البترول الوطنية
KNPC

KNPC TECH

Issue 07 | TECH Magazine

Issued by : Corporate Communication Department
Kuwait National Petroleum Company
July 2025

Contents

Editor's Note

We keep up our target in documenting and disseminating the works and research papers of KNPC Engineers.

A couple of articles have already been published in international magazines. These articles mirror the expanding involvement of our experts in major oil and gas related events.

As part of KNPC effort in facing the environmental-related issues, we tackle here a key subject associated with KNPC's energy transition strategy in conjunction with the pledged net-zero greenhouse gas emissions by 2050 for Kuwait Oil Sector. Another article talks about sour water contamination and the corrective measures taken to prevent repetition. A third covers the sludge handling and treatment facility and sustainable management solutions.

We shed light on alarm rationalisation with two articles as operators experienced frequent alarm surges after the commissioning of Clean Fuels Project (CFP) Units, and the implemented solutions to mitigate the nuisance.

One article talks about monitoring the Reid Vapor Pressure Parameter, and speeding process of lab tests. RVP plays a critical role in blending and storage of fuel.

We are confident that the subjects of this issue will be to the satisfaction of our tech-focused readers.

Rakan Al-Fadala
Manager, Corporate Communication

Leveraging Gas Towards Energy Transition and Sustainability: **KNPC's Strategic Initiatives**

As the industry shifts towards sustainable energy solutions, KNPC is committed to utilising natural gas to lower greenhouse gas emissions and support the energy transition. This paper outlines KNPC's strategic initiatives aimed at achieving energy transition goals and ambitious targets for reducing energy consumption and greenhouse gas emissions.

Fatemah Al-Shamroukh
Sr. Environment Engineer, HSE Dept.

Introduction

KNPC launched various projects and initiatives, such as the Flare Gas Recovery Units (FGRUs) and energy efficiency improvements, designed to reduce environmental impact and promote operational excellence. Key projects include the installation of FGRUs to recover flare gases, the Zero Non-Emergency Flaring Project to significantly cut down flaring at gas plants and refineries, and energy efficiency enhancements across operations.

The Company has also developed advanced health, safety, and environmental (HSE) systems, including the Smart Leak Detection & Repair (LDAR) and Relief Gas Maintenance System (RGMS), to monitor and mitigate hydrocarbon emissions. Significant investments in projects have been made aiming to producing clean fuels and establishing a robust greenhouse gas inventory to guide its energy transition planning. By integrating advanced technologies and sustainable practices, KNPC is addressing environmental and energy-related challenges, positioning itself as a leader in leveraging natural gas for a more sustainable energy future. These efforts also contribute to the United Nations Global Sustainability Development Goals.

KNPC, a subsidiary of Kuwait Petroleum Corporation (KPC), is responsible for petroleum refining and gas processing in Kuwait, meeting local fuel demands for power generation and transportation, while supplying products to the international market. KNPC also manages a widespread petroleum distribution and retail network in Kuwait, which includes two depots and 65 filling stations.

Energy Transition at KNPC

At the COP27 Summit in Sharm El-Sheikh, Kuwait pledged to reach net zero greenhouse gas emissions by 2050 for its oil sector, and by 2060 for the entire country. In alignment with this, KPC has developed an Energy Transition Strategy to achieve the vision of net zero by 2050. KNPC has established a Multi-Disciplinary Committee to monitor and report on energy transition projects. The mission of the KPC 2050 Energy Transition Strategy is to remain a responsible hydrocarbon producer, advancing sustainability by minimising emissions and developing new energy businesses.

KPC Energy Transition Strategic Initiatives are summarised below:

KPC Strategic Initiative	Definition
Renewables & storage	Use renewable sources of energy to abate scope 2 emissions from grid-sourced power as well as self-generated power.
Energy efficiency	Extend the current energy efficiency efforts (Energy Management System, heat recovery, green buildings) as well as implementing quick wins/cost-positive efficiency initiatives on the assets (i.e., optimise processes, digitalization & automation, enhance heat network, etc.).
Flaring Energy Efficiency	Ensure further flaring reduction across KPC's assets to reach zero flaring (excl. technical flaring) beyond 2040.
Offsetting	Offset up to 15% of emissions to reach Net-Zero through widely used methods such as forestation and soil carbon sequestration.
CCUS (Carbon Capture, Use & Storage)	Implement CCUS to offset emissions to reach Net-Zero. CCUS technology is expected to become more mature and available in the long-term, which is an instrumental abatement lever for emissions that are hard-to-abate.
Advanced mobility & retail	Increase EV penetration in European markets to reach the number of charging points as aligned with peers' announcements.
Recycled plastics	Build waste collection and (plastics) waste sorting infrastructure before recycling capacity build-up in Kuwait.
Biofuels	Hedge sourcing risks for KPC's retail business to achieve renewable share, avoid penalty fees and meet the growing global market with focus on 2nd generation biofuels.
Green Hydrogen	Enter the green hydrogen business assuming low cost of domestic solar PV and storage.

Table 1 - KPC Energy Transition Strategic Initiatives

Concept of Net Zero and KNPC

Net zero refers to balancing the amount of greenhouse gases emitted with an equal amount of emissions removed from the atmosphere, resulting in no net increase. KNPC has been assigned specific energy transition targets to help KPC achieve net zero by 2050.

#	Target	Metric	KPC	KOC	KGOC	KNPC	KIPIC	PIC	KOTC	KPI	KUFPEC
1	Renewanles	GW of installed capacity	17	11	1	2	3	1	<1	<1	<1
2	Energy Efficiency	% improvement vs. a benchmark year	8-12%	8-12%	8-12%	8-12%	8-12%	8-12%	8-12%	8-12%	8-12%
3	Flaring	Date to reach zero routine flaring	2040	2030	2040	2040	2040	-	-	2040	2040
4	CCUS	Carbon storage, M t/yr	26	26	-	-	-	-	-	-	-
5	Offsetting	Afforestation area, sq km	500	500	-	-	-	-	-	-	-
6	EV Charging	# of charging points, k CPmn	18	-	-	0.6	-	-	-	17.4	-
7	Biofuels	Volume of biofuels produced, M t/yr	13.0	-	-	← 0.5 →		-	-	12.5	-
8	Recycled plastics	Volume of plastics recycled, K t / yr	120	-	-	-	-	120	-	-	-

Figure 1 - K-companies ET Targets to Support KPC Reach Net Zero by 2050

KNPC's Strategic Initiatives and Projects implemented to support its energy transition programme

KNPC has launched numerous projects and initiatives to improve environmental and energy performance, significantly contributing to its ambitious energy transition targets and the UN Global Sustainability Development Goal:

a- Fired Heaters and Boilers Energy Efficiency Improvement Programme

KNPC's refineries and gas plant consume energy in the form of fuel gas, steam, and electricity. The Company has a robust heater efficiency improvement programme that monitors major energy-consuming units, aiming to optimise operations by tracking key energy parameters such as combustion efficiencies and heat exchanger performance.

b- Reduction in Gas Flaring at MAA & MAB Refineries

KNPC has commissioned two Clean Development Mechanism (CDM) Projects, Flare Gas Recovery Units (FGRUs) at its Mina Al-Ahmadi (MAA) and Mina Abdullah (MAB) Refineries. These projects recover refinery waste gases, using them as fuel and reducing greenhouse gas emissions. The FGRU at MAA is Kuwait's first CDM Project registered under UNFCCC.

Site	Annual GHG Reduction Estimated	Cost of the Project
MAA	54,419 Tons CO2	36,436,050 USD
MAB	91,736 Tons CO2	67,322,831 USD

Table 2 - Annual GHG Reduction and Cost of Projects at MAA & MAAB

c- Leak Detecting and Repair programme (LDAR):

KNPC has developed a smart leak detection and repair programme to minimise fugitive emissions from equipment and valves. The Company uses advanced infrared cameras to detect leaks and prioritise repairs.

d- Relief Gas Management System (RGMS):

The purpose of RGMS is to reduce routine loss of hydrocarbon to flare due to passing of pressure relief valves. The RGMS survey identifies the passing PSVs to the flare system and open valves are also detected.

Ultrasonic part of acoustic emission from a passing valve due to turbulence is measured at 3 locations - up/down/on the valve to estimate the leaks. The monthly report includes flaring details (flare wise & total quantity), nonfunctioning flare FTs, quantity and financial loss in "$" from each passing valve, details of passing valves (class, type, maintenance etc.).

e- Inventorisation of the Green House Gases (GHG Inventory):

KNPC has developed a comprehensive GHG inventory to measure and manage emissions, aligning with international guidelines and supporting Kuwait's Oil Sector strategic initiatives.

f- Renewal Energy and Alternatives to Add Value to KNPC Business:

KNPC is exploring various alternatives, including the feasibility of using waste streams, CCUS, second-generation biofuels, and green hydrogen production, to support its net-zero carbon targets.

Conclusion

KNPC is addressing critical environmental and energy challenges, positioning itself as a leader in leveraging natural gas for a sustainable energy future. By implementing a wide range of projects aimed at energy efficiency and environmental protection, KNPC is making significant strides in achieving its energy transition goals and contributing to the UN Global Sustainability Development Goals.

Replace Pressure-Reducing Valves with Backpressure Turbogenerators

The MAA Refinery has a complex steam system which has expanded significantly over the years. As a result, a large amount of steam is being let down via desuperheaters to meet the refinery MP and LP steam requirements. It is proposed to install steam turbogenerators to replace steam let-downs and utilise energy to either produce power or act as a prime mover.

Abdullah Al-Mutairi
Specialist, TPL - Gas Operations - MAA

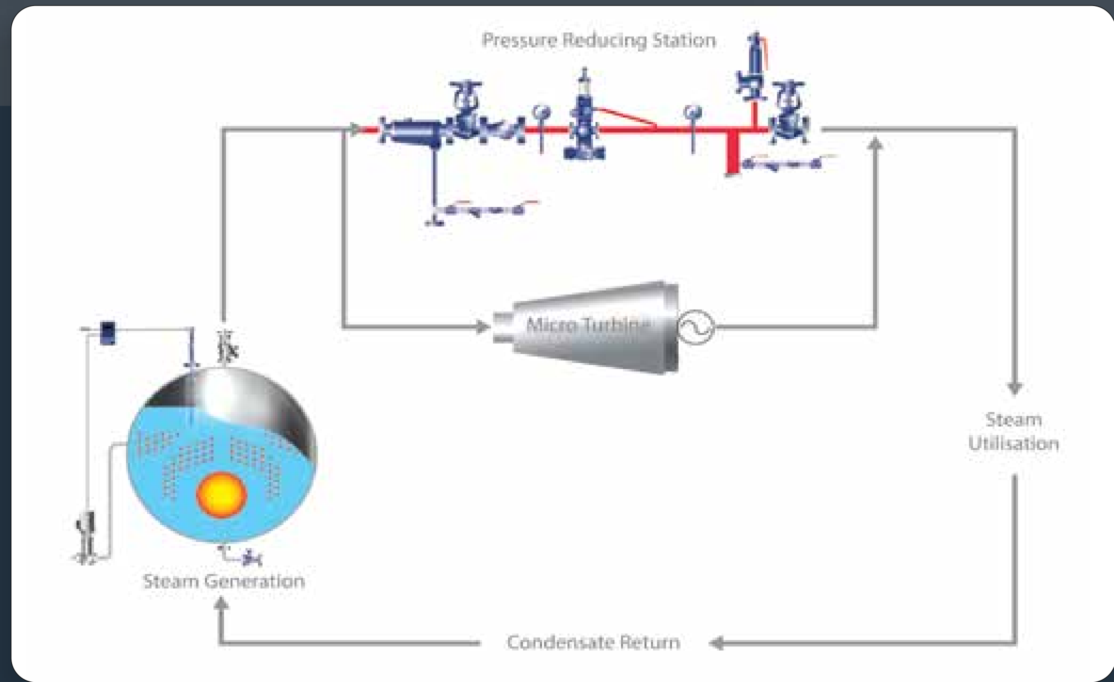
Introduction

Many industrial facilities produce steam at a pressure higher than that demanded by process requirements. Steam passes through pressure-reducing valves (PRVs - also known as letdown valves), at various locations in the steam distribution system to let down or reduce its pressure. A non-condensing or backpressure steam turbine can perform the same pressure-reducing function as a PRV while converting steam energy into electrical energy.

In a backpressure steam turbogenerator, shaft power is produced when a nozzle directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator. The steam turbine does not consume steam. It simply reduces the pressure of the steam that is subsequently exhausted into the process header.

Passing plant steam through a turbogenerator typically installed in parallel to a conventional pressure reducing station, enables operators to use the energy released by the resulting pressure drop to supplement their electricity supply. Meanwhile, the outlet steam is used by the downstream application as in a conventional system.

In MAA Refinery we have done the feasibility study on all the letdown stations except the small one with less pressure drop and less flow, along with AMEC we have studied 29 letdown stations, UHP to HP, HP to UMP, HP to MP and UMP to LP steam.



Stage 1 in the study (Data collection)

Identifying the total amount of steam being let down (considering the normal operation parameters) is 415 tons to produce MP and 295 tons to produce LP.

Stage 2 in the study

Finding out (7) letdown stations out of 29 feasible for implementing the backpressure turbogenerators in parallel with the PCV, eliminating the rest by considering the below factors:

- The capacity of the letdown stations.
- The pressure drops.
- Line size limitation.
- Normal operating flow.
- Possibility of isolation for the lines tie-in.
- Securing the additional steam generation in place of the BFW quantities specially for the UHP and HP let down.

