993. The sulfur levels in diesel have become more stringent going down from 8000 ppm in the seventies to Ultra Low Sulfur Diesel 10 ppm today. Passenger cars and heavy-duty engines have also undergone substantial modifications following introduction of regulated emission requirements and introduction of Euro grades.

Since 1998, Clean Air For Europe (CAFÉ) program was developed regarding fuel along with matching emerging emissions technology. Airborne particulates and ozone (formed by reaction of HC & NOx) emitted by road transport were identified as being most concern to human health.

Diesel Sulfur SPEC change



Diesel fuel parameters affecting vehicle performance are as follows:

- Lowering aromatics decreases hydrocarbons (HC) and Carbon Monoxide (CO) emission
- Decreasing density of diesel reduces HC, CO & Nitrogen oxides (NOx)
- Decreasing Poly-aromatics of diesel reduces HC, NOx and PM
- Increasing Cetane rating reduces HC and CO

De-Sulfurization of transportation fuels reduces emissions of sulfur oxides (SOx), which cause acid rain. It also reduces particulate matter (PM) emissions, which cause respiratory illness like emphysema and bronchitis. Sulfur removal improves the performance of the particulate traps on diesel engines and the catalytic convertors used to reduce emissions of hydrocarbons and NOx from automobiles.

Considering above global requirements, KNPC has also taken requisite measures under Clean Fuel Project (CFP) and accordingly, its first Diesel Hydro-treater, Unit-216 has been commissioned at MAB in September 2019 for producing ULSD of 10 ppm sulfur, meeting Euro-V grade and other international specifications. This is a quantum leap in KNPC's overall commitment for environment protection.

Diesel Unit 216 produces ULSD

MAB Refinery Quarterly Newsletter

Prepared by: Operational Planning Team – MAB

MAB performance

Mina Abdullah Refinery (MAB) performance during the annual Quarter (April-June 2020) was fine with the implementation of key PIP ideas, which resulted in total gain of US$ 9.7 million. Major items include:

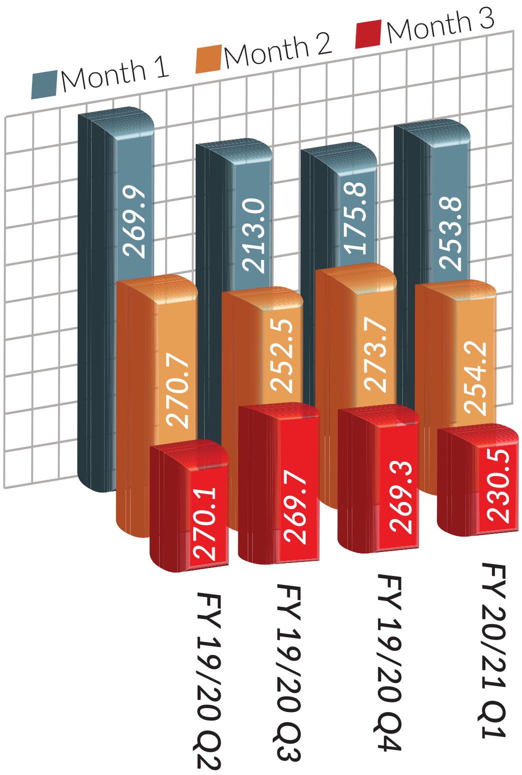
- RCD-02 operated Black oil service with economic benefit of approximately US$ 3.3 million
- Bunker Fuel oil production with economic benefit of US$ 6.4 million
- MAA Coker Kero receipt/processing started in U-15/16 before CFP KHT-115 commissioning
- Cold Naphtha processing @ 1.2 - 1.5 KBPD is being maximized in U-17 to clear the inventory

Highlights

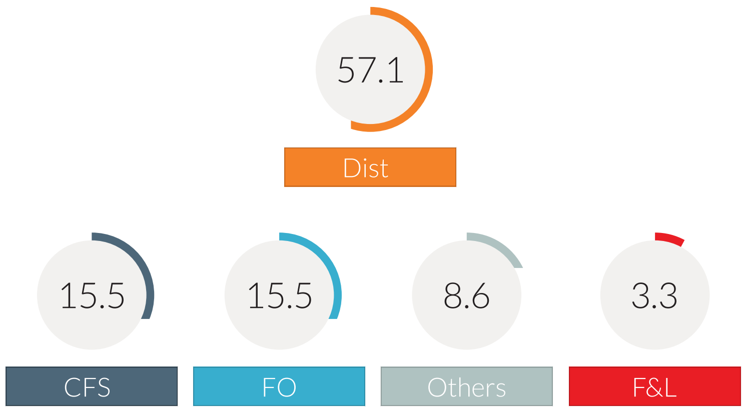
The first mixed cargo of MAA Coke and MAB Coke was exported on 24th May, 2020 in V/L Pola Elisaveta.

The Fractionator tray repair jobs in CDU-11 were completed in April 2020 with average feed rate during the Quarter was 165.8 KBPD. As well, the HCR-14 Catalyst change/M&I commenced on 23rd Feb 2020 and was completed on 18th April 2020.

The RCD-02 was shut down from 3rd May till 27th May 2020 due to C-01 seal oil leak. Thereafter, it was kept idle till 11th June as per KPC request.



Crude unit feed rates



Product yields wt%

Latest price update / AG Platts

- Crude price average was US$ 25.6 /Bbl during the Quarter
- LPG price was higher than Naphtha for the Quarter (average US$ 66.8 / ton)
- ULSD was higher than ATK (average US$ 7.3 /bbl)
- Fuel Oil prices average was US$ 157.0 /ton
- Bunker Fuel Oil prices average was US$ 234.6 $/ton

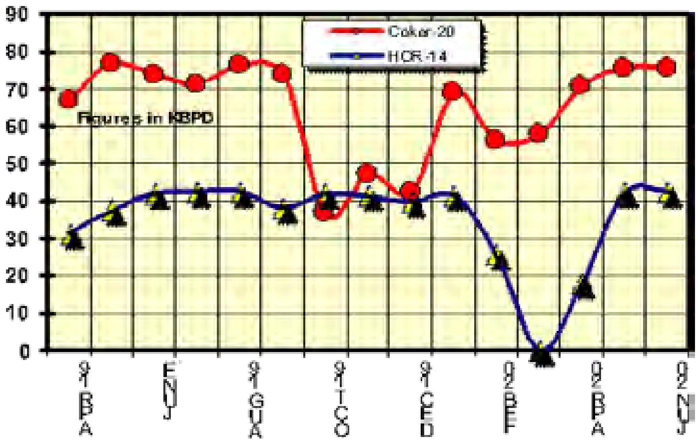
Global news

Due to lower demand as a result of Covid-19, major observation were recorded, mainly the maintained lower oil prices during the Quarter. The Gasoline cracks average was US$ 3.0 /bbl, Jet cracks average was US$ 0.61 /bbl, Diesel cracks average was US$ 7.9 /bbl, Fuel Oil cracks average was US$ -1.1 /bbl, and the Bunker prices were higher than Fuel Oil prices by Average US$ 77.6 /t.

Performance update

Q1 2020

Crude throughput	:	**246.2**	**KBPCD**
Distillate yield	:	**57.1**	**Wt%**
Fuel Oil	:	**15.5**	**Wt%**
EII	:	**81.8**	
Process units utilization	:	**85.4**	**%**



Conversion Units' feed rates

CDU Unit 111 - MAB

CDU Unit 111
264,000 B/D
CFP - MAB

Ship Tracking System

The Ship Tracking System (STS), as the name suggests, is meant for effective monitoring of ship loading operation, identifying time lapsed while each sub-operation, timely communication to stakeholders for next step and finally lead to achieve objective of finishing the operation in a given stipulated time frame.

Khalid Mane Al-Ajmi
Team Leader Operations, MAA

STS tool is generated from brainstorming process by Area-8 "Oil Movement Operation" MAA. The development started from analyzing Product Shipment Customer Satisfaction Index (PSCSI) monthly reports where it was observed that ship delay hours were, due to various reasons, on increasing trend, which became a matter of concern for Top Management.

In order to address the issue, Area-8 Oil Movement Operation suggested to establish a system to track ship loading operations effectively starting from tank filling operations to the departure of the ship from MAA-Piers. The system was developed in coordination with relevant divisions and implemented successfully with necessary training to stakeholders.

Initially during August-2018, the ship delay hours were analyzed and recorded using excel sheet, which was created by Area-8 Oil Movement Operation The sheet highlighted some common repeated reasons giving the opportunity to optimize tank farm-terminal operations and cargo planning.

Over a period of time various discussions, meetings were held between the stakeholders (Operations Planning division, Oil Accounts, Laboratory, Area-8 Oil Movement Operation, KOC, Maintenance) to get rid of delays while loading operations. Each department's inputs were considered and ship tracking was started more precisely mentioning exact reasons for the delay and department responsible for that. For each successive months, Area-8 Oil Movement Operation prepared such records for effective tracking by gathering data from various departments.

In March-2019, Area-8 Oil Movement Operation suggested Manufacturing Optimization Group (MOG) to develop a system so that each stakeholder department can feed their data on common portal as and when sub activity related to shipping operations finishes. MOG started developing a system with necessary aids from Area-8 Oil Movement Operation and all stakeholders.

The system was developed and made live on KNPC portal in Nov-2019. Each section (Operations Planning, Oil Accounts, Laboratory, and Area-8 Oil Movement Operation) has been trained for data entry to fill their part, while the system captures the date and time, and if there is any delay for data entry, an alarm will be issued by the system. In the end of the process, the system will count the total loading hours and shows the delay highlighted with red background, while green highlighted background shows no delay indication.

Area-8 Oil Movement Operation (Vessel Delay Analyses Excel Sheet)

	Vessel	Jetty	Berth No.	Prod-I Prod-II Bunker	QTTY MT	Rate MT/ Hr.	Tanks allocated	Filling complet. Time	Arrival Time/ Date	Commnce Loading Time/Date	Complet. Loading Time/ Date	Berth vacated Time/Date	Delays From/To Reason	Delay Hrs/ mn	Delay Analysis	Action
1	STI Beryl	NP	15	ATK	23620	1900			8:30 hrs 2.8.18	12:45 hrs 2.8.18	15:35 3.8.18	8:55hrs 3.8.18	No delay			
2	Zing Yu	NP	15	Naptha	54569	3300	470/ 467/ 468	30/12:30 2/10:30 3/5:15	14:14 8.8.18	20:05 3.8.18	1:25 5.8.18	5:00 5.8.18	1- from arrival at anchor 22:51/29.7.18 to accepted 00:01/30.7.18 before range	2:10	Last tank (TK 468) filling completed at 3.8.2018 / 5:15	OPAB & OPLN
3	Spottail	NOP	6	PCNA	55000	2000	467/ 468/ 469	28/11:55 29/11:55 29/23:50	11:45 30.7.18	16:25 30.7.18	00:50 1.8.18	4:25 1.8.18	From accepted 00:18/28.7.18 to 4:25/30.7.18 cargo not ready	52:22	Last tank (TK 468) filling completed at 29.7.18/17:20	OPAB & OPLN
4	Kaifan	NOP	5	HSD Bunker	32600 650	1200	668 Bunker 702	2/17:20	20:30 3.8.18	1:05 4.8.18	6:25 5.8.18	10:45 5.8.18	From NOT accepted to 00:01/3. 8.18 cargo not ready	17:39	TK-668 Filling completed 2.8.18/17:20	OPAB & OPLN
5	Hafina Aus	NP	16	ATK	8445	870			12:00 4.8.18	6:40 4.8.18	4:35 5.8.18	8:40 5.8.18	No Delays			
6	Maersk MIY	NP	15	GO	44000	1270	822 669	6/10:20 5/15:40	20:30 7.8.18	1:40 8.8.18	16:25 9.8.18	20:35 9.8.18	From 00:01 5/8/18 to 16:45/7.8.18 cargo not ready	58:53:00	TK-668 Filling completed 6.8.18/10:20	OPAB & OPLN
7	STI Ville	NOP	5	ATK	41503	2400			2:05 8.8.18	6:55 8.8.18	14:40 9.8.18	18:40 9.8.18	No Delays			
8	Nord Larspur	NOP	3	PCN	55000	2000	469/ 468/ 467	5/19:20 6/11:20 7/23:10	7:50 8.8.18	12:30 8.8.18	23:30 9.8.18	3:10 10.8.18	From 3:42/4.8.18 to 6:30/8.8.18 cargo not ready	98:48	TK-668 Filling completed at 7.8.18/23:10	OPAB & OPLN

STS final report

Vessel	NORDIC TRISTAN	CAPTAIN JOHN	AL SOOR II	SIFSAFAH	NEW ADVANCE
Start Layday	29/07/2020	29/07/2020	31/07/2020	02/08/2020	04/08/2020
End Layday			01/08/2020	03/08/2020	
Product	ATK	FULL RANGE NAP	GAS OIL	GAS OIL	Low Viscosity Cutter Stocks
Parcel Size (MT)	32.20	54.40	21.50	21.40	80.00
Item No	0037A	0106	0097A	0042	0382
Spec No	3001 A	1031	4052 PSO	4067	
Tank Allocated	61-532,61-533	34-424,61-468	61-667	61-668	61-753,61-754,22-758
Berth	LP-06	LP-05	B-15	B-16	LP-04
Fill Rate	3200	4700	1700	1250	0
Shoreline sample request		29/07/2020 16:35:00	31/07/2020 22:15:00		
Shipping system readiness					04/08/2020 22:00:00
NOR tendered	31/07/2020 11:55:00	30/07/2020 16:18:00		02/08/2020 00:01:00	05/08/2020 00:01:00
NOR Accepted	31/07/2020 17:40:00	30/07/2020 19:10:00		02/08/2020 00:01:00	05/08/2020 02:15:00
Berthing Fax Sent	31/07/2020 11:45:00		31/07/2020 22:30:00		
Pilot on-board	31/07/2020 14:05:00	30/07/2020 16:35:00	01/08/2020 02:50:00	02/08/2020 14:30:00	05/08/2020 00:01:00
Arrive at berth	31/07/2020 15:50:00	30/07/2020 17:40:00	01/08/2020 04:15:00	02/08/2020 15:40:00	05/08/2020 01:00:00
Inspector Notified	31/07/2020 15:50:00	30/07/2020 17:40:00	01/08/2020 04:15:00	02/08/2020 15:40:00	05/08/2020 01:00:00
Inspector Arrived	31/07/2020 16:50:00	30/07/2020 18:40:00	01/08/2020 04:40:00	02/08/2020 16:00:00	
Shore tanks gauging	31/07/2020 17:50:00	30/07/2020 19:40:00	01/08/2020 05:00:00	02/08/2020 16:20:00	
All fast at berth	31/07/2020 17:40:00	30/07/2020 19:10:00	01/08/2020 05:10:00	02/08/2020 17:10:00	05/08/2020 02:15:00
Gangway placed	31/07/2020 17:50:00	30/07/2020 19:25:00	01/08/2020 05:25:00	02/08/2020 17:25:00	05/08/2020 02:25:00
VSL Quarantine Clearance	31/07/2020 17:50:00	30/07/2020 19:25:00			
VSL Customs Clearance	31/07/2020 18:50:00	30/07/2020 20:25:00	01/08/2020 06:25:00	02/08/2020 18:25:00	05/08/2020 03:25:00
Loading Master onboard	31/07/2020 18:50:00	30/07/2020 19:30:00	02/08/2020 06:25:00	02/08/2020 18:25:00	05/08/2020 03:25:00
Ships Tanks Inspected	31/07/2020 20:30:00	30/07/2020 21:00:00	01/08/2020 08:20:00	02/08/2020 19:40:00	05/08/2020 05:00:00
Hose(Loading Arm) Connection	31/07/2020 20:00:00	30/07/2020 19:45:00	01/08/2020 07:00:00	02/08/2020 19:40:00	05/08/2020 04:00:00
Loading Commence	31/07/2020 20:40:00	30/07/2020 21:10:00	01/08/2020 08:25:00	02/08/2020 19:50:00	05/08/2020 05:10:00
Suspended for Sampling	31/07/2020 21:10:00	30/07/2020 21:55:00	01/08/2020 08:40:00	02/08/2020 20:25:00	05/08/2020 05:30:00
Loading resumed	31/07/2020 23:45:00	30/07/2020 23:40:00	01/08/2020 10:45:00	03/08/2020 00:20:00	
Loading completed	02/08/2020 00:20:00	01/08/2020 16:55:00	02/08/2020 01:30:00	04/08/2020 07:40:00	
Loading Arm (Cargo hose) disconnected	02/08/2020 03:30:00	01/08/2020 20:30:00	02/08/2020 05:00:00	04/08/2020 11:30:00	
Vacate Berth	02/08/2020 04:20:00	01/08/2020 21:30:00		04/08/2020 13:05:00	
Cargo Preperation Time	261:3:17	237:51:23	NA	95:19:18	173:39:59
Waiting Time (6 Hours)	3:0:0	2:0:0	NA	19:49:0	2:55:0
Loading Time (30 Hours)	27:40:0	43:45:0	17:5:0	35:50:0	NA
Accounting/Documentation (6 Hours)	4:0:0	4:35:0	NA	5:25:0	NA

Demurrage stands for the charges payable to the owner of a chartered ship on failure to load or discharge the ship within the time agreed by KPC and customer. Any time delay in performing the activities related to ship loading operation directly or indirectly may lead to demurrage charges to KNPC-MAA. In order to eliminate/reduce such charges, each activity must be well planned and well executed in stipulated time frame by respective departments.

While initial tracking of shipping, Area-8 Oil Movement Operation found that for many instances, reasons were mentioned as cargo not available. Through brainstorming, Area-8 Oil Movement Operation found that there were many reasons behind cargo unavailability like unit shutdown, cargo off spec, quality certificate delay, sampling delay, tank shutdown in emergency, etc. Each reason was analyzed with relevant divisions to put a hold on increasing trend of delay hours. Moreover, Area-8 Oil Movement Operation suggested establishing a system where all stakeholders can input the details pertining to their activity so that at the end a consolidated report can be generated through the system for effective analysis of delay hours.

Time boundation for each activity was not formalized initially. Through successive discussions with various departments, the same was standardized.

Product ship tracking systems attributes

- Provides a platform to know the current status of ship and time consumed for each activity completed.
- Makes a comprehensive tool that saves on time for data collection for the time consumed related to each task.
- Automatically calculates time consumed for activities and total time.
- Facility to enter remarks for more clarification by relevant divisions.
- Facility to upload sailing telexes and other documents for oil accounts.
- Facility to generate a report in PDF format for each ship with all minute details (i.e. activity start date/time, end date/time, time spent, remarks, etc.).

Through careful observation of report generated by STS, a conclusion can be drawn easily for the activities which consume time more than stipulated, with necessary further investigation can be initiated to avoid future repetition.

The STS is a powerful tool commonly shared by all stakeholders and utilized for easy and effective tracking of each ship and its loading operations. A weekly/monthly/yearly report can be prepared utilizing the data to know/control the delay hours, which subsequently contributes to the elimination/reduction in demurrage charges to the compny. Moreover, such data shall remain in the system for the future references as well.

IMO and its Effect on the Oil Market

On 27 October 2016, the International Maritime Organization (IMO), a specialized agency of the United Nations (UN) devoted to the safety and security of shipping and marine pollution, announced that beginning on 1 January 2020, the maximum sulfur content permitted in marine bunker fuel will be reduced from 3.5% by mass (m/m) to 0.5% m/m on a global basis.

Naila Baqer
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Introduction

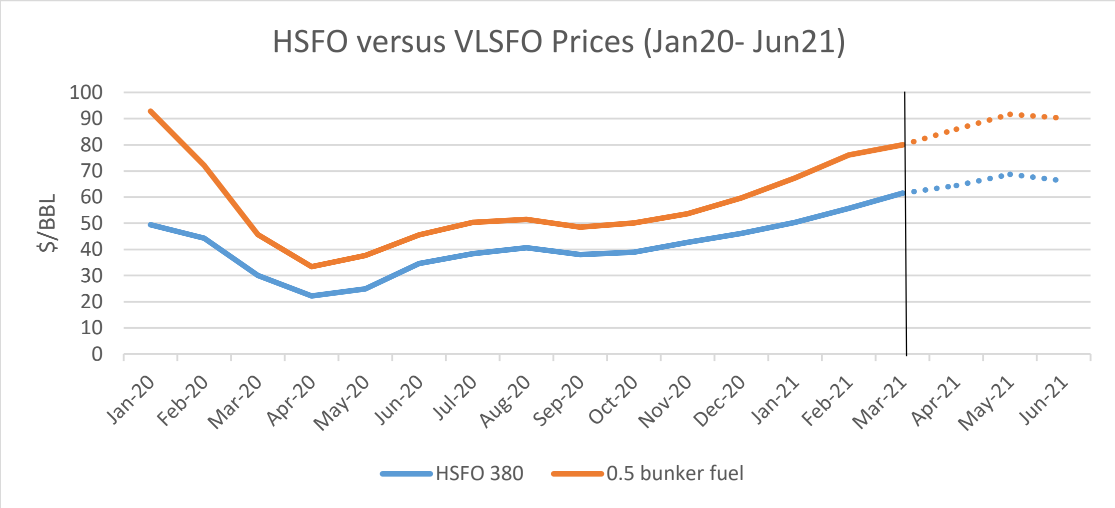
The IMO sulfur content regulations will have a very significant impact on both the refining and shipping industries. The refining industry has three different options: alter its current product slate, increase the supply of low-sulfur fuels and manage excess.

Shipping companies will have to choose between one of three main pathways if they are to comply with the sulfur cap:

1. Switch to purchasing low-sulfur bunker fuel,
2. Install exhaust gas cleaning systems (scrubbers),
3. Switch to alternative fuels such as LNG.

