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From the Desk of the

Director General

Greetings from the Federation of Indian Petroleum Industry (FIPI)!

As I start writing this section, India and the rest of the world is still grappling with the biggest and worst of its kind of health crisis human kind has seen in over a century. Apart from the tragic loss of lives, the sudden collapse of economic activity resulting from the COVID-19 pandemic is unprecedented. It appears that until a vaccine is developed, the world may have to live with the virus. However, even during these difficult times, it is imperative that businesses must continue uninterrupted while observing the necessary precautions and prioritizing social distancing.

The pandemic, which has already claimed over 10 lakh lives globally by the end of September, has had a debilitating impact on the world's economy. A recent UNCTAD report indicates that the global economy is set to contract by 4.3 per cent in 2020, leaving global output by year's end over USD 6 trillion short of the pre-COVID estimates. The most significant economic and social damage due to COVID will be in the developing world, where levels of informality are high, commodities and tourism major sources of foreign exchange, and fiscal space has been squeezed under a mountain of debt. The pandemic is expected to push between 90 to 120 million people into extreme poverty in the developing world. While the global economy has now started coming back on track, the recovery is not uniform across geographies.

The India story on economic front has not been very different either. As result of the COVID inflicted lockdowns, the Indian economy is expected to see significant contraction in 2020. By September end, the number of new COVID-19 cases has witnessed some fall. Some experts are of the opinion that the country has already seen its peak and the numbers are only set to fall from these levels. Green shoots of recovery were clearly visible in the Indian economy by the end of September. ICRA report shows that rail freight traffic recorded an expansion after contracting for four straight months till July. The agricultural sector in the country has emerged as a pillar for the Indian economy during these difficult times. Most experts believe that for India to chart a speedy recovery, the agricultural sector in the country will have to play a crucial role. In this direction, the recently introduced farm reforms will go a long way in further strengthening the agricultural sector in the country.

The oil and gas sector was among the worst hit sectors due to the spread of COVID – 19. The COVID induced lock down in the country brought down the sales of petroleum fuels in India by as much as 75 per cent in April. While the consumption of diesel dropped by over 70 per cent that of ATF fell by as much as 90 per cent during the month. The fuel consumption in the country has made a significant recovery since. In the month of September, consumption of gasoline is already 2 per cent above the previous year. Diesel consumption, which is also seen as a broad representative of a country's economic performance, has also risen by 15 per cent over August, and now is 94 per cent of the pre-COVID levels. Consumption of ATF has already grown 15 per cent from the August levels, but still remains 60 per cent below the pre-COVID levels.

As the old adage goes, adversity is the true test of character. With immense pride I inform you that during the COVID inflicted lockdown, the oil marketing PSUs pushed profit making to the back seat and ensured seamless supply of fuel and LPG at great personal risk. During lockdown, our OMCs provided free LPG cylinders to over 8 Crore underprivileged households under the Pradhan Mantri Ujjwala Yojana (PMUY). The fuel supplies to all the essential services were also maintained during the lockdown. LPG has emerged as the only fuel to record continuous growth through the period, recording 12 per cent higher consumption than last year. It is expected that the consumption of most petroleum fuels in the country will surpass the pre-COVID levels by the end of the year 2020.

During the pandemic, OMCs quietly rolled out BSVI petrol and diesel which should help to reduce emission. In another recent move, the Government of India has also allowed for 18 per cent Hydrogen blend in CNG as automobile fuel (H-CNG). We strongly believe that this will significantly lower emissions and promote the use of greener fuels for transportation in the country. Though H-CNG an interim step, it is a move towards Hydrogen Economy.

It is worth mentioning here that despite an otherwise gloomy global market outlook, the oil and gas sector in India achieved some major milestones during the year. The new fuel retail policy has now eased the entry requirements for fuel retail business to a minimum net worth of INR 250 crores. This will go a long way in attracting private investment in the country's fuel retail market.

During the second quarter of FY 2020-21, FIPI was at the forefront advocating for the industry issues and pain points with all relevant stakeholders. FIPI has been highlighting the issues faced by the industry in the aftermath of COVID lockdowns and the support required across the oil and gas value chain for the sector to cope up with these challenging circumstances. In line with this and in consultation with its members, FIPI shared inputs on the proposed draft amendment relating to determination of unified tariff with the Ministry of Petroleum and Natural Gas (MoPNG). In light of the falling natural gas prices in the international markets, the present domestic gas pricing formula, which is indexed to international markets, is yielding extremely low prices making domestic production of gas unviable. Taking account of the situation, FIPI has requested the Government to review the domestic gas pricing mechanism.

At FIPI, we firmly believe that any policy decisions must be based on well informed and rigorously established objective evidence. In line with this, during the second quarter, FIPI has completed the report on 'Natural Gas for Power Generation' with KPMG as knowledge partner. The report explores the various ways natural gas could be made viable for power generation in the country. To discuss the report, FIPI had organized a workshop on 'Reliable 24X7 Power Supply Through Clean Energy' on 14 August, 2020. The workshop was attended by Mr Amar Nath, JS, MoPNG; Mr S K Chatterjee, Chief – Regulatory Officer, CERC; Mr Ghanshyam Prasad, JS, MoP; Mr S K Mishra, Director, SECI and Mr Rajesh Mediratta, Director, IGX among other dignitaries. The workshop witnessed overwhelming participation and interest from both natural gas and power industry in India.

FIPI organized a 'Young Professional's Forum: Leadership in Times of Transition' on 20th-21st August 2020. The Forum marked the biggest event of the Young Professionals in the energy sector taking place over a virtual platform. The Forum was addressed by Mr Tarun Kapoor, Secretary, MoP&NG who was the Chief Guest. Eminent Speakers list included Mr. Prabhat Singh, Managing Director & CEO, Petronet LNG; Mr. Sashi Mukundan, Regional President and Head of Country, India, BP Group; Mr. Vipul Tuli, MD, Sembcorp; Mr. Mahesh Kolli, CEO, Greenko; Mr. Maheep Jain, Executive Director, EverSource Capital and Mr. Gautam Reddy, MD, India and Bangladesh, Schlumberger amongst other industry professionals. The event witnessed an overwhelming participation from over 500 young professional from across the Indian oil and gas value chain.

FIPI partnered with ET Energy World to organize a 'Virtual Summit on City Gas Distribution'. The Summit witnessed stalwarts from the Indian CGD industry discussing the challenges faced by the sector in realizing the Hon'ble Prime Minister's vision of increasing the share of gas to 15 per cent in the Primary Energy Mix.

In addition, during the last quarter, FIPI partnered with many reputed organizations to organize webinars on key issues relevant to the industry. FIPI partnered with Global Counter-Terrorism Council (GCTC) in association with the Ministry of External Affairs, Central Board for Irrigation & Power (CBIP) and MitKat Advisory to organize 'Energy Security Conference'.

FIPI joined hands with the Confederation of Indian Industry (CII) and Hydrogen Association of India (HAI) to organize webinar on "Hydrogen-The Time is Nearer". The webinar deliberated on the future role and prospects of hydrogen in India's energy mix.

As the health and safety issues are at forefront, FIPI jointly with Environics and Breathe Easy organized a webinar on 'Enhance Workplace Wellness and Personal Immunity'. The webinar was aimed at raising public awareness about healthy workspaces and ensuring immunity during the ongoing pandemic.

When we emerge from the ongoing crisis, the world will be a very different place. We are already witnessing a number of these changes in our everyday life at home and at work places. With new digital technologies, people are now discovering that they could collaborate and connect with each other while working from home. Employers are also discovering that their employees could be just as productive, if not more, while working from home. Many organizations in oil and gas sector are now realizing that digital technologies are not another 'good to have' option any more but an imperative to keep up with the changing business environment. In the post-COVID world, technologies will play a key role in helping oil and gas companies adapt to the new normal which will enhance productivity, profitability & Safety.

We all have lived through difficult economic crises in the past and have emerged stronger and more resilient. The coming few months may prove difficult but Indian oil and gas companies are well placed to weather this storm and learn fruitful lessons during this period to make their businesses more robust. Going forward, they will have to prioritize the health and safety of their employees only as much as ensuring profitable business operations. I am confident that like all previous pandemics, the COVID-19 crisis will pass and in time to come, we will see a new wave of energy in the transformed way of working which will the new normal.

On behalf of the Federation of Indian Petroleum Industry, I want to thank all our Members for their continued support, trust and confidence. I take this opportunity to reassure you that FIPI will always be at the forefront advocating for a supportive policy ecosystem for the larger good of the nation.

Wishing you & your family a very happy and prosperous festive season ahead.

Dr. R. K. Malhotra

FEDERATION OF INDIAN PETROLEUM INDUSTRY

CORE PURPOSE STATEMENT

To be the credible voice of Indian hydrocarbon industry enabling its sustained growth and global competitiveness.

SHARED VISION

- A progressive and credible energy advisory body stimulating growth of Indian hydrocarbon sector with global linkages.
- A healthy and strong interface with Government, legislative agencies and regulatory bodies.
- Create value for stakeholders in all our actions.
- Enablers of collaborative research and technology adoption in the domain of energy and environment.
- A vibrant, adaptive and trustworthy team of professionals with domain expertise.
- A financially sel -sustaining, not-for-profit o ganization.

For more details kindly visit our website www.fipi.o g.in

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NATURAL GAS

Imbalance Management Services in the Natural Gas Pipelines for India: Way forward

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Petroleum and Natural Gas Regulatory Board

Government of India has a stated vision to transition India to a gas-based economy, increasing gas penetration in primary energy mix from existing about 6% to 15% by 2030. Expansion of gas infrastructure and offering affordable supply will be the key to unlocking the gas demand in India. The total natural gas pipelines laid in the country is 16,944 kms and another 15,579 kms are under various stages of execution. The total capacity of operating LNG terminals is 42.5 MMTPA and that of upcoming terminals is 34 MMTPA. India was the fourth largest importer of LNG in 2019, after Japan, China and South Korea, catering about 53 per cent of gas demand. Due to decrease in domestic gas production and increase in gas consumption, import dependency on gas has been steadily increasing from FY 2011-12 to FY 2019-20. These statistics from PPAC clearly show an upward trend in the imports of LNG.

Import of Liquefied Natural Gas (MMTPA)									
Year	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Total LNG Imports	13.6	13.3	13.4	14.0	16.1	18.8	20.7	21.7	25.6
LNG Imports (% of total gas consumption)	28	31	34	36	41	45	46	47	53

Source: PPAC – LNG importing companies and DCIS. Expansion of Gas infrastructure

Petroleum and Natural Gas Regulatory Board (PNGRB), is taking proactive steps to boost the natural gas consumption in the country. After 9th and 10th City Gas Development bidding rounds in the country, 136 Geographical Areas (GAs) were awarded resulting in total 230 GAs in the country covering about 71% of the population and 53% geographical area in the country. In addition, PNGRB is streamlining and continuously evolving its regulations to support development and ease of doing business in the Indian Gas Market. Key for the development of any gas Market is increase in liquidity and development of short term gas market. Towards this, certain reforms are underway which are:

1. Establishment and operation of regulations of a Natural Gas Trading Hub

The Central Government, vide a Policy Directive has assigned the function of regulating the establishment and operations of gas trading exchange(s) to PNGRB which is expected to secure equitable distribution and increase availability of natural gas by creating a free gas market to usher in a gas based economy in the country. PNGRB recently webhosted Gas Exchange Regulations for public comments and conducted an open house to finalize the regulations.

2. Rationalization of Natural Gas Pipelines Tariff

While making tariff regulations, PNGRB is required to safeguard the consumers' interest and at the same time allow recovery of cost of transportation to pipeline entities in a reasonable manner. Towards this, PNGRB has webhosted drat unified tariff Regulations for public comments and conducted an open house to finalize the regulations. The objective of unified tariff is to make gas affordable in all parts of the country, the creation of infrastructure would get a boost as customers would no longer have to pay additive tariffs of multiple pipelines if they are not located near a gas source. This would also encourage customers to switch over to consumption of gas a fuel as there is a switching cost involved in moving from more traditional sources of fuel to gas. Thus, the creation of customers their willingness to pay the new rationalized tariff structure would provide a much-needed boost to the infrastructure creation within this industry.

While many such reforms are underway, and are in advanced stages of completion, for the sake of brevity, the above should suffice in giving a clear signal to the readers, the industry, and the consumers that the regulatory body is taking a forward looking approach and is making all out efforts in increasing the consumption of gas in the energy basket and reaching the targets that the Honourable Prime Minister has set out for us.

In order to give a fillip to the gas exchange that has recently come online as well with a view to utilise the idle capacity of natural gas pipelines in the country, PNGRB is deliberating on the inclusion of certain additional services under Imbalance Management Services Regulations which were notified by PNGRB in the year 2014.

PNGRB constituted an industry committee to review the imbalance management services regulations and expand the scope of Imbalance Management Services in line with global practices. Expanding the Imbalance management services will not only promote the short-term gas market but would also provide more options to the shippers for managing their imbalances.

What is Gas Imbalance?

Gas Imbalance is a phenomenon when there is a mismatch between the quantity of gas received at Entry point and delivered at Exit Point. If the shipper off-takes less quantity of gas from the pipeline system than injected into it, then, the shipper is creating positive imbalance and if shipper off-takes more quantity of gas from the pipeline system than injected into it, then, the shipper is creating negative imbalance. PNGRB Access Code regulations provide to levy a penalty of one-half the transportation charges on the shippers beyond the tolerance limits for creating positive or negative imbalances in the pipelines.

PNGRB, therefore, with a view to giving transporters and shippers an opportunity to manage their imbalances introduced the Imbalance Management Service Regulations in 2014. As per these regulations, transporter can provide imbalance management services (IMS) namely Deferred Delivery Service (DDS) to facilitate all the shippers on its pipeline to manage transportation imbalances. For providing these services, transporter may charge a fee which shall not exceed 25% of the applicable transportation tariff (declared by PNGRB). For this purpose, a deferred delivery service is one under which a transporter and a shipper, under a separate agreement, agree on a day-wise plan for receipt of the shipper's natural gas quantities into the pipeline and for its delivery by the transporter to shipper on a deferred basis after a few days subject to pipeline capacity availability. This enables the shippers to manage demand supply fluctuations and to optimize their business operations. The present regulations that offer DDS alone are effective until 31.10.2020.

It was felt that the gas market in India has reached the next level of maturity and therefore various Imbalance management services that are offered internationally in the matured markets be looked into. US and European Union have been chosen as suitable models for this purpose. As these markets are more mature than our gas market, it was felt that closer analysis of these would give sufficient direction to crystallize the way forward for the Indian environment.

European Commission

The European Commission Gas Balancing code focuses more towards promoting short term gas market; therefore codes prefer settlement of gas imbalances through the transparent short-term products like intra-day or day ahead market. The code resorts to other balancing services only if these short-term products are not feasible technically or financially. The major objective of the Gas Balancing code is to facilitate gas trading across balancing zones thus contributing towards the development of market liquidity and to give network users the certainty that they can manage their balance positions in different balancing zones throughout the Union in an economically efficient and non-discriminative manner. The major features of the Gas Balancing under the code are as below:

a. General Principle of Balancing System:

The network users shall be responsible to balance their balancing portfolios in order to minimize the need for transmission system operators to undertake balancing actions set out under this Regulation. The transmission system operator (TSO) shall undertake balancing action to maintain network within operation limit and to achieve end of the line-pack position with economic and efficient operation of the network.

b. Balancing Period:

EU regulations provide for balancing settlements on day end basis. However, there is provision for intra-day (before day end) settlement with the special approval of the national regulatory authority.

c. Imbalance Charges (IMC):

Imbalance charges are linked to the Gas price and shall take account of the prices associated with TSO's balancing actions, if any, and of the small adjustment. The same are calculated on the following principle

1. Negative Imbalance:

For buying gas (by shipper), price would be the higher of a) highest price of any purchases of gas in the transmission system operator network in respect of the gas day or b) the weighted average price of gas in respect of that gas day, plus a small adjustment.

2. Positive Imbalance:

For selling gas (by shipper), price would be the lower of a) lowest price of any purchases of gas in the transmission system operator network in respect of the gas day or b) the weighted average price of gas in respect of that gas day, minus a small adjustment.

There is a principle of neutrality followed in the European Union which states that the TSO shall not gain or lose by the payment and receipt of daily imbalance charges. TSO shall after adjusting reasonable cost incurred in the balancing activities pass on the revenue or cost due to balancing actions to the network users.

The neutrality charge for balancing shall be paid by or to the network user concerned. The national regulatory authority shall set or approve and publish the methodology for the calculation of the neutrality charges for balancing, including their apportionment amongst network users.

d. Tolerance Limits:

Tolerance limits are the limits within which, network users are allowed to keep the imbalances provided the same is not impacting the pipeline operations. In order to maintain discipline among shippers, tolerances may only be applied in the European Context in case network users do not have access to the following:

1. Short term wholesale gas market that has sufficient liquidity;
2. Gas required to meet short term fluctuations in gas demand or supply; or
3. Sufficient information regarding their inputs and off-takes.

Tolerances shall then be applied:

4. with regard to network users' daily imbalance quantity;
5. on a transparent and non-discriminatory basis;
6. only to the extent necessary and for the minimum duration required.

e. Imbalance Management Services (IMS):

Following are some of the services allowed in EU for managing the imbalances.

1. Line-pack flexibility:

A transmission system operator may offer line-pack flexibility service to network users. The line-pack flexibility service shall be limited to the level of line-pack flexibility available in the transmission network.

Gas delivered to and off-taken from the transmission network by network users under this service shall be taken into account for the purpose of calculation of their daily imbalance quantity. The revenue neutrality mechanism shall not apply to the revenue from line pack flexibility service unless otherwise decided by the national regulatory authority. Presently in India, this is being offered as Deferred Delivery Service.

2. Trading of Imbalance Portfolios:
Network users can trade their balancing portfolios during the day. They have to provide the information to the TSO with all the required details within the specified timelines.

3. Short term Standardized Product (Cash out):
TSO plays the role of settling the imbalance quantities with the help of the Short-Term Standardized product. The short-term standardized products shall be traded for delivery within a day or on a day ahead basis seven days a week. TSO has to give priority to short term standardized products for balancing actions over the other balancing services.

f. Information Obligation of Transporter:
TSO is required to provide information to its users to support the network user in managing its risks and opportunities in a cost-efficient way.

United States
The regulatory authority for management of such Imbalances is the Federal Energy Regulatory Commission (FERC). Broadly the general policies of FERC are:

1. A pipeline entity assessing imbalance penalties on its shippers must make imbalance Management Services available to the shippers;

2. Before imposing imbalance penalties, the pipeline entity must allow its shippers to net and trade imbalances;

3. Imbalance penalties are not required, but if they are assessed by a pipeline entity, imbalance penalties may only be assessed where necessary to ensure system reliability.

4. A pipeline entity that assesses imbalance penalties must provide to shippers, on a timely basis, as much information as possible regarding the imbalance and overrun status of each shipper and the entire pipeline system imbalance; and

A pipeline entity that assesses imbalance penalties may not retain the penalty revenues, but must credit the penalty revenues (net of costs) to the non-offending shippers.

In addition to the regulatory scenario in these two countries, the evolution of Imbalance management, which is called deviation settlement mechanism in the Power Sector has also been examined. Notwithstanding the mechanism involved, it has been found that the band of intolerance for imbalances was slowly compressed over time and that eventually lead to market maturation and a reduction in deviations.

The above principles were studied with the prevailing practises in which the following Imbalance Management Services are being offered across various countries. These are explained as below:

a. Parking & Lending:
In Parking Facility, shipper can leave gas into the pipeline system and in Lending, shipper can take gas from the pipeline system on loan. This would provide the opportunities to the shippers in managing their gas portfolios and avoid imbalance penalties. These opportunities would also create some liquidity in the short-term gas market and would be useful for development of the short term gas market.

b. Netting and Trading:
Netting will facilitate shippers to adjust their imbalance portfolios under different Gas Transmission Agreements with the transporter. Similarly, in trading option, Shipper can trade their imbalance portfolios with other shippers on the network. These activities should result in the reduction in the overall imbalances of the shippers.

c. Line Pack Flexibility:
This service is similar to Parking and Lending; however, this service is restricted to only the shippers of the network and is carried out between transporter and individual shippers by allowing shippers to avail of the line pack of the transporter to the extent it does not impact the operational integrity of the pipeline.

d. Operational Balancing Arrangement (OBA):
An OBA is signed between the interconnected gas pipeline transporters, wherein all properly scheduled quantities are deemed as delivered and

any difference between scheduled and measured quantities at points, are covered by the OBA between the interconnecting parties at that point. All imbalances at the interconnect point are operational imbalance and needs to be cured only by the parties of OBA.

While these are being offered by transporters in other countries, the adaptations of these product offerings, and the fleshing out of the relevant regulations in the Indian context, taxability and other issues would be a detailed exercise involving various consultative procedures. These processes are already in the pipeline, which will be webhosted for public comments and we can expect some outcome of these detailed deliberations in the near future that would benefit the industry by developing the short term market, increase in utilisation of natural gas pipelines and widening the opportunities to shippers to cure their imbalance penalties and incentivise those maintaining the system discipline.

NATURAL GAS

Key Features of Liberalized Gas Markets - International Experiences

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Federation of Indian Petroleum Industry (FIPI)

The process of gas market liberalisation is intended to generate benefits for consumers through efficient and competitive market structures and processes. In a liberalised market, competitive pressures drive both producers and retailers to increase efficiency and reduce costs to be able to compete on price and service. Also, in order for competition to develop, there needs to be competing gas sources supplying the wholesale market and a number of companies that compete in the end user market. A competitive market will drive the following desirable behaviour from the market participants.

- Producers will look to develop new sources of supply at minimal cost and use existing sources more efficiently.
- Transporters and their users, Shippers, will aim to reduce supply and transport costs by negotiating new contracts and by using the network more efficiently.
- Suppliers to consumers will develop innovative products and services tailored to customer requirements to incentivise customer switching.
- All will aim to maximise the efficiency of their operations by optimising their business structure.

This would lead to benefits for consumers resulting in:

- efficient gas prices linked to supply/demand fundamentals;
- increased consumer choice;
- higher quality of service;
- improved security of supply;
- better consumer protection; and
- access to innovative products that are tailored to specific consumer needs.

Liberalisation of gas markets involves a number of steps as shown in below Fig. 1. The steps do not necessarily have to be taken in this order although until the first three are achieved it will not be possible to progress further. A few countries have achieved all 9 steps but, for those done so, the process has required about a decade (and can take longer). Although not included in Fig. 1, but crucial to the process, is the development of regulation and government policy to ensure the progress of liberalisation.

Fig. 1: Stages of Liberalisation of Gas Markets

STEP 9	Indices Derived for long Term Contracts
STEP 8	Liquid Forward Curve Develops
STEP 7	Futures Exchange Created
STEP 6	Entry of Non-Physical Players
STEP 5	OTC-Brokered
STEP 4	Balancing Rules and Standardised Trading
STEP 3	Price Discovery and Disclosure
STEP 2	Bilateral Trades
STEP 1	Third Party Access to Pipelines and Regasification Terminals

Source: Oxford Institute for Energy Studies

The opening of natural gas markets has unfolded at different rates in different countries, and countries have different market fundamentals – from being self-sufficient to net importing countries and from mature to growing markets. However, such processes have all proceeded from the same common objective to encourage competition and market liquidity to the benefit of end users. Some of the key features that are common to all liberalized gas markets have been listed below in no particular order:

I. Third Party Access to Infrastructure

Third Party access (TPA) or "Open access" is a key part of gas market reform as it in principle, allows more gas and LNG suppliers, distributors and retailers to gain access to pipeline and regasification terminal capacity on equal and transparent terms. The concept of TPA is that the owner of gas import and/or transportation infrastructure, or the owner of the right to use that infrastructure, must make capacity in that infrastructure available to third party users in return for a fee or tariff.

An infrastructure owner may do this voluntarily, if it has available capacity and simply wants to earn a tariff from that capacity. Alternatively, the owner may be required by law to open up capacity to other, third party users who have no ownership interest in the infrastructure. A regulated TPA regime leads to more widespread infrastructure usage, as well as greater competition and the diversification of gas supply for downstream customers.

In Asia, regulatory TPA has the most visibility in Japan, Malaysia, Thailand and Singapore, while India has a program that is applied on a step-by-step basis and the rapid development of natural gas pipelines and improvements in their interconnections will help to accelerate TPA. A well designed, carefully calibrated TPA regime could be a major force behind the further development of the market and a valuable way for existing players and new entrants to develop and utilize the gas infrastructure necessary to access those markets.

II. Unbundling of Infrastructure

The unbundling of the infrastructure was a major step during the liberalization of the US and European gas markets. During the EU gas reform, it is stated "ownership unbundling as the most effective tool by which to promote investments in infrastructure in a non-discriminatory way, fair access to the network for new entrants and transparency in the market".

Also, the unbundling is a fundamental pre-condition for gas market liberalisation, as it enables cost reflective pricing of the different services. This is essential if new entrants are to be able to compete fairly. In particular, it enables an efficient TPA regime in gas transportation and in turn enables the entry of gas traders into the market who compete with supply companies through gas price arbitrage, promoting competition and liquidity in supply.

Pipeline interconnections, standard contracts for the purchase and sale of gas, standard gas specifications, capacity allocation mechanisms and dispatching arrangements are some of the important aspects to be developed for facilitating TPA.