The study analysed the following items for each chosen case

Technical factors:

- Single or double turbogenerator.
- How much power can be generated.
- The designed generator specification.

Economic factors:

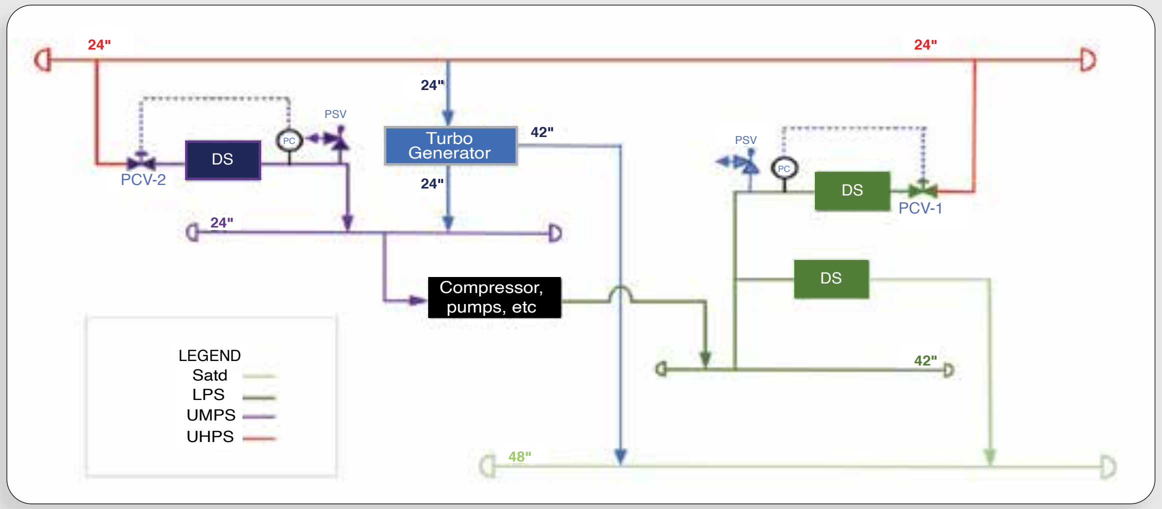
- Electricity cost.
- CAP.
- NPV.
- Payback years.

Example

PCV 1/ PCV2 Let Down Station:

- Around 150 t/h of UHP steam is let down to UMP steam and the same amount of UHP steam is let down to LP steam in unit 1. Unit 2 is identical to unit 1.
- It is proposed to use a single turbogenerator to replace both the UHP to UMP and UHP to LP let down stations in each unit. UHP steam will be let down to LP steam with UMP steam extraction.

Control Valve Tag No	Typical Flow (T/h)	Max Capacity (T/h)
UHP to UMP Let Down		
PCV-1	149.5	179.4
UHP to LP Let Down		
PCV-2	150.2	178



PCV 1 / PCV2 Turbo Generator Specification:

Parameter	Flow (T/h)	Pressure (kg/cm² g)
UHP Steam Inlet	357	59.8
UMP Steam Extraction	179	38.7
LP Steam Exhaust	178	14.1

PCV1/ PCV2 Turbo-Generator Economics:

Parameter	Datasheet Typical Flow	Target Data
Turbo-Generator UMP Steam Extraction Flow (T/h)	149.5	103.5
Turbo-Generator LP Steam Exhaust Flow (T/h)	150.2	141
Turbo-Generator UHP- UMP Stage Efficiency	75%	72%
Turbo-Generator UMP - LP Stage Efficiency	75%	74%
Power Generation (MW)	22.6	19.9
Required Additional Boiler Steam Production/ Reduction in BFW Required For Desuperheating (T/h)	40.8	37
CAPEX(MM$)	54.7	
NPV @Hurdle Rate (MM$)	142	
IRR	49%	
Payback (years)	3	

The amount of UHP steam generated in the boilers is increased for the turbogenerator case. The reason for this is that the turbogenerator is replacing the letdown stations and desuperheaters, where some Boiler Feed Water is converted to steam.

As a result, additional steam must be generated to replace the BFW and satisfy the steam demand. This additional steam will have to be provided by the Utilities Area boilers.

The turbine UMP steam exhaust temperature is 380-385°C, like the normal UMP steam temperature of 382°C.

The turbine LP steam exhaust temperature is 160-180°C and it is routed to the saturated LP steam header or the saturated LP steam desuperheater.

As can be seen from Table PCV 1/ PCV 2 Turbo-Generator Economics, the payback time of the UNIT 1/2 turbo- generators is approximately 3 years.

This is a very lucrative opportunity assuming there is capacity in the boilers to provide the additional steam required.

Conclusion of the Chosen Example PCV 1&2

By considering the payback years and after analysing all the known obstacles, it is feasible to replace the mentioned PCV 1 by turbogenerator sized 179 t/hr. and PCV 2 with a sized 173 t/hr.

It is worth noting that with the current proposed designs for STG's, they will be installed in parallel to existing let-down stations to maintain flexibility for operations to manage. For example, during turndown operations that require steam consumptions beyond available turndowns of the STG's, STG's will have to be bypassed and the PCV's used during this time until full operations are resumed.

Final Compression Between the Chosen Let Down Station:

Parameter	PCV-7	PCV-6	PCV-5	PCV-4	PCV-1/ PCV-2	PCV-3
Turbo-Generator Steam Flow (T/h)	226.6/97.3	323.9	97.3	62.9	149.5/150.2	91.5
Power Generation (MW)	10.6	5.3	4.9	3.3	22.6	2.0
Required Additional Boiler Steam Production (T/h)	8.1	8.1	-	0.8	40.8	3.4
Estimated cost (MM$)	43.6	25.4	23.7	17.5	27.4	17.9
Payback time (Years)	6	8	5	6-7	3	17

Sour Water **Contamination**

Feed sour water quality change can negatively affect the unit performance. This article presents sea salt carry-over from upstream unit to sour water system consequences, corresponding causes, corrective actions and recommendations to prevent similar situations.

Abdulaziz Khajah
Process Engineer
TSD - MAB

Introduction

MAB Sour Water Stripper Unit (SWS U-26) consists of two parallel stripping trains (Train 1 and 2); each train is designed to handle around 1250 GPM of sour water. The principle of SWS Unit is to remove Hydrogen Sulfide (H_2S) and Ammonia (NH_3) from the sour water by stripping, using low-pressure steam (60 PSIG) as a heating medium for re-boiling. Treated water to be supplied back to refinery users, with a quality of (max. limit) 35 ppm of NH_3 & 10 ppm of H_2S content.

As MAB-RMP (Refinery Modernisation Project) units has a total load of sour water around 1000 - 1200 GPM, hence only one train of SWS is running (handling the full refinery load) & the other train kept on stand-by condition.

Whereas, the unit shutdown frequency is every 4 years for maintenance and inspection.

Incident Sequence of Events

U-26 TR-2 was running normally with average on-spec quality of stripped sour water (treated water). Starting from 19th of Jan. 2021, it was observed that Stripper Tower (T-26-201) & Reflux Drum (V-26-202) levels were sharply fluctuating indicating tower flooding phenomena. Hence, on 28th of Jan. 2021 feed sour water was diverted to U-26 TR-1, but still same upset observations were happening in TR-1 (level fluctuation and tower flooding). Thereby, decisions were taken to segregate the sour water feed between U-26 TR-1&2, trying to minimise the flooding severity of the tower. Both trains were operating in parallel (with partial controllable flooding) up to until next ARDS Block Shutdown window, in order to take U-26 TR-2 for shutdown. Whereas, the refinery sour water generation load will be on the lower side during that window.

On 20th of Feb. 2021, ARDS U-12 TR-1 went for maintenance and inspection shutdown, hence sour water load to U-26 was reduced gradually. Therefore, starting from 1st of Mar. 2021, U-26 TR-1 were capable to handle the full load (around 800 GPM) with stable treated water quality and operating parameters (such as Tower & Reflux levels & SWS gas), U-26 TR-2 were taken for Emergency Shutdown for full inspection of the Stripper Tower (T-26-201), Reboiler (E-26-202), Reflux Drum (E-26-202) and Heat Exchangers (E-26-201).

During the period from 12th of Jan. 2021 to 3rd of Mar. 2021, the treated water quality was off spec (above 35 ppm of NH_3 & 10 ppm of H_2S content), hence were sent to RETF U-56 Off-spec Tanks. In addition, during the period from 11th of Jan. 2021 to 6th of Mar. 2021, around 100 KSCFH of SWS gas (which consists of around 35% of H_2S) were being routed to the flare due to the upset in U-26.

After completing the shutdown job, U-26 TR-2 were commissioned on 7th of Apr. 2021, with sufficient performance & normal behaviour of Tower & Reflux levels.

Observation

A multi-disciplinary team inspected the Tower (T-26-201) to find the root cause of the incident (Flooding Phenomena), following are the observation findings:

- Trays# 1 to 50 were fully plugged with fouling/deposit material with a thickness of around 2 inches (covering all the valve trays, clearance & downcomers).
- One segment of tray#1 downcomer found to be cracked.
- One segment of the treated water baffles (segment below tray #1) found be fallen & bended.
- Trays #from 50 to 60 were relatively clean & no fouling has been founded on the trays surface (Note feed to the tower is on tray #56).
- Some missing valve trays, and internal of the tower (shell) were partially covered with the same fouling/deposit material.

Action Taken

Several meetings were held between all respective divisions to address and finalise the S/D job scope. Following are the job that has been carried out:

- Initially, all trays were cleaned by hydro-blasting inside the tower.
- Stripper Tower (T-26-201) was inspected and found that 70% of the fouling material were removed. However, still there was around 30% of fouling material still unreachable (as in the shell side, bottom surface of the trays & bottom valve trays were fouled restricting their movement & opening). Hence, it was decided to remove/drop all the 60 trays and clean it properly once again outside the tower.
- Cracked downcomer segment of Tray#1 and treated water baffle segment were attended.
- Some missing valve trays were installed, and other damaged ones were replaced.
- Steam Reboilers (E-26-202), Sour Water Exchangers (E-26-201), Reflux Drum (V-26-202) and Finfans (EA-26-201) were cleaned.
- I&C attended some pending job on the tower shell and connection lines.

Figure : Condition of U-26 TR-2 Deposit Trays - Before & After Cleaning

Troubleshooting and Analysis

Several samples of the fouling/deposit material from the trays surface have been collected and analysed in MAB LAB for several tests (Table 1):

Table 1: Analysis of the Fouling/Deposit Material From U-26 TR-2 Stripper Tower

Test	Sample #1	Sample #2	Sample #3
Color/ appearance	Dark grey - black	Dark grey - black	Light grey - white
NH3	485 ppm	550 ppm	650 ppm
Sulfides	72 ppm	100 ppm	14,000 ppm
Sulfur	-	-	-
Ca	800 ppm	2000 ppm	2500 ppm
Cl	70 ppm	400 ppm	-
Si	3000 ppm	2000 ppm	-
Mg	165,000 ppm	256,000 ppm	296,000 ppm
Na	1800 ppm	2500 ppm	-
Fe	6600 ppm	7500 ppm	-
C	-	0	0
Loss of Ignition	45%	38%	37%
Moister	-	-	14%

In view of the above, Magnesium salt content noticed to be very high in all sample results, this indicating that sea water slippage is being received (from users) along with sour water feed to U-26 Stripper Tower. Noting that U-26 is not designed to receive sea water.

Sea salts (which includes Ca, Cl, Mg, ... etc.) are not being tested neither from refinery users nor from U-26 (as it is not expected to receive sea water along with sour water). However, from 10th to 15th of Feb. 2021, sour water from each refinery user has been tested for sea salts and found to be on the higher side for serval units (U-20 & U-15). Action has been taken immediately from respective units to stop the source of sea water and prevent any leak.

Based on the above table results, Mg salt was noticed on the extreme higher side despite the other salts; hence, we suspect that Mg salt has been reacted with Ammonium Hydroxide to form Magnesium Hydroxide and Magnesium Carbonates. Those materials are non-soluble in water and attempt to participate on the surfaces such as trays.

Moreover, loss of ignition was noticed to be relatively high, reflecting of some hydrocarbons (heavy such as residue) content in the fouling/deposit materials. This indicates that oil is carried over (from users) along with sour water feed to U-26 Stripper Tower.

In view of the above, U-26 is designed to receive oil by maximum 8% of the feed sour water, and to be removed/separated by oil skimming facilities from the sour water in the Sour Water Flash Drums (V-26-101/103) and Sour Water Tanks (TK-26-101/103), before the sour water is sent to the Stripper Tower (T-26-101/201).

Conclusion

- U-26 Stripper Tower (T-26-201), trays were plugged with severed fouled/deposit materials that affect the tower performance and caused flooding, leading to emergency S/D of the unit.
- The plugged/deposit materials are related to:
  1. Sea water salts that are being received (from users) along with feed sour water to the unit.
  2. Heavy hydrocarbons that are being received (from users) along with feed sour water to the unit.

Recommendations

1. U-26 treated water to be tested for Ca, Cl, Mg and oil content additional to the routine tests.
2. Each refinery user to test their sour water stream for full analysis (NH3, H2S, Cl, Ca, Mg and Oil content) as a routine test.
3. Ensure the efficiency/operability of U-26 oil skimming facilities.
4. Study the need to install a set of filters on the feed sour water to U-26.
5. Study the need to install Cl analyser on the feed sour water to U-26.