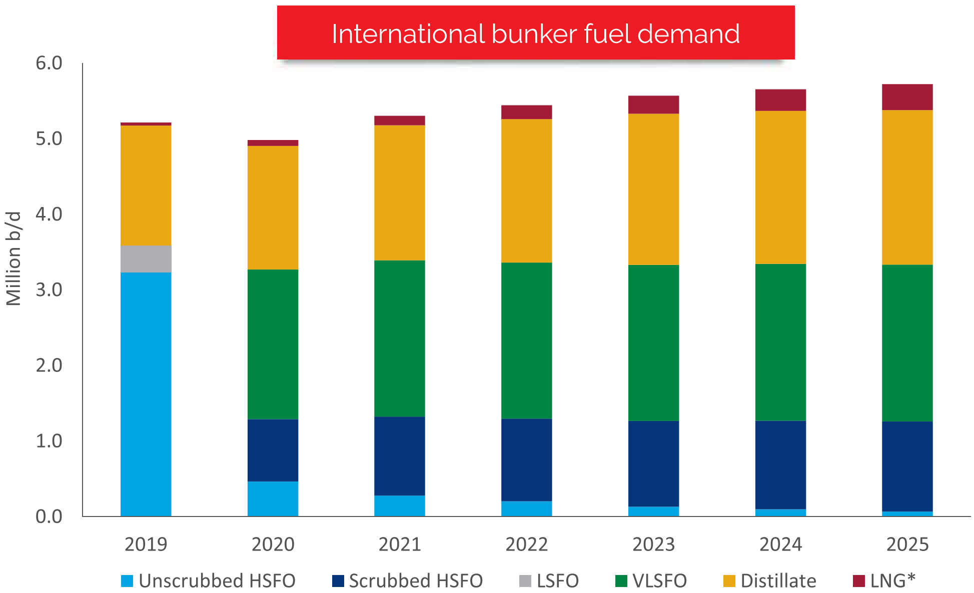
The greatest uncertainty remains the level of compliance with the new regulations since various countries with a coastline are not signatories to the IMO treaty, and it is unclear to what extent they will enforce the new regulations. Nevertheless, many refiners and bunker suppliers made announcements about their plans to produce and/or deliver 0.5%S VLSFO, but few provided firm details on specifications of their blends, or on their expected cost.

The initial average price premium of LSFO over HSFO in January 2020 was $43/BBL, gradually declining to average almost $29/BBL for 1Q'20. As VLSFO supply improves, differentials dropped further, averaging $19/BBL in 1Q'21. This registers a drop of $10/BBL year-on-year. However, differentials are expected to widen again in the range of $23 – 27/BBL during 2021 as middle distillate demand rises, refinery throughput increases and supply of HSFO becomes plentiful with vaccination programs expanding.

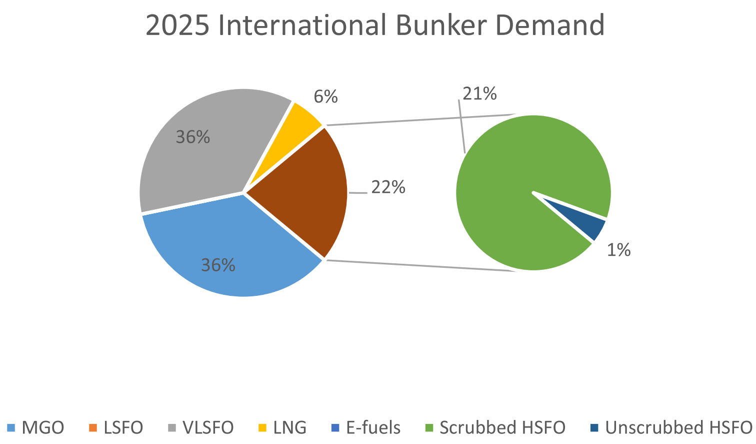


Also following the IMO implementation in January 2020, there was a strong call on gasoil resulting in a significant increase in the consumption of 0.5%S compliant marine gasoil (MGO) which immediately dissipated by Feb.'20 due to Covid-19.

However, while the share of MGO in the bunker market will for some time remain at current levels, there are now concerns about the increasing middle distillate component in VLSFO blends. This has emerged because of the large increase in availability of middle distillates following lower levels of demand for gasoil and jet which have started from 2Q'20. Nevertheless, IHS projects that VLSFO will account for 35% to 40% of total bunker fuel consumption worldwide.



Source: Wood Mackenzie



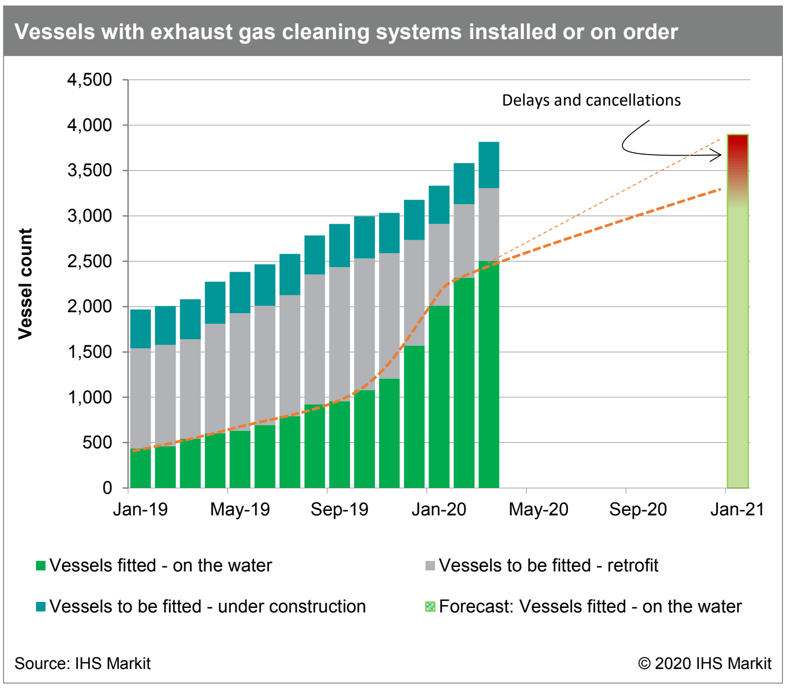
Compliance by region

Installing a scrubber is a cheaper option to comply with the global Sulfur cap than switching to MGO. While LNG is particularly attractive for vessels, it is not available at all ports. The daily demand of HSFO has dropped by about two mbpd from year 2019 to 2020. Low sulfur fuels have displaced this drop of HSFO.

Despite the growing compliance to IMO regulation, and as COVID-19 is still affecting shipping's bottom line and the temptation to pick up cheaper non-compliant material cannot be ignored.

VLSFO penetration, at the expense of Marine Gasoil, has reached approximately 60% of the 0.50% sulfur product pool (vs. 50% in 4Q19), while COVID-19 reduce total bunker fuel consumption, denting gasoil demand further. There were a total of 2,009 vessels fitted with scrubbers by January 2020. Scrubber uptake for year-end 2020 was revised downwards by 300 ships to reach 3,600, as ship-owners postpone or even cancel orders. The volume of scrubbed HSFO was expected to grow steadily during 2020, but the current Covid-19 pandemic disturbed the whole process.

Pre-Covid-19, the shipping industry had adopted a new motto where "Coming together is a beginning. Keeping together is progress. Working together is success"; collaboration is necessary.



Singapore accounts for over half of the Asian bunker market, and represents over 70% of Asian bunker sales growth since 2000. Global volume of scrubbed HSFO is expected to grow steadily after 2020, rising to around 1.2 mbpd by 2025, half of it is bunkered in Asia.

90% of HSFO is expected to be scrubbed from 2025 onwards, when there is near full compliance with the 0.5% global sulfur cap. Most scrubbed fuel oil is consumed outside Europe and North America.

Supply and demand of HSFO & VLSFO

Relatively weak gasoline cracks, but higher prices for low Sulfur residues for blending into VGO will incentivize some refiners to divert VGO away from FCC units and into the bunker fuel pool. Europe needs to clear its fuel oil surplus to other regions for upgrading in Asia and the USGC. The Russian fuel oil surplus falls slightly.

It is likely to export low Sulfur residues to other markets.

However, despite the significant uptake of VLSFO and the large reduction in HSFO consumption in the bunker pool, the VLSFO-HSFO price spread did not continue to widen into 2020, as previously anticipated.

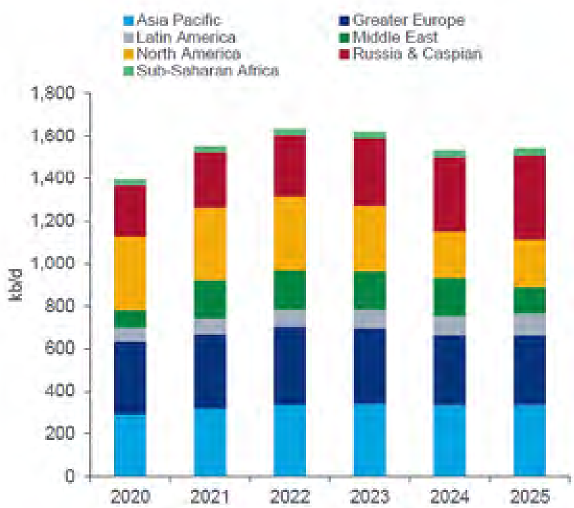
Ultimately, the combination of large-scale strategic buying of VLSFO ahead of the January 2020 implementation date, and much greater supply than anticipated from the refining system, caused somewhat of a 'supply overhang' in VLSFO markets.

HSFO markets have also defied expectations with HSFO prices showing great resilience since January 2020 due to a combination of the following:

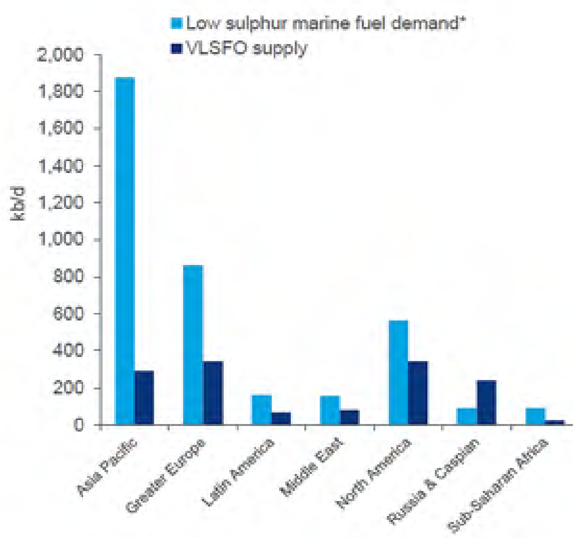
a) The success of the global refining system in minimizing HSFO yields.
b) A large increase in interest from US refiners in processing HSFO as feedstock.
c) The substantial uptake of scrubbers.
d) Recent refinery run cuts owing to the impact of the Covid-19 pandemic and spring maintenance.

Pre-Covid-19, low sulfur marine fuel demand in Asia was expected to rise by 730 kbpd to 1.9 mbpd in 2020. While some imports of VLSFO from other regions are expected, the rise in distillate use was expected to be around 800 kbpd. In Europe, gasoil use in the marine sector was expected to rise by 100 kbpd from 290 kbpd in 2020. North America was expected to see only a 20 kbpd rise in gasoil use in bunkers in 2020 from 270 kbpd. These expectations have now been pushed to 2022.

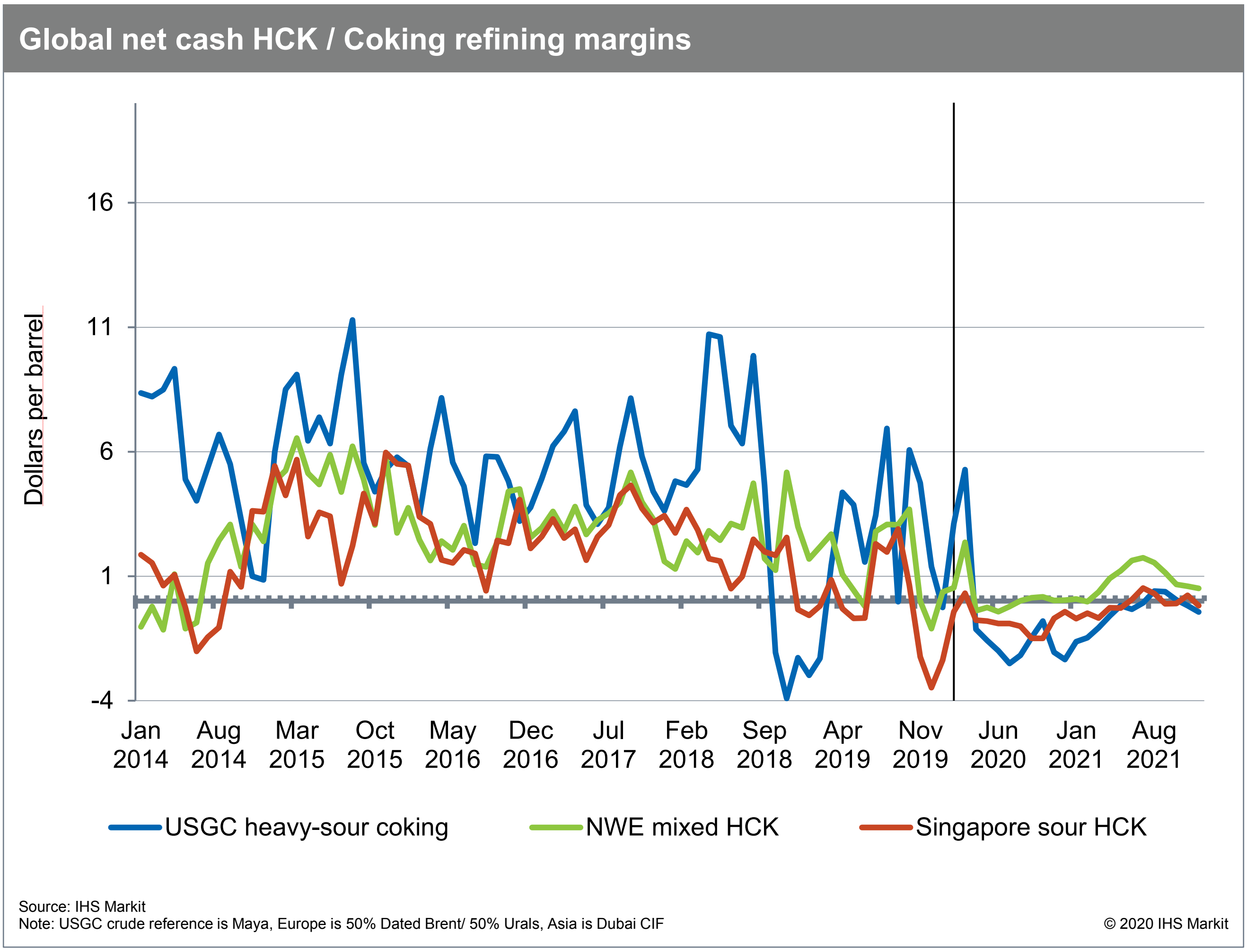
Global VLSFO supply forecast by region (kbpd)



VLSFO demand Vs. marine fuel demand 2020



Also, deep conversion margins are now suppressed, contrary to previous expectations. The massive, unexpected product demand destruction in 2Q'20 till date, has effectively and completely overridden the market impact of 'IMO 2020'.



Conclusion and summary

The extent of global demand destruction is dependent upon the scale and duration of the Covid-19 outbreak. In addition to how effectively each government can mitigate an economic shock induced by Covid-19 containment measures.

Middle distillate demand plunged outside the bunker sector. This ensured its availability for the bunker pool, which in its turn negatively affected scrubber installations for HSFO. However, concerns over increasing middle distillates in VLSFO has caused the blend to become less viscous.

The usage of a less viscous fuel in a fuel pump designed for high viscosity may result in leakages and insufficient heating of fuel pipes carrying less viscous fuels could impede fuel flow, both of which may lead to an insufficient quantity fuel being pumped into the combustion chamber of a vessel.

Other reasons for delays in scrubber installations were partly due to manpower limitations relating to the Covid-19 pandemic. In truth, the economic incentive for ship-owners to install scrubbers has reduced considerably due to narrower high-low-sulfur fuel differential, and some shipping operators are now choosing to pull back from investing in scrubbers – temporarily or altogether – as they desperately seek to reduce costs amid the decline in global trade.

However, with the expected rise in demand of middle distillates in 2H'21 and beyond, the VLSFO-HSFO differential is expected to widen and installing scrubbers may become economically attractive again.

Last, but not least, the compliance with IMO regulations is expected to reach over 99% in all markets by 2025.

ARD Unit 112 - CFP - MAB

Gasoline Production
Unit 107 (ISOM)
CFP - MAA

Gas Chromatography Design & Operation at Custody Transfer

Some liquid products are purchased/sold on volume basis and some on weight basis. However, most of the gas products are sold and purchased on the basis of its calorific value measured in British Thermal Unit (BTU).

Huwaida Mubarak
Team Leader, Instrument Maintenance
MAB

Introduction

It is difficult to store gas and get the average sample; therefore, sampling is done once per shift or once per day. This often leads to error in energy measurement and requires correction of the meter. As a solution, Gas Chromatography, a method for determination of gas quality is used for custody transfer.

Custody transfer occurs when gas ownership is exchanged between parties; and sometimes, the exchange ensues money payment. Therefore, accuracy in calculating the amount of fluid or gas transferred is of paramount importance as even a small error in measurement can add up, leading to financial loss and huge mistakes in custody transfer transactions.

GC accurately calculates the quantities and components of a flowing gas as well as the physical properties. The analysis of the flowing gas is also important for critical gas measurement applications including contaminant monitoring for pipeline integrity, product quality, and many more.

GC is used in natural gas custody transfer applications. They provide information on the gas quality and composition—with components such as methane, ethane, propane, butane, pentane and heavier hydrocarbons, water vapour, carbon dioxide, nitrogen and hydrogen sulphide.

Custody Transfer or in other words "Fiscal Metering" plays an important role in oil and gas industry.

Familiarity with its terms, meaning and affecting factors help us to act better in this sensitive and expensive field in yielding good profit.

Custody transfer system is like the cash register, the better we design it, the lower the extra cost would be and the margin of error is less if Gas Chromatograph is used. If you want to buy or sell some valuable liquids, you should be able to measure the quality and quantity of that gas product accurately.

In custody transfer, "accuracy" is of utmost importance to both the seller and the buyer, when transfer of products takes place.

Gas chromatograph technology

The GC technology separates and measures the individual components of gas or liquid samples. It automatically samples and analyzes process streams. Valve and column arrangements are provided to separate natural gas sample into its constituents. The column used are standard 1/8-inch packed columns. Analysis cycle time is generally 10 to 12 minutes. The analyzer is calibrated for its maximum accuracy by means of certified standard gas blends.

As measurement errors, especially in custody transfer, can be highly expensive, application of Gas Chromatography technology helps to achieve very accurate measurements.

As an example, 1% error in sampling can potentially cost:

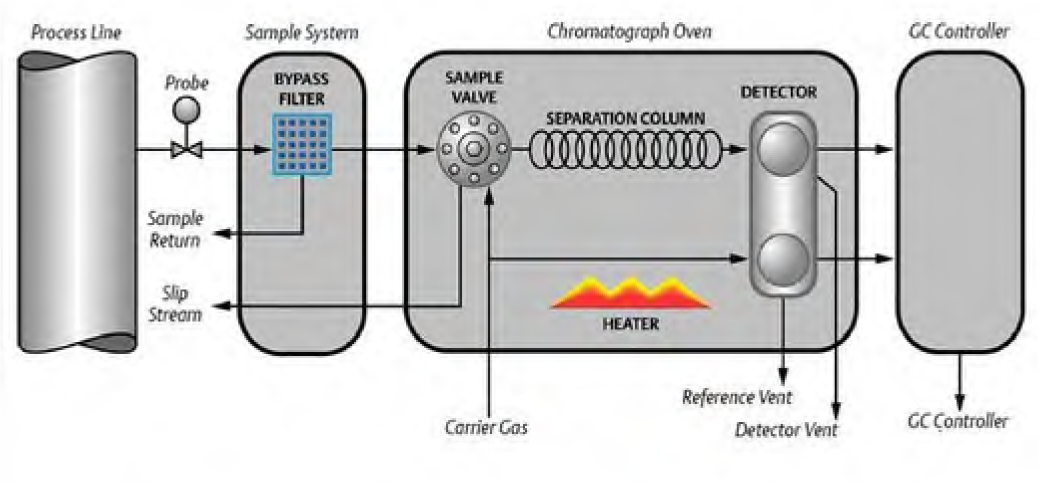
1600 MMSCFD x 1200 BTU/SCF x 8 $/MMBTU x 365
= 5.606 billion $/annum X 0.01
= 56.06 million $/annum

The individual components and concentration measured by GC is used to calculate the Calorific

Value and Specific Gravity using Gas Processors Association (GPA) component data. Then the chromatograph data is multiplied with flow rate data to calculate total energy value in BTU.

1. Function components of GC

The components of GC includes Sample Handling Systems, Chromatograph Oven and Controller Electronics, as seen in the following diagram:



A typical chart below shows the Gas Composition analyzed by Laboratory and Process Gas Chromatograph

Component	Units	Concentration (Lab 1)	Concentration (Lab 2)	Concentration (Analyzer)
H2	%vol.	0.0	0.0	0.000
H2O	%vol.	0.0	0.0	0.000
N2	%vol.	0.3	0.2	0.280
O2	%vol.	0.0	0.0	0.000
H2S	%vol.	0.2	0.2	0.200
CO2	%vol.	1.0	1.0	1.000
CO	%vol.	0.0	0.0	0.000
C1	%vol.	73.3	73.2	73.290
C2	%vol.	14.0	14.0	13.950
C3	%vol.	7.9	7.9	7.850
i-C4	%vol.	0.9	0.9	0.900
n-C4	%vol.	1.9	1.9	1.900
i-C5	%vol.	0.3	0.3	0.340
n-C5	%vol.	0.2	0.2	0.240
C6	%vol.	0.0	0.1	0.050
C7+	%vol.	0.0	0.1	0.000
TOTAL	%vol.	100.0	100.0	100.000
AVG MW	----	22.0	22.2	22.1
Calorific Value	BTU/ft^3	1178.8	1187.4	1181.9

2. Factors affecting the accuracy of measurement

- Joule Thompson effect (Condensation)
- Reference gas
- Base temperature
- Dry basis
- H_2S
- Neo pentane
- Heavy component

a) Joule Thomson Effect

In Thermodynamics, the Joule–Thomson Effect describes the temperature change of a real gas when it is forced through a valve while keeping it insulated or gas temperature changes in relation to pressure change.

Sample to be controlled typically between 15 to 30 psig.

Majority of application of the sample will be considerably at higher pressures.

Cooling of natural gas is kept at 7oF per 100 psi.
Some of the larger hydrocarbon components will begin to drop out of the gas phase into the liquid phase. The temperature at which this begin to occur is hydrocarbon dew point.

Temperature of the sample to be maintained at least 30oF above hydrocarbon dew point. Use of heated regulators, insertion regulating probes and heat traced tubing is used to overcome JT effect.

b) Condensation of reference gas

Considering the temperature in Kuwait during summer peaks at 55˚C to winter at -3˚C, the gas component C5/C6 state varies. Gas component C5/C6 in this temperature may remain in gas phase or turn out into liquid phase.