III. Gas Storage Facilities

Natural gas storage plays a vital role in smoothing out fluctuations in seasonal and peak demand and also plays an important role for security of gas supply and for optimizing the whole gas value chain. Natural gas market participants all along the gas value chain benefit from the capability to store natural gas until it is needed in response to market demands caused by weather or other events. Storage, such as underground gas storage (UGS) in depleted oil and gas fields, aquifers, salt caverns, built near market centres, and LNG Tanks are the most common ways in the developed consuming countries to ensure reliable and secure gas supplies.

At the end 2018, there were 662 UGS facilities in operation in the world with a global working gas capacity of 421 bcm. US is by far the most important country in terms of installed working gas capacity, with 136 bcm, Russia (75 bcm), Ukraine (32 bcm), Canada (28 bcm) and with and Germany (24 bcm), together these five countries concentrate 70% of the worldwide capacities.

The breakdown of UGS by type of storage shows the dominance of depleted fields, representing 73% of the total number of sites and 79% of global working gas volume. However, market liberalization has brought some important changes in the gas storage market. Today, flexibility is a key asset in liberalized markets. This trend can be seen in the growing importance of salt cavern storage. This type of storage allows high injection and withdrawal rates, and the working gas can be cycled several times per year. At the of end 2018, 99 salt caverns facilities were in operation in the world representing 15% of the total number of sites.

In the long run, gas storage helps in maintaining operational stability, meeting peak demand, and narrowing price differentials due to weather or events like demand destruction. In liberalized markets, storage is also used as a financial tool to arbitrage price differentials between different points in time.

IV. Gas Pricing Reforms

Natural gas is yet to evolve itself as a truly global commodity with global benchmarks. Consequently, since different natural gas markets have developed to different degrees, there are three major gas pricing mechanisms found globally: netback pricing; oil linked pricing; and gas on gas based market driven pricing.

Reform of natural gas pricing mechanism is the gradual shift away from regulated pricing mechanisms towards achieving completely open market pricing based on competition among various gas sources. Looking at all the liberalized gas markets globally, there is a noticeable trend that all these markets started out as Government controlled markets with regulated pricing and charted the journey towards completely market determined prices.

In the US, for example, the Government controlled the natural gas prices using a 'cost plus' method to import prices. During this period, the US Government controlled the long distance pipeline prices and local Government organizations used to fix the prices paid by the end users. However, this system resulted in very low prices leading to widening of the gas between supply and demand of gas in the country. Consequently, the Government eased the controls over the price of natural gas and evolution of gas trading opened the doors for open market pricing.

V. Gas Trading Hubs

The gas trading hubs is key to the establishment of transparent price signals and the development of price indices has a widespread influence throughout the market. The world's first and perhaps most famous physical hub is Henry Hub in Texas, USA, which played a significant role in the development of the liberalised US interstate wholesale gas market. Similarly, the process of gas market liberalisation in Europe has resulted in a number of trading hubs being established, a key determinant of liquidity that set the spot price for gas.

While NBP and TTF are described as virtual hubs, they are in essence little different to the physical hub that is Henry Hub. NBP and TTF are virtual in the sense that there is no exact physical location on a map where they can be identified. Virtual hubs are usually easier than physical hubs for traders to operate in, due to the guarantee of delivery and the lack of requirement for traders to obtain capacity, but this has not prevented the success of Henry Hub being used to price spot contracts in the US.

The liberalised hub price has a greater degree of volatility than the oil-indexed prices, reflecting the supply/demand balance. As hub liquidity matures, financial instruments may be developed, and additional participants may be attracted to the market, benefitting both sellers and buyers. The derived futures products are the next step after the successful establishment of a spot market.

VI. Presence of independent Transmission Systems Operator (TSO)

To ensure a level playing field for all participants and to avoid any dominant market player from taking advantage of its market position, it is imperative to provide non-discriminatory access to pipelines and other gas infrastructure. Creation of an independent Transmission Systems Operator (TSO) can go a long way in guaranteeing equitable access to all parties. It is the responsibility of the TSO to ensure the optimal management, coordinated operation and effective execution of all contract terms according to the Gas Transmission Agreement (GTA) in a natural gas transmission network. It is the responsibility of the TSO to ensure that any available capacity in the pipeline is made available to the interested parties without any discrimination.

To ensure non-discriminatory access to infrastructure, accurate, availability of timely and reliable data presented in a transparent manner is crucial to build confidence among market participants. The availability of real time data of the traded price and volume guarantees that the trade transactions are fair to both buyer and the seller. Proper mechanism needs to be put in place to provide transparent information about closing bid-offer, back up or down pricing and daily price fluctuations. Information on energy consumption, pipeline data on physical flows, capacity availability (and timing of capacity booking), exchange information on volumes and prices are some of the other key data points that need to be made available to all participants to facilitate informed decision making by all parties.

VII. Independent and Transparent Regulatory Authority

The administration of all liberalized gas markets usually constitute of an overall energy administrator and an energy regulator, with powers divided between the two bodies. While the energy administrator is mainly concerned with energy policy, the energy regulator is more concerned with establishing order within the energy market, promoting competition and resolving of disputes among industry members. The role of the regulator gets even more important in sectors where natural monopolies exist.

The role of a regulator in a liberalized gas market includes:

a. Prevention of discriminatory or preferential treatment
b. Prevention of unfair pricing practices
c. Prevention of infrastructure redundancy and wastage
d. Promotion of competition
e. Promotion of safe and environmentally friendly infrastructure
f. Ensuring best in class service

Most liberalized gas markets are characterized by the presence of a strong regulatory body. To name a few Federal Energy Regulatory Commission (FERC) in the US; The Office of Gas and Electricity Markets (OFGEM) in the UK, Federal Cartel Office (FCO) in Germany and Petroleum and Natural Gas Regulatory Board (PNGRB) in India have played a commendable role in this direction.

Conclusion

Liberalization of natural gas markets and their administrative regimes is a long and gradual process. Looking at the timelines of most of the developed gas markets from around the world, it is clear that the market liberalization process involves progression from complete Government regulation and price determination to a position where pricing controls are eased, market and sale functions decoupled, eventually leading to a fully liberalized gas market, where market forces determine the price of gas.

Opening up of the gas market requires a concoction of factors such as favourable political environment, infrastructure and supportive Government policies. A favourable global/domestic market environment can further accelerate this progress.

There are ample international experiences where due to ineffective application of reforms, Governments have struggled to open up their natural gas markets. In most countries, the process of natural gas market reform has been slow and tortuous and there is no one size that fits requirements of all gas markets. The liberalization process has to be tailored to fit the requirements of each market, taking into account its present political and economic climate and the effectiveness with which required policies and measures have been implemented. In this regard, a well-defined roadmap with specific timelines for reforms could go a long way towards establishing a vibrant and robust gas market.

UPSTREAM

Geochemical Characterization of Causes of Low Resistivity Low Contrast Reservoir



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Abstract

Low resistivity phenomenon in pay sands is mainly due to the presence of conductive minerals such as clay minerals, pyrite and formation salinity. Clays have been identified as leading cause of low resistivity pays. It may be difficult to distinguish clay from shale with common wire-line measurement. Clay also complicates the log analysis in low resistivity pay zones. Challenges are being faced to identify the causes of low resistivity on real time basis and with the help of cuttings available at the drill sites within in the short timing of 24 hours. The present study is an attempt to explain causes of low resistivity in clastic reservoirs using cuttings available at the drillsites within a short period of time. This is a laboratory method based on cutting samples present at drillsites for identifying the resisitivity due to clay mineralogy, heavy minerals /conductive minerals and salinity of sediments which generally requires logs' post analysis and interpretation of the data that cannot be done within the drilling timeframe. The method includes determination of clay minerals, heavy conductive minerals and formation salinity through Cation Exchange Capacity (CEC), Degree of Pyritization (DoP) and sediment salinity respectively. This technique has been developed by studying core samples of selected wells of Cambay Basin.

No single factor can be attributed to explain low resistivity in any particular basin. The study was carried out on 12 cores from 09 wells of Cambay Basin. The high concentration of heavy conductive minerals is the major cause of low resistivity in Well # C and Well # D. The high concentration of clay minerals is the major cause of low resistivity in Well # A, Wel l# E, Well # F and Well # G. While in Well # H and Well # I high salinity along with effect of clay (moderate), presence of heavy conductive minerals (moderate) are the causes of low resistivity. This methodology may be useful to investigate the causes of low resistivity in pay zones thereby minimising the exploration risk in future.

Introduction

Low resistivity pay or low contrast pay was first discovered in the Pleistocene sand stone in offshore Gulf of Mexico, Louisiana, USA. Through years of exploration and study, low resistivity pay has been recognized as a worldwide phenomenon. Geo-scientific literature has indicated that globally exploration of low resistivity and low contrast pay sands is a high risk and high reward venture.

The term low resistivity pay is usually used to describe a pay zone that either had relatively low resistivity or calculated 'wet' using conventional well log calculations. In recent years the term "low contrast, low resistivity (LCLR) pay" has replaced "low resistivity pay". The term low contrast is added to emphasize that the pay zone resistivity may differ from adjacent "wet" or "shaly" intervals. This definition also allows classification of subtle pay zones that do not have extremely low resistivities, but have little resistivity contrast with adjacent beds.

The reasons for low resistivity phenomenon are classified mainly into two groups. The first consists of reservoirs where the actual water saturation may be high, but water free hydrocarbons are produced. The mechanism responsible for the high water saturation is usually described as being caused by micro-porosity. The second group consists of reservoirs where the calculated water saturation is higher than the true water saturation. The mechanism responsible for the high water saturation is described as being caused by the presence of conductive minerals such as clay minerals and pyrite in a clean reservoir rock. The resistivity data must be corrected for the effect of these conductive minerals to reduce the calculated water saturation to the more reasonable levels associated with water free hydrocarbon production.

Most formations logged for potential oil or gas production consist of rocks which without fluids would not conduct an electrical current. There are two types of rock conductivity: a) Electrolytic conductivity which is a property for water containing dissolved salts and b) Electronic conductivity which is a property of solids such as graphite and metal sulphides i.e pyrite. [Hamada G. M. et. al.] This paper deals with the case of low resistivity pay zones encountered due to the occurrence of clay minerals and Pyrite. Resistivity may be lower than expected due to the presence of conductive minerals or excess conductivity due to exchangeable cations in clay minerals. Unusual rock or fluid properties, usually related to pore throat size and distribution may lead to lower than expected resistivity of rock/fluid system. [L. M. Etnyreand J.C. Mullarkey].

Salinity of formation water affects the resistivity of reservoir sands. High formation water salinity will lower the resistivity of the sands as high salinity formation water will make the water more conductive thus lowering the resistivity of the reservoir sands. This effect is more where the reservoirs are silty/ clayey as more bound water is associated with clay/ silt and capillaries (micro porosity). Clay minerals have a substantial negative charge which attracts cations such as Na+ and K+ when the clay is dry. When the clay is immersed in water, cations are released, increasing the water conductivity thus lowering the reservoir resistivity.

This study has attempted a geochemical laboratory based methodology for characterizing the low resistivity zones with reference to conductive clay, conductive minerals and salinity variations in clastic reservoirs.

Low Resistivity Low Contrast in Western Onland Basin (Gandhar Field)

The Gandhar field is situated in the Broach Depression in the southern part of Cambay Basin. The hydrocarbon accumulations in the field is primarily by updip pinch out of Middle–Late Eocene Ankleshwar Formation (fluvio deltaic sandstones) onto the NW rising flank of the Broach Depression, and possibly by drape over the SSW plunging Gandhar Nose, which formed during Early Miocene compression [M. Chaudhary et al] Most hydrocarbon production in the Gandhar field comes from the deltaic sands of the Hazad member. GS-12 sand unit of Hazad member displays low resistivity and in few cases it is hydrocarbon bearing [M. Chaudhary et al].

Twelve core samples from nine wells (Well # A, Well # B, Well # C, Well # D, Well # E, Well # F, Well # G, Well # H and Well # I) were selected for study and all these have low resistivity zones ([M. Chaudhary et al, 2015)[Table-1]. Location of the studied well and generalized lithostratigraphy of Cambay Basin is given in figure 2.

S.No.	Well Name	Depth (m)	CC No.	CEC	Average GR value #	Salinity (ppm)	Conc. Of Pyrite Iron (ppm)	Degree of Pyritization (DoP)
1.	A	2748-2753	CC-1	30.86	44.16	935	32053.33	0.56
2.	B	3063.5-3072.5	CC-1	12.28	-	584	34960	0.43
3.	C	2844-2853	CC-3	12.29	50.5	386	110724.44	0.63
4.	D	2802-2819	CC-1	17.02	44.16	351	148546.67	0.72
5.	E	2794-2803	CC-1	29.76	56.8	502	33266.67	0.39
6.	F	3526.5-3535.6	CC-1	24.75	36.6	222	46480	0.60
7.	F	3522.6-3524.0	CC-2	22.52	36.5	280	33733.33	0.51
8.	F	3697-3703	CC-3	19.71	19.28	210	26822.22	0.37
9.	G	3582.5-3591.5	CC-1	27.98	58.33	770	23706.67	0.13
10.	H	2904.1-2910.0	CC-1	5.15	20.4	228	26480	0.14
11.	H	2918-2920.10	CC-2	8.9	25	1577	44124.44	0.48
12.	I	2771-2774.31	CC-1	12.42	26	1297	39115.56	0.55

Table 1: Results of core samples studied from Gandhar Sand, Western Onland Basin
 # Average Gamma Ray value is calculated from GR log

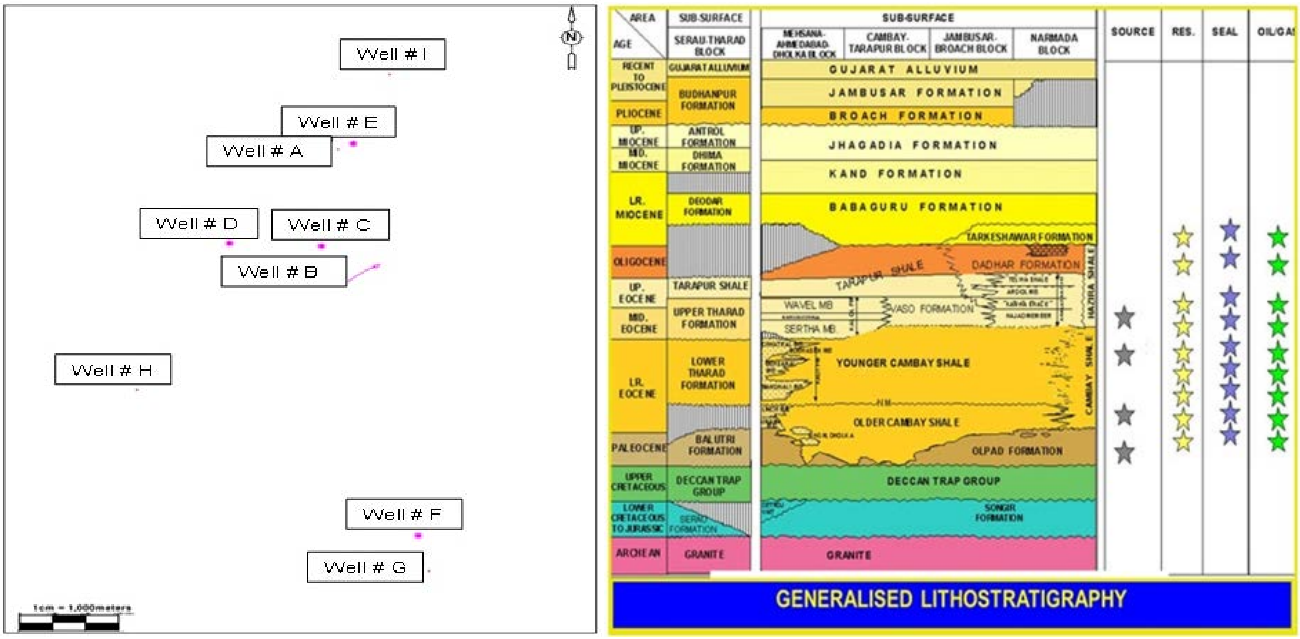

Figure:2 Location Map of selected wells and Generalized Stratigraphy of Cambay Basin

Methodology Adopted

Flowchart of the designed methodology is depicted in Figure-1

Figure-1: Flowchart of the designed methodology

Estimation of Cation Exchange Capacity (CEC)

Crushed sample was hydrated with distill water for 10-15 hours and 0.5 ml of 1N sulphuric acid and 1 ml of 0.1 M Methylene blue was added to the flask. The unreacted Methylene Blue was measured using Ultra –Violet spectrophotometer at 664 nm wavelength. The results obtained were compared with the predefined standard value as follows:

Sediment Texture	CEC (meq/ 100g)*
Sands (light coloured)	3-5
Sands (dark coloured)	10-20
Loams	10-15
Silt Loams	15-25
Clay and clay loams	20-50
Organic rich	>50

** Courtesy TFREC, Washington State University, USA*

Estimation of Degree of Pyritization (DOP)

For estimating DOP we need acid soluble iron and pyritic iron. The mathematical formula for estimating DOP is as follows

$$DOP = \frac{\text{Pyritic Iron}}{\text{Pyritic iron+ acid soluble iron}}$$

Acid soluble Iron 5ml of concentrated HCl was added in crushed sample and for stability of oxidation state complexing mixture was added (i.e 5ml of 20mM ethanolic o-phenantroline (o-phen) solution and 5ml of 20mM of Ethylene Diamine Tetra Acetic acid disodium salt dihydrate (EDTA)). The diluted solution was subjected Ultra violet spectrophotometer at 245, 254, 266 and 510nm wavelength. [S.Schaffer et al 1996].

Pyritic sulphur In Crushed sediment sample add 20% zinc acetate solution, and 3 ml 50% NaOH solution. Filter the precipitate using Whatmann filter # 42. Dissolve the precipitate in 5 ml concentrated Nitric acid. Add complexing mixture. The diluted solution was subjected to Ultra-violet spectrophotometer at same wavelength as above. The results were compared with the predefined values of the amount of pyritizable iron with respect to DOP values given as follows:

Pyritizable Iron	DOP values
Low	<0.3
Moderate	0.25-0.55
High	0.5-0.9

Estimation of salinity in sediment samples

Sediment samples were hydrated with water in 1:2 ratios for 24 hrs., filtered and titrated with the known quantity of $AgNO_3$.

Results and Discussion

Well # A 2748-2753m, WON Basin

Lithology as per sedimentological studies on core is shale/ sandstone/ clay and oolite. Cementing material is calcareous. The resistivity of this sand is in the range of 4-5 Ωm accompanies by very high density 2.63 g/cc [FER]. Grains are mostly rounded to sub rounded moderately sorted. The reason for low resistivity in this interval is high amount of clay which is inferred by high CEC value 30.86 meq/ 100g sediments, moderate Av. GR values on log confirms the presence of calcium/ magnesium carbonates and high amount of heavy conductive minerals. High amount of heavy conductive minerals are present in the section is inferred from high DOP value (0.56) in this interval which is further validated by very high density in logs.

Well # B, 3063.5-3072.5m, WON Basin

This interval has dominance of sandstone with minor amount of clay. Grains are mostly fine to medium grained sub-angular to sub-rounded, medium sorted, non-calcareous [WCR]. The predominance of sand over clay is supported by low CEC value 12.28 meq/ 100g sediment. The amount of pyritizable iron is moderate which can be explained with DOP values (0.43).

Well # C, 2844-2853m, WON Basin

In this interval of the well the cause of resistivity is heavy conductive minerals as Degree of Pyritization (DOP) is high (0.63) which infer high amount of pyritizable iron which was established by earlier comprehensive sedimentological study carried out on cored sample of GS-12 unit in this well which shows it to be quartz wacke: Fine to coarse grained, poorly sorted containing sub-angular to sub-rounded quartz grain (70%), non-calcareous in nature, carbonaceous silty clay matrix (30%) with occasional presence of traces of altered Biotite. Sandstone is texturally immature. SEM studies indicate that scattered and also clusters of Pyrite and Siderite and Hematite are present in small quantity in this sample. XRD analysis shows the presence of clay mineral dominated by Kaolinite (91.8%) followed by chlorite (8.2%). Amount of clay is less as CEC values are low (12.29 meq/ 100g of sediment).

Well # D, 2802-2819m, WON Basin

In this interval lithology as per conventional core sandstone, shale and silty shale [FER] which is also reflected in its low CEC value (17.02 meq/ 100 g sediment). The cored sample has quartz wacke lithology. These samples are represented by fine to medium grained, poorly sorted, sub-angular to rounded quartz grains, non-calcareous in nature, held in carbonaceous clay matrix (40-10 %) with traces of altered Mica. Sandstone is texturally immature with Ferruginous clay. The presence of Ferruginous clay is confirmed by high value of DOP (0.72). The main cause of low resistivity in this cored sample is Ferruginous Clay.

Well # E, 2794-2803m, WON Basin

The cored sample of this interval has CEC value of 29.76 meq/ 100g sediment and average GR value is 56.8 API which indicates that the lithology is mixed with sand and silt which is established further with the megascopic analyses carried out on samples at drill site [WCR]. Lithology of sample is Quartz wacke. Sample is represented by fine to medium grained, moderately sorted immature angular to sub-angular, as well as, sub-rounded quartz grains, non-calcareous in nature along with traces of Mica and shale rock fragments. Around 20 % carbonaceous clay matrixes are present. Presence of moderate amount of Pyritizable iron is represented by the DOP values i.e. 0.39, same is confirmed by the SEM studies which reveals Chlorite clay coating the grains and Kaolinite filling the pore. Scattered pyrite in small quantity and pore filled Kaolinite is observed.

Well # F, 3522.5-3703m, WON Basin

Three cores CC-1, CC-2 and CC-3 in interval 3522.5 m to 3703 m have been studied having depth 3522.6-3524.0 m, 3526.5-3535.6 m and 3697-3703 m respectively. The clay content was moderate in all the three cores ranging from 19.71 to 22.52 meq/ 100 g sediments but in CC-3 the percentage of sand and silt was substantially higher than the other two cores. The same signatures are evident on GR log with average GR vaue for CC-1, CC- and CC-3 as 36.66, 36.5 and 19.28 respectively. Presence of high content of conductive minerals in CC-1 and CC-2 is well explained by the DOP values 0.60 and 0.51 respectively, but in CC-3 moderate concentration of pyritizable iron is expected from DOP value i.e 0.37. The cored samples are having Quartz wacke facies which are fine to coarse grained, poorly sorted, immature containing angular to sub rounded quartz grains, clay clasts along with carbonaceous clay matrix (12-13%).

Well # G, 3582.5-3591.5m, WON Basin

This interval is having sand and shale alterations which are well explained by CEC value by (27.98 meq/ 100 g sediment) and confirmed by moderate

Av. Gr value 58.33 API. Sedimentological studies explained it as Quartz arenite which is fine to coarse grained, poorly sorted, textural maturity consisting of mostly sub-rounded quartz grains, non-calcareous in nature. Minor carbonaceous matter and Kaolinite clay are also observed as binding material. Degree of Pyritization (0.13) is very low suggests no impact on resistivity due to heavy conductive minerals. NPHI-RHOB crossplot and integrated processed output shows influence of Quartz and clay minerals (Kaolinite and Chlorite). Influence of heavy minerals like pyrite is also seen. (figure-3)

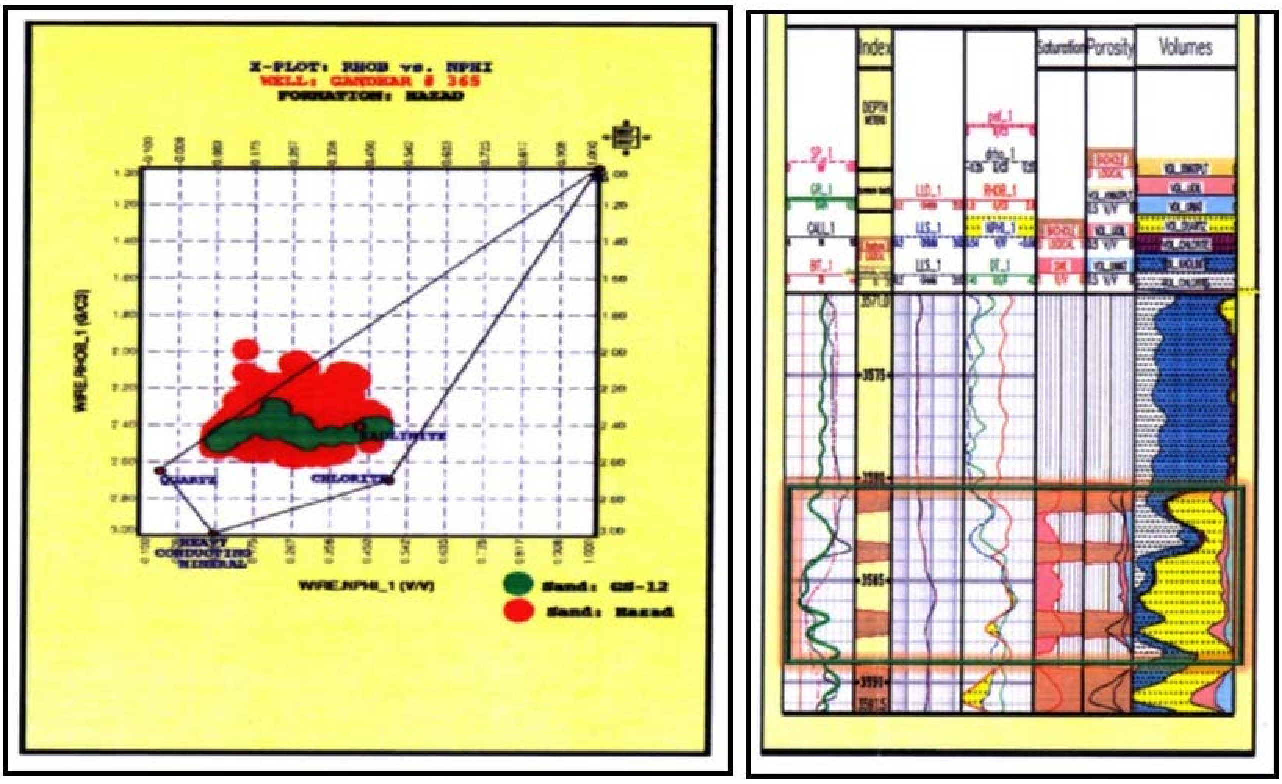

Figure-3 NPHI-RHOB X plot and integrated processed output. The green envelope (GS-12) of NPHI-RHOB X plot shows influence of Quartz and clay minerals (Kaolinite and Chlorite). Influence of heavy minerals like pyrite is also seen.