Alarm Rationalisation at **KNPC Refinery**

Feras Al-Mutairi
Senior Engineer Projects

Mathew Isac
Instrument Design Specialist

Sunaina K. Vijayan
Instrument Engineer

Sriram Rajappa
Instrument Design Engineer

The Clean Fuels Project at Mina Abdullah Refinery (MAB) involved incorporation of 33 new units into the existing facilities resulting in the addition of +90,000 field instruments and +200,000 alarm points.

Introduction

The commissioning phase of the Clean Fuels Project at MAB Refinery commenced in January 2021 and spanned over a period of about 15 months. Before final commissioning, each sub-facility underwent Mechanical Run Tests (MRTs), Functional Tests, and Pre-commissioning Tests, during which changes transpired.

Following completion of commissioning, operators experienced frequent alarm surges in specific sub-systems, exceeding the allowed engineered limits. The below figure shows the alarm counts faced for a sub-system prior to the Alarm Rationalisation Activity.

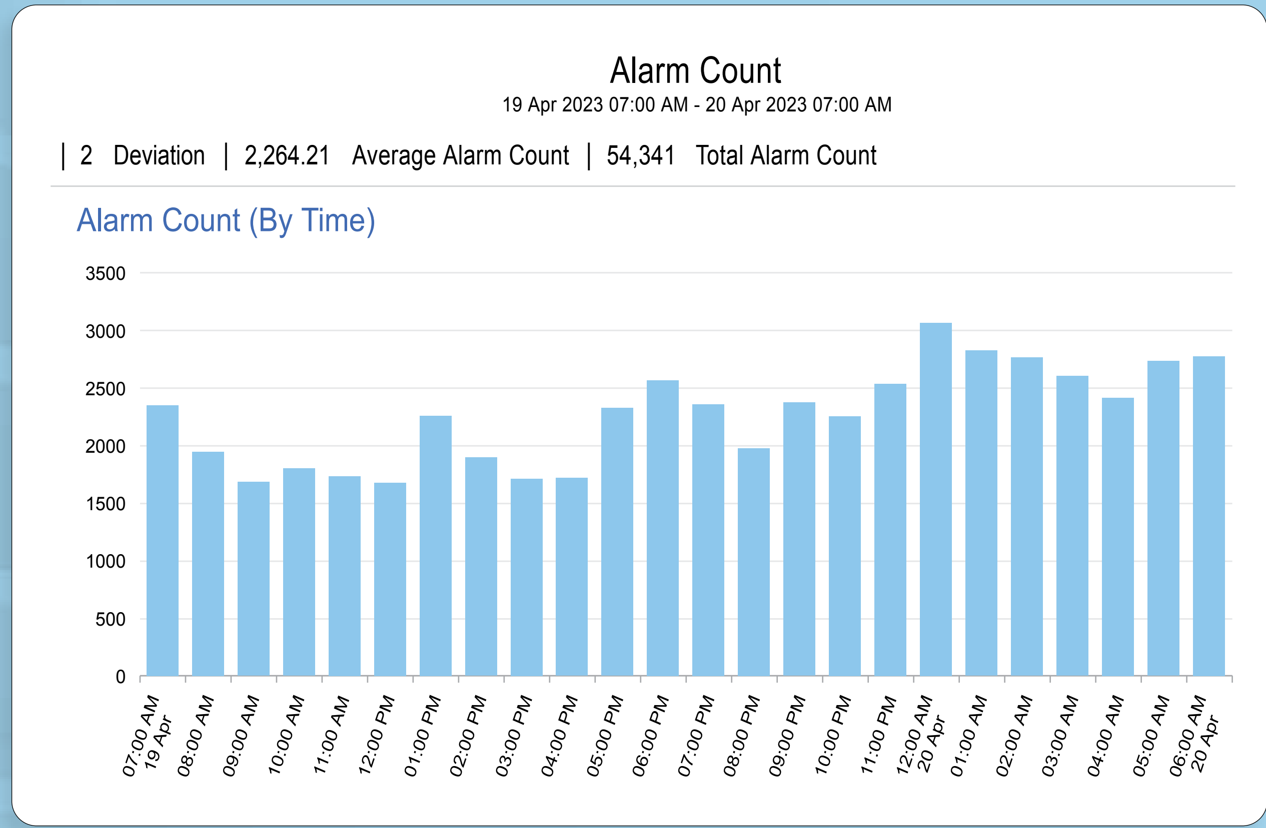


Figure 1 - Alarm Count Before Rationalisation Exercise

Since this sub-system is handled by 5 operators, it can be inferred that the average alarm rate reached over 450 alarms per hour per operator, exceeding the Company's acceptable limits. The number of alarms that can effectively be handled by one operator per hour may differ from company to another as these targets are governed by company's policy documents.

The reasons identified for the alarm surges were:

1. Implemented alarm configuration being different from Engineered (Alarm Objective Analysis/Alarm Study Report).
2. Temporary changes to alarm settings during site tests were not reinstated back to their original settings.
3. Lack of alarm suppression techniques for equipment which were idle or on stand-by mode.

The above findings necessitated the implementation of an Alarm Rationalisation Process.

Alarm Rationalization Process:

Alarm management is a wide scoped topic of discussion which essentially deals with the work process and implementation of good engineering practices from a regulatory point of view. The standards used in widespread for alarm management are mainly the ISA 18.2 Standards and the EEMUA191 Guidelines. Alarm rationalization is the process of reviewing, validating, and justifying parameters that meet the criteria for an alarm. Below flowchart illustrates the key steps involved in the entire alarm rationalization exercise.

Develop MAD Table
↓
Review purpose of an alarm
↓
Review constraints
↓
Review the consequence severity based on RAM
↓
Review process safety time
↓
Review allowable time in exceedance
↓
Review Notification Limit Priority
↓
Review Alarm priority
↓
Review Operator actions
↓
Review suppression and mode dependent techniques

Mitigation Plan

During the Engineering, Procurement, and Construction (EPC) phase, contractors conducted an Alarm Objective Analysis (AOA) / Alarm study and provided the Company with a unit-wise Alarm database table. It was observed that the spreadsheet provided by the various EPC contractor's varied in format and style resulting in inconsistent and non-standardized document across different units.

Further, discrepancies were detected between the Alarm database table provided by contractors and its implementation in the Control Systems. Due to the absence of a consolidated Alarm database for the entire facility, verifying the credentials of each engineered alarm against the implemented ones posed a significant challenge for the Company as it required scanning through multiple documents and systems. With over 200,000 process related alarms in MAB, the task of carrying out alarm verification for all units was humungous.

Solution

To address the above concerns, the Company's Projects Department developed an in-house tool titled "AlaR" (Figure-2).

This tool facilitated the import of data from diverse Excel sources and the consolidation of information from different spreadsheets with varying formats, resulting in the creation of a comprehensive Master Alarm Database (MAD). The MAD Table serves as a single point of reference for all alarm-related information, listing 30-35 parameters for an alarm point. These parameters align with the essential data required according to the Company's Alarm Management Philosophy. This tool gathered data from project engineering sources such as alarm database table, SmartPlant Instrumentation database as well as from implemented sources namely extracts from the Control Systems Database.

The tool could run a comparison for each alarm point, pinpointing disparities between the engineered values and their implementation in the Plant Control System. Refer figure 3 and 4, where the various disparities are distinguished by means of colour.

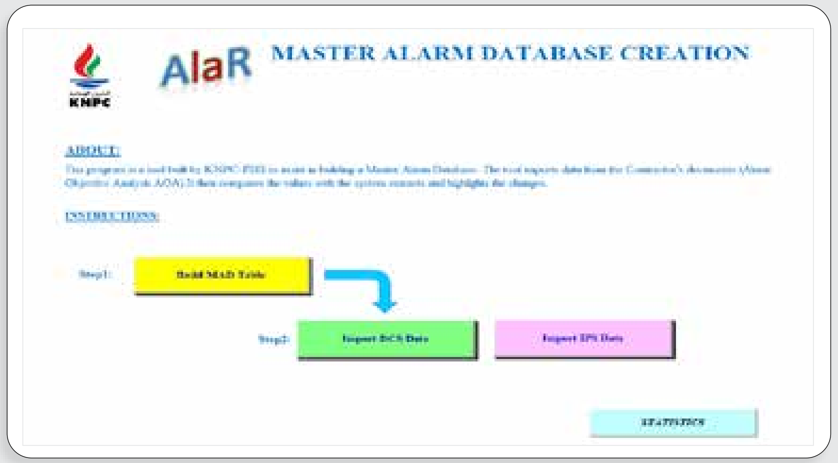


Figure 2 - AlaR Module-1 - Master Alarm Database Creation.

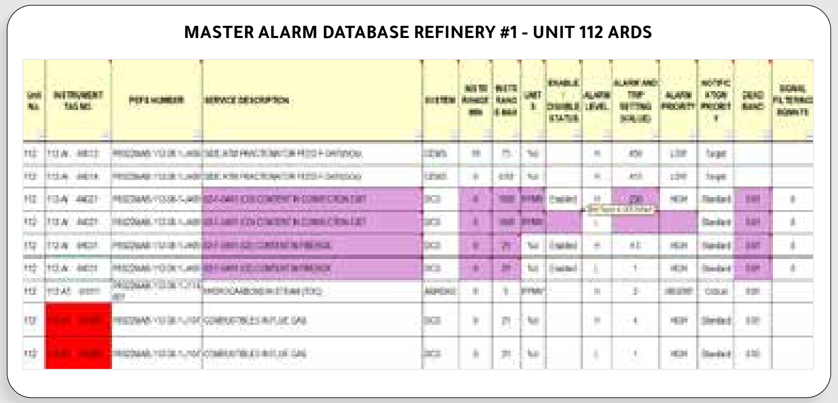


Figure 3 - MAD Table Highlighting the Discrepancies.

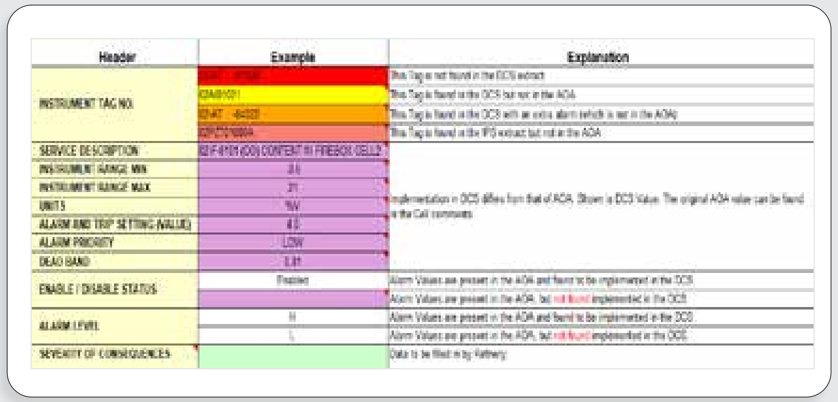


Figure 4 - Various Discrepancies Found by AlaR.

This module significantly aided the Company in consolidating information from various sources and establishing a comprehensive Master Alarm Database. This will, ultimately, aid the Company to conduct continuous assessments and audits to align with the Alarm Management Life Cycle in accordance with ISA 18.2.

Once the Master Alarm Database was ready, a Taskforce was nominated comprising of Process, Operations, Process Safety, Engineering and Maintenance Groups to conduct Alarm Rationalisation Workshops for the evaluation of the alarms of concern. The AlaR tool contained a module which included a tag view feature, enabling the review and commenting of each tag during the Alarm Rationalisation Workshop and the generation of tag-wise reports (refer to Figure 5). These reports were subsequently utilised as approved attachments to the Management of Change (MOC) procedures. The comments and recommendations from the workshop were also logged onto the Master Alarm Database to document the history of changes.