Reference gas containing large hydrocarbon components will begin to drop out of the gas phase during winter leading to incorrect measurement of analyser. The reference gas has to be heated and kept in controlled environment.

c) Base temperature

The comparison between the base temperature of 15oC and 15.56oC can result into a substantial measurement error corresponding to a potential loss in custody transfer. Therefore, adopting standards for calculation of volume and energy is more significant. One common mistake happens, suppose the contract agreement between the consumer and the supplier is 15oC as its base temperature and 14.696 psia as base pressure, but for energy measurement it adopts (Gas Processors Association) GPA 2172 table which takes temperature of 60 OF (15.56oC) and pressure 14.696 psia.

This difference in base temperature can result in energy measurement error up to 0.19%.

d) Measurement errors due to moisture

The measurement of moisture content in natural gas is extremely important, from a technical perspective and in order to ensure conformance to contractual specifications.

Typically, this measurement is one of the most difficult to perform successfully.

Natural gas sources are generally dirty, corrosive, heavily moisture laden and at high pressure.

Prior to transportation, water is separated from raw natural gas. However, some water still remains present in the gaseous state as water vapour.

e) Measurement errors due to temperature

Normally the base temperature of 60˚F is often considered as 15˚C. But in reality, it is 15.56 ˚C, and this leads to an error of 0.19% which cost up to 10.6 Million USD/annum in Custody Transfer.

f) Reference gas temperature

Generally, reference gas cylinder is stored outside the analyser house. During low ambient temperature there is potential condensation when temperature goes below 0˚C. Then this error could be very high mainly for rich gas service.

The ambient temperature affects gas temperature.
1oC error of temperature can cause a measurement error of 0.33%. Temperature sensors to be insulated to negate environmental temperature effect.

g) H_2S - Hydrogen Sulphide

GPA standard considers zero value for H_2S in the calorific value calculation. But the Gas Chromatograph takes into account the calorific value of H_2S.

h) Measurement errors due to "Analog to Digital Converter"

Generally, signals travel in analog form and then converted to digital form.

- Analog signal is 4 to 20 mA
- The analog signal have to be converted into digital by ADC
- ADC will have several errors, the significant one being the quantization error.
- The error is measured in Least Significant Bit (LSB).
- For an 8 bit ADC, an error of one LSB is 1/256 of the full range, equivalent to 0.4%.
- 12 bit ADC will have an error of 0.024% and higher bits still less.
- Hardware to be purchased with higher bit ADC (i.e. 12 bit, 16bit, or higher) to reduce measurement error.

i) Errors due to C6+ measurement

Most GC can analyse gas composition up to C6 but heavier hydrocarbons C7, C8, C9 etc. can be found in natural gas.

An availability of C7, C8 of 0.1 mole % each and C9, C10 of 0.05 mole % can cause a change in compressibility factor resulting in 0.056% reduction in natural gas volume. This can cause a higher calorific value resulting in 0.466 % increase in energy.

Normally C6+ is measured by GC, a fixed split ratio (based on gas analysis done in lab) can be introduced to reduce these errors.

Conclusion

A number of conclusions were noted and need to be addressed for achieving higher degree of accuracy in measurement through Gas Chromatograph.
Details as follows:

Sr. No.	Factors affecting measurement accuracy	Mitigations in Gas Chromatograph
1	Condensation	To be avoided in the sample line and heater should be inside the Sample Handling System of the Analyzer House and Oven of GC.
2	Reference gas	It should be stored such that no condensation occurs and quality is maintained. (Expected error more than 1%)
3	Base temp	To consider 60°F as 15.56°C and not as 15°C (Error 0.19%)
4	Dry basis	All custody transfer should have water measurement and composition to be adjusted
5	H2S	H2S calorific value should not be considered (0.2% to 2.0%)
6	ADC	8 Bit Analog to Digital Conversion to be avoided. (Error 0.40%)
7	Neo pentane	Should be analyzed and used for calculation
8	Heavy component	C6/C7 in Stream can create huge Error. (Expected error more than 1%)

Finally, it is necessary to use very accurate calibration standards since heavy hydrocarbons, CO_2, and water vapour have a major effect on accuracy. In cold regions, it becomes very important to keep the calibration gas cylinder warm to prevent condensation of the heavy components.

ARD Technology

Heavier crude oils are expected to have more of atmospheric residue, sulfur, metals and asphaltenes compared to lighter crudes, making them difficult candidates for handling/processing; hence, the need to different design refineries. Atmospheric Residue Desulfurization (ARD) is a widely used method to solve this problem.

Ahmed Al-Motawa
Sr. Process Engineer – MAB

Introduction

Petroleum fractions contain varying amounts of impurities that could be harmful to downstream process units and to product qualities. Most important among them are organic compounds containing sulfur, nitrogen and metallo-organic compounds containing a few parts per million of nickel and vanadium. Since most of these impurities tend to concentrate in the heavy ends of the petroleum fractions, the removal of contaminants from heavy residues becomes one of the most significant areas in refining.

Crudes are generally classified/characterized into:

• Light	API > 34
• Medium	API 22 - 34
• Heavy	API < 22
• KEC	API 30.5

ARD Functions

Desulfurization (HDS) of Atmospheric Residue (by catalytic hydrogenation) to LSFO which is useful in obtaining quality feed for the downstream FCC, Hydrocracker and Coker Units. Along with Sulfur, much of metals (HDM), nitrogen (HDN) and asphaltenes are removed. Due to some hydrocracking, significant quantity of Naphtha and Distillate are additionally produced as upgraded product.

Chemistry of residue desulfurization

ARDS process involves several chemical reactions, essentially characterized by the addition of hydrogen molecule to hydrocarbon molecule, breaking of C-S, C-N and C-C bonds and the elimination of impurities as H_2S and NH_3. Essential reactions are as follows : 1. Hydro-desulfurization: $R\text{-}SH + H_2 \rightarrow RH + H_2S$ 2. Hydro-denitrogenation: $R\text{-}NH_2 + H_2 \rightarrow RH + NH_3$

Hydro-demetalation

$$M\text{-}P + H_2S \rightarrow M\text{-}PH_2 \rightarrow MS_x + RH$$

Hydrocracking

$$R\text{-}CH_2\text{-}R' + H_2 \rightarrow RCH_3 + R'CH_3$$

Hydrogenation

$$\text{Aromatics} + H_2 \rightarrow \text{Saturate}$$

Where R is a hydrocarbon chain.

Composition of ARDS catalysts and selection

Residue desulfurization catalysts are generally Cobalt-Molybdenum (Co-Mo) or Nickel-Molybdenum (Ni-Mo) type and almost always supported on alumina (Al_2O_3). - (Co-Mo) catalyst is generally preferred for HDS activity. - (Ni-Mo) catalyst for HDN activity.

Alumina is the most widely used carrier because of the following:

- Inexpensive.
- Structurally stable over the temperature range for most catalytic reactions.
- It can be prepared with a wide variety of pore sizes and pore size distribution.
- Alumina has the mechanical properties required to withstand crushing and break-up during catalyst handling and the force applied to the catalyst by the pressure drop across the reactors.

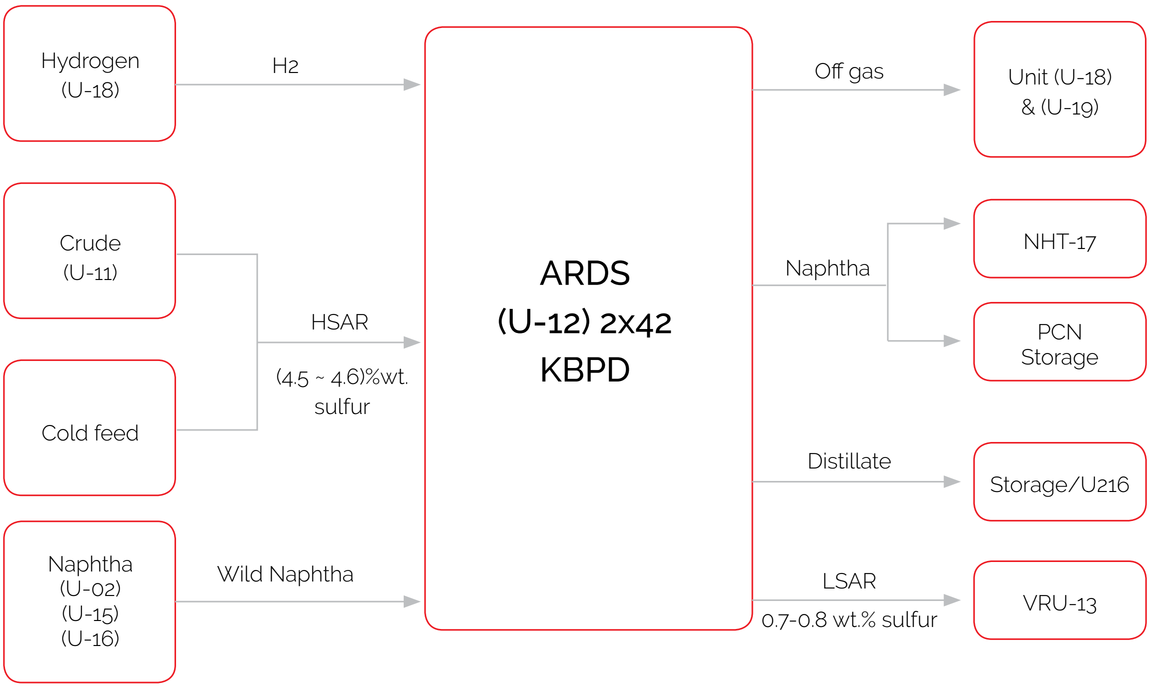
Challenges of the refinery without ARDS Unit

- Vacuum rerun units feed stock with high sulfur ~ (4.5-5) wt.%.
- Coker units feed stock with (9 -10) wt.% sulfur.
- Issue of disposal of very high sulfur green coke.
- Associated metallurgical concerns in the downstream units due to high Sulfur and temperature.

Introduction of RMP ARDS

The Refinery Modernization Project (RMP) included the introduction of Process Licensor: UOP for Fixed Bed Reactors & CLG for OCR reactors
Units/Trains: One ARDS Unit (U-12) consists of two identical independent parallel trains with one common fractionator.
Capacity: U-12 : 84 KBPD (42 KBPD each train)
Run Length: (12 – 15) months M&I and catalyst replacement 60 months for Fractionator S/D.

Feed and product routing



Product yields

Product	Yields, SOR	Yields, EOR
	LV.%	LV.%
Naphtha (C5 -320°F)	1	2.5
Distillate (320-680 °F)	18.0	24
LSFO (680+ °C)	84.00	76.0
VGO (680-975 °F)	44	42.0
VR (975+ °F)	40.0	34.0

Feed specification

Specifications	Limits
Gravity, °API	11.5 - 12.5
Total Sulfur , Wt %	4.5 – 5.0
Total Nitrogen , ppmw	2600 – 3000
CCR ,Wt %	11.5 – 13.0
Vanadium, ppmw	80 – 100
Nickel , ppmw	25- 35
Asphaltenes, Wt %	4.5 – 5.5
Sodium, ppmw	3 – 8
Distillation, TBP, Vol%	
IBP	580
5%	700
10%	750
30%	880
50%	1020

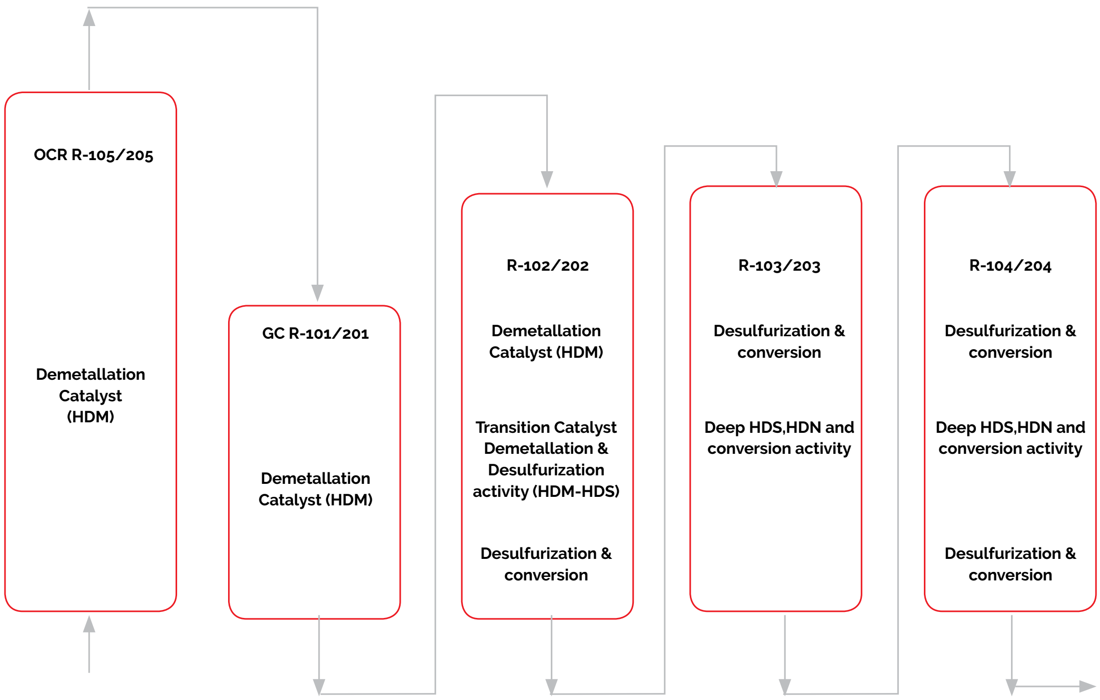
Product specifications

Product	Yields, SOR	Yields, EOR
	LV.%	LV.%
Naphtha (C5 -320°F)		
- API	60	60
- Sulfur, ppm	20	30
Diesel (320-680 °F)		
- API	31.9	33
- Sulfur, ppm	1000-1200	1000-1200
- Viscosity, cSt @ 50°C	3.8	3
- Pour Point, °C	< 0	< 0
LSFO (680+ °F)		
- API	20.0	20.5
- Sulfur, Wt %	0.75	0.85
- Nitrogen, ppm	1400	1600
- Viscosity, cSt @ 50°C	220	170
- Carbon Residue, Wt %	7.0	6.0

General operating condition

General Operating condition of one train ARD unit in MAB Refinery		
Feed Temp.	ºF	390-410
Feed Rate		42
OCR WABT R5	ºF	670-730
FB WABT R1+R2+R3+R4	ºF	700-760
System pressure	PSI	1640
Make-up H2	MMSCFD	85-95
OCR G/O Ratio	SCFB	1500-1850
compressor speed	KRPM	12-13.5
C1 Suction Flow	KSCFH	4200-5300

Catalyst arrangement



Total Catalyst Volume for one train is 1187 m^3

OCR revamp project in 2004

Over the years, Crude processing capacity of MAB Refinery was increased from 198.5 KBPD to 270 KBPD. This necessitated augmenting processing capacity of the ARD units to upgrade the additional quantity of Atmospheric Residue to increase the refinery profitability.

A common facility for on-line replacement of catalyst from each of the OCR reactors was also installed as a part of the revamp.

OCR (On-stream Catalyst Replacement) is an up-flow expanded bed reactor retrofitted ahead of the fixed bed reactors in each of the trains.

OCR revamp objectives

The OCR project was initiated to meet major objectives. Increase capacity of ARDS unit from 66 KBPD to 84 KBPD. (28% increase), Increase of fixed bed reactors catalyst run length to 15 months from 11 months, and get an expected increase in distillate yield of about 5 %wt.

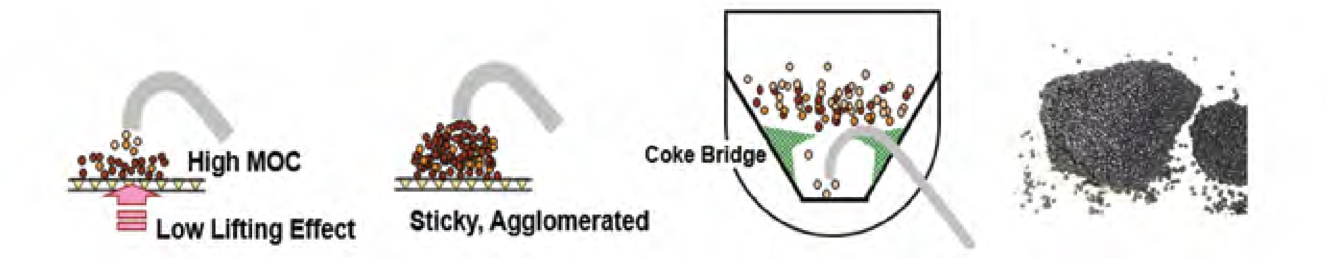
Brief description of OCR operation

The catalyst used in the OCR reactor is de-metallization catalyst designed to remove major metals from the feed. This helps in keeping fixed bed reactors catalyst, primarily high desulfurization activity type, in good condition throughout the cycle length. The operation envisages withdrawal of ~3-4% vol. of spent catalyst and add equivalent quantity of fresh catalyst each week. Thus total catalyst is replaced every 250-300 days on oil. This helps maintaining the catalyst bed activity at the required level through the run.

Major challenges post OCR revamp project

The major challenges encountered include the catalyst agglomeration and coke build up in the OCR reactors. Also, unacceptable loss of catalyst activity in OCR is also observed. Other challenges include the catalyst attrition losses and AL slippage from OCR to GC reactors, fouling up of first fixed bed reactor, spent catalyst dumping difficulties in OCR as well as in FB Rx's, and extension of shutdown duration.

Catalyst agglomeration & coke build up in the OCR reactors.



- Unacceptable loss of catalysta ctivity in OCR.
- Catalyst attrition losses and AL slippage from OCR to GC reactors.
- Fouling up of first fixed bed reactor.
- Spent catalyst dumping difficulties in OCR as well as in FB Rx's.
- Extension of shutdown duration.

Introduction of CFP ARDS

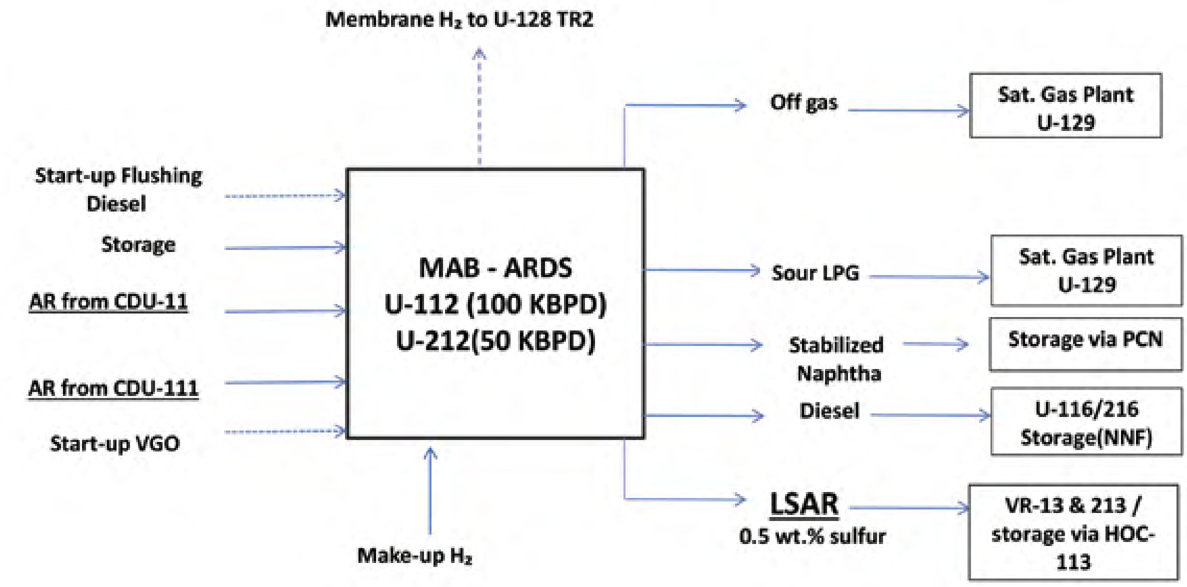
Process Licensor: CHEVRON LUMMUS GLOBAL LLC (CLG)
The purpose behind the introduction of ARDS in the Clean Fuel Project, is to produce LSAR with a sulfur content of 0.5 wt% while producing the maximum amount of diesel within the time limits of acceptable catalyst run length.

When CFP is commissioned, we shall have:
Two units/Trains:

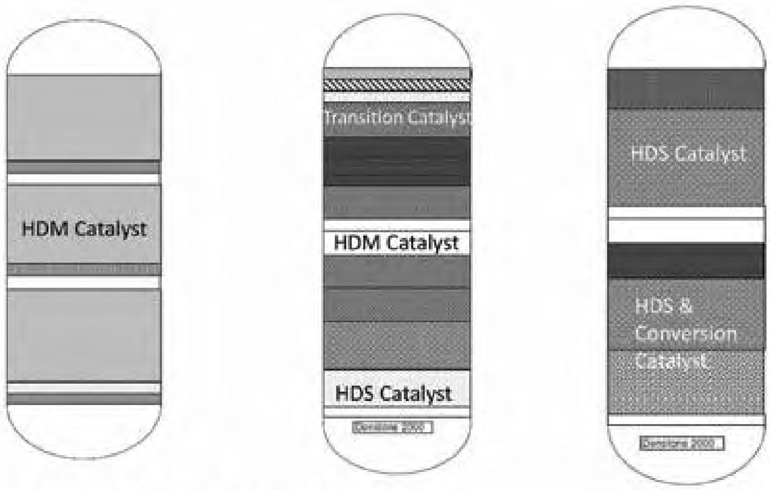
1. U-112 (consists of two independent parallel trains) with 50 KBPD of capacity for each train
2. U-212 (consists of one train) with 50 KBPD of capacity.

Run Length is 15 months M&I and catalyst replacement 60 months for Fractionator S/D.

