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CONTENTS

06 The Digitization of Refinery Data Collection at KNPC Process
08 KNPC's Digital Refinery Maximo Oil & Gas Enterprise Solution
12 MAB Quarterly Newsletter
14 MAB Refinery Gears-up for New IMO Regulations
16 Ship Loading Operations at MAA Refinery
20 Transport in Transition The Rise of the Electric Vehicles
23 Premature Failure of FCC SWT Stripper Overhead Piping in Ammonium Bisulfide Environment
29 Application of High Velocity Thermal Spray Coating
31 Linear Programming and KNPC Planning
35 Salient Design/Features Adopted in CFP
39 Innovation & Challenges in LPG Train-4 Commissioning
43 New Training Outlook in MAA Refinery
50 Pneumatic Testing of Piping Managing the Hazards for High Energy Test
55 Hydrogen Rich Sour Gas Processing in HP Unit
58 An Approach to Process Management of Change
59 KNPC Process for Learning from External Incidents

EDITOR'S NOTE

Khuloud Saad Al-Mutairi
Manager Corporate Communication

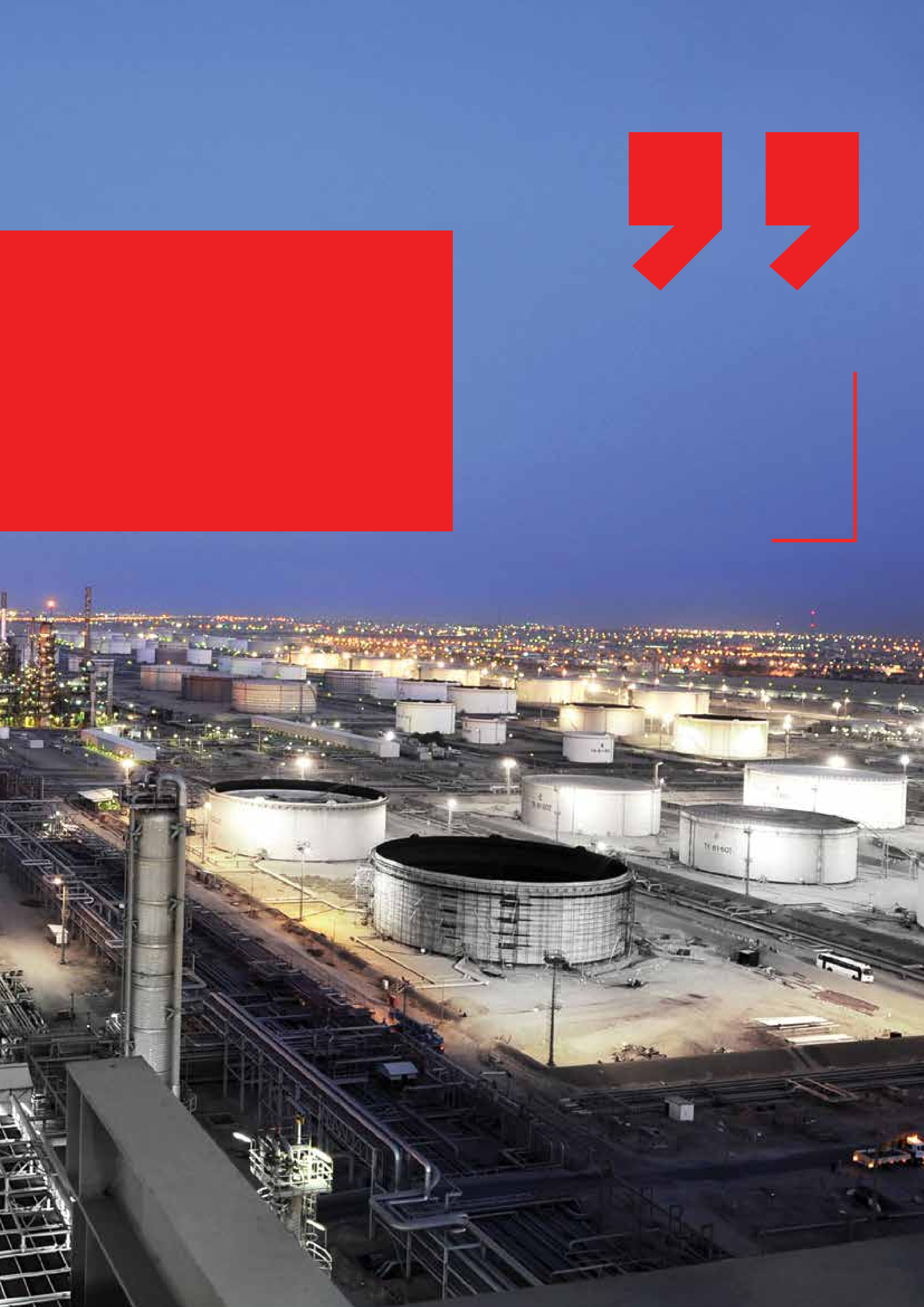
It gives me great pleasure to present you with the 4th issue of the KNPC TECH Magazine, a publication that tackles technical papers and studies prepared and delivered by KNPC Engineers. This publication serves as a suitable platform for KNPC Engineers to share with the wider community in KNPC and the general public their technical know-how and best practices with the aim to enrich our knowledge on such subject matters.

I would like to capitalize on this opportunity and draw your attention to a featured article within this issue tackling the "Field Training" of five female Engineers, a unique experience within KNPC and the Oil sector as a whole, whereby the female Engineers undertook an extensive field training over a one year period on production units, processes, systems, maintenance, risks, emergencies and other field related practices to name a few. This initiative proved to be a successful one as it tackles healthy diversity within our workforce, while ensuring a qualified and skilled team, irrespective of gender, will be ready to run this vital sector in the future.

Other articles being featured focus on the ever-increasing competition within the refining industry as KNPC moves towards "Smart Refinery" whereby Digitalization and Connectivity become key components to enhance efficiency, reliability and safety of the refining processes and consequently, our competitiveness.

The topic of stringent measures being imposed by the International Maritime Organization has been a hot one, thus, we featured an article on this important subject matter with regards to Bunker Fuel Sulfur content and our Refineries' readiness to take on this challenge.

Finally, I invite you today to browse through our KNPC TECH Magazine and benefit from the various topics, rich articles and case studies featured within that cover a broad range of technical material as we continuously strive to make them available to the wider segment of our readers. I shall look forward to hearing back from you, providing us feedback on the content covered in our issues.



The Digitization of Refinery Data Collection at the KNPC Process

It is true now more than ever that efficiency and productivity have become a strategic must in the refining industry. Sharp competition, growing demand for higher product qualities and ever-increasing complexity require refiners to find new solutions. Needless to mention the ever-needed higher speed and accuracy, as much as reducing operational costs and searching in every nook and cranny to save every savable Fils. Refiners need also to increase efficiency, i.e. less unscheduled shutdowns, ultimate reliability and near-to-zero accidents.

Such objectives are no longer fanciful, but rather essential to stay alive. One way to achieve those goals is to rely more on cutting-edge technologies. Automation, high-tech sensors and advanced communication are now the tools that the refiners leverage to be competitive enough. With increased digitization and automation, KNPC is well on its way for a "Smart Refinery."

Abdulaziz Al-Duaij
DCEO- Support Services

Digital operator rounds

Digital Operator Rounds (DOR) is a solution that is being implemented as part of the Kuwait National Petroleum Company's digitization strategy. The solution aims to digitalize the operational activities of field operators across KNPC's refineries by relying on a completely digital infrastructure for data collection. The solution uses handheld devices that the operators utilize to collect structured refinery data, which is synced to dedicated servers for data collection, verification and analysis.

Operational activities, also known as "Operator Rounds," are one of the most valuable sources of data when it comes to making decisions that improve reliability and safety at the KNPC. By implementing the Digital Operator Rounds solution, KNPC reduces the maintenance costs through early fault detection, which allows controllers and supervisors to perform efficient analysis, proactive decision making and stay up to date when it comes to operational insight.

An overview

An Operator's Round is one of an operator's daily tasks where he/she checks and verifies multiple meter readings throughout the refinery. This is done to make sure readings are within safe limits, checks equipment for any required maintenance and ensures everything is operating as expected.

In the past, Operator Rounds were performed using pen and paper. An operator would go Round each unit with his clipboard and write down each meter's reading on the paper. Once the operator is done with the Round, readings are taken back to the service building so that a supervisor may review them. The supervisor reviews and approves the readings, and then they are stored in physical files; this is done daily, multiple times a day.

Challenges

Completing rounds this way gets the job done, but lacked luster in many ways. Human errors do occur as an operator may take down the wrong reading by mistake, miss a few meters during the Round, or even skip a few readings because the sun was too hot. We had no way of managing any of this.

This also applies to the supervisor. Some of the readings might not be legible; and there are no indications if a reading was abnormal. In average, 700,000 readings are taken every month.

Solution

With all of these challenges, our solution was clear, we had to digitize the whole process. This is where the Digital Operator Rounds (DOR) solution came into place. DOR utilizes handheld devices that the operator would use instead of pen and paper, and a database for information storage that supervisors would utilize for analysis and validation.

A major benefit that the solution offers is the standardization of data collection formats across all refinery units. Other benefits include the digitization and automation of field data collection performed by operators with the aid of the detailed and guided workflows that the hand held devices offer, and the centralization and mass collection of data in the SAP HANA database. The latter allows for in depth analysis that aids in real time fault detection and the reduction of production down times.

How is it different

The device offers multiple methods of reducing human error. The restrictions, guidelines and real time authentication ensure that the operator does not enter incorrect data. The device will also confirm that the operator is following scheduled Round and visiting all meters by utilizing GPS technology in order not to miss or skip a meter.

As soon as the operator returns to the service building, the device will automatically connect, prompt synchronization of the data and uploading into the database.

The supervisor will get the meter's description, location, expected limits, and the actual readings for each meter. The data is quickly filtered to view readings that fall out of bounds, and any attachments such as photos or comments by the operator for these specific readings are viewed.

The software also offers extensive information when it comes to preventative and predictive analysis.

The supervisor will get statistics on how many readings are abnormal as well as analytics on which readings are commonly reoccurring that might require preventative actions. Access for the trend Analysis reports that display the graphical analysis for each meter over a set period is also given.

All readings are being utilized by the Supervisor View to generate statistics that reflect operator performance.

Finally, all of the features listed above have their own reporting capabilities that offer concise and detailed reports for each feature. This is immensely helpful to the supervisor in terms of peer review and upper management reporting.

Other benefits

Guided workflows on the mobile handheld devices ensure that consistency and best practices are applied by every operator. The devices are being used round the clock throughout all the shifts, 24 hours a day, 7 days a week. This digitization of operator rounds significantly reduced the carbon footprint of KNPC by eliminating up to a million paper templates per year.

With the project's implementation, there were a total of 116 training sessions for all operation units, which covered a total of 1306 operators, controllers and supervisors.

The future

The DOR solution's backend has the complete infrastructure of an IOT solution's backend. IOT is a natural evolutionary step in refineries across the globe, and as we begin to integrate IOT data collection technologies into the KNPC's refineries, we will be able to streamline the process into the DOR solution. The functionality of DOR may be simplified into three main aspects: Data collection, Data Storage and Data Analysis. When time comes to integrate IOT into the system, we shall only require to update the Data Collection aspect of the solution by replacing the handheld devices with IOT sensors that would automatically feed data into our database.

Now as for software and the Data Analysis aspect, we are already looking into ways to incorporate artificial intelligence and machine learning into our analysis. Our system already offers methods to aid the supervisor's decision making in terms of predicative and preventative maintenance, but with AI and Machine learning, we could have the system take care of the maintenance itself and notify the supervisor with actions that he might need to look into without requiring to review the data manually.

Challenges are always faced when it comes to change; one of the major challenges included properly promoting and encouraging operators to utilize the new digitized solution over the pen and paper approach that they were used to.

However, after initial doubts and feedback, currently the vast majority of operators prefer their handheld devices to the old methods, mostly due to its improvements on efficiency with their workload.

So far, the solution has been successfully implemented across 29 refinery units in Mina Abdulla Refinery and is fully functional with outstanding results.

Further expansions are scheduled for other units and refineries, with plans in motion to begin implementing the solution at the Mina Al-Ahmadi Refinery.

KNPC Digital Refinery

Maximo Oil & Gas Enterprise Solution

Refining industry is facing unprecedented challenges. More stringent environmental conditions for better fuels specifications, world oil market upheavals, tougher competition, higher safety standards and pressure for reduced costs. Resorting to advanced technologies throughout the organization's infrastructure and services seems to be the best solution. With increases in refining complexities cutting-edge systems are needed to analyze the company's management as well as operational and physical state of the infrastructure. Predictive analytical methods are essential to take precautionary measures, prevent possible future accidents and ensure full reliability. As well, optimization capabilities are also needed to lower costs and boost profitability.

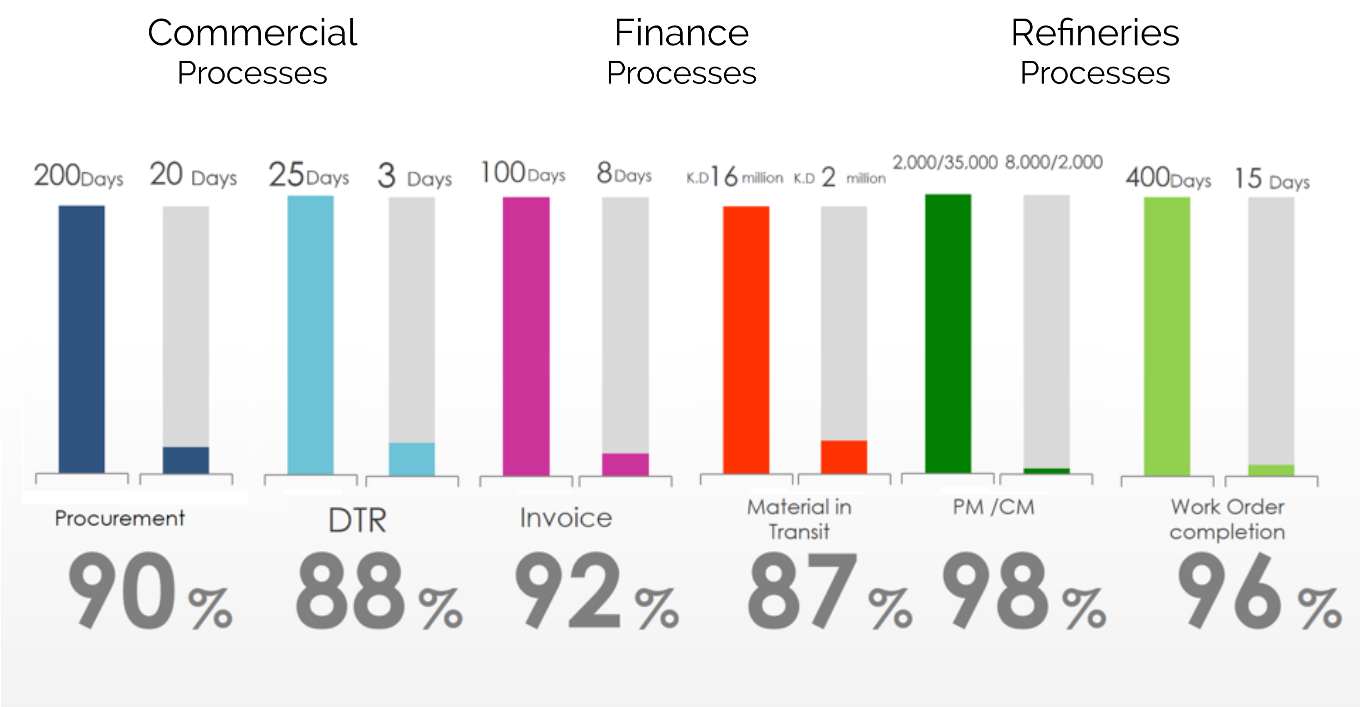
Nabeel Haidar
Team Leader, Enterprise Applications
IT Department

KNPC has implemented, and heavily customized, Maximo's Oil & Gas Enterprise solution to allow its core business processes to be fully automated, a step towards the company's goal of achieving a truly "Digital Refinery."

Such objectives are no longer fanciful, but rather essential to stay alive. One way to achieve those goals is to rely more on cutting-edge technologies. Automation, high-tech sensors and advanced communication are now the tools that the refiners leverage to be competitive enough.
With increased digitization and automation, KNPC is well on its way for a "Digital Refinery."

Maximo

Maximo Oil & Gas brings together traditionally separate business functions into a single integrated platform that combines the most common business systems and departments such as finance,



commercial, maintenance, and operations.
The project's implementation covers covers all KNPC sites as well as KAFCO subsidiary sites with over 300 training sessions for more than 2500 users from maintenance, operation and HSE.

Some of the main components of the solution include Electronic Work Permits, Operator's Logs, Risk Assessment, Work Conditions, Defect Elimination, and Failure Reporting. KNPC has been one of the first companies in the Gulf region with Electronic Work Permit implementation inside Maximo's Asset Management System.

Standardization

One of the major challenges with implementing the solution was the standardization of business processes across various KNPC refineries, and migrating all of them into a single platform, as well as transforming the work permit infrastructure into an electronic system instead of the previous manual methods.

Saving time

Utilizing this solution, KNPC reduces the data transfer rates s, the invoice cycle times, the purchase cycle times, and improves the procurement cycle immensely. In addition, the company decreased the time needed to complete asset maintenance and enhanced its work order preventative-maintenance versus corrective-maintenance ratio [PM/CM ratios (8,000/ 2,000) prior to Maximo (2,000/ 35,000)],

Plans include upgrading to Maximo 7.6, which would introduce the latest technologies such as IoT (Internet of Things) where data collection will be fully automated, including analytics, preventative maintenance, and even predictive maintenance by utilizing AI technologies.

How it was

An operator sits at his/her desk and all of a sudden receives an email from his supervisor about an unplanned shutdown on a specific pump that requires maintenance. Per the process, the operator rushes to the site and examines the pump. The operator realizes the necessary action and raises the maintenance request.

This specific request requires materials from the Procurement Department, tools from the Instruments Department, and an engineer from the Contract Department. Requests need to be forwarded to the said departments.

Per the requirements of the Job Plan, the engineer collects his work permit, performs the maintenance. A report is submitted to the unit supervisor.

This process worked. It got the job done, maintenance was conducted in a reasonable time, functionality was restore. But it wasn't perfect, we knew we could improve many aspects of the whole process, there were challenges:

Challenge No.1: reports done manually. Something goes wrong, someone notices it, and the concerned person is notified. Still, plenty of room for improvements.

Challenge No.2: support information in regard to the asset or work order is need, then the whole process is delayed until the work order is completed.

Challenge No.3: Delayed communication. Each concerned department has a different point of communication and process. If the request is delayed in a certain department, the whole work order is delayed.

Challenge No.4: Consistency. Ensuring that the job plan fits the requirements properly and has a consistent record of satisfactory results, is crucial for success.

Challenge No.5: Authentication. Work permits are a critical aspect for Health and Safety when conducting work orders. It ensures that the person is properly certified and trained to perform a specific task, and such an authentication procedure needs to be of the highest caliber.

Challenge No.6: Analysis. The final and possibly most important challenge. The information we gather from a completed work order is of utmost importance. We need to learn about what went wrong, why it went wrong, and how we addressed to be better arm ourselves for future events.

This is a short and standard scenario of a small work order, and the aspects that could be improved.

The solution

Maximo operators are constantly logging their routine tasks. Any abnormalities in these logs are directly reported through Maximo and raised as a work request. Consequently, the operator no longer needs to examine the site after receiving the work request as the examination is conducted in advance.
Since the routine tasks are constantly logged, detailed information from past inspections that are stored in

Maximo will accompany the work request sent to maintenance.

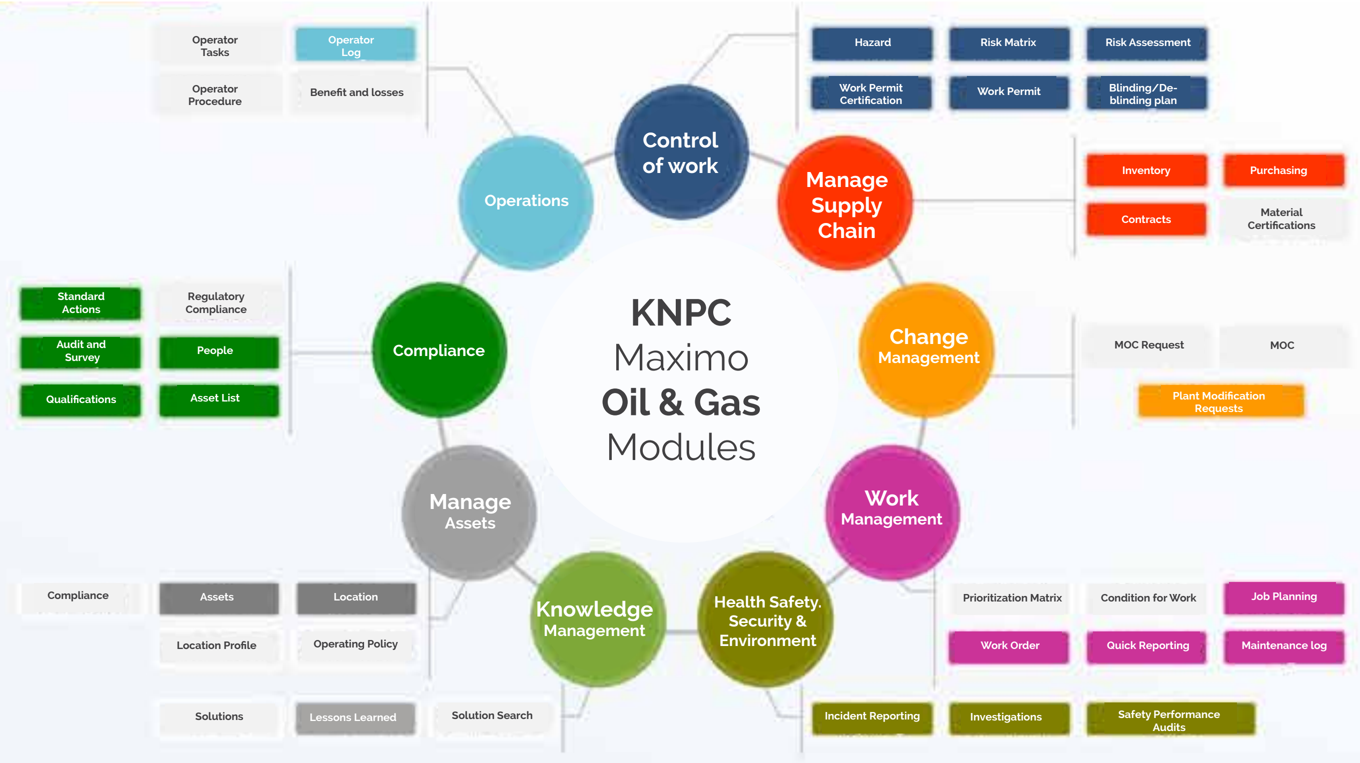
Within the work order creation, the required labor/resources are selected. Maximo then forwards the work order to the departments responsible for providing the required labor/resources. In case of stock unavailability, Maximo triggers a procurement/purchasing process.

A set of preapproved job plans are automatically attached for frequent/standard work orders. These preapproved job plans are selected by utilizing historic data that helps determine the most optimal job plans for each task.

Electronic Work Permit is requested by the labor, and the approval process is initiated within Maximo after which the permit is sent to the requester. Maximo searches the KNPC's HSE training database to automatically verify the laborer's qualifications and certifications before issuing the permit.

After task completion, the laborer uploads all of his/her logs into Maximo. This is used for future tasks, analytics, and labor/material consumption.