KIPIC ALARM RATIONALIZATION WORKSHOP

UNIT NO.	02	PEFS NUMBER	P055AZOR-02-08-1-J409		
INSTRUMENT TAG NO.	02-AI -04031	INSTRUMENT RANGE MIN	0		
SYSTEM	DCS	INSTRUMENT RANGE MAX	21	UNITS	%V
SERVICE DESCRIPTION	02-F-0401 (O2) CONTENT IN FIREBOX			Compare Flag	DCS

Field name	Alarm level				Change Requirement
	LOW LOW (LL)	LOW (L)	HIGH (H)	HIGH-HIGH (HH)	
ENABLE / DISABLE STATUS		Enabled	Enabled		
ALARM AND TRIP SETTING (VALUE)		1	4.5		
ALARM PRIORITY		HIGH	HIGH		
NOTIFICATION PRIORITY		Standard	Standard		
DEAD BAND		0.01	0.01		
SIGNAL FILTERING REQUIREMENTS		0	0		
RATIONALE FOR THE ALARM SETTING		PROPER OXYGEN CONTENT FOR COMBUSTION	PROPER OXYGEN CONTENT FOR COMBUSTION		
PURPOSE OF THE ALARM		PREVENT FROM LOW EFFICIENT COMBUSTION	PREVENT FROM LOW EFFICIENT COMBUSTION		
CONSEQUENCE OF NO RESPONSE		DECREASE IN HEATER EFFICIENCY	DECREASE IN HEATER EFFICIENCY		
INSIDE OPERATOR ACTION		CHECK OXYGEN CONTENT AND DRAFT AT HEATER ARCH. Check FT-070 and open FV-070 as necessary. OPEN STACK DAMPER CONTROLLER IF REQUIRED	CHECK OXYGEN CONTENT AND DRAFT AT HEATER ARCH. Check FT-070 and close FV-070 as necessary. CLOSE STACK DAMPER CONTROLLER IF REQUIRED		
OUTSIDE OPERATOR ACTION		VISUALLY CHECK DRAFT, STACK CONTROL DAMPER AND BURNER REGISTER POSITION, PILOT AND MAIN FLAMES Check FV-070 position locally Check stack damper position	VISUALLY CHECK DRAFT, STACK CONTROL DAMPER AND BURNER REGISTER POSITION, PILOT AND MAIN FLAMES Check FV-070 position locally Check stack damper position		
PROCESS SAFETY TIME		20	20		
OPERATOR RESPONSE TIME					
SEVERITY OF CONSEQUENCES					
METHOD FOR ALARM SUPPRESSION					
STATIC SUPRESSION					
DYNAMIC SUPPRESSION					
SHELVING					
GROUP (INTERLOCK)					
REMARKS					
KIPIC REMARKS (Review Cycle 1)		world cup 2023	India wins		

LEGEND:

To be filled by LNGI	Compared AOA with DCS/IPS Extracts
From AOA	Mapped

WORKSHOP REMARKS:

FINAL ACCEPTANCE SIGNATORIES:

Figure 5 - Tag wise Report from AlaR-Module2

There were variety of general issues which were noted during this workshop. Some of the major recommendations which helped in reducing the high alarm counts are listed below:

1. Suppression of alarms were suggested, for certain plant states such as shutdown or maintenance condition, or for certain modes of operations when process units or spare equipment are not in use but alarms are active e.g., low-flow alarm for a pump when the pump is not running.
2. Priority of the alarms were re-assessed and determined based primarily on the severity of the consequences and the time to consequence. Best efforts were taken to reach the Alarm priority distribution as defined under the Company's Alarm Philosophy:

Alarm Priority	% of Total Alarms
Emergency/ Critical	~5%
High/ Standard	~15%
Low/ Target	~80%

The above distribution may differ among Companies as this is managed as a KPI under the Company's Policy document.

3. Several cases were found where multiple alarms were being annunciated for the same process conditions. These cases were meticulously evaluated and alarms were optimised. For e.g.,
   a. Cases where IPF pre-alarms were available on DCS systems, the redundant alarms configured under the IPF transmitters were removed.
   b. The IPF trip alarms are known to create alarm floods, so these were set to "Journal" priority, i.e., these were logged as an event without notification.
   c. For multiple voting trip inputs (e.g., 2oo3), a single voted alarm was annunciated rather than individual multiple alarms.
4. The Deadband and the Signal filtering requirements for the Bad-actor alarms were also reviewed in order to tackle the chattering and fleeting alarms.

Conclusion

The preparation of the new Master Alarm Database and the facilitation of the Alarm Rationalisation Workshops paved a clear path on how to administer the Alarm Management Lifecycle in an efficient manner and reduce the staggering alarm counts within acceptable limits.

Comparing Alarm count as illustrated in Figure -1 to a more recent date, it can be inferred that the Alarm counts have significantly reduced by over 30 folds after the implementation of the change recommendations proposed during this Rationalisation Workshop.

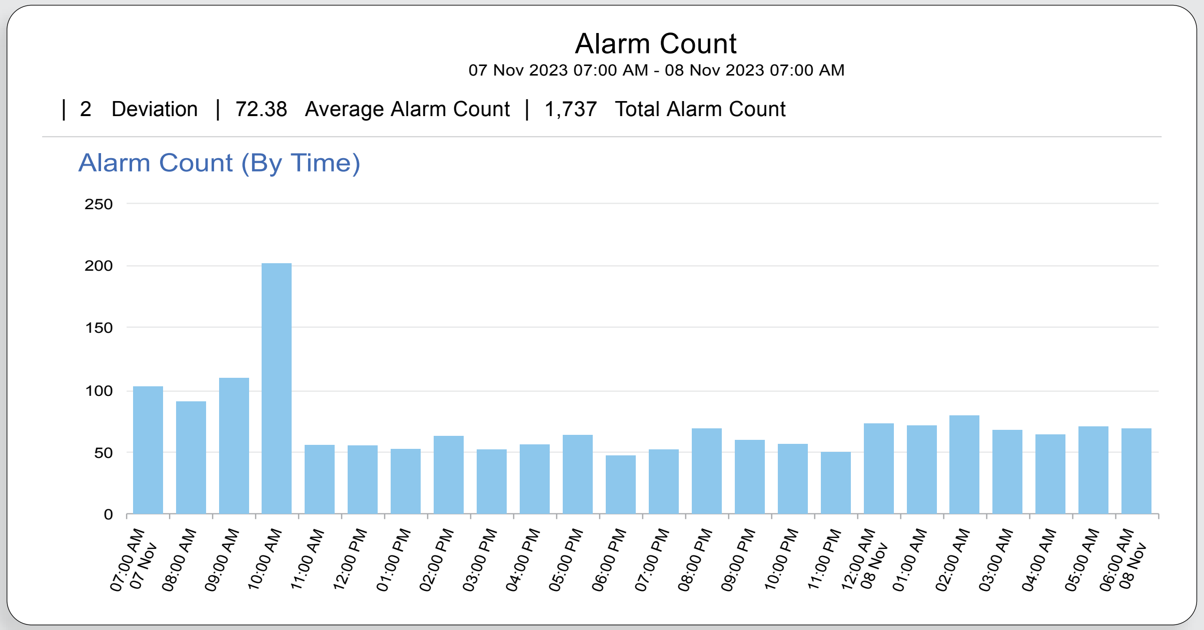


Figure 6 - Alarm Count After Rationalisation Exercise

While commercially available software and consultant options were available for this purpose, the in-house tool has proven highly advantageous and cost-effective for the Company. It not only allows customisation to meet the Company's specific needs but also promotes the development of expertise among the Company's resource.

Following AlaR's success in KNPC MAB Refinery, KIPIC Liquid Natural Gas Import facility and KIPIC Al-Zour Refinery have also adopted this tool, for their in-house Alarm Rationalisation Exercise.

Acknowledgments:

Special acknowledgment goes to Mr. Reyad Al-Tourah, Manager of Projects Department, Mr. Nael Al-Buloushi, Team Leader Projects and Mr. Feras Al-Mutairi, Senior Engineer Projects, who played pivotal roles in nurturing this idea with their experience and motivation.

Implementation & Automation of Alarm Management System in a Complex Control Environment



Ahmed Maqbool
Specialist, TPL.,
TSD - MAA

Shekha Al-Mansour
Senior Process Control Eng.,
TSD - MAA

Markand Joshi
Process Control Eng.,
TSD - MAA

In the recent past, MAA Refinery has implemented Alarm Management System (ALMS) applications and associated tools to retrieve, store and historise process units alarms and events data from different DCS systems. ALMS data is utilised for creating reports, developing KPI's as per international standards, conducting Alarm Rationalisation and incident investigations.

Introduction

Mina Al-Ahmadi Refinery (MAA) is a complex refinery employing different DCS systems installed in multiple control rooms. One of the main objectives of process control and automation is to employ process control applications and tools for safe, optimum and enhanced operations. Due to the recent advancements in process control and operations technologies, MAA Refinery also strives to acquire the state-of-the-art technology to assist operations for optimum performance in a safe environment.

Due to the complexity of the control rooms and installation of multiple Distributed Control Systems (DCS), implementation and integration of Alarm Management System (ALMS) with the DCS systems was achieved by utilising different types of interfaces and gateways. Additional efforts were made to ensure seamless and safe transfer of ALMS data and events from OT to IT environment within the realm of OT and IT cybersecurity.

Implementation Strategy

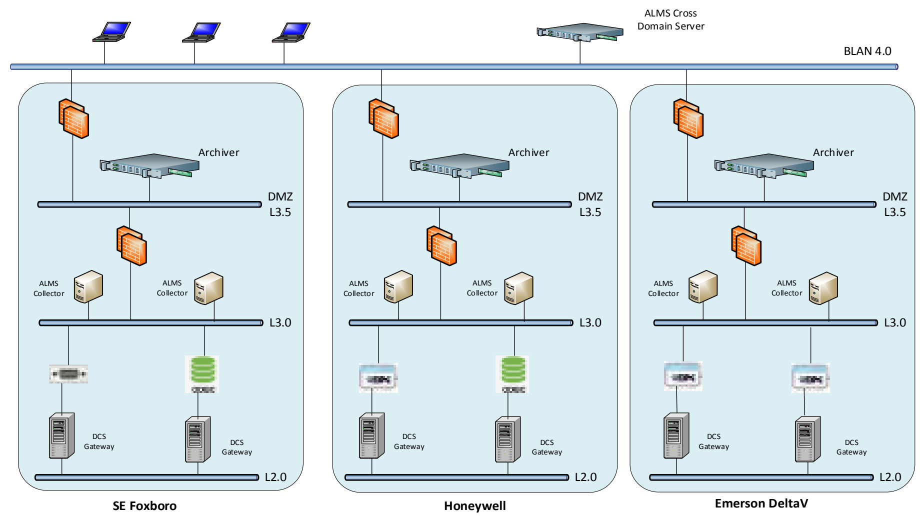
Based on the communication protocols and interfaces multiple Alarms Collectors were installed and configured on L3 to interface with the DCS devices and gateways resident on L2 and L3. MAA Refinery utilises two different ALMS software across five main control rooms, numerous Field Auxiliary Rooms (FAR) and remote-control rooms. The primary role of Alarm Collectors is to collect Process Alarms and events, Operator actions, System Alarms, Diagnostic Alarms and Instrumented Protective System/Fire & Gas System (IPS/FGS) sequence of events.

Multiple archivers are installed on L3.5 demilitarised zone (DMZ) to segregate and store alarms data from different control rooms and DCS systems. Archivers are configured to retrieve Alarms Data from the collectors. It then processes messages with different formats received from the collectors and stores in the Archiver Database. Design and number of archivers is based on the size of databases and long term historisation, which will allow the end users to access current and historised alarms data with ease and fast response.

Cross Domain Server is integrated with all the archivers to provide data and reporting tools to refinery wide users via applications and Instrumented Protective System/Fire & Gas System (IPS/FGS) on web platform. Some of the tools available to the end user are:

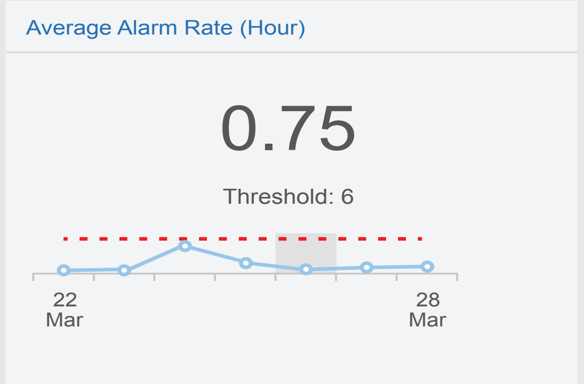
- Availability of on-line DCS alarms data (historic and current) for analysis and reporting.
- Generation and customisation of different types of reports, KPIs and Alarms Data, which can be exported to Excel for further analysis and trouble shooting.
- Graphical representation of different types of Alarms and KPIs.

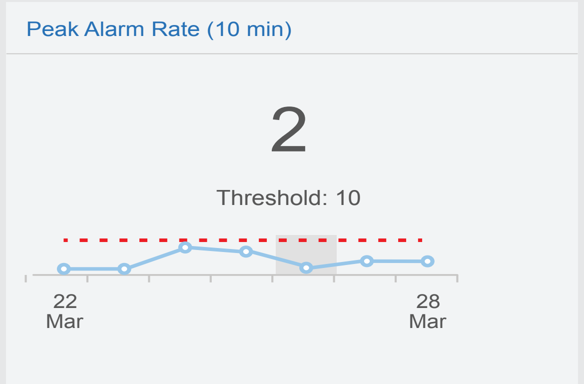
ALMS are critical for safety, optimization and enhanced operations in industrial processes. Implementation and integration of ALMS across various systems poses unique challenges.