Well # H, 2904.1-2920m, WON Basin

In this interval two cored samples CC-1 and CC-2 were studied at depth 2904.1-2910.0m and 2918-2920.1m, respectively. The clay content was not very high 5.15 and 8.9 meq/ 100g sediment shows the presence of sand which is further confirmed by Formation Evaluation Report which reveals in interval 2900-2911.5 m is sand and consists of two sub- layers. The top layer in the interval 2900-2902.0m is shaly. The layer in the interval 2902.2-2907.0 m is a low resistivity (around 5- 8 Ωm). The average shaliness is 16 %. The second sub layer in the interval 2907.5- 2910.5 m having high resistivity 15- 17 Ωm. The estimated average shaliness is 9%. The presence of pyritizable iron is seen in both the cores but in CC-2 (0.48) it is substantially higher than CC-1(0.14).

Well # I, 2771-2774.31, WON Basin

This interval has moderate shaliness which is confirmed by CEC values at this interval i.e. 12.42 meq/ 100 g sediments and having low Av. GR Value 26 API. The cored sample of GS-12 unit in this well shows to be sandstone: light grey, moderately hard, massive, fine to medium grained, poorly sorted containing Quartz and clay matrix containing dark gray shale intercalations. Sandstone is non-calcareous. XRD analysis shows kaolinite (95.2%) as the dominant clay mineral with minor chlorite (4.8%). High concentration of heavy conductive minerals (0.550) may be a reason for low resistivity in this interval.

The actual formation water salinity (27324 ppm NaCl) is estimated as ten times of the sediment salinity (1297 ppm NaCl) at depth interval 2771-2774.31m at 105.5^{0}C.

CONCLUSION

From the above discussion it is clear that no single effect can be attributed to the cause of low resistivity in any Basin, in fact, is a combination of two or more of the effects.

A methodology is developed for explaining causes of low resistivity in clastic reservoirs using cuttings available at the drillsites within a short period of time. Methodology provides a laboratory method based on cutting samples present at drillsites for identifying the resistivity due to clay mineralogy, heavy minerals /conductive minerals and salinity of sediments which generally requires logs post analysis and interpretation of the data that cannot be done within the drilling timeframe.

Based on the study, causes having a dominant role in lowering the resistivity can be concluded as follows

The main causes of low resistivity in studied core samples of GS-12 sand of Gandhar Field, WON Basin are high content of clay (Well # A), moderate to high concentration of heavy conductive minerals (Well # H, Well # E, Well # F, Well # A, Well # B, Well # I, Well # D and Well # C) and high salinity (Well # H and Well # I).

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Views expressed in this paper are of authors only and not necessarily of the organization they belong to.

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UPSTREAM

Analysing the E&P Impact on Marine Environment: A Case Study Around Offshore Installations of Mumbai High, ONGC

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Abstract

These E&P activities, including geophysical/ geological surveys, drilling of wells, production testing, processing of oil, gas and produced water, transportation of oil and gas by pipelines, etc., may have adverse impacts on marine environment. Therefore, being "India's energy anchor" and the most prestigious public sector unit, ONGC has formulated an environment protection policy to minimise such negative impacts on the environment. Subsequently, Institute of Petroleum Safety, Health and Environment Management (IPSHEM), a committed arm of ONGC for promoting higher standards of health, safety and environment management in Petroleum Sector, has been conducting environmental monitoring surveys since 1994 in western offshore region.

The paper is aimed to describe the strategies, procedures and methodologies adopted in the process of the offshore environmental monitoring program. The environmental impacts of offshore operations are measured in terms of various meteorological, hydrographical, physical, chemical and biological parameters. These include a thorough investigation of water and sediment, and biological characterisation studies like Abundance, Biomass, Taxon Diversity, etc. for phytoplankton, zooplankton and benthic communities. Besides fulfilling the stipulation of MoEF&CC, Govt. of India, the findings of the survey will also generate a valuable data bank, which will prove instrumental in strategizing mitigation measures prior to redevelopment and extension of offshore E&P activities in the future.

1. Introduction

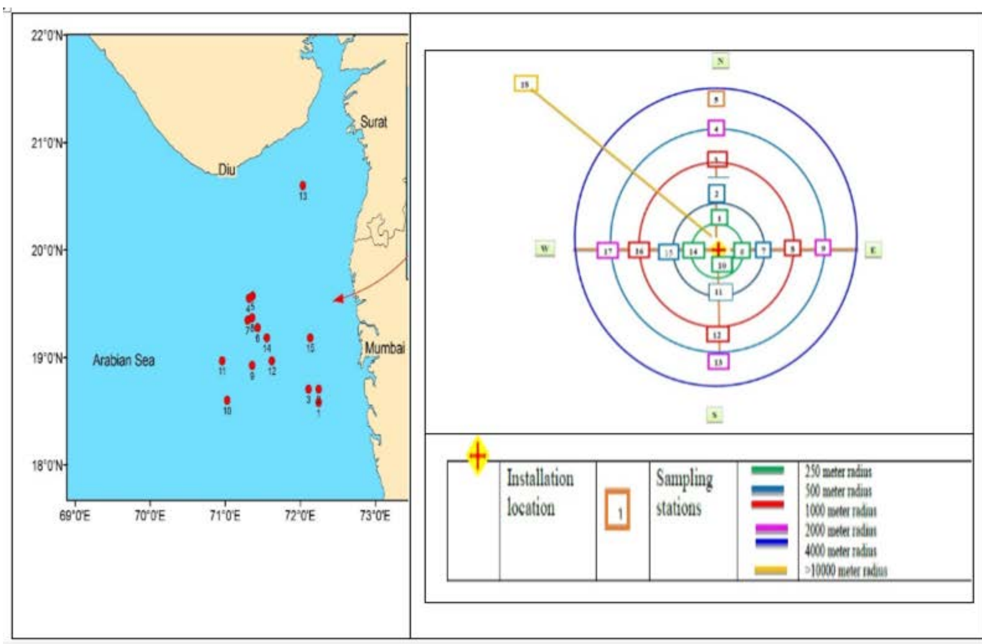
Sea water around the world may vary in chemical composition, hydro-chemical parameters and many other biological characteristics. Though, the reasons for these variations include river water mixing, ground water upwelling, differential evaporation and inputs from many natural and anthropogenic activities, releasing of the industrial and domestic wastes in the coastal water is thought to be the main cause in deteriorating water qualities and seabed environments worldwide. Like water column, the chemical and biological characteristics of sediment and other benthic organisms may also vary due to different natural and manmade activities on sea.

Present paper deals with the strategies, methodologies and various procedures adopted for collection and laboratory analysis of those parameters which are important indicators to describe marine ecological health. Therefore, scope of study for execution of study as shown below has been made with reference to OSPAR commission guidelines;

1. Measuring of Meteorological data like Latitude, Longitude, speed, heading, coarse, depth, wind crest, wind speed, wind direction, air temperature, relative humidity, pressure etc at all sampling locations.
2. Collection of Surface, Middle and Above Bottom sea water samples around all locations and analysis for Hydrological parameters, Chemical, Determination of levels of petroleum hydrocarbons in water column at surface, middle and bottom, Analysis of chlorophyll-a from surface & bottom water sample, Dissolved heavy metal and mercury analysis
3. Sediment appearance at sampling, Petroleum hydrocarbon content, Sediment quality- Total Phosphorous and total nitrogen, Organic carbon analysis,Sediment Chlorophyll-a of the study area. Heavy metal analysis of sediments.
4. Collection of fish samples from each location and analysis for Petroleum hydrocarbon content and Heavy metal analysis of Fish samples
5. Collection of phytoplankton, zooplankton and benthic fauna (Micro and Macro) for analysis of abundance, component, population density, Texon - diversity (group level), biomass and diversity index. Biodiversity Index and Shannon-Wiener Index for Zooplankton and Benthic fauna to be studied, The ABC analysis to be carried out for benthic fauna, Quantitative and qualitative nature of fish potential (species diversity and yield)

2. Study Area

The study area extends geographically from 18° N to 21° N, 70° E to 73°E covering major oil and gas fields of ONGC in the western continental shelf. The depth of water column varies from 30 to 80 m. The nearest area to the coast is at an aerial distance of about 60 Km while the farthest station is approximately 180 km away. Locations of offshore platforms are given in Fig.1. Thirteen offshore installations and two drilling rig locations were covered in present study in accordance with OSPAR Commission Guidelines



Sl.No.	Station Name
1	HRA
2	NLM
3	BLQ
4	NA
5	NQ
6	SHP
7	ICP
8	BHS
9	B-193
10	NBP
11	B-192
12	WO-16
13	TPP-TCPP
14	Sagar Gaurav
15	Sagar Jyoti

Map showing sampling locations in the study area, Locations & sampling methodology

3. Methodology

3.1 Sampling Strategy

Offshore research vessel, equipped with computerized weather monitoring system, a well-set laboratory for on board analysis and facilities for preservation of collected samples, had mobilised for sampling. Sampling strategy was governed by OSPAR Commission Guidelines as shown in Figure 1. Sampling was done from a total of 18 different sampling locations around each installation, including one reference point.

3.2 Sample Collection and Preservation

Sea water samples were collected from water column - surface (1 m below the surface), mid depth and above bottom (3-4 m above the sea bed) using Niskin samplers of 10 L capacity. A Grab of 25 cm x 30 cm dimension and approximately 1.5 kg capacity having a penetration depth of 10 cm was used for the collection of sediments. This medium version of the grab was used to prevent likely damage to pipelines etc. in case of any accidental strike on flow lines. Fish Sampling was done by conducting the trawl net operation. Zooplankton samples were collected with a modified Heron-Tranter (HT) net, having $0.25 m^2$ mouth areas and 330 µm mesh size. The net was towed horizontally at a uniform speed of 1.5 knots for five minutes. A horizontal haul of similar plankton net of 60µ.

All collected samples were brought to shore laboratory under frozen conditions for further analysis. Sea water samples were preserved in polythene bottles after addition of metal free hydrochloric acid. Sediments samples were collected in aluminium foil and preserved at -20^oC. Zooplankton samples were preserved in 5% neutral formalin for further identification and quantification. Sediment samples were made to stand in 5% buffered Rose-Bengal formalin for 24 hours and then sieved on-board the vessel using standard sieves for collection of benthic organisms. Samples of fish and fish tissues were preserved in aluminium foils at -20^oC for subsequent determination of hydrocarbons and heavy metals in the laboratory.

3.2 Laboratory Analysis

Soon after collection, samples of seawater were analysed on-board for pH and nutrients (Nitrate, Nitrite, Phosphate and Silicate). Petroleum Hydrocarbons were extracted with spectroscopic grade n-hexane and the extract was preserved at 5^oC. Temperature, Salinity and Dissolved Oxygen were determined using CTD profiler and the values were verified using manual methods. After initial processing on-board, zooplankton samples were further studied for population density, biomass, faunal composition and taxon diversity with standard procedures. The methods followed for analysing various parameters have been taken from standard procedures on the subject of offshore environmental monitoring and conform to US EPA standards.

4. Results and Discussion

The present Comprehensive environmental study has generated vast amount of information which will be helpful to create data bank of various environmental indicators in the study domain. It has been decided to present significant sediment parameters and heavy metals. This is due to sediments are often considered as environmental indicators in aquatic environment because contaminants in the aqueous phase eventually get deposited to the seabed through various physical, chemical and biological processes. It is therefore provided data gives basic information for environmental researchers to assess the contamination levels.

However, the summary of all measured parameters is given below;

1. The oil exploration and developmental activities in Mumbai High, Neelam, Heera and Mumbai High Bassein have not caused any appreciable changes in the hydrographic regime of the water column so far. Hydrographic parameters like temperature, salinity, pH, dissolved oxygen etc. were governed by the general circulation pattern in the sea. No noticeable influence of the activities at the fixed installations was observed during the study.

2. The nutrient levels observed both in water column and sea bed were within the background values and the variations if any are within the limits expected in a dynamic marine system. No significant effects of anthropogenic inputs could be inferred.

3. The primary productivity of the water column got a little bit influenced by the activities of the installations as indicated by the chlorophyll-a values, which were observed slightly in lower range and there was a marginal variation in the chlorophyll content within the stations. However, values are well comparable to earlier studies.

4. Although Phytoplankton and Zooplankton were varying in its diversity and abundance between the region of various installations and reference site, the abundance and diversity of zooplankton is very well comparable with the other coastal areas. This typical characteristic of plankton population observed is that they tend to occur in patches.

5. As per the physical characteristics of sediments are concerned, no presence of drill cuttings, no presence of debris and no large conspicuous fauna observed in the sediments. Only few empty shells were observed in the sediments. Smell of H2S found, but no smell of oil was found from the

from the sediments collected. Comparing the colour of sediments based on the Munshell chart, it was observed that no contamination of oil was found in the collected sediments.

6. Benthic communities at the bottom was more or less uniform.

7. No oil spillage or traces of any pollution observed in the surrounding of the all the installation surveyed.

8. The continuous monitoring among this season especially in the same season will give more value for the impact analysis of these installations on marine ecosystem.

9. Population density of demersal fish is higher in the study area which reflects rich fishing grounds.

10. Petroleum Hydrocarbon content in the water column around maximum stations was bellow detection limit and the range was comparable to the concentrations observed in reference stations in Mumbai High as well as reference points for NLM and HRA. The values were also well below the toxicity limits for marine organisms.

11. Hydrocarbon content in sediments and fish samples around the study area are comparable to previous study.

12. Heavy metal concentrations in seawater were comparable to those recorded for reference stations and the values were also very much below the toxicity limits for marine organisms.

13. Distribution of heavy metals in sediments was in line with the literature values recorded in the Gulf area. The average values of heavy metals around each installation was worked out and tabulated. It was observed that there is no major variation in the values around any installation.

14. Heavy metals in fish samples around Mumbai High area are comparable to other oceanographic range and values are lower than the toxicity limit.

5. Conclusion

Monitoring of Marine Environment has become an important module to know the pollutants generated from exploration and production activities. OSPAR guidelines are useful to collect the necessary environmental evidence for assessing the unforeseen impacts on marine environment, effective management and to identify the new areas of concern. From the assessment study, it is deduced that there is little or no effect of offshore oil and gas operations on the general hydrography of water column, and availability of essential nutrients to the plant growth in the marine environment and well comparable with the reported values of oceanographic literature. Environmental impact of offshore operations on the biological productivity was found to be insignificant from the recorded observations. The concentrations of most metals were observed to be very low. In water column, however Zinc & Iron concentrations were slightly higher. It is opined that monitoring of marine environment should be done periodically to ensure ecological balance and to avoid anthropogenic contamination. Therefore, regular monitoring of marine environment should be given great attention to control the anthropogenic input into the coastal environment, particularly zones where E&P operations are structured. The safe disposal of industrial effluents should be practiced to avoid such contamination. Also, the laws enacted to protect the environment should be enforced effectively.

8. References

1. OSPAR Guidelines for Monitoring the Environmental Impact of Offshore Oil and Gas Activities, 2004-11.
2. Environmental monitoring around ONGC installations in the Western Offshore region – Reports from 1994-95 to 2019-20 by IPSHEM, ONGC.

Table: 1 Concentration of sediment parameters

Sl No.	Station Name	Petroleum Hydrocarbon (µg/gm)	Organic Carbon (%)	Phosphorous (µg/gm)	Nitrogen (µg/gm)	Smell of H_2S	Smell of oil
1	HRA	82.03	8.68	15.47	79.26	Yes	No
2	NLM	103.94	8.29	10.33	75.81	Yes	No
3	BLQ	104.08	12.71	16.66	52.51	Yes	No
4	ICP	102.14	25.01	21.36	55.04	No	No
5	BHS	104.26	12.4	11.26	80.14	Yes	No
6	SHP	112.85	13.2	21.67	60.5	Yes	No
7	NQ	109.91	11.08	24.49	69.94	Yes	No
8	NA	97.75	10.4	24.72	62.47	Yes	No
9	B-193	100.28	19.8	10.95	94.67	No	No
10	NBP	114.98	13.9	16.2	60.11	No	No
11	B-192	100.28	19.08	10.95	94.67	No	No
12	WO-16	117.49	13.37	29.51	92.96	No	No
13	TP-TCPP	90.67	9.5	15.91	55.61	No	No
14	RIG SAGAR JYOTHI	119.75	14.55	7.44	75.97	No	No
15	RIG SAGAR GAURAV	122.01	15.58	16.67	73.34	No	No
16	Avg. at Ref. Statn	65.38	11.33	16.08	63.38	No	No

Table.2: The concentration of heavy metals in sediments

Sl No.	Station Name	V	Cr	Fe	Co	Ni	Cu	Zn	As	Cd	Ba	Pb
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1	SHP	11.86	18.59	1.59	5.71	12.85	7.16	12.88	5.08	0.018	385.38	4.03
2	HRA	11.80	9.10	1.45	4.57	10.18	6.25	11.53	4.63	0.017	397.81	4.23
3	ICP	14.64	9.29	1.01	3.18	7.77	4.54	4.34	5.20	0.00	356.71	1.98
4	TPP	17.74	16.28	1.39	4.61	11.04	6.79	7.75	7.60	0.018	419.00	2.72
5	BLQ	47.33	59.46	3.69	23.35	42.66	53.50	58.85	5.72	0.00	86.55	5.13
6	NLM	18.68	19.66	1.25	3.70	10.85	9.34	7.69	3.55	0.049	86.41	1.29
7	NA	17.50	16.77	1.23	3.54	10.89	6.71	7.45	3.11	0.031	98.38	1.30
8	RIG-SJ	35.32	37.01	3.46	14.83	30.66	38.87	41.16	4.09	0.001	131.40	4.23
9	B-193	13.19	20.98	1.44	4.58	10.04	5.86	9.35	4.13	0.01	323.09	2.66
10	NQ	39.65	49.71	3.86	17.68	32.87	40.56	48.56	5.41	0.053	153.92	6.98
11	WO-16	7.05	8.40	1.08	2.50	7.91	3.74	5.41	6.06	0.045	121.92	1.94
12	B-192	11.41	15.78	1.23	3.96	8.98	4.30	6.68	4.00	0.00	276.18	3.59
13	RIG-SG	16.17	16.68	1.69	5.81	15.05	11.93	16.63	1.95	0.00	67.08	4.29
14	NBP	4.31	5.53	0.71	2.28	5.35	1.32	2.61	1.99	0.00	175.15	2.45
15	BHS	20.33	8.31	1.95	5.80	16.15	17.00	19.06	1.75	0.00	33.58	4.96
16	Avg. at Ref. Statn.	18.247	19.412	1.722	6.668	14.916	13.7373	16.568	4.2953	0.0191	194.60	3.3886

UPSTREAM

Petrophysical Core Analysis at KDMIPE: An Aid to Reservoir Characterisation



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1. Introduction

Ever increasing demand of hydrocarbon coupled with aging of producing fields culminated into venturing in more challenging environment for exploration and exploitation of oil to cater energy needs of India. World energy demand is increasing while producing fields around the world are in a maturing and declining phase. The days of easy oil recovery & production are over and now hydrocarbons have to be explored and exploited in more challenging and complex reservoirs. Oil industry will always depend on accurate reservoir data for proper field development. Core analysis data, geological information, and data from well testing, provide a fundamental basis to understand the reservoir's storage and production capacity. The nature of different reservoirs may vary with respect to geometry, origin and content, therefore, reservoirs have to be modelled individually. Core analysis plays a very important role for realistic reservoir characterisation in Oil industry.

In KDMIPE, Petro-physics Division came into existence in 1962 with the establishment of Petrophysics Labs with bare minimum infrastructure. In last three decades the Petrophysics Laboratory has taken a massive leap in terms of technology and is upgraded to state of-the-art laboratory catering to the needs of modern day challenges in the exploration and exploitation of Hydrocarbons. With continuous evoluation of technology in terms of Log data acquisition by latest Logging Tools, the Petrophysics laboratory of KDMIPE has been constantly upgraded and now boasts of some very state-of-the-art tools such as NMR core analyser, AVS-700, KEYPHI etc. The laboratory carries out routine core analysis –RCAL and Special core analysis-SCAL for the measurements of dynamic petro-physical parameters and petrophysical constants. In addition to these measurements, studies are also carried out for the computation of elastic constants and measurement of primary and shear velocity on core samples. NMR core analyser computes reservoir parameters which are free from lithology effects for accurate reservoir characterization.

The main objective of core analysis is to reduce uncertainty in reservoir evaluation by providing data representative of the reservoir at ambient and reservoir conditions. Core Analysis tests are performed and provide information about the reservoir fluids storage capacity (porosity), flow capacity and distribution (permeability), fluid type and content (saturation) and lithology, Electrical properties, rock mechanical parameters, T2-cutoff, elemental concentration of radioactive minerals.

2. Methodology

Conventional core plugs are collected for the analysis. All the core plugs of 1"/ 1.5"diameter are cut parallel to the bedding plane and in cylindrical shape. After cutting the plugs are made in the shape of perfect cylinder in the laboratory to make compatible with the measuring system. Due care has to be taken in perfect measurement of the dimensions of the plugs. Plugs are prepared in such a fashion so that they can be loaded in the system. The suitable nomenclature is given to the core plugs for proper identification of wells name & depth. All plugs are soxhlated with toluene to ensure complete removal of hydrocarbons and then with methanol to remove the salt from these samples completely. After soxhlation they are dried in oven at 40° C for 1 day to make samples dry. After that, physical measurements (length, diameter and weight) are carried out for all the plugs. Mixture of Acetone and Plastic is used for coating of core plugs to avoid further damages and entrance of gas from sides of the core. Now the samples are ready for further study.

3. Petro-physical parameters & constants measurements studies

Porosity, Bulk density and Grain density of individual core plugs are determined at varying pressure (400 psi to 10000 pi) using Boyle's law with the help of state-of-the-art equipment, 'KEYPHI'(Fig 1a). Permeability is determined by using Darcy's law with the same equipment, which employs a pressure fall-off apparatus.

Fig 1. (a)

Fig 1. (b)

Fig 1. (a) Automated multi-sample Permeameter and Porosimeter (KEYPHI). Fig 1(b) resistivity meter

The method used here is called "Boyle's law Single Cell Method" for direct void volume measurement. Pore volume is determined with a gas charged reference cell of reference volume and initial pressure, which is then vented into the sample's pore volume. The sample is held in a core holder, which utilizes an elastomer sleeve and end plugs. An isostatic confining pressure (stress) is applied to the sleeve by means of a confining gas circuitry.

The samples are fully saturated with brine at 200 gpl to minimise the effect of clay. Generally default parameters of Archie's constants (Tortuosity factor (a), Cementation factor (m), Saturation exponent (n)) are used for estimation of hydrocarbon saturation. However, the actual core derived values being more accurate, might be different for a particular formation. Therefore, it is necessary to evaluate a,m,n values in the core for the concerned field & Formation. To determine petrophysical constants a, m, n values, the parameters-limiting formation factor, saturated porosity, water saturation, resistivity index need to be computed. Limiting Formation Resistivity Factor 'Flim' is determined by measuring the resistivity 'Ro' of core plugs fully saturated with brine of 200 gm/lt salinity with help of resistivity meter (Fig 1b). The resistivity of brine 'Rw' is determined from the standard correlation. Limiting formation resistivity factor 'Flim'' is then calculated using the relation:

$$\text{'Flim'} = Ro / Rw$$

The Archie's constant 'a' and cementation factor 'm' have following relations with Flim' and 'ϕ'

$$\text{'Flim'} = a / \text{'}\phi\text{'}^m$$

After establishing these parameters, core plugs are de-saturated by means of a centrifuge. The de-saturated weights and their corresponding resistivities are measured at each stage.