Complete utilization

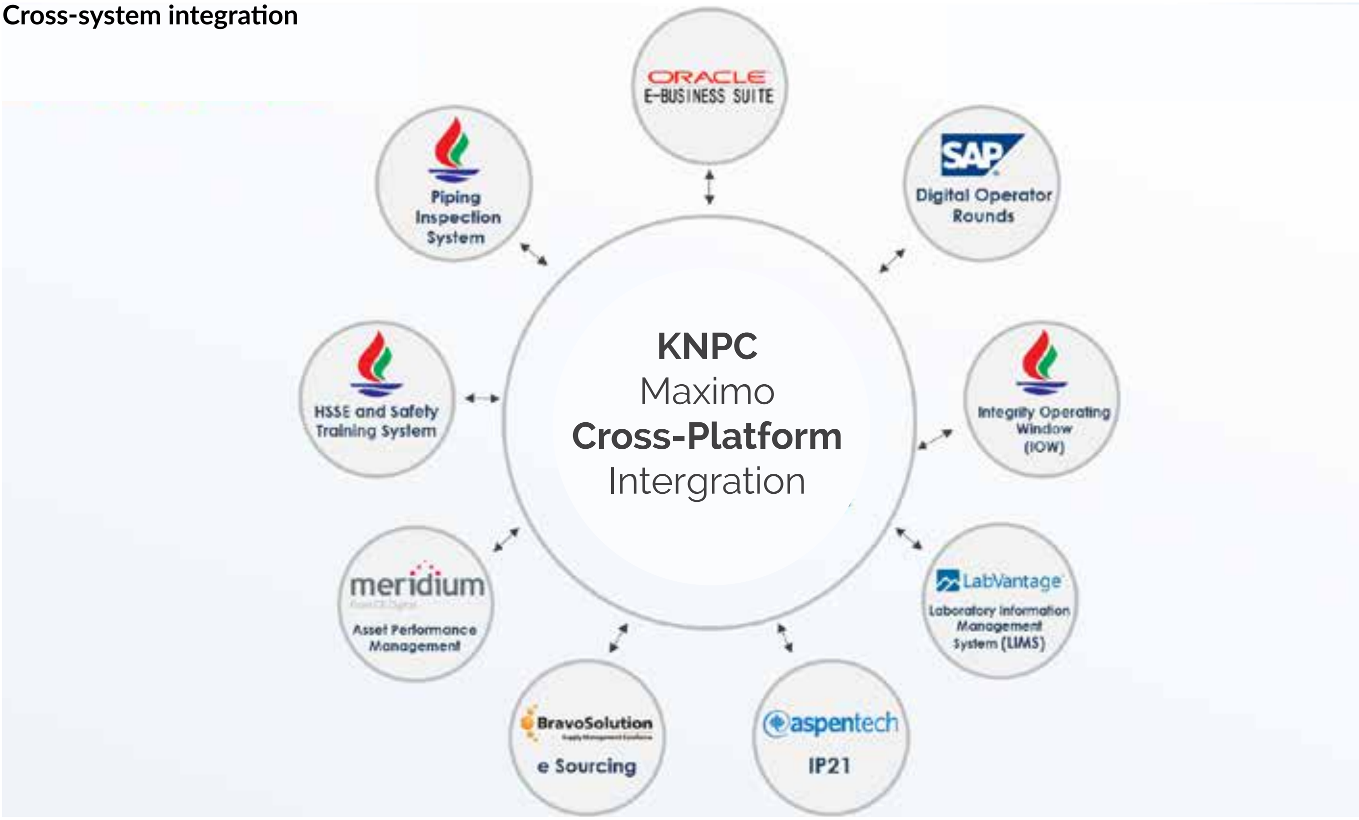


Aspects of every module utilized by KNPC

The KNPC utilizes cross-platform integration with various in-house and 3rd party systems as seen in the figure below.

These cross-platform capabilities offer mutual benefits to Maximo and the already existing systems within KNPC.

Cross-system integration



KNPC maximo utilization

WORK ORDER TRACKING	PERMIT TO WORK	PURCHASE ORDER
8,201,759	1,079,206	270,306
ASSETS TRACKING	APPROVED VENDORS & CONTRACTORS	DESKTOP REUISITIONS (DTR)
493,114	19,668	238,562
ITEMS MASTER	INVOICES	CONTRACTS
340,158	335,503	8,723

Number of Work Orders, Permits, Assets, Contracts etc. registered within the system since it went live

Improvements gained by utilizing maximo within KNPC

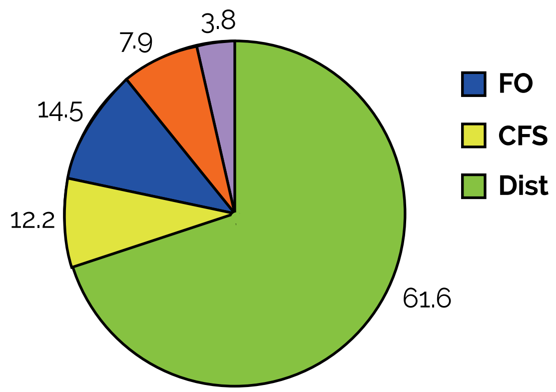
Prior to Maximo, PM/CM was at a negative ratio (Preventative Maintenance was lower than Corrective Maintenance). The preventative Maintenance became larger after Maximo, which is how it should be. Preventative Maintenance should always be higher than corrective.

MAB Quarterly Newsletter

Prepared by: Operational Planning Team-MAB

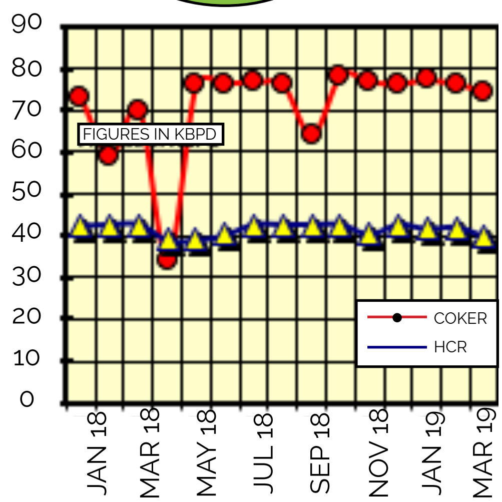
MAB performance

Mina Abdullah Refinery (MAB) operated satisfactorily during the quarter with Refinery / process utilization in Quartile 1. The crude throughput was 271.6 mbpd during the quarter. Whereas, the HCR-14 operated at average feed-rate of 41.0 mbpd with Coker Gasoil (CGO) processing @ 2-3 mbpd as per Profit Improvement Program (PIP). The ARDS-12 operated at average feed-rate of 83.8 mbpd and the Coker operated at average feed-rate of 76.1 mbpd.

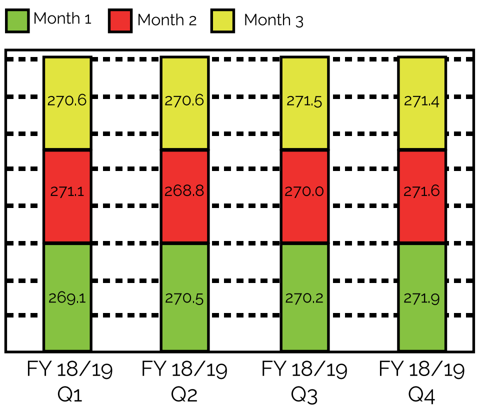


Highlights

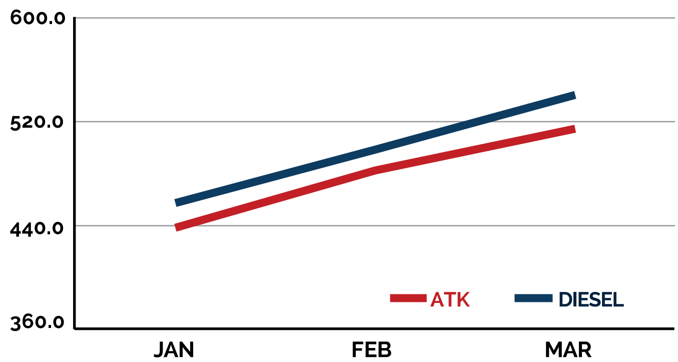
The Quality give away was US$ 0.15 million only (Actual) vs US$ 3 million (Budget). The RCD-02 shutdown was carried out for inspection of tower thickness.
It is worth mentioning that the implementation of PIP ideas resulted in total gain of US$ 9.8 million for the quarter; whereas, the CGO processing in HCR -14 resulted in economic benefit of US$ 2.9 million. The High Sulfur Acid Residue (HSAR) processing in Vac-13 Tr-I Unit as per PIP opportunity to enhance Conversion Feedstock (CFS) resulted in a total benefits US$ 3.0 million.



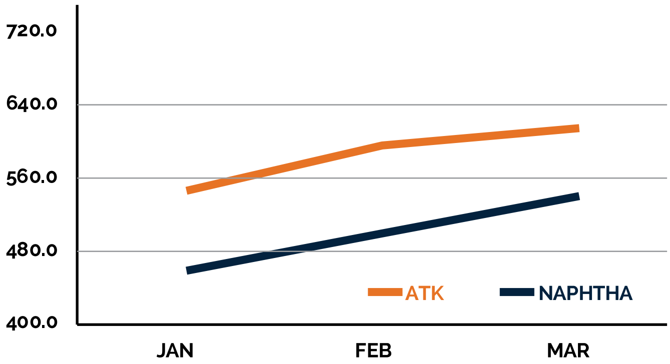
Crude TPut Last 4 quarters



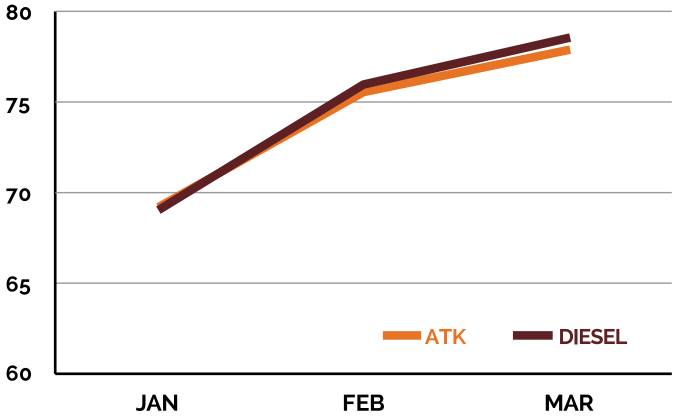
Price in US$/TON



Price in US$/MT



Price in US$/Bbl



Latest prices

The Crude prices were in range from US$ 51 – 68 per barrel during the quarter. The LPG prices were lower than Naphtha for the quarter at average US$ 20.8 per ton. The Crude oil world demand is expected to be in the range of 100 Million bpd, with expected growth of 1.4 mmbpd compared to the previous year.

It is notable that the oil prices are on a rising trend as Brent reached US$ 67 per barrel in March 2019, mainly due to better market fundamentals. Due to high availability of sweet grades, the Sweet Sour differential lowered globally.

However, the 500 ppm Diesel was higher than ATK at average price of US$ 0.3 per barrel. The Fuel Oil prices ranged between US$ 310 to US$ 427 per ton during the quarter.

The Gasoline cracks were up in USA/Europe/Asia due to higher demand. But the Jet cracks were down in USA/Europe/Asia due to lower demand.
The Diesel cracks were lower in USA/Europe/Asia markets due to lower demand. Similarly, the Fuel Oil cracks were down globally due to the same reason. Refinery utilization were 84.4 %, 83.7 % & 77.7% in USA, Europe & Asia respectively.

SOLOMON results – MAB Q4

Q4 2018	Quartile
Refinery Utilization %	87.5 1
Process Utilization %	92.1 1
Energy Intensity Index (EII)	85.2 2
Operational availability	96.1 2
Mechanical availability	96.6 2

Performance Update

Jan–Mar 2019		
Crude thruput	271.6	KBPCD
Distillate yield	61.6	Wt%
Fuel Oil	14.5	Wt%
EII	85.2	
Ref Utilization	87.5%	
Conversion units utilization	96.8%	

MAB Refinery Gears-up for New IMO Regulations
(Bunker Fuel Oil 0.5 % S)

International Maritime Organization (IMO) has mandated revised regulations related to bunker fuel by specifying Bunker Fuel Oil Sulfur as "0.5 wt %" maximum starting in year 2020.

Nawal Al-Badou,
Team Leader, Operational Planning - MAB

KNPC, being a responsible refiner, is gearing up to meet the new IMO regulations to save the earth. Accordingly, and in order to meet the above challenge, Mina Abdulla Refinery has taken requisite measures by reviewing all in-house resources, available blend streams, units' operations after forming dedicated task-force and initiating modifications requirements on a fast track basis.

Consequently, MAB feels proud in projecting its readiness plans for Bunker Fuel Oil production (BFO 0.5 % Sulfur), and is quite hopeful to commence above grade BFO per plan in 2020 based on latest outlook / CFP commissioning schedule thereby adding another jewel in the crown to its illustrious tally of accomplishments.

IMO measures cover all aspects of international shipping – including ship design, construction, equipment, staffing, operation and disposal – to ensure that this vital sector remains safe, environmentally sound, energy efficient and secure.

IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and prevention of marine and atmospheric pollution by ships.

A new scene, big challenges

The world shipping industry is getting on a new scene. In a milestone decision for world environment, January 1st, 2020 has been set as the date for implementing a substantial cut in sulfur content of the fuel oil used by ships. As of this date, the sulfur content of fuel oil shall not exceed 0.5 % instead of the current 3.5 %. A significant cut with multiple implications.

The new limits are set by the International Convention for the Prevention of Pollution from Ships (MARPOL), which is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. According to IMO, the reduction in sulfur oxide

emissions resulting from the lower global sulfur limit is expected to have a significant beneficial impact on the environment and on human health, particularly that of people living in port cities and coastal communities, beyond the existing emission control areas.

To comply with the new regulations, the Ship-owners do not have many options. The time left to change their engines to use low-sulfur fuel oil is very short. Until a permanent and commercially sustainable solution is adopted, they may resort to the exhaust gas cleaning systems (scrubbers) which clean the emissions before release into the atmosphere.

As well, low-sulfur fuel oil, gas oil or LNG can be used. LNG as bunker fuel needs new storage space, supply chain logistics and worldwide LNG bunker infrastructure. Ships need also to be retrofitted to burn LNG, another complex operation that require modification of existing engines, and related piping systems.

Each option, however, has its own setbacks, but all require high and quick investment.

Massive pressure

In turn, the oil refineries will be put under massive pressure. They need to change today's normal utilization rates to produce the required volumes of low sulfur fuel oil or gas oil. They are making quick modifications to their configuration and production to meet the new demand. This is a major product shift of a global scale being required from refiners over such a very short space of time. Whatever decision they may take, a huge investment is urgently required to solve this complex problem.

High sulfur fuel oil is a natural by-product of the limited cracking capacity; and the refiners will be left wondering what they will do with the surplus production.

Whatever option selected, refiners and ship-owners are facing tough challenges. The new refining units of our big national project, CFP, gives KNPC a giant step ahead of other refiners. By 2020, KNPC shall produce ultra-low sulfur fuel oil to meet IMO new regulations.

Ship Loading Operations at Mina Al-Ahmadi Refinery

Kuwait Petroleum Corporation (KPC) contracts with customers on long-term basis for cargo supply. Major part of the cargo sale is done through advance contractual agreements; whereas the remaining part is kept on contingency basis (i.e. unplanned shutdowns, customer requirements, etc..).

Khaled Al-Ajmi
Team Leader, Operations - MAA

Operating plans

Based on the contract agreements, the product demand is issued for various plans (Five year, Budget, Mid Term Operating Plan and Net Inventory Forecast). The Manufacturing Optimization Group and Corporate Planning Department of KNPC provide the Mid Term Operating Plan for KPC to finalize the sale agreements regarding quantity, duration and other. Moreover, KPC arranges the schedule of cargo for the next six months with ship nominations.

KNPC- MAA Operations Planning Team issues daily plans (based on KPC weekly supply plan and MAA units condition) to Tanks and Terminal (Operations Area 08) that includes details about cargo quantity receipt from different units to storage tanks, blending ratios, sampling, ship berthing details, contractual quantity, product specifications, supply header, supplying tanks, berthing terminals.

Tanks and terminal

The Tanks and Terminal (Operations Area 08) plays a major role for cargo readiness and dispatch according to broad planning of KPC through MAA Operations Planning Division with performance of specialized operations, such as:

Receipt & blending

Outlet streams from various refining units are diverted to storage tanks through blenders as per MAA-Operations Planning instructions. Blending operation is basically to meet client and international specifications, and thereby adding significant value to their business. Products like Gasoline and fuel oil blending require professionals with an intimate knowledge of petroleum chemistry, ship loading systems, terminal tankage, pumps and pipelines. Blending facility in MAA refinery provided to produce finished products like MOGAS (UL-91/95/98), PCNA, ATK/JP-8/JA-1, GASOIL, Low Sulfur Fuel Oil (LSFO), Light Fuel Oil (LFO), Heavy Fuel Oil (HFO) .

Sampling

Once product receipt is completed in storage tanks, sampling is performed to draw a representative sample of tank content by highly trained third party sampling specialists. Industry approved methods, including ASTM, API and other relevant standards, are utilized while samples are extracted from the storage tanks.

Analysis and certification

The process of analysis and certification is performed to analyze concentrations of hydrocarbon compounds using the up-to-date and cutting-edge techniques, and a detailed composition information is produced on the molecular and elemental components of the final refined product. Independent verification and certification of the products quality are carried out by a well renowned third party inspectorate. This demonstrates our commitment to quality to both clients and stakeholders. Post cargo readiness in storage tanks - Berth line sampling, is carried out by the Inspectorate to ensure berth readiness as per customer product specifications. Once particular berth is ready, the Harbor Master – KOC, is informed to berth the ship.

Ship berthing

Berthing of vessel is a specialized job involving the use of several equipment. As the ship's staff is not familiar with the local meteorology and port topography, then the services of an expert (Pilot) is provided by KOC on behalf of KNPC-MAA. The Pilot has to take into account various factors, such as vessel size, vessel displacement, wind speed and directions, water currents, fender capacity, state of the ship's trim, draft and freeboard, the ship's equipment and maneuvering aides, condition of the berth, mooring arrangement (including length of lines, certified bollard strength), tugs rating, etc.. while berthing of the ship. As the maneuver proceeds, the berthing plan, devised by the Pilot, remains flexible with an alternate plans in mind in anticipation of any change in the circumstances. As the ship approaches the berth, the Pilot plans to bring the ship parallel to the berth and stops just short of the berthing position, clear of the forward and aft ships (if there are any). Once the ship is all stopped off the berth, the Pilot uses the assistance of the tugs and thrusters (a secondary jet/propeller on a ship used for accurate maneuvering) to get the vessel in position. He asks the officers in charge of the mooring stations forward and aft to send the spring lines first. The spring lines keep the vessel from moving forward and aft. Then the headlines/stern lines are sent. Once all the lines are made fast, all the winches are usually put to 40% auto tension (most common), and the springs are kept on brake. Generally, ships are fitted with various instruments such as the conning display, voyage management system etc. to indicate whether the ship is moving ahead or astern. The ship's speed and the amount of set and drift is indicated as the ship makes sideways. Once the ship is berthed, quarantine and custom clearance for the ship are carried out, followed by an opening meeting between ship and shore operating personnel.

Cargo loading to ship

Once the ship is berthed and ready in all aspects, an opening meeting is carried out between shore and ship operating personnel to discuss in detail the cargo loading procedures. Once an agreements is reached about minimum & maximum discharge/receipt cargo flow rate, temperature, pressure, top up rate, ramp up, ramp down details, emergency scenarios & actions, communication details, ship un-berthing plans, ballasting, etc., the loading arm connection is carried out in co-ordination with ship staff as per standard operating procedure. The loading arms installed at MAA-refinery are Rotating Counter weighted Marine type Arm (RCMA) and is equipped with a vertical riser base assembly supporting the arm, counter weights, purging connection, power emergency release system (PERC) with double ball valve assembly, multi-flange quick connect / disconnect coupler (QCDC) etc.

Ship tank inspection

Ship tank inspection and shore tank gauging shall be carried out by the third party inspectorate with KNPC-MAA officials before loading start up and final clearance is given to control room operator to line up the system for loading start up by gravity. Once cargo loading by gravity transfer is confirmed by the ship, the clearance for pump start up is given. Number of pumps to be started depends upon agreed flow rate. The pressure at the inlet of the loading arm is continuously monitored for the desired range to make sure that the loading operation is under control. However, various interlocks and safety logics are provided to take care of loading operations and self-shutdown of system in case of abnormal conditions of any reason. Hourly reconciliation is carried out by ship and shore quantity to ensure cargo is being transferred at intended destination. As the loading nears the agreed contractual quantity, the loading rate is reduced to top up rate (as agreed before) for smooth and safe stoppage of loading operation. Auto Sampling facility is provided for each product at loading berth itself. During the course of loading, a sample on intermittent basis is taken from loading lines. At the end of loading, the sample CAN shall be sent to Laboratory for relative density analysis that is used for final cargo quantification.

Quantification & ship un-berthing

Shore and Ship tank manual gauging is performed by inspectorate for quantity finalization. Once initial clearance is given for quantification, loading arms draining and disconnection is carried out by shore operating staff. Metering skids are also provided on berths for accurate quantification of cargo dispatched. They are designed in accordance with the requirements of the API Manual of Petroleum Measurement Standards. Each stream of skid is fitted with a PD Meter (Positive Displacement) as the primary device. The downstream pressure and temperature measurements are taken allowing the flow computer to make on-line correction for changes in process conditions. At the end of loading, metering skid batch report is generated based on final relative density (through auto sampler) by control room operator as a reference for accurate quantification. Once quantification formalities are completed, the Ship Un-berthing is proceeded by KOC-Harbor master on behalf of KNPC in co-ordination with the ship staff.


ORIENTAL GREEN

Transport In Transition

The Rise of the Electric Vehicles

Changes are sweeping through the automotive industry. Environmental awareness and public concern towards global warning and carbon emissions are resulting in more people reverting to the electric vehicles (EVs). Technology advances in batteries, communication networks, sensors and machines are pulling timelines forward in a way that would have seemed impossible just a few years ago. Government plans are already set to boost this trend to increase the number of EVs on the roads.

Naila Baqer
Team Leader Market Research

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Market Research

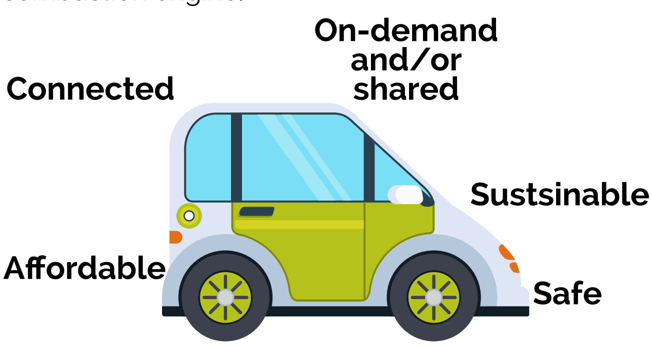
Uptrend

By the end of 2018, the number of combustion engine cars sold is estimated to be around 81.5 million units. While the market for EVs continues to gain momentum, EVs account for just %1 of global light vehicle sales at present despite them surpassing one million units in 2017, representing a growth in new electric car sales of 54% compared with 2016.

In countries with restricted oil production, switching to EV cars was justified as not relying on imported oil and they produce less emissions and less noise. However, EVs are expensive and the infrastructure for recharge is neither easily available nor accessible.

Currently, EVs present one of the largest uncertainties facing global commodity markets.

Rapidly changing EVs economics and technological innovations will always be disrupting oil. They are starting to challenge the supremacy of the internal combustion engine.



Although representing a small share of the market today, global EV sales are expected to accelerate rapidly over the next 20 years with some European countries reaching close to 100% of incremental sales by 2040.

EVs future success depends on further declines in battery costs and continued government support through legislations on emissions and providing governmental subsidies. With battery costs falling, EVs are forecasted to capture 13% of global passenger car vehicle sales by 2035. By 2040, battery costs are forecasted to be five times cheaper than today, making EVs competitive across all car market segments. This means that EVs will become an actual threat nearing 2040.

Electrification of other transport modes is also developing quickly, especially for two-wheelers and buses. In 2017, sales of electric buses were about 100,000 and sales of two-wheelers are estimated at 30 million; for both modes, the vast majority was in China.