Feed and products routing



Loading diagram



Total Volume of catalyst per train is 1668 m^3

KNPC MAB ARDS evolution

1958

RCD Unibon U-02

- 2 parallel reactors
- Target product S 1.7%
- Cycle length 6 months
- Throughput 35.0 MBPD

1987

ARDS U-12

- 2 train
- Each train 4 fixed bed reactors in series
- Target product S 0.7%
- Cycle length 12 months
- Throughput 33.0 MBPD

2004

ARDS Revamp U-12

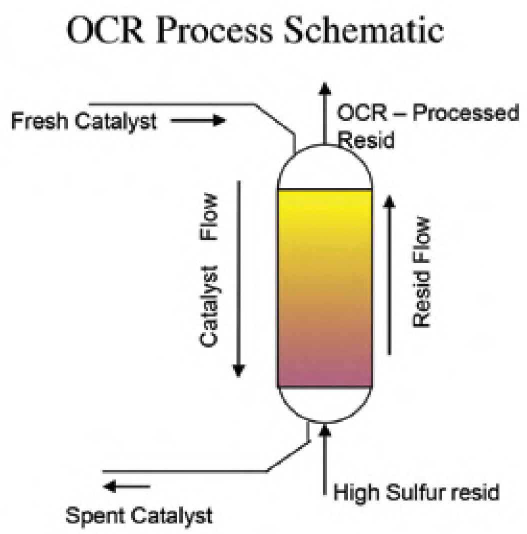
- Retrofitted with OCR Reactors upstream of Fixed Bed Reactors.
- 2trains
- Target product S 0.7% with
- Cycle length 15 months
- Throughput 42.0 MBPD

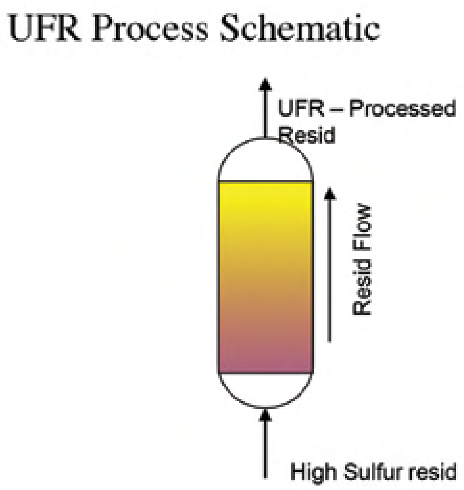
2020

ARDS UFR U-112/212

- 3 trains
- Each train 2 UFRs, total 6 reactors
- Target product S 0.5%
- Cycle length 15 months
- Throughput 50.0 MBPD

Comparison between OCR & UFR





RMP ARDS Vs CFP ARDS

Item	U-12	U-112/212
Unit Capacity, KBPD	84	100/50
Licensor	UOP & CLG	CLG
Trains	2 Trains (42KBPD/train)	3 Trains (50 KBPD/train)
Make-up Hydrogen Purity	97%	99.80%
Cold Feed processing	100%	25% max.
Turndown ratio	50%	50%
Number of Reactors	5 reactors/train	6 reactors/train
H2S Scrubber	Two sections - Water wash - Amine section	One Section - Amine section
Amine Type	Mono-ethanol amine (MEA)	Methyl Di-ethanol Amine (MDEA)
Reactor design	OCR: Inlet deflector, chimney tray, cone support, two quench piping headers, one catalyst dumping nozzle and outlet basket. FB: one bed, Bubble cup tray at the top	UFR: Three Beds, Inlet deflector, Chimney tray, two interbed distributor trays, two Quench piping header, three catalyst dumping nozzle at each bed & outlet basket. FB: two beds, Inlet basket, Perforated tray with chimney tray at the top, interbed Mixing tray.
Filters bypass	Available (Normally closed)	Available (Normally closed)
Feed Surge drum	One surge drum for cold and hot feed	Two surge drum one for cold feed and other for reactors
Catalyst Loading	Sock loading	Sock & Dense loading (Dense loading only for FB Rx's)
Fractionator Design	26 Trays	3 packed sections above the flash zone and 10 stripping trays below the flash zone
H2 Membrane	NA	Available

ARDS in KNPC CFP & ZOR

Item	MAB		MAA		KIPIC	Total
	U-12	U-112/212	U-41/42 U81/82	U-141	U02/12 /22	
Unit Capacity, KBPD	84	100/50	145	50	330	756
Licensor	UOP & CLG	CLG	UOP	CLG	CLG	
Trains	2	3	4	1	6	16
No. of Reactors	10	18	16	6	36	86
Catalyst Required (M3 per year)	4000	5000	3100	1665	9930	23700

GT5 - Clean Energy to the World

Refinery Hydrocarbon Loss Measurements Methodology in KNPC

KNPC operates highly integrated complex refineries which include vastly developed units (Hydrocracking, FCC, Hydro-treating, Coking, etc.) with a combined capacity over 800,000 BPD, with more than 20 elevated flare stacks, different input and out streams that make hydrocarbon accounting a challenging task.

Ahmed J. Al-Terkait
Snr. Eng. Manufacturing Excellence

Introduction

High hydrocarbon loss was reported in 2014/2015 financial year; the same was captured by State Audit Bureau and raised in the parliament. This rang a bell for deeply review the overall KNPC methodology in accounting the hydrocarbon loss, and at the same time, to compare our practices with the international standards. A committee was formed to develop a standard methodology for measurements, quantification and loss calculation for KNPC Refineries. A detailed study was done on existing KNPC loss estimation practices and was compared with international best practices. The standards of Institute of Petroleum (IP HM31 document), Solomon accounting standards, and Shell best practices were reviewed. The practices of Chevron and KPI refineries in Europe were also studied.

After detailed analysis, a standard definition of refinery losses was established. A methodology was proposed for unifying the hydrocarbon loss procedure and methodologies across KNPC refineries in term of measurement, quantification, classification and pricing. The reported Book value loss was corrected and reduced by 80.9% by adopting the proposed methodology.

Establishing a standard definition for Refinery losses

Refinery Loss = Refinery input – Refinery output – Fuels + (Δ Inventory)

*Where Δ Inventory = Current Stock – Previous Stock

Accountable losses are broken-down into controllable and non-controllable losses. While unaccounted loss is the unidentified losses that could be due to metering inaccuracy or incorrect accounting in loss estimation.

a) Controllable losses:

Losses that can be reduced to the bench mark levels based on the refinery configuration.

- Hydrocarbon loss through Flares: The largest sources of controlled refinery loss. The figure shall include all the flaring activities including the unit upsets. Hydrogen flaring to be reported separately for accounting purpose
- H/C loss due to Bio-treatment: The H/C is being a loss once it enters into the Bio-treatment downstream of the recovery process. This could be minimized by isolating the hydrocarbon leak source and enhance the recovery process.
- H/C in Sludge: Sludge generated from MAA is processed in MAB WWT to recover the hydrocarbon. The unrecovered oil in the sludge is considered as a hydrocarbon loss. While oil recovered is reported as a gain in the report. Reporting is based on Operations Sludge generation report and is approximate. Same to be verified with MAB to prevent double accounting when reported.
- H/C in Sea Water effluent: Occurs due to sea water cooler leaks. The water analysis shall be done before the final effluent, where the sea water gets mixed with the outlet of WWT unit.
- API Evaporation & Process Fugitives: API is an open type and the evaporation loss is estimated approx. 0.02 on Slop generated quantity. Process Fugitives leaks from valves flanges.. etc.
- Hydrogen Venting: Venting to flare, atmosphere and downgraded to fuel gas system.

b) Non-Controllable losses:

Losses that are part of normal Refinery operation.

- Carbon loss as CO_2 from HP Units: When Methane and other hydrocarbons are used in steam reformer to manufacture hydrogen; the carbon in form of CO_2 is generated. It is considered as a loss when vented to atmosphere in term of mass balance with zero value.
- H_2 loss as H_2O from SRU Units: During sulfur recovery in SRU, the hydrogen in the H_2S is converted into H_2O.
- Nitrogen Loss as NH_3: Nitrogen in crude is considered as impurities and converted to NH_3 in hydro-processes.
- FCC Coke: The burned coke heat is required for operating the FCC. Its value to be considered as fuel gas.
- CCR Coke: Carbon loss as CO_2 during catalyst regeneration and vented to atmosphere
- Flare Pilot & Purge: Required as part of operation. To be considered as part of the fuel gas consumption.
- VOC Emissions: Non-controlled emissions (i.e. tankage evaporation)
- Hydrocarbon in dispatched Ash (WWT) / waste: Oil content in ash post hydrocarbon recovery process.

Standardize the basis of loss estimation

Controllable Losses	Old Price Basis	New Price Basis	(Ton/month)	Standard Methodologies & Practices references
H/C loss through Flares (Ex H2)	ARI	FG Price	Measurable	Chevron feedback , International Standards IP HM 31
H/C loss to Bio-treatment	ARI	ARI	Estimated	IP HM 31 Document Page 34
H/C in Sea Water effluent	ARI	ARI	Estimated	Record Available , to be reported
API Evaporation & Process Fugitives	ARI	ARI	Estimated	Records available, to be re-classified and reported as per the standards. IP HM31 Document Page 8
Hydrogen Venting	H2 Price	H2 Price	Measurable	Record Available. To be included in loss report for MAA & MAB

ARI: Average Refinery Input FG: Fuel Gas FOE: Fuel Oil Equivalent

Gas flaring

Non-controllable Process Losses	Old Price Basis	New Price Basis	(Ton/Month)	Standard Methodologies & Practices references
Carbon loss as CO_2 from HP Units	ARI	Zero Value Product if not sold	Estimated	International Standard IP HM31 Doc Page 34 & Solomon Methodology
H2 loss as H_2O from SRU Units	ARI	Zero Value Product if not sold	Estimated	International Standard, IP Doc page 7 Record available to be reported.
Nitrogen Loss as NH3	ARI	Zero Value Product if not sold	Estimated	International Standard IP HM31 Doc Page 34
FCC Coke	ARI	To be Considered as Fuel based on FOE instead of loss	Estimated	Solomon Methodology
CCR Coke	ARI	Zero Value – part of Opex	Estimated	IP HM31 Document page 7
Flare Pilot & Purge	-	To be Considered as Fuel	Measurable	Solomon Methodology
VOC Emissions	ARI	FOE price	Estimated	Solomon Methodology
Hydrocarbon in dispatched Ash (WWT) / waste	ARI	FOE price	Measurable	Found in IP document Page 9

Effluent sea water is another source of H/C loss

Reconciliation methodology

KNPC is well established in accounting and reconciliation. For the hydrocarbon loss through flaring, reconciliation methodology is done by the relieve Gas Management Team RGMT & Technical Services Division in order to ensure accurate figures and reduce the flaring if possible. This is being done by utilizing the software developed in web21 (Figure-3) and the diagnostic tools (Figure-2).

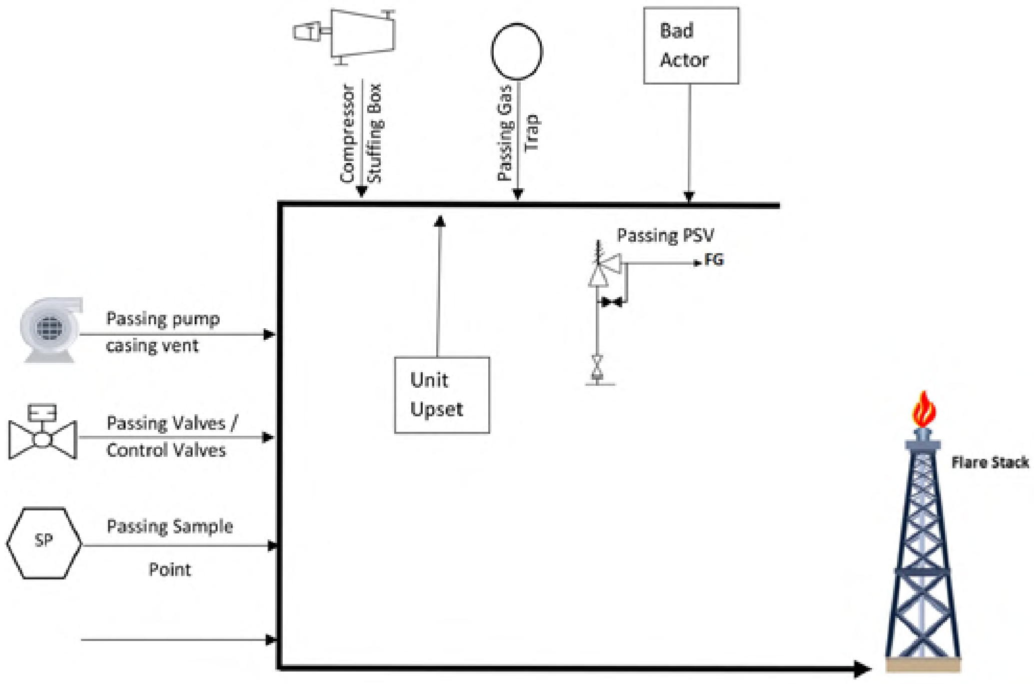


Figure 1: Typical flaring sources

At Sludge Treatment Plant

AccuTrack : Small Hand held device to measure the sound for the passing valves / elements with no temperature deferance

IR Camera: Used for identifying passing valves by identifying the temperature deferance

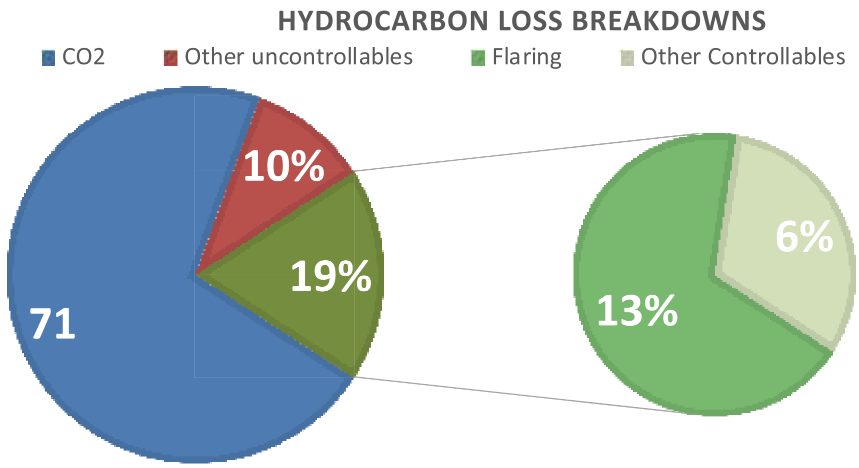
Figure-2: Diagnostic tools

Unit	Tag. No.	Description	Flaring	Value	Flare Instrument Specification		
					Value open %	Flow Range NM3/H	High Alarm
FUP Main Flow Meter (A)	62F104.PV	FUP H/C Flare 62-101		-0.00	-	0-20000	NIL
FUP Main Flow Meter (B)	62F105.PV	FUP H/C Flare 62-102		0.25	-	0-20000	NIL
FUP ARD (Unit 81)	81FI323.PV	Reactor H/C COMM HDR		-1.27	-	0-10000	13
	81FI325.PV	FRACT.H/C COMM HDR		-4.17	-	0-3000	13
	81FI326.PV	COMP.COMM HDR		741.42	-	0-2000	13
	81PRC077.OP	V-028 FRAC GAS KOD	No	31.19	50-100	-	NIL
FUP ARD (Unit 82)	82FI323.PV	REACTOR H/C COMM HDR		...	-	0-10000	NIL
HCR (Unit 84)	84FI513.PV	FLARE GAS REACTOR SIDE		-8.86	-	0-5000	50
	84FI514.PV	FLARE GAS FRACTIONATOR		495.60	-	0-2000	1000
	84PC116A.OP	V-110 FEED Surge Drum	No	-5.00	50-100	-	NIL
	84PIC301.OP	V-301 CLPS Off Gas HR/FLARE	Yes	57.97	0-100	-	NIL
	84PIC304.OP	V-320 FRACTIONATOR OVERHEAD	No	-5.00	50-100	-	NIL

Figure-3: Web-21 Reconciliation sheet for FUP flares

Conclusion

- H/C Loss Book Value reduced by 80.9 %
- Improvement in physical HC Loss reported by Solomon since 2014 study.
- KNPC is within the international companies practices. < 1%
- KNPC reached the boundary for the first quartile for 2018 Solomon study with H/C loss of about 0.24%.



- 81% of the refinery reported loss found to be zero value, wherein 71% due to CO2 venting from HPU
- Max Unaccountable Loss for MAA = 0.7% & MAB = 0.5% (2015 study)
- Totally new sources of losses have been identified

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Austenitic Stainless Steel Susceptibility to External Chloride Stress Corrosion Cracking Under Cold and Hot Insulation

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This paper discusses the study and comparison of two cases of failure in austenitic stainless steel piping where it experienced a very severe External Chloride Stress Corrosion Cracking (ECSCC) attack, while the operating temperatures were beyond the susceptibility range for both scenarios. Therefore, a failure investigation was conducted to explore the possible root cause of such peculiar and unexpected failure. The study and analysis on the morphology of the failed samples, History, operating parameters, and the influence of the aged insulation gave a clearer image and illustrate the failure mechanism.

On April 2018, a failure of the gas plant trains cold blow down line BD-22008 - 1 P1J-4" occurred. The failure was a rupture in SS 304L 4" located at the pipe rack. The cold blow down system is designed for unit protection and for hydrocarbon draining, and it is very critical in emergency operations. Failure in the cold blow down can lead to the gas plant trains shutdown.

This study provides an excellent example where knowledge and methodology have been applied effectively for this failure assessment.

Failed piping

After collecting specimen of the failed piping, a series of examination started. Once data are obtained, analysis took place to conclude the root-cause of the failure. Failure analysis results shall be taken in consideration to determine the corrective actions for more reliable and safe operations of the gas plant.

After a few months of the failure in the gas plant, we observed similar failure in the other side of Mina Al-Ahmadi refinery (MAA) at the CCR unit. The failure was in the form of cracks on hydrogen recycle line.

The line supplies auxiliary hydrogen to the reduction zone at the top of the first reactor. In normal operation, the line is closed. Specimens of the failed piping was collected and investigation started for this failure independently.

Observation

Cold blowdown line

Piping history

The specifications of the piping:

- Line Material: SS (AISI 304L)
- Service: Cold Blow Down (Methane, Ethane, Propane)
- Operating Temp. Max/Min: -28 ˚C/ -101 ˚C
- Operating Pressure: 1 kg/cm2
- Max Design Pressure: 14.2 kg/cm2
- Nominal Thickness: 3.05 mm

Table 1: Inspection history of the BD-22008-1P1J-4"

Year	History	Remarks
Apr 2018	· Failure	Line Rupture
Mar 2010	· Visual Inspection · Ultrasonic Thickness Check	Satisfactory
Jun 2009	· Visual Inspection · Ultrasonic Thickness Check	Satisfactory
Sep 2005	· Visual Inspection · Ultrasonic Thickness Check	Satisfactory
Oct 2003	· Visual Inspection · Ultrasonic Thickness Check	Satisfactory
Aug 2002	· Visual Inspection · Ultrasonic Thickness Check · DP Test	Satisfactory
Nov 2001	· Visual Inspection · Ultrasonic Thickness Check · DP Test	Satisfactory
Dec 1998	· Visual Inspection · Ultrasonic Thickness Check · DP Test	Satisfactory
1978	Commissioned	

Visual examination

The rupture observed in the top section of the pipeline with about 0.9 m opening (Fig. 1a and 1b). Though the fracture edge was brittle in nature, yet the sample showed some degree in ductility. Multiple cracks were observed adjacent to the rupture (Fig. 1c). The sample does not indicate any form general corrosion internally or externally. No coating system was observed on the metal surface.

Chemical composition

The chemical composition of the piping material was tested by Optical Emission Spectrometer (OES), and the test results confirmed to the design requirement of the 304L SS (Table 2).

Stereomicroscopic examination

Specimens cut from the failed sample were examined by stereomicroscope. The results indicate multiple cracks and aggressive pitting attack on the external surface (Fig. 2a), while at the internal surface the crack severity were observed in lesser degree (Fig. 2b).

Optical microscopy analysis

Specimens were prepared for the metallography examination of the cross-section. The etching was made electrolytically using 10% oxalic acid. (Fig. 3) Shows the cross-sectional optical graphs, the graphs give a clear evidence of cracks initiated from the external surface. The cracks has a trans-granular nature with very extensive branching. The cracks were deep and some almost reached the internal surface. Pitting is also found on the external surface.

Scanning Electron microscopic examination

A specimen of the external surface was examined by scanning electron microscope (SEM). The resulting graph shows an indication of cracks and pits (Fig. 4).

Energy dispersive spectrometry examination

The sample subjected to SEM was examined using Energy Dispersive Spectrum (EDS) (Fig. 5). The EDS results for the locations near the crack (Location 'A' and 'B' in Fig. 4) show peaks in the chloride and sulfur range in addition to the alloying elements, and EDS for locations away from the crack show peaks for the alloying elements with negligible amounts of chloride and sulfur.

Dye penetrant examination

Due to the rupture observed on the pipeline with linear crack adjacent to the rupture, therefore, Dye Penetrant (DP) examination carried out for the whole pipeline to indicate any further cracks. Some locations experience severe linear cracks indication Locations:

1. At the rupture location (Cracks were observed)
2. Location close to the rupture. (Cracks were observed) (Fig. 6a)
3. At the burnery side. (Cracks were observed) (Fig. 6b)
4. Location near to the train 2 side. (No cracks observed)

Insuolation material examination

Samples of the insulation materials was collected from varies locations at the cold blow down line:

1. Sample # 1: at the rupture location. (Cracks were observed)
2. Sample # 2: location close to the rupture. (Cracks were observed)
3. Sample # 3: at the burnery side. (Cracks were observed)
4. Sample # 4: location near to the train 2 side. (No cracks observed)
5. Sample # 5: new insulation material.

Lab analysis was conducting to determine leachable chloride, sodium, and pH (ASTM C 871) on the insulation materials, the results are shown in (Table 3).

Recycle Hydrogen Line

Piping specification

The specifications of the piping are as shown below:

- Line Material: SS 304 - 1.5"
- Service: Recycled Hydrogen Operating Temp. Max/Min: 410 ˚C/ 118˚C
- Operating Pressure: 6.8 kg/cm2
- Hydro test pressure: 42.3 kg/cm2

Visual examination and DP test

The failure was in form of cracks on hydrogen recycle line, as you see in the (Figure 7). Dye penetrate testing reveled many cracks at the valve body and at the piping near the valve.

Optical microscopy analysis

(Figure 9), shows cross-sectional photos were taken from the Hydrogen recycle line specimen by optical microscope showing the cracks. Similarly, the hydrogen recycle line from the CCR unit examination shows similar cross-sectional cracks to cold blowdown line in the gas plant. Where in this case the photos show that the cracks are very deep that it actually reaching the internal surface.

SEM & EDS examination

Both SEM and EDS test conducted on the hydrogen recycle line shows similar results to the cold blowdown line. Where the results show peaks in the chloride range in addition to the alloying elements near the crack, while the EDS Results for locations away from the crack show peaks for the alloying elements with negligible amounts of chloride (Figure 9).