The cross-plot on log-log scale is generated between 'Flim' vs. porosity (fig 2a) . The intercept on 'Flim' - axis at Porosity = 100% determines the value of Archie's constant 'a' and the slope of the best fit line determines the cementation factor 'm'. The values of resistivity index 'I' and corresponding water saturations 'Sw' is calculated. Saturation exponent 'n*' is computed by a plot between I and Sw (fig 2b). The relationship between I and Sw is given by:- $I = Sw^{-n}$

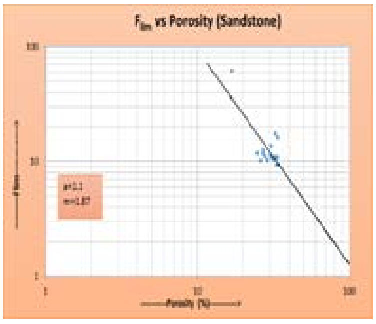

Fig. 2 (a)

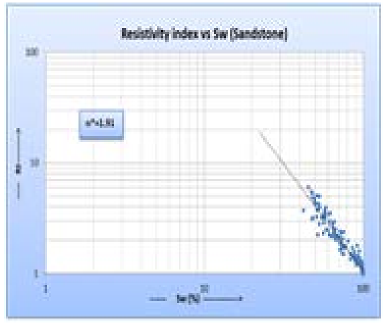

Fig. 2 (b)

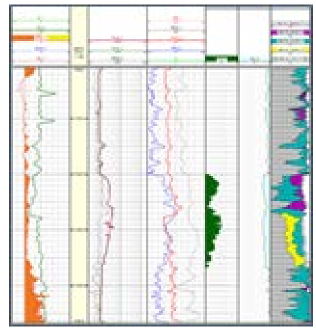

Fig. 2 (c)

Fig. 2(a) Cross-plot between Limiting Formation Factor and Saturated Porosity. Fig 2 (b) Cross-plot between Resistivity Index and Water Saturation. Fig2(c) core based standardized multi-mineral processing model

The core based realistic Petrophysical parameters viz.', porosity, grain density, 'a', 'm', 'helps in the development of a standardized multi-mineral petrophysical log processing model for complete and realistic formation evaluation (Fig 2c).

4. Nuclear Magnetic Resonance(NMR) core studies

This state -of -art equipment, Benchtop NMR core analyser is capable of measuring T1 distribution , T2 distribution, T1+T2 distribution, Free Induction Decay and Saturation profiling on core plugs of 1" and 1 ½" Diameter. It provides Lithology independent porosity, total NMR porosity, porosity and pore size distributions, free-fluid index, permeability, irreducible fluid saturation and fluid typing. The determined T2 Cutoff value is used for realistic estimation of saturations. NMR log data provides lithology independent measurement to deliver porosity & pore size distributions. Accurate T_2 cut-off value plays a critical role in estimating the producibility of the reservoir. Accurate T_2 cut-off value can only be computed through core analysis-NMR core analyser on core samples for a particular reservoir.

Fig 3 (a)

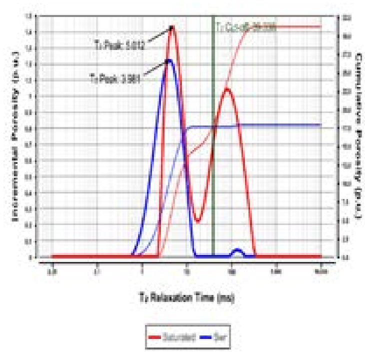

Fig 3 (b)

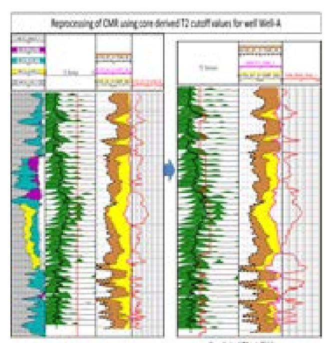

Fig 3 (c)

Fig 3 (a) Nuclear Magnetic Resonance (NMR) System. Fig3(b) T-2 Distribution on core plug. Fig3(c) Reprocessing of CMR using core derived T2 cut off values

Prior to NMR measurements made on core plugs, the NMR core analyzer (Fig 3a) system is calibrated with 1 inch probe. For making the measurements each core plug is placed in core holder in-between the permanent magnet in magnet case of system and T1, FID & T2 distribution (Fig 3b) is obtained with the GIT software. After this the sample is fully de-saturated and the study is repeated in de-saturated condition. Data obtained is subsequently processed to obtain desired results viz. Total NMR porosity, Clay bound water, Cut-off, Permeability, Effective porosity, Free fluid Index, Bulk volume irreducible.

Normally, default T2cut-off values used are 92 or 100 ms for carbonates. However, studies show that this value may not be true for heterogeneous carbonate reservoirs. The core derived T2 cut-off are observed much lower than the standard values. Core based T2 cut-off values are used to reprocess the NMR data (fig 3a). So NMR core analyser play very important role to demine the T2-cutoff value of reservoir and aids in realistic reservoir characterisation.

5. Acoustic velocity core measurement studies

Subsurface formations are subjected to high stress, which influence the acoustic parameters of the rocks. It is essential to understand the role of pressure on these parameters. The compressional wave and shear wave velocity play an important role in identifying the fluid typing in reservoir rocks saturated with different fluids. Fluid identification in heterogeneous reservoirs rocks become more challenging as logs are unable to distinguish the fluid type. The state-of-the-art equipment AVS-700 core analyser computes the Compressional Wave Velocity (Vp) and Shear wave velocity (fig 4a) equipment at different confining pressures with different fluid. From these measurements various rock mechanical parameters and elastic constants viz. Lame's constant, Poisson's ratio, Acoustic Impedance, Bulk modulus, Shear Modulus are determined.

Fig 4. (a)

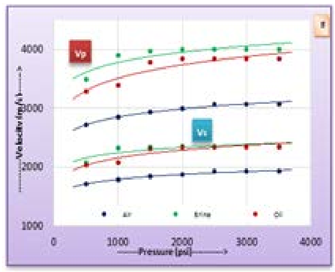

Fig 4. (b)

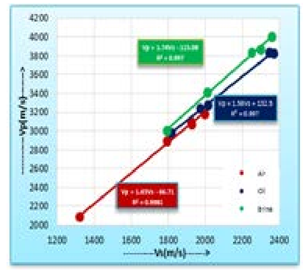

Fig 4. (c)

Fig4.(a) AVS-700 system. Fig4(b) Cross-plot between Velocity & Pressure. Fig4(c) Relationship between Vp & Vs

For determination of Vp and Vs, the core plug is placed in the pressure vessel between two platens which consist of piezoelectric transducers, one of which acts as an emitter and the other as a receiver. A compressional ultrasonic (P) and two orthogonally polarized shear waves (S1 & S2) are propagated through the core sample. A short duration electrical pulse is supplied to the emitter transducer which is converted into mechanical wave on impact by the emitter. This wave is now transmitted to the core sample. After travelling through the core sample, the pulse is picked up by the receiving transducer, reconverted to an electrical signal and complete waveform is displayed on the oscilloscope. The velocities are calculated as follows:

$$Vp = Lp / \Delta Tp$$

$$Vs = Ls / \Delta Ts$$

Where V = Pulse propagation velocity in m / sec.

L = Pulse travel distance in centimeters

ΔT = Effective pulse travel time (i.e. measured time minus zero time correction)

Sonic travel time $\Delta T = 1/V$

Pressure vs. Velocity cross plot analyzes the variation of velocity with pressure (Fig 4b). These transform may be used to evaluate shear velocity where shear log data is not available. Relationship between Vp and Vs give transform which is very helpful in identifying fluid character in heterogeneous and complex reservoir where characterization of fluids become difficult from logs alone. These inputs are used for identification of gas reservoir by Vp/Vs ratio; Rock physics/Geo-mechanical modelling for stimulation of Wells/ hydro fracturing and Well bore stability modelling.

6. Conclusions

Core analysis gives the only direct and quantitative measurement of hydrocarbon reservoir properties which provide the foundation of formation evaluation for building static and dynamic reservoir models. Core analysis reduces uncertainty in reservoir evaluation by providing data representative of the reservoir. The core based realistic Petrophysical parameters viz.', porosity, grain density, and constants 'a', 'm', 'helps in the development of a standardized multi-mineral petrophysical log processing model for complete and realistic formation evaluation thus giving exact picture of the reservoir in terms of porosity, hydrocarbon saturation and pay thickness of a reservoir. Acoustic measurement on core sample helps in the identification of fluids like gas by Vp/Vs ratio. Acoustic core data is used in Rock physics/Geo-mechanical analysis for stimulation of Wells/ hydro fracturing and in well bore stability analysis. NMR measurements provide lithology independent parameters such as porosity and its distribution. Thus Petro physical core analysis plays a vital role in the realistic reservoir characterisation of formations for better exploration and exploitation of hydrocarbon. Petrophysics laboratory, KDMIPE, ONGC is making its valuable contribution in this direction.

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PIPELINE

Reverse Flow in Pipeline

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Objective of the concept:

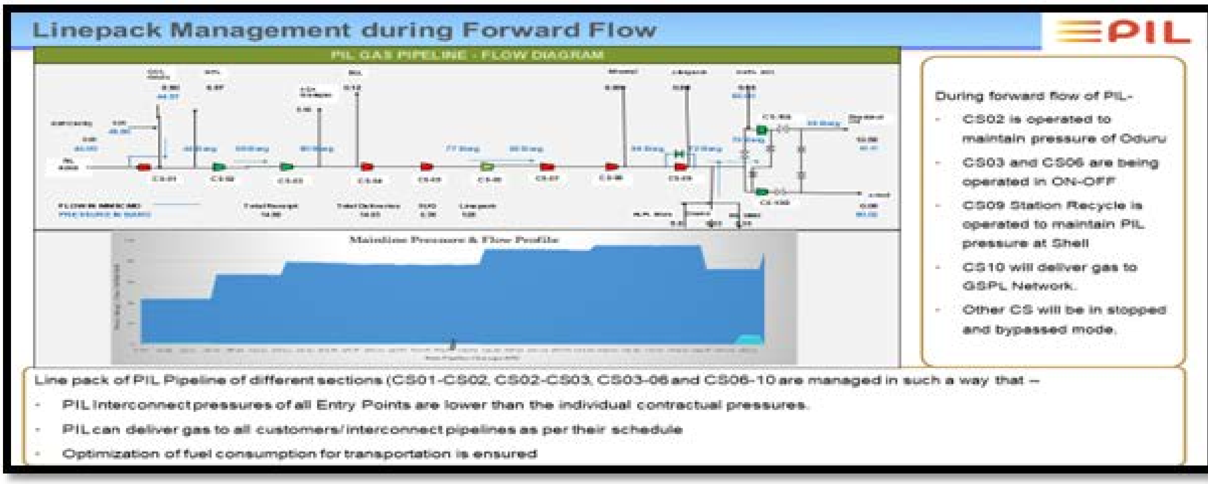
(i) Establish pipeline's capability to flow gas in both directions as per customer requirement and
(ii) Maximise usage of pipeline's space for storage of gas.

Reference of Reverse Flow in process streams, evokes an ominous effect as it is an indication of conditions going out of operator's control, which may result in equipment damage.

In the pipelines' domain, Reverse Flow is not a common phenomenon. Pipelines are generally laid to connect sources at one end to the consumption points at the other end, allowing gas to flow only in one direction. As a practice followed across the world including India, pipelines are named after the source and delivery point, case in being West-East pipeline of China for evacuating gas from sources in Tarim Basin in western China to consumption points in the eastern sector or Yamal-Europe pipeline evacuating gas from Yamal area in Siberia to European countries. It is considered, that reversing pipeline flow can impact several aspects of pipeline's operation, integrity and maintenance. Hence, any change in the direction of flow necessitates major commercial and technical de-risking processes.

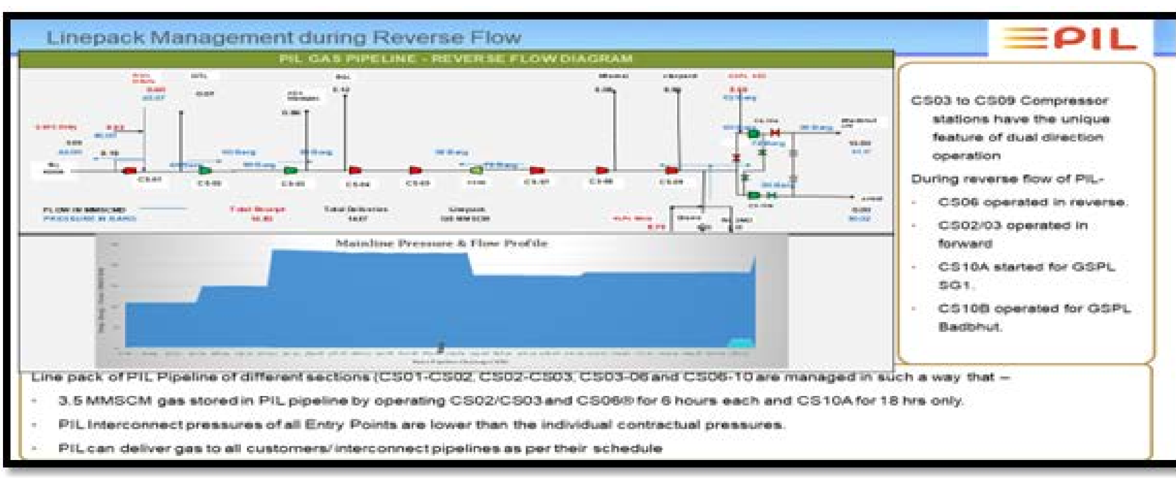
In today's scenario, there is an exception; PIL Pipeline. 48 inch in diameter and 1375km long natural gas transmission PIL pipeline is built with a flexible design to enable two way gas flow based on the availability of natural gas. The pipeline enables gas to flow from East coast to West coast and vice versa, depending upon the availability of gas from the sources. The pipeline presently connects the gas sources on the Eastern and Western shores to the demand centres enroute the pipeline and other parts of India through linkages with other pipelines. As required for any long and large capacity pipeline, PIL pipeline too is equipped with compressor stations (CS), 10 of them dividing the pipeline into 9 segments in a linear pattern. The intermediate CS incorporates a combination of valves, to manoeuvre gas to flow forward or backward along the pipeline.

Currently, gas is received into both Eastern and Western segments of the pipeline. However, the direction of physical gas flow is from east to west. In the view to maintain optimal compression energy and survival volume at entry and delivery points, a suitable line pack is integral to the pipeline.



With continuous changes in the energy sector, gas storage within the pipeline for consumers has evolved as a business opportunity. This is feasible only if suitable space is available within the pipeline. There is a need to create additional space in the western segment of the pipeline for storing larger volume of gas from an RLNG source on the west side for a customer. The requirement necessitates shifting of a part of line pack to the eastern segment against the general flow of gas from East to West.

An appropriate method was evaluated for meeting the business requirement by partially using the reverse running feature at one particular Compressor Station. The method included isolation of the pipeline into 3 segments viz. (i) Eastern segment to be maintained at a low pressure to continue receiving gas from the Eastern sources (ii) Western segment to receive gas from the RLNG source on west coast and (iii) a middle section into which gas is compressed to higher pressure and packed from the Western segment by reverse running of Compressor station no.6.



After shifting the required quantity of gas from the western segment, the reverse running of CS 06 is stopped. Normalisation by optimisation of line pack across the 3 segments is conducted once the storage requirement is fulfilled.

The reverse running operation of Compressor Station was reviewed in detail for uninterrupted business operation. Simulations were carried out to study and ensure seamless continuity of operation at all times. The logic and instrumentation involved in the process, were identified and reviewed for delivering required performance.

As a part of the reverse flow, the gas would flow in certain sections of the station piping for first time since its operation 12 years ago. Thus, it was important to handle the debris that had accumulated in such sections with the help of Scrubber in order to avoid impairment of other equipment of the Compressor Station.

A full-fledged trial run was carried out with reverse running of CS 06 on June 1, 2020 before carrying out the business operation for de-risking all aspects of the reverse running. The trial run helped in clearing accumulated debris from pipeline sections, which helped in smooth operation of business volumes. The debris trapped in the Scrubbers was retrieved and chemically analysed to assess internal condition of the pipeline sections.

The capability of pipeline to reverse flow was effectively used in a carefully calibrated operation to continue smooth and normal receipt and delivery activities, while creating additional storage space in the pipeline.

After successful reverse running of Compressor Station, the mode has been incorporated in the regular operations of PIL pipeline to meet business needs.

After successful reverse running of Compressor Station, the mode has been incorporated in the regular operations of PIL pipeline to meet business needs.

Conclusion:

The capability of PIL pipeline could be established to switch flow gas in forward (Andhra Pradesh to Gujrat) or reverse (Gujrat to Andhra Pradesh) direction along the 48" dia, 1375 kms long linear stretch, based on customer requirements. Since gas was flowing into the pipeline from both ends during the reverse running of Compressor Station, higher boundary conditions for maximising gas storage services opportunity could also be established. Such flow reversal achieved through appropriate operation of intermediate compressor stations located on the pipeline and isolation of pipeline segments using main line valves is a unique feature of PIL pipeline.

Mr. Suresh Raghavanachari is a stalwart in Indian hydrocarbon industry, with 43+ years of experience. He started his career with ONGCL's Bombay Offshore project in the year 1977. He was associated with GAIL and handled different portfolios viz. execution hydrocarbon processing complexes, Operation of Pipelines and Petrochemical complex, SBU for OFC based telecom business and Marketing of polymer, natural gas, etc. In the year 2007, Suresh joined Reliance for marketing gas production from offshore fields. Currently, he dons the role of Chief Operation Officer (COO) at PIL, responsible for gas pipeline operations.

Over the years, Suresh has occupied an array of leadership roles such as Executive Director in GAIL, President (Pipeline Operations) in RIL, CEO of Reliance Gas Pipelines Ltd. (RGPL) and has been a member on the Boards of Indraprasta Gas Ltd.(IGL) - Delhi, China Gas Holding – Hong Kong and India Gas Solution (JV of Reliance and BP).

DOWNSTREAM TECHNOLOGY

Influence of Internal Carburization and Creep Cavitation on Microstructure and Mechanical Properties of VBU Process Heater Tubes

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Abstract

Carburization occurs inevitably in VBU process heater tubes handling heavier fraction of crude oil at high operating temperature and high carbon potential atmosphere. It leads to the degradation of microstructure and mechanical properties of furnace tubes. Besides creep, carburization often plays the life limiting role in such process heater tubes. These tubes are designed for 10^5 hours of operation based on its creep strength properties. However, tubes may run safely even beyond creep life due to availability of sound mechanical properties, lower in-service degradation achieved by proper inspection and maintenance and operation within design limits. On the contrary mal-operation such as operation beyond design temperature, improper decoking etc can lead to early failures. Thus assessment of residual life of VBU heater tube is essential to understand present health condition particularly w.r.t. creep and carburization damage and take a conscious decision to run beyond design life. It not only helps the plant operator to safely run the unit but also reduces inventory costs by utilizing full potential of the material.

This study investigates health condition of VBU process heater after service life of around 20 years. The various destructive and non-destructive studies were carried out to assess the present condition of heater tubes. Microstructural analysis by Optical Microscopy, SEM and EPMA indicated severely carburized structure with presence of micro voids adjacent to grain boundaries. It is believed that carburization leads to lowering in toughness but increases the strength properties. So normally if carburized solid shows good strength properties, decisions are taken for high temperature operation with caution during shutdown for minimized mechanical / thermal shocks. In the present study, carburized solid were tested for high temperature accelerated creep studies which clearly revealed poor creep strength properties. After taking into account all the test results of mechanical properties (Hardness, tensile, impact and creep) as well as corroborating the same with microstructural findings, decision to replace the heater was recommended.

1.0 Introduction

Visbreaking is one of the major residue upgrading processes of oil refinery. Visbreaking is being practiced since the 1930s and is a long-time workhorse with regard to bottom-of-the-barrel up gradation. It is a mild liquid-phase thermal cracking process, which reduces the viscosity and pour point of the feed stock so that valuable gas and distillate products are obtained in the downstream operation. A significant portion of the petroleum residue is processed via Visbreaking, which proves its testimony to the success of the process.

Keywords: VBU: Visbreaker unit, EPMA: Electron Probe Micro Analyzer, micro voids, Carburization, creep.

Atmospheric residue (AR), vacuum residue (VR), and slops obtained from different refinery units act as the feedstocks for the visbreaking unit. In the process, the feedstock is passed through a furnace where it is heated to a temperature of around 480 ° C (895 F) under an outlet pressure of about 100 psi [1]. The high temperature operation necessitates use of high temperature materials mainly Cr-Mo steel in its critical components like heaters. High temperature heater components of petroleum refineries are designed for specific duration of operation commonly known as design life. However, premature failure of these components may occur for a variety of reasons like design faults, fabrication deficiency, selection of improper materials, process deficiencies, errors in installation and environmental effect or by process of accelerated aging [2]. Many degradation mechanisms e.g. carburization, corrosion, erosion, creep, fatigue etc. during operation set in the material and grow with rate depending on the operating parameters like temperature, pressure, thermal and mechanical shocks etc.

Carburization is one of the major concerns for fired heater tubes where Carbon pickup due to presence of carbon rich environment provides easy path for diffusion of carbon into the components material during service and form carbides of different Stoichiometry. As a result some of the important mechanical properties of the material get deteriorated. However the kinetics of such damages do not follow any standard pattern and is dependent on multiple variants like initial microstructure, temperature, oxidation kinetics, operation history of coking/ decoking etc. Increase in hardness of the components, deterioration in low temperature toughness and ductility of material is normally observed under such circumstances. On the contrary, Carburization provides initial strengthening effect in 5Cr-Mo and 9Cr-Mo steels along with enhanced creep life. However, once the carburized zone begins to crack, it is no longer considered as load bearing and corresponding increase in stress can accelerate the creep life consumption [3, 4].

The Remaining life assessment (RLA) of high temperature components such as heaters plays crucial role to predict probability of premature failure of the components and decision for run/ replacement of the components. Another objective of RLA activity is to ensure maximum utilization of material's potential beyond design life [5]. In this paper, a VBU heater tube was investigated for its health condition after service life of around 20 years. Effect of carburization and creep cavities on integrity of the component was evaluated through high temperature accelerated creep studies and assessment of creep and carburization manifestation by EPMA.

2.0 Sample details

A cut tube sample of P91 metallurgical grade of VBU unit was received for health assessment after service exposure of 20 years. The details of the operating parameters and design parameters are given in Table 1

Table.1: Design and operating conditions of heater tubes

Parameter	Conditions
Year of installation	1998
Tube metallurgy	A213T91
Specification of feed	Vacuum Residue
Tube design dimensions	101.6 mm x 12.7 mm
Tube metal design temperature	650 ^{0}C
Design pressure	53.0 kg/cm^2
Operating pressure	13.0 - 18.0 kg/cm^2
Hydro test pressure	79.0 kg/cm^2
Corrosion allowance	3.0 mm
Past history of RLA	No RLA study done earlier No failure observed in the past

3.0 Experimental work

Detailed laboratory investigation has been carried out on the tube sample to assess the influence of carburization and creep cavities on the serviceability of heater. The investigations include visual inspection, chemical analysis, microstructure study, and hardness measurements, determination of room and high temperature mechanical properties and impact energy and long term creep tests. The following enumerates the findings of the study:

3.1 Chemical composition analysis

Chemical composition of the tube material was analyzed by using spark spectrometer (Angstrom make, US) at inner, mid-section and outer surface of the sample to establish cross-sectional distribution of carbon content in the sample.

3.2 Microstructural analysis

Metallographic samples were cut on circumferential thickness (CT) section and these samples were polished upto mirror finish and then etched with Nital (95% Ethanol + 5% HNO_3) for microstructure analysis observed under optical microscope (Leica make).

3.3 Mechanical characterization

Testing samples from the tube were fabricated as per the requirement of tensile testing, impact testing, and creep testing following the procedure of ASTME8, ASTM E23 and ASTM E139 respectively.

Tensile properties at room and elevated temperatures were evaluated by using Universal Tensile Machine (UTM, Instron make UK) with the specimen size of 6 mm X 6 mm and gauge length 50 mm.

Impact toughness of material was analyzed by using Charpy V-notch impact machine (Zwick Roell, Germany) with full size samples of 10.0 mm x 10 mm x 55 mm, hardness measurements were carried out by using universal hardness testing machine (Zwick Roell, Germany make).

High temperature accelerated creep testing was carried out by using electro mechanical creep machines (Zwick Roell, Germany make).

3.4 Fractograpic analysis

Fractograpic analysis of tensile and impact tested samples was carried out using Scanning electron microscope (SEM, Hitachi make).

3.5 Electron Probe Micro analysis (EPMA)

The qualitative elemental mapping of carbon and identification of segregation of grain boundary micro voids (creep cavities) was done by using EPMA (SHIMADZU make, Japan).

4.0 Results and Discussions

Visual inspection of as received heater tube sample revealed slight oxide scale on external surface. No visually observable mechanical damage or internal corrosion was seen. Also, no diametrical growth and thickness reduction was noticed. The as received photographs of the sample shown in Fig 1.

Fig. 1: As received photograph of tube Samples (external and internal surface)

Spark spectrometer was used to analyze the chemical composition of the tube material. Sample was analyzed at inner, outer and CT section and the results are shown in Table 2.

Table.2: Chemical composition analysis of heater tube

Test result	Element								
	C	Si	Mn	P	S	Cr	Mo	V	Nb
ID	0.38	0.41	0.41	0.02	0.005	8.02	0.98	0.20	0.10
MID	0.11	0.46	0.41	0.02	0.005	7.79	0.92	0.20	0.10
OD	0.10	0.40	0.41	0.02	0.005	8.06	0.94	0.21	0.10
As per ASTMA213T91	0.07-0.14	0.2-0.5	0.3-0.6	0.02 max	0.01 max	8-9.5	0.85 - 1.05	0.18-0.25	0.06-0.10

The results clearly indicate the carburization of the heater tube sample at inner section. This was further confirmed by elemental mapping of carbon by EPMA as shown in Fig.2. Normally, the carburization starts from the inner wall of furnace tube. Therefore, the carbon content decreased gradually toward the outer part. The maximum carbon content reached 0.38 wt. % in the carburized zone and lower carbon content 0.10 % (initial concentration) at the outer wall of furnace tube.