EVs impact on the oil market

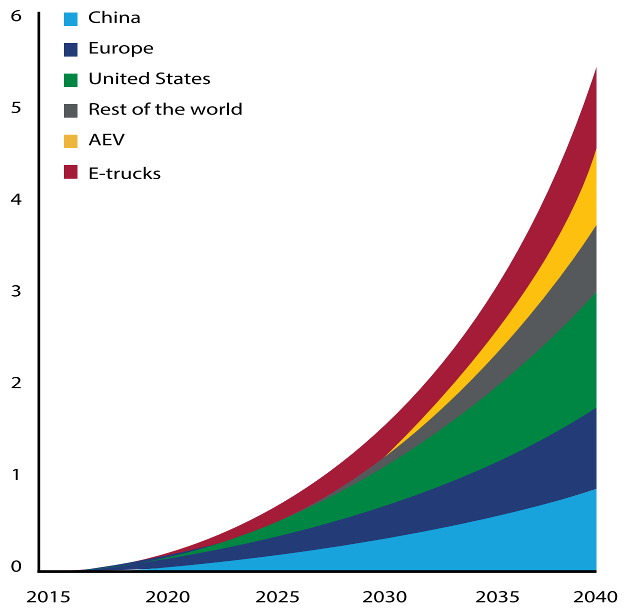
EV is one of the most important factors that will shape oil markets long term.

By 2035, EVs are forecasted to displace 1.6 mmbpd of oil demand (about 6% of global gasoline demand). By 2040, they are expected to displace almost 5.5 mmbpd of gasoline and diesel demand. Much of this will be in China, Europe and the US. Around 1 in 9 cars sold globally will be electrified, bringing the total EV fleet to 280 million with a total car fleet of 2.5 billion cars in 2040.

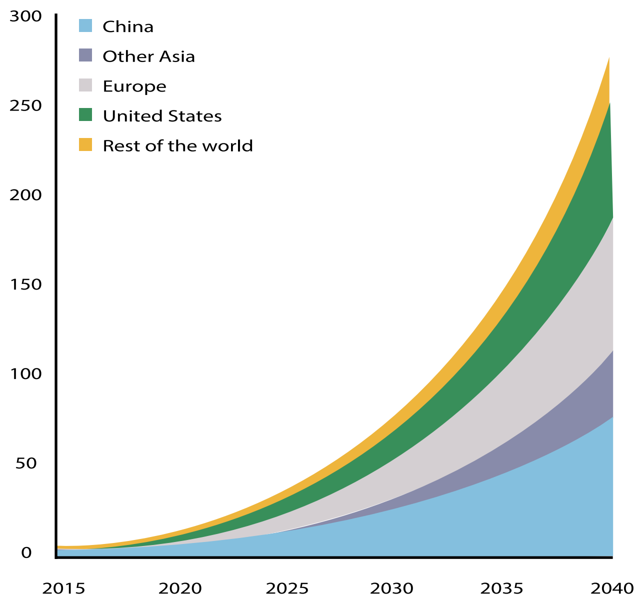
The greatest impact will be in the US, mainly due to higher miles travelled versus China and Europe. And since the US is the largest market for gasoline demand, the US gasoline market will be the highest affected by Evs.

EVs will be globally distributed in the following regions and mainly dominated by; Europe (80 million), China (77 million), and the US (71 million).

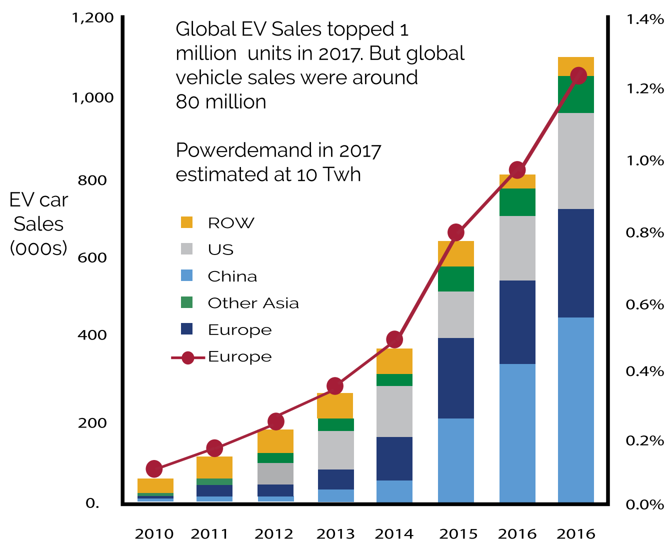
Global oil demand displaced by Evs



Global electric vehicle stock



Global EV sales by region (2010-2017)



China indirectly controls EV Market

Not only is China the site where many of the essential parts are manufactured, China's government aims to have 5 million electric vehicles on the road by 2020, which is both aggressive and optimistic as well allowing car companies to avoid the hefty tariffs currently imposed on electric vehicles, it's also home to the world's biggest market for electric cars. China already accounts for about half of electric vehicle sales worldwide, and these numbers will only continue to grow.

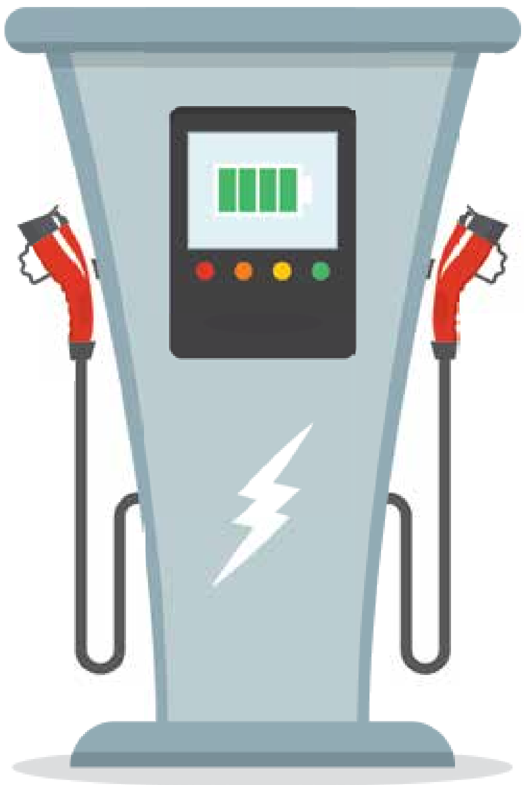
Last year the Chinese government released a "road map" that shows a plan to replace at least one-fifth of new car sales with alternative fuel vehicles by 2025. The European Union (EU) is now trying to make the continent a more attractive place for both makers and buyers of electric vehicles. This year the European Commission released an action plan that aims to foster heavier investing in battery technologies on European soil by offering more funding, among other incentives.

Conclusion

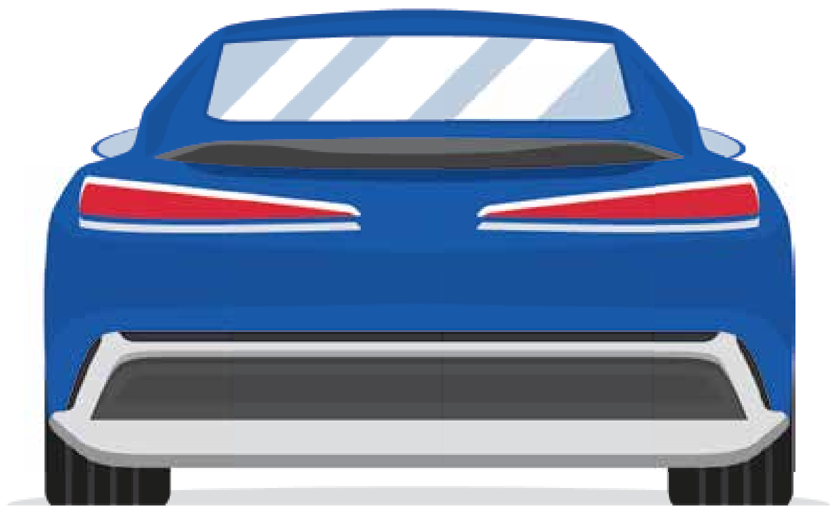
Although EVs for road transport boost energy efficiency, require no direct fuel combustion, rely on electricity and have substantial potential to enhance economic and industrial competitiveness and to attract investment; it requires a considerable amount of infrastructure, especially in remote and rural areas like mountains, forests, etc.

Manufacturers of EVs are currently subsidized; but how long will governments keep on subsidizing manufacturers? And will each region/ country agree on a specific year to stop the subsidies or will they to prices and demand once manufacturers are no longer subsidized?

We cannot dismiss EVs as a threat to oil demand, but if carefully planned, oil-producing countries can minimize the speed of the decline on oil demand from this sector.



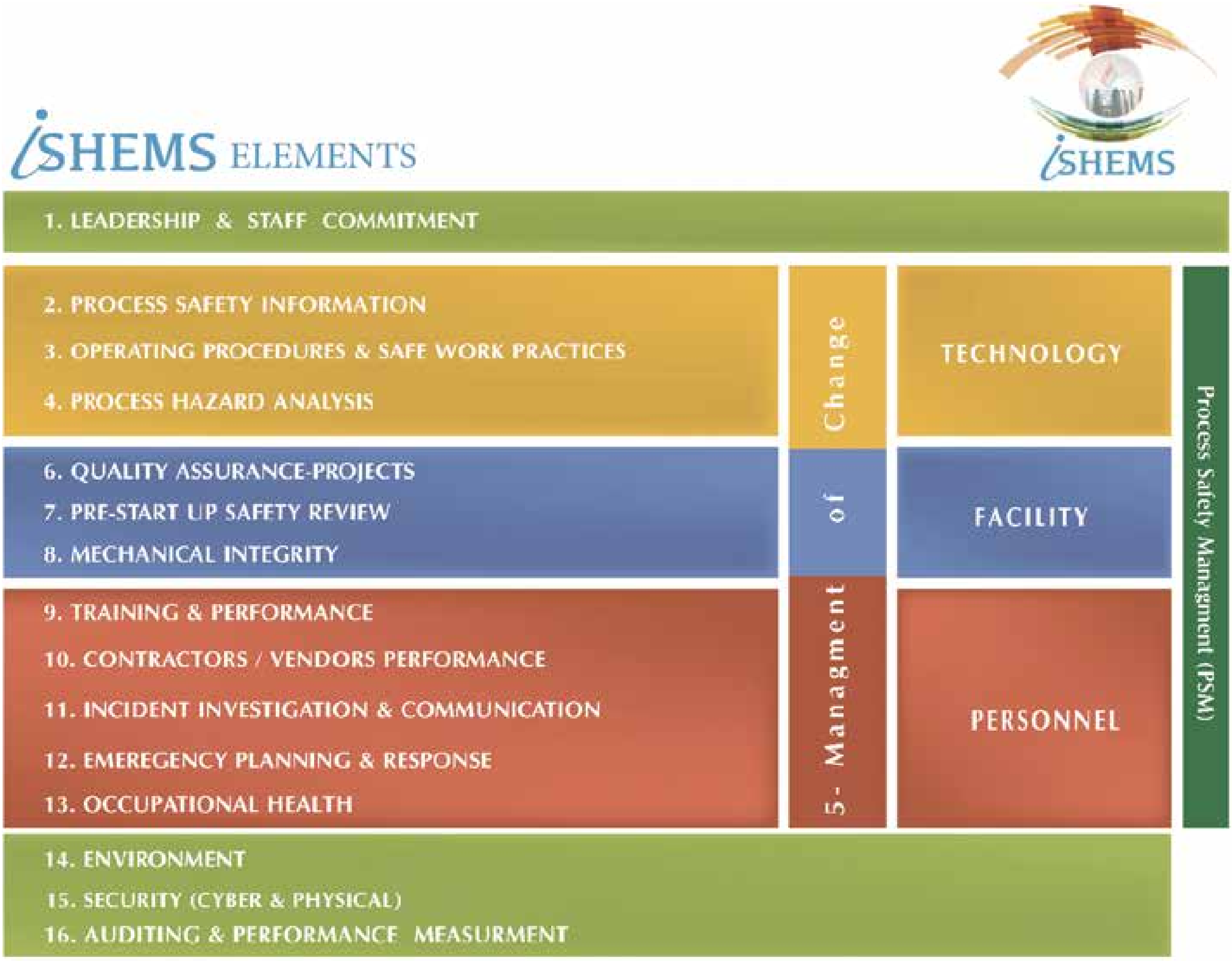
CHARGING STATION



Premature Failure of FCC SWT Stripper Overhead Piping in Ammonium Bisulfide Environment

PSM & Mechanical Integrity
KNPC Process Safety Management Consists of sixteen key Elements. The eighth element is related to the Mechanical Integrity, which emphasises on the Predictive, Preventive, and Deficiency Elimination to maintain reliable and safe operations.
This text outlines how Root-Cause Analysis (RCA) and Failure Investigation Study (FIS) can provide a corrective action for more reliable and safe operating environment.

Mohammad Al-Masilit
Corrosion Engineer - MAA



Introduction

The Sour Water Treatment of Fluid Catalyst Cracker Unit (FCC SWT # 195) was commissioned in Dec 2015 to treat sour water from FCC unit # 86.

Barely after one and ½ years of service, frequent leaks were observed in overhead condenser (E-195-103) outlet piping. Then Several Other leaks were observed leading to the full replacement of the line in April 2018, followed by an investigation of the failure. The case study of the premature failure of FCC SWT Unit stripper overhead piping in Mina-Alahmadi Refinery (MAA) gives a good example about a corrective action which has been taken based on the failure analysis results and the industry's best practice. Specimens of the failed piping were collected to conduct the failure Investigation.

This study provides an excellent example where knowledge and methodology have been applied effectively for the assessment of this type of failures.

Plant description

The Unit receives the sour water from FCC Unit and produces treated sour water with less than 20 ppm of Ammonia and less than 10 ppm of H_2S. The Unit feed capacity is around 200 gallons per minute.

The separated acid gas at the accumulator is routed to the Sulfur Recovery Unit, and water is Reflux to the Stripper. The downstream of AFCs piping (SS304L) was found severely corroded and developed several leaks.
For The Sour Water Stripper Overhead System, it starts with the vapors at the top of the stripper where it is cooled and condensed in Titanium air fin-fanned coolers. The produced two-phase flow at the outlet of the cooler consists of acid gas and saturated sour water.

At the overhead accumulator, the acid gas is separated and routed to the sulfur recovery unit; whereas, the sour water is pumped back to the stripper as a Reflux. All leaks were located in the air fin-fanned coolers austenitic stainless steel (SS304) outlet piping.

Date	Observation	Location on Sketch
Jul. 2017	First leak on the 3" elbow	37
Oct. 2017	Other 3" elbow leaked	28
Dec. 2017	Pinhole on 5"below	72
Feb. 2018	Multiple locations leaked: - 6" elbow - Multiple locations 3' elbow Ut Scanning on the line indicate 30%-385% loss of thickness in several locations	60 10, 11, 13, 38
Apr. 2018	The line was fully replaced in kind in view of several leaks/clamps. Failure investigation was taken up.	

Process analysis

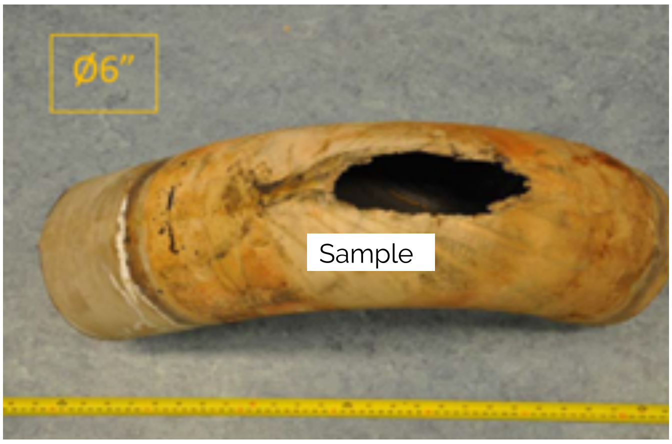
The investigation process included visual examination, checking the chemical composition of the specimens, applying Non-Destructive Test (NDT) ultrasonic scanning techniques, examination of the micro-structure by optical microscopy analysis, scanning of electron microscopic examination, energy dispersive spectrometry examination and process parameters analysis.

The following testing, examination and data analysis have been utilized as Inputs in the study:

Visual examination

Specimens collected from the failed piping.

We can see a 3" vertical section that was Connected directly with the Finned-Fan Cooler outlet. It experienced a severe thinning causing perforation



Here, we can see a 6" Elbow having a significant perforation in the bottom section

Chemical composition

The Optical Emission Spectrometer (OES) method was used. The results are conformant with the design requirement of the 304L.

Material composition results by OES (wt. %)

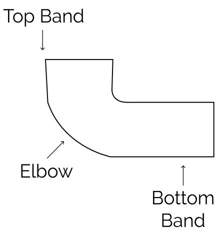
C	Cr	NI	Mo	Mn	P	S	SI	Fe
0.014	18.30	8.66	0.12	1.26	0.020	0.002	0.29	Bal.

Testing of the chemical composition of the metal indicates a typical Austenitic stainless steel Grad 304 with no significant changes.

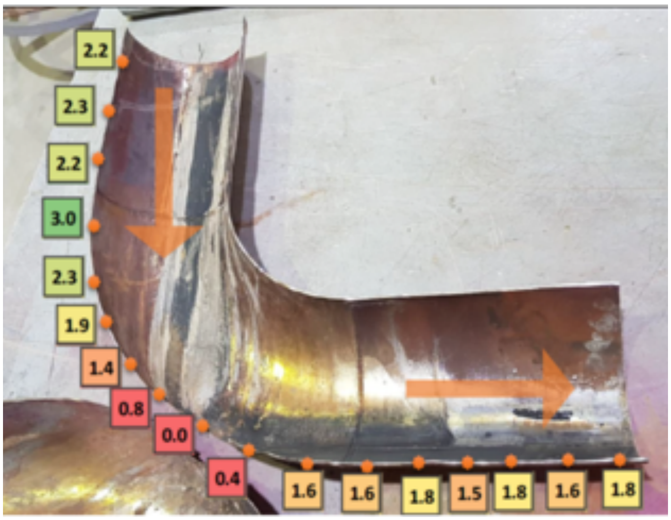
NDT ultrasonic scanning

Full Ultrasonic scanning survey was conducted on 4" Elbows with nominal thickness of 3.05 mm. In the 4" Elbow, indication of sever thinning at the Bottom section and the elbow downstream. In addition, it illustrates how thinning starts after the weld joint where turbulence can occur.

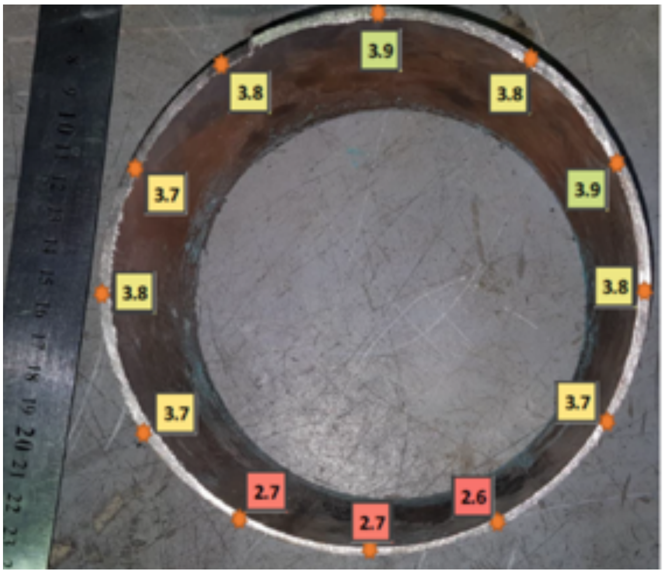
	Top		Side			Bottom			Side			Top
	12	1	2	3	4	5	6	7	8	9	10	11
Top Band	2.0	1.8	2.1	2.0	1.7	1.5	1.8	1.9	2.0	2.1	2.0	2.0
Elbow	3.0	2.8	2.6	2.4	1.6	1.5	1.7	2.3	2.8	3.0	3.1	2.7
	3.1	2.9	2.4	2.2	1.5	1.2	1.1	1.7	2.4	2.9	3.5	3.6
	3.4	2.6	2.3	1.8	1.2	1.4	1.5	1.7	2.3	2.4	3.4	3.4
	3.3	2.8	2.5	1.8	1.3	1.2	1.5	1.5	2.3	2.9	3.0	3.4
	3.1	2.8	2.5	1.8	1.3	1.2	1.5	1.5	2.3	2.4	3.0	3.4
Bottoom Band	2.3	2.3	2.5	2.0	1.6	0.0	0.0	1.8	1.8	2.4	2.3	2.3
	2.4	2.2	2.0	1.8	1.4	1.8	1.6	1.6	2.0	2.2	2.3	2.2
	2.6	2.2	1.9	1.8	1.7	1.6	1.6	1.6	2.1	2.2	2.4	2.4
	2.7	2.5	2.3	2.0	1.4	1.5	1.6	1.6	2.1	2.3	2.6	2.7
	2.7	2.5	2.3	2.0	1.7	1.7	1.9	1.9	2.1	2.5	2.6	2.7
	2.7	2.6	2.4	2.2	1.8	1.9	1.9	1.9	2.1	2.5	2.6	2.7
	2.6	2.7	2.6	2.0	1.8	1.8	1.9	1.9	2.1	2.5	2.7	2.7



3	mm	
2	mm	
1	mm	



Similar Case can be seen in the 6" elbow. A Cross-Sectional illustration with UT Data on the 6 O'clock Position. Nominal thickness is 3.40 mm.



US scanning of coupon from a straight horizontal 6" pipe section with nominal thickness of 3.40 mm. This coupon was obtained from a horizontal straight section. It indicates a relatively severe thinning at the 5, 6 and 7 O>clock positions in the liquid phase region compared to the top section of the gas region.

Corrosion rate calculations

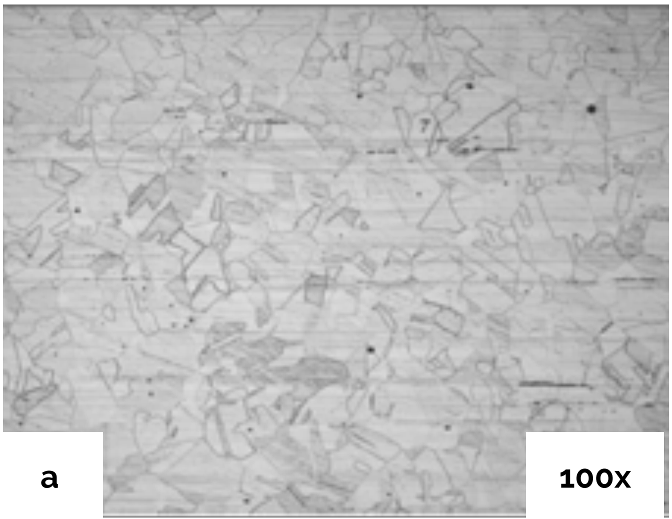
Based on Corrosion Rate calculations, we can find the most severe thinning in elbows with corrosion rate of almost 100 mills per year. Moderate severities are found in the vertical segments and elbows downstream, with relatively less severe corrosion rate in the horizontal straight Sections.