Discussion

After the intensive lab testing and examination, it was concluded that the failure in the cold blow down line BD-22008-1P1J-4" was caused by ECSCC. The microscopic transgranular nature of the cracks is a fundamental characteristic of chloride stress corrosion cracking, also the presence of chloride that indicated by EDS analysis and the high level of leachable chloride in the insulation material revealed a clear evidence and supporting of the suggested mechanism. In Addition, the stereomicroscopic examination and optical microscopy analysis indicating aggressive pitting in the external surface and cracks initiated from the external surface.

Austenitic stainless steel (Type 300 Series) are susceptible for the ECSCC if the proper conditions of tensile stress, temperature, and an aqueous chloride environment are met. The occurrence of the ECSCC can be seen usually in metal skin temperatures in the range of 60˚C to 175 ˚C; however, as shown in graph below (Fig. 12), ECSCC can occur at 50 ˚C if higher concentration of chloride is present. Despite of the cold blowdown BD-22008-1P1J-4" operating temperature is much lower than 50 ˚C, the nature of only-in-emergency operating manner of the cold blowdown which exposing the line to the ambient temperature (while not being in use) most time of the year. Therefore, this can lead to metal skin temperatures as high as 50 ˚C.

The chloride contamination of the external metal surface is a critical part of the ECSCC mechanism. The source of the chloride could be externally caused by environmental factors such as rain or dust. The high levels found of chloride in the insulation material can be cause by aging of the insulation material, which led the chloride to concentrate by water evaporation from the metal surface. The sodium silicate content in the insulation material thought to retard or prevent the chloride SCC. Aging of the insulation material can cause the sodium silicate to be leached away with time from the insulation material leaving the metal surface without protection.

Insulation materials that do not absorb water (such as polyurethane) are usually preferred for such applications, yet this will not prevent or provide immunity to ECSCC. Therefore, preventive measures shall be considered by strict testing of the chloride content of the new insulation material and for a sample of aged insulation material in every scheduled inspection. In addition, NDT technics especially dye penetrate examination, which gives the best indication of SCC, shall be considered in every scheduled inspection.

The absence of coating system in the failed section was an important factor Causing the massive scale of the cracks in the line. An appropriate coating system without defects and free of chloride with periodic inspection and repairing shall prevent and eliminate the ECSCC.

Conclusions

Based on the observations, analyses, metallographic examination, and the NDT, the following can be concluded:

1. The failure in the cold blow down line BD-22008-1P1J-4" was caused by ECSCC.
2. Aging of the insulation material causes chloride to concentrate driving the ECSCC mechanism.
3. The absence of coating system contributes in the failed of the cold blow down line

Recommendations

1. Strict testing of the chloride content of the new insulation material and for samples of the aged insulation material in every scheduled inspection.
2. Dye penetrate examination shall be considered in every schedule inspection.
3. An appropriate coating system without defects and free of chloride with periodic inspection and repairing shall be considered

Table 2: Material composition results by OES (wt. %)

C	Cr	Ni	Mo	P	S	Si	Fe
0.024	18.50	11.15	0.12	1.26	0.020	0.29	Bal.

Table 3: Insulation lab analysis (ASTM C 871).

Parameter	Sample # 1	Sample # 2	Sample # 3	Sample # 4	Sample # 5
Chloride (ppm) (ASTM D 4327-11)	5060	8150	3120	5860	400
Sodium (ppm) (ASTM D 1976-12)	198	348	256	375	347
pH of water extract (5% Solution)	2.42	2.84	3.21	4.03	6.78

Fig. 1a: The rupture pipe as found condition on the pipe rack

Fig. 1b: The collected sample

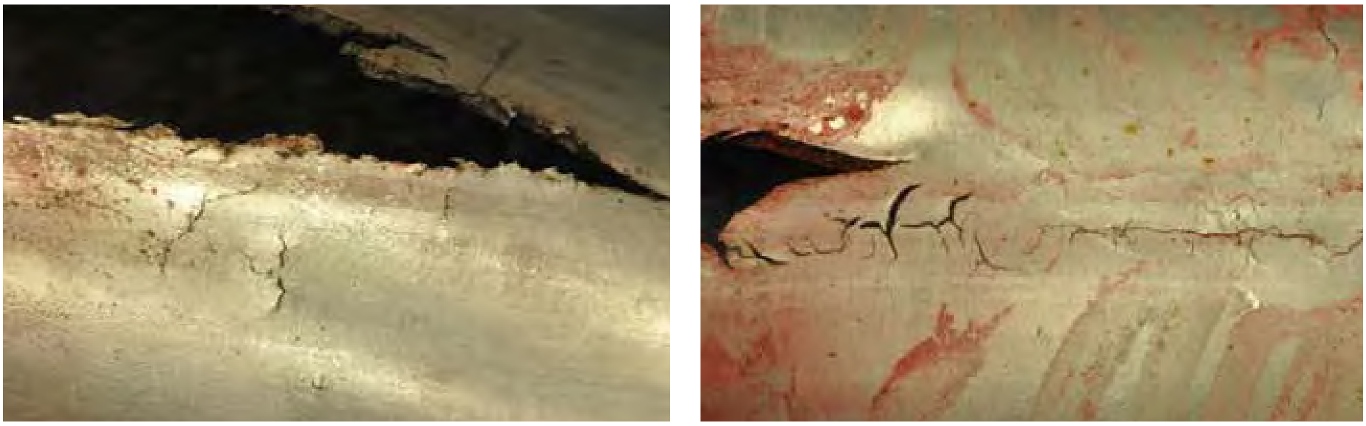

Fig. 1c: Cracks adjacent to the rupture

Fig. 2a: Stereo micrograph (External).

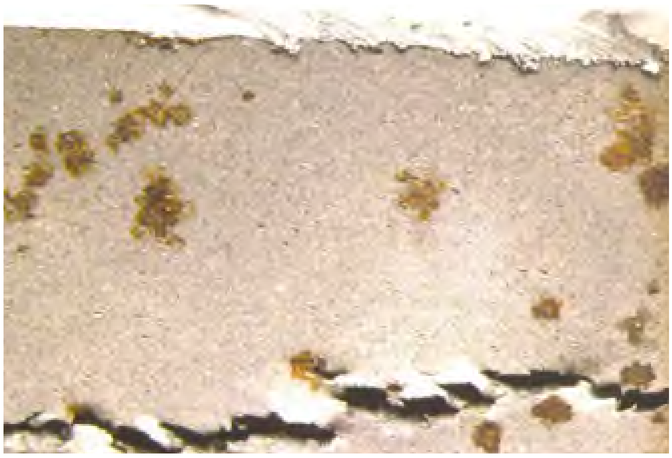

Fig. 2b: Stereo micrograph (Internal).

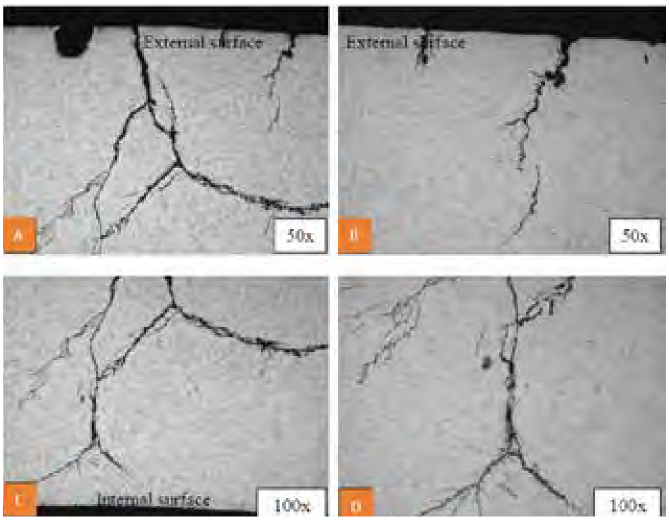

Fig. 3: Cross-sectional optical Micrographs.

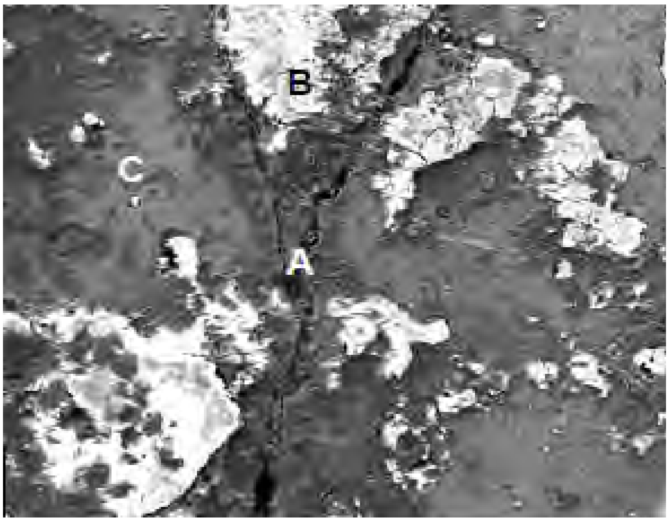

Fig. 4: SEM graph of the external surface.

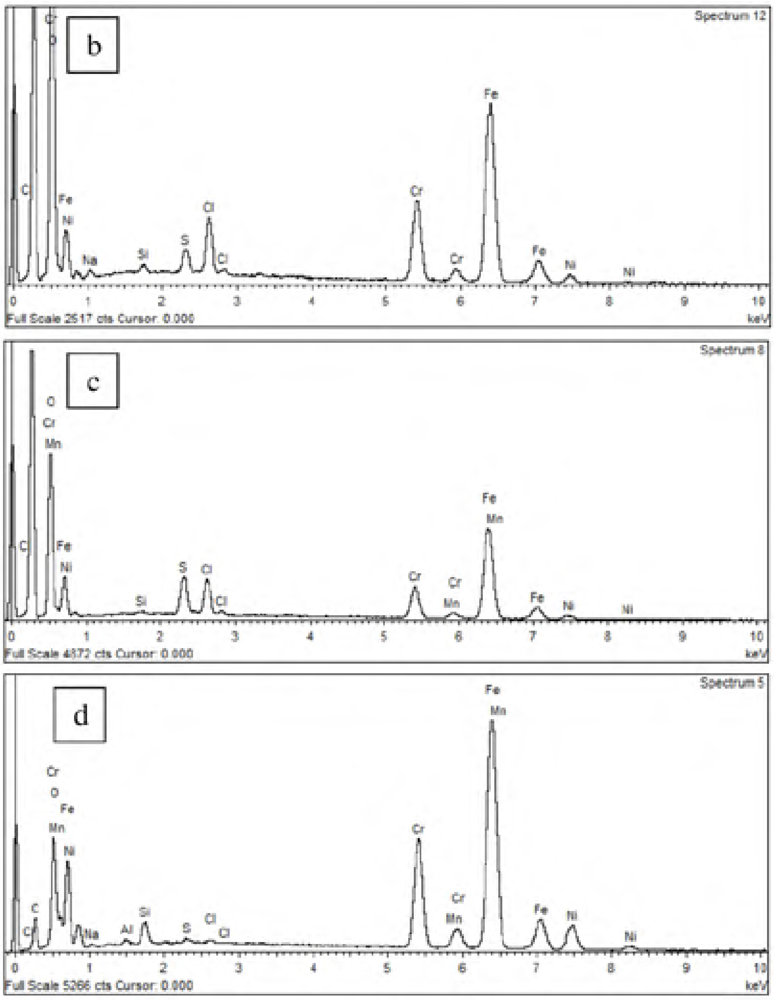

Fig. 5: SEM graph of the external surface.

Fig. 6a: Linear Indication in Locations Close to the Rupture

Fig. 6b: Linear Indication in Locations at the Burnery Side

Fig. 7: Recycle hydrogen line cracks.

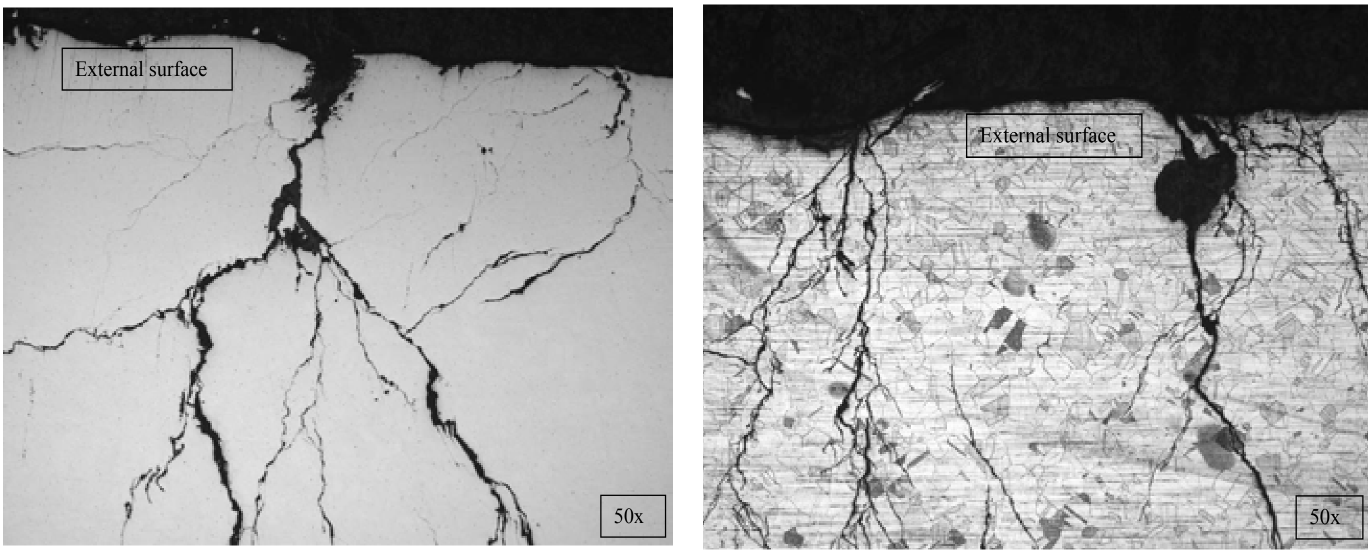

Fig. 8: Optical Microscopy Analysis Recycle Hydrogen Line.

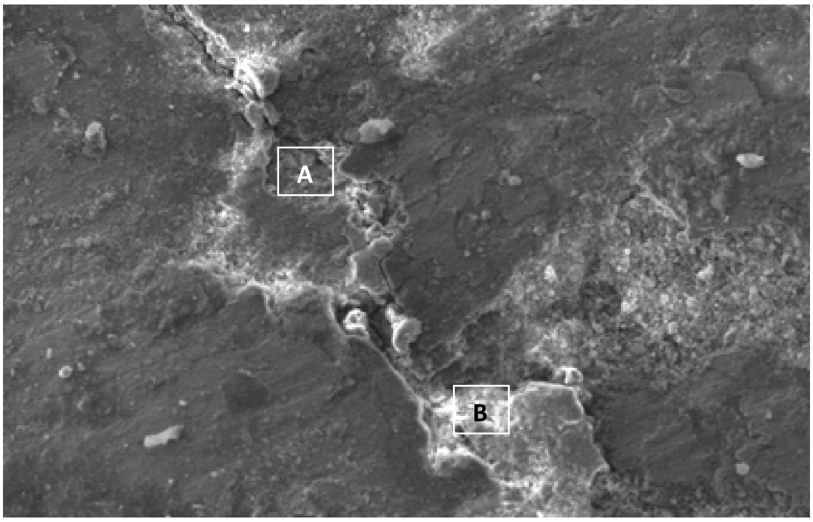

Fig. 9: SEM results for Hydrogen recycle line.

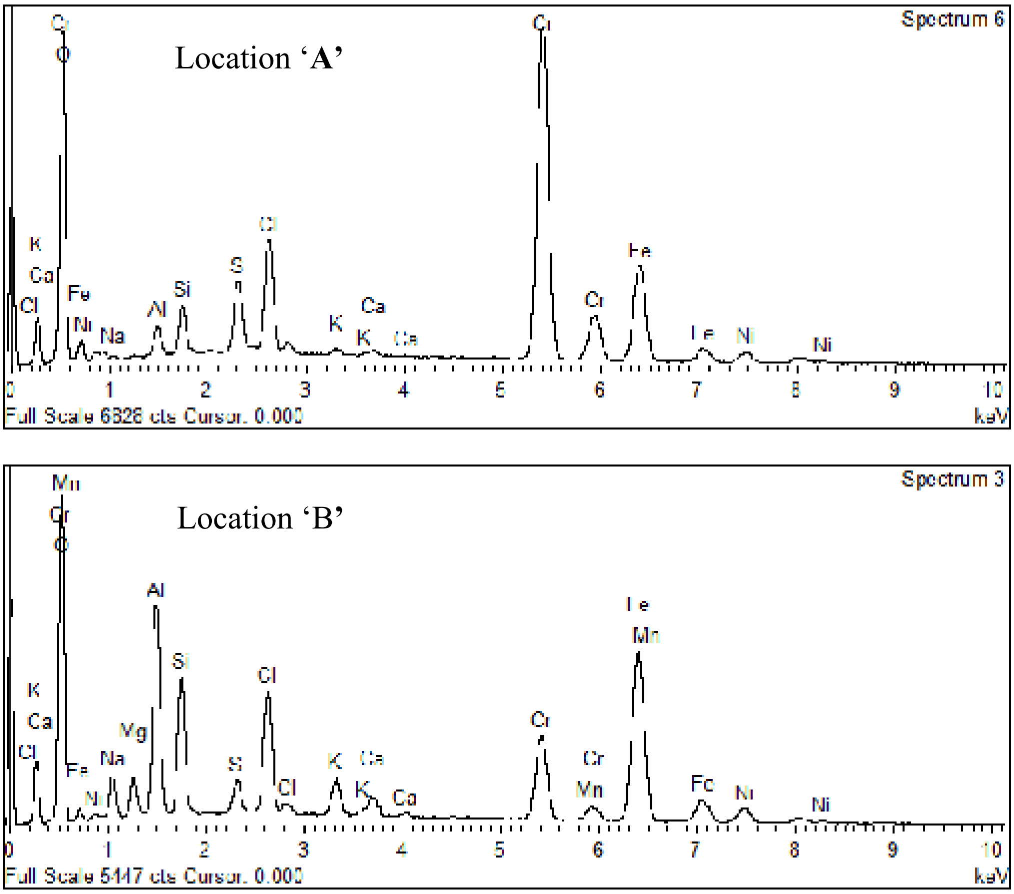

Fig. 10: EDS results for the hydrogen recycle line..

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Energy Efficiency Improvement and Emission Reduction Initiatives at KNPC Refineries

Petroleum refining is a very energy intensive process. Energy use is also a major source of emissions in refineries, making energy efficiency improvement an attractive opportunity to reduce emissions, reduce operating costs and increase profit margins.

Musaed Salman
TL, Environment

In order to further improve its energy performance, KNPC has embarked upon establishing a robust and effective Energy Management System (EnMS), in line with the Global ISO 50001:2018 Standards. KNPC's initiatives on energy efficiency improvement and emissions reduction, along with its strategy to implement the EnMS to strengthen and support energy efficiency improvement initiatives and activities are discussed in this article.

Introduction

Petroleum refineries provide inputs to virtually all sectors of the world's economy, including transportation (road, air, and marine), manufacturing industry, electricity & water sectors, domestic and agriculture sectors, etc. KNPC supplies energy in different forms to fuel the national needs and fulfill the export requirements.

Petroleum refining is a very energy intensive process. Typically, worldwide refineries spend about 30-50 % of their operating costs on energy (oil, gas, steam and electricity, etc.). Energy is a major cost factor as well as an important prospect for cost reduction. Energy use is also a major source of emissions in refineries.Making energy efficiency improvement is an attractive opportunity to reduce emissions, reduce operating costs and increase profit margins. It is noteworthy that in Kuwait, on a national level, KNPC refineries contribute about 7-10 % of total Greenhouse gas emissions (mainly CO_2).

KNPC is proactive in its role in energy efficiency improvement. It maintains a key focus on energy usage in its Operations, Maintenance, Projects and all other energy intensive activities. As early as in 2009, based on KPC Document 18, Energy Management Cells (EMC) were established at the three refineries (MAA, MAB & SHU). Further, multi-disciplinary Energy Management Team (EMT), headed by MTS-MAA was started in 2017 to improve energy performance at MAA and MAB refineries in a unified manner. Initiative details of respective refineries are given in sections 5 and 6. At refineries, high importance is given to closely monitor and improve energy efficiency performance of heaters/boilers and steam distribution system, which alone consume more than 60% energy at refineries. Other focus areas include overall fuel consumption, electricity consumption, flare and hydrocarbon losses, motors and pumps efficiency performance monitoring etc. Necessary and timely actions are taken to ensure energy efficient operations.

1. EnMS implementation in line with ISO 50001:2018

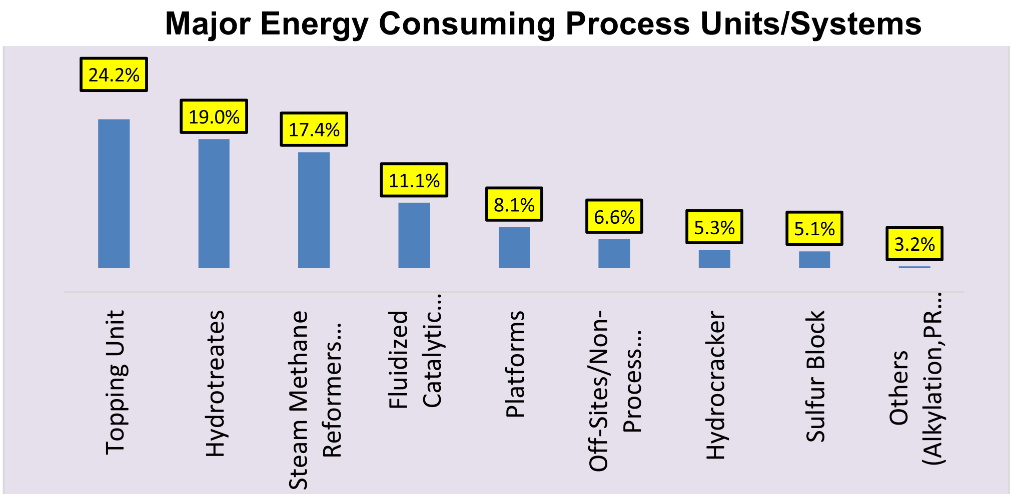
In order to further improve its energy performance, KNPC has embarked upon establishing a robust and effective EnMS in line with the Global ISO 50001:2018 Standard. Successful implementation of this system will support KNPC in taking its energy performance to higher pedestals. The ISO 50001 is the International Standard for Energy Management Systems, which supports organizations to continually reduce their energy use, energy costs and their greenhouse gas emissions. The standard specifies the requirements to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy security, energy use and consumption.