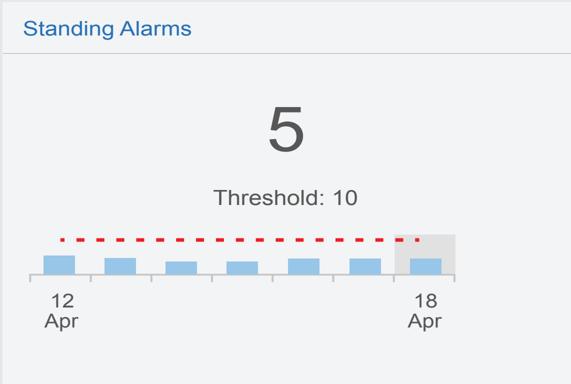


KPIs

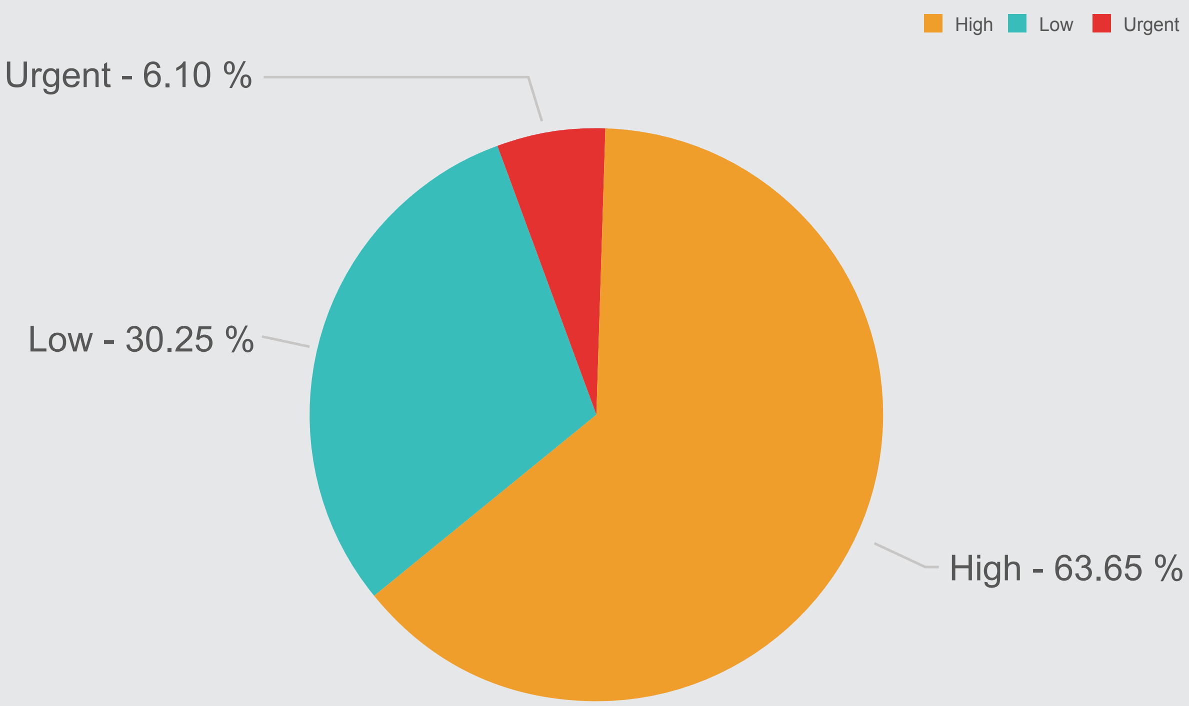
ALMS KPIs have been customised utilising ALMS software and associated tools to reflect compliance with International Standards and guidelines. These KPIs are reported to all the stakeholders for follow up and required action. These KPIs assist in ascertaining the bad actors and subsequent actions allow us to achieve desired targets as per International Standards. Some of the ALMS KPIs are shown below.







Alarm Prioity Distribution



Priority	Percentage	Count
High	63.65	12,435
Low	30.25	5,909
Urgent	6.10	1,192

Key Challenges

Integration with Legacy Systems: Integration with old DCS systems that lack standard data formats or have restricted communication capabilities and do not support latest and standardised communication protocols like OPC and ODBC.

Alarm Database Size: Proper sizing of Alarm Database to ensure that the Alarms Data transfers from the collectors to archivers is seamless with no extended delays.

Alarms Categorisation: Careful planning and designing are required to ensure that ALMS DB is populated with the required alarms, so that the DB does not get overloaded with unnecessary alarms and messages.

Configuration and Maintenance: Complex ALMS setups require specialised expertise in SQL, DCS configuration, Network configuration and Software (Like OPC, ALMS, backup & recovery) which end up increasing resource demands. It requires close coordination between IT and OT Teams.

Best Practices

Data Standardisation: Conduct detailed assessment of existing DCS systems and interfaces to define a clear plan for communication protocols. Standardising the message format at DCS level and using latest and open protocols (like OPC, ODBC). Establish a robust rule file, which can process events and messages, to avoid junk data being stored in ALMS DB.

ALMS Servers Virtualisation: Virtualisation of ALMS servers is highly recommended to ensure high availability and uptime of ALMS. Quick and easy recovery of ALMS applications, in case of errors and corruption. Dynamic online allocation of resources to meet ALMS DB requirements and expansion.

End User Training: Provide refresher training to the end users for maximum usage of ALSM applications and associated users tools.

Summary

With the recent advancements in the technology and availability of Control Support Applications, the role of Alarm Management System (ALMS) has taken a centre stage to fulfill the requirements of safe and enhanced operations. Alarm Management Systems have become imperative to ensure compliance with International Standards for Insurance related commitments and safe operations. ALMS KPIs assist in ascertaining the bad actors on a continuous basis. Subsequent actions allow us to achieve the desired targets as per International Standards.

Unique challenges were posed due to the complexity of the control rooms and installations of multiple DCS systems at KNPC's MAA Refinery. Implementation and integration of ALMS with the DCS systems was achieved by utilising different types of interfaces, gateways and communication protocols. Additional efforts were made to ensure seamless and safe transfer of ALMS data and events from OT to IT environment within the realm of OT and IT cybersecurity.

Integration and automation of ALMS at MAA Refinery has resulted in the reduction of nuisance and chattering alarms, benchmarking against international standards, increasing operator's efficiency by not getting distracted with the unwanted alarms or nuisance alarms, where there is no action required from the Control Room Operator. Automation and continuous availability of Process and Instrument alarms data for Refinery wide users has also assisted in engaging proactive approach to alarm rationalisation, maintenance and troubleshooting of field devices to ensure safe and continuous operations to reap maximum benefits and profits.

Data-Driven Innovation in Action: **Virtual Analyser at KNPC**

Afnan Al-Darwish
Sr. Process Control Eng., TSD, MAA

Barrak Al-Khaldi
Operational Planning Eng.
TSD - MAA

Awadh Al-Duwaikh
Mechanical Maintenance Eng.
Maintenance Dept. MAB

In modern refinery operations, product quality and compliance depend on the ability to monitor key parameters in real time. One such parameter is Reid Vapor Pressure, which reflects fuel volatility and plays a critical role in blending and storage.

Introduction

At KNPC's Mina Al Ahmadi Refinery (MAA), Deisopentaniser Unit (DIP) faced a critical challenge in monitoring Reid Vapor Pressure (RVP). The unit relied solely on one daily lab sample to ensure product specifications were met. This delay created a 24-hour blind spot-during which off-spec production could go undetected and impact downstream operations.

To address this, KNPC developed a virtual analyser using historical DCS and lab data. The model, built entirely in-house, provided real-time RVP predictions with 97% accuracy, validated against actual lab results. This innovation eliminated reliance on delayed lab samples, enabling faster response, better control, and improved product quality.

Beyond technical performance, the virtual analyser delivered significant financial value. It could have prevented up to US$ 910,000 in losses over the past two years, and projected savings reach US$ 16 million over five years-all without the cost and delays of a physical analyser, which typically requires over US$ 150,000 and multiple years to deploy.

This paper highlights how KNPC leveraged existing tools and process knowledge to develop a low-cost, high-impact solution - one that's now being scaled across other refinery units.

In modern refinery operations, product quality and compliance depend on the ability to monitor key parameters in real time. One such parameter is Reid Vapor Pressure (RVP), which reflects fuel volatility and plays a critical role in blending and storage.

At MAA Refinery, DIP Unit is responsible for extracting isopentane from the KNG stream to support Mogas blending. The remaining n-C5 product must meet a strict RVP specification of 10.5 psi or lower.

Like many process units, DIP had long relied on daily laboratory samples to monitor RVP. While this method provides accurate results, it introduces a significant delay in feedback-leaving operations without real-time visibility.

To overcome this, KNPC explored using existing process and lab data to develop a virtual analyser-a predictive model capable of estimating RVP continuously.

Problem Statement

In DIP Unit, the Deisopentaniser is responsible for separating isopentane from the KNG stream to support Mogas blending. The remaining stream-rich in normal pentane (n-C5)-must meet a Reid Vapor Pressure (RVP) limit of 10.5 psi or lower. This is a critical specification, as any deviation can affect downstream blending, storage safety, and overall product quality.

However, the unit relied entirely on a single RVP lab result per day to verify this parameter. This approach left operators with a major limitation: they had no visibility into RVP behaviour throughout the day. If off-spec material was being produced, it wouldn't be discovered until the next morning-after the product had already moved downstream.

This delay introduced several operational risks:

- Potential transfer of off-spec product into blending tanks
- Inability to take timely corrective action
- Increased reliance on operator intuition rather than real-time data
- Risk of product on giveaway or loss of recoverable material

While physical online analysers could offer real-time monitoring, they come with significant drawbacks: high cost, long procurement and approval cycles, and ongoing maintenance requirements.

The team needed a solution that could deliver accurate, timely RVP estimates using existing resources-a fast and reliable alternative to bridge the gap until a physical analyser could be procured and installed.

This is what led to the development of a virtual analyser-a data-driven tool that could be deployed quickly, support daily operations, and improve decision-making in the meantime.

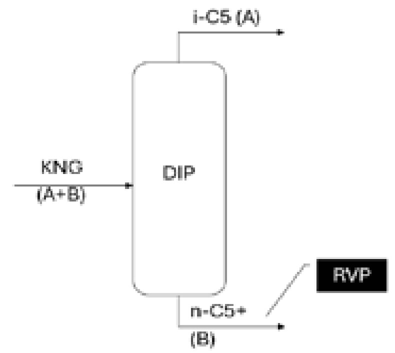


Figure 1 Simplified Process Flow of DIP Unit
The virtual Analyser predicts RVP for the n-C5 product stream after isopentane extraction from the KNG stream.

Virtual Analyser Concept

A virtual analyser is a software-based model that estimates process measurements in real time using existing operational data. Unlike physical analysers, which require hardware, procurement, and installation, virtual analysers use mathematical models built on historical lab and process data to generate continuous predictions. They offer a flexible and cost-effective way to gain insight into key quality parameters without physical instrumentation.

In the case of DIP Unit, the objective was to estimate RVP for the n-C5 product stream-a critical parameter for meeting gasoline blending specifications. Instead of relying on delayed lab results, a virtual analyser could provide continuous, real-time visibility to support operational decision-making.

The core idea was to use two types of data already available in the plant:

- Historical lab results for RVP
- Live and historical process data from DCS

By analysing the relationship between these variables, the team aimed to develop a reliable model that could be deployed as a fast, interim solution-filling the gap until a physical analyser could be installed.

Methodology and Model Development

To build the virtual analyser for RVP prediction, the team used a structured, data-driven approach combining historical lab results with process variables available from DCS. The objective was to create a predictive model that could estimate RVP values in real time with high accuracy, minimal complexity, and no need for external development.

Data Collection and Preparation

Two years of historical data were extracted, including:

- Lab-tested RVP values for the n-C5 product stream
- Relevant process variables such as flow rates, temperatures, and pressures from DIP Unit

The data was cleaned, aligned, and filtered to remove noise, inconsistencies, or outliers that could affect model performance. A total of several hundred data points were prepared for model development.

Modeling Tool

To support model development and deployment, the team used a self-service advanced analytics platform. This tool allowed engineers to explore data trends, test regression models, and validate predictions using historical lab and DCS data.

The platform was chosen for its ability to:

- Handle time-series process data effectively
- Enable fast prototyping and iteration
- Support integration with live plant data for real-time monitoring

Model Training and Testing

The historical dataset was divided into two portions:

- 75% used for training the model
- 25% used for testing and validation

Various regression techniques were applied, and the model that demonstrated the best balance between simplicity and accuracy was selected. It was then tested against unseen data to ensure it could generalise well to future conditions.

The model was configured to run continuously using live process data, updating RVP predictions throughout the day and displaying them for the operations team alongside other key performance indicators.

Solution Implementation

Once the model was developed and validated, it was deployed in DIP Unit for real-time operation. The virtual analyser was configured to run continuously, using live process data from the DCS to generate updated RVP predictions throughout the day.

Integration with Operations

The virtual analyser output was made accessible to the operations team through the existing control room dashboards. No new hardware or software installation was required, and the model ran in the background as part of the existing digital environment.

Operators were trained to monitor the estimated RVP trend just like any other process variable. If the prediction began to drift toward the specification limit, they could make timely adjustments before a lab result confirmed any deviation.

This approach provided a practical, easy-to-adopt solution that fit seamlessly into the operators' workflow-bridging the gap between process control and lab-based quality checks.

Operator Engagement

Feedback from the Operations Team was positive. They appreciated having continuous visibility into RVP, which helped reduce uncertainty and improve coordination with downstream units. The tool gave them more confidence in daily decision-making and allowed for faster response to process changes.

The success of the initial deployment in DIP Unit led to interest from other units in the refinery, who requested similar tools for their own applications.

Model Accuracy & Validation

Following deployment, the virtual analyser's performance was closely monitored by comparing its real-time RVP predictions against daily lab results. In the majority of cases, the model demonstrated strong alignment, maintaining up to 97% accuracy under typical operating conditions.

The prediction trend remained consistent with actual lab data, allowing operators to monitor RVP throughout the day with confidence. This helped support faster decision-making and reduced the risk of off-spec product moving downstream.

While the model was designed based on historical data patterns, it continued to perform reliably during day-to-day operations. As with any data-driven model, close monitoring ensures performance remains in line with expectations, especially when process conditions change over time.

Economic Impact

The implementation of the virtual analyser in DIP Unit has shown significant potential for cost avoidance and operational savings.