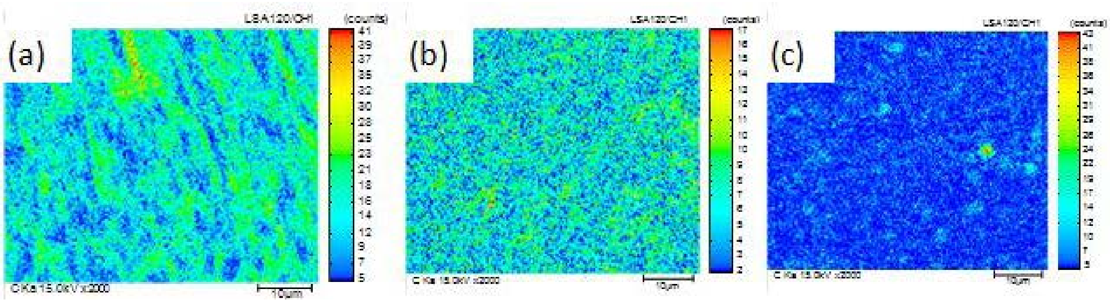

Fig.2: Qualitative Carbon elemental mapping by EPMA: (a) inner surface (b) mid- section and (c) outer surface.

The microstructure analysis carried out at different zones of the cross-section of the heater tube sample. As compared to mid-section and outer surface of the tube, densely accumulated network of carbides were seen at inner surface as shown in Fig.3. This corroborates to the carburization at inner surface of the tube section. The matrix shows tempered bainitic structure with carbide coarsening, indicating service induced degradation of the material.

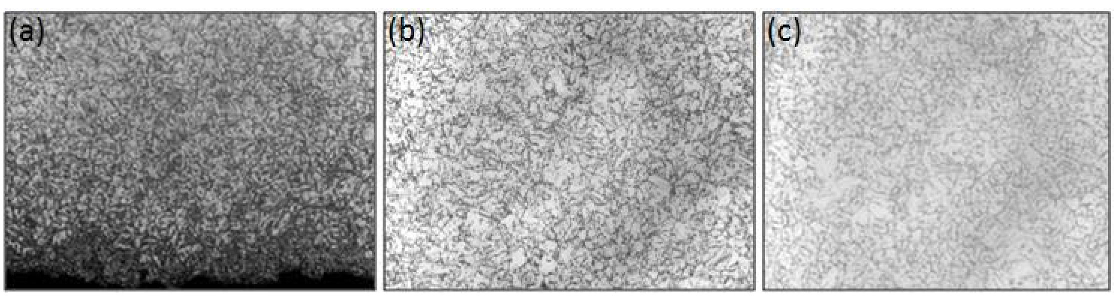

Fig. 3:Microstructure of heater tube sample at 500X magnification : (a) Inner surface (b) mid-section and (c) Outer surface.

Tensile testing was carried out at room and elevated temperatures as per ASTM E8 standard. The test results showed ultimate tensile strength (UTS) at room temperature below the specified limit of API 530, suggesting service induced deterioration of material. However, yield strength (YS) of the material was seen well above the API 530 specified limits as shown in Fig 4. Also percentage elongation at room temperature was found significantly lower (i.e. 18%) against the specified limits of 30% indicating loss of toughness of the material during service.

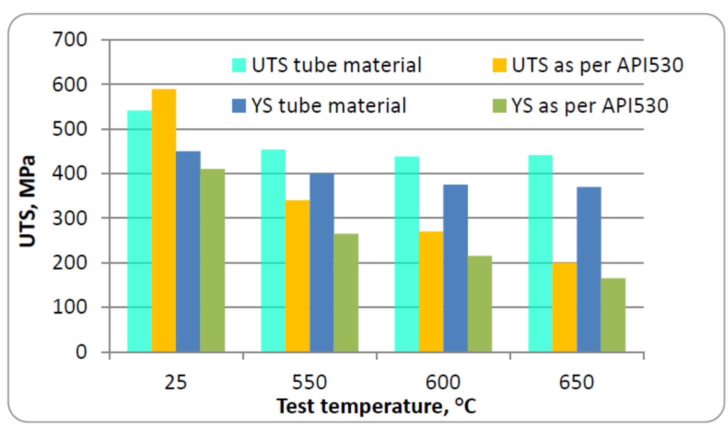

Fig.4: Tensile test results compared with specified limits of API 530

Impact testing indicated almost zero toughness at room temperature taking samples from fire side of the tube. The nil impact toughness at room temperature is due to the internal carburization and grain boundary voids. Further, fractography was carried out for impact tested and tensile tested samples at room temperature. Impact fracture surface indicated bright brittle fracture surface with enormous cracks as shown in Fig.5a, whereas tensile fracture surface is seen to have ductile surface features along with numerous cracks (Fig 5b). This clearly indicates material possessing poor toughness.

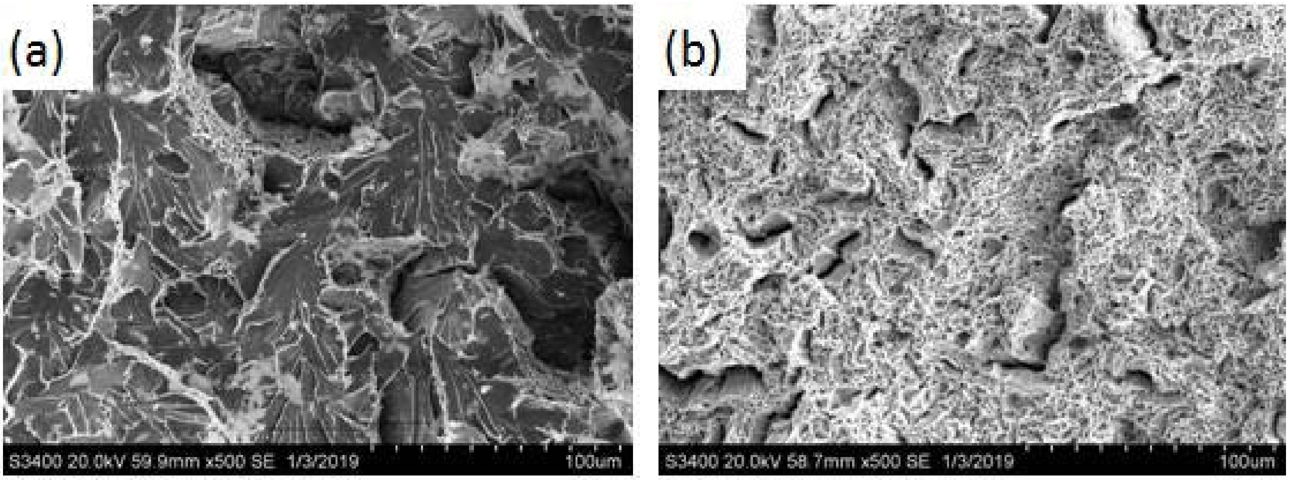

Fig.5: Fractography of room temperature tested samples (a) Impact sample (b) Tensile sample.

The hardness results of sample were in the range of 96.7 to 97.5 HRB, against the maximum specified limit of 90 HRB in ASTM A 213. This increase in hardness is due to the carbon pickup in the material during the service.

Creep tests were conducted in laboratory under accelerated stress and temperature. The test conditions along with the rupture time are given at Table 3. Larson miller parameter (LMP) was calculated and is tabulated in the same table. The LMP values obtained at the test stress have been marked on the API 530 curve (Fig. 6). Only a section of the curve has been used for better clarity. It is seen that all the LMP points marked are positioned considerably below the minimum rupture line. This clearly indicated that no significant useful creep life left in the material.

Table.3: Creep testing details of the sample

S. No.	Test Temperature(ºC)	Test stress (MPa)	Time to rupture (hrs.)	LMP
1	740	32	145	32.579
2	730	32	100	32.096
3	723	32	220	32.213
4	715	32	620	32.398
5	700	32	720	31.970

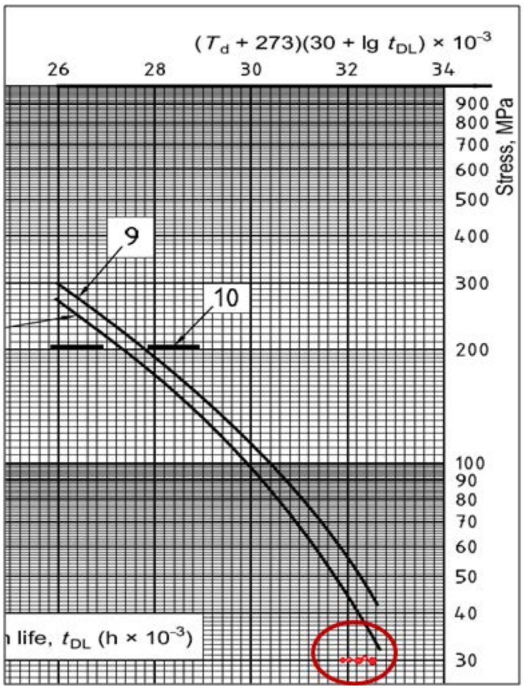

Fig.6: Stress vs LMP plot of P91 metallurgy specified in API 530[6].

The samples prior and post creep testing were observed under EPMA by using Back scattered electron (BSE) mode. As received sample BSE micrograph clearly revealed the segregation and chains of creep cavities adjacent to the grain boundaries. This clearly indicated advanced tertiary stage of creep and material needs immediate repair or replacement [7]. Coarsening of the creep cavities, dissolution and fragmentation of carbide network were observed after creep tested sample as shown in Fig.7.

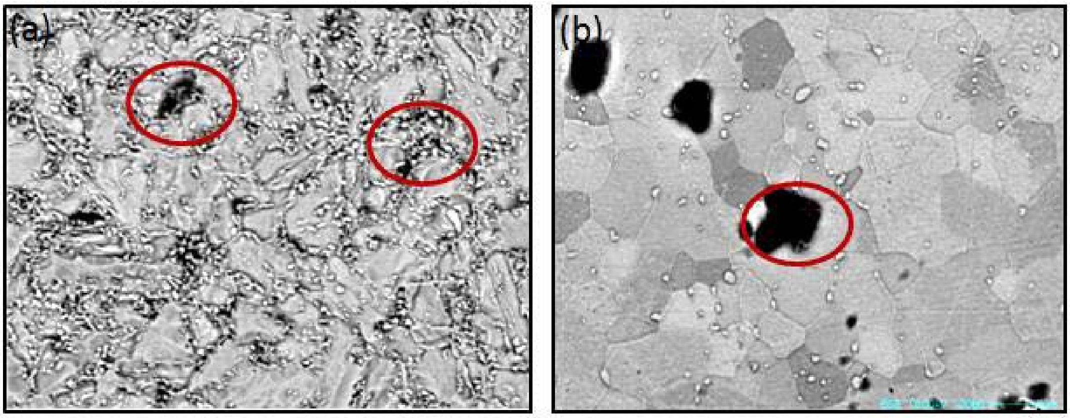

Fig.7: Creep cavities indicated in BSE micrographs: (a) As received sample (before creep testing) and (b) After creep testing

5.0 Conclusion & Recommendations

The study indicated the heater tubes to have suffered severe internal carburization with presence of segregated chains of creep cavities adjacent to grain boundaries. It is confirmed that nil impact toughness and reduction of percentage elongation of material is due to the effect of internal carburization and creep cavities owing to long term exposure at high temperature. High temperature accelerated creep studies also clearly revealed advanced tertiary stage of creep damage, material needs immediate repair or replacement. On considering all the testing results of mechanical properties (Hardness, tensile, impact and creep) as well as corroborating the same with microstructural findings, decision to replace the heater was recommended.

6.0 Acknowledgements

The concerned refinery is thankfully acknowledged for providing the test sample and operation data of past. Also, thanks are due to IOCL management for permitting the publication of this work.

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DOWNSTREAM TECHNOLOGY

Cost Effective and Technically Viable Options for Trouble Free Operation & Capacity Enhancement of Claus Based Sulphur Recovery Units in Refineries and Chemical Industries


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Abstract

Increased processing of more sour crudes and adoption of stringent environment regulations in respect of sulfur emissions demand enhancement of processing capacity of operating sulfur recovery units (SRU) in refineries. Oxygen enrichment in SRU is the proven way of increasing the capacity. Oxygen enrichment increases the throughput of process gas by reducing nitrogen in the combustion air. Oxygen enrichment is the low cost approach in providing 100% SRU redundancy, and application of this process for grass root units reduces the overall size of the unit, and hence overall capital investment. Oxygen enrichment process in a running SRU improves the overall hydraulics of the unit by reducing the back pressure. This process also increases the intensity and stability of the flame providing better reliability of SRU operation, and better destruction of contaminants like heavy hydrocarbon, ammonia etc.

Different levels of oxygen enrichment are employed, like low, medium and high level oxygen enrichment, based on the concentration of oxygen, level of capacity enhancement needed, and existing plant configuration. Several techniques are adopted for enrichment of air by oxygen either by using vaporized liquid oxygen, or by using dedicated plants based on Vapor Pressure Swing Adsorption (VPSA) / membrane process, or by using waste nitrogen from near-by air separation units. At the outset, taking waste nitrogen seems economically viable, but its feasibility depends on the availability and the proximity of the air separation unit from SRU. Selection of suitable enrichment process is governed by level of capacity enhancement, initial and operating cost, availability of the source of oxygen etc. This paper provides an elaborate study on selection of oxygen enrichment process for different levels of capacity enhancement and suitable source of oxygen enrichment with case studies. This paper also details impact of oxygen enrichment in existing SRUs, and its effect on downstream tail gas treating units.

1. Background

Oxygen enrichment in SRU is the proven way of increasing the capacity of sulfur recovery units (SRU) in refineries processing more sour crudes. Oxygen enrichment increases the throughput of process gas by reducing nitrogen in the combustion air. Oxygen enrichment is a low cost approach for providing 100% SRU redundancy, and application of this process for grass root units reduces the overall size of the unit, and hence overall capital investment.

Keywords: Oxygen enrichment, SRU capacity enhancement, Claus process, VPSA, LOX

Beside the benefit of capacity enhancement, application of oxygen enrichment in the combustion air provides trouble free operation of sulfur recovery unit by reducing the back pressure of the unit, minimizing sulphur entrainment in the process gas and improving the overall sulphur recovery.

Selection of suitable enrichment process is governed by level of capacity enhancement sought, initial and operating cost, availability of the source of oxygen etc. This paper provides an elaborate economic study on selection of oxygen enrichment process for different levels of capacity enhancement and a suitable source of oxygen for the enrichment with case studies. This paper also details impact of oxygen enrichment in existing SRUs, and its effect on downstream tail gas treating units.

2. Introduction

Expansion activities of refinery, need for processing heavy and sour crudes, and tightening of sulfur content in finished products have led to increased production of hydrogen sulfide (H_2S), and ammonia (NH_3). This demands an increase in sulfur recovery processing capacity for refineries. While refiners consider various processes to address these sulphur cap requirements, oxygen enrichment of Claus based sulphur recovery units (SRU) provides the most effective and economical solution.

Conventional SRU reaches the limit of its processing capacity once the back pressure of the system reaches the maximum design value. Oxygen enrichment reduces the overall gas flow to SRU main burner by reducing the quantity of nitrogen entering the main burner. This in turn allows the increase in processing capacity of acid gas flow rate and hence increases the overall sulfur production. Moreover, oxygen enrichment raises the flame temperature, ensures stable flame in the main burner of SRU and reduces back pressure when the unit is operated at the design throughput.

Three types of oxygen enrichment are employed in refineries namely low-level, medium-level and high-level oxygen enrichment, depending on concentration of oxygen, level of capacity enhancement required, and existing plant configurations. There are a number of ways to enrich the combustion air with oxygen like use of vaporized liquid oxygen (LOX), oxygen from vapor pressure swing adsorption (VPSA) unit, and waste nitrogen from nearby air separation units.

The main bottleneck to SRU capacity enhancement could be the operating cost associated with oxygen usage. Economy of the oxygen enrichment depends mainly on the source of oxygen. Routing of excess waste nitrogen available in the refinery is the most economical way for capacity enhancement, but the same may not be applicable to medium level and/or high level capacity enhancement, as the availability of excess oxygen from air separation unit is limited. In the same way, oxygen from VPSA can be expensive for low capacity enhancement projects. Level of capacity enhancement depends on the refinery's demand, quantity of heavy or sour crude processed, hydraulics limitation of the unit etc. while the selection of the source of oxygen depends on the desired capacity enhancement, proximity of the existing oxygen generating units (air separation unit, LOX supplying units), capital and operating costs.

Research and Development Division of Engineers India Limited has developed oxygen enrichment technology (OXYENRICH^{TM}), and commercialized the technology in a number of Indian refineries, to meet the demand for capacity enhancement of SRUs and trouble free operation of existing SRUs. This paper aims to provide the refineries a detailed review for the selection of efficient and economical options for capacity enhancement of sulfur recovery units.

3. Oxygen enrichment technology

Claus process is the conventional method for processing H_2S rich streams to recover sulphur from acid gas and sour gases generated in amine recovery unit (ARU), and sour water stripper unit (SWSU), respectively. Claus reaction is broken into two steps. In first step, one third of the hydrogen sulphide (H_2S) is oxidized to sulphur dioxide (SO_2), which then reacts with the remaining H_2S to form sulphur in the second reaction in presence of activated alumina, as catalyst. The reactions taking place in the main burner and other parts of SRU are as follows,

$$3H_2S + 3/2\ O_2 \rightarrow SO_2 + 2H_2S + H_2O \quad (1)$$
$$2H_2S + SO_2 \leftrightarrow 3S + 2H_2O \quad (2)$$
$$3H_2S + 3/2\ O_2 \leftrightarrow 3S + 3H_2O \quad (3)$$

Besides the Claus reaction, there are several other reactions occurring in main burner e.g. combustion of hydro carbon to carbon dioxide, combustion of ammonia to nitrogen and water, decomposition of H_2S to hydrogen and sulphur. All these reactions are highly temperature dependant. Low temperature in burner results in incomplete combustion of ammonia resulting in formation of ammonium salts at the downstream equipment in SRU.

Oxygen enrichment process replaces nitrogen (reaction 1) in the combustion air by oxygen, this helps in reduction of total coolant in main burner with a resultant increase in burner temperature and reduction in back pressure of the unit.

3.1 Types of oxygen enrichment

Depending on the range of oxygen concentration (~ 20% to 100%), different types of oxygen enrichment are employed for capacity enhancement. Normally, these are categorized into following three types.

3.1.1 Low level oxygen enrichment

The first level of oxygen enrichment considers oxygen concentrations up to 28%. This is the simplest and most cost effective means of increasing the capacity of SRU. This technology involves the injection of oxygen into the combustion air piping system of SRU (Figure 1). Additional capacity enhancement of 25% to 30% can be achievable through this technology. Low level oxygen enrichment can be implemented in any existing SRU without any modification in existing piping and equipment, including TGTU section. Hence, this technology requires minimum capital investment and modification.

Injection of oxygen for low level oxygen enrichment can also be effected through all other viable oxygen sources discussed earlier. i.e. from LOX, oxygen from VPSA. Optimal configuration has to be selected based on a thorough economical study and plant configuration.

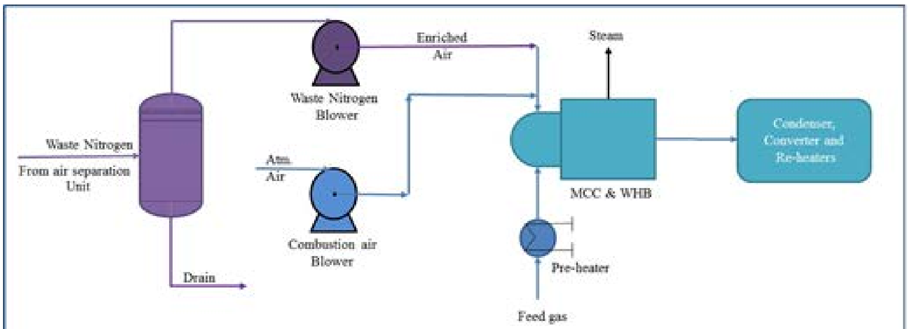

Figure 1 : Capacity Enhancement using Waste Nitrogen

3.1.2 Medium level oxygen enrichment

The second level of oxygen enrichment considers oxygen concentrations from 28% to 45%. Oxygen concentrations higher than 28% would require special piping system to handle the extra oxygen. As the oxygen concentration increases from 28% to 45%, temperature is likely to increase beyond 1500 deg C, and would reach refractory design temperature. If special provisions are not considered to minimize the burner temperature like recycle of tail gas back to the burner (Figure 2), use of steam etc., new burner with adequate refractory system would need to be employed. In some cases, new burner configuration involves injecting the oxygen directly into main burner through a dedicated lance. Heat transfer capacity of MCC waste heat boiler and condenser I requires evaluation to meet the required outlet temperature. If SRU is followed by TGTU, quench section and absorber section also need to be evaluated for increased capacity. Oxygen from LOX or VPSA is considered depending on the scale of capacity enhancement.

3.1.3 High level oxygen enrichment

Oxygen concentration from 45% to 100% at the main burner falls under high level oxygen enrichment i.e. ambient air is almost completely eliminated from the combustion air. An additional capacity of up to 150% of design capacity can also be obtained by using high level oxygen enrichment. High oxygen concentration quickly increases the combustion temperature beyond refractory design temperature. So, special provision is employed to bring down the combustion temperature either through recycling tail gas from downstream equipment or through specialized burner designed to handle pure oxygen.

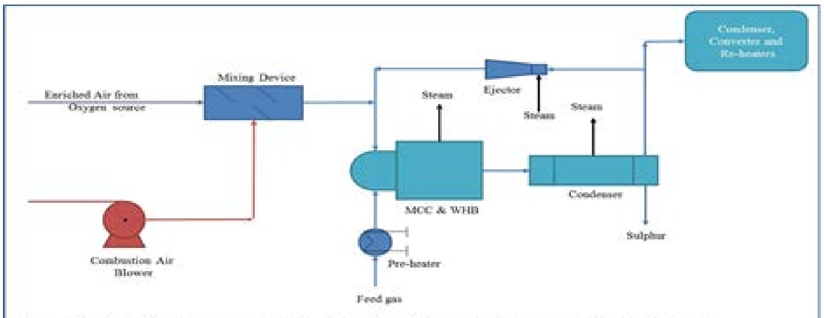

Figure 2 : Capacity Enhancement using Injection of Vaporized oxygen to Combustion Air

4. Modes of oxygen enrichment

Oxygen supply can be made available from a number of sources -each possible source and its merits and demerits are discussed below,

4.1 Oxygen from nearby air separation units (i.e. Nitrogen plant)

As discussed earlier, waste nitrogen from nitrogen plant normally consists of 25-30 vol% of oxygen, and is the most economical option for oxygen enrichment process, in general. Provision to route this enriched oxygen to SRU depends on proximity of the nitrogen plant, quantity, stability of the oxygen concentration etc. If the nitrogen plant is far away, then a dedicated blower (refer figure 1) to push the gas to SRU and extra control measures are required for this scheme, which increases the Capital investment for this option. Capacity enhancement of up to 30% of the original design capacity can be achieved using waste nitrogen.

4.2 Oxygen from vaporized liquid oxygen (LOX)

Another option is LOX, which contains maximum purity of oxygen ranging to ~99.5 vol%. LOX can be an economical option where the oxygen use on the main burner is intermittent. LOX requires a continuous inventory as locating cryogenic oxygen plants near to SRU is restricted (Figure 3). Refineries often choose to transport the LOX from offsite. Due to this limitation, use of LOX for capacity enhancement that involves transporting anything above 10-15 TPD is a costlier option. In addition to transportation challenges, availability of suppliers, safety issues in storage of oxygen pose a greater challenge.

4.3 Oxygen from vapor pressure swing adsorption (VPSA)

VPSA process is used to separate gases in a mixture by exploiting their difference in adsorption capacity on a solid surface. Solid adsorbent in VPSA column adsorbs nitrogen more strongly than oxygen thus producing 90% - 93% vol% of oxygen. VPSA is the perfect option for higher level capacity enhancement. If waste nitrogen is not available / suitable for particular refinery, VPSA is the next best option for low to medium level capacity enhancement. VPSA provides a sense of flexibility and comfort to the operators by having a dedicated oxygen source, and VPSA also ensures continuous availability of oxygen.

Though capital investment and operating cost are quiet high compared to other option, operating company will save substantial investment cost in installing a VPSA unit rather than going for new SRU. Co-produced nitrogen can also be utilized for other purposes in the refinery.

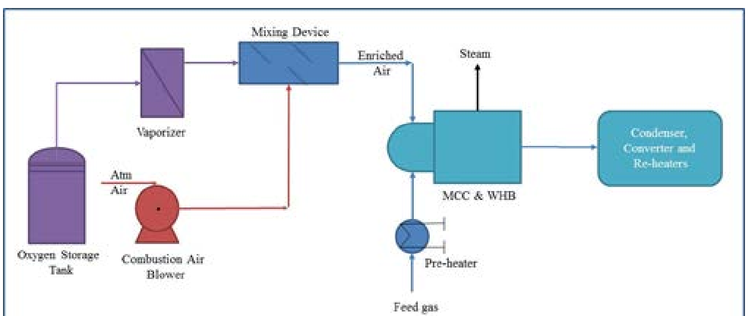

Figure 3 : Capacity Enhancement using Injection of Vaporized oxygen to Combustion Air

	Waste N_2	LOX	VPSA
O_2 Concentration	22-30%	~99.5%	90-93%
Level of enrichment	Low	Low	Medium, High
N_2 co-product	Yes	No	Yes
Location limitations	No	Yes	Yes
Oxygen concentration pattern	Variable	Steady	Variable
Operator intervention	Moderate	Moderate	Frequent

Table 1: Selection of suitable oxygen supply

5. Impact of oxygen enrichment in existing SRU and TGTU

5.1 Impact on SRU and incineration section

With oxygen enrichment being implemented in a number of refineries as the cost effective measure over installation of a new SRU, impact of existing piping and equipment needs to be reviewed for efficient operation of the unit. It is important to upgrade the combustion air control system for oxygen enrichment scenario. Control measure to handle high burner temperature, lack of oxygen from source is implemented in the shutdown scheme to ensure refractory reliability and safe operation of the unit.