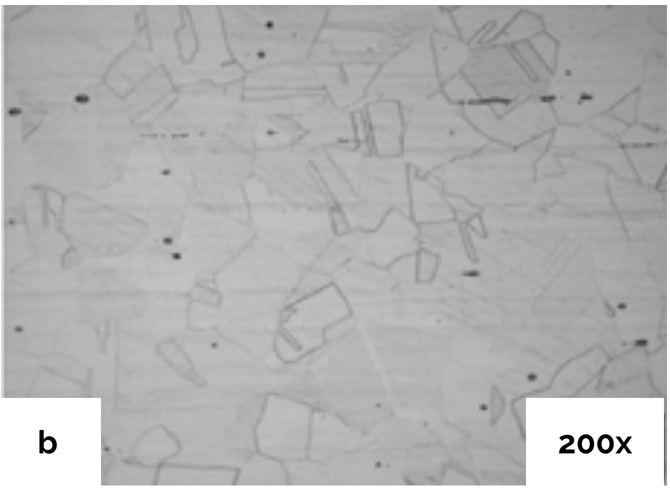
Corrosion Rates for different segments of the Line:

Description of SS304 line Segments	Corrosion Rate mm/y (mpy)
3" Section (Elbows)	2.4 (95)
4" Section (Elbows)	1.7 (68)
6" Elbows	2.1 (86)
6" Straight segment (Vertical)	1.4 (56)
6" Straight segment (Horizontal near elbow)	1.1 (45)
6" Straight segment (Horizontal away from elbow)	0.75 (30)

Optical microscopy analysis

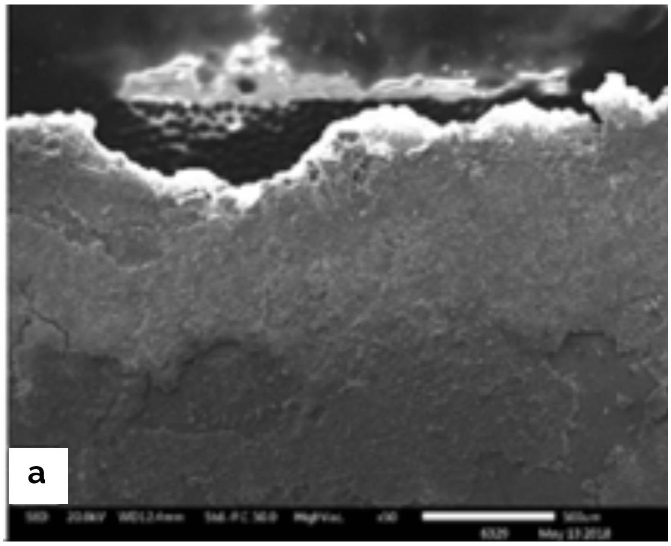
Typical austenitic stainless steel SS304 solution annealed. The optical microscope shows a typical Austenitic stainless steel grad 304 with solution annealing with no significant changes.



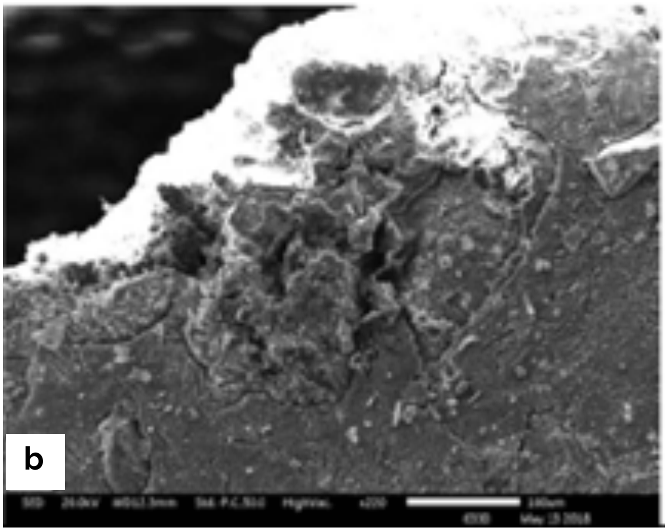


SEM & EDS Examination

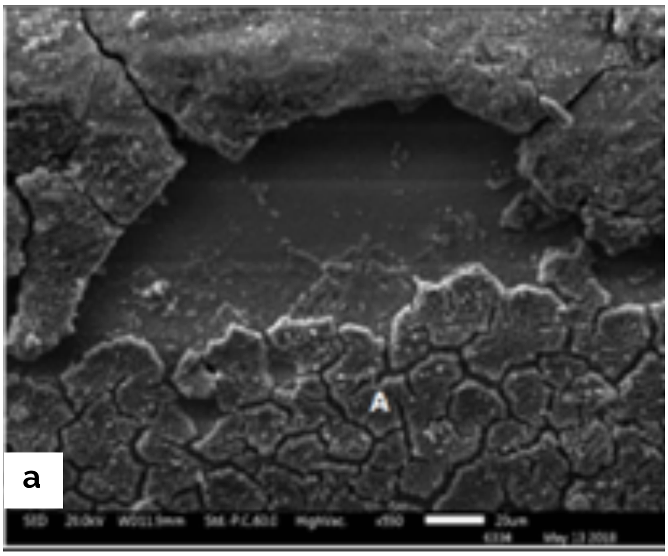
A specimen taken from a 6" elbow near the perforation location



SEM of the internal surface of 6" elbow near the perforation x50

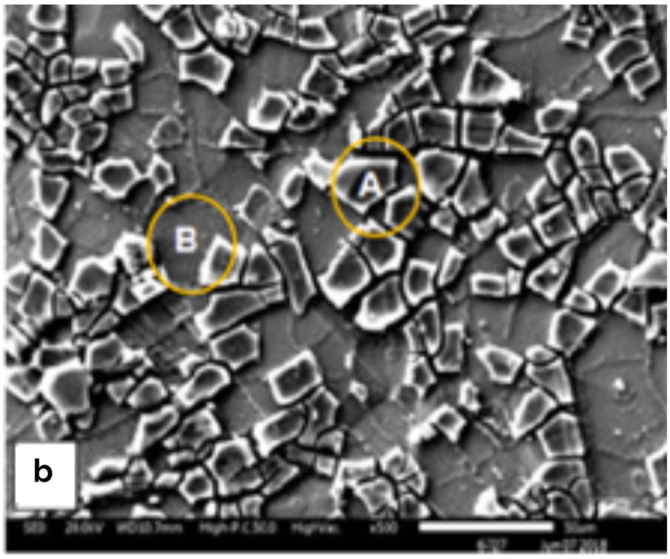


SEM of the internal surface of 6" elbow near the perforation x220



SEM of the internal surface of 6" elbow x550

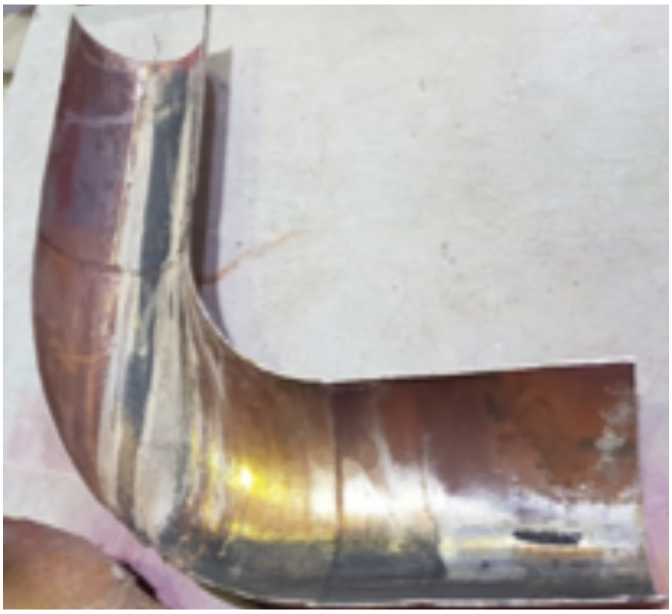
An electron microscopy scanning and energy dispersion spectroscopy were conducted on the failed specimens. At high magnification using the scanning electron microscope, an evidence of scale removal could be detected. Other locations with the bare metal exposed by the scales removal can be seen.



SEM of the internal surface of 3" piping near the condenser outlet x550.

Discussion

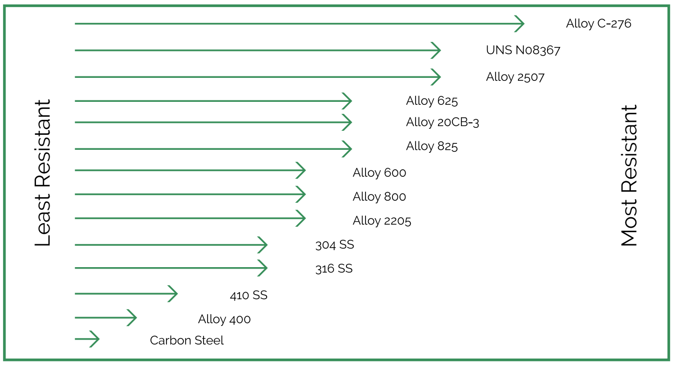
The morphology of the failure attributes to flow assisted corrosion (impingement and erosion-corrosion).



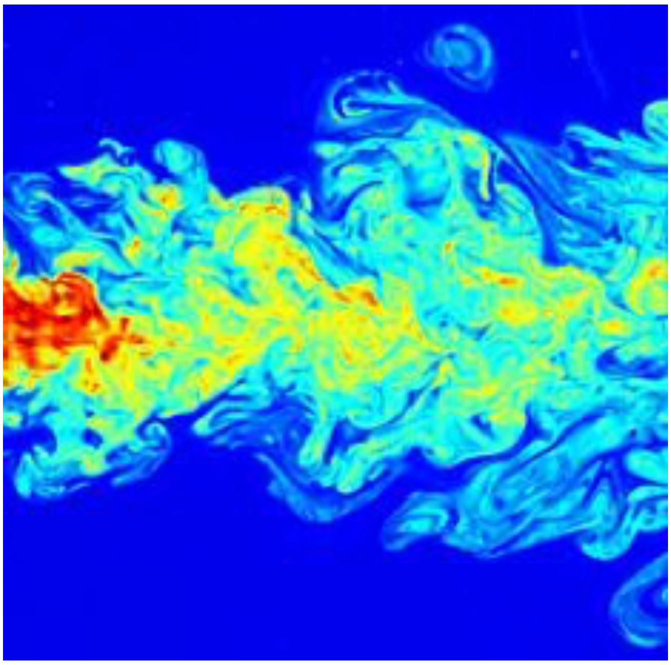
After the intensive testing, examination and analysis, it was found that the morphology of the failed piping can be attributed to flow assisted corrosion by Ammonium Bisulfide. Where the sulfide scales formed on the metal that are usually passive, were removed by erosion-corrosion exposing the bare metal causing accelerated thickness reduction.

In these conditions, the sulfide layer produced on the surface of the metal is porous/flaky and non-protective that can be easily detached.

Metallurgy



The resistance of austenitic stainless steel is relatively high to ammonium bisulfide, yet it has its limitations.



Factors

The Limitation of the usage of Austenitic stainless steel in Ammonium Bisulfide environment can be summarized in three factors. The three factors are found to be the case in our operating unit:

- First, the high velocity and turbulence that were caused by the Two-Phase Flow.
- Secondly, the high concentration of Ammonia and H2S in the Acid Gas causing the liquid phase to be saturated with Ammonium
- Bisulfide at all temperatures.
- Finally, Contamination of Chloride and Cyanide even in small amounts can accelerate the sulfide layer removal and cause accelerating thickness reduction.

Conclusions

- The failure is attributed to erosion-corrosion
- Most severe corrosion rates are found in flow disruption locations
- Corrosion rates of SS304L in current operating environment was approx. 100 mpy
- The failure of the stripper overhead piping was caused by ammonium bisulfide erosion-corrosion
- The most affected locations are found in regions with high velocity and turbulence like Elbows, Vertical Sections, and Liquid
- Flow impingement With such High Corrosion Rate of 100 Mills per Year Austenitic stain less steel 304 is found to be unreliable for such harsh environment

Recommendations

- Upgrade material to Incoloy 825 with CA = 3.0 mm for all sizes
- The industry's best practices, based on API survey of several cases in different refineries were followed
- An up-gradation of high nickel-alloys are found to be reliable solution for such cases

In this case, Hastelloy C-276 can be the first and best choice material for plant integrity, reliability and safe operation based on life cycle of the piping However, considering material availability, weldability and in-house experience of lncoloy 825 our second best choice It was finalized that Incoloy 825 with Corrosion allowance of 3mm instead of the previous corrosion allowance of 1mm to be the preferred material for up-gradation in our unit.

Application of High Velocity Thermal Spray Coating

Accelerated Amine corrosion of Amine Regeneration Towers in all three trains of Amine Regeneration Unit in Mina Abdullah Refinery (MAB) resulted in reduction of the Inspection Interval from 4 years to 2.5 years.

Even though epoxy coating was applied in affected areas, further extensive repairs and replacements were carried out in every shutdown, thus extending the shutdown duration for these towers. Inspection & Corrosion Division explored the use of Metalspray TM HVTS cladding as an alternative coating material.

Eng. Mohammed Al-Otaibi
MAB

Eng. Abdulrahman Al–Shedouki
MAB

Background

The Amine Regeneration Unit in MAB consists of three parallel trains delivering 1600 GPM of lean amine solution to amine gas absorbers. A by-product of this process is H_2S rich acid gas stream, which is routed to the sulfur plant for recovery of sulfur.

The Amine Regenerator Towers were commissioned in 1988 and are in service for last 22 years. They are subjected to corrosion by hydrogen sulfide and carbon dioxide in vapor phase and amine degradation products.

The history of the towers reveals corrosion in the Carbon Steel middle and bottom sections. The worst affected area of the shell has been replaced with a new CS plate in 2006.

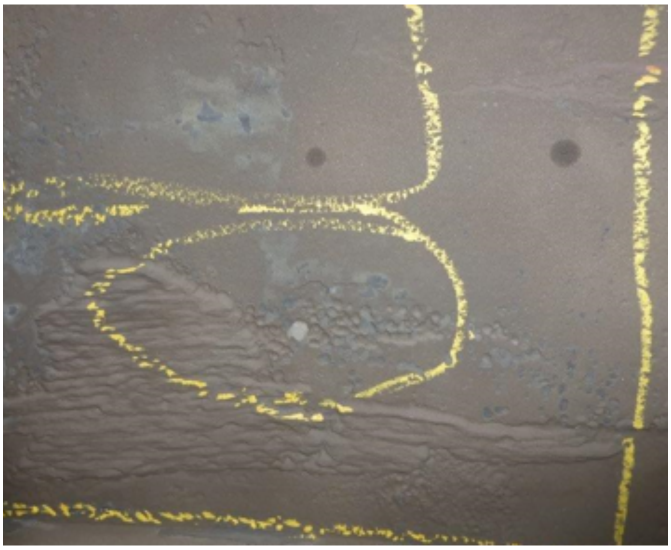
Tower Operating Conditions		Inlet/outlet Operating Conditions
Pressure	22 psig	In : 50 psig
Temperature	266oF	In : 320F
Regenerator Tower components		Metallurgy
Shell & Top section (above Tray #18)		Carbon steel cladded with stainless steel 304
Shell & Top section (below Tray #18)		Carbon steel
Trays		Stainless steel 304

Operating conditions and metallurgy
20 wt. % Mono-ethanolamine is received from the various H_2S removal services

Problem overview

In normal operation, rich amine feed is 3980 GPM at 1520 F. Out of this, 2158 GPM is supplied from ARDS Unit-12. After the ARDS revamp, acid gas loading increased from 0.35 to 0.43 mole/mole. This led to increased localized corrosion characterized by pitting and erosion of the carbon steel sections.
Areas of high corrosion rate are:

- Shell area of carbon steel below the SS clad ding (below tray # 18): The corrosion at this] area is due to flashing of rich MEA
- Shell bottom section: Nozzle N6 feeds vapor to the regenerator tower. Condensation of the vapour at the nozzle caused corrosion of the shell bottom section
- The support bracket for bottom tray seal pan: Corrosion of the carbon steel support bracket was due to galvanic coupling between it and the SS bottom tray.



Localized corrosion characterized by pitting, grooving and erosion

Discussion
Factors affecting amine corrosion:

Type of amine

MEA, DEA and MDEA are the three most popular amines used for acid gas treating. Historically, MEA has the worst reputation for corrosion problems. In Mina Abdullah refinery, MEA is being used for removal of H_2S.

Amine concentration

When amine strength and acid gas loading increases, the corrosivity also increases. High strength amine cannot achieve high mole/mole equilibrium-rich loading like lower strength amine can. This condition can increase the potential for acid gas flashing. In our refinery the concentration of the MEA is maintained between 16 to 20 wt. %.

Acid gas loading

Acid gas loading is measured in terms of moles of acid gas (H_2S) per moles of active MEA. There is a potential for corrosion when acid gas loading is greater than 0.35 mole/mole for rich solutions.

Amine degradation

Reaction of amine with oxygen results in amine degradation products like Heat Stable Amine Salts. An excessive accumulation of HSAS above about 2% wt. can significantly increase corrosion rate.

Temperature

Thermal degradation of amine also occurs when reboiler wall skin temperature is greater than 350oF. Furthermore, acid gas flashing and severe localized corrosion can occur at temperatures above 220oF if the pressure drop is high enough.

Velocity

In the absence of high velocities and turbulence Amine Corrosion is usually uniform. High velocity and turbulence cause acid gas to evolve from solution, resulting in more localized corrosion. Higher velocities and turbulence also disrupt the protective iron sulfide film. For carbon, steel velocity limits are 3 to 6 fps for rich amine.

Principle of thermal spray coating

Thermal spray is an application technique, through which molten material is propelled at high speed onto a cleaned and prepared surface. It solidifies and forms a solid layer on the metal substrate.
The type of material used is NiCrMo thermal spray having a Hastelloy C276 chemistry. The coating applied has a porosity of less than 1% and a bond strength upwards of 25 MP. It is suitable for acidic conditions, wet/dry Sulphur and chlorine containing environments.

Coating process

The internal surface coated was 10 ft below the cladded section, thus covering an area of 401 square feet. The coating was applied to:

- an average thickness of 24.7 mils
- minimum thickness of 14.5 mils
- maximum thickness of 45.4 mils.

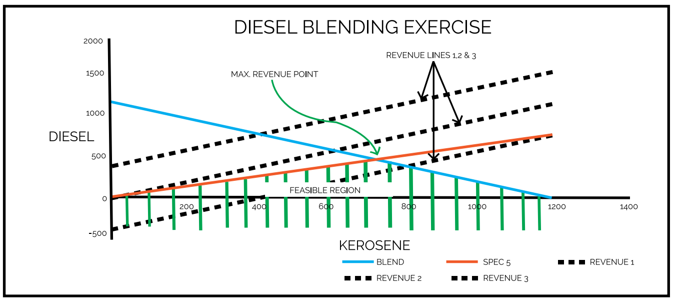
After the HVTS coating was completed, thermal spray sealing was also applied as a final topcoat layer designed to seal off microscopic pathways found in the thermal spray coating. Quality check was carried out by the contractor and witnessed by KNPC Inspection & Corrosion Division as per ITP.

Linear Programming and KNPC Planning

The petroleum refining is very complex where all process units, utilities and off sites are operating together and many products produced at the same time. To prepare a Refinery Operating Plan, a manual mathematical technique can be used as a convenient method to calculate and produce the refinery unit throughputs, mode of operations, utilities and material balance, but this is not a feasible and optimum solution and normally takes a long time (may be couple of days).

Ahmad Ibrahim Hamdoun
Advisor - TPL (Planning)
Manufacturing Optimization Group (MOG)

Linear Programming (LP) is a mathematical optimization technique to produce a feasible and optimum solution for refinery operations within a very short time (may be few minutes, depends mainly on the LP model size). It obtains a feasible and optimum Refinery Operating Plan, together with its driving forces and constraints. This plan used as a target for the actual operation and decision maker to operate the refinery. Accordingly, the LP is the most imported tool for Planning Departments.



1- History of KNPC LP

First KNPC LP Model was developed in 1968 with Shuaiba Refinery start-up on the IBM - 1800.

In 1971 / 1972, KNPC started using the MAGEN – IV LP System prepared by Haverly System Inc.

KNPC Refineries Global Model was developed utilizing OMNI System in the 80's.

In 1992, new KNPC LP Model was developed utilizing PIMS (Process Industry Modeling System).

The Model was upgraded in 2002 using XPIMS.

2- KNPC planning

KNPC planning has been using LP since 1968 for the following:

To produce the following KNPC Plans:

- Strategic Plan (10-20 Years)
- 5 Years Plan (annual cycle)
- Budget Plan year (annual cycle)
- 18 months Plan (Quarterly)
- 6 Months Plan (weekly)

In addition to above, the LP is used for:

- Optimizing Refinery Operations
- Feed-stocks & products evaluation
- Economic studies
- Others

3- Basics of linear programming

3.1- Definition

Linear Programming is a mathematical system to solve problems by using a set of simultaneous linear equations / in-equations (in Matrix form) to determine the optimum solution an objective function is created for the maximum profit.

Simple problem can be solved by using simple algebraic or graphical methods, but larger problem (similar to Petroleum Refinery) requires computer using special programs (Linear Programming software).

3.2- Linear programming technique

(Example of a Simple Problem)
To understand the Linear Programming technique, we will see the below simple problem and its solutions.

Example of a simple problem:
A small machine shop produces two modules, Standard & Deluxe. Each standard model requires 4 hours of grinding and 2 hours of polishing, each deluxe module requires 2 hours of grinding and 5 hours of polishing. The manufacturer has 2 grinders and 3 polishers, in his 40 hours week. He makes $3 profit on each standard module and $4 on each deluxe module. He can sell all he can make of both. How should the manufacturer produce from the standard & deluxe modules to maximize his profit?

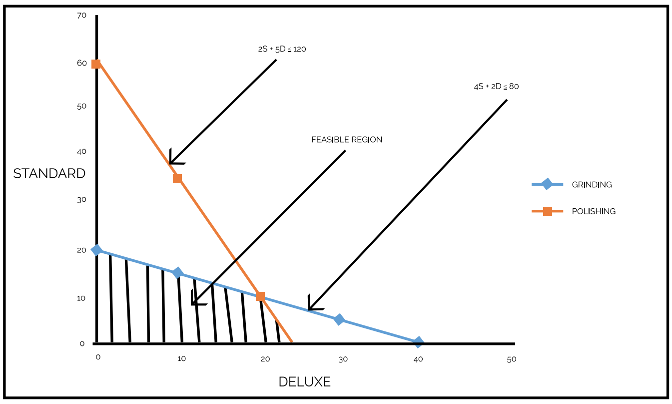
To start solving the problem:
1st. we convert the problem into mathematical form (Equations):
Total hours of grinding are 2 Machines x 40 Hrs = 80 hours
Total hours for polishing are 3 Machines x 40 Hrs = 120 hours
Assume that the shop produces “S” standard models and “D” deluxe models in a week.
Total profit equation:
$3S + 4D = Max\ \$$ (I)
Grinding hours can be utilized to form the Grinding Equation:
$4S + 2D \leq 80$ Hrs (II)
Polishing hours can be utilized to form the Polishing Equation:
$2S + 5D \leq 120 \leq$ Hrs (III)

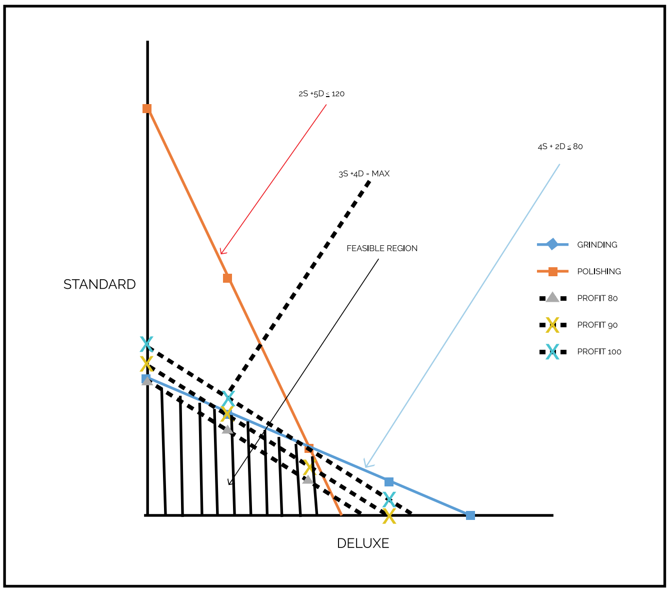
There are three methods to solve the above problem:
- Graphical
- Algebraic
- Matrix

3.2.1- The graphical solution
Plot the grinding & polishing lines
Any point in the feasible region solves the problem.
As you can see there are thousands of solutions.
To select the optimum one, we should plot the profit equation (3S +4D = Max) as follows:

Assume the maximum profit is $ 80, 90 or 100, then the profit equations will be 3S + 4D = 80, 90 or 100 and plot these lines.

The below chart shows that the profit lines are parallel, and the max profit is at the top corner of the feasible area of the grinding & polishing lines, the intersection point is (20 , 10).