As per the system, the term "Energy" includes electricity, fuels, steam, heat, compressed air, etc.. In refineries, a very large quantity of energy in various forms like primary energy (gas and oil) and secondary energy (steam, electricity, thermal etc.) is used in all its operations. The main energy consumption areas in refineries include, heaters/boilers, steam distribution system, pumps, compressors, turbines, motors, fans, distillation, flaring, compressed air system and electricity (for lighting, HVAC, etc.). These provide substantial energy efficiency improvement and financial saving opportunities. It is broadly estimated that a 1% annual reduction in energy consumption will result in saving of more than 20,000 Standard Refinery Fuel Tons (SRFT), which is a saving of about 7-8 Million USD/Yr.

2. Energy efficiency improvement at MAA Refinery

Energy is mainly consumed in form of fuel gas, steam, FCCU coke and electricity. For all major energy consuming process units, their specific energy consumptions are closely monitored to achieve targets with respect to specific steam consumption, combustion efficiencies of heaters, heat exchanger fouling estimation, flare loss, heat loss to run-down coolers etc. Some of the initiatives are discussed below.

Broadly, the major energy consumers at MAA refinery are as follows:



2.1 Optimization of fired heaters and boilers operation

Key energy parameters like excess O2% in flue gas, stack exit temperature, draft pattern improvements and process pre-heat improvements etc.. are closely monitored through regular field audits/surveys and tracking of recommended action plans. An in-house automation system has been developed for real-time monitoring of refinery fired heaters efficiencies. Periodic external cleaning for convection section coils is also carried out. For operating the heater at high efficiency levels, stoichiometric combustion control (CO control) has been completed in Crude Distillation Unit-3. In CCR Platformer heaters, high emissivity ceramic coating on refractory surfaces of radiant section and on radiant tube surfaces has been completed.

2.2 Optimization of steam systems

Regular field audits and survey are carried out, which include defectives steam traps identification audit, insulation audit and condensing turbines audit etc.. Corrective measures identified based on audits are implemented. Monthly steam balancing, which also includes condensate recovery is carried out regularly. Activities in following areas are worked upon; establishing of real-time steam traps management system, replace steam traps with high-efficiency steam traps, real-time Energy Management System, Visual MESA.

2.3 Projects, studies and initiatives

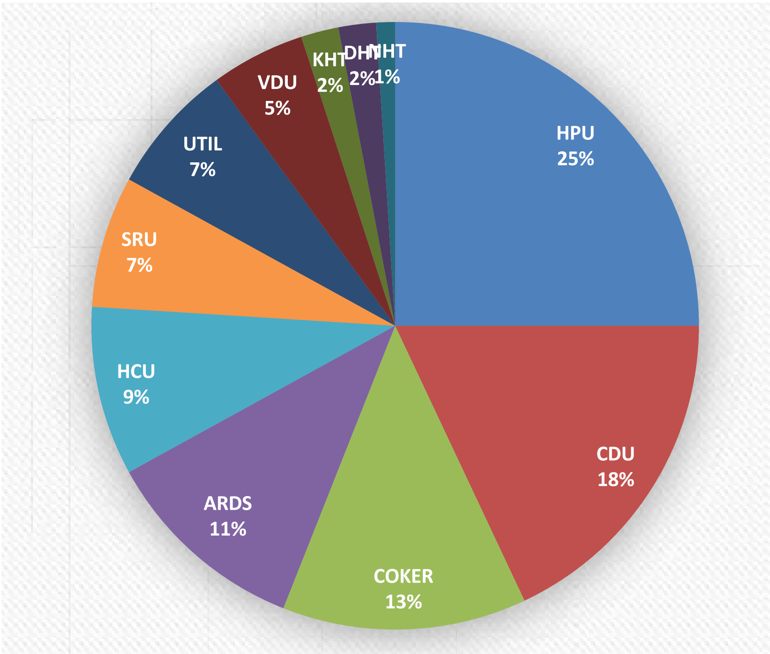
a. In CDUs 4 and 5, integration of crude column overhead with crude preheat train and replacement of crude/residue exchangers (E-11) with "Compablocs" to improve preheat temperature.
b. In ARDs, hot feed and use the excess energy available to maximize steam generation/ superheat.

c. In CDU-4 Pre heat trains, fouling monitoring pilot project, with M/s. Aspentech using Aspen HYSYS
d. Standard Energy Optimization based on top 10 bad actor equipment identified. The corresponding equipment is followed up for implementation of identified solutions suggested for mitigating root causes of repetitive failures.

3. Energy efficiency improvement at MAB

Energy is mainly consumed in form of fuel gas, steam and electricity. The focus areas for energy management are: to increase refinery financial margin, reduce greenhouse gas emissions and enhance efficiency of process systems. Some of the initiatives are discussed below.

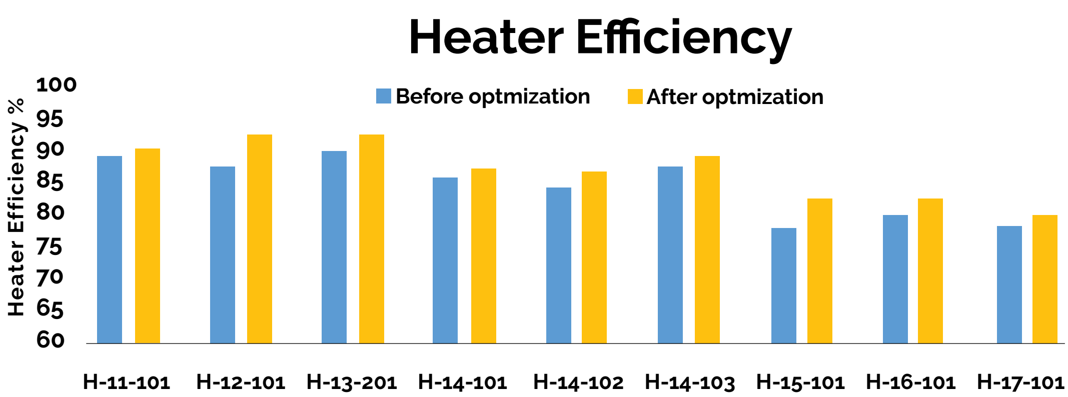
Typically, the main energy consumers at MAB refinery are:

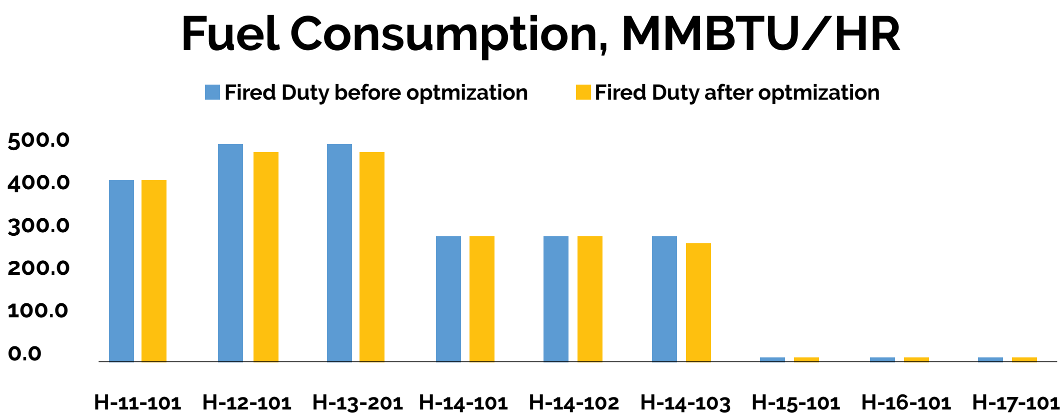


Some of energy saving initiatives and achievements of MAB refinery are as follows:

3.1 Improvement in Fired Heater efficiency - U-11/13/14/15/16/17

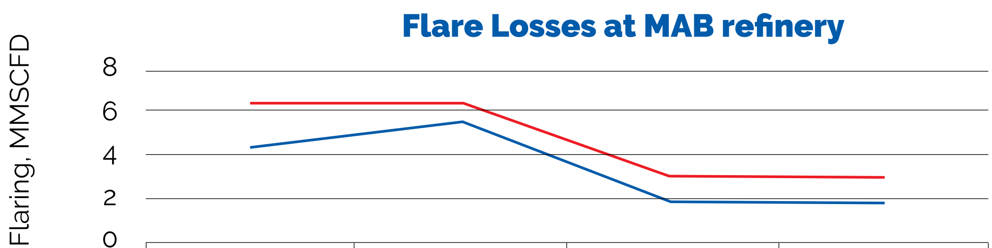
This initiative has resulted in a substantial reduction in fuel consumption. The details are provided below:





3.2 Reductions in flaring losses at MAB

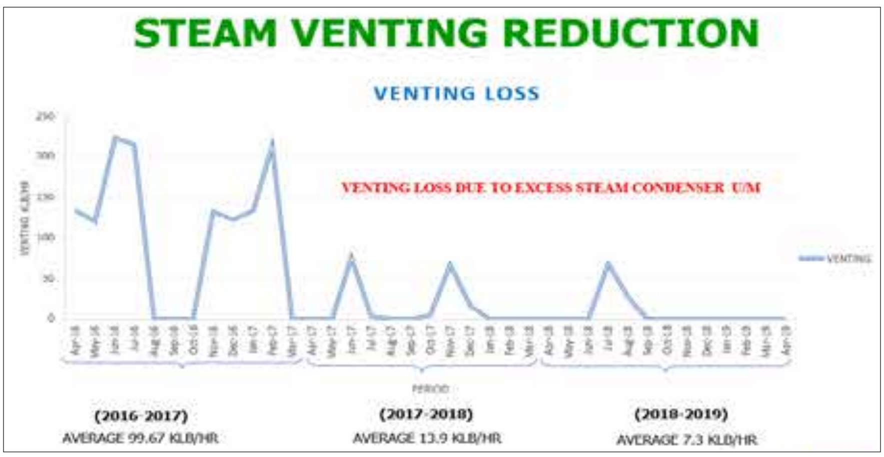
Commissioning of MAB Flare Gas Recovery unit (CDM Project, unit no. 49) in 2018 has resulted in a very significant reduction in hydrocarbon losses due to flaring. The recovered gases are utilized in refinery, resulting in significant energy efficiency improvement translating in large saving in money terms as well as reducing in overall CO_2 emissions.



	2016 - 2017	2017 - 2018	2018 - 2019	2019 - 2020
Actual	4.3	5.6	1.8	1.8
Target	6.4	6.4	3	3

3.3 Reductions in steam venting

Dedicated efforts towards stopping of steam venting and optimization of letdown stations load has resulted in accrued saving by about 5 Million $ per year.



3.4 Projects, studies and other efficiency improvement initiatives

Improvement in Fired Heaters

a. On line Heater Efficiency monitoring tool
b. Online cleaning of convection section
c. HPU Reformer Air Preheater replacement
d. SSRP Boiler Air Preheater Condensate Recovery

Improvement in steam system

a. Revalidation of overall refinery online steam balance, including checking and recalibration of steam meters
b. Steam trap performance audit/surveys and repair
c. Steam Leak survey and repair
d. Insulation survey and repair

Others

a. Optimization of flaring during startup and planned shutdowns
b. Real time energy monitoring Visual Messa model
c. Review of the steam balance and let down in CFP
d. Existing lighting replacement with LED lighting for street light and buildings in house
e. Fin fan efficiency improvement study

4. Energy efficiency measures incorporated in CFP

4.1 CFP, MAA Refinery

a. Hot feeding between process units and high efficiency heaters by design
b. Continuous optimization of excess air in major fired heaters, like Coker heater by having a check on stoichiometric air demand through process control
c. Energy efficient technology for Hydrogen Reformer fired heater
d. Use of FRP blades in fin fan coolers. Variable speed drives installed in fans
e. Setting up "Energy baseline for CFP units," considering catalysts run conditions, summer/winter, low capacity/severity etc. Develop steam balance/condensate recovery integrated with existing refinery

4.2 CFP, MAB Refinery

a. For effective energy utilization, CFP surplus refinery fuel gas is discharged to existing MAB fuel gas header
b. Majority of heaters/boilers designed with balanced and forced draft (more than 90 % efficiency) to save fuel consumption

Energy Efficiency Improvement and Emission Reduction Seminar

In line with above initiatives, KNPC HSE Department, Environment Division, arranged a company-wide seminar on the theme "Energy Efficiency Improvement and Emission Reduction" at its KNPC Head Office on 29 January, 2020. More than 150 KNPC and its contractor employees from various departments and divisions (key energy consuming areas) keenly participated in the seminar.

MAA & MAB Process divisions and Environment division, HSE, delivered four highly technical papers which addressed different areas related to energy efficiency improvement & emissions reduction at KNPC and the same are summarized in this article.

Initiatives in heater/boiler efficiency management, steam management, flaring reduction and status of ongoing and future energy efficiency improvement projects were shared. Presentations were made by Sr. Process Engineer Ghaleyah Alazmi, Process Engineer Vijayaraghavan G. (both for MA) and Sr. Process Engineer Wasemia Alshammari and Process Engineer Heba Al-Ghareeb (for MAB refinery).

c. More than 50 % fin fans (air cooler) designed with variable speed drive to save electrical energy
d. Steam system has two headers for essential and non-essential HP steam. Furthermore, the refinery steam header pressure and steam demand are synchronized with steam boiler master controller to distribute the load equally and optimize energy
e. In Hydrogen Production Unit, configuration includes Pre-Reformer, Reformer, HTER, MTS and PSA with multiple beds. The Unit is designed for Lower Steam to Carbon Ratio preserving the tube life and Lower Refinery Fuel gas consumption. Further, the HTER system configuration for large-scale Hydrogen production with improved energy efficiency. HTER / Pre-reformer technology facilitating Lower Reformer Capex
f. Sulfur block features, use of Controtrace instead of steam tubing/jacketing resulting in less tubing and steam traps compared to conventional tube tracing, and lower steam consumption compared to steam jacketing. Low temperature SCOT Catalyst in SRU-123, leads to about 60 % reduction in energy consumption. Further, using Methly Di-ethanol Amine (MDEA) solvent in Sulfur unit results in 35 % lesser reboiler steam requirements
g. Hydrogen Membrane System in ARDS units design for Hydrogen recovery from Purge gas streams and more than 92 % H_2 recovery with purity at 98 %

5. Summary and path forward

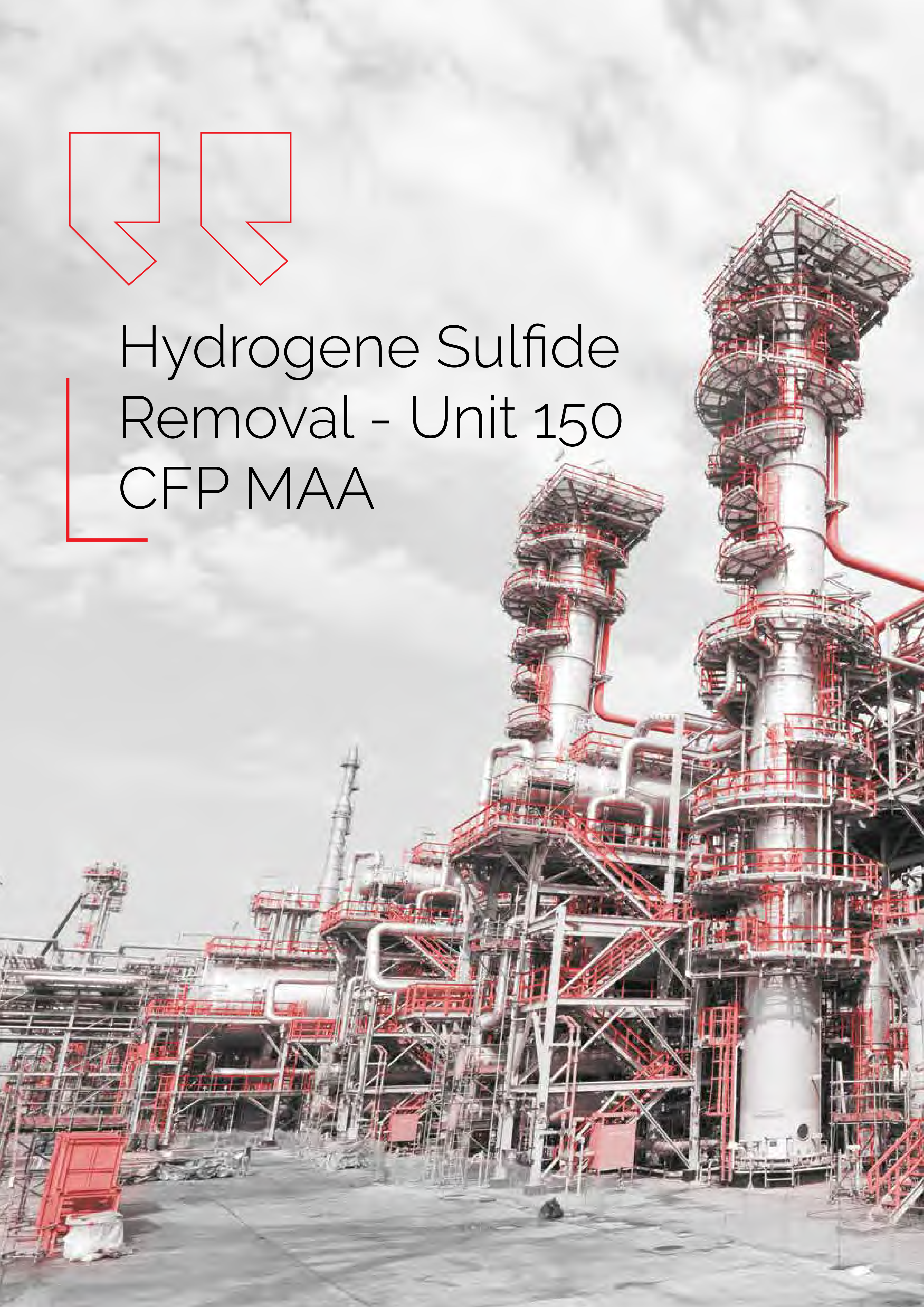
KNPC has embarked upon setting up a robust and effective Energy Management System (EnMS), meeting all the stipulated requirements. The key requirements of energy efficiency improvement and emission reductions are already interwoven in the KNPC's operating/maintenance/project strategies. Implementation of a robust system gives an opportunity to introspect, identify gaps, address them strongly, work sincerely on areas of improvement, and adapt best practices/procedures to take KNPC's energy performance on a higher trajectory of continual improvement.

Towards achieving this on a priority basis, the following activities either have been completed or are in advanced stages of completion: KNPC energy policy, energy management system manual, training of auditors, engagement of certification agency, basic energy review and identification of significant energy users etc.

Wholehearted support from all stakeholders is solicited to establish a robust system aimed at saving large quantity of energy, reducing emissions and increasing our company's net financial profit. KNPC looks back on its achievements in areas of efficiency improvement and emissions reduction with a sense of pride and strives for achieving future excellence.

ARD Unit 141 - CFP - MAA

Hydrogene Sulfide Removal - Unit 150 CFP MAA



Importance Of Identifying Proper Location of Mercury Guard Bed

Mercury guard bed is an essential part of gas pretreatment section, to avoid Mercury contamination of units and avoid damage to downstream cold box aluminum exchangers. It is important to identify the appropriate location of Mercury guard bed during the design stage of project. The following parameters need to be considered in deciding the Mercury guard bed location and the type of adsorbent.

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Team Leader
Operations Area 3 - MAA

Eng. K.S. Sabapathi
Process Department-MAA

Mercury guard bed downstream of driers will help in minimizing the capital cost of the project in terms of metallurgy. Also, this location provides the flexibility of loading either metal-based or carbon based adsorbent. Downside is if the feed gas contains H2S and CO2, which will form moisture in the presence of metal- based adsorbent.

$$H_2S + CO_2 \Leftrightarrow COS + H_2 0$$

Mercury guard bed

The above reaction will affect the performance of NGL section due to hydrate formation. Hence for feed with H2S and CO2, Mercury guard bed need to be upstream of driers.

Mercury guard bed, which is located upstream of driers, need to install metal-based adsorbents. As sulfur impregnated carbon based adsorbents lead to potential sulfur leaching in the presence of moisture. This configuration increases the operating cost of Mercury guard bed.

Also, Mercury guard which is located on wet gas stream (upstream of driers) may have to be sized for wet services which may lead to higher capital cost of the project. It is also beneficial to locate the vessel upstream of feed gas compressors to avoid Mercury contamination on the compressor. It operates on lower pressure with possible lower cost.

Considering the above, it is prudent to install the Mercury guard bed downstream of driers if the feed gas is free of H2S/CO2. For feed with H2S and CO2, it is economical to shift the Mercury guard bed upstream of the feed gas compressor, to minimize the capital cost of the equipment. In addition, locating the Mercury guard bed at the battery-limit of the unit help in avoiding contamination of pipelines/equipment by Mercury.

Corrosive Mercury

Natural gas fields around the world contains Mercury. Process plants with brazed aluminum heat exchangers, are susceptible to corrosive attack by Mercury. After Algerian plant disaster, awareness is increased to prevent such failure by installing the Mercury guard bed at the most suitable location.

Many competitive products, like sulfur-impregnated activated carbon, can be used in protecting process plant equipment from Mercury ingress from natural gas streams.

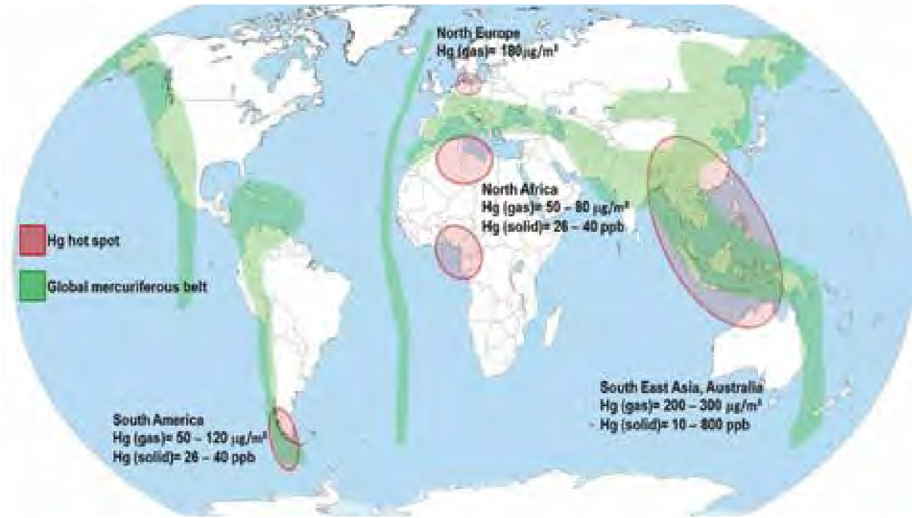
A comparison of three different locations are discussed with respect to advantage and disadvantage.