Hydraulics of the acid gas and sour gas line is evaluated. Normally, these lines are designed with 20% margin. So, when the capacity enhancement exceeds this limit, evaluation of acid and sour gas lines is required. In addition, feed gas KODs and feed control valves are also to be checked for adequacy. If not given due importance, this may create hydraulic limitations in oxygen enrichment and reduce the attainable capacity enhancement.

High burner temperature increases the load on the downstream heat exchanging equipment, especially to MCC waste heat boiler and Condenser I. As mass flow and temperature shall be higher in these equipments, replacement of the MCC waste heat boiler and condenser I may be required for medium and high level oxygen enrichment. So, proper evaluation of design parameters is to be carried out for the adequacy check.

Sulphur pit storage capacity, pelletizer processing capacity, incinerator and reduction furnace section have to be given careful attention before implementing oxygen enrichment in existing SRU.

5.2 Impact on tail gas treating unit (TGTU)

Less amount of nitrogen in tail gas from SRU during oxygen enrichment enables lower mass flow of tail gas to TGTU than in normal air operation; this reduces the load on TGTU pre-heater. As more water is being produced through Claus reaction, adequacy of quench recirculation section needs to be evaluated critically. Temperature of recirculation flow typically fixed at 40 deg C during conventional operation. If quench cooler is not adequate to handle the extra condensed water, temperature of recirculation raises up. This leads to carry over of unsaturated water over to absorber column which then condenses, leading to reduction in amine concentration which in turn affects the absorption efficiency of the amine.

As more H_2S gets into TGTU during oxygen enrichment, amine circulation circuit, including regeneration section, has to be reviewed for adequate supply of excess amine to absorb additional hydrogen sulphide.

6. Benefits in existing SRU and TGTU

Oxygen enrichment provides trouble operation of SRU which encounters number of operating problems. Refinery considers this technology not only for capacity enhancement of the unit but also for smooth operation. By reducing the process gas flow in the unit, the unit is operated at significantly low back pressure. Sulphur deposition of the catalyst bed, pipes and condensers is minimized because of less sulphur entrainment in the process gas flowing through the unit. High temperature in the main burner provides additional benefit on sulphur recovery. It is observed that 0.5-1% enhancement in sulphur recovery is realized when the unit uses oxygen enriched combustion air.

7. Conclusions

Oxygen enrichment technology is one of the most favored options for refiners for processing additional acid gases and ensuring trouble free operation. In Claus Sulphur recovery unit, the process needs a proper technical and economical evaluation in selection of source of oxygen like waste nitrogen, liquid oxygen, and oxygen for VPSA unit. Optimum configuration is chosen based on extra acid gas for processing, existing piping and equipment condition, availability of oxygen, and budget availability. If refinery generates adequate waste nitrogen and requires capacity enhancement up to 30%, the most economical option is the use of waste nitrogen.

Vaporization of liquid oxygen is the suitable option for low capacity SRU with minimum requirement of capacity enhancement. Transportation and storage of LOX becomes an economical challenge for high capacity enhancement. In this situation, oxygen from VPSA can be a viable option for medium level capacity enhancement; for high level enrichment later, a dedicated oxygen plant near by SRU becomes a suitable option.

SRU and TGTUs designed with oxygen enrichment for future capacity enhancement could be a prudent capital investment for refiners. Selection of cost effective and technically viable option of capacity enhancement depends on level of capacity enhancement, adequacy of existing equipment, proximity of oxygen source etc., Refiners and licensors should work closely to determine the best mode of oxygen enrichment.

M/s Engineers India Limited being the licensor and technology provider of oxygen enrichment technology (OXYENRICH™) provides concept to commissioning of oxygen enrichment units for capacity enhancement for grass root and existing SRUs. EIL has revamped a number of SRUs for low and medium level capacity enhancement.

8. Acknowledgement

We sincerely acknowledge the management of M/s Engineers India Limited, New Delhi, India for providing constant support and consent for publishing this paper.

TAXATION

Equalisation Levy and its Impact on Oil and Gas Industry

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Digitalization has completely changed the way business is run. Gone are the days when groceries were purchased at shops, cabs hired by wave of hands or straining the vocal cords, movies watched only at theaters or televisions. Today movies are watched/ music is heard online on smartphones, meetings are held online, demand is created by disseminating information and marketing online, cars and even houses are bought online – the list is endless. Such rapidly evolving ways of conducting business digitally have posed concerns for governments regarding the modality of taxing cross border transactions. To give an example, income of a foreign company providing content streaming services to Indian customers, is generally not taxed in India on account of beneficial provisions of tax treaties between India and various jurisdictions. This is because generally tax treaties provide that income of a foreign company is taxable in India only if it has a physical presence in India.

To address this, the Organization for Economic Cooperation and Development ('OECD')/ G-20 countries under the Base Erosion and Profit Shifting ('BEPS') Project released Action Plan 1[1] addressing the tax challenges arising from digital economy. This Action Plan provided alternatives to various countries through which they can consider taxing digital transactions.

1. Source: https://www.oecd.org/tax/beps/beps-actions/action1/

India has opted for one of the alternatives, which is Equalization Levy ('EL'). EL is a tax levied in India on the gross amount of consideration earned by a Non-Resident ('NR').

Vide Finance Act, 2016, the Government of India ('GoI') introduced an EL @ 6% on the consideration paid to NR for specified services in the form of online advertisement, provision of digital advertising space or other services related to online advertisement. With effect from 1 April 2020, scope of EL was further expanded by amending Finance Act, 2016 to levy a tax on consideration received/ receivable by NR E-commerce Operators ('EOP') for providing or facilitating E-commerce Supply or Services ('ESS') to specified persons.

Following are the brief features of such ESS EL:

1. EOP is a NR who owns, operates or manages digital or e-commerce facility or platform for online sale of goods or online provision of services.

2. ESS EL is applicable when NR EOP provides online sale of goods/ services or both or sale of advertisements or sale of data collected under specified circumstances.

3. The NR engaged in the activities enumerated above is obligated to pay the ESS EL @ 2%

4. Exclusions: The provisions of ESS EL shall not be triggered where NR EOP has a Permanent Establishment ("PE") in India or turnover threshold of INR 2 crore is not met or online services are covered under existing advertisement EL (introduced in 2016).

5. Where NR pays ESS EL on income from facilitating of online supply/ services, such NR shall be exempt from other provisions of the Income Tax Act, 1961 ('the Act') with effect from 1 April 2021. There is no clarity whether 1 April 2021 refers to financial year or assessment year. If the reference is to the financial year, doubts persist whether for the first year of applicability of ESS EL, no exemption is available under the Act.

It is important to note that EL is not a part of the Act, but is part of the Finance Act, 2020 and thus it is a levy separate from income tax, though it is charged on gross receipts from India.

Impact on Oil and Gas ('O&G') sector:

The Indian O&G sector is of a vast expanse encompassing a host of Multi-national Companies ('MNCs') and renowned international business houses. Various NR players/ Indian Public Sector Enterprises ('PSUs') engaged in O&G activities in India procure goods and services from outside India. The new age O&G companies procure goods/ provide services through digital platform to their customers/ group companies. There is possibility that such activities of O&G companies may come under the scanner of the tax authorities for applicability of ESS EL.

Further, the language of ESS EL provisions is wide and in absence of any clarifications/ FAQs, is subject to diverse interpretations. As a result, there are certain nuances/ issues that may be faced by such NR O&G companies in providing services/ supplies in India.

Following are illustrative issues likely to be faced:

1. Online sale of equipment/ material:

For undertaking operations and execution of contracts in India, material and equipment etc. are required. Indian companies may procure such equipment/ material online from the website/ platform of the NR supplier, whereas delivery thereof shall be through physical movement of equipment/ material.

In such a case, since the entire sale is not concluded on digital platform, there could be a challenge in evaluating applicability of ESS EL provisions.

Another aspect on online supply is where order for equipment/ material is made on modes like email/ telephone. While email/ telephone is merely a communication channel, however, due to wording of the law and lack of clarifications, there is a possibility that the tax authorities may allege such transactions fall under ESS EL provisions. This is because one may contend that email or telephone is a digital facility and hence if sale is concluded on such digital facility EL would be applicable on such sales.

Further, clarity is required regarding determination of turnover/ gross receipts on which ESS EL is payable eg. whether EL is applicable on the gross receivable or on net receivable after considering rebates/ discounts/ sales returns, etc.

Thus, it is imperative that NR entities looking at O&G operations in India/ bidding for O&G contracts factor in provisions of ESS EL at contract planning/ bidding stage.

2. Online supply of software:

The O&G industry involves extensive use of software for different processes like managing daily oilfield service operations, to model the pipe and flowlines to predict and monitor flow both in the well and at the surface, etc.

Where a NR (not having a PE in India) makes sale of software for O&G activity to a Indian company through its website (which is owned, managed or controlled by such NR), such sale may be regarded as online provision of goods / service and fall under the ambit of ESS EL.

Further, it shall be worthwhile to note how the tax authorities interpret the provisions of ESS EL in the following cases:

- Where a NR hosts such software on a platform of a third-party web server owner. In such a scenario, the right to control the web server is not with the NR and the Indian company can use software as and when required;

- Where NR supplies software through pen drive/ CD ROM even though the order for software was placed online on the website/ portal of the NR supplier. In such a scenario, though the order was placed online, sale of software is made through physical medium and hence one can contend that this is not online sale of goods.

3. Inter-company transactions:

There are various transactions that may take place between group companies. Group synergies may be effectively utilized for executing contracts. Following is the illustrative list of group company transactions:

- Supply of goods;
- Data analytics service;
- Web hosting;
- Online trainings;
- Internet based back-end services/ infrastructure.

Where a NR group company enters into above-mentioned transactions with specified persons (eg. Indian subsidiary, group company, etc.) through online mode i.e. emails or accessing internal software, there is an exposure that such transactions may get covered within the ambit of ESS EL (as there may be an inter-company cross charge for the same). It is pertinent to note that on some of the aforesaid transactions, NR may already be paying taxes as Royalty / Fees for Technical Services (FTS). Thus, it needs to evaluate as to whether it is required to pay EL on such transactions or it is required to pay taxes on the transaction as Royalty / FTS.

Further, ESS EL is a levy on gross turnover/ sales/ receipts without deduction of any expenses and disregards profits/ losses incurred, business structure. E.g., it is not clear in a case where a NR is just a facilitator and arranges services from a third party whether such NR will need to pay EL on the gross amount charged (which includes third party charges) or only on the convenience fees charged.

Further, ESS EL provisions are not restricted to services provided only to Indian entities and extend to service provided to NR as well for e.g. EL is applicable on sale of unprocessed data collected from a person who is resident in India or from a person who uses IP address located in India. In case data collected from India is shared by NR with group companies for a consideration, then EL may also arise on such gross consideration.

Applicability of ESS EL to inter-company transactions could inter-alia, have following ramifications:

- Increase in tax cost of the group;
- Increase in bid price for contracts;
- Impact on project viability.

4. Provision of FTS:

Prior to introduction of ESS EL, taxability of a NR providing services relating to O&G contracts and qualifying as FTS were covered under specific tax provisions related to O&G activities. Further, in certain tax treaties, beneficial provisions for non-taxability of FTS were also adopted by NR.

With the introduction of ESSL EL, such services provided by NR through online platform are likely to be covered under ESS EL provisions.

Consequently, where transactions are subject to ESS EL, other provisions of the domestic tax law shall not be applicable and hence, it may not be possible for NR taxpayers to resort to favorable treaty provisions.

Conclusion:

The GoI is quickly responding to taxing digital economy and is introducing amendments in the domestic tax law. It would be interesting to see going forward how the ESS EL provisions are interpreted by the tax authorities, especially the manner in which they proceed to question NR taxpayers. For NR taxpayers engaged in O&G activities, it is of utmost importance to undertake a detailed evaluation of ESS EL provisions with respect to their India operations.

INFORMATION SYSTEMS

Business Continuity Planning for Information Systems

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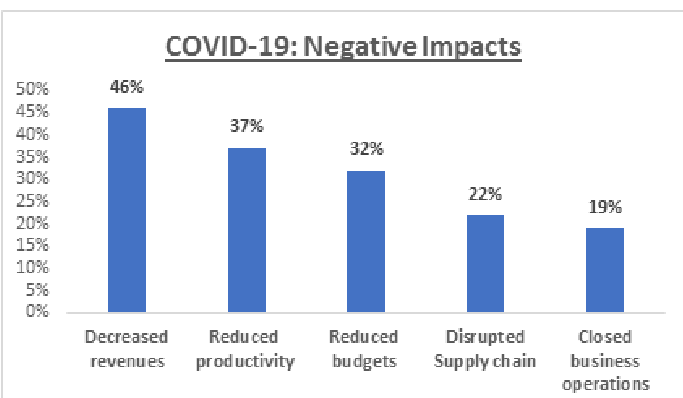
1. Introduction

In last 100 years of modern industrialization, Businesses have survived onslaught of many manmade as well as natural calamities. Whenever factors like social unrest, political uprising, Tsunamis, earthquakes, flood etc. created havoc, businesses came out resiliently, survived and progress further. Businesses have witnessed losses with respect to infrastructure such as damaged production facilities (example Factories and offices), disrupted supply lines and seizures of markets. The past problems that our businesses faced, were limited in nature. They either affected only few segments of business; for a small duration of time or they were limited to certain geographical areas only. Businesses learnt from these experiences and came out with Business Continuity Plans (BCP) to survive.

However, the recent COVID-19 pandemic has posed unprecedented challenges to our businesses. The impact of COVID-19 is global and multifaceted with short as well as long term consequences. The challenges posed by COVID-19 were never experienced before and our existing business continuity strategies, plans and systems are inadequately equipped to support the businesses in such eventuality.

A study was conducted by ISACA (USA) in April, 2020, involving more than 3,700 senior business executives across 123 countries to assess the impact of COVID-19 on their organizations and their preparedness to tackle the problem.

The outcome is astonishing as majority of the respondents said that their organizations have not been able to avoid the negative effects of COVID-19 on business. Their major concern areas are:



Information Systems are the backbone of modern-day businesses and any disruption in Information Systems may lead to revenue losses, disruption of supply chains, lower customer satisfaction and reputational losses. These disruptions may further jeopardize the very existence of the businesses. So, to ensure continuity of business, we have to ensure continuity of Information Systems.

2. Business Continuity Management (BCM) Plans for Information Systems

An effective BCM plan protects the interests of the organization's stakeholders and reputation. BCM evolve around six assets viz. People, Premises, Technology, Information, Supplies and Stakeholders. Accordingly, continuity strategies are planned to support BCM.

BCM of Information Systems is an all-encompassing management approach to make Information Systems more agile and resilient through identification, prevention and mitigation of operational risks. BCM of Information Systems consists of:

- Business continuity planning (BCP)
- Contingency planning (CP)
- Disaster recovery planning (DRP)

A robust and effective BCM involves robust processes and can bring organizational resiliently out of crisis. However, inappropriate approach and incorrect assumptions by BCM practitioners may render the outcome of the BCM project.

3. Major Challenges to Business Continuity Management for Information Systems

Major challenges in designing, implementation and execution of effective and successful Business Continuity Plans in today's organizations are:

- Commitment and involvement of top leadership (Management Buy-in)
- Data dynamics involving volume, complexity and veracity of data
- Mismatch between planning and execution approach
- Incorrect/inappropriate assumptions in framing Business Continuity and Disaster Recovery Plans

3.1 Commitment and involvement of Top Leadership

3.1.1 Delegation by Senior Management

Challenge: In some organizations, senior executive sponsors of the BCM project are too busy and the responsibility is delegated to a mid-level manager to oversee the project. This reduces the visibility of the project at the organizational level and may also result in lack of serious cooperation from relevant departments/functions.

Solution: This challenge can be resolved by setting up a cross-functional steering committee that consists of key stakeholders. The committee should meet periodically to resolve issues.

3.1.2 BCM Implementation for the Wrong Reasons

Challenge: When senior management tends to think that a typical sort of disaster has never occurred and therefore there is no business case for allocating scarce resources, it often results in a lackadaisical attempt at implementing business continuity to satisfy only regulatory requirements or close audit observations.

Solution: This issue can be addressed by undertaking a sustained BCM awareness campaign among key stakeholders, highlighting the benefits of achieving resilience from their perspective: meeting current and prospective customer demands and regulatory compliance, avoiding liability, and maintaining a competitive edge.

3.1.3 Business and IT Disconnect

Challenge: In today's highly competitive markets, businesses are often compelled to respond dynamically to a competitor's offerings. With stringent timelines to conceptualize and launch new products and services, business managers sometimes do not give advance notice to the IT infrastructure team to build necessary capacities.

Solution: This failure to align technological capability with business needs and growth projections often results in solution gaps, false expectations and performance issues that adversely affect organizational reputation. These issues can be avoided by systematic planning and collaboration between business and IT.

3.1.4 Technology-only Approach Towards Resilience

Challenge: While planning resilience, sometimes businesses rely more on technology and lose focus on other resources such as people, premises, data, processes and supplies. It results to inadequate and less effective BCPs where critical components i.e. Technology, HR, data and processes are not in sync with each other.

Solution: The issue can be tackled by creating appropriate awareness among stakeholders, identifying risks and single points of failure for organizational resources, recommending suitable risk mitigation measures to ensure the continuous availability of resources, and incorporating BCM processes into day-to-day operations.

3.1.5 Lack of Consensus Between Senior Management and Operations Management

Challenge: Lack of consensus at different levels of management can be prominent when conducting business impact analysis (BIA). Example: Non-agreement between Senior Management and Operations Management on Maximum Tolerable Period Of Disruption (MTPOD) and Recovery Time Objectives (RTOs) for different services and processes.

Solution: The issue can be addressed by breaking the BIA into parts. The first part of the BIA should be conducted with senior management to obtain MTPOD values for all services/products and respective functions that support the delivery of the services/products. The second part has to be conducted with operational management in a more detailed to identify department-specific MTPOD values and RTOs. The values given by senior management should be treated as preliminary values and need to be validated by the operational management of respective departments. Any difference in the MTPOD values of senior management and operational management need to be resolved by achieving consensus of opinion.

3.1.6 Absence of a Single BCM Framework Across Multiple Offices

Challenge: The BCM framework followed at all locations may not be consistent for present day global organizations that have multiple locations in multiple countries. Sometimes it may be due to difference in local Government policies and regulations to which business have to abide by.

Solution: Consistency in approach and BCM documentation can be achieved by adopting an international BCM standard/framework across the enterprise. In such BCM frameworks, local regulations can be placed as sub-clauses or as addendums to standard clauses.

3.2 Lack of Understanding of Data Dynamics

Sometimes, BCM practitioners fail to understand or to take into consideration the data dynamics like the different sources and repositories of business data, frequency of data updation, importance of different sets of data. This may lead to:

3.2.1 Inappropriate Data Recoveries:

Challenge: When data from core applications or core storage locations is identified as critical and data backup strategies evolve around only this data. Here data stored at end-user terminals or department specific resources like scripts/spread sheets /local data bases is left behind. It may be critical business data and in case of outage may disrupt the business.

Solution: The end-user computing resources need to be incorporated into the backup cycle to ensure that data backup is available for retrieval when required. Alternatively, the functionality provided by the end-user computing systems should be incorporated into the enterprise applications.

Further, building up the IT Infrastructure in a structured way by envisaging immediate, medium and long term business data needs is required. It will facilitate robust and synchronized recovery of lost data, continuing business transactions during an outage and restoration post recovery etc.

3.3 Mismatch Between Planning and Execution Approach for BCM Processes

This section presents the key issues, challenges and resolutions related to an inappropriate approach in executing BCM processes.

3.3.1 Business Specific Risk Assessments:

Challenge: Tailoring a BCM approach to suit an organizational context is a challenge faced in many BCM projects. One size doesn't fit all. If some BCM approach suits one organization it never implies that the same will suit to the needs of another organization.

Solution: Conducting a unit/entity specific risk assessment may not always be sustainable. Adopting a service/product-based approach for risk assessment is more effective and sustainable. In this approach, each team conducts a risk assessment for its resources, including technology, data, people, processes, premises and supplies. A corporate team such as a BCM organization can coordinate the risk assessments; consolidate and analyse the results; and facilitate selection, approval and deployment of risk mitigation measures at the enterprise level.

3.3.2 Equal Weight Assigned to All Risk Attributes

Challenge: Sometimes, the risk assessment approach itself became a challenge for BCM. There are different methodologies to carry out a risk assessment. When a risk priority number (RPN) is computed by giving equal weight to three attributes: Severity, Likelihood and Non-detectability. It may lead to unnecessary investments for low-severity risks.

Solution: To avoid such problems and consequences we may add another parameter which is Criticality—the product of severity and likelihood. Through this we may prioritize our efforts and allocation of resources accordingly.

3.4 Incorrect/Inappropriate Assumptions in Framing Business Continuity & Disaster Recovery Plans

3.4.1 Inappropriate Business Impact Analysis (BIA) Approach and BCM Tools

Challenge: Using BIA tools to conduct analysis by functional area and not considering the impact of a disaster on the entire business is an incorrect approach. This will lead to significant efforts because individual business functions will tend to overstate the importance of their function. However, if questioned correctly, management will give an entirely different answer about its relative importance in the context of a broader disaster impact.

It may also occur that the approach adopted by the BCM team when conducting certain activities (such as BIA and risk assessment) may not map exactly with the approach built into the tool. This may lead to inappropriate findings and accordingly wrong BCM policies.

Solution: BIA has to be approached in the context of a unit wide disaster that affects all business functions at the site. Knowledge of the tool and its workflows at the time of developing BCM documentation will help in avoiding rework during implementation of the BCM tool.

3.4.2 Incorrect/inappropriate assumptions in framing BCPs and DRPs

Challenge: Sometimes, business continuity plans are built on assumptions that may not include all relevant factors, their probability and other limiting factors. For example, scope of plans is chalked out on an unstated assumption that only the organization in question will be impacted by a disaster.

Another typical assumption is that employees will travel to support operations at remote sites. Local area or regional disasters, especially those that may result in injury and death, can make employees reluctant to go far from home.

The current COVID-19 pandemic has proved BCM assumptions for almost every business wrong. A COVID-19 like situation was never thought of and BCPs were not ready for the situation. Every business is affected through loss of life/ health issues of employees, disruption of supply chains and revenue losses.

Solution: Business Continuity Plans need to encompass an organization's expectations and the permissions or requirements it will communicate to its employees. A hard-line, enterprise-first approach will not be well received. But one that tells employees to first take care of themselves and their families during a disaster may garner more employee support. Planner should consider all relevant factors which are global as well as local and their far reaching impact while working on Business Continuity Plans.

The COVID-19 crisis was impossible to envisage with conventional learning, experiences, predicting techniques and methods. However, there are many lessons businesses can learn and evolve their BCMs.

4. Summary

BCM related with Information Systems is crucial for modern businesses to evolve and flourish in face of new challenges. The present COVID-19 situation has offered challenges as well opportunities to rethink and plan BCM strategies which are more contemporary, future ready as well as able to give much needed agility to businesses. To make BCM more adaptive, businesses have to focus more on People safety, Reliable communication channels with stakeholders, Agility and flexibility in financial resources, Better approach for resilience and readiness for recovery.

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SUSTAINABILITY

Water Conservation: The Cradle of Sustainability

ENGINEERS INDIA LIMITED

Abstract

Water conservation is the need of the hour not only for satiating the needs of the growing population but also for having sustained operations of the industry.

Water consumption in any industry is due to water incorporated in the product, water evaporated to atmosphere and water discharged to the environment. The water incorporated in the product is the water consumed in the reaction and will depend on the quantity & quality of crude processed, the quantity & quality of products produced and the process technology. The water evaporated to atmosphere will depend on the heat integration within the refinery. The water discharged to environment will depend on the quality of fresh water used, the effluent quantity & quality discharge limits and losses such as steam loss, water leakages etc.

A study was carried out under the aegis of Center of High Technology for establishing the water consumption of thirteen petroleum refineries in India. A bottom to top approach was adopted for carrying out the water balance of each refinery based on the operating data. This approach involved carrying out the water balance for each process unit which provided a better understanding of the sources of effluent generation, the opportunities of condensate recovery and the possibilities of reuse of water in the process units. Sampling and analysis of effluent streams provided the scope of segregated treatment of these streams before routing to Effluent Treatment Plant or process improvements to generate the quality of effluent stream as envisaged during the design stage. A highlight of the study was the estimation of leaks in the underground cooling, fire & drinking water networks which are major contributors towards water consumption.