Where: Deluxe Modules = 20 and Standard Modules = 10.
Accordingly, the maximum profit is 3x10 + 4x20 = 110 $

3.2.2- The algebraic solution
The problem summarized (in Equations) as follows:
$3S + 4D = P$ (Max $) (I)
$4S + 2D \leq 80$ hrs (II)
$2S + 5D \leq 120$ hrs (III)

The manufacturer should produce either Standards or Deluxe models or both of them, then S & D are +Ve or one of them is zero:
$S \geq \& \geq 0$

To solve equations (II) & (III) we should convert them to equality:
$4S + 2D + X = 80$ (II)
$2S + 5D + Y = 120$ (III)
Where: X & Y are +Ve or equal zero and called the slack variables

The basic solution is when S = 0 & D = 0, then:
X = 80 & Y = 120 at this solution P = 0
The profit (P) will start increasing by increasing the values of S & D

Re-write equations (II) & (III) in term of X & Y:
$X = 80 – 4S – 2D$ (IV)
$Y = 120 - 2S – 5D$ (V)

In equation (IV): By increasing S, X will be decreased, and X will be zero when $S = 20$

In equation (V): By increasing S, Y will be decreased, and Y will be zero when $S = 60$
Re-write equations (IV) & (V) in term of S:
$S = 20 – X/4 – D/2$ (VI)
$S = 60 – Y/2 – 5D/2$ (VII)

Let us see the profit equation (I) by replacing the S by its value from equation (VI):
$P = 3(20 – X/4 – D/2) + 4D = 60 – 3X/4 + 5D/2$
(VIII)

So, the profit is increased to 60, if both X & D are zero, and it will further increased if D increased.
Replace D in term of X & Y in equation (VIII), by using equations (VI) & (VII):
$20 – X/4 – D/2 = 60 – Y/2 – 5D/2$
$D = 20 – Y/4 + X/8$ (IX)
$P = 60 -3X/4 + 5(20 – Y/4 + X/8)/2$
$P = 110 – 7X/16 – 5Y/8$

As the coefficients of the variables X & Y are negative, the maximum value of P is 110.
The maximum profit (solution) is $ 110, same as the Graphical Solution.

Deluxe Modules = 20 (Eq. IX) and Standard Modules = 10 (Eq. VI)

3.2.3- The matrix solution

To represent the problem in a matrix form, we write the previous equations as follows:
Equation Grinding $= 4S + 2D \leq 80$
Equation Polishing $= 2S + 5D \leq 120$
Equation Profit $= 3S + 4D =$ Max.
First we change the In-equations to Equations, by using the Slack Variables X & Y (as per the Mathematical Solution), where X 0 & Y 0.

Equation Profit $3S + 4D =$ Max.
Or $P - 3S – 4D = 0$ where: P = Profit
Equation Grinding $4S + 2D + X = 80$
Equation Polishing $2S + 5D + Y = 120$

Put these equations in a matrix form:

	P	S	D	X	Y		RHS
PROFIT	1	-3	-4	0	0	=	0
GRINDING	0	4	2	1	0	=	80
POLISHING	0	2	5	0	1	=	120

Where:
S & D are Unknown, Columns
X & Y are Slack Variables and they will be calculated in the matrix as any variable
GRINDING & POLISHING are the constraints, Rows
PROFIT IS THE Objective Function, to get optimum solution

RHS is the Right Hand Side
To solve the matrix, we do the following:
We choose the greatest coefficient in the profit equation and replaced by its value, here it is D.

To get the optimum solution (maximum profit), the coefficients of the profit equation should become positive.

The 1st leaving variable should be the one with minimum ratio. The ratios are 80/2 & 120/5, in simplified form are 40/1 & 24/1, the minimum ratio in the Polishing Equation.
$2S + 5D + Y = 120$
$D = 24 – 2S/5 – Y/5$

Replace D in the profit & grinding equations by the above value:
$P – 3S -4(24 – 2S/5 – Y/5) = 0$ $P – 7S/5 + 4Y/5 = 96$
$4S + 2(24 – 2S/5 – Y/5) = 80$ $16S/5 + X – 2Y/5 = 32$
Polishing Eq. will remain $2S + 5D + Y = 120$

Matrix will be as follows:

	P	S	D	X	Y		RHS
PROFIT	1	-7/5	0	0	4/5	=	96
GRINDING		16/5	0	1	-2/5	=	32
POLISHING	0	2	5	0	1	=	120

The 2nd leaving variable is in the Grinding Equation:
$16S/5 + X – 2y/5 = 32$ $S = 10 – 5X/16 + Y/8$

Replace S in the Profit & Polishing Equations by the above value:
$P – 7/5(10 – 5X/16 + Y/8) + 4Y/5 = 96$ $P + 7X/16 + 5Y/8 = 110$
$2S + 5D + Y = 120$ $2(10 – 5X/16 + Y/8) + 5D + Y = 120$
$5D – 5X/D + 5Y/4 = 100$

The Grinding Eq. will remain the same in the second matrix.

Matrix will be as follows

	P	S	D	X	Y		RHS
PROFIT	1	0	0	7/16	4/5	=	110
GRINDING	0	16/5	0	1	-2/5	=	32
POLISHING	0	2	5	-5/8	5/4	=	100

Coefficients are positive and the optimum solution is @ $ 110 profit.

The Standard models are:
16 S/5 + X - 2 Y/5 = 32
S +5 X/16 – Y/8 = 10, then:
S = 10

The Deluxe models are:
5D – 5 X/8 +5 Y/4 = 100
D – X/8 + Y/4 = 20, then:
D = 20

The result is same as the algebraic and graphical solutions.

As the petroleum refining is very complex and hundreds of equations have to be solved and obtain a solution, therefore the matrix method is the easiest one to use.

Accordingly,LP is using the matrix method to solve the petroleum refining problem.

4- LP concepts

With the LP is clearer now, the following are the LP concepts:

4.1- Constraints

Matrix Rows, equalities or inequalities equations that link the variables and set limits in the problem.

Constraint Types:
Material Balance, unit or blend in / out.
Capacity, process unit

Specification Blending, maximum or minimum spec
Objective Function, maximum profit
Etc.....

4.2- Variables

Variables are the unknowns of the problem, the LP solution gives their values (matrix columns, vectors).
Variables give the optimum result.
Variable Types:

Blending streams & products (formula or spec)
Purchases & sales
Etc..

4.3- Right Hand Side (RHS)

RHS is the constant value to the right of the equation, it controls the activity of the rows.

If row is Less or Equal (LE), the RHS sets the activity of this row to Upper Limit (UL).
If row is Greater or Equal (GE), the RHS sets the activity of this row to Lower Limit (LL).

Most of the RHS equals to Zero, except Capacity row is greater than Zero.

4.4- Range

Range is the difference between the upper and lower limits on row activity (between minimum & maximum levels).

4.5- Bounds

Bounds are limits applied to column activity.
Lower limit (LO), upper limit (UP) & fixed limit (FX).

4.6- Matrix coefficient

Matrix coefficient is a constant multiplying a variable in an equation (like yield, utility consumption, capacity, etc...).

Salient Design/Features Adopted in Clean Fuels Project

Rising oil demand in combination with tighter product quality specifications in developing regions, particularly Asia, requires increasing the specifications of fuels to meet premium quality and quantity targets. KNPC embarked on Clean Fuels Project (CFP) to upgrade / expand Mina Abdullah (MAB) and Mina Al-Ahmadi (MAA) refineries. MAB crude processing capacity will be augment from 270 mbpd to 454 mbpd. The combined MAB & MAA capacity will be 800 mbpd.

Wasemia Al-Shammari
Process Engineer - MAB

K. Daniel Jeyasankar
Process Engineer - MAB

Enhanced conversion of Low Sulfur Fuel Oil (LSFO) to higher value products through Bottom of Barrel (BOB) processing is the primary objective of the project utilizing ARDS / Coker / Hydrocracking technologies in both refineries. Significant addition to hydroprocessing units boasts KNPC as one of the highest upgrading capacities in the region. This involves installation of new process units along with required auxiliary/supporting facilities and revamping of existing units at both refineries with an objective to meet stringent global market product specifications (Euro-V) and demand for transport fuels.

In addition to this, there will be an integration between the existing refineries to have a higher operational flexibility with optimum utilization of existing infrastructure in order to minimize intermediate stock build-up during planned and unplanned shutdown of the process units. The offsite facilities (storage, blending and shipping/logistics facilities) at SHU were modified to support and be integrated with the refinery operations.

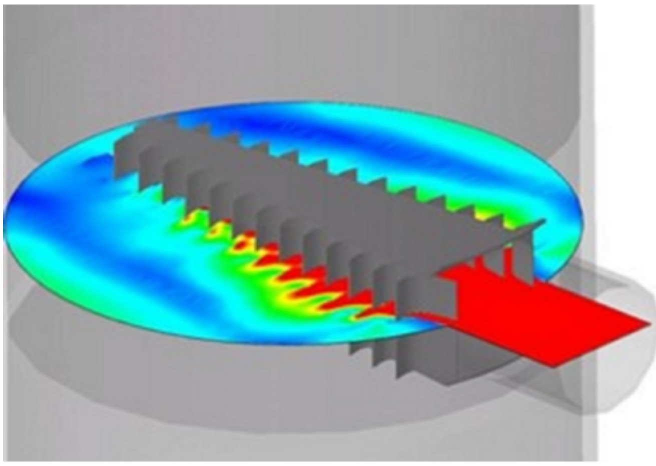
The article focus on some of the salient design features/ technologies adopted in Clean Fuels Project of MAB Refinery. Addition of following units are implemented as part of MAB Refinery CFP:

- Crude and Vacuum Distillation Unit
- Atmospheric Residue De-Sulfurization Unit
- Hydrocracker Unit
- Distillate Hydrotreating Unit
- Naphtha Hydrotreating
- Continuous Catalytic Regeneration Unit
- Support units viz., Hydrogen Production Units,
- Sulfur Block Units
- Utilities and off-sites

Crude Distillation and Vacuum Distillation Unit :

Adoption of preflashing in the Preflash Drum is favorable due to the reduction in vapor pressure of crude allowing the drop in the design pressure in the equipment downstream of the Preflash Drum with consequent cost savings. Enhanced residence time is an added advantage.

Implementation of Schoepentoeter in the inlet of horizontally oriented preflash drum coupled with routing of the Preflash Drum vapor to the crude tower flash zone results in effective handling of entrainment and foaming from the Preflash Drum. This feature in Crude Unit prevents potential discoloration of the products lifted from the flash zone.

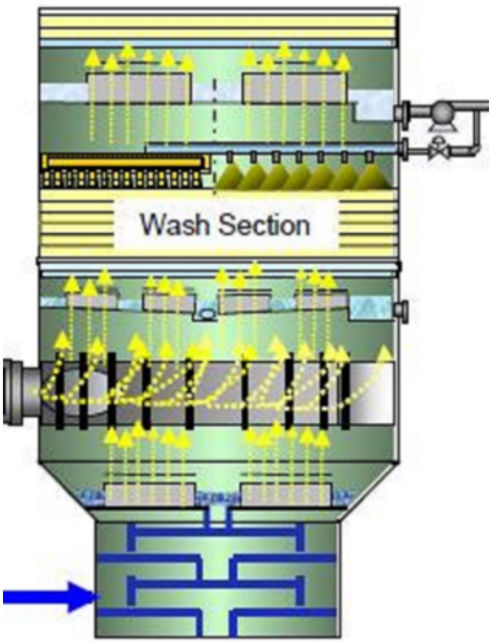


(Schoepentoeter in preflash drum)

Vertical exchanger in Crude Column overhead cooling system for overhead vapor and crude service mitigates the potential of chronic corrosion problems due to the elimination of accumulation of corrosive low pH water and self-draining.

(Vertical exchanger: Crude Overhead / Crude)

Application of packed bed in the Wash, Trim Gas Oil and Heavy Vacuum Gas Oil (HVGO) sections of the Vacuum Distillation Column results in lower pressure drop with significant improvement in heavy distillate recovery for conversion feed stock from long residue.



(Packed bed in vacuum column)

Atmospheric Residue De-Sulfurization Unit (ARDS)

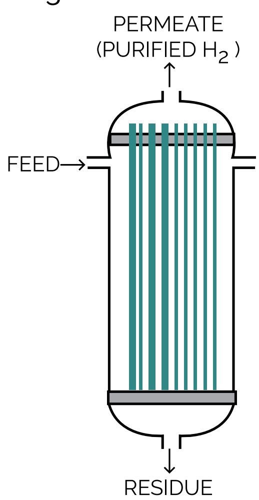
Atmospheric Residue De-Sulfurization Unit (ARDS)

Beginning in 2020, the new International Maritime Organization (IMO) regulations will reduce the limit of sulfur content in marine fuel from 3.5% to 0.5%. The implementation of the regulations will cause an oversupply of High-Sulfur Fuel Oil (HSFO), which will severely disrupt refinery dynamics. MAB, with increase in complexity post CFP with hydrocracking, coking and residue desulfurization units is well positioned that enable maximization of compliant fuel oil (based on requirement) as well as middle distillate production.

Application of Up Flow Reactor (UFR) upstream of the conventional Fixed Bed Reactor system in Atmospheric Residue De-Sulfurization Unit provides the clean-up of severe difficult feed of High Sulfur Atmospheric Residue (HSAR) with significantly cleaner feed for the downstream Fixed Bed Reactors resulting in improved cycle length. With the implementation of UFR, guard bed objectives with small pressure drop enhances cycle length improvement.

(Up Flow Reactor)

Application of membrane system for recovery of Hydrogen from high pressure purge gas (without reducing the pressure and then pressurizing as in the case of PSA) with high purity. As well, the recovery is an added advantage.

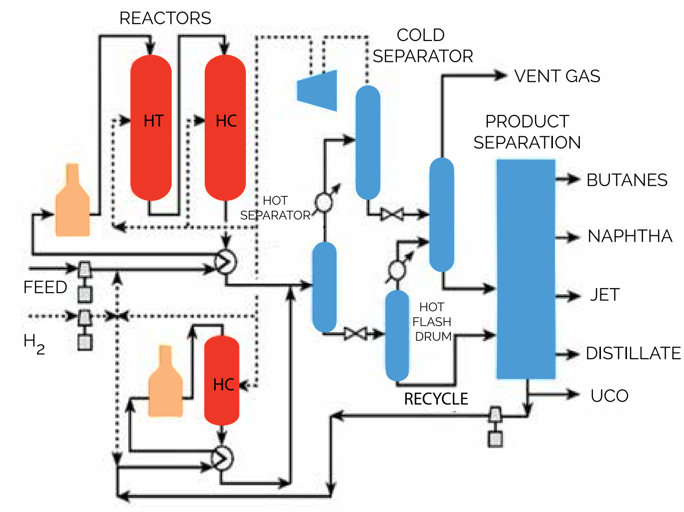


(Membrane System)

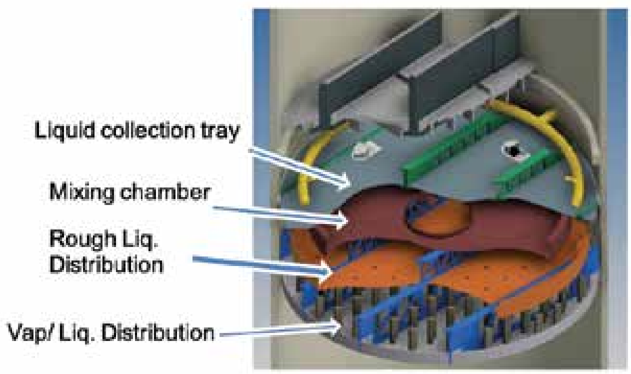
Hydrocracker unit

Stringent quality requirement combined with growth in demand of transportation fuels makes Hydrocracker unit as the preferred choice for MAB CFP. Application of two stage hydrocracking unit with a combination of separate treating and cracking reactor in the first stage followed by separation of oil and gas and a second stage cracking with recycled Uncoverted Oil (UCO) feed results in maximization of selectivity of middle distillate and overall conversion.

Hydrocracking process is highly efficient due to the application of proprietary liquid distribution system and consequent excellent distribution of the feedstock and hydrogen over the catalyst bed allowing maximum utilization of catalyst.

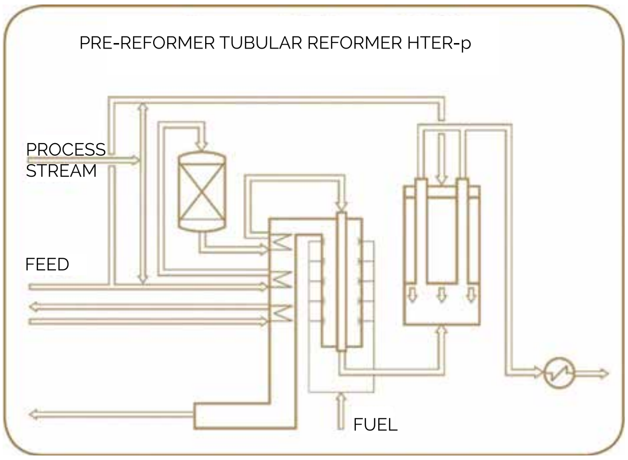


(Two-stage HCR with separate treating followed by cracking)



Hydrogen production unit

Boosting of Hydroprocessing capacity warrants for substantial increase in Hydrogen demand. Application of integrated pre-reformer, heat exchanger reformer (HTER) with Steam Methane Reforming (SMR) results in improved energy efficiency due to effective use of waste heat from SMR mainly for H2 production with minimum steam production, making the process economically attractive with lesser plot area for the comparable capacity.



Energy and environment

Integrated use of PSA off gas for fuel in SMR in Hydrogen Production Unit is highly energy efficient.

Application of Low NOx burners with the predicted NOx emission of 25 ppmv (guarantee 69 ppmv) in the Crude Heaters enhances KNPC commitment to cleaner environment. Other environmental friendly features applied are treatment of Vacuum off gas with Amine for H2S elimination and further use in Vacuum Unit heater, recycling of stripped H2S from molten sulfur to the front end of Claus reaction section for reduced SOx emissions from Sulfur Recovery units and air sparging of molten sulfur for reduction in H2S.

With the application of salient design features/ technologies in CFP, MAB refinery is well poised to achieve complete bottom of barrel conversion and ability to meet stringent product specifications as well as demand in domestic and international markets in environmental friendly way.

Clean Fuels Project

Enhanced Conversion

Innovation and Challenges in LPG Train-4 Commissioning

KNPC has commissioned LPG Train-4 Unit for gas, condensate and LPG processing. Several challenges were faced during design, construction and commissioning of the Unit and some innovative ideas are implemented in this project. This paper is mainly divided into two sections, firstly the challenges faced during design, construction, commissioning and secondly about the innovative ideas that are implemented in this project

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Sr. Specialist, Process Engineering – MAA

Karthik Rajagopalan
Process Engineer – MAA

Challenges

Lower seawater (cooling water) pressure

Seawater is used in Train-4 unit as cooling water. Seawater supply pressure for the unit was designed at 3.5 bar. Dedicated sea water supply pumps are envisaged in design of the unit. The supply pumps are to be procured and installed by another agency, which is outside the scope of the project.

In spite of continuous follow-up, the concerned pumps could not be procured and installed in time. However, the main unit construction was completed and was ready for commissioning. In order to proceed with commissioning of the unit, without the dedicated seawater pump, KNPC has internally studied various options.

Existing seawater in gas plant is designed for much lower pressure (5 bar compared to 7 bar for the new system at the pump discharge). Few interconnections were envisaged between existing and new seawater headers for emergency purpose. Hydraulic calculations were carried out and it was found that existing header jump overs can handle the design flow rate. However, the sea water supply pressure will be lower (2 bar) at battery limit leading to potential vacuum at high level exchangers.

Detailed study was conducted by contractor for operating the plant with lower seawater pressure. The contractor has agreed that the plant can be operated up to 90% capacity with lower sea water supply pressure.

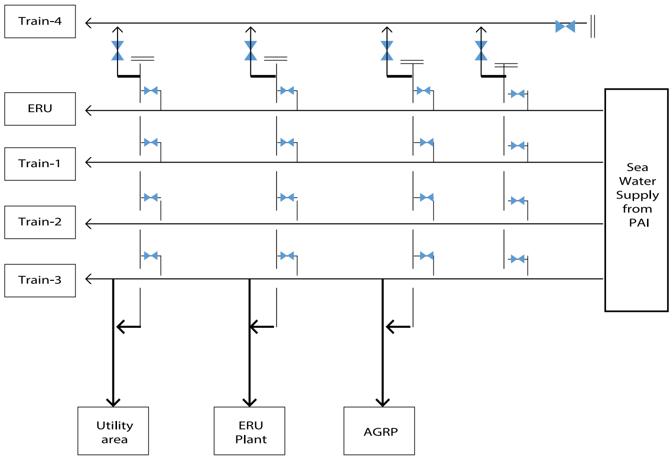
Limitation was identified in 2 seawater coolers.

On feed gas compressor discharge cooler:

Limitation was observed in seawater Plant was commissioned with lower sea water pressure (1.8 to 2 bar) and is being operated at 100% capacity discharge cooler due to elevation of the exchanger. However, temperature at the outlet can be maintained by operation of additional air coolers in the discharge circuit. Flow direction was also reversed to reduce the impact.

On propane regeneration cooler:

Higher Propane temperature is observed at the outlet of the cooler (52°C against 45°C design). This will lead to loss of Propane due to partial condensation. Flow direction was reversed to reduce the impact.



B) Non-availability of Ethane

To facilitate compliance to Montreal Protocol, Train-4 was designed to avoid usage of Chlorofluoro carbons, as refrigerant. In order to cool Propane product below the boiling point -45˚C, deep refrigeration system was envisaged.

Deep refrigeration system uses Ethane and Propylene as refrigerant. Refrigerant is compressed and condensed and is used to cool Propane product to -45˚C.

For this system, Ethane is designed to be sourced from nearby petrochemical complex. However, this supply line was not ready; so KNPC carried out various simulation studies to identify alternative refrigerant mix.

Based on simulation, it was found that it is possible to replace Ethane with Methane. Instead of design refrigerant mix of 70:30 (Propylene: Ethane), it was decided to use 91:9 (Propane: Methane). Methane content in the mix was limited due to discharge design consideration like pressure, temperature and the condenser duty. The modifications were completed.

By this proposal, KNPC went ahead with commissioning of Train-4 without the availability of Pure Ethane for refrigeration and equipment are functioning normal.

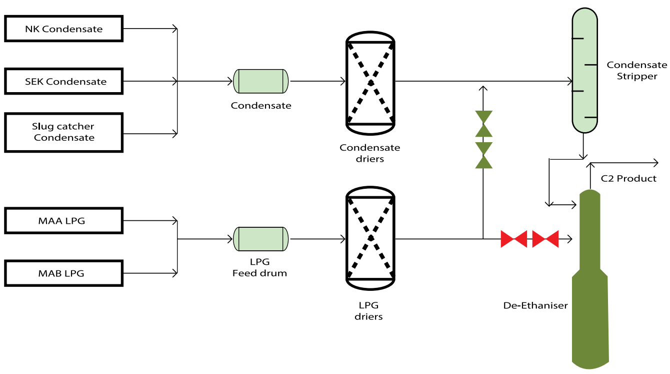
C) Ethane purity

After commissioning of Train-4, Ethane purity could not be achieved to design level. Higher Methane slip was encountered in Ethane product. KNPC identified possible sources of Methane slip / leak through various equipment and eliminated the causes one by one.

It was finally concluded that the balance line (Feed gas) going to LPG feed drum is causing absorption of Methane rich gas (used for pressure balancing in LPG). The feed drum is operated at 37 bar pressure. Due to difference in partial pressure of vapor and liquid phase, Methane is getting absorbed in liquid LPG continuously at around 2 to 3 Knm3/hr.

Feed LPG from the drum is pumped directly to De-Ethaniser through drier system. When Methane is continuously getting absorbed in LPG, it lands in De-Ethaniser overhead along with Ethane, producing off-spec Ethane product.

In order to solve this problem, KNPC has decided to route LPG through condensate stripper. Condensate stripper will remove the Methane components from the feed LPG so that De-Ethaniser feed will have lower C1 content. After this change of feed routing, Ethane purity has improved to design level.



Also the metering skid should be designed to provide output in desired units of measurement. All the conversion need to be performed within the metering skid. This will ensure accuracy of measurement of desired components with same accuracy.

