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SPECTRUM

SPE Mumbai Section

2025

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Source: OilandGasiq

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From the Desk of Chairman, SPE Mumbai Section

Niladri . K. Mitra
Chairperson, SPE Mumbai

Dear Members and Colleagues,

It is with great enthusiasm that I present this issue of our Spectrum newsletter, which aims to bring together valuable insights, fresh perspectives, and innovative ideas. Since the last issue of Spectrum in August 2024, we have witnessed significant developments in the oil and gas sector. As we move forward, we remain committed to fostering knowledge exchange, technical advancements, and professional growth within our community.

The new SPE Mumbai Chapter Board took over its responsibilities on January 1, 2025, with a renewed focus on enhancing engagement and broadening our impact. One of our major initiatives is the organization of the Annual SPE Oil and Gas Conference, scheduled for May 2026. This flagship event will provide a platform for industry professionals, academicians, and young engineers to collaborate and discuss evolving technologies and market trends.

Additionally, we are working towards increasing the frequency of our Spectrum newsletter to ensure timely dissemination of industry insights. To achieve this, we are strengthening our editorial subcommittee by involving young and enthusiastic members, thereby fostering a dynamic exchange of knowledge.

This year also marks the 35th anniversary of the SPE Mumbai Chapter, a milestone that reflects our continuous commitment to excellence and community building. We have been actively working to increase participation and engagement among new members, encouraging them to contribute to the growth of our chapter.

On the global front, crude oil prices have seen a decline to $70 per barrel, possibly influenced by changing international regimes. Meanwhile, India has been adopting cutting-edge oil and gas technologies, including advanced 3D seismic imaging, hydraulic fracturing for shale gas extraction, enhanced oil recovery (EOR) techniques, wireless surface readout technology for drilling operations, and advanced LNG regasification technologies. Companies like ONGC and private industry players have been at the forefront of implementing these innovations to enhance domestic production and reduce dependence on imports.

Our Tech Connect initiatives have been instrumental in knowledge-sharing, with recent sessions including Schlumberger's presentation on First-Ever Gas Engine Driven Horizontal Pumping System wells and an in-depth analysis of stimulation techniques for oil and gas wells. Looking ahead, we are planning an exclusive session in April on East Coast KG Basin projects, focusing on float-over installation techniques for offshore platform decks—an approach that reduces costs and avoids the use of derrick barges. Similarly, McDermott will sponsor a session on jacket installation via the submerged pulling method, further enhancing our understanding of cost-effective offshore operations.

With an exciting year ahead, I encourage all members to actively participate in our events, contribute to our newsletter, and join us in celebrating 35 years of excellence. Let's continue to innovate, collaborate, and grow together.

SPE Mumbai Section Membership Sees Remarkable Growth

SPE Mumbai: A Legacy Since 1990

Established in 1990, the SPE Mumbai Section has been a pillar of knowledge and professional growth for petroleum engineers in the region. Over the past three decades, it has consistently provided a platform for technical discussions, industry collaborations, and student development programs, playing a key role in advancing the energy sector in India.

With the ongoing growth in membership, SPE Mumbai Section continues to build a strong community of professionals and students dedicated to innovation and excellence in the oil and gas industry.
The Society of Petroleum Engineers (SPE) Mumbai Section has witnessed a significant surge in its membership over the past year, strengthening its presence in the region and enhancing professional and student engagement in the energy sector.

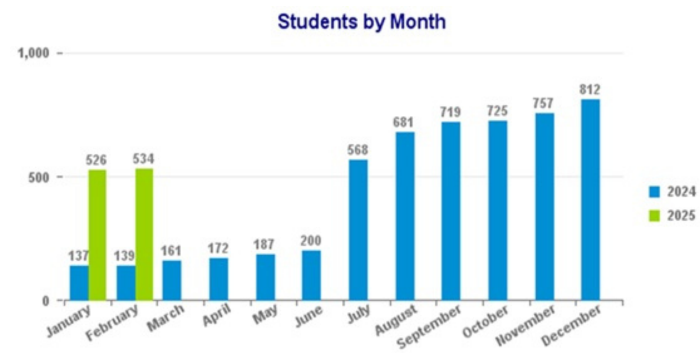
Growth in Professional Membership

The number of professional members in the SPE Mumbai Section has grown from 393 to 438, reflecting an increasing interest among industry professionals to engage with SPE's technical resources, networking opportunities, and career development programs. The steady rise in membership underscores the value that SPE Mumbai provides to petroleum engineers, geoscientists, and industry professionals.

Student Membership Sees a Massive Increase

One of the most notable developments has been the exponential growth in student membership

The number of student members has risen from 139 to 534, a remarkable increase attributed primarily to the addition of the Indian Institute of Technology (ISM), Dhanbad, to the SPE Mumbai Section. This inclusion has significantly boosted student participation, offering young engineers access to valuable resources, mentorship, and industry exposure.