Types of Mercury

Mercury takes on several different chemical forms, depending on the hydrocarbon in question. These discrete categories exist in natural gas, condensate and crude oil. Elemental and organic Mercury fall into the category of being hydrocarbon soluble. Ionic Mercury species are water soluble and comprise examples that include both sulphate and chloride salts of Mercury ($HgSO_4$ and $HgCl_2$). Suspended Mercury is a broadly defined descriptor comprising particulates including Mercury containing species such as HgS.

Levels of Mercury in natural gas different areas of the world have varying levels of Mercury in their natural gas reservoirs. Figure 1 shows average Mercury levels that have been reported to UOP. In recent years, Mercury levels have increased from typical highs of 25 or 40 ug/Nm3 to levels exceeding 1000 ug/Nm3 in the Pacific Rim area. With a greater understanding of levels in specific geographical areas has come a greater level of expectation in terms of what is required to remove Mercury both on- and off-shore in a variety of locations worldwide.

Figure 1- Mercury level in the world



Need to protect equipment

Aluminum heat exchanger and cold box integrity will be compromised if Mercury is not removed in LNG/NGL units. Catastrophic failure happened in 1970s, due to accumulation of Mercury in the cryogenic recovery section of an LNG production plant at Skikda, Algeria. It was found that a combination of Mercury and water at temperatures around 0˚C caused corrosion in Aluminium tubes constructed from aluminium alloy 6061. Subsequent studies revealed far more data on the mechanistic details of how Mercury reacts with aluminium, with aluminium diffusing into the Mercury drop let followed by conversion to Al_2O_3 by reaction with air and water.

The consequence is that Mercury goes into aluminium and significantly reduces the thickness of aluminium-containing equipment. Specifically, LME has been responsible for a number of failures in the 40 years since the Skikda incident. LME can cause crack initiation and propagation, particularly in the proximity of a weld. In order to safeguard against the catastrophic failure of cryogenic equipment, ALPEMA has proscribed that typical maximum levels of Mercury are now required in and around these valuable cold boxes within gas processing trains. One level that has found prominence is that the gas entering cryogenic equipment contains no more than 10 ngHg/Nm3 gas.

Mercury removal process options

Two approaches are considered in Mercury removal. These options can be categorized as non-regenerative adsorbents and regenerative adsorbent solutions for Mercury contaminant removal. In the latter case, Mercury is not removed but diverted to other stream which will not see the aluminium equipment.

Regenerative adsorbents

A layer of silver-containing molecular sieve inside the dehydration vessels can protect of aluminium heat exchangers. The active silver forms an amalgam with the Mercury, and its zeolitic substrate adsorbs moisture in the gas to be treated. This is used on one of our NGL units for the last ten years without any problem. This approach offers flexibility in being Re-generable, as the Mercury-containing gas is bypassed around any cryogenic equipment into the sales gas. If necessary, condensed Mercury can be collected and the Mercury-entrained gas further treated with a small, non-regenerative guard bed, so that it is not passed to the sales gas.

Non-regenerative adsorbents

There are two types of non-regenerative MRU namely metal sulphide and carbon systems beds. The common and traditional approach to Mercury removal has historically been through the use of sulfur-impregnated carbon beds. Existing sulfur-impregnated activated carbon options tend to be less effective at positions upstream of molecular sieve drying systems or glycol injection due to the risk of capillary condensation in the micropores of the carbon sub-structure. However, the metal sulphide are better in this regard.

Reclaiming Mercury from spent adsorbents

Molecular sieve-regenerative
As the Mercury is passed to the regeneration gas in properly regenerated beds, the spent adsorbent contains no Mercury, and therefore no issue.

Carbon beds

After the carbon is discharged from an MRU, it is usually sent to a specialized plant, where Mercury is reclaimed via vacuum distillation. There is no useful purpose for the remaining carbon and it undergoes high-temperature incineration.

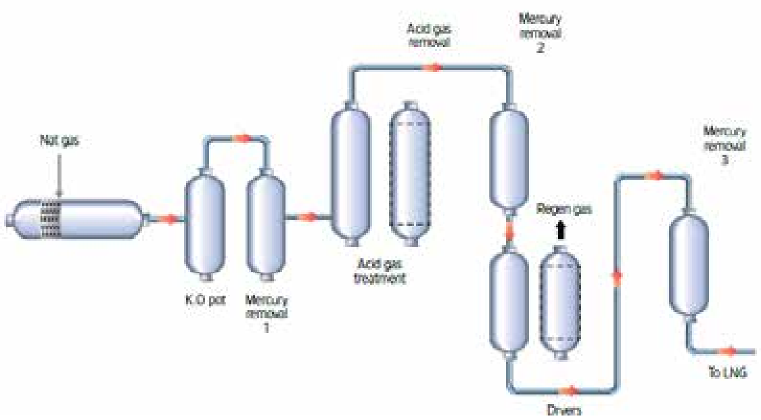
Metal sulphides

Specialized processes are used for Mercury reclaiming from metal sulphides. For both carbon-based and metal sulphide-based adsorbents, controls are in place to ship material internationally from source (gas processing plant) to destination (reclaim facility). The paperwork and experience required to accomplish such transportation is complex and requires very careful consideration.
Considering the above, KNPC has installed Mercury guard after the drier.

Table - 1 Mercury guard location

Location	Advantage	Disadvantage
Before the acid gas removal	No contamination, since it is first unit	Feed impurities might wash the sulphide and react with Hg guard
Before the molecular sieve driers	Partial contamination	Amine and liquid water carryover will affect the performance
After the molecular sieve driers	Easiest duty since gas is clean	All of the upstream equipment contaminated.

Fig 2 - Mercury guard bed location



The downside is when the feed gas contains H_2S and CO_2, as it will form moisture in the presence of metal-based adsorbent.

$H_2S + CO_2 \leftrightarrow COS + H_2O$

The above reaction has occurred and affected the performance of NGL section due to hydrate formation. Hence for feed with H_2S and CO_2. Therefore, Mercury guard bed shifted to the upstream of driers.

Conclusion

There are various treatment options available for Mercury removal from natural gas plant feed and product streams. A careful evaluation of pros and cons of these options along with its with respect to capital cost, operation cost, environmental issue has to be analyzed for location. Presence of ppm level impurities and its reaction with other components can result in serious outages. It is a prudent to exercise caution to select the location of Mercury guard.

Mercury Bed at GT-4 - MAA

Cybersecurity and Safeguarding Existing ICS Infrastructures

Mina Al-Ahmadi Refinery (MAA) is one of the major refineries in Middle East region. MAA hosts several control rooms with different Distributed Control Systems (DCS) operating since the 1980's. MAA is also facing challenges to safeguard industrial control systems against internal and external cybersecurity threats without causing operation interruptions in order to uphold integrity and reputation of the Refinery.

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As a short-term plan, periodical Internal Cybersecurity assessments were conducted for DCS systems to identify vulnerabilities and cybersecurity risks, followed with implementing remediation to minimize/ eliminate these vulnerabilities and cybersecurity risks to the DCS systems.

In order to endure cybersecurity compliance as per ISA99/IEC62443 guidelines, plans are underway to upgrade Operation Technology (OT) systems in all the control rooms at MAA Refinery.

This paper shows the actions initiated two years back to implement and improve the integrity and safety of our control systems and the path forward to ensure safe and smooth operations of our Refinery.

Introduction

MAA Refinery is a complex refinery with multiple control rooms housing different Integrated Control and Safety System (ICSS) systems from different Operational Technology (OT) vendors (Honeywell, Schneider and Emerson).

MAA Refinery cybersecurity focus

- IT and OT Integration
- DCS Vendors
- Microsoft (Windows and Applications)
- IT/OT Networks
- Third-Party Vendors

Assessment

With the emerging internal and external cybersecurity threats, safeguarding DCS for uninterrupted operations poses numerous challenges. Except few, the bulk of the OT systems are running on MS Windows platform. Due to inherent security risks of MS Operating Systems, OT systems become vulnerable to security breaches. Moreover, phased out MS OS pose additional security risks, due to non-availability of security patches. Additional challenges are being faced due to IT/OT integration and transformation to take advantage of Digitalization technology. Hence, KNPC has formed committees and teams to handle:

- Detailed analysis and assessments of existing OT systems to identify security vulnerabilities.
- OT Cybersecurity compliance roadmap.
- IT/OT integration and to bridge the gaps between IT and OT environment.

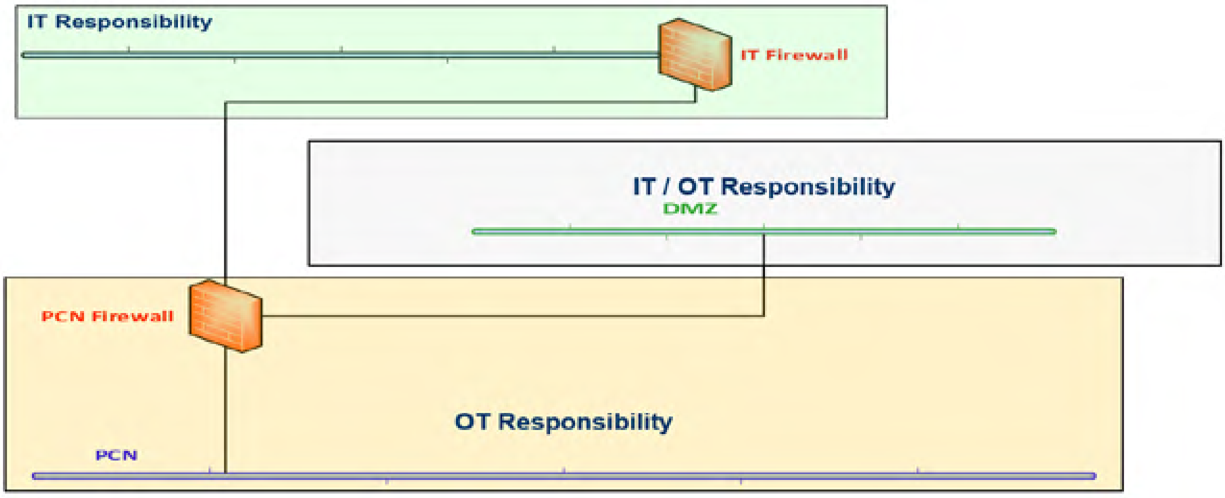
Action plan

KNPC has adopted a two-pronged approach to tackle OT cybersecurity threats and vulnerabilities:

1. In-house Assessments of existing OT systems on periodical basis to take corrective actions and implement remediation (wherever possible and approved by the OT vendor's Cybersecurity Team) based on outcome of the assessments.

2. Plan and implement Hardware, Software and Control Networks upgrades of OT systems to:

- Comply with ISA/IEC62443 guidelines (1)
- Upgrade phased out MS OS
- Upgrade Control software
- Upgrade Process Control Networks to establish levels, segmentation and Demilitarized Zones (DMZ).



Moreover, establishing Security Operations Center (SOC) on 24/7 basis is one of the solutions to remediate the cybersecurity threats. The functionality of SOC is to build a "flagship" converged IT-OT SOC with highly skilled resources and in-house capabilities to support securing KNPC core business and serve the interest of KNPC stakeholders. The company's SOC function will be responsible for continuously monitoring KNPC overall IT and OT cyber security posture. The SOC will act as a clearinghouse for all cyber security events generated to identify, analyze, investigate and escalate cyber security related incidents to ensure the security and integrity of KNPC's data and systems.

Conclusion

Due to advancements in Technology, OT cybersecurity compliance is a continuous journey and we shall unceasingly strive to follow the best practices and international standards to secure and safeguard OT systems from any intentional/ unintentional incident and internal/external threats.

MAXIMO

(1) ISA99/IEC62443:
International Society for Automation (ISA) = ISA
International Electrotechnical Commission = IEC

LNG Capacity Enhancement Without Modification

LNG is injected into the High Pressure fuel gas network in Kuwait which supplies fuel to power stations. The LNG facilities at MAA Refinery were originally designed for seasonal operation at a capacity of 500 MMSCFD. The rising energy demand necessitated an increase in LNG injection capacity, which in turn allowed more valuable gas oil to be exported. The increase in LNG injection capacity was achieved without any major modification or capital investment.

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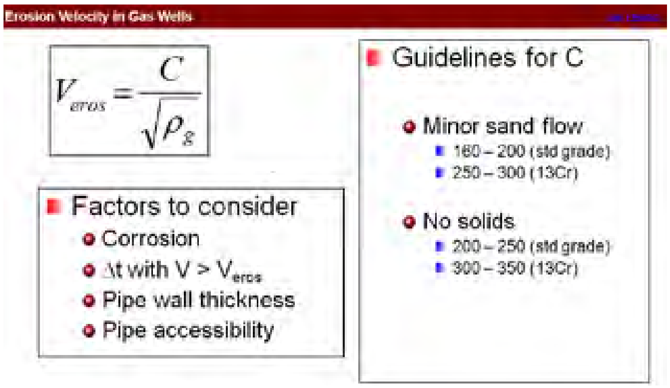
Introduction

The LNG Unit at MAA receives LNG at a dedicated berth, transfers this LNG to the Floating Storage and Regasification Unit (FSRU), and injects it into the High Pressure Fuel Gas Network through dedicated facilities comprising High Pressure Unloading Arm, two sea-water heat exchangers, a dedicated 24 inch 5 kilometer (appx) long pipeline and custody transfer meters. This high pressure fuel gas network supplies fuel to the power generation units in Kuwait. The quantity of LNG injected into the network varies throughout the year depending on the power demand and peaks in summer (May-September). The unit was designed to handle 500 Million Standard Cubic Feet per Day (MMSCFD).

Evaluation

The Process Engineering Team decided to investigate the possibility of increasing the injection rate beyond the design values since the demand for energy was increasing annually. Preliminary findings indicated that the system had been designed with economic velocity as the criteria instead of erosion velocity. (The ship manifold has higher pressure and it is being letdown. KNPC has highlighted that velocity need not be used as a criterion instead Erosion as per API14E can be used as limit).



A consultant was engaged to confirm the possibility of higher velocity through the existing pipelines as a higher velocity is translated into a higher capacity. The report by the consultant concluded that the injection rate could be increased to 750 MMSCFD. However, as the maximum allowable velocity through the High Pressure Loading Arm was 40 m/s, only 690 MMSCFD was possible through the existing system. Accordingly, the injection rate was successfully increased to 690 MMSCFD.

Higher flow rate

The HP Loading Arm vendor was contacted and requested to confirm if it could handle the higher flow rate and velocity. The vendor submitted a report indicating that the HP Loading Arm could handle gas velocity of up to 60 m/sec without any adverse impact. Following this confirmation from HP Loading Arm vendor, the injection rate was increased to 750 MMSCFD in October 2016.

A software model was developed in Aspen Hysys to simulate the process of gas injection into the fuel gas network. The model was tested against previous data at 500 MMSCFD and 690 MMSCFD. The pressure drop and temperature profile predicted by it closely matched the plant values, indicating that the model was a good representation of the physical process.

Using this verified model, it was found that the injection rate could be increased to 900 MMSCFD without exceeding the loading arm limit of 60 m/sec. It was further concluded that the injection rate could be increased beyond 750 MMSCFD to 900 MMSCFD without any major investment. The operator of the FSR Unit confirmed that the onboard high pressure pumps and sea water heat exchangers could deliver the higher flow rate at the temperature and pressure required for 900 MMSCFD.

A consultant was appointed by KNPC to establish the maximum possible injection rate through the system without any hardware modifications. The feasibility study by the consultant confirmed that 900 MMSCFD was indeed possible without any modifications to the existing infrastructure (except for one valve replacement).

It was decided to carry out a test run to establish the findings of the report. The FSRU operator (GOLAR) was accordingly informed of the decision and the test run date. However, the FSRU operator conveyed their inability to provide the higher pressure required for a flow rate of 900 MMSCFD (above 90 barg) and that the maximum pressure at which they could safely operate was 88 barg.

Within the limits of this constraint, a test run was started on 5th Sep, 2017. The injection rate was gradually increased to 880 MMSCFD, and this injection rate was sustained for a period of 24 hours. The test run was successful.

LNG import

- Test run was conducted and proved that it could operate at 880 MMSCFD. This is mainly due to the limitation in the ship LNG pumps, which could not deliver the required pressure at high pressure
- This replaces the Gas Oil used in Gas Turbines in the power plants operated by MEW
- Average approximate cost difference between LNG and Gas oil is 2 $/MMBTU
- Saving to Kuwait is about $ 40 million/annum

LNG capacity enhancement

LNG Profitability		
Original LNG Injection Rate	MMSCFD	750
Enhanced LNG Injection Rate	MMSCFD	880
Increase	MMSCFD	130
LNG Calorific Value	BTU/SCF	1000
Additional Energy	MMBTU	130,000 (130 x 1000)
Energy Cost using Gas Oil	$/MMBTU	7.5
Energy Cost using LNG	$/MMBTU	5.5
Additional Benefit	$/day	260,000

Marine scope

- The study, from a marine point of view, has been focused on assessing the feasibility of operating a larger FSRU at the jetty on a year-round basis and determine whether the LNG jetty (Gasport 10) is, also, acceptable for FSRU operation. Vessels has been analyzed up to QFlex size. The following marine studies have been developed and have proven the feasibility of phase I:
- Metocean study: To update the marine conditions existing at the site
- Ship Geometrical Compatibility Study: Atlantic Max and QFlex are compatible with the existing berths on a year-round operational basis
- Dynamic moored vessel analysis: the studied high-capacity vessels (173,000 and 216,200 m3) show favorable moored vessel behavior according to the simulated metocean conditions.
- Maneuvering study: available navigational and maneuvering areas have been defined with no interference to any existing facilities
- Thermal Dispersion Study: the temperature difference in water, between inlets and outlets, is lower than 10 °C, as required by K-EPA
- Berth Availability Analysis: berth availability as per metocean data sources used.

Conclusion

LNG import is very important to meet the growing energy demands of Kuwait. LNG import facilities were designed only for an injection rate of 500 MMSCFD. However, a re-evaluation of process design revealed hidden capabilities in the existing facilities, which helped the company achieve its objective of higher injection rate without revamping the current set-up. The name plate capacity of the facilities would soon be revised to 880 MMSCFD.

MAA Refinery - Bunker Fuel Oil Challenge

Stable and Compatible VSLFO Production

Studies have been conducted on strategies for production of bunker fuel oil with reduced sulfur and catalytic fines concentration limits. However, these studies conclude that refiners must face challenges in terms of bunker fuel oil stability and compatibility. In addition, Heavy Fuel oil prices / demand will diminish, which force refineries to find alternate options for the disposal.

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MAA

Eng. Muthusamy Rajendran
Operational Planning - MAA

Introduction

To find strategies for bunker fuel oil production, Mina Al-Ahmadi Refinery (MAA) had conducted feasibility and pilot studies. These pilot small-scale preliminary studies, aimed to investigate whether blending ratio considered for the feasible components are available in MAA to produce on specification VLSFO bunker fuel oil for longer periods. Subsequently, the results and analysis of the trial run concluded that order of blending and stream qualities are the best ways for increasing the level of compatibility in blending fuel oil.

This article provides a comprehensive analysis of very low sulphur fuel oil (VLSFO) quality constraints and MAA's experience of VLSFO production.

Bunker fuel – An easy guide

The name, 'bunker fuel' dates to steam-powered ships, which at the time were powered by coal and stored their 'fuel' inside of 'coal bunkers' onboard the ship. Now, in place of coalbunkers, ships have fuel tanks, but they are still often referred to as bunkers.

Maritime vessels use bunker fuel to power their motors. Some watercrafts indeed use diesel i.e. Marine gas oil (which is considered a low sulfur fuel oil) as their source of bunker fuel. However, for most commercial ocean-going vessels, they currently rely on heavy fuel oil (HFO) to generate power onboard to propel their ships across the ocean. These are highly polluted and a cause of respiratory diseases and are a component of acid rain that damages vegetation and wildlife.

The Emission Control Areas (ECA) limit was gradually reduced from its initial value of 1.5% to 1.0% (2010) and finally to 0.1% (2015). The global limit was set to 3.5 % in the first step (2012). Effective on Jan' 1st, 2020 the new regulations of the International Maritime Organization (IMO) had banned ships from using fuels with a sulphur content above 0.5%, compared with the limit of 3.5%.

Fig 1: The gradual reduction of the bunker fuel oil sulfur spec

Note that the utilization of approved alternative means of emissions reduction, which are at least as effective as using compliant fuels, is also permitted. An exhaust scrubber designed for reducing the SOx content to the level required is considered equivalent, and fuels with higher sulphur content may still be used on vessels equipped accordingly. However, usage of exhaust scrubbers is limited due to restriction in disposing of wash water and most ports are not allowing vessels to discharge washwater near these facilities.

Fig 1: The gradual reduction of the bunker fuel oil sulfur spec	HFO (RM-GRADES)	MDO (DMB, DFB)	MGO (DMA, DFA, DMZ, DFZ)
S ≤ 0.10 %	ULSFO RM	ULSFO DM	
0.10 % < S ≤ 0.50 %	VLSFO RM	VLSFO DM	
0.50 % <S	HSFO RM*	HSFO DM*	

Table 1: Fuels names after 1st January 2020

**Fuels allowed only for ships with exhaust reduction technologies yielding Sulphur oxide reductions equivalent to using fuels compliant with the respective sulphur limit.*

Refinery challenges for VLSFO bunker fuel production

Most fuels used in the market after January 1st, 2020 are VLSFO. The switch to VLSFO affected refinery production as it is unlikely that HFO products can simply be de-sulphurized to create compliant fuels. Instead, VLSFO will consist of blends of fuels produced from different refinery streams. These blends are expected to have higher fractions of paraffinic products, which will affect the properties of VLSFO. It is important to state that VLSFO must be compliant with ISO 8217:2017 [1] and fit within the same RM grades as used before 2020. Below is the listed some important parameters which have huge challenges while meeting ISO 8217:2017 specification of VLSFO.

Compatibility and/or stability: Depending on the origin and production process used, VLSFO blend streams can be aromatic or paraffinic in nature. This could lead to compatibility problems between different fuel streams.