Aswell, sample stream for analysis are recovered back to the process system based on pressure differential. However, due to sample tubing pressure drop, it was found that in various locations sample flow to the analyser is not consistent. Sample routing was changed to either fuel gas or flare header based on the pressure available. Design objective to be made clear and should percolate through the design document.

D) Metering skid commissioning

Train-4 is designed to have metering skids to measure feed and product streams. Each metering skid is provided with flow measurement, Composition analysis.

For flow measurement – Ultrasonic meters are used
For composition – Gas Chromatography is used

KNPC need the following outputs from metering skids for custody transfer, as gas/liquid streams need different outputs.

- Mass flow
- Volume flow
- Energy
- Composition

However, for liquid streams, the density was not measured. Density was calculated from liquid composition based on empirical correlations. The accuracy of the density measurement was under question for custody transfer applications. It is preferred to have a dedicated density measurement for liquid streams for accurate measurement.

Innovations

A) High Integrity Pressure Protection System (HIPPS)

HIPPS system is used in Train-4 due to necessity as blocked case cannot be considered in the design. This may deprive fuel gas to entire country and can further lead to potential power outage, if entire feed is routed to flare . We have made this part of design even before HIPPS was introduced in API 521 2007 edition. Train-4 is designed with HIPPS system to minimize the quantity flared during emergency. HIPPS will have a set point below the design pressure of the equipment. Once HIPPS is activated, feed and energy input to the column is isolated. Isolation helps in preventing the pressure increase further. In order to ensure the reliability of HIPPS system, all pressure measurements are made 2 out of 3 voting.

In order to ensure the integrity of HIPPS isolation valves, all valves are made double isolation valves (With Tight Shut off specification) as per API specification.

Demethaniser column in Train-4 is 58 m high. HIPPS system is implemented for the column to reduce PSV size and flare load. In case of high pressure in this column, feed and reboiler of the column is isolated with double HIPPS valve. PSV and flare line size could be reduced to very small size like 1" or 2" Where in the governing case for pressurization is Fire case when the column is boxed up.

In addition, there is also a provision for Emergency Depressurisation (EDP) system in the demethaniser. Operator can activate the EDP logic during emergency for quick depressurization.

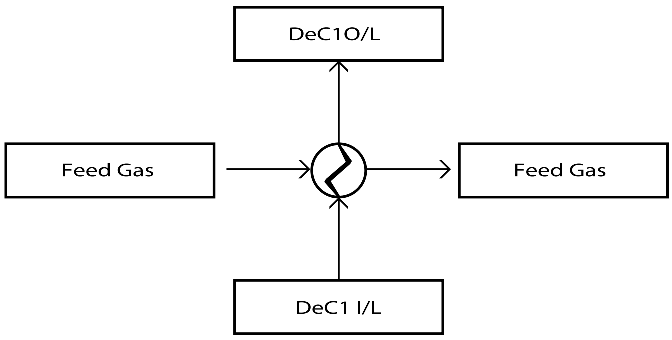
B) Feed gas sub-cooling using De-methaniser bottom stream

Normally driers are designed for saturated moisture content so that plant can operate even with upstream unit problem. This has led to requirement of designing very big driers. It is expected that upstream unit will operate within the limit most of the time.
In order to reduce the quantity of molecular sieve requirement it is proposed to cool the process gas and condense the water. It is not possible to cool with sea-water because of ambient temperature limitation.

Demethaniser column in Train-4 is designed to separate lighter components from gas feed. Bottom liquid is further processed in fractionation section to recover products. This liquid is pumped to Deethaniser through a heat exchanger at compressor discharge where the feed gas is chilled.

Feed gas moisture adsorption is favored at lower temperature. By reducing the temperature of wet feed gas, adsorption capacity of molecular sieves will get increased by 50%.
By heating the DeC1 bottom liquid, DeC2 feed temperature has increased resulting in better separation and energy efficiency.

Heat duty of the exchanger was 20 MMBTU / hr.



C) De-Butaniser side reboiler

Normally air cooler or water cooler is designed to cool compressor discharge gas and thermal energy is wasted. Generally, low level heat available (less than 100˚C) is not utilised. Train-4 has many distillation towers operating at bottom temperature at around 120˚C. We have identified that it is possible to use this low-level heat for intermediate reboiler. Process temperature at this location is lower than 100 ˚C.

Therefore, it is proposed to use compressor discharge heat to reboil in debutaniser column. It is expected to save about 35 mmbtu/hr of energy, approximately one third of crude heater capacity. Cooler common inefficiency in a chemical plant or refinery is the cooling of process streams that should not be cooled.

Feed gas in LPG Train-4 is compressed to higher pressure for process requirement. In the process of compression temperature of the discharge gas increases. The heat available in the discharge gas can be utilized in low pressure distillation column reboiler stream.

To recover the heat from the discharge feed gas, side reboiler stream was withdrawn from De-butaniser Column. This stream was heated by the feed gas stream to minimize the overall heat input to the column.

By commissioning this equipment, 25% of overall heat duty of bottom reboiler was saved.

- Equivalent steam saved in debutanizer reboiler was 17 MT/hr.
- DeC4 Reboiler stream Temperature: 80˚C
- DeC4 Reboiler Return Temperature: 82˚C
- Compressor discharge Temperature: 102˚C
- Feed gas after cooler Temperature: 87˚C

This novel idea of integrating feed gas discharge cooler with debutanizer reboiler helped in utilizing the heat available in feed gas.

New Training Outlook in Mina Al-Ahmadi Refinery

For the first time in KNPC as well as in Kuwait, a group of female Process Engineers were trained in Operations Department in Mina Al-Ahmadi Refinery (MAA) to enrich their career and propel towards cultural diversity at work. Trainees had to pass three levels, viz., field and panel operator's training and supervisory training. During field training, the engineers were required to line up the process Unit, and perform usual operators' activities. Panel Operation training included operating the control panel of the Unit and instructing field operators, during normal operation & emergencies. Last but not the least, handling supervisory tasks required observing field and panel operators' activities. Challenges that female engineers faced were mainly in their exposure to a new work environment. The outcome of this program was in increasing engineers' competency and confidence in operating the Unit. Engineers gained experience on professional level to deal with different process Units In addition to approaching with better communication with different personalities. The success of this experiment required not only an efficient training but also support and encouragement from Operations Department. This unique concept brought in the training protocol ensured the most effective grooming.

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Introduction

This paper presents a unique experience of training process female engineers in the KNPC, Mina Al-Ahmadi (MAA) Refinery for the first time in Kuwait history. The training was planned by the Professional Women Network (PWN), which was established under the KPC to support female professions in oil sector. The networks' members took the initiative in 2016 to structure a training program of process female engineers in Operations Department. The program was specially designed to meet objectives that serve the company and its employees. 1st, bringing in much needed gender diversity at the work place to meet future challenges. 2nd, providing engineers with hands on experience in Operations. 3rd, enhancing their technical knowledge of Chemical Engineering by working on the Structured on Job Training (SoJT) modules side by side with Operations training. 4th, developing the engineers to be competent and effective manpower assets for the future by stepping up their understanding of detailed Plant Operations clubbed with basic Process Engineering inputs.

Candidates were selected according to competency; however, other factors were taken into account: a) Demonstrating confidence through posture, voice and ease of answering. b) Verbal and nonverbal communication. c) Interests to work in a refinery environment and joining the attachment program. d) Self-confidence and readiness to work during emergencies. e) Working beyond working hours. f) Volunteering to perform any required job to improve safety and operability of the Units. g) Willingness to contribute when the job requires teamwork, such as, supporting other groups in their shutdown activities, performing other roles when the division is under staffed, and providing services to others that are beyond assigned responsibilities. Based on the above selection procedure, five female-engineers were chosen to participate in this training program.

The ladies were assigned to a refinery units and two to the gas plant. This paper discusses the experience of the ladies that were assigned to the refinery, more specifically on the Hydrocracker (HCR) Unit.

The training program plan included training the engineers extensively over a period of 10 months in Operations Department. The training structure consisted of awareness of Unit Line up, hands-on field and panel operators activity, control logistics, emergency scenarios, start-ups and shutdown procedures, pumps/compressors systems, HSE Risk Register, risk assessments, maintenance, inspection and safety. They subsequently played roles of field operator, panel operator, and supervisor. The outcome of the training program was as follow: a) In-depth knowledge of operational activities, typically not covered by SoJT. b) Confidence in running and managing the Unit during normal operation and emergencies. c) Gained an edge in future tasks in troubleshooting exercises, HAZOP studies, Unit reviews, meetings and other workflows, where the operational knowledge and command is foundational and an essential element for decision-making processes. d) Brought in the much needed gender diversity to the workplace. f) Prepared competent engineers those were later assigned to handle Clean Fuel Project (CFP) units. g) Training was restructured for newly joined employees to include the Operations knowledge in the SoJT modules.

Methodology

SoJT is the planned process of having experienced employees training new hired employees on a set of work in the actual work setting. Every new hired employee can receive the training needed regardless of which experienced employee or locations they are assigned to.

Courses have to be completed before assigning the fresh engineers to a Unit. The courses include an orientation program in their department and in other company's departments and the necessary HSE training. The SoJT consists of multi modules, each contains a number of tasks to be completed. Experienced engineers are assigned as mentors and checkers to advise and supervise the engineers until the tasks are completed. This training program has to be concluded within 150 to 300 working days.

For the Process Engineering Department, SoJT modules included topics that could be covered during the Operations Department training. In other words, completing these modules would bring better insight by covering the theoretical and practical sides of the topics. Examples of tasks that were completed during the Operations Department training are: a) Analyzing reasons for emergency shutdown. b) Optimizing Process Unit yield. c) Initiating new project/modification proposals. d) Participating in process catalyst dumping and loading. e) Providing troubleshooting advice to Operations Department. The proposed training plan for the three female engineers was completing the SoJT tasks by the termination of Operations training program. Also participating in revamping the SoJT program by including the synergy of operational training to enhance its effectiveness.

Operations department training

Operations Department is the heart of any refinery in the world due to its role in running the units at normal and critical conditions. The core of the operations strategy in training is to prepare a competent operator to handle the unit at emergencies, start up and shutdown, on the control panel, and as a supervisor. This section of the paper illustrates the female engineers' training stages in MAA refinery Operations Department, more specifically in the HCR Unit. Operation training was divided into several stages.

A) Field operator training: The program started in October 2016 by training the female engineers in the field for four months, including the field operator acceptance certification and handover. The training began with the HCR Unit lineup, allocating the equipment and instruments, familiarization with the Process Flow Diagrams (PFD) and Piping and Instrumentation Diagrams (P&ID). The trainees had to understand valve types and classifications, sample points and collection procedures, handling equipment during normal operation, startup/shutdown, and emergencies. The training was concluded by field operator examination in the presence of the trainees, shift controller and Operation Section Head. The next step was handing over the Unit to the females to start routine activities of the field operators. The routine job started with initial checkup on the Unit's health to report its condition, and the equipment conditions, to the control panel operators, in addition to any abnormality and leaks or damaged insulations on the pipes. Furthermore, as field operators, they collected routine and extra samples on daily and weekly basis, according to the laboratory schedule. They had to take immediate actions when the control panel operators or supervisors required a job on site. Moreover, the female engineers followed up on work permits, handed over equipment and received them from other departments. It is worth mentioning that during their field training, they were capable to observe and suggest modifications to improve Unit's operation in safety, energy and profits areas. This part of training was extremely important for the control room operation stage, as it added experience and propelled their knowledge enough to help them in charting the sequence of actions they could take in case of emergencies without jeopardizing the Unit's safe operation. At the end of this training stage, his Excellency, Issam Al-Marzouq, Minister of Oil, appreciated the female engineers.

B) Control room operator training: In February 2017 the Control room training was started to enhance knowledge in the Process Unit and prepare them to operate it safely on the panel. The operators had to clearly understand the function and importance of each equipment, history of failures, deviations in operating parameters and concerned departments to be contacted when there was an issue. This was followed by understanding the most common emergencies for the entire Refinery, such as failures in electrical power, seawater, instrument air, and boiler feed water circulation, as well as the Unit's major emergencies such as the losses of make-up hydrogen compressors, recycle gas compressor failure, and feed pump failure. The female trainees had to understand all control loops in the system to give them a perspective of how each equipment was affected by operating parameters, and how would that affect other equipment, entire Unit and the Refinery in general. For control room operation, the engineers were assigned for two weeks training. they performed Control Room Operator activities on the simulator such as starting up and shutting down the Unit. Furthermore, the supervisor created a number of emergencies via the simulator on troubleshooting and taking quick actions. At the end, the ladies returned to the control rooms and remained under a sequence of trainings within three different shifts per week. They had daily monitored the Unit, dealt with actual troubleshooting and mock drills, communicated with field operators and other divisions, reviewed emergencies history and had daily oral examinations. This training had paid off when the females contributed in a major emergency, to be discussed later, and turned out at the end to shutting down the 1st stage of HCR Unit for 38 days causing significant production loss.

At the end of the training, the engineers were examined and accepted as Control Room Operators by Operations Section Head, Controller and two engineers. The following step was handing over Control Room Operator routine activities, which included; overall Unit checkup for any abnormality, filling the daily log book, ensuring collection of required samples and adjusted operating parameters according to the lab results, taking actions to the system alarms to ensure Unit safe operation, equipment commissioning and decommissioning as per standard procedures and following up work permits and related jobs. The engineers faced many emergencies, and participated as effective and competent operators and trusted team members.

C) Supervisory training: In July 2017, the females began an Operation Supervisor training structured by an expert from the training cell. The plan included supervisory activates during Unit startup, shutdown and emergencies. In addition, issuing work permits and work orders. The engineers attended health and safety related courses including work permits and gas testing. They were examined by Operations Section Head and Controller and were accepted as first female Operations Supervisors in Kuwait. During handing over supervisors' routine activities, the engineers supervised mock drills to ensure implementing the gained knowledge.

Results and observations

As in any new beginning, people face the fear of not being accepted in an environment comprised of male colleagues only, the challenge was harder. There are varieties of reasons in our communities that restrict women from working in a male-dominated workplace. Not only that the Operations department had been run by only male employees. Also the society's perception was always that this work nature requires male workforce. Therefore, the main challenge that the female engineers faced was in gaining their male colleagues trust, acceptance and support. The challenge included dealing daily with different employees in personalities and cultural backgrounds, as the work nature of Operations department is based on three different shifts. As a result, being the only three ladies in this environment required handling huge responsibilities specially on learning and working with them to prove to their colleagues their competency and ability.

These responsibilities and challenges included gaining and applying knowledge in a very short period of time during the three training stages as it was mentioned previously. It is worth mentioning that the field training was at summer time and not only that the outside temperature reached up to 45^{o}C, but also the equipment like heaters operate very high in temperature up to 400^{o}C . In addition, part of ladies control room operator training was during the holy month of Ramadan, which made it more challenging. Not only fasting and lack of sleeping but also the control rooms are not equipped for female needs of rest rooms and praying rooms. At that time, male colleagues showed great Initiative by providing private rest and prayer rooms for the females. It is worth mentioning that the acceptance, support that the ladies received from Operations department during all the training stages were the main reasons behind the success of this training program. It was acknowledged that operating the refinery either in the field or in the control rooms is a definitely challenging environment to work in as males or females operators.

On the professional level, the major challenge was in the difference of work nature for process engineers and operation engineers. The process engineer's job depends mainly on applied theoretical aspects, while operation engineer's relies more on the practical side. The female engineers previous job included more office work and less of visiting plant site, however, the operations job was moving constantly between the field and the control room. Moreover the nature of operations work requires immediate actions, and sometimes under stressful emergencies to ensure safe operation of the Unit. The ladies showed improvements in their stress handling skills especially in dealing with emergencies while they were trained for control room operator position. Furthermore, they learned to manage their time efficiently to merge between their operations training and completing required Process Engineering tasks. They also showed strength in handling different challenging physical activities along with their male colleagues. The HCR Unit, which was chosen for the ladies to train on, is considered to be an economically important Unit for the KNPC that also operates with severe conditions. This helped the engineers to gain experience on professional level since they started training with different sets of knowledge tools on personal and professional level. The three engineers worked prior to the training in different Units for one year and a half, as Modhi handled crude distillation Units, while Fatemah was assigned in the Continuous Catalytic Reforming Units. Despite Sara's background in Shuaiba Refinery Isocracker Unit, which has differences in design and operating conditions than the Mina Al-Ahmadi HCR Unit. In short, the experience the ladies gained added value on a personal and professional level to pave their way in handling future jobs.

Conclusion

The paper presented training experience of female engineers in the KNPC Operations Department, for the first time in Kuwait history. The training program idea was proposed in 2016 by Professional Women Network, which is an organization which supports females in the oil sector and involves mentoring and grooming from senior professionals in K-Companies. The training plan was structured to prepare five UD female Process Engineers into competent operators within 10 months period. The candidates were selected based on criteria that mainly included personal impression and impacts. They were chosen for their willingness and ability to be trained in a different environment and job nature. The program goals were propelling the engineers' career by adding to their experience a combined knowledge of detailed Plant Operations along with Process Engineering basic inputs. Furthermore, achieving gender diversity at work to meet future challenges. During 10 months of training, the females were trained and passed acceptance in field, control room and supervisory training. Along with the Operations training, they had to complete SOJT tasks given by the Process Engineering department to help them in practicing the theories in these tasks on the actual field. The trainees faced and overcame personal and professional challenges such as learning in a shorter period than the usual operator, may need attending field operation activities during summer in a Unit with sever operation conditions, more physical activities, differences in work nature and merging SOJT with Operations training. On the contrary, the acceptance received from their male colleagues paved their way to defeat obstacles as they provided them with professional training, handed and trusted them with responsibilities, and allowed them to participate in Unit emergencies by providing exclusive panel, and private prayer aswell as rest rooms. The female engineers were also able to enhance personal and professional skills like time management, stress management during emergencies, proficiency in communication and Improved mental coordination and quick actions. Thus, the efficiency of the training provided to the female engineers, besides the acceptance from their Operations colleagues resulted not only in success of the program, but also built competent and confident engineers that participated in major emergency in the HCR Unit and assigned in major projects like CFP. In addition, it paved the way for freshly joined engineers by re-structuring OJT and SOJT to include similar Operations training that will propel KNPC future.

CASE STUDY

In the HCR Unit first stage, the feed charge pump takes suction from the feed surge drum. The feed oil from first stage feed pump is mixed with hydrogen rich recycle gas from the recycle gas compressor at 185 kg/cm2.g. A minimum recycle gas ratio of 758 NM3/M3 of oil feed is maintained to the first stage reactor section. The recycle gas ensures uniform distribution of feed on top of the catalyst bed and maintains the desired hydrogen partial pressure at reactor inlet. The combined feed oil and recycle gas at 152˚C enters the tube side of feed effluent exchanger. The reactor effluent stream on the shell side heats the combined feed to 401˚C before introducing it to the reactor feed heater. The heater is a natural draft, fuel gas fired heater, which provides the heat to bring the feed mixture to the reaction temperature. During normal operation, the furnace is operated with a T of about 19-28˚C. This temperature rise across the furnace provides a flexibility to quickly reduce the reactor inlet temperature in an emergency by shutting down the furnace. In this case, a signal is sent to to shutdown valve to cut off the fuel gas to furnace.

Emergency sequence of events

The sequence of events started on 31st of January 2017, when the first stage compressor seal oil turbine pump pressure was not adequate. Automatically, seal oil motor pump started to develop the required pressure; however, it had tripped on overload. The operators restarted the seal oil turbine pump successfully, however it tripped again later on the same day. The seal oil overhead tank, which provides a surge volume that serves the compressor for 15 minutes to allow restarting the pump, alerted with a low low level alarm. As a result, the recycle gas compressor also tripped. As mentioned previously, when the compressor tripped, a signal was sent to the heater fuel gas pressures valve to cut-off the fuel supply in order to trip the heater. On the 1st of February 2017, an unsuccessful attempt was made to start the recycle gas compressor due to continuous ingress of oil inside the compressor barrel. Then the first stage charge feed pump stopped, which led to serious and severe increase in heater's outlet temperature. Eight Multi Thermocouple Indicators (MTIs) on heaters' tubes recorded high tube skin temperatures. The figure was generated on February 1st 2017, and it shows eight different trends where the temperature reached 800˚C, which was 300-350˚C over the normal reading.

Reactor feed furnace (H-84-100) firing was cut off on the same day. Then on the following day, oil from compressor barrel was drained and a successful attempt was made to start the compressor. However, extremely high heater's tube skin temperatures were observed on both heater passes. The compressor was stopped and the HCR first stage was shutdown on the 2nd of February 2017. The next step was improving heater performance and solving the high skin temperature problem. Therefore, heater tubes were partially X-rayed, cut for visual inspection, where coke was observed and cleaned. Once job was completed, an attempt was made to restart the HCR on 20th of February 2017, however it failed due to raising of tube skin temperatures in south cell of feed. Thus, on the 22nd of February 2017, the heater tubes' joints were cut for visual inspection. As a result, heater tubes, outlet joints, and reactor inlet distributor and top perforated tray were cleaned. The Unit was started on the 10th of March 2017. Total shutdown days were estimated to be 38 days with huge loss in production. The female engineers contributed during the shutdown in the field activities and attended the heater cutting and cleaning procedures. They were also given an exclusive control panel by their Operations colleagues to work as a team in starting up the HCR Unit, even when the job required staying after working hours. The great team work between the male and female colleagues played a role in starting up the HCR Unit successfully, Until steady operation was achieved.


414

Pneumatic Testing of Piping

Managing the Hazards for High Energy Tests

This article was developed and published in the ASME PVP 2018 conference in Prague, Czech Republic as a result of collaborative effort between Bader Arti and subject matter experts from Chevron during his secondment with Chevron through KUFPEC on the Wheatstone Project in Australia as he was the lead mechanical engineer of the downstream unit of the project (2015-2018). Wheatstone Project is a Chevron-Operated LNG plant and KUFPEC is a 13.4% joint venture partner on the project.

Pneumatic pressure testing is used extensively during construction of LNG plants to avoid the problems that can be caused by water that may be left in a piping system (particularly in valves) if hydrotesting was performed. Due to the much greater compressibility of gas, there is significantly more energy (and thus risk) associated with a pneumatic test than with a hydrostatic test.

A major gas project safely conducted numerous pneumatic tests with stored energies of up to 6,675 MJ. Observing a commonly used limit of 270 MJ would have resulted in hundreds of additional closure welds.

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This paper discusses practical aspects of performing pneumatic testing, the risk mitigations put in place and present two calculation methods that can be used to check whether exclusion zones for blast wave pressure are adequate for fragment throw.

Introduction

A commonly used piping design code, ASME B31.3 Process Piping [1] requires that all piping be subjected to a hydrostatic leak test, but recognizes that hydrostatic testing may be impractical in certain special circumstances and allows pneumatic testing as an alternative. The very low temperatures associated with cryogenic piping in LNG plants mean that even tiny amounts of residual water that may remain after hydrostatic testing cannot be tolerated. Furthermore, some systems (e.g. flare lines) are unable to handle the weight of water associated with hydrotesting. Thus, pneumatic testing is commonly used in the construction of LNG plants.

Pneumatic testing is performed at a lower pressure (1.1 x design) than a hydrostatic test (1.5 x design x temperature factor). Two main dangers are associated with explosive failure during a pneumatic test: blast wave and fragment throw. The two relevant safety standards, ASME PCC-2 Repair of Pressure Equipment and Piping [2] and AS 3788 Pressure Equipment-In-Service Inspection [3] only provide calculation methods for protection against blast wave pressure. However, no method is provided to quantify a suitable exclusion zone to guard against fragment throw. Note that the 2015 edition of ASME PCC-2 added Minimum Distances for Fragment Throw Considerations in Table III-2. A lesson from a fatal industry incident during a failed pneumatic test was that setting exclusion zones only based on blast wave pressure or on total stored energy can be non-conservative.

A major gas project safely conducted numerous pneumatic tests with stored energies as high as 6,675 MJ. Both AS 3788 and ASME PCC-2 recommend limiting stored energy to 270 MJ (271 MJ in ASME PCC-2), but do not prohibit exceeding it. This limit of 270 MJ is impractical for many of the piping systems tested due to both test pressure (up to 170 bar) and line size (up to DN1800), and would have resulted in hundreds of additional closure welds.