Over the past two years, it is estimated that the tool could have helped prevent up to $910,000 in losses by reducing the risk of off-spec product and unnecessary reprocessing. These figures are based on fluctuations in naphtha and Mogas prices, as well as the value of material that may have been downgraded or wasted due to delayed RVP detection.

Looking ahead, the projected savings over a five-year period are estimated at $16 million-achieved through better quality control, optimised recovery, and fewer blending disruptions. These benefits are realised without the need for capital investment in hardware, as the virtual analyser was developed using existing resources and tools available within the refinery.

Compared to a traditional physical analyser, which typically costs over $150,000 and requires years for approval, procurement, and installation, the virtual analyser provided a faster, lower-risk alternative that delivered measurable financial impact within weeks.

The economic case has strengthened interest in expanding the tool to other units and applying similar data-driven approaches across the refinery.

Scalability & Future Plans

The success of the virtual analyser in DIP Unit generated strong interest across the refinery. Based on positive feedback and the proven impact, the Operations Team requested that the tool be implemented in Train 4's deC4 tower. The deployment was completed using the same data-driven methodology, and the projected savings from this second application are estimated at $1.5 million over five years.

These results confirm that the virtual analyser approach is scalable and repeatable, with potential benefits across multiple units. By leveraging existing tools and in-house expertise, KNPC has demonstrated that digital solutions can be developed quickly and deliver measurable value-without requiring large capital investments.

Moving forward, similar models are being explored for other key quality parameters and process units, reinforcing the role of data-driven innovation in supporting operational excellence.

Conclusion

The virtual analyser developed at KNPC provided a fast, cost-effective solution for real-time RVP monitoring. It improved product quality, reduced risk, and delivered measurable financial impact using existing data and tools.

Its success in DIP Unit -and subsequent deployment in Train 4- demonstrates that data-driven solutions can scale quickly and add real value to refinery operations.

Processing Non-Standard Feedstock in DCU

In DCU, a series of complex reactions and diffusion processes take place resulting in the elimination of substituent of atoms and groups from the organic molecules. The series of reactions is a thermal conversion of organic materials known as carbonisation reaction, in which the organic materials is converted to carbon and graphite.

Abdulaziz Doukhi
Eng.-C, Operating, Clean Fuels Project
MAA

Introduction

The delayed coking process is a semi-continuous process that transfers a heated charge to coke drums providing an appropriate residence time for the thermal reaction to be finalised. The main reaction of the delayed coking processes is the thermal cracking reaction which converts heavy residue feed into lighter products and coke. Long reaction time is required to produce gaseous and lighter liquid products from heavy liquid feedstock (James G. Speight., 2015). In a Delayed Coker Unit (DCU), the residue feed is heated up to 507 degrees, which is the temperature at which the thermal reaction is starting. The heated residue is then being sent to accumulation vessels or coke drums which allows the feed to reside longer times for the thermal reaction to being completed. The effluent of these drums is quenched after a certain time to end the thermal reaction and then sent to a fractionator which will work on separating the products from the vapor line relative to their boiling point.

In Mina Al-Ahmadi Refinery (MAA), a Delayed Coker Unit (U-136) has been designed by ABB Lummus Global as a part of the KNPC Clean Fuels Project (CFP). The major equipment of the unit are the fractionator (V-101), wet gas compressor (C-301), coker heater (H-201A/B), and a heater charge pump (P-102 A/BT), in addition to two pairs of coke drums (V-201 A/B/C/D). The heavy feed of the unit is taken from two vacuum residue units (U-183 and U-83) to produce lighter products such as refinery fuel gas (RFG), liquefied petroleum gas (LPG), Naphtha, kerosene, light coker gas oil (LCGO), heavy coker gas oil (HCGO) and anode grade green coke.

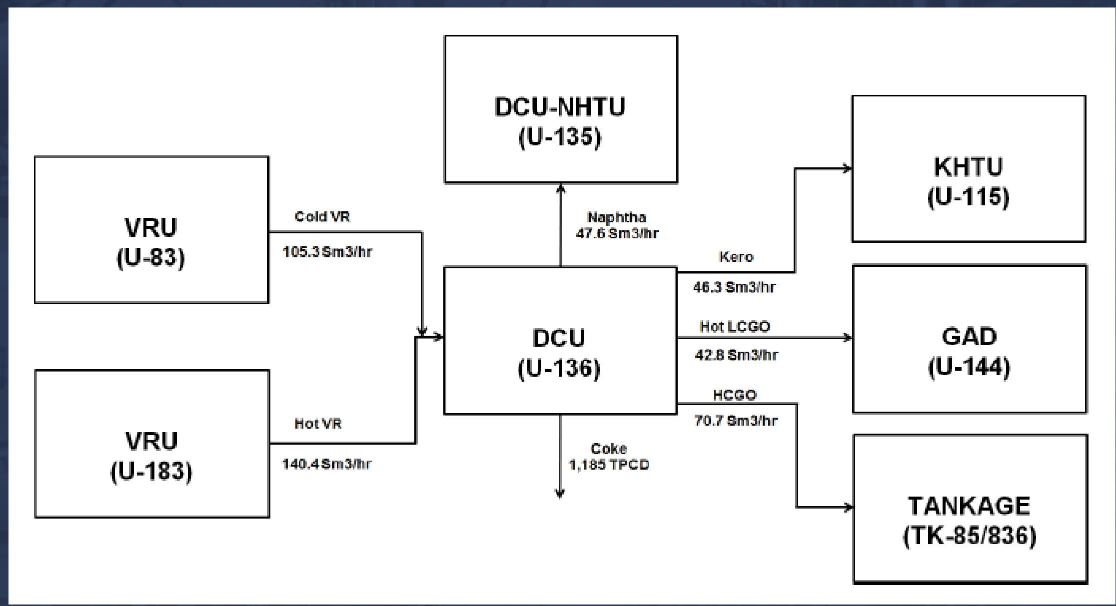


Figure 0-1: Block Diagram of U-136 (Operating Manual Delayed Coker Unit (U-136).

The figure above represents the block diagram of the delayed coker unit which depicts the main routings of the feedstock and products of the units in addition to their approximate amount.

In DCU, a series of complex reactions and diffusion processes take place resulting in the elimination of substituent of atoms and groups from the organic molecules. The series of reactions is a thermal conversion of organic materials known as carbonisation reaction. Thermal conversion in such reactions converts organic materials to carbon and graphite. Carbonisation reactions additionally result in the aromatisation and subsequent polymerisation along with the formation of large aromatic carbon molecules.

Recently, an additional type of feed has been implemented and processed in the delayed coker which is the Low Sulfur Atmospheric Residue (LSAR), the main feed to the Vacuum Rerun Unit (U-183). LSAR is the primary product of ARDS units resulting from processing crude oil. Additionally, LSAR is produced from all Atmospheric Residue Desulfurisation (ARDS) units in MAA which are ARDS-141 in CFP, ARDS-41/42 in RMP, and ARDS-81/82 in FUP. One common line for all trains of FUP and RMP routed to VR unit in CFP while a separate line is providing LSAR from the new ARDS-141. The implementation of LSAR was through establishing and optimising a jump-over line from the no normal flow line from U-41/42/81/82 to the vacuum residue line routed DCU.

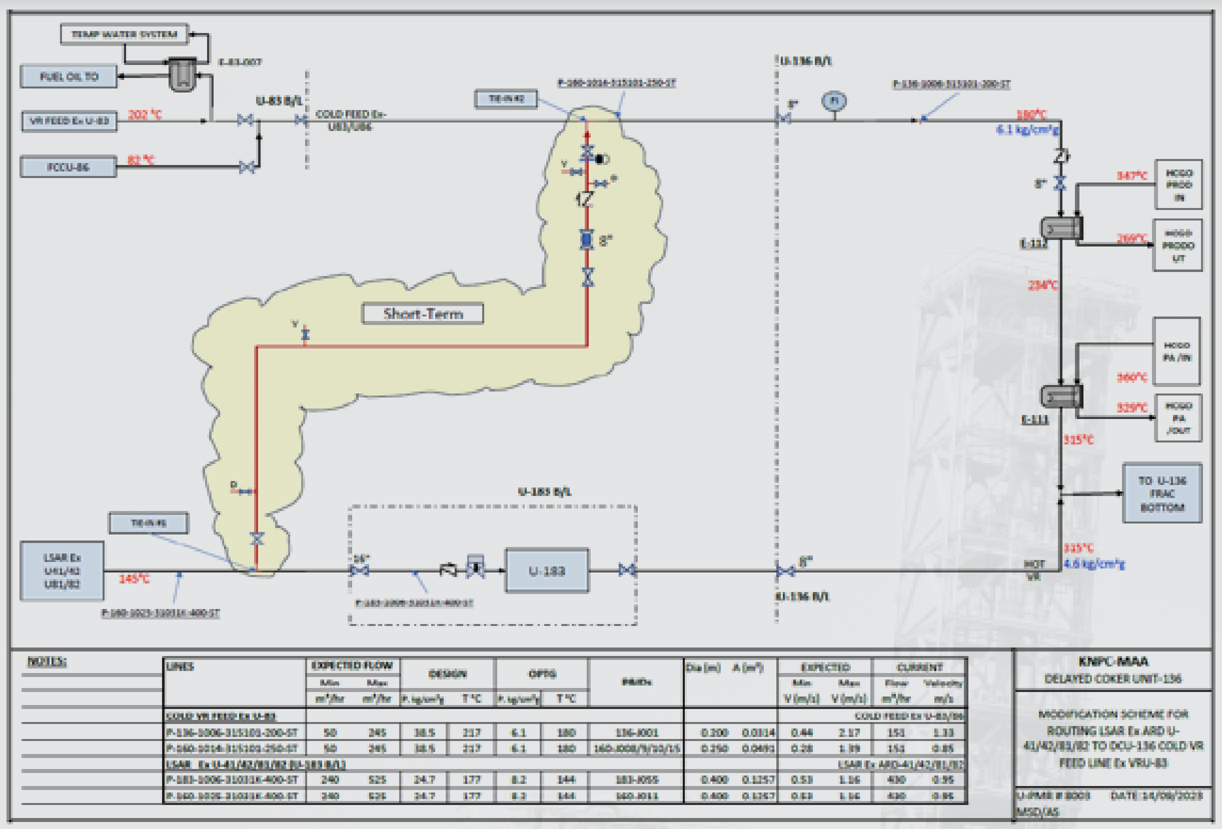


Figure 2: LSAR Jump-Over to DCU.

The figure above depicts the PEFS of LSAR jump-over to VR line routed to delayed coker unit before its battery limit. It also demonstrated the needed isolation valve, valve size, non-return valve, and required blind locations. Processing LSAR in DCU will result in a positive impact on the operation of the unit considerably as it will allow maintaining higher throughput during an upset of one of feed units. In addition, it will allow proper shutdown in case of both feed units failure by avoiding tarry drum emergency handling. The next table provides a comparison between the normal VR from U-83 and LSAR which indicates that the latter is slightly lighter than normal cold feed.

Table 1: Major Specifications of LSAR and Cold VR feed:

Specifications	LSAR	VRU-83
Density	0.938	0.975
Total Sulfur (wt%)	0.7-0.8	1.24
CCR (wt%)	6-6.5	12.7
IBP (°C)	333-	449

The first step for the implementation of the new jump-over line is to initiate a Plant Modification Request (PMR) which can be defined as any change to the existing Plant that results in modification in KNPC engineering drawings, document, and process conditions. The plant modification has objectives which are set by the Company such as ensuring that implementation of the Plant Modification does not adversely affect the integrity of the Plant, inherent safety, reliability, and elements of process safety management of technology and subtle changes are fully addressed. In addition, the process to be efficiently optimised from proposal initiation until the implementation stage will ensure successful usage of company resources and plant profitability improvement. All changes during the PMR should be well reviewed and documented. Plant modification requests can be classified into five types which are normal PMR, urgent PMR, emergency PMR, subtle change, and software change. Each PMR type will have different conditions and requirements. For example, urgent PMR requires the implementation of the modification to be completed within 30 days of approval.

Procedure

LSAR processing in the delayed coker unit started by raising an urgent PMR since it aims to increase the throughput of the unit and will significantly aid in avoiding tarry drum emergencies in case of both feed failure. A task force has been formed to discuss several aspects of the PMR made of Operation Team from Clean Fuels Project MAA, Maintenance Department, Inspection and Corrosion Department, process from Technical Services Department, safety engineer in addition to different personnel from other departments. After proposing PMR U-MAA-8033 for LSAR jump over from U-41/42/81/82 to delayed coker unit, the first aspect has been discussed regarding whether to perform cutting and welding for the tie-in or to execute hot-tapping. Based on team discussion, it was agreed to perform hot tapping tie-in since the first option requires the shutdown of the unit.