It is noteworthy that the water consumption in a refinery is indicated by measuring the water from river, wells or municipal supply which is termed as fresh water consumption. However, the water consumption can also be met by other sources such as desalinated sea water, treated sewage, collected rain water etc. Hence, increasing the use of other sources helps to reduce fresh water consumption with no impact on water consumption. Water consumption of a refinery can only be reduced by adopting measures impacting the factors on which it depends.

With the objective of developing unit wise norms as well as norms for overall water consumption of a refinery, it was important to define an indicator of water consumption independent of the feed / product capacity of a refinery or a process unit. This indicator was named Specific Water Consumption (SWC) which is defined as the water consumption per unit feed / product capacity.

Keywords: Water Conservation, Sustainability, Specific Water Consumption, Zero Liquid Discharge

The paper shall bring out the range of SWC of process units in refineries and of overall SWC of refineries. The measures that can be adopted in short & long term will be presented. These measures will not only reduce water consumption but will also establish efficient water management leading to reduced size of Zero Liquid Discharge systems which are expensive. An overview of nascent technologies and the challenges in their implementation will also be provided.

Introduction

With the planet's second largest population in India at 1.3 billion, and expectant growth to reach 1.7 billion by 2050, India is struggling to provide safe, clean water to most of its populace. A glance at the World Bank's latest statistics reveals the magnitude of the problem: 163 million Indians lack access to safe drinking water; 210 million have no access to improved sanitation; 21 percent of communicable diseases are linked to unsafe water and 500 children under age five die from diarrhoea each day in India.

All the refineries are already aware about criticality of fresh water availability for industrial applications and it is even more crucial for refineries which actually requires significant amount of water to run the refinery & petrochemical operations. Many Indian refiners have been facing severe issues of shortfall in desired quantity of water, which has forced the refinery & petrochemical to run at lower throughput. Some of other coastal refineries have been required to purchase the fresh water at significant rates.

Water conservation is the need of the hour not only for satiating the needs of the growing population but also for having sustained operations of the industry. **The study has identified a fresh water saving potential of ~3200 m^3/hr in thirteen Indian Refineries.**

2. Water Consumption

Consumption of water in a refinery can be due to the following ways:
• The water incorporated in the product, which is the water consumed in the reaction and will further depend on the quantity & quality of crude processed, the quantity & quality of products produced and the process technology.
• The water evaporated to atmosphere, which will further depend on the heat integration within the refinery.
• The water discharged to environment will depend on the quality of fresh water used, the effluent quantity & quality discharge limits and losses such as steam loss, water leakages etc.

Overview of the use of water is indicated in Figure 1 where

WC = Water Consumption, m^3/hr
A_1 = Water Evaporated from Reservoir, m^3/hr
A_2 = Effluents generated from Refinery, m^3/hr
A_3 = Water Evaporated from Open Basins or Ponds, m^3/hr
A_4 = Treated Effluent released to Environment Water Body, m^3/hr
A_5 = Refinery Cooling Tower Evaporation & Drift Losses, m^3/hr
Z = Recycle Water, m^3/hr

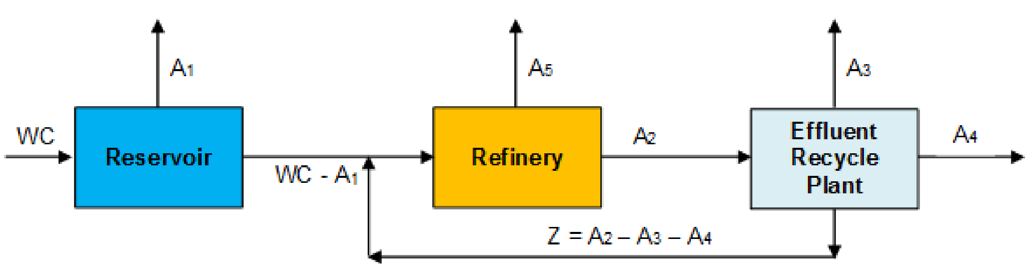

Figure 1: Water Consumption in Overall Water Balance

The amount of water incorporated in the product (WIP) can be calculated by overall balance as follows:

$$WIP = WC - A_1 - A_3 - A_4 - A_5 \quad (1)$$

Rearranging Equation (1) for Water Consumption, we get:

$$WC = WIP + A_1 + A_3 + A_4 + A_5 \quad (2)$$

The water consumption in a refinery or a process unit is directly proportional to their feed or product capacity. With the objective of developing unit wise norms as well as norms of overall water consumption of a refinery, it was important to define an indicator of water consumption independent of the feed / product capacity of a refinery or a process unit. This indicator was named Specific Water Consumption (SWC) which is defined as the water consumption per unit feed / product capacity and is given by the following equation:

$$SWC = \frac{WC}{114.2 * TH} \quad (3)$$

Where

SWC = Specific Water Consumption, m^3/ton of feed

WC = Water Consumption, m^3/hr

TH = Throughput or Feed / Product Flow Rate, MMTPA

3. Methodology of Study

The following data was obtained from various refineries for carrying out the study:

- Design data of existing water / waste water treatment plants
- Actual flow measurement of the identified inlet & outlet water / steam lines of process units
- Actual flow measurement of the identified inlet & outlet water lines of water / wastewater treatment plants
- Analysis of samples of the identified feed and effluent water lines of process units
- Analysis of samples of the identified feed, outlet and reject streams of water / wastewater treatment plants

A study was carried out under the aegis of Center of High Technology for establishing the water consumption of thirteen petroleum refineries in India. A bottom to top approach was adopted for carrying out the water balance of each refinery based on the operating data. This approach involved carrying out the water balance for each process unit which provided a better understanding of the sources of effluent generation, the opportunities of condensate recovery and the possibilities of reuse of water in the process units. Sampling and analysis of effluent streams provided the scope of segregated treatment of these streams before routing to Effluent Treatment Plant or process improvements to generate the quality of effluent stream as envisaged during the design stage.

4. Study Results

It is noteworthy that the water consumption in a refinery is indicated by measuring the water from river, wells or municipal supply which is termed as fresh water consumption. However, the water consumption can also be met by other sources such as desalinated sea water, treated sewage, collected rain water etc. Hence, increasing the use of other sources helps to reduce fresh water consumption with no impact on water consumption. Water consumption of a refinery can only be reduced by adopting measures impacting the factors on which it depends.

The Specific Water Consumption and Specific Fresh Water Consumption are represented in Figure 2. The various refineries have been labeled from A to M in order to maintain the data privacy. The refineries are arranged on x-axis in increasing order of capacity from A to M. Specific Water Consumption (SWC) for Refinery A & B is very high (>1.5) and that for Refinery E, F & G is low (0.6-0.0.8). As such, there is a lot of potential for water savings in Refinery A & B. Specific Fresh Water Consumption (SFWC) for Refinery A, F, H & I is significantly different from their respective SWC which indicates high usage of alternate sources of water for consumption.

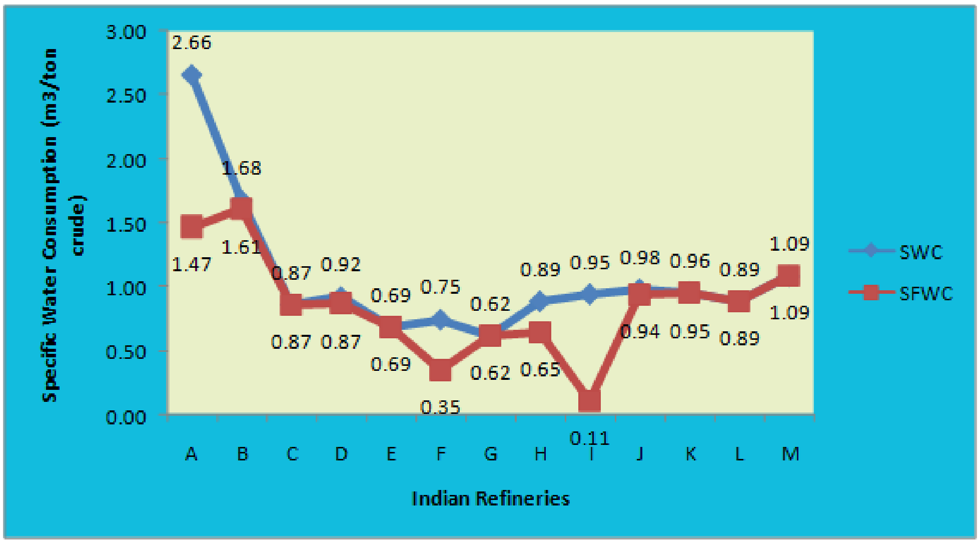

Figure 2: Specific Water & Fresh Water Consumption of Indian Refineries

The Actual & Ideal Water Consumption is plotted against the refinery capacities in Figure 3. Ideal WC is calculated using Equation (2) assuming zero liquid discharge to environment either through direct discharge to any water body or leaks to ground water. The Ideal Water Consumption increases quite linearly with the increase in capacity of refineries and the Actual Water Consumption follows a similar trend. However, the gap between the Actual & Ideal Water Consumption increases with the increasing capacity of the refinery. This is in line with the fact there are more losses such as water leakages, steam loss etc. for larger refineries.

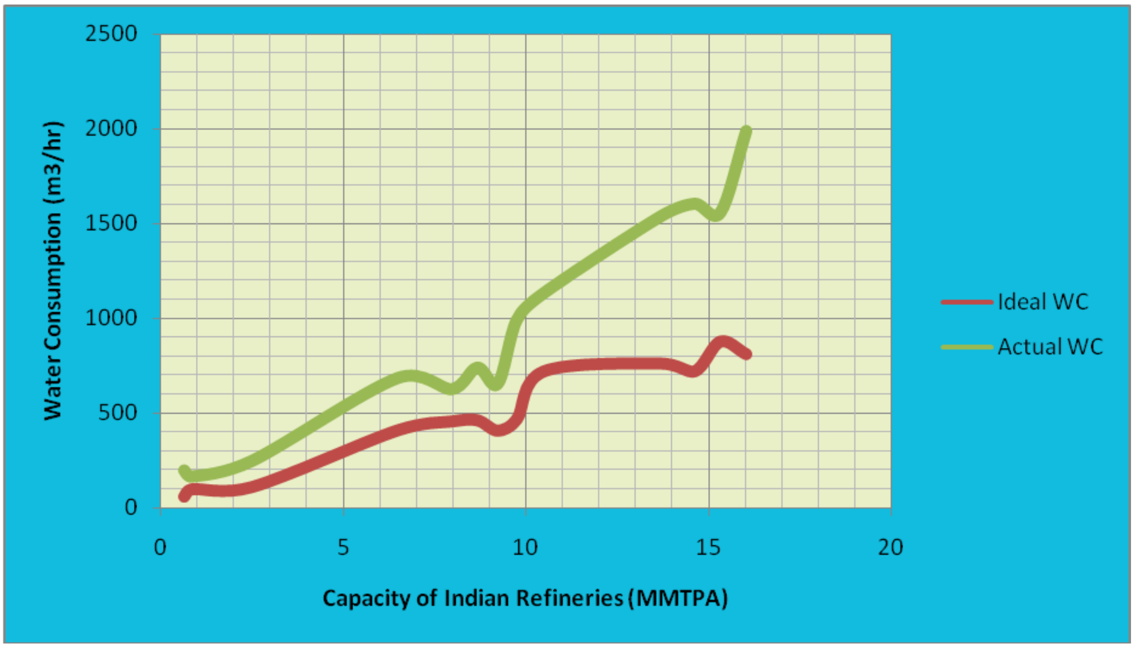

Figure 3: Actual & Ideal Water Consumption Vs Refining Capacity

The water consumption of Indian refineries and their distribution between various sources such as fresh water, rain water, sewage, sea water and recycle water is indicated in Figure 4. Sea Water equivalent is used to indicate the sum of sea water cooling tower drift and evaporation losses and desalinated water from sea water desalination plants.

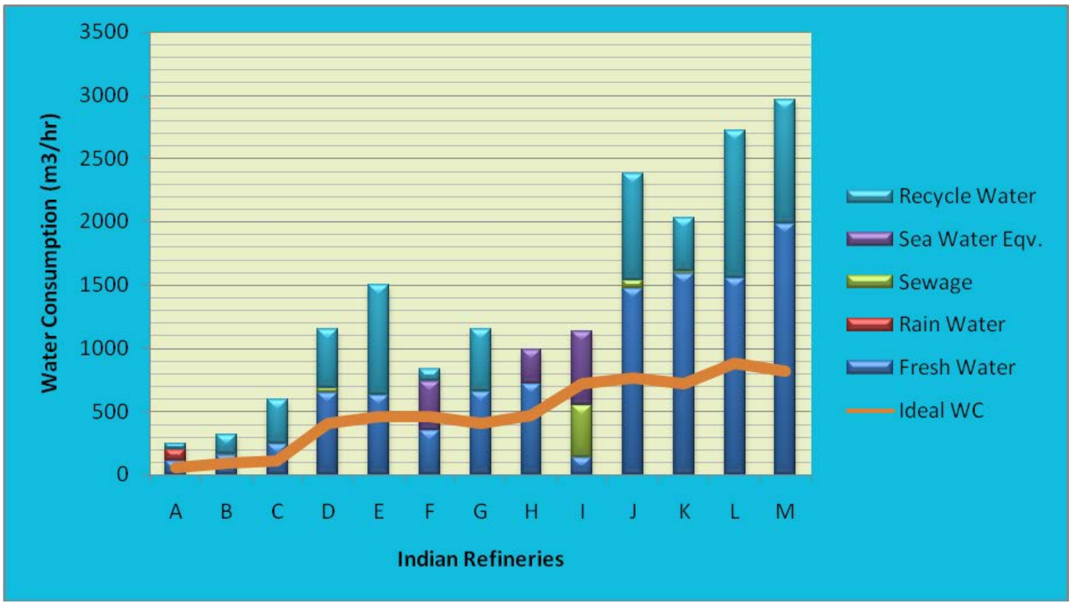

Figure 4: Water Consumption of Indian Refineries

Gross Water Consumption (GWC) is the sum of Net Water Consumption (NWC) & Recycle Water. The recycle water contributes the highest percentage of GWC in Refinery B, C & E (> 45%) and the lowest percentage of GWC in Refinery H, I & F (<15%). However, high percentage of recycle water is not the only way to reduce fresh water consumption. On one hand Refinery F has 11% recycle water consumption whereas on the other hand its fresh water consumption is lesser than the ideal water consumption due to use of sea water as an alternate source for water consumption. Availability of sea enabled Refinery H, I & F to reduce fresh water consumption even at reduced percentage of recycle water. Similarly, Refinery A made use of rain water and Refinery D, I & J made use of sewage for reducing fresh water consumption. However, use of alternate sources does not reduce the GWC.

The various modes of water consumption in a refinery vis-à-vis water incorporated in product (including any losses), evaporation & drift Losses in cooling towers, unrecovered blowdown in cooling towers such as leaks, evaporation losses in reservoirs and effluent discharged to environment were suitably distributed within the process units to calculate the SWC of each process unit. The Specific Water Consumption of major process units in Indian Refineries is indicated in the table below.

Table 1: Specific Water Consumption of Major Units in Indian Refineries

S. No.	Major Units	Specific Water Consumption (m3/ton)			Basis
		Minimum	Maximum	Average	
1	Atmospheric / Vacuum Distillation Unit	0.06	0.33	0.15	Feed
2	Naptha Hydrotreating & Isomeraization Unit	0.02	1.23	0.45	Feed
3	Naptha Hydrotreating & Reforming Unit	0.15	2.80	0.62	Feed
4	Diesel / VGO Hydrotreating Unit	0.03	0.24	0.12	Feed
5	Diesel / VGO / Kero Hydrodesulfurization Unit	0.03	0.15	0.10	Feed
6	Fluidized Catalytic Cracking Unit	0.25	1.36	0.62	Feed
7	Hydrocracking Unit	0.09	0.21	0.14	Feed
8	Delayed Coker Unit	0.13	0.77	0.34	Feed
9	Hydrogen Generation Unit	2.13	16.29	9.74	Product
10	Sulfur & Amine Block	0.00	31.40	5.24	Product

SWC of process units will decrease with the reduced discharge to environment either through direct discharge to environment or leaks to ground water. Hydrogen Generation Unit is a major consumer of water as steam is consumed in the reforming of naphtha or natural gas for producing hydrogen. Other major consumers of water in refineries are Fluidized Catalytic Cracking (FCC) where there are evaporative losses in Belco Scrubber and Delayed Coker Unit where there is consumption in the form of coke cutting & cooling water. SWC of these units is less because of high value of feed throughput in denominator. SWC of Sulfur & Amine Block is high because of the small value of sulfur production in denominator.

5. Water Conservation Techniques & Best Practices

The refiners are mostly focused on producing high quantity and quality of products from crude oil. As such, the water management in the refinery is often ignored. Good water management practices, incorporating water pinch principles, can help to reduce water consumption at minimal cost. Some of these measures, along with an idea of the percentage of untapped water savings through implementation of recommendations, are given in the Table 2.

Table 2: Percentage of Untapped Water Savings for Recommendations

S. No.	Plan	Recommendations	Percentage of Untapped Water Savings
1.	Short Term	Segregation of High TDS Streams from good quality streams	10-15
2.		Reducing Fire, Service, Drinking & Horticulture Water Consumption	30-35
3.	Long Term	Reducing Fire & Drinking Water Leaks	0-10
4.		Reducing Cooling Tower Leaks, Increasing COC of Cooling Towers & Using Raw Water in place of ETP Treated Water Use as Cooling Water Make Up	15-20
5.		Implementation towards ZLD Technologies	20-25

Condensate & Boiler Blowdown should be recovered at the point of generation in the process units. The unrecovered condensate and boiler blowdowns routed to Storm Water Channel should then be used as fresh water after proper treatment. This is possible only if no contaminated stream (with high Oil & TDS) is allowed to be routed to Storm Water Channel. Also, steam tracing should be replaced with electrical tracing (e.g. offsites area where condensate is not normally recovered) in order to reduce steam / water consumption as stream losses would be obviated. Cooling Tower Blowdown is a high TDS stream and should be collected in localized sumps near the cooling towers and pumped to Effluent Treatment Plant (ETP). Further, Stripped Sour Water should be utilized as Desalter Wash Water after treatment, if required. Avoiding the routing of the lean (low TDS, BOD, COD, Ammonia etc.) streams to ETP will reduce the hydraulic load on ETP (by around 30%) thereby increasing the residence time and reducing ETP upsets, which do not allow operating the downstream RO Plant, increasing the refinery fresh water consumption temporarily.

The study revealed that the fire, service, drinking & horticulture water consumption were very high as compared with the estimated values. These can be reduced by checking the day and night pattern of fire water make up, carrying out regular fire water audit, utilizing industrial vacuum cleaners / high pressure cleaners for floor cleaning, installing flow meters for drinking water accounting, installing foam & mist type nozzles (which will reduce the water consumption through taps by 90%) and utilizing spray / drip irrigation methods.

Preparing an Overall Water Balance from the stream flow values obtained after finalizing water balance of process units and reasonable assumptions based on operation feedback helped to estimate the leaks in underground network of cooling towers, fire water and drinking water. These estimated underground leaks are huge and can be avoided by having an above ground network. Also, fresh water should be utilized as make up to cooling towers as this will enable increasing the cycle of concentration. The use of good quality water as make up will reduce the probability of leakages due to corrosion issues. Further, it helps to avoid ground water contamination issues due to the effect of cycles of concentration on ETP treated water make up and cooling water chemical treatment.

All the aforementioned steps can not only provide water savings but also reduce the capacity of the Zero Liquid Discharge System (Reverse Osmosis followed by Evaporator & Crystallizer). The Evaporator & Crystallizer system is very expensive to install and operate. Also, there is a challenge to find non-hazardous landfills for continuous salt disposal over a long period of time.

6. Technology Overview

Various technologies that can be utilized for water conservation were identified and discussions with system suppliers were carried out as part of the study. These technologies are presented in Figure 5.

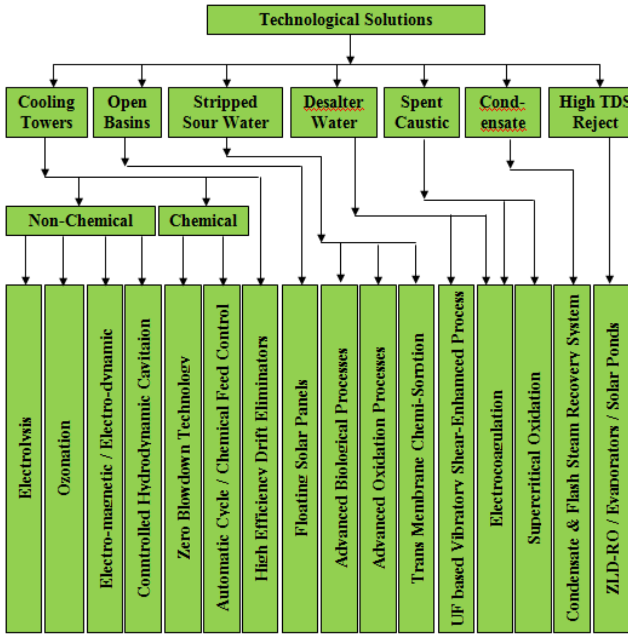

Figure 5: Technological Solutions for Water Conservation

Condensate & Flash Recovery Systems are a must for water conservation. Electrolysis process involves precipitation of hardness from circulating cooling water for increasing COC of cooling towers and is already working on plant scale. Evaporator & Crystallizer is a good option for end of the pipe solution for high TDS streams but comes with the challenge of establishing a cost effective metallurgy of the plant and disposal of solids. High efficiency drift eliminators and floating solar panels are already implementable on plant scale. Other technologies are promising for specific solutions but are either on lab or pilot scale.

7. Conclusion

The Specific Water Consumption for most (~85%) of the thirteen Indian Refineries is in the range of 0.62 – 1.1 m^3/ton crude. Around 73% of the 56 European Refineries (for which data is provided in BAT[1] Reference Document for the Refining of Mineral Oil & Gas) have Specific Water Consumption less than 1.1 m^3/ton crude. This indicates that the Indian Refineries are better placed than the European Refineries in terms of water conservation. However, the upper limit of the industry benchmark for the supply of raw filtered water that integrates drift & evaporation losses as well as blowdown is 0.66 m^3 per metric ton of processed crude oil as per EHS Guidelines2 for Petroleum Refining produced by World Bank. Hence, there is a lot of potential for saving water, the extent of which will vary from refinery to refinery. Some water savings can be achieved through short term measures at minimal cost while the balance water savings will require long term measures at substantial cost. These good water management practices along with commercialization of new technologies shall pave the way towards water conservation which is essential for a sustainable future.

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1. Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil & Gas, https://eippcb.jrc.ec.europa.eu/reference/BREF/REF_BREF_2015.pdf

2. Environment, Health & Safety Guidelines for Petroleum Refining by World Bank, https://www.ifc.org/wps/wcm/connect/bde2da1d-3a09-400b-be24-3f6a60353ddc/2016-EHS+Guidelines+for+Petroleum+Refining+FINAL.pdf?MOD=AJPERES&CVID=lxPS7Bu

OIL AND GAS IN MEDIA

Recent PNGRB Regulation Paves the Way for Gas Exchanges in India

A recently released regulation by the Petroleum and Natural Gas Regulatory Board (PNGRB) directs that a shareholder in a gas exchange will have to cut his stake in a gas exchange to 25 per cent or less within five years of its launch. However, the Board does not prescribe a ceiling for the shareholding in the first five years.

The new regulatory framework is set to pave the way for setting up of natural gas exchanges in the country. Natural gas exchanges will facilitate the trade of physical contracts and will mark a key step in development of natural gas markets in the country. The recent regulation empowers PNGRB to issue licenses to operate an exchange, investigate and cancel the license. It also clearly draws the contours of membership and shareholding of exchange, contract settlement and appointment of directors.

While PNGRB has retained mod of the regulations unveiled for consultation in July a key provision regarding shareholding limit by a non-member has been changed. The draft provided for a maximum 15 per cent shareholding by a non-member shareholder at any time, which has now been raised to 25 per cent.

MoRTH Includes 18 % Blended H-CNG as Automotive Fuel

The Ministry of Road Transport and Highways has notified a regulation for various alternative fuels to further promote sustainable transportation. The notification amends the Central Motor Vehicles Rules 1989 to include H-CNG as an automotive fuel.

Mr Nitin Gadkari, Minister, Road Transport and Highways informed that "After testing use of H-CNG (18 per cent mix of hydrogen) as compared to neat CNG for emission reduction, the Bureau of Indian Standards has developed specifications of hydrogen-enriched compressed natural gas (H-CNG) for automotive purposes as a fuel,"

The Ministry of road transport and highways had issued a gazette notification laying down quality specifications and allowing use of both bio-CNG and hydrogen blended in CNG up to 18 per cent in motor vehicles on 25 September. This is being considered a major step by the Government towards handling the winter pollution in the National Capital Region (NCR). HCNG has 70 per cent lower carbon monoxide and 25 per cent lower hydrocarbon than CNG though the NOx level is the same. As per the directive of the Hon'ble Supreme Court, IOCL and IGL have collaborated to put up the first semi-commercial plant as a pilot project for conducting the study on the use of HCNG fuel in 50 BSIV compliant CNG buses in Delhi.

The MoRTH notification also authorizes use of bio-CNG which unlike HCNG needs further emission control measures since it emits carbon-di-oxide and has other impurities. The Union government along with states like Haryana and Punjab is also pushing for converting the residual bio-mass, that is burnt by farmers in winter to clear their fields for fresh sowing, into bio-CNG.