Codes and standards requirements

ASME B31.3 cautions against pneumatic testing due to the hazard of released energy stored in compressed gas. Appendix F directs the user to ASME PCC-2, Repair of Pressure Equipment and Piping, Article 5.1, for equations and considerations to safely test pneumatically. Local Australian (AS) regulations also need to be complied to. AS 3788 Pressure Equipment – In-service inspection, Appendix D16, provides the minimum requirements for pneumatic pressure testing.

Both ASME PCC-2 and AS 3788 provide minimum exclusion zones based on the damage that could be caused by a blast wave resulting from the instantaneous release of all the stored energy of the test media. In AS 3788 the exclusion zones are fixed for given stored energy brackets. ASME PCC-2 allows the user to set the exclusion zone based on the level of risk that an Owner is prepared to take. ASME PCC-2 Article 5.1 §6.2 (f) (7) lists size and travel distance of fragments as a factor to consider as part of a hazard analysis, but no further details are provided as to how to perform this. The 2015 edition introduced Table III-2 but (as will be explained later) this table has limitations.

Note that both ASME PCC-2 and AS 3788 do not distinguish between piping and pressure vessels. The theory behind the (blast wave) exclusion zones is more applicable to pressure vessels as the energy is concentrated densely in one packed volume. With piping systems, the energy is usually distributed over a large area. In the event of a dramatic pipe rupture, it is not possible for all the energy to be released at once since most of the energy will be some distance from the opening and will need time to travel to the ruptured area. This is true for ductile materials. For a brittle material, a lot more energy could be released as the material does not first yield but suddenly fails. To avoid brittle failure, limits are set on the minimum testing temperature.

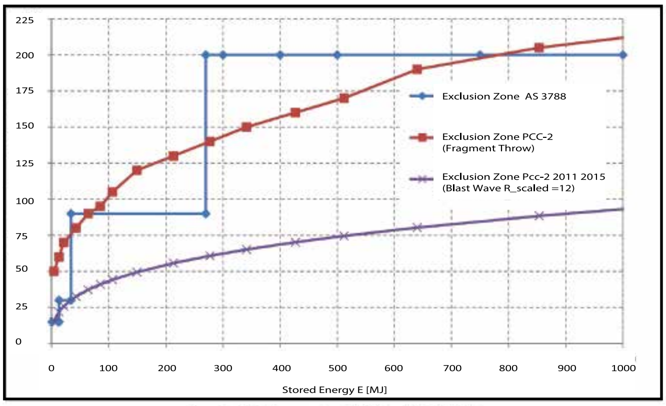

Figure 1: Exclusion zones for AS 3788 and ASME PCC-2

Figure 1 graphically illustrates exclusion zones as a function of stored energy for various standards. The project defined a High Stored Energy test (requiring owner review) as one exceeding 270 MJ. For blast protection, AS 3788 is more conservative than ASME PCC-2. At energies of less than 270 MJ and greater than 800 MJ the fragment throw exclusion zone of PCC-2 (2015) results in a greater exclusion zone than AS 3788. Contractually, the 2015 edition was not in place and the project used a standard 200 m exclusion zone for tests above 270 MJ. It should be noted that Australian Standards and the corporate piping standard require 100% RT/UT on all butt welds prior to pneumatic testing, exceeding the requirements in ASME PCC-2. The Australian Standards allow relaxation of this requirement subject to owner›s approval and a critical engineering assessment. Fragment throw would presumably be one of the issues addressed by a critical engineering assessment.

The project evaluated fragment throw using methods available in the public domain which will be discussed later – in some cases these did result in larger exclusion zones. While not shown, it should be noted that at 20,000 MJ (about 3 times the largest project test) the PCC-2 blast wave exclusion zone (for R^{scaled} = 12) reaches 200 m. R^{scaled} is a consequence factor [2]. A value of 2 m / ($kg^{1/3}$) or less would be fatal while a value of 20 or greater would have no biological effect.

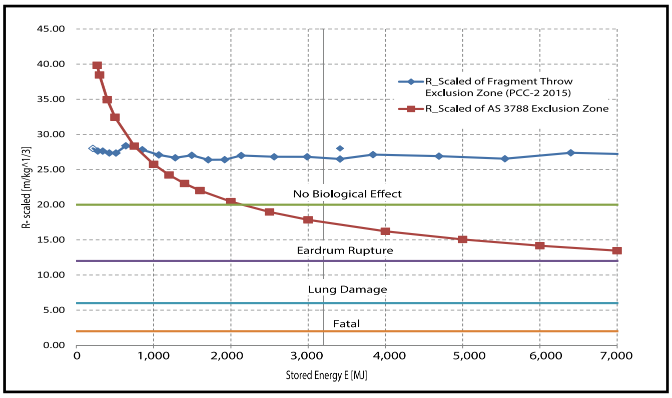

Figure 2: Rscaled values against stored energy

Figure 2 illustrates equivalent R^{scaled} values PCC-2 (2015) Table III-2 and the AS 3788 standard 200 m exclusion zone for tests above 270 MJ against stored energy.

The various PCC-2blast wave R^{scaled} values are included. The relatively constant R^{scaled} value of the PCC-2 fragment throw table suggests that the underlying theory behind this table is similar to the PCC-2 blast protection methods. By using a Rscaled value of 27 in PCC- 2 equation III-1, a user would obtain very similar exclusion zones to PCC-2 (2015) Table III-2.

Industry incident

In 2009, an explosion happened at the Deep-Water Port construction site in Shanghai [4]. The explosion occurred during a pneumatic test of 600 m of DN900 pipe. The testing pressure of this system was 15.6 MPa, however the explosion occurred at 12.3MPa.

The explosion resulted in 1 fatality and 15 injuries which were caused by the fragments of the exploded piping system. The worker who was fatally injured was 350 m away when he was hit by a scaffolding rod. The remaining injured workers were performing insulation works 100 m away from the explosion location. The exclusion zones are shown in Table 1 below. The killed worker was 350 m away, substantially more than the minimum safe distance. This unfortunate incident indicates that while the (pre-2015) exclusion zones will protect personnel from a blast wave they do not guarantee safety against fragment throw.

Table 1: Exclusion zones in meters from different standards for a 15.6 MPa (est. 544 9 MJ) pneumatic test

	ASME PCC-2 (2011)(1)	AS 3378	ASME PCC-2 (2011)(2)
Exclusion zone	198	200	420

(1) This is the exclusion zone for blast wave per PCC-2 using R^{scaled} = 12 (ear drum rupture). Using a R^{scaled} = 2 (fatality) would require an exclusion zone of only 33 m.

(2) The 2015 edition of ASME PCC-2 introduced Table III-2 (fragment throw).

Fragment throw

ASME PCC-2 (2015) requires minimum distances per Table III-2 when fragments are at risk of being created. If these distances are not achievable, the distance may be evaluated using methods available in the public domain. Two such methods are presented here, F3D Method and Baum's Method.

These methods are for specific piping components only – they do not consider other items in the vicinity (e.g. scaffolding or tools). Both methods are independent of the total stored energy.

Symbols used:

V – velocity [m/s]

P – test pressure [Pa]

A – inside area of fragment on which pressure acts [m2]

D – inside diameter of fragment [m]

R – end cap inner radius [m]

m – mass of fragment [kg]

F – dimensionless initial acceleration [-]

a – speed of sound in test medium [m/s]

F3D Method

This method is suited for analyzing small items on branch connections that could become projectiles if a weld was to fail or a threaded connection suddenly disengaged. The projectile is launched by the pressure acting on it. The method assumes that the pressure force acts on the projectile for a length equal to 3 diameters of the projectile. This is the work done on the projectile and it is all assumed to be converted to kinetic energy. With the energy and mass known, the velocity can be calculated. Simple projectile motion formulas are used to calculate horizontal travel distance. The volume of the major header is deemed so large that there is negligible loss of pressure as the fragment is launched.

The choice of the factor 3 was selected to remain consistent with the factor used by a 3rd party consultancy who performed a study for exclusion zones in the module yards for the project. The literature upon which this method is based [6,7] stated that a value of 2 was more accurate. Thus, the factor of 3 provides a design margin. The initial velocity is:

$$V = \sqrt{\frac{6.P.A.D}{m}}$$

Baum's Method for end caps

The F3D Method is unsuitable when the fragment is the same size as the main header – for example if a the buttweld on an end cap or blind flange was suddenly to fail. The Baum methods [8] calculate realistic upper limit values derived from experimental test data.

A dimensionless initial acceleration F (independent of fragment type) is calculated:

$$F = \sqrt{\frac{P.A.R}{m.a^2}}$$

Different equations are used, depending on the fragment type, to calculate an upper limit velocity. For the fragment type "end cap" the velocity is:

$$V = 2a\sqrt{F}$$

Substituting for F, the initial velocity is:

$$V = \sqrt{\frac{2.P.A.D}{m}}$$

The Baum end cap method is identical in form to the F3D method, except that the Baum method will result in a velocity of $\sqrt{3}$ less than the F3D Method. It could be said that the Baum end cap method is the F3D method using a factor of 1, or perhaps the FD method. Standard tables (Table 2) were developed.

Table 2: Exclusion zones in meters for blind flanges using Baum end cap equations

	Test Pressure [barg]				
	10	21	10	30	60
DN100	19	32	13	29	50
DN300	65	123	40	100	188
DN500	101	194	59	151	288
DN600	122	235	67	173	332
DN900(A)	131	252	74	194	373
DN1200(A)	148	287	126	339	657
	CL-150 Flanges		CL-300 Flanges		

Table 2 can be used to obtain information about whether a system may have components at risk if exceeding the exclusion zone in place for fragment throw. For example in a Cl150 system being tested at 21 bar with a 200 m exclusion zone already in place, only components larger than DN500 require investigation. This could be a variety of options: performing full RT/UT on the at-risk components, locally increasing the exclusion zone or considering how well restrained the component is, i.e. the Baum method assumes an unrestrained flange at the end of a line, but a flange pair within a line would pose a much lower risk.

Table notes:

- Yellow indicates that further investigation is required; 200 m exclusion zone assumed to already be in place.
- Total failure of butt weld on weld neck flange
- Weld neck flange with blind, nuts and bolts ejected as a unit
- Launch parameters 45˚ from 10m
- Baum equations (end cap method) used

Test medium

Air was used for pneumatic testing at the project. The quality of air is an important consideration. The project specification specified "dry clean oil-free air" and that "oil lubricated compressors shall not be used." This was realized to be an unreasonable requirement – high volume, high pressure compressors that are not oil lubricated are extremely difficult (if not impossible) to obtain. The strict definition of dry and oil-free would mean zero oil or water in the air. However, to achieve absolute zero would be impossible.

The corporate piping standard and ASME PCC-2 provide a more reasonable approach by specifying that the air conform to Class 1, 2 or 3 per ISO 8573-1. This allows the user to select the appropriate level of air quality for a tested system. This was the approach ultimately used by the project. Oil lubricated compressors were used, but the air was run through a filter system to achieve Class 0 or Class 1. The major drawback is that there is no practical way to verify air quality at site. The filter vendors provide laboratory reports and certification showing that a filter system met a specified standard, but there is no practical satisfactory way to quantify this at a remote construction site. ASTM D4285 does provide a practical, qualitative method to check for oil in compressed air but is not a very scientific method and is open to interpretation. This presents an opportunity for future revisions of corporate and industry standards.

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Example of a high stored energy test

The pneumatic test with the largest stored energy performed at the project was two 1.4 km long DN750 loading linepipes tested at 34 bar (stored energy 6,675 MJ; 200 m exclusion zone per AS 3788). The air was run through a filtration system to give Class 1 per ISO 8573 Part 1.

A check per ASTM D4285 was performed prior to testing. This test was 25 times the recommended maximum stored energy limit of 270 MJ – observing this limit would have required at least 25 closure welds. Additional factors taken into consideration:

- Piping material was stainless steel 304L, a highly ductile material
- The warm ambient conditions (local night time temperatures are above 15˚C) reduced the probably of brittle failure
- The lines had been hydrostatically tested in module yards at 48 bar (typically in approximately 50 m sections)
- All site hook-up circumferential butt welds received 100% RT/UT per line class requirements
- The energy was distributed over a large area
- Location of the line on a jetty provided a natural exclusion zone and there is only one access point to the jetty
- The Rscaled value associated with this test was above 12 – i.e. no biological effect risk

ASME PCC-2 Article 5.1 § 5.2 mentions relevant factors to consider when performing a detailed hazard analysis – many were applicable to this test. Taking these into account, the risk was deemed to be relatively low despite the high stored energy. Due to the fact that all hook up-welds had received 100% RT/UT and all lines had been tested at 48 bar in sections previously, fragment throw was not deemed a credible scenario. However, if fragment throw was a concern, Table 2 could have been used with linear interpolation (not strictly speaking correct, but acceptable as a first pass estimate) to obtain an estimate for the exclusion zone required for DN750 Cl300 flange assembly at 34 bar: 206 m. This would indicate that further investigation is required.

Conclusion

A major gas project used a risk based approach supported by additional engineering and hazard analysis to conduct high stored energy pneumatic tests up to 6,675 MJ. Methods to estimate fragment throw for specific components were developed based on available literature. These revealed that basing exclusion zones solely on total stored energy can be inadequate. These are the key lessons learned from this effort:

- Attempting to observe a 270 MJ limit will result in an undesirably high number of closure welds
- Avoid unnecessarily tight specifications for purity of test medium – a fit for purpose approach is recommended (e.g. a flare line versus piping going to a cryogenic heat exchanger)
- The authors are not aware of any method to quantify air quality from a compressor
- Extra precautions should be taken to ensure all threaded plugs are properly engaged – the exclusion zones required to guard against fragment throw are impractically large
- For any pneumatic test always consider fragment throw and the blast wave exclusion zones it may be necessary to perform additional NDE or increase exclusion zones
- Accounting for mitigating factors in a hazard analysis may support a high stored energy pneumatic test as an acceptable option

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- **Tom Dang is a piping and valve engineer with Chevron Energy Technology Co. (ETC) - Piping, Valves and Heat Exchanger team.**
- **Jaan Taagepera is Sr. Engineer with Chevron Energy Technology Co. (ETC) with a focus on pressure vessel design and analysis. He is a member of the ASME post Construction Committee and Chair of that committee's Subcommittee on Repair and Testing which has the primary responsibility of developing and maintaining ASME PCC-2, Repair of Pressure Equipment and Piping.**

Hydrogen Rich Sour Gas Processing in HP Unit

In order to avoid down gradation of high value Hydrogen to Fuel gas system, best practice of processing an alternate feed / excess H2 rich sour gas in HP unit as feed was implemented in MAA Refinery.


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Senior Process Engineer

Omair Al-Shammari
Process Engineer

Introduction

Hydrogen unit

Hydrogen Production (HP) units are designed to process High Pressure Fuel Gas, which mainly contains Methane (97% C1), and produce Hydrogen with 97% purity.

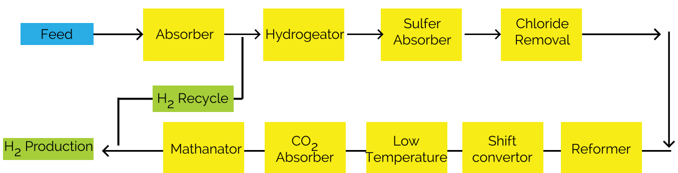


Figure1.1: Block Flow Diagram of the Hydrogen Production Unit

Hydrogen recovery unit

Hydrogen Recovery (HR) Unit is designed to process the following units' off gases:

- ARD off gas
- CCR off gas
- HCR Off gas

These off-gases are fed to the HR unit as H2 rich sour gas, to produce 99.9% pure H2. H2 rich sour gas contains around 70% H2, and the remaining percentage consists of C1, C2, C3+ and H2S. The feed stream is processed in a common feed gas absorber, where H2S removal takes place in order to reduce H2S level to 50 ppm maximum. The HR unit capacity is 130 kNm2/hr of H2 sour gas, with CCR off gases being the main contributor to the HR feed stream.

H2 rich sour gas processing in HP units

During both CCR units shutdown in April/May 2015, HR unit feed was reduced. Therefore, in order to increase the HR unit feed, the second ARD off gas compressor (C-88-051) was started at 100% load. As a consequence, around 10 kNm3/hr of additional ARD off gas (total 32 Knm3/hr.) were routed to the HR unit since 7th May 2015.

After starting of both CCR units in June 2015,

- HR feed gas compressor vibration increased above alarm limit (60 microns) when the total feed to HR unit increased above 120 kNm3/hr (design 125 kNm3/hr).
- H2S to the PSA, downstream of the absorber, increased sharply above design limit (50 ppm) during the first week of July'15 due to ADIP pump problem in ARD Units. High H2S ARD purge gas was routed to H2 rich sour gas header increasing its capacity.

Action taken

In order to avoid H2 product loss from the H2 sour gas stream to the Fuel Gas header, around 13 kNm3/hr of H2 rich sour gas processing started in HP units since the 7th of July 2015. In addition, to ensure that all H2S in the H2 rich sour gas stream is removed in the HP feed gas Absorber, the following actions were taken:

1. ADIP flow to Absorber (V-48-051) increased from 20m3/hr to 28m3/hr.
2. ADIP content in Lean ADIP to HP units was

increased from the design value of 28 wt.% to 32 wt.%.
3. Regular analysis of H_2S in Treated gas/ADIP outlet by MAA laboratory and periodic checking by Operations using lead acetate paper.

Process effect from the implementation of subject opportunity:

- Reducing H_2 losses to fuel gas system
- Stopping the Recycle H_2 in HP unit feed
- Reduction in the LP Fuel gas consumption in HP units.

Conclusion

By processing H_2 rich sour gas in HP unit, the following was achieved:

- Recovering around 10 kNm3/h of H_2 product
- Reducing the LP Fuel gas consumption by 1.06 kNm3/h
- Stopping the recycle H_2 to the feed stream (3 to 5 kNm3/h)
- Enhancing the unit reliability.
- Improving the catalyst life.

The benefit for processing 13 kNm3/h of H_2 rich sour gas in HP units is 0.66 MM$/Month.

Hydrogen Unit

An Approach to Process Management of Change

Changes are inevitable in any processing facilities during both design and operational phases. Proper management of these changes is of utmost importance in order to address the associated risk. Identifying the changes that need careful attention becomes the key for the management of change process.

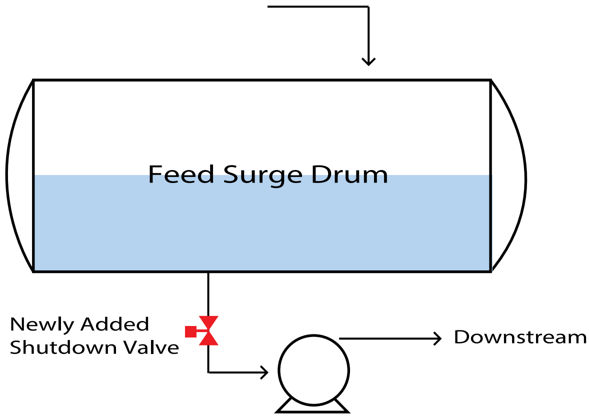
Anand Gupta
TRAC Engineer - MAB

Introduction

A number of incident investigation reports identified that ineffective management of changes (MOCs) is the major contributing factor for the incidents. Consequently, the industry has developed elaborate MOC processes. Nevertheless, in the author's experience, it is still not uncommon to find that the MOC team failed to identify changes that need to be subjected to MOC process or failed to identify all hazards associated with the change under review. This can be attributed to the lack of knowledge of the original basis of design, or insufficient experience. One of the other factors could be that some MOCs introduced new hazards which were not relevant to the original design, and thus were not envisaged. Through a series of case studies, this paper illustrates how following typical MOC procedures/checklists may not be adequate on its own to meet the objectives of such process and significant hazards may remain unidentified.

1. MOC related to addition of new safety devices

Typically, when changes are related to introduction of safety devices to the process, a general mindset would believe that the overall level of the safety will be enhanced and the negative aspects may be overlooked. This is especially true when older facilities are undergoing modernization and safety devices are added following the latest industrial standards.



Example: Introduction of a new shutdown valve (SDV)
System: Feed Surge Drum of a process unit. The feed is received from offsite and is fed to the unit through Feed Pump.

Change: To align with best industry practice, a new SDV is added to the bottom outlet of the Feed Surge Drum. Provision of a remotely operated SDV can help minimize the leak inventory in case of a loss of containment scenario downstream. This SDV can be actuated automatically by Emergency Shutdown (ESD) or Fire & Gas System (FGS).

MOC analysis: It was believed that introduction of the shutdown valve will make the system safer and the MOC process is only adopted to check the effect on pump performance and operating procedure.

Issue/Challenge: The potential issue being overlooked is the possibility of increasing the demand on other safety systems in case of failure of the newly added SDV. Unintentional closure of the new SDV will potentially impact on some of the Safety Instrumented Functions (SIFs), such as High High Level (LAHH) function on the Feed Surge Drum and Low Low Flow (FALL) function at the Feed Pump discharge. The cumulative frequencies of initiating events for both SIFs will likely increase depending on the safe failure rate (s) of the new SDV. This might increase the integrity requirement of the SIFs and, in the worst case (e.g. if the Safety Integrity Level (SIL) increases), may even result in hardware changes to the existing SIFs. Therefore, it is necessary to perform detailed MOC analysis whenever new safety devices are introduced and consider the consequence associated with safe failure of the device. In this example, detailed HAZOP and SIL Classification are mandatory, and if required, SIL Verification and Safety Requirement Specification (SRS) needs to be updated together with all the necessary software and hardware changes to meet the new integrity requirement.

2. MOC related to modification of operating condition

It is fairly common to see changes to operating conditions with the aim to improve the efficiency of the process. Especially when the new operating condition is within the design limit of the original design, it is often believed that no detailed MOC is required. This thinking may be dangerous given plant engineers sometimes might not be aware of all the other limitations of the system even if the operating condition is within the ultimate design condition.

3. MOC related to replacement of parts or materials

Example for replacement of transmitter System: Pressure transmitter on a vessel which is connected to the ESD system and will trigger the PAHH trip function on detection of high pressure. The PAHH trip was rated as a SIL 2 function.

Change: The pressure transmitter is replaced with a new transmitter of alternate make.

MOC analysis: The transmitter's range and design conditions are similar to the original transmitter; hence no MOC process was deemed necessary.

Issue/Challenge: Caution should be taken when replacing any component connected to ESD, especially those rated as SIL 1 or above. Instruments from different manufacturers typically have different failure rates, diagnostic capabilities and manufacturer's recommendation for proof test coverage and interval. Hence if the replacement transmitter has a higher failure rate or lower proof test coverage as specified by the manufacturer, the system requires re-evaluation of SIL verification calculation to ensure that integrity requirements of the SIF are still met. Additionally this also requires updating the Safety Requirement Specification with new information from the Safety Manual of the new instrument.

4. Conclusion

The importance of good MOC is well understood. MOC is one of the routine exercises being practiced in operating plants; hence it is not a new issue for many engineers. However, it is not uncommon to find that some risks are not identified by the initial MOC process and operation is allowed to continue.

Many of the unrevealed risks are often identified during a periodic review such as a revalidation HAZOP. However, in some instances, the risk is only identified after the consequence has occurred (such as the catalyst poisoning example). Therefore, there is always an area for improvement. Many have learnt the lessons the hard way, but by understanding the mistakes in the examples presented in this paper, hopefully it can help you to avoid similar situations in the future.

KNPC Process for Learning from External Incidents

Safety is an evolving field. The users, i.e. line organization, must keep learning and improving all the time to operate their business with sustained profitable outcome and this requires health, safety and environment (HSE) risks to be as low as reasonably practicable. The guiding principle in HSE risk management is to establish control of all relevant sources of hazard.

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Despite all efforts, many organisations have problems in reducing the number of HSE 'incidents,' the combined set of occurrences of both accidents and near misses.

This can be partly attributed to the failure to learn from incidents. Incidents are an outcome of organisational failure causes that should have been addressed.