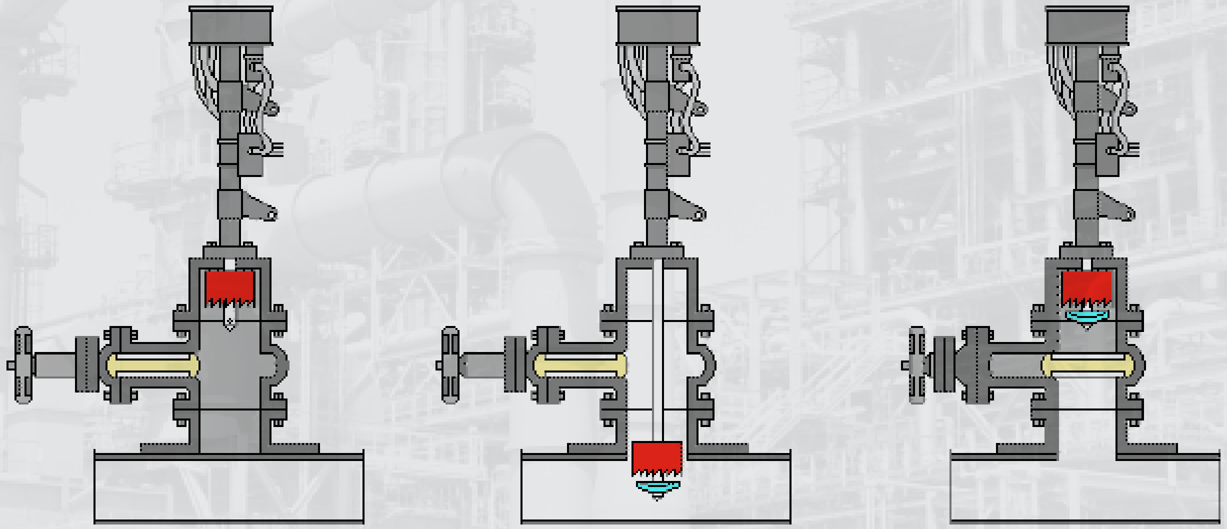


Figure 3: Hot Tapping Procedure (S. Werner).

Hot tapping is the procedure of tie-in through a pressurised line or system by drilling or cutting. For hot tapping procedures, major parts are required for successful and safe execution which are the fitting such as a split tee, valves, and hot taping machine. The procedure is done by cutting through the wall of the pipe after ensuring acceptable wall thickness exists. The section of the pipe will be removed as a result of the cutting which is called the coupon demonstrated cyan color in the figure above. The valve will then be isolated allowing for safe retrieval of the coupon. It is also recommended to use new gaskets and valves since it will be a permanent part of the line.

The hot tapping procedure for the LSAR jump-over line initiated by installing proper support then to start welding the stub on the live lines including VR line in addition to an 8 inches valve. After each welding job and modification to the line, a hydrotest and leak test procedures were performed. The hydrotest was done using lube and the target pressure was set to be around 6kg/cm2. The next table provides a consecutive summary of the major jobs performed regarding the new jump-over line.

Table 2: LSAR Jump-Over Main Events:

Job Description	Daily progress
Scaffolding modification	Day 1
VR line stub and support welding	Day 2
8" gate valve fixing and hydrotest	Day 3
LSAR stub/sleeve welding and hydrotest	Day 4
LSAR and VR lines hot tapping	Day 5
Line support concrete filling	Day 6
Painting and sandblasting	Day 7
Non-return valve installation	Day 8
Tracing steam connection	Day 9
Line insulation fixing	Day 10
Stenciling work	Day 11

The new line specifications were determined based on the existing VR and LSAR lines which were both made from carbons steel A106 Grade B taking into consideration the difference in corrosion allowance. On the other hand, line spec-break to be marked in the approved PEFS noting that line class 31031K to be followed from tie-in 1 to spec break and class 315101 to from tie-in 2 to spec break. It should be noted that, thickness survey was carried out for the hot tapping location to ensure proper thickness of the line which was successful.

After finishing PMR related work, it was planned to commission the line on 3rd of December 2023 due to U-83 planned shutdown and to be resumed for 19 days. It was ensured that commissioning preparation of the line has been completed properly such as priming and checking for any possible leakage. Then VR from U-83 and HCO from U-86 were replaced with LSAR from ARDS-41/42/81/82 with around 40m^3/hr with 170°C temperature in addition to maximising U-183 feed up to 180m^3/hr resulting in maintaining the unit throughput at 80~85%. It should be pointed out that processing LSAR can be done to maintain 100% throughput notwithstanding that the unit licensor stated it will be limited to 50% during the non-availability of cold feed. Operating parameters were adjusted by operations to ensure effective processing of LSAR and maintain product yield and specifications within acceptable range. Appropriate communication was required for the completion of the replacement job between Area-10 Operation and Area-3 Teams with no defects. The procedure to be followed during any upset of upstream units resulting in delayed coker unit feed loss such in the case occurred lately with the emergency shutdown of U-83 where DCU throughput has been maintained successfully at 100%. For instance, unplanned shutdown of U-83 has been encountered on 11/4/2024 leading to a loss in cold feed.

LSAR has been processed to overcome the shortage of throughput and it was successfully maintained at 100%. It should be noted that in case of both DCU feed loss encountered, LSAR can be processed with a flow of 120 $m!/hr$ for 10-12 hours to overcome the tarry drum then unit to be safely shutdown.

Discussion and Results

Table 3 below indicates the specifications of the delayed coker unit for two cases in which the first one is while processing both hot and cold vacuum residue in addition to heavy cyclic oil from U-183, U-83 and U-86 respectively. The second case is regarding processing low sulfur atmospheric residue instead of cold VR stream. Analysis of the combined feed in both cases were found relatively similar except for slight deviations such in the case of the asphaltene and conardson carbon residue content which was lower while processing LSAR.

Table 3: LSAR Analysis in Combined Feed Stream:

Parameter	VR Combined Stream	VR Combined Stream with LSAR
API Gravity	13.3	13.4
Asphaltene (wt%)	5.07	4.64
Relative Density	0.9774	0.9765
IBP (°C)	304	313
5 % (°C)	421	408
10 % (°C)	473	450
20 % (°C)	536	520
30 % (°C)	561	550
Sulfur, Total (wt%)	1.29	0.99
Carbon Residue, Conradson (wt%)	12.3	10.5

Tables 4-7 below reflect delayed coker unit products analysis by obtaining a sample of the specifications collected daily including HCGO, LCGO, Kerosene, Naphtha, and treated gas. The sample of the analysis before processing LSAR was relevant to the results obtained on 13th November 2023. On the other hand, products specifications collected from the data found on 15th December 2023 when LSAR was processing in the unit.

Mainly, API gravity was found to be higher while processing LSAR indicated that lighter feed would result in lighter products such in the case of HCGO when it increased by 4.3 as demonstrated below. All other specifications of all products except for coke were significantly close with changes to be considered negligible. That is due to the proper operation of the delayed coker unit in which parameters were adjusted as needed to maintain products quality. Yield of products was correspondingly reduced due to a decrease of the unit throughput to a total of 220m^3/hr but sustained at satisfactory quantity.

Table 4: HCGO Product Analysis:

Parameter	With LSAR	Pre-LSAR
Carbon Residue, Conradson (wt%)	0.12	0.10
API Gravity	22.5	18.2
Relative Density	0.9189	0.9454
Flash Point (°C)	>110	185
Total Sulfur (wt%)	0.71	1.06
IBP (°C)	298	279
FBP (°C)	494	497

Table 5: LCGO Product Analysis:

Parameter	With LSAR	Pre-LSAR
Carbon Residue, Conradson (wt%)	0.002	0.002
API Gravity	32.3	31.6
Relative Density	0.8641	0.8674
Flash Point (°C)	>110	121
Total Sulfur (wt%)	0.33	0.47
IBP (°C)	248	246
95 % (°C)	353	353
FBP (°C)	365	365

Table 6: Kerosene Product Analysis:

Parameter	With LSAR	Pre-LSAR
API Gravity	43.3	43.5
Relative Density	0.8094	0.8086
Flash Point (°C)	68	60
Total Sulfur (wt%)	0.12	0.16
Freezing Point (°C)	-53	-56
FBP (°C)	244	242
IBP (°C)	180	177

Table 7: Naphtha product Analysis:

Parameter	With LSAR	Pre-LSAR
API Gravity	70	70.7
Relative Density	0.7023	0.6998
RVP (psi)	16.8	17
Total Sulfur (wt%)	0.14	0.18
FBP (°C)	156	149
IBP (°C)	18	11

Table 8: Treated Gas Product Analysis:

Parameter	With LSAR	Pre-LSAR
C1 Methane (%)	49.3	52.5
C2 Ethane (%)	19.3	18.4
C3 Propane (%)	9.8	7.4
Total Olefins (%Mole)	10.1	8.6
H2S (ppm)	60	40
Molecular Weight	19.52	18.65
Calorific Value (BTU/SCF)	1077.25	1028.24
Relative Density	0.2904	0.2875
Hydrogen Content (%)	9.3	10.7

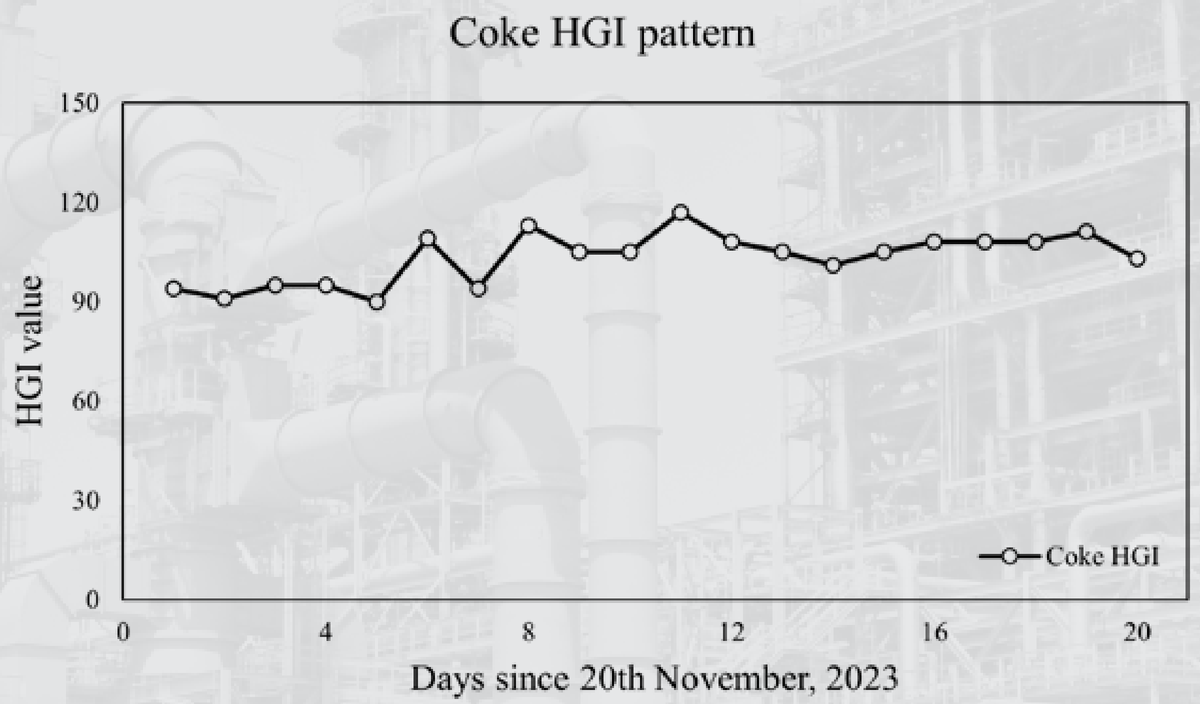


Figure 4: HGI Value Pattern.

The major effect of processing LSAR in the delayed coker unit was the Hardgrove Grindability Index (HGI) of the petroleum coke product as illustrated in the figure above for the HGI values of one month from 20th of November to 20th of December 2023. Starting LSAR processing reflected negatively on the HGI of the coke leading its value to significantly increase. The higher value was encountered after 9 days of processing the new feed which was found to be 117 when the design value was 60-80 as per unit manual. Several operational aspects have been modified to resolve the issue such as increasing heater coil outlet temperature, reducing ARDS-141 severity, increasing recycle ratio, and maximizing U-183 VR feed.

The table below provides the details of products yield in different cases compared to the design yield of the unit. Case 1 represents processing only Vacuum Residue feedstock from U-83 and U-183, whereas Case 2 represents processing both Vacuum Residue and LSAR. The latter case reflected significant change to the products yield except for the HCGO and Coke which were found to be higher by 3.9% and less by 6.2% respectively. Associating the actual yield on the second case to the design yield concludes that obtained production is valid and within acceptable range of unit operation.

Table 9: Products Yield:

Product	Design Yield (%)	Case 1 Yield (%)	Case 2 Yield (%)
Fuel Gas	4.2	6.2	5.7
Naphtha	14.5	12.6	13.8
Kerosene	14.4	10.4	9.9
LCGO	23.1	24	26.2
HCGO	22.3	26.3	30.2
Coke	21.5	20.5	14.3

Conclusion

The new line implemented urgently to process LSAR from U-41/42/81/82 in the delayed coker unit through a jump-over line to cold VR-83 line. Hot tapping through live line has been performed to avoid any possible unit distribution. LSAR processing initiated on 2nd of December 2023 during U-83 shutdown and sustained for 19 days in which the hot VR was flowing around 180 $m!/hr$, while LSAR flow was maintained at 40 $m!/hr$. Product specifications were analysed and found to be normal except for the HGI of coke in which it reflected higher values. Several actions were performed by Operations and Process Departments to mitigate that issue. Moreover, Operation Team overcame an emergency of cold feed loss from U-83 by processing LSAR on April 2024 and successfully maintaining throughput at 100%. All in all, LSAR processing in DCU was completed successfully leading to increasing the throughput during the loss of cold feed and thus growing a profit equivalent to 9.5 MMUSD$.