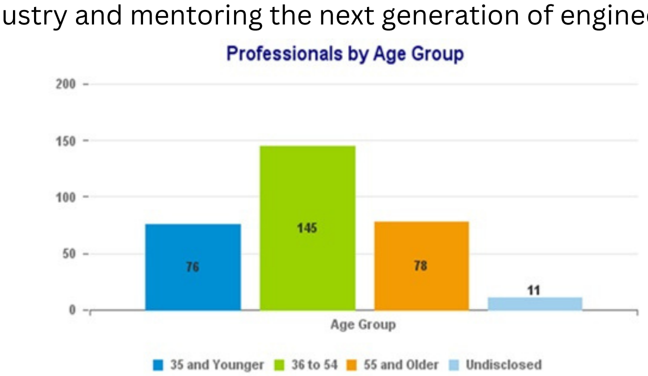
Breakdown of Student Membership
A detailed breakdown of student membership in key institutions under SPE Mumbai Section is as follows:

- Indian Institute of Technology Bombay: 33 members
- Indian Institute of Technology (ISM), Dhanbad: 365 members
- MIT Pune: 74 members
- Nowrosjee Wadia College: 59 members

This expansion signifies the increasing enthusiasm of young professionals in the petroleum industry and the role of SPE Mumbai in fostering knowledge-sharing and innovation among students.

Membership Distribution by Age Group

Analyzing the age distribution among professional members, 145 of the 438 members fall within the 36-54 years age bracket. This segment represents a critical group of experienced professionals actively contributing to the industry and mentoring the next generation of engineers.



Assessing Reservoir and Completion Performance using Spectral Acoustics along with Conventional Production Logging

Remke Ellis
Domain Champion,
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Introduction

This article explores challenges many Operators face today – the compliance of reservoir and completion performance to field development plan in order to maximise longevity of optimal production. In this article we examine the importance and added value benefits of acquiring Chorus (spectral acoustic log) and conventional Production Logging Tool (PLT) data to this effect. We refer to previously published case studies for which spectral noise logging and conventional PLT data allowed oil and gas companies to resolve poor performance issues in both production and injection wells; reviving overall production levels and sustaining field life.

Reservoir and Completion Component Flow

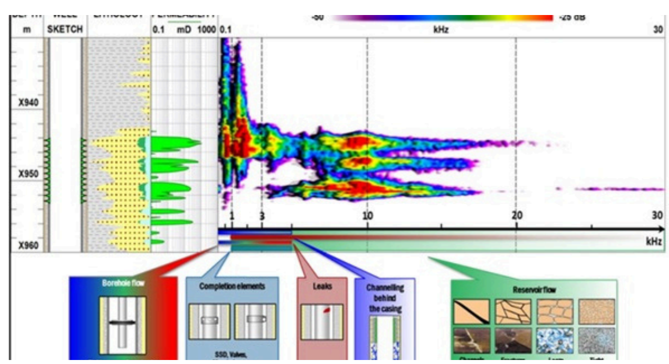
Reservoir flow noise is produced by grain-to-grain, pore throat and fracture vibrations caused by transfer of energy from the flowing fluid to the media. Completion flow noise is typically generated by the vibration (resonation) of the production string (tubing or casing), pipe through-holes (leaks), perforation tunnels, and cement channels. Each source of noise can be distinguished based on acoustic frequency range, amplitude and continuity of the signal with wellbore or reservoir unit limits. Combing acoustics and temperature measurements with conventional PLT measurements from flowmeters, heat-exchange sensors etc. allow for differentiating between flow occurring within the borehole or that behind pipe[1]. In the same way assessment of reservoir performance (acoustics) and completion performance (PLT) is achieved, all with the same survey run.

Cscade – temperature analysis

Though temperature logging has been extensively used over several decades, the more recent development in simulation methodology and advanced numerical temperature modelling has enabled better interpretation and understanding of fluid flow. The methodology includes thermal model validation and accounting for injection / production history fluid volumes and temperatures. Additionally, the sensitive input parameter, of active unit thickness which previously has been assumed from open-hole logs, is now measured directly with the Spectral Acoustics (Chorus). This data acquisition now aids in a more robust and representative quantitative determination of fluid flow profile[2].