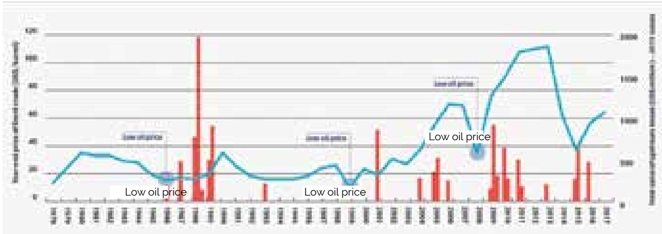
By analysing them to identify organisational failures in preventing those incidents, valuable lessons to learn from are determined. Identifying the unwanted deviations and learning from them leads to safer and more reliable processes, which will result in fewer incidents.

We could learn for free from incidents occurred to others, in recent or distant past. Most importantly, however, reducing risk by learning from incidents means to take 'real' action, and not to just talk about. Use the knowledge and lessons learned (LLs) to bring about actual change in establishing, maintaining and improving control measures.

Oil price versus incidents

Given the challenges that face the energy industry today, from adjusting to a prolonged period of low oil prices, to the new and disruptive technology, the potential for serious incidents or major losses has never been more crucial.

Crude oil price vs upstream losses by year- 1974-2015
Source: Marsh Research



Oil industry loss records

To help bring this information to the industry, insurance broking and risk management company "Marsh" has been collecting and recording data on major property damage losses in the energy industry for the past 25 years, and now has a database with more than 10,000 incidents from across the global industry. This data can support organizations in their hazard identification activities, highlighting the particular exposures relevant to the technologies they are developing and managing these based on historical loss records. This information should be complemented by that collected and recorded on losses and near misses within organizations to further support improvements in risk management practice.

As we enter the era of big data and analytics, loss data is an invaluable resource that enables correlations to be identified between causes of losses, risk management practices, and possible outcomes. Despite the significant efforts in safety design and management systems, catastrophic incidents are still happening. Could it be that the industry is not learning lessons from the past? It is evident that losses with common causes continue to occur across various parts of the industry. (Table 1).

Date	Plant type	Event type	Location	Country	Property Damage (US$ M)
02/11/2016	Exploration offshore	Mechanical damage	Jubilee field	Ghana	450
12/1/2016	Refinery	Fire	Burgondi	Italy	250
01/11/2017	Refinery	Fire	Rwais	United Arab Emirates	1,000
01/30/2017	Chemical	Fire	Pori	Finland	276
03/14/2017	Refinery	Fire	Alberta	Canada	220

Table 1: Largest losses 2016-2017 (Source: Marsh Research)

In many of the cases examined in Marsh report, minor incidents have escalated in an uncontrolled manner to result in major events. The consequences of those events were not significantly mitigated and resulted in major physical damage and other significant impacts.

Using risk-engineering surveys to evaluate risks

Examining past events can help think about the barriers that would have prevented and mitigated these losses. This understanding can then be used to identify potential major hazard exposures, as well as the measures required and their effectiveness in reducing the likelihood of the loss.

Engineers should continue to analyze the experience of accidents and near-miss events to identify any common issues or causes.

As per Marsh report, analysis of risk improvement recommendations made during the course of engineering surveys over the past two years provides an indication of the risk control measures that were considered as being below the best practices in industry (Fig. 1). The dominant topics of the recommendations are "systems of work" (e.g. permit to work, shift handover communication, and MoC) and "inspection" (e.g., staffing levels, competency, philosophy, and data analysis). Focus on "systems of work" as cited in loss reports reflects their critical importance to the safe operation of energy facilities. Furthermore, the study by the Lloyd's Market Association concluded that "mechanical integrity failure" was responsible for 57% of man-made losses.

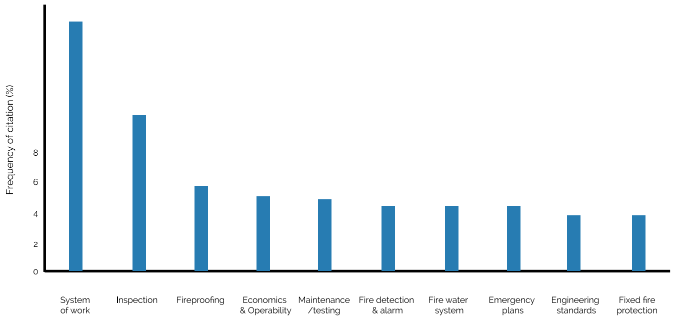


Fig 1: 10 Most commonly cited topics, (by %) 2016-17 (Source: Marsh Research)

Date	Plant type	Event type	Location	Country	Property Damage 1 (US$ M)
07/06/1988	E&p Offshore	Explosion, Fire	Piper Alpha, North Area	United Kingdom	1.960
01/11/12017	Refinery	Fire	Ruwais, Abu Dhabi	United Arab Emirates	1.000+
06/08/2009	Chemical	Explosion, Vapor Cloud Explosion (VCE)	Pasadena, Texas	United States	1,520
03/19/1989	E&p Offshore	Business Interruption	North Sea	Norway	910
03/15/2001	E&p Offshore	Explosion, Fire	Baker, Gulf Mexico	United States	900
09/25/1998	E&p Offshore	Explosion	Roncador Field. Campos Basin	Brazil	850
09/25/1988	Gas Processing	Explosion (VCE)	Sale, Longford, Victoria	Australia	810
04/24/1988	E&p Offshore	Blowout	Enchova Campos Basin	Brazil	760
09/21/2001	Fertilizer	Explosion	Toulouse	France	730
06/25/2000	Refinery	Explosion, Fire	Mna Al-Ahmadi	Kuwait	720
05/04/1988	Chemical	Explosion	Henderson Nevada	United States	690
01/19/2004	Gas Proccessing	Explosion, Fire	Skikida	Algeria	690
04/01/2015	E&p Offshore	Fire	Abktun, Bay of Campeche	Mexico	690
05/05/1988	Refinery	Explosion (VCE)	Norco Lousiana	United States	670
03/11/2011	Refinery	Explosion, Fire	Sendai	Japan	650
04/21/2010	E&p Offshore	Explosion, Fire	Gulf of Mexico	United States	640
07/27/2005	E&p Offshore	Explosion, Fire	Mumbai High North	India	520
11/14/1987	Chemical	Explosion (VCE)	Pampa, Texas	United States	520
12/25/1997	Gas Proccessing	Explosion	Bintulu, Sarawak	Malaysia	510
02/04/2011	E&p Offshore	Business Interruption	North Sea	United Kingdom	500

Table 2: The 20 largest losses 1978 - 2017 (Source: Marsh Research)

Reformulating concept of risk

Risk means possibility of harm, defined in terms of probability of the harm during the lifetime of the plant and its anticipated severity. Risk expressed as R, is thus the product of frequency F and a measure of severity S: $R = F . S$

However, such formula is tenable only when a statistically valid number of incidents is available. When considering a hypothetical case (such as referenced to an isolated case study), i.e. one for which a statistically insufficient number of typical incidents has been reported within the chemical industry, it calls for a reformulation of the risk. The new interpretation of the risk holds that the risk is composed of the fundamental risk Ro and the preventative (technical & organizational) and mitigative measures, P and Q: R = Ro . (P . Q)

Fundamental risk Ro is a combination of material properties, h (e.g. explosive limits, flash point, pH value, reactivity, etc.); specific dangerous material property, e (maximum pressure, fire load, reaction enthalpy, toxicological concentration level or dose, etc.); and the material inventory, M: Ro = h . e . M
Important theoretical limiting cases for safety / risk can be derived directly from this as follows:
Inherent safety: Ro = 0
Integrated safety: P = 0
Additive safety: Q = 0
Worst-case scenario: (P, Q) = 1

The sequential course of an accident or near-miss can also be represented by the above concept of risk. The following basic questions about event analysis are derived from the incident chain of events:

- What happened?
- What caused it?
- What was missing or didn't work that should have prevented it?
- What was responsible for its deterioration?
- What was missing or didn't work that should have mitigated it?
- What were the lessons learned?
- What measures can be derived?

Well investigated reports of external incidents present invaluable resource that enables correlations to be identified between causes of losses, risk management practices, and possible outcomes. The understanding can then be used to identify potential major hazard exposures, as well as the measures required and their effectiveness in reducing the likelihood of the loss.

Case histories

An essential feature of the learning process in safety and loss prevention is the study of case histories (of past incidents). Learning from the incidents is the best tool for incident prevention or loss prevention program as well as it is necessary part of HSE Management system. When something happened around the world and we learn and implement lessons from those, is the finest proactive approach toward HSE improvement and development.
Two types of case histories can be chosen according to one or more of the following criteria:

- The incident is well known, generally by name; Involved major loss of life and/or property;
- The physical events and escalation are of interest and are considered instructive, particularly in respect of the cause. A team workshop approach especially assists in:
- In assessing and uncovering potential risks and taking appropriate action.
- To develop a mental action plan of how to apply the LLs to the groups the representatives belong to
- To alert and instruct regarding any weaknesses in organization's systems.
- To alert and instruct regarding any weaknesses in organization's systems.

There are three main tools used to identify LLs from accidents:

Chronology of an accident

Chronology of an accident is also known as "story telling." It is the re-enactment of a situation based on a chronological series of events. Using this tool is a common and intuitive way to understand and describe what happened. Although effective, it is insufficient for analyzing and understanding all of the causes. If causes are missed, solutions may be ineffective.

Root Cause Analysis

RCA is a systematic process used to identify why an accident occurred and its contributing factors. The results are used to implement corrective actions to prevent recurrence of this event and similar losses.

Defences in depth

The Defences in Depth (DID) (Swiss-cheese model) is based on the layers of defences just prior to the accident that should mitigate the results of the unsafe condition. If the systems defences function as intended, the hazard is controlled and an accident is prevented. Safety deficiencies are represented as holes in the defences to show the importance of reducing or eliminating safety deficiencies. Typical layers of defences in depth are Management system elements, Standards and industry practices, Legal and other requirements, Safe work practices, guidelines, work instructions, Risk Registers.

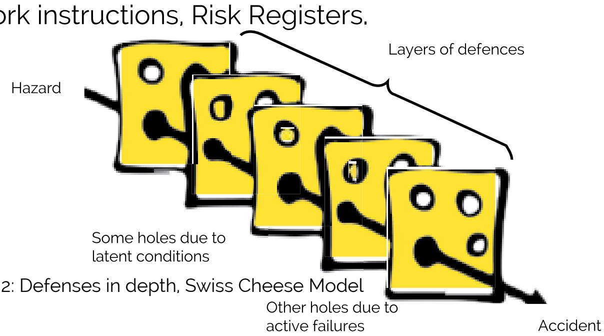


Fig 2: Defenses in depth, Swiss Cheese Model

Learning culture is good safety culture

Safety culture is a widely practiced process and now required by the recently released International Standard ISO 45001:2018 on Occupational Health and Safety Management System. It's clause on Leadership and Commitment puts onus on Top Management to develop, lead and promote a culture in the organization that supports the intended outcomes of the OHS management system.

Safety culture is the collection of the beliefs, perceptions and values that employees share in relation to risks within an organization, such as a workplace or community. Safety culture is a part of organizational culture, and has been described in a variety of ways. The Chernobyl disaster highlighted the importance of safety culture and the effect of managerial and human factors on safety performance. The term 'safety culture' was first used in International Nuclear Safety Group's 'Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident' (1986).

Among the most important factors of a 'good' safety culture is continuous organizational learning through practices such as feedback systems, monitoring, and analysis. A broken safety culture is responsible for many of the major process safety disasters that have taken place around the world over the past 20 years or so. Typical features related to these disasters are where there had been a culture of «Ignoring lessons learned», where safety critical information was not extracted, shared or enforced.

A good safety culture can be promoted by senior management commitment to safety, realistic practices for handling hazards, continuous organizational learning, and care and concern for hazards shared across the workforce. The Keil Centre under Health & Safety Executive, UK, developed the Safety Culture Maturity Model (SCMM) to facilitate objective discussion about safety culture and to identify specific actions to improve safety culture. One of key elements of the ten elements of SCMM is Learning organization.

The Safety Culture Maturity Model ladder divides culture into fuve categories:

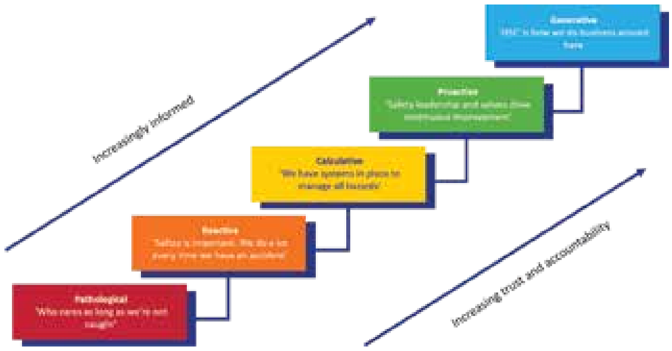
Generative: organizations set very high standards and attempt to exceed them. They are 'Learning Organizations'. They use failure to improve, not to blame. Management knows what is really going on, because the workforce tells them. People are trying to be as informed as possible, because it prepares them for the unexpected. This state of (chronic unease) eflects a belief that despite all efforts, errors will occur and that even minor problems can quickly escalate into system-threatening failures.

Proactive: moving away from managing HSE based on what has happened in the past to preventing what might go wrong in the future. The workforce starts to be involved in practice and the Line begins to take over the HSE function, while HSE personnel reduce in numbers and provide advice rather than execution.

Calculative: focus on systems and numbers. Lots of data is collected and analyzed, lots of audits are performed and people begin to feel they know "how it works". The effectiveness of the gathered data is not always proven though. Effectiveness of learning is not evident.

Reactive: safety is taken seriously, but only after things have gone wrong. Managers feel frustrated about how he workforce won't do what they are told.

Pathological: people don't really care about HSE and are only driven by regulatory compliance and/or not getting caught. Learning process is poor.



Learning organizations

A learning organization is a company that facilitates the learning of its members and continuously enhances their capacities to create results and transforms itself. Organizations do not organically develop into learning organizations; there are factors prompting their change. As organizations grow, they lose their capacity to learn as company structures and individual thinking becomes rigid. When problems arise, the proposed solutions often turn out to be only short-term and re-emerge in the future.

A learning organization is not cultivated effortlessly. It arises from a series of concrete steps and widely distributed activities, not unlike the workings of business processes such as logistics, billing, order fulfillment, and product development. Learning processes involve the generation, collection, interpretation, and dissemination of information. They include disciplined analysis and interpretation to identify and solve problems; and develop both new and established employees.

For maximum impact, knowledge must be shared systematically and clearly. Sharing can take place among individuals, groups, or whole organizations. Knowledge can move laterally or vertically within a firm. The knowledge-sharing process can be internally focused, with an eye toward taking corrective action.

Perhaps the best-known example of this approach is the U.S. Army's After Action Review (AAR) process, now widely used by many companies, which involves a systematic debriefing after every mission, project, or critical activity. This process is framed by four simple questions: What did we set out to do? What actually happened? Why did it happen? What do we do next time? (Which activities do we sustain, and which do we improve?) In the army, lessons move quickly up and down the chain of command, and laterally through sanctioned websites. Then the results are codified. Such dissemination and codification of learning is vital for any organization.

Organizations have no memory

Widely acknowledged guru of Process Safety Management Trevor Kletz wrote that Organizations do not learn from the past. It is rather, individuals within those organizations that learn. However, they leave the organization, by promotion, transfer, reassignment, retirement and resignation. The individuals take their knowledge with them, and the organization as a whole forgets.

Organizations thus have no memory. This process needs to be established, maintained and improved. For accidents not to recur we need to have a 'corporate memory program'. The history needs to be remembered, recovered, and where necessary 'invented'. Following are some principles of 'Organizational Learning:

- Make efforts to improve the corporate memory – have a structured process in place
- Management participation and support, allocate priority
- Spread the message to employees, contractors and stakeholders
- Discussions are better than lectures – utilize communication means
- Remembering the message repeatedly
- Finding and discussing old reports from the company and outside

Gathering LLs from major incidents

A traditional approach to learning from incidents is that when an analysis is performed with care and lessons are formulated, this will lead to the prevention of incidents. However, learning from incidents should not only focus on preventing recurrence, but also on making an organisation inherently safer and on improving the learning from incidents process itself. Effective learning from incidents entails follow-up steps and actions that lead to effective interventions. Moreover, the learning process itself should be evaluated. To improve the learning from incidents process, it is necessary to gain insight into the steps of this process

This is essentially a five-step process:

- Reporting & registration of incidents
- Analysis of the incident, understanding and determination of root causes
- Generation of realistic recommendations
- Implementation of recommendations
- Evaluation of effectiveness

To improve learning, an approach that considers all steps is necessary. Consequently, there has to be feedback loop on each step and to locate any steps where learning potential is lost.

Our efforts

Health Safety and Environment Department at KNPC recognizes the importance of organizational learning and has put in place systems and programs to ensure the same. Some notable among them are:

- Establishment and adoption of standards
- Safe work practices and guidelines
- HSE website on company intranet
- LLs repository
- Seminars and workshops
- Center of Excellence - HSE
- HSE moments
- Incident Alerts
- KNPC Procedure

KNPC has established a procedure for management of LLs that is intended to have in place uniform and systematic approach to share and implement the LLs from KNPC as well as external incidents, have in place a committee to derive recommendation for implementation of LLs to relevant areas at KNPC, and maintain database for LLs.

LLs identification internal incidents

Like most of the companies in high hazard industry, incidents occurring within KNPC are reported, investigated and lessons disseminated through a structured process. The process is known as Incident Reporting and Investigation procedure.

External incident identification

What KNPC has something very special is a highly structured process to deal with external incidents. These are the incidents occurring in other companies, in some other part of the world, and sometime entirely different industry but present a potential for KNPC to improve its systems, processes and/or practices.
Such sources may include other K-companies, other refineries, oil & gas business, chemical industries, project and construction industries, power industries and in general, incident throughout the world which is having a learning value.

HSE Department identifies the incidents through the various sources like trade publications, media news, websites, and individual or company membership of professional associations and discussion groups, etc. Reports published in public domain by investigative agencies such as US Chemical Hazard Investigation Board, UK Health & Safety Executive, and Indian Oil Industry Safety Directorate make invaluable resource. Any employee can identify an incident to use it as LLs and communicate to the HSE Department.

Pre-evaluation of incidents

Identified HSE personnel pre-evaluate the incidents and screen for their potential for KNPC to learn some valuable lessons. Great emphasis is placed to what quality and detail the investigation report offers. Sometime even voluminous reports prepared by even government appointed bodies offer low quality root cause analysis and findings, failing to go beyond their biases and compulsions.

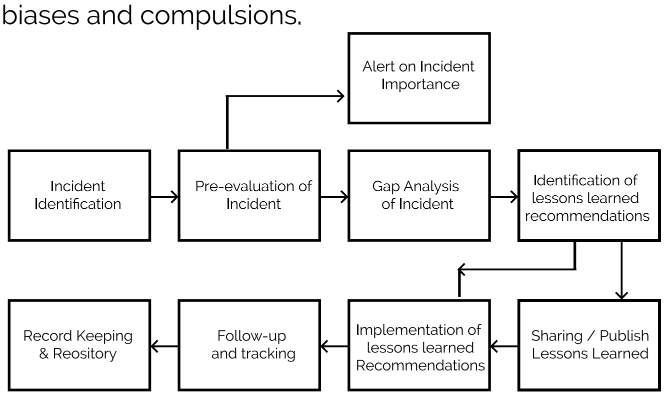


Fig 5 Five step learning process

Analysis of incident by Committee

A multi disciplined Lessons Learned Analysis Committee (LLAC) is established to perform gap analysis with respect to KNPC business, identify specific recommendations/findings and issue detailed consolidated report. The committee consists of senior members from technical departments representing various functions and specialties, nominated by respective Department Manager.

Functions of LLAC

The committee is tasked with conducting quarterly meeting, study pre-evaluated incidents and re-evaluate for LL consideration, identify recommendations applicable to KNPC, and identify the action items for each department/division for further gap analysis/ field survey/ input requirement from other subject experts. The LLAC also conducts follow-up meetings other than regular meeting until preparation of final, prepares recommendation report for particular incident, issues detailed recommendation report with clear action items for respective Site/Department/Division, follows-up for action items/recommendation and discuss the progress in subsequent meetings.

Roles and responsibilities of LLAC members

The member serves as a subject expert to the committee, and provides relevant professional opinion with reference to standards/ practices/ procedures.
If a member does not have the concrete idea/ opinion on certain issue, (s)he can refer or take help from the other experts/relevant personnel outside the committee in order to provide technically correct input. The member also serves as the site/ department representative based on the incident and gap analysis requirement; (s)he may coordinates with other departments as assigned.

Implementation of LL recommendation

Based on the outcome of LLAC deliberations, HSE Department prepares LL publication in a standardized format stating brief description of incident, what went wrong, what we can learn & implement in the company business, and Site/Department/Division wise recommendations to implement the LL. The recommendations include specific action owner/ responsible Dept./Div., and target completion date for each action item. This detailed report is issued to all the identified action owners to initiate action and enter in eRTS.

Respective action owner/responsible Manager/ TL are required to implement the recommendation within prescribed time limit and update the implementation status in eRTS.

Communicating the LLs

As part of the standardized report a synopsis is issued highlighting the incident, major lessons for KNPC and functions and trades that need to pay attention to. All Team Leaders/ Section Heads/ Area engineers/ Shift Supervisors are required to share the lessons to employees and contractors through following communications means:

QHSE management review meetings, Department/ Divisional QHSE communication meetings, Site Operations meetings, Tool box talks, job briefing meeting, e-mail, display on noticeboard

Team Leaders may even arrange training classes internally on LL for their Division/ Shift personnel.

HSE Department shares the LL through several means, such as:

- Popup
- Webmaster email
- Uploading on HSE Portal
- Seminar/ workshop / special training
- Revision of procedure/ training course
- Actions as identified by the committee

Follow up and tracking

The application eRTS is used for follow-up and tracking for implementation of recommendations of LL. HSE Department follows-up for eRTS entry and update of status in eRTS periodically. The process is periodically audited to ensure the system is functioning effectively and continually improving. Key performance measures are presented before the management for their review and recommendation.

Records & repository

The committee maintains the necessary record of sharing LLs, MoM, recommendations closure action, and attendance sheets. HSE Department maintains record of incident data, publications, implementation status report and other relevant documents.

All the relevant popup, presentations training material and database are made available on LLs portal.

Responsibilities

Managers & Team Leaders

- Encourage employee for LL identification
- Nominate required personnel for LLAC
- Share LLs to all concerned staff
- Send staff to attend LLs workshop/ training/ meetings
- Implement identified recommendation for respective Dept./Div.
- Update the recommendation status in eRTS timely

Employees

- Provide input for Lessons LLs from external sources in prescribed format
- Attend LLs workshop/training/meetings
- Implement LLs in day to day jobs
- Provide timely update on recommendation implementation to the Management

Conclusion

Wanting to learn from errors and failures means wanting to improve continuously. Failures that come to light in the process may have a long case history, because running plant has its origin in a product idea. This product idea passes through research and development, feasibility study, front-end engineering, planning, procurement, construction, and commissioning until safe operation is achieved. The operation itself is supported by maintenance, inspection, training and development, support engineering, quality control and other management processes. Many people work in this process chain, and therefore it is worthwhile to convert LLs from incidents into understandable knowledge and concentrate on the specific needs of the participants in the process chain. Technology can help to place these experiences, discoveries, and knowledge within immediate reach of everyone, identify his/her concern, and make them directly available.

Key Takeaways

- Failure to manage a business sustainably can be attributed to failure to learn from incidents.
- Lessons are not learned until some actual changes are effected.
- Loss data is an invaluable resource to control risk. Marsh report 2018 indicates risk control measure during the past two years have deteriorated.
- Risk is composed of fundamental risk, and preventative and mitigative measures. Story telling is not the same as learning from case studies. Events need to be analysed to determine root causes to strengthen defences in depth, evaluate ones own preventative and mitigative barriers.
- Learning organization is cultivated by taking concrete steps.
- Organizations do not learn from past. Individuals learn but they leave. Organizations have no memory. The process needs to be established, maintained and improved.
- Good safety culture demands continuous organizational learning, not ignoring the lessons learned.
- Organization's learning process must include periodic evaluation of the learning process itself.
- It is worth while to convert lessons learned from incidents into understandable knowledge and concentrate on specific needs of participants in process chain.
- KNPC has a structured process for learning from external HSE case studies. A multidiscipline committee operates under the facilitation of HSE Department.

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