References

(1) James G. Speight., 2015. Fouling in Refineries. Gulf Professional Publishing.

(2) Operating Manual Delayed Coker Unit (U-136).

(3) S., W. Introduction to hot tapping and line stopping, What is a Hot Tap, why it is made and how to make a Hot Tap in a pipe line. Available at: https://www.wermac.org/specials/hottap.html (Accessed: 20 April 2024).

Sludge Handling & Treatment Facility and Solutions to Sustainable Management

Oily sludge is an emulsion of solid particles, heavy oil and water that settle at the bottom of product storage tanks. High quantities of sludge can interfere with normal tank operation. Sludge Handling and Treatment Facility is installed to treat and process sludge from all three KNPC Refineries and local marketing.

Ritaj Boushehri
Environment Engineer
MAB

Introduction

The primary objective of this paper is to propose and evaluate the adoption of composting as an innovative, sustainable solution for managing oily and bio sludge generated in KNPC by analysing the Sludge Handling & Treatment Unit (U-58), addressing the operational challenges, highlighting possible solutions with economic and environmental benefits.

Feed Specifications

The approximate annual quantities of sludge generated in KNPC Refineries are as follows: (will vary based on refinery unit operations)

MAB/SHU/LM: 22,324 M3/year

MAA: 33,946 M3/year

Total: 56,270 M3/year

Effluent Treatment Philosophy

A) Primary Treatment

The High Solids Pre-treatment Unit (HSPU) is the first stage for treating high solids contaminated sludge through heat.

B) Secondary Treatment

The secondary treatment begins with centrifuges, which separates the pre-treated sludge into oil, water and solids.

C) Polishing Treatment

Oil will be further treated in high-speed centrifuge.

D) Storage and Recovered Phases

The recovered oil and water from the process is stored in two steam-heated vessels where the quality can be tested; to confirm output specification is being reached.

Products

a) Recovered Oil

b) Recovered water

c) Recovered sediments will be transferred to the National Cleaning Company (NCC).

Five-Year Analysis

Five-year data was gathered from the process monthly statement of Heavy Engineering Industries & Shipbuilding CO. for U-58 from January 2017 to December 2021. This data contained untreated oily sludge received by U-58 from all KNPC sites and amounts of product recovered. Table 1 shows the amount of sludge received by U-58 and Figure 1 shows a clearer view of the amounts of sludge received during the years from different KNPC sites. During the five-year period, MAB had the highest amount of oily sludge generated and the lowest was local marketing.

Table 1: Untreated Oily Sludge Received in m3:

Year	MAA	MAB	SHU	LM
2017	434.694	4836.048	12820.325	0
2018	2114.412	6885.211	4975.418	0
2019	1566.558	16430.826	2766.849	0
2020	3253.538	17122.647	1480.961	14.309
2021	16583.824	8806.191	1821.21	144.411

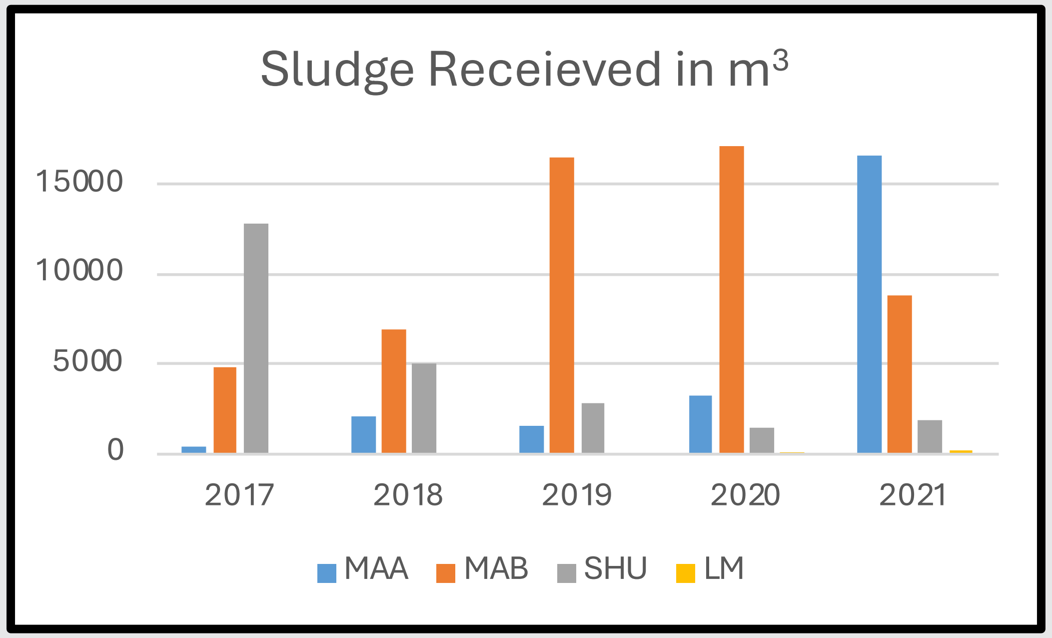


Figure 1: Untreated Oily Sludge Received

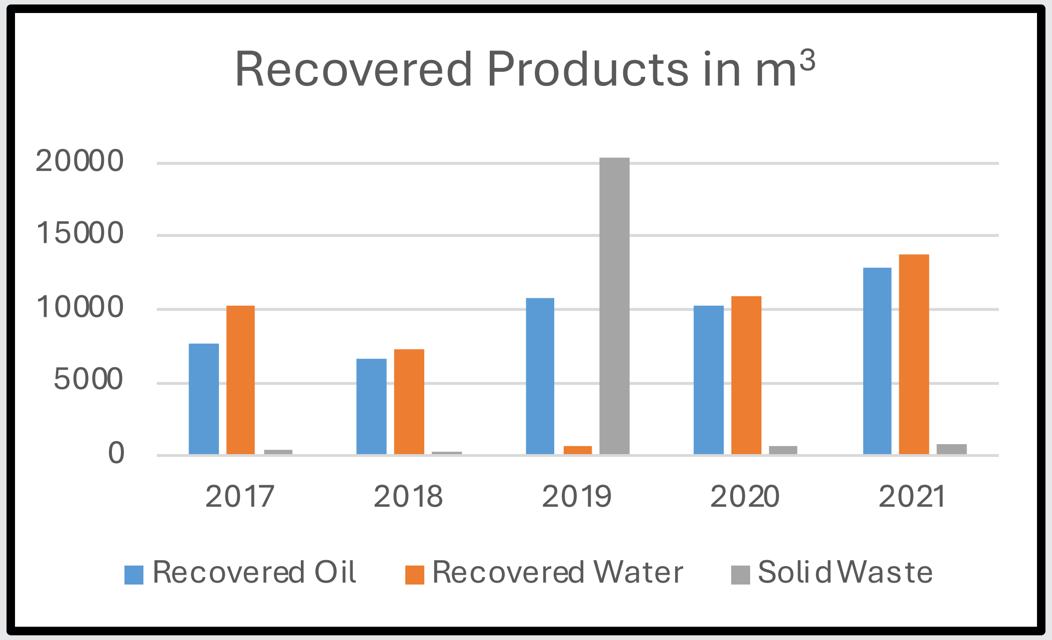


Figure 2: Recovered Products

Figure 2 shows the amounts of recovered products during the years 2017-2021. As shown in the figure, in 2019 there were high amounts of solid waste recovered, which could indicate that the type of sludge was mostly solid. This means in 2019, high amounts of solid waste were disposed of to the NCC. On the other hand, the figure shows that processing the untreated oily sludge would result in waste reduction and recovering products such as oil and water.

Cost Saving Analysis

Operating costs were found to be around KD 31,000 per month. Slop oil was found to be worth KD 146 per metric ton. One metric tons of solid waste cost KD 31 to be disposed to the NCC, if sludge is mixed with soil. As a result, it was found that with U-58 the Company had saved around KD 8,000,000, during the five-year period (2017-2021).

Sustainable Sludge Management at KNPC:

Composting Solutions for Refinery Waste

Globally, the refining industry is increasingly pressured to adopt sustainable practices, aligning with broader environmental goals. Waste management in the refineries, especially sludge from bottom tanks, presents unique challenges. In KNPC the integration of bio sludge from wastewater treatment adds complexity. With the high cost of solid waste disposal, composting emerges as a strategic solution.

Current Challenges in KNPC

- **Sludge Quality and Equipment Protection:** On some occasions, the unit will not handle sludge with high viscosity for equipment protection.
- **Sediment Disposal:** The current practice of landfilling sediment is costly and environmentally unfriendly, driving the need for alternative strategies.
- **Odor Management:** Odor from processing both types of sludge can impact operational efficiency.

Proposed Composting Solution

- **Co-composting:** Mixing sludge with organic materials can control odor and improve compost quality, allowing for the integration of bio sludge with oily sludge: co-composting by mixing oily sludge with green waste (like grass clippings and leaves). This blend helps dilute contaminants, manage odor, and create a nutrient-rich compost. The process involves:
  - Collecting both sludge types and organic waste.
  - Mixing them in the correct carbon-to-nitrogen ratio.
  - Composting in windrows or in-vessel systems, turning the piles regularly to ensure even decomposition.
- **Aerobic Composting:** This method is known for effectively degrading hydrocarbons from oily sludge and organic matter from bio sludge, reducing both volume and pathogens: Dealing with chemical waste employs aerobic composting by constructing large, aerated composting bins sludge is placed. Aeration force is used through pipes to maintain oxygen levels, which:
  - Accelerates decomposition, significantly reducing the volume of sludge.
  - Generates enough heat to kill pathogens and break down hydrocarbons.
  - Produces a compost that can be used in land reclamation projects.
- **Vermicomposting:** Although primarily for bio sludge, it can enhance compost quality even with limited input, offering a niche solution within our waste management. Vermicomposting can be used for bio sludge by setting up dedicated worm beds where:
  - Bio sludge is pre-treated to remove any harmful substances.
  - Red wigglers (Eisenia fetida) are introduced to consume the sludge, producing vermicast.
  - The resulting vermicompost can be sold to organic farmers for improving soil structure and fertility, particularly for high-value crops like vegetables and fruits.
- **Microbial Degradation:** Utilising specific microorganisms to break

down hydrocarbons in oily sludge can optimise the composting process. Microbial degradation programme can be implemented when dealing with hydrocarbon-rich sludge where:

- Using a consortium of bacteria specifically for their ability to break down hydrocarbons, including Pseudomonas and Bacillus species.

- These microbes are inoculated into the sludge in controlled conditions, often in bioreactors where temperature, moisture, and oxygen are managed to optimise microbial activity.

- The process not only detoxifies the sludge but also prepares it for further composting or direct soil amendment, reducing the environmental footprint of the waste.

Implementation Strategy

• **Pilot Project:** A pilot project is recommended to evaluate the composting process with our unique sludge mix, assessing both feasibility and effectiveness.

• **Infrastructure Adjustments:** Modifications to the existing sludge handling unit infrastructure or the addition of dedicated composting facilities are essential to manage varying sludge quality.

• **Regulatory and Compliance:** Ensuring adherence to local environmental standards is crucial for the implementation of composting practices.

Economic & Environmental Benefits

• **Cost Reduction:** Composting can lower disposal costs by avoiding landfill fees, potentially saving KD 155,000 per year. When combined with the unit's existing savings of 2,000,000 KD annually, total cost reductions could reach up to KD 2,155,000 per year.

• **Revenue Opportunities:** Compost sales could generate up to 4,000,000 KD over five years based on a price of KD 0.16 compost per liter, translating to an annual income of KD 800,000.

• **Total Economic Impact:** Over five years, the initiative could yield an economic benefit of KD 14,775,000, with an annual benefit of approximately KD 2,955,000, making composting a financially viable strategy.

• **Environmental Benefits:** Minimising landfill use reduces environmental impact and supports soil health, aligning with broader sustainability objectives. By composting 25,000 tons of sediment over five years, there's a significant reduction in environmental footprint and could qualify for carbon credits by preventing methane emissions and enabling carbon sequestration in soil.

Additional Costs to Consider

Capital Expenditure (CapEx):

- **Infrastructure:** Costs for setting up composting facilities like windrows, in-vessel systems, or vermicomposting units.

- **Equipment:** Machinery for turning compost, aeration systems, leachate collection, etc.

Operational Expenditure (OpEx):

- **Labour:** Costs for personnel to manage the composting process, including monitoring, turning, and quality control.

- **Utilities:** Electricity for aerators or other equipment, water for moisture control.

- **Materials:** Additional organic materials for co-composting, microbial cultures for degradation, or worms for vermicomposting.

- **Maintenance:** Regular upkeep of equipment and facilities.

Regulatory and Compliance Costs:

- **Permitting**: Fees for obtaining necessary permits or environmental compliance checks.

- **Testing:** Costs for regular testing of compost quality to ensure it meets standards for sale or use.

Miscellaneous

- **Training:** Educating staff on new processes.

- **Transportation:** If compost needs to be moved off-site for sale or use.

Conclusion

The adoption of composting as a strategy for managing both oily and bio sludge in KNPC presents a compelling case for sustainability in the refining industry. By turning waste into a resource, this proposed solution not only addresses the immediate challenges of cost and environmental impact but also sets a new standard for waste management practices. With potential economic benefits over five years, and significant reductions in environmental degradation, composting proves to be both economically beneficial and environmentally responsible. This approach positions KNPC at the forefront of sustainable innovation, encouraging a shift towards more circular and efficient waste management systems within the sector.