Oil India Blowout

On May 27, a major blowout took place at a producing gas well of OIL at Baghjan in Tinsukia district, Assam while carrying out a routine workover job around 10.30 hrs. The well was on work-over operation to isolate a lower producing gas zone as it was under depletion and to switch over to an upper zone. Accordingly, the lower gas zone was isolated and upper zone was perforated which produced gas. But a leakage was observed in the well head. While replacing the leaked well head temporarily by plugging the upper zone with a cement plug, a kick was observed and the well suddenly resulted in blowout. Well was flowing gas & condensate uncontrollably. Well control personnel from OIL & ONGC were deployed immediately to control the well.

OIL AND GAS IN MEDIA

Based on the media reports & press briefing by OIL, the following information was gathered and presented. To control the blow out, experts from Alert Disaster Control, Singapore were engaged by Oil India. On 9th of June, fire engulfed the gas well. Fire tenders were deployed immediately to control the fire. Joint site visit was carried out by OIL, ONGC and experts from M/s Alert to plan for well control operations. Oil India lost three of its personnel (Two firefighters and one Electrical Engineer) during the course of blowout control operation in the last three months.

To control the blowout & to carry out well capping operation, cooling of the operational site is required by spraying water. Arrangements were made to spray water to the wellhead while well capping operation was underway. Digging of pits for water storage and connection of filling line from Dangori River to water pit was also done. Civil works were performed to raise the boundary of the pit to prevent overflow. However, heavy rains affected the work at the site for several days which led to delays.

The well-capping operation was initiated on August 18th and the capping blowout preventer (BOP) stack was successfully placed over the wellhead. The process of restoration of diversion of the flow of gas from the well head to Baghjan EPS and two flare pits were successfully implemented on September 13th. Operation was carried out after experts from M/s Alert and OIL completed the checking/inspection of the wellhead and safety inspection along with specific Job Safety Analysis of the entire system yesterday. The flow of gas was diverted to EPS at around 8.40 am on 13th September after closing the BOP and flaring part of the gas which was diverted to two flare pits. Wellhead pressures and other related parameters are monitored constantly.

On September 29, Mr. Sushil Chandra Mishra, Chairman and Managing Director (CMD) of Oil India Limited (OIL) stated that, it will take another eight weeks to kill the gas producing well in Baghjan in Tinsukia district. Following the incident, OIL has rehearsed the Stand operating procedure (SOP) pertaining to well operations. Mr. Mishra, while addressing media persons virtually on Tuesday, said: “Things are under control at well site. We have managed to divert the gas and there is no fire at the blow out well. OIL is getting a snubbing unit from Canada for killing the well. This may take another three to four weeks and we will need another three to four weeks to get things here. ”

Due to blowout, protests and blockades, total of 30 oil wells and 3 gas wells were shut in the Baghjan region. Since 27th May, 2020, 8013 MT of Crude oil & 10.24 MMSCM of natural gas were lost cumulatively.

FIPI EVENTS

Young Professionals Forum: Leadership in Times of Transition

The Federation of Indian Petroleum Industry (FIPI) in association with Boston Consulting Group (BCG) as knowledge partner organized the Young Professionals Forum between 20-21 August, 2020. The Forum, which was earlier scheduled for March 2020, marked the biggest event of the Young Professionals in the energy sector taking place over a virtual platform. The two-day program provided the young professionals with a range of engaging sessions and activities to stimulate their mind to look for future business solutions. The Forum witnessed participation of more than 500 young professionals working across the globe in oil and gas value chain. The Forum was attended by Mr Tarun Kapoor, Secretary, MoP&NG; Mr. Prabhat Singh, Managing Director & CEO, Petronet LNG; Mr. Sashi Mukundan, Regional President and Head of Country, India, BP Group; Mr. Vipul Tuli, MD, Sembcorp; Mr. Mahesh Kolli, CEO, Greenko; Mr. Maheep Jain, Executive Director, EverSource Capital and Mr. Gautam Reddy, MD, India and Bangladesh, Schlumberger among other industry professionals.

The Young Professionals forum was basically designed for our leaders of tomorrow and had a participation not only from industry professionals from India but also from overseas from countries like USA, UK, France, Angola, Oman, Algeria, New Zealand etc. The programme focused on themes like Digitalization, Energy Transition, Looking Beyond COVID 19, Leadership in post Covid world and career progression which were very relevant in today's context. The discussions in each session were moderated by experts from BCG.

An important highlight of the programme was an online poll survey conducted live with the participants which revealed interesting results on several questions of vital importance concerning the industry.

Over the two days, the Young Professionals Forum proved hugely successful in providing forward looking and engaging sessions for the young executives in the oil and gas industry. To keep the audience invested in the panel discussions, the moderators frequently asked questions raised by the audience to the esteemed speakers. The Forum was accessible live through both Facebook and Zoom and witnessed an overwhelming participation through both the channels.

NEW APPOINTMENTS

Smt. Vartika Shukla takes over as Director (Technical) of EIL

Smt. Vartika Shukla has assumed charge as Director (Technical) of Engineers India Limited (EIL) w.e.f. August 1, 2020.

Smt. Shukla graduated in Chemical Engineering from Indian Institute of Technology, Kanpur in 1988 and is certified with an Executive General Management Program from IIM (Lucknow).

Smt. Shukla started her career as a Management Trainee in EIL's Process Division in 1988. She possesses over 32 years of extensive consulting experience comprising Design, Engineering and Implementation of complexes in Refining, Gas Processing, Petrochemicals, Fertilizers etc. She has led to the successful completion of many prestigious projects for clients in Oil & Gas and Petrochemical Industry both in India and Overseas.

She has a wide spectrum of experience across diverse functions of the Technical Directorate. She has steered Process Design, R&D and the entire functions of Engineering i.e., Piping, Equipment, Instrumentation, Electrical, Structural etc. She has been steering several new Initiatives in the areas of BioFuels, Digitalization, Energy Efficiency, Make In India and StartUp Initiative of EIL.

Mr. E.S. Ranganathan takes charge as Director (Marketing), GAIL

Shri E.S. Ranganathan assumed charge as Director (Marketing) of GAIL (India) Limited on 1st July 2020.

An Instrumentation & Control Engineer from NSS College of Engineering, Palghat in Kerala, Shri Ranganathan is an MBA with specialization in Marketing. He has close to 35 years of rich and diverse experience in Oil & Gas sector, particularly in Project Execution along with Operation & Maintenance of Natural Gas pipelines, Gas Marketing, Business Development and Business Information Systems entailing engineering and planning, process management, scope management, resource management, schedule management, Enterprise Resource Planning, Technology Upgradation, Vendor Management and Quality Assurance.

Prior to his appointment as Director (Marketing), Shri Ranganathan served as Managing Director, Indraprashtha Gas Limited and Executive Director (Corporate O&M), GAIL and was instrumental in commissioning Dahej – Vijaipur, Vijaipur- Dadri and Bawana Nangal Pipeline Projects. A firm believer in leveraging technology for business solutions, Shri Ranganathan played a pioneering role in using technology towards SMART working in the field of O&M and project Management.

Mr. H. Shankar takes over as Director (Technical) of CPCL

Mr. H. Shankar has assumed charge as Director (Technical) of CPCL on 1st October 2020.

Mr. Shankar holds a Bachelor's Degree in Mechanical Engineering from Osmania University, Hyderabad. He also holds a Masters Degree in Business Administration in General Management from Maharaja Sayajirao University. He has nearly 3 decades of experience in the areas of Engineering, Maintenance, Project Construction, Project Management, Materials & Contracts Management and in depth knowledge in Health, Safety and Environment.

STATISTICS

INDIA: OIL & GAS

DOMESTIC OIL PRODUCTION (MILLION MT)

		2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020	% of Total
Onshore	ONGC	6.1	5.8	5.9	6.0	6.1	6.1	1.5	38.9
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	0.7	19.8
	Pvt./ JV (PSC)	9.1	8.8	8.4	8.2	8.0	7.0	1.6	41.3
	Sub Total	**18.5**	**17.8**	**17.6**	**17.5**	**17.3**	**16.2**	**3.8**	**100**
Offshore	ONGC	16.2	16.5	16.3	16.2	15.0	14.5	3.6	92.2
	OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pvt./ JV (PSC)	2.7	2.5	2.1	1.9	1.9	1.5	0.3	7.8
	Sub Total	**18.9**	**19.1**	**18.4**	**18.1**	**16.9**	**16.0**	**3.9**	**100**
Total Domestic Production		37.5	36.9	36.0	35.7	34.2	32.2	7.7	100.0
	ONGC	22.3	22.4	22.2	22.2	21.0	20.6	5.1	66.0
	OIL	3.4	3.2	3.3	3.4	3.3	3.1	0.7	9.7
	Pvt./ JV (PSC)	11.8	11.3	10.5	10.1	9.9	8.4	1.9	24.2
Total Domestic Production		**37.5**	**36.9**	**36.0**	**35.7**	**34.2**	**32.2**	**7.7**	**100**

Source : PIB/PPAC

REFINING

Refining Capacity (Million MT on 1st September 2020)

Indian Oil Corporation Ltd.	
Digboi	0.65
Guwahati	1.00
Koyali	13.70
Barauni	6.00
Haldia	8.00
Mathura	8.00
Panipat	15.00
Bongaigoan	2.35
Paradip	15.00
Total	**69.70**

Chennai Petroleum Corp. Ltd.	
Chennai	10.50
Narimanam	1.00
Total	**11.50**

JV Refineries	
DBPC, BORL-Bina	7.80
HMEL,GGSR	11.30
JV Total	**19.10**

Bharat Petroleum Corp. Ltd.	
Mumbai	12.00
Kochi	15.50
Total	**27.50**

Hindustan Petroleum Corp. Ltd.	
Mumbai	7.50
Visakhapattnam	8.30
Total	**15.80**
Other PSU Refineries	
NRL, Numaligarh	**3.00**
MRPL	**15.00**
ONGC, Tatipaka	**0.07**
Total PSU Refineries Capacity	**142.57**

Private Refineries	
RIL, (DTA) Jamnagar	33.00
RIL , (SEZ), Jamnagar	35.20
Nayara Energy Ltd. , Jamnagar #	20.00
Pvt. Total	**88.20**

Total Refining Capacity of India 249.9 (5.00 million barrels per day)
Nayara Energy Limited (formerly Essar Oil Limited)
Source : PPAC

CRUDE PROCESSING (MILLION MT)

PSU Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
IOCL	53.59	58.01	65.19	69.00	71.81	69.42	12.93
BPCL	23.20	24.10	25.30	28.20	30.90	31.53	5.07
HPCL	16.20	17.20	17.80	18.20	18.44	17.18	3.97
CPCL	10.70	9.60	10.30	10.80	10.69	10.16	1.33
MRPL	14.60	15.53	15.97	16.13	16.23	13.95	1.86
ONGC (Tatipaka)	0.05	0.07	0.09	0.08	0.07	0.09	0.02
NRL	2.78	2.52	2.68	2.81	2.90	2.38	0.63
SUB TOTAL	**121.12**	**127.03**	**137.33**	**145.22**	**151.04**	**144.71**	**25.80**

JV Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April-June 2020 (P)
HMEL	7.34	10.71	10.52	8.83	12.47	12.24	2.03
BORL	6.21	6.40	6.36	6.71	5.71	7.91	1.16
SUB TOTAL	**13.55**	**17.11**	**16.88**	**15.54**	**18.18**	**20.15**	**3.19**

Pvt. Refineries	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April-June 2020 (P)
NEL	20.49	19.11	20.92	20.69	18.89	20.62	4.36
RIL	68.10	69.50	70.20	70.50	69.14	68.89	15.30
SUB TOTAL	**88.59**	**88.61**	**91.12**	**91.19**	**88.03**	**89.51**	**19.65**

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April-June 2020 (P)
All India Crude Processing	**223.26**	**232.90**	**245.40**	**251.90**	**257.17**	**254.38**	**48.64**

Source : PIB Release/PPAC

CRUDE CAPACITY VS. PROCESSING

	Capacity On 01/09/2020 Million MT	% Share	Crude Processing April - June 2020 (P)	% Share
PSU Ref	142.6	57.1	25.8	53.0
JV. Ref	19.1	7.6	3.2	6.6
Pvt. Ref	88.2	35.3	19.7	40.4
Total	**249.9**	**100**	**48.6**	**100**

Source: PIB/PPAC

POL PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	April - June 2020 (P)
From Refineries	217.1	227.9	239.2	249.7	257.4	258.2	51.0
From Fractionators	3.7	3.4	3.5	4.6	4.9	4.8	1.0
Total	**220.7**	**231.2**	**242.7**	**254.3**	**262.4**	**262.9**	**52.0**

DISTILLATE PRODUCTION (Million MT)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Light Distillates, MMT	63.2	67.1	71.0	74.7	75.4	76.8	15.6
Middle Distillates , MMT	113.4	118.3	122.5	127.5	130.8	130.2	24.0
Total Distillates, MMT	176.6	185.4	193.5	202.2	206.1	206.9	39.6
% Distillates Production on Crude Processing	**77.8**	**78.5**	**77.8**	**78.8**	**78.6**	**79.9**	**79.7**

Source: PIB/PPAC

PETROLEUM PRICING

OIL IMPORT - VOLUME AND VALUE

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Quantity, Million Mt	189.4	202.9	213.9	220.4	226.6	227.0	44.8
Value, INR ₹000 cr.	687.4	416.6	470.2	565.5	783.4	716.6	64.7
Value, USD Billion	112.7	64.0	70.2	87.8	112.0	101.4	8.5
Average conversion Rate, INR per USD (Calculated)	61.0	65.1	67.0	64.4	70.0	70.7	75.7

OIL IMPORT - PRICE USD / BARREL

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Brent (Low Sulphur - LS-marker) (a)	85.4	47.5	48.7	57.5	70.0	60.9	29.2
Dubai (b)	83.8	45.6	47.0	55.8	69.3	60.3	30.8
Low sulphur-High sulphur differential (a-b)	1.7	1.8	1.7	1.6	0.7	0.6	-1.6
Indian Crude Basket (ICB)	84.16	46.17	47.56	56.43	69.88	60.47	30.38
ICB High Sulphur share %	72.04	72.28	71.03	72.38	74.77	75.50	75.50
ICB Low Sulphur share %	27.96	27.72	28.97	27.62	25.23	24.50	24.50

INTERNATIONAL PETROLEUM PRODUCTS PRICES EX SINGAPORE, ($/bbl.)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Gasoline	95.5	61.7	58.1	67.8	75.3	67.0	31.0
Naphtha	82.2	48.5	47.1	56.3	65.4	55.2	27.8
Kero / Jet	66.6	58.2	58.4	69.2	83.9	68.5	30.5
Gas Oil (0.05% S)	99.4	57.6	58.9	69.8	84.1	74.3	37.8
Dubai crude	83.8	45.6	47.0	55.8	69.3	60.3	30.8
Indian crude basket	84.2	46.2	47.6	56.4	69.9	60.5	30.4

CRACKS SPREADS ($/ BBL.)

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Gasoline crack							
Dubai crude based	11.7	16.1	11.1	12.0	5.9	6.8	0.2
Indian crude basket	11.3	15.6	10.6	11.4	5.4	6.6	0.6
Diesel crack							
Dubai crude based	15.7	12.0	12.0	13.9	14.8	14.0	7.0
Indian crude basket	15.3	11.5	11.4	13.4	14.2	13.8	7.4

DOMESTIC GAS PRICE ($/MMBTU)

Period	Domestic Gas Price (GCV Basis)	Price Cap for Deepwater, High temp Hingh Pressure Areas
November 14 - March 15	5.05	-
April 15 - September 15	4.66	-
October 15 - March 16	3.82	-
April 16 - September 16	3.06	6.61
October 16 - March 17	2.50	5.30
April 17- September 17	2.48	5.56
October 17 - March 18	2.89	6.30
April 18 - September 18	3.06	6.78
October 18 - March 19	3.36	7.67
April 19 - September 19	3.69	9.32
October 19 - March 20	3.23	8.43
April 20 - September 20	2.39	5.61
October 20 - March 21	1.79	4.06

Source: PIB/PPAC/OPEC

GAS PRODUCTION

Qty in MMSCM

	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
ONGC	22088	23429	24677	23746	5351
Oil India	2937	2881	2722	2668	650
Private/ Joint Ventures	6872	6338	5477	4766	785
Total	**31897**	**32648**	**32875**	**31180**	**6785**

		2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Onshore	Natural Gas	9294	9904	10046	9893	2319
	CBM	565	735	710	655	153
	Sub Total	**9858**	**10639**	**10756**	**10549**	**2472**
Offshore		22038	22011	22117	20631	4314
	Sub Total	**22038**	**22011**	**22117**	**20631**	**4314**

Total	**31897**	**32649**	**32873**	**31180**	**6786**
(-) Flare loss	1049	918	815	923	253
Net Production	30848	31731	32058	30257	6533

	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Net Production	30848	31731	32058	30257	6533
Own Consumption	5857	5806	6019	6053	1404
Availabilty	24991	25925	26039	24204	5129

AVAILABILTY FOR SALE

	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
ONGC	17059	18553	19597	18532	4125
Oil India	2412	2365	2207	2123	512
Private/ Joint Ventures	5520	5007	4235	3549	492
Total	**24991**	**25925**	**26039**	**24204**	**5129**

CONSUMPTION (EXCLUDING OWN CONSUMPTION)

	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Total Consumption	49677	53364	54779	57884	12132
Availabilty for sale	24991	25925	26039	24204	5129
LNG Import	24686	27439	28740	33680	7003

GAS - IMPORT DEPENDENCY

	2016-17	2017-18	2018-19	2019-20 (P)	April - June 2020 (P)
Net Gas Production	30848	31731	32058	30257	6533
LNG Imports	24686	27439	28740	33680	7003
Import Dependency (%)	44.5	46.4	47.3	52.7	51.7
Total Gas Consumption*	**55534**	**59170**	**60798**	**63937**	**13536**

* Includes Own Consumption

Source:PIB/PPAC

SECTOR WISE DEMAND AND COMSUMPTION OF NATURAL GAS

Qty in MMSCM

		2017-18 (P)	2018-19 (P)	2019-20 (P)	April - June 2020			
					April	May	June	Total
Fertilizer	R-LNG	7781	8711	9539	708	818	875	2401
	Domestic Gas	6862	6258	6519	581	754	699	2034
Power	R-LNG	2645	2869	3595	27	160	352	539
	Domestic Gas	9375	9194	7473	711	772	709	2212
City Gas	R-LNG	3881	3981	4746	125	384	184	693
	Domestic Gas	4659	5240	5736	256	195	323	774
Refine y Petrochemical Others	R-LNG	11109	12650	13169	854	1049	1141	3044
	Domestic Gas	5225	5225	5061	628	738	853	2219

Source:PPAC

1. CGD INFRASTRUCTURE

		As on 31st March 2018	As on 31st March 2019	As on 31st March 2020	As on 31st July 2020 (P)
PNG	Domestic	42,80,054	50,43,188	60,68,415	71,93,498
	Commercial	26,131	28,046	30,622	33,932
	Industrial	7,601	8,823	10,258	11,115
CNG	CNG Stations	1,424	1,730	2,207	2,290
	CNG Vehicles	30,90,139	33,47,289	37,10,916	37,37,213

Source: PPAC/Vahan

2. MAJOR NATURAL GAS PIPELINE NETWORK

Company		GAIL	GSPL Groups	PIL	RGPL	IOCL	Others*	Total
Natural Gas	Length (KM)	11,774	3,144	1,460	312	155	171	**17,016**
	Capacity (MMSCMD)	230	48	85	4	20	3	**390**

* Includes AGCL, DFPCL, ONGC and excludes CGD pipeline network

Source: PPAC/PNGRB

3. EXISTING LNG TERMINALS

Location	Companies	Capacity (MMTPA) April 2020	Capacity Utilisation (%) April- July 2020 (P)
Dahej	Petronet LNG Ltd	17.5	80.7#
Hazira	Shell Energy India Pvt Ltd	5	93.3
Dabhol*	RGPPL (GAIL- NTPC JV)	5	30.4
Kochi	Petronet LNG Ltd	5	14.3#
Ennore	Indian Oil LNG Pvt Ltd	5	9.3
Mundra	GSPC LNG Ltd	5	32.2
Total Capacity		**42.5 MMTPA**	32.2

*To increase to 5 MMTPA with breakwater # For the period April-June 2020

Source: PPAC

Member Organizations

S No	Organization	Name	Designation
1	Antelopus Energy Pvt Ltd	Mr. Suniti Bhat	Chief Executive Officer
2	Axens India (P) Ltd.	Mr. Philippe Bergault	Managing Director
3	Baker Hughes, A GE Company	Mr. Neeraj Sethi	Country Leader
4	Bharat Oman Refineries Ltd.	Mr. Mahendra Pimpale	Managing Director
5	Bharat Petroleum Corporation Ltd.	Mr. K. Padmakar	Director (HR) and CMD (Incharge)
6	BP Group	Mr. Sashi Mukundan	Regional President and Head of Country, India
7	Cairn Oil & Gas, Vedanta Limited	Mr. Sunil Duggal	Group CEO, Vedanta Ltd.
8	Chandigarh University	Mr. Satnam Singh Sandhu	Chancellor
9	Chennai Petroleum Corp. Ltd.	Mr. S.N. Pandey	Managing Director
10	Chi Energie Pvt. Ltd	Mr. Ajay Khandelwal	Director
11	CSIR-Indian Institute of Petroleum, Dehradun	Dr. Anjan Ray	Director
12	Decom North Sea	Mr. Will Rowley	Interim Managing Director
13	Deepwater Drilling & Industries Ltd	Mr. Naresh Kumar	Chairman & Managing Director
14	Dynamic Drilling & Services Pvt. Ltd.	Mr. S. M. Malhotra	President
15	Engineers India Ltd.	Mr. J.C. Nakra	Chairman & Managing Director
16	Ernst & Young LLP	Mr. Rajiv Memani	Country Manager & Partner
17	ExxonMobil Gas (India) Pvt. Ltd.	Mr. Bill Davis	CEO
18	GAIL (India) Ltd.	Mr. Manoj Jain	Chairman & Managing Director
19	GSPC LNG Ltd.	Mr. Anil K. Joshi	President
20	Haldor Topsoe India Pvt. Ltd.	Mr. Alok Verma	Managing Director
21	Hindustan Petroleum Corporation Ltd.	Mr. M.K. Surana	Chairman & Managing Director
22	HPCL Mittal Energy Ltd.	Mr. Prabh Das	MD & CEO
23	IHS Markit	Mr. James Burkhard	Managing Director
24	IIT (ISM) Dhanbad	Prof. Rajiv Shekhar	Director
25	IMC Ltd.	Mr. A. Mallesh Rao	Managing Director
26	Indian Oil Corporation Ltd.	Mr. S.M. Vaidya	Chairman

S No	Organization	Name	Designation
27	Indian Strategic Petroleum Reserves Ltd	Mr. H.P.S. Ahuja	CEO & Managing Director
28	Indraprastha Gas Ltd.	Mr. A.K. Jana	Managing Director
29	Indian Oiltanking Ltd.	Mr. Rajesh Ganesh	Managing Director
30	IPIECA	Mr. Brian Sullivan	Executive Director
31	Invenire Petrodyne Ltd.	Mr. Mannish Maheshwari	Chairman & Managing Director
32	Jindal Drilling & Industries Pvt. Ltd.	Mr. Raghav Jindal	Managing Director
33	LanzaTech	Dr. Jennifer Holmgren	Chief Executive Officer
34	Larsen & Toubro Ltd	Mr. S.N. Subrahmanyan	CEO & Managing Director
35	Maharashtra Institute of Technology (MIT), Pune	Dr. L.K. Kshirsagar	Principal
36	Mangalore Refinery & Petrochemicals Ltd.	Mr. M. Venkatesh	Managing Director
37	Megha Engineering & Infrastructures Ltd.	Mr. P. Doraiah	Director
38	Nayara Energy Ltd.	Mr. B. Anand	Chief Executive Officer
39	Numaligarh Refinery Ltd.	Mr. S.K. Barua	Managing Director
41	Oil and Natural Gas Corporation Ltd	Mr. Shashi Shanker	Chairman & Managing Director
41	Oil India Ltd.	Mr. Sushil Chandra Mishra	Chairman & Managing Director
42	Petronet LNG Ltd.	Mr. Vinod Kumar Mishra	Director (F) and MD & CEO (Addl Charge)
43	Pipeline Infrastructure Ltd.	Mr. Akhil Mehrotra	Chief Executive Officer
44	Rajiv Gandhi Institute of Petroleum Technology	Prof. A.S.K Sinha	Director
45	Reliance Industries Ltd.,	Mr. Mukesh Ambani	Chairman & Managing Director
46	SAS Institute (India) Pvt Ltd.	Mr. Noshin Kagalwalla	CEO & Managing Director-India
47	Schlumberger Asia Services Ltd	Mr. Gautam Reddy	Managing Director
48	Shell Companies in India	Mr. Nitin Prasad	Country Chair
49	South Asia Gas Enterprise Pvt. Ltd.	Mr. Subodh Kumar Jain	Director
50	Total Oil India Pvt. Ltd.	Mr. Alexis Thelemaque	Chairman & Managing Director
51	University of Petroleum & Energy Studies	Dr. S.J. Chopra	Chancellor
52	UOP India Pvt. Ltd.	Mr. Mike Banach	Managing Director
53	VCS Quality Services Private Ltd.	Mr. Shaker Vayuvegula	Director
54	World LPG Association	Mr. James Rockall	CEO and Managing Director

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