Blending of aromatic streams with paraffinic streams result in sludge formation (after prolonged time in a tank, even if initially stable) due to a change in solubility properties of the subsequent blend.

Eng. Mayank Garg
Operational Planning, MAA

Viscosity: The viscosity of fuel oils must be in accordance with ISO 8217:2017 [1]. VLSFO fuels are expected to have a broad range of viscosities even within the same grade. Some types of VLSFO will have low viscosity levels like distillate marine (DM).

Cold flow properties: In VLSFO having high fractions of paraffinic components, exposure to prolonged cold conditions may lead to wax formation, which in turn could affect the cold flow properties of the fuel.

Calculated Carbon Aromaticity Index (CCAI): The CCAI provides an indication of the ignition properties or ignition delay of the fuel based on fuel viscosity and density. In view of the broad range of density and viscosity values of VLSFO, resulting CCAI values can also vary considerably.

Catalytic fines: The level of catalytic fines in VLSFO are unknown and might vary depending on the refinery streams from which the fuel was produced.

Blending of VLSFO

The major challenge refineries face are to keep the asphaltenes micelles in colloidal solutions of fuel oil. High aromaticity of fuel oil helps to achieve the same. In addition, if an aromatic cutter is poured into a paraffinic base, then the initial small volume of aromatics in a paraffinic medium will just disturb the low aromaticity of the paraffinic base there by increasing the probability of asphaltene sludging.

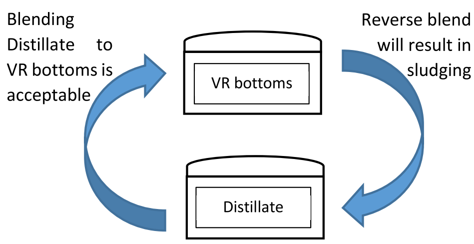

Fig 2: Blending direction

In the opposite situation, where paraffinic blend stock is poured into an aromatic medium, the aromaticity at the interface of the two liquids will be predominantly by the aromatics and will always keep asphaltenes in the solution.

Based on typical examinations of VLSFO blend stocks properties, they can be classified as high aromaticity base (50 - 60 %) (i.e. vacuum bottoms and visbreaker tar bottom) and two types of cutter stocks (aromatics and paraffinic).

Aromatic cutters are typically from FCC units and include light cycle oil (LCO), heavy cycle oil (HCO) and slurries or clarified oils (CLO). These cutters are highly aromatic liquids, at 80% or higher. Paraffinic cutters are typically from atmospheric and vacuum distillation units, such as atmospheric gasoil (AGO), light and heavy AGO and vacuum gasoil (VGO). These cutters have low aromaticity of around 30%–50%.

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DESCRIPTION	ARD Resid.	VR Resid.	GAS OIL	TGO
Specific gravity	0.9302	0.9890	0.8450	0.9068
Sulfur, wt. %	0.46	0.7	0.0005	0.16
Visc., cSt @50ºC	175	5000	4.0	96.0
Visc., cSt @50ºC	175	5000	4.0	96.0
Vanadium, ppmw	7.5	36	-	-

Table 2: Typical properties of the components available in MAA Refinery.

Considering asphaltene content and aromaticity, VLSFO fuel oil blends can be categorized as paraffinic blends, aromatic blends, and hybrid blends.

Paraffinic blends

These blends typically use vacuum tower bottoms and the cutter [e.g., light atmospheric gasoil (LAGO), heavy atmospheric gasoil (HAGO) or ultra-low-sulfur diesel (ULSD)].

SN	Blend Component	Aromaticity
1	Vacuum tower bottoms	Nearly 80%
2	Gasoil	30%– 40%

Vacuum residue (VR) from the vacuum distillation units (VDU) can be blended with low Sulphur stream to produce the required product keeping that resulting blend aromaticity above 40 by controlling the blend ratio and order of blending. GO dropping in vacuum tower bottoms will help to achieve the required aromaticity. VR blend with distillate, final blending aromaticity could drop below 40% and can lead to sludging depending on the blend ratio and the order of blending.

Aromatic blends

These blends typically use “cracked” blend components, such as visbreaker tar bottoms, and highly aromatic cutters, i.e. LCO and HCO.

SN	Blend Component	Aromaticity
1	Visbreaker tar bottoms	47%–56%
2	LCO and HCO	More than 80%

Any aromatic blend will always have an excess of aromaticity (more than 50%) and be stable.

Hybrid blends

These blends typically use paraffinic blend components such as atmospheric tower bottoms, vacuum tower bottoms and mixtures of both paraffinic cutters, such as AGO, LAGO and HAGO; and aromatic cutters, i.e. LCO and HCO.

SN	Blend Component	Aromaticity
1	Atmospheric tower bottoms + vacuum tower bottoms	50%–60%
2	Gasoil	30%–40%
3	Cycle oil	More than 80%

Depending on the blend recipe, a hybrid blend is not guaranteed to always have an excess of aromaticity (more than 50%) and be stable.

The changes in fuel production resulted in different nature and quality fuels. New fuels (VLSFO), compliant with this 0.5 % S limit, are likely to display a wide variability of physical and chemical properties even between fuel batches of the same ISO specification.

Potential of refineries to produce VLSFO

The considerable decrease of fuel sulphur content in 2020 had a substantial effect on the bunker fuel production. In response to this severe reduction in the regulations, refineries will have to make capital investments and innovative technologies/methods to reduce the amount of sulfur and particulates in fuel oil. Apart from this, HSFO production required to be minimized in anticipation of a drop in value.

As VLSFO must be compliant with ISO 8217:2017 to meet IMO requirements, blending of available components in the refineries plays a very vital role in the production. The major concern is the compatibility between different VLSFO blends. VLSFO blending is a mess from fuel oil stability and compatibility points of view.

KNPC experience with VLSFO production

KNPC two refineries have state-of-the-art units and make an integrated refining complex. Both produce clean-burning fuels conforming to Euro-V standards. As per design, KNPC will produce around 39,800 BPD of LSFO with a viscosity of 380 and 180 cSt. The components considered in KNPC refineries to produce LSFO is atmospheric residue from CDUs, treated residue (ARDR) from the ARD units, VR from the VDU, distillate, LCO and HCO from the FCC.

The option of producing the desired VLSFO product from atmospheric residue is not possible due to high sulphur content (4.26%). Diverse options tried at KNPC for producing VLSFO along with associated limitations, subsequent product quality is presented in detail.

The ARD unit at MAA Clean Fuels Project (CFP) can produce residue with sulphur content of around 0.46% 'S' which will be further processed in the Vacuum Unit to keep feed sulphur at the lowest level possible. ARD distillate can be used as a cutter to blend with VR bottoms.

Option 1: Hydrotreated ARDR

KNPC's new ARD unit's product can be directly supplied as BFO without blending of another stream with sulphur of 0.46% (wt.). ARDR sulphur will depend on the level of desulphurization and will vary from start of run (SOR) to end of run (EOR).

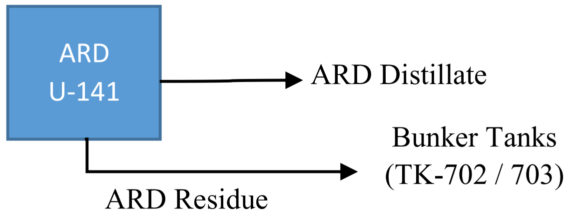

Fig 3: ARD Units

To route ARDR to appointed VLSFO tanks a project modification (PMR) is required with controls in the unit and offsite area. The required PMR is raised, and expected completion will be by July'24.

PARAMETER	UNIT	ARD
Carbon Residue, Conradson	% mass	3.98
Sulfur, Total	% mass	0.4
Density @ 15 °C	kg/L	0.9259
Viscosity, @ 50 °C	cSt	173
Sludge, Hot Filtration	% mass	0.036
Hydrogen Sulphide (Liquid phase)	ppm	0.02
Vanadium (V)	mg/kg	5.3
Ash	% mass	0.02
Sediment	% mass	0.04
Asphaltenes	% mass	1.72
CCAI	Calc.	795

Table 3: Typical properties of the ARD residue in MAA

Asphaltene analyser

Impact: There will be a reduction in conversion unit feed rate, namely hydrocrackers (HCRs), FCC units and coker units, since part of KNPC's ARDR will not be processed in the vacuum re-run units, thus VGO/TGO/VR loss. Therefore, Naphtha, ATK & diesel production will also be reduced.

Option 2: VR residue blending with diesel

VR from the VDUs can be blended with a low sulphur stream to produce the required product.

To reduce the sulphur in VR bottom, feed sulphur was kept exceptionally low. That has resulted in achieving VR bottom sulfur 0.84 %. Further adding 10-ppm sulfur gasoil, the resulting sulfur reduced to less than 0.5 wt. % as per VSLFO requirements.

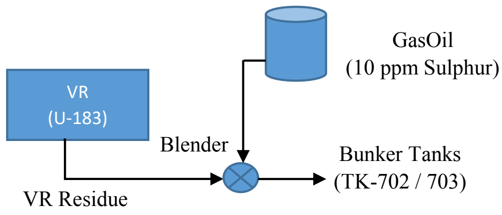

Fig 4: VR / ARD units

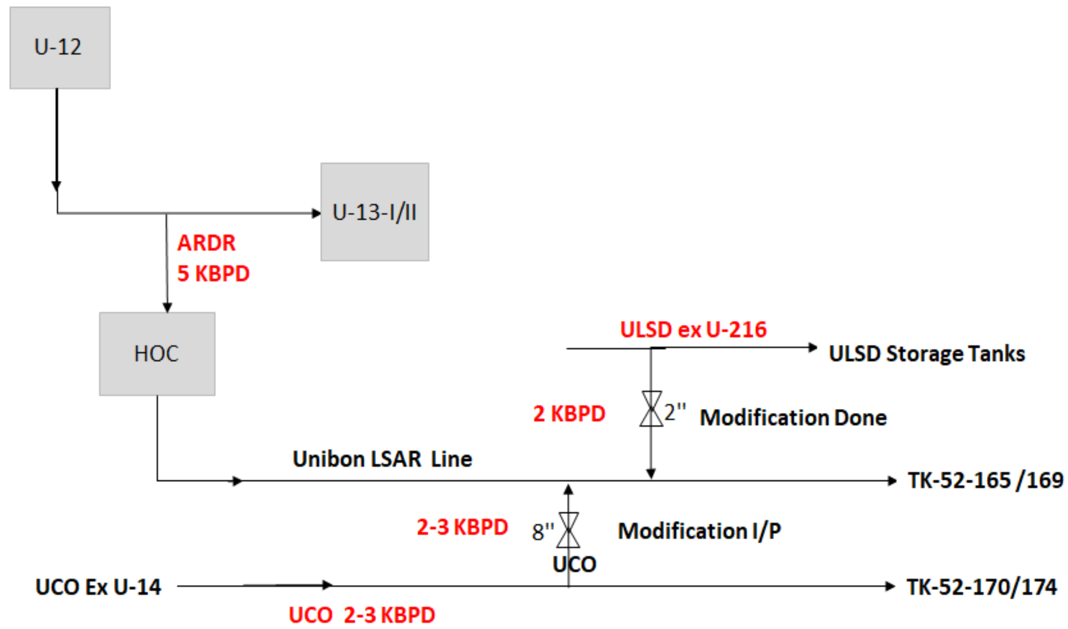

Fig 5: MAB units blend

Total sediment tester instrument

PARAMETER	UNIT	RESULT
Ash	% mass	0.02
Density @ 15 °C	kg/L	0.9047
Flash Point, PMCC	°C	108
Hydrogen Sulfide	mg/kg	0.93
Pour Point	°C	3
Relative Density @ 60/60F	-	0.9052
Sulfur, Total	% mass	0.48
Total Sediment Potential	% mass	0.04
Vanadium (V)	mg/kg	7.2
Viscosity, Kin. @ 50 °C	cSt	45
Aluminum (Al) & Silicon (Si)	mg/kg	5.7
CCAI	-	793.1

Table 4: Results of the final blend

The blended fuel oil viscosity quality is extremely low at 45 cSt compared to a max of 380 cSt and CCAI is close to max limit.

Impact: However, it requires about 45% of 10 ppm gasoil as cutter stock. That may lead to the possibility of final blending aromaticity to drop below 40% and can lead to sludging. Hence, this option has an inherent risk associated with that.

Option 3: Diesel as bunker fuel

Diesel can be supplied as bunker fuel at prevailing market prices. KNPC economics will not be affected if bunker price is same as export gas oil price. In this case, the bunker will be 10 ppm gas oil.

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Section Head Opr - CFP

Option 4: Using Low sulfur ARDR, ULSD and UCO

MAB had successfully done the trial run for the lab blend with ARD residue and mix of TGO & UCO to produce low sulfur fuel oil. However, the blend viscosity was around 20 to 40 cSt. Initial blended batch was stable and desired results were achieved. However, compatibility issues were observed in the subsequent batches. Executing the modification shown below, MAB successfully prepared first batch of VLSFO.

PARA	UOM	MAB VLSFO (1)	MAB VLSFO (2)	VLSFO Import 1st Cargo
Sulphur	% Mass	0.39	0.50	0.46
Density @ 15° C	Kg/ L	0.894	0.896	0.937
Flash Point	°C	110	>110	104
Kin. Visc., @50° C	cSt	37.2	40.0	345
Tot sediment Potential	% Mass	0.1	0.06	NA
H2S (liq phase)	ppm	0.2	0.2	0.5
Ash	% Mass	0.06	0.02	0.03
Alu+ Sili (Al+-Si)	mg/ kg	4.0	4.6	NA
Vanadium (V)	-	5.7	6.7	NA
CCAI	-	785	785	800

Table 4: MAB bunker fuel oil results

Option 5: VR & TGO

MAA finally achieved the most economic and feasible way of producing the VSLFO using ARD distillate, VR Vacuum residue and trim gas oil (TGO) streams. To achieve the above, ARD unit was run with ARD residue product sulphur of 0.35 wt. max. VR unit must process low sulphur ARD residue from ARD unit without mixing with high sulfur ARD residue from other MAA ARD units.

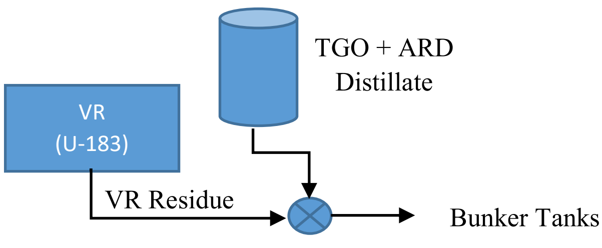

Fig 6: VR Residue with TGO blend

PARAMETER	UNIT	Result
Aluminum (Al) & Silicon (Si)	mg/kg	0.1
Ash	% mass	0.02
CCAI	-	800.1
Density @ 15 °C	kg/L	0.9353
Flash Point, PMCC	°C	114
H2S Hydrogen Sulfide	mg/kg	0.3
Phosphorus (P)	mg/kg	0
Pour Point	°C	-3
Relative Density @ 60/60F	-	0.9358
Sulfur, Total	% mass	0.45
Total Sediment Potential	% mass	0.1
Vanadium (V)	mg/kg	10
Viscosity, Kinematic @ 50 °C	cSt	276

Table 6: MAA bunker results

By the above operating condition, the vacuum residue will have sulphur of 0.7 wt. percentage max and viscosity will be around 4000 - 5000 cSt @50˚ C. Blending low sulfur ARD distillate (sulphur -250 ppm) and Trim Gasoil from VR (sulfur limit of 0.15 wt. %), with vacuum residue the required VLSFO production was achieved.

MAA issues while handling the imported materials

To fulfill the VLSFO bunker fuel requirements, 40 KT was imported with 0.46 wt. % sulphur on 16-17/12/19 into MAA bunker tanks. Prior to import, both tanks were cleaned, and the associated system was flushed thoroughly using 500-ppm gasoil. Upon completion of import, both the tanks were certified as per IMO specifications.

During this period, MAB produced a batch of 34 KT VLSFO as per option # 4. KPC arranged the vessel and upon loading, ship composite sample at MAB port was reported to be meeting all specifications (sulphur - 0.495 wt. %); however, a prior discharge at MAA sulphur was exceeding the limits (0.508 Wt. %) and upon KPC-QC clearance was received into bunker tanks.

The shore tank upon receipt was reported 0.50 wt. %. Vessel "Sedra" was loaded on 31/01/20 and the composite "Sedra" sample sulphur was 0.51 wt. %. Few samples at various locations were collected and the sulphur results were marginally exceeding the limits.

In view of such a narrow range of the results, exceeding the sulphur limits with no available facility for correcting the product, MAA requested to dispose the product. Upon KPC arranging a vessel to load the product, the tank samples result of Sulphur were 0.44 wt. % & 0.51 wt. % respectively. However, during the preceding, few weeks' results of samples collected at separate times were found to be inconsistent and mixers were kept on achieving consistency.

PARAMETER	UNIT	VLSFO (1)	VLSFO (2)
Aluminum (Al) & Silicon (Si)	mg/kg	24.88	43.8
Ash	% mass	0.03	0.03
Density @ 15 °C	kg/L	0.937	0.9354
Flash Point, PMCC	°C	104	100
H2S Hydro. Sulfide	mg/kg	0.5	0.5
Relative Density @ 60/60F	-	0.9376	0.936
Sulfur, Total	% mass	0.46	0.46
Total Sed. Potential	% mass	0.04	0.04
Vanadium (V)	mg/kg	3.8	3.7
Kin. Viscosity, @ 50 °C	cSt	345	348
CCAI	-	800	798

Table 5: MAA bunker tanks results

From the above it can be inferred that it is imperative that all receipts of this grade fuel oil should have 0.47 Wt. % max (95 % confidence level). The above clarifies the challenges met and efforts exerted from by all concerned at MAA side to meet KPC VLSFO requirements.

Conclusion

With the new IMO 2020 low-sulfur regulation, bunker production MUST use low-sulfur blend components to be compliant. Sludge issue by calculating the fuel's compatibility and stability. The asphaltene content and aromaticity of fuel oil is critical to its fitness for use.

KNPC achieved the most economically feasible way of producing VLSFO by using Distillate, VR and TGO streams originated from latest CFP units. This VLSFO meeting IMO 0.5 BFO specifications with minimum viscosity of 250 cSt as well as stable product due to low asphaltene content of the VR.

With the above accomplishments, MAA is in the position to meet the KPC mandatory requirements of VLSFO IMO BFO of 20-25 KT/month with financial benefit of 10.87 MM US $/ year. As well, it will help MAA to modify the production slots based on the economics and market demands.

Abbreviations

HFO : Heavy Fuel Oil
MDO : Marine Diesel Oil
MGO : Marine Gas Oil
HSFO : High Sulphur Fuel Oil
ULSFO : Ultra Low Sulphur Fuel Oil
VLSFO : Very Low Sulphur Fuel Oil
DM : Distillate Marine (fuel that does not need heating)
RM : Residual Marine
IMO : International Marine Organization

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[1] IMO, Revised MARPOL Annex VI, London, 2016.
[2] Industry News dated 14/10/20. (https://www.nepia.com/industry-news/no-scrubs-more-ports-declare-ban-on-egcs-discharges
[3] ISO (International Organization for Standardization), ISO 8217:2017 (E) Petroleum products - Fuels (class F) - Specifications of marine fuels, Geneva, 2017
[4] Hydrocarbon Processing, DECEMBER 2019 | Volume 98 Number 12.

Sulfur Analyser Instrument

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KNPC Leading 3D Printing Initiative in Oil & Gas Fields

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KNPC and other oil and gas companies around the globe are on the verge of entering a new era of many challenges and obstacles to overcome. Digitalization is one of the innovative solutions that has been considered as a part of KNPC strategy 2040 for improving operational excellence.

Introduction

KNPC is the leader in oil & gas field in Kuwait to validate three dimensional (3D) metallic printing technology as a part of the digital trasnfromation. The technology is also known as "Additive Manufacturing" (AM), which is considered an alternate of conventional manufacturing method. The objective of 3D printing technology is to reduce procurement cycle, make the company self-reliant in providing critical spare parts, improve mechanical avalibility and provide innovative solutions to overcome operating challenges. Also the geographical location of Kuwait makes it more important to have an alternate manufacturing method specially situations like pandemics.

The 3D printing (or AM) is the construction of a three-dimensional object from a computer-aided design (CAD) model or a digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together). 3D printing is being widely used in the field of medical, aviation, space, art and jewelry, construction, etc.

How it is done

Typically, the process will generate support and construction of the final shape layer by layer. There are many techniques available in the market for metal AM such as, Powder Bed Fusion (PBF) and Atomic Diffusion. PBD can be further divided into Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Direct Metal Laser Sintering (DMLS), and Electron Beam Melting (EBM). Based on the adavantages of the technique and experience, KNPC has selected SLM for pilot study. Other known companies, like Boeing

3D printed Titanium impeller

777 and NASA, have also used PBF AM in their final products. Still, there are certain limitations as per current development with respect to material, size, mixing of different metals, unavailability of some specifications and data of existing spare parts, unavailabilty of codes and standards for some metals, etc.

3D printable models can be created using a CAD package, via a 3D scanner, or by a digital camera and photogrammetry software. The deviations in 3D printable models can be identified and corrected before printing by employing personal experience and simulations. The manual modeling process of preparing geometric data for 3D computer graphics is similar to arts such as sculpting.

KNPC R&T has started the inititve through collaboration with Quality Assuarance, Maintenance at MAA and MAB refineries and Commercial departments. The selected two parts were based on the specific criteria for manufacturing and field testing trial, in order to validate the technology for the added value in refining business. The reputed companies in this field were initially screened for their capabilties and technology to understand such new field for executing the study. In this pilot study case, a Stainless Steel Control Valve plug and a Titanium Impeller were selected.

The identified scope of work followed the applicable ASTM codes and quality assurance testing plan. At present, the selected parts have been maufactured using 3D printing are under field trial phase.

The 3D manufactured spare parts were suceessfully installed at related units and their performance is accepatble. This success of 3D printing pilot study will open up new opportunities considering such promising technology towards digitalization implemetation in oil & gas fields. Additive Manufacturing is at early development stage and more applications for oil & gas will build up experience for optimizing business portofolio in achieving targeted goals for improving operations performance.

General challenges experienced with the team are mainly pertaining to the, knowldge level among the team on 3D printing technology features and limitations, no references of metal additive manufacturing in oil sector as KNPC was the first company to launch pilot study for metals, defining selection criteria for parts to be manufacured and absent of the technology ASTM Standards, QA tests at the time of study execution.

3D printed 316 stainless steel valve plug

KNPC Taskforce and CANAR Trading Team – 3D manufactured spare parts deliverables