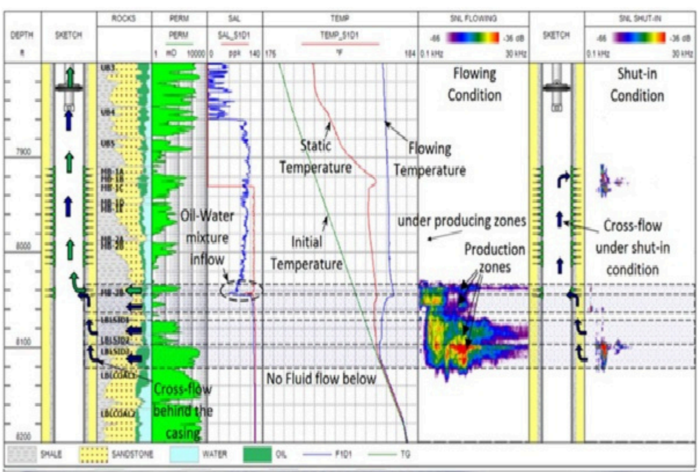
Chorus – spectral acoustics

Chorus is specifically designed as a passive acoustic hydrophone, recording sound in the frequency range of 8Hz to 60kHz. Spectral Acoustics captures noise associated with liquid or gas movement through a media. This noise is generated from the streamlining (vibration) of the media and from within the fluid itself (if flow is turbulent). The frequency of the noise is inversely proportional to the cross-sectional area (aperture) of the flow path. The volume intensity (amplitude) of the noise is dependent on the fluid and medium properties, and proportional to the delta pressure and flowrate. Chorus is used to survey producer and injector wells, under both shut-in and flowing conditions. For shut-in surveys Chorus captures noise associated with any cross-flow, especially fluid cross-flowing behind completion components (tubing and casing). This allows for assessment of completion isolation performance (cement, packers, SSDs, etc) and realisation of inter-layer differential pressure depletion. Under flowing conditions Chorus captures noise associated with reservoir flow, enabling assessment of layer performance (e.g. for identifying stimulation candidates) and out of zone contributions (water breakthrough / thief injection).



Injector Wells

The primary objective of injector wells is to ensure that water or gas is effectively placed into the targeted formation layers, to maintain reservoir pressure and mobilise hydrocarbons. Failures in completion component isolation (principally cement sheath or ISO-packers) can result in significant volumes of injected fluid bypassing the target zone. Insufficient layer pressure support and reservoir sweep results, causing reservoir conditions to deviate from field development plan and negative impact on production forecasts and recovery factor. Furthermore, if a polymer or surfactant injection is planned, it is important the calculated volume of chemical reaches the target layer. In this case conventional PLT could provide quantitative perforation tunnel injection profile (within the wellbore), however what happens after the fluid leaves the perforation tunnels is not realized. Under shut-in conditions Chorus identified cross flow occurring behind casing, and under flowing conditions identified behind pipe (reservoir) injection profile. This behind pipe injection profile was then quantified by temperature simulation.



Producer Wells

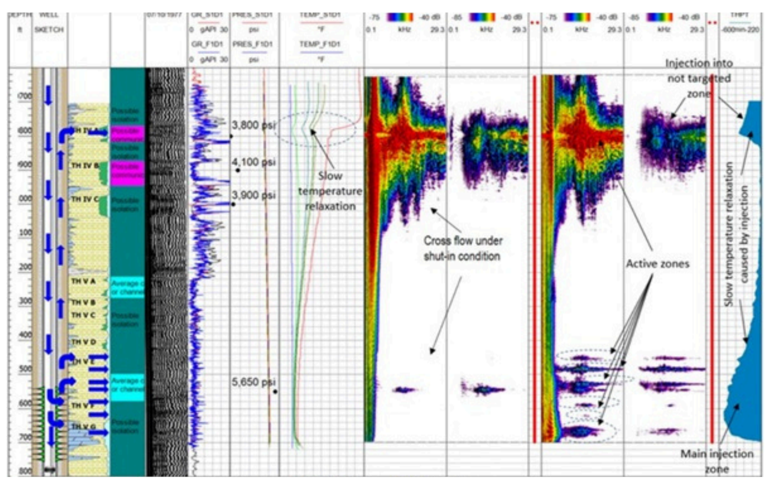
Optimal production is achieved when reservoir productivity index and completion component (cement sheath, ISO-packer) isolation performance is strong. Under-producing pay zones result in delayed, and often uneven, layer production. Completion component isolation failure allows for out of target interval reservoir and/or aquifer fluid contribution. For smart completions this means a total loss of production / injection control. In this case, Chorus has identified contribution of layers outside the perforation interval and provided evaluation of the pay zone interval performance. Assessing wells with this measurement allows for effective work over planning with respect to water shut-off strategy and reservoir stimulation well candidates.

Conclusion

Assessing reservoir and completion performance is critical for effective reservoir management; sustaining optimal productivity and maximising recovery. Spectral acoustics captures and distinguishes between noise generated from flow occurring within the completion itself (leaking pipes and packers, cement channels, etc.) and flow happening 3 – 5 meters into the formation itself (matrix and fractures).

For Injectors: · Locate and constrain limits of injection into layers behind pipe (within and out with perforation interval) · Detect and differentiate between wellbore and behind casing cross-flows · Identify leaks occurring across any completion components (tubing, casings, packers, completion jewellery, cement)

For Producers: · Locate and constrain limits of producing layers behind pipe (within and out with perforation interval) · Detect and differentiate between wellbore and behind casing cross-flows · Identify leaks occurring across any completion components (tubing, casings, packers, completion jewellery, cement)



Innovative Chemicals Driving the Future of Petroleum Production

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SPE

Dr Zarana Patel
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The petroleum industry has been a cornerstone of global energy production for over a century, fuelling everything from transportation to manufacturing. Yet, as the world confronts pressing environmental challenges, the demand for cleaner, more efficient energy sources has never been greater. In response, the petroleum industry is undergoing a remarkable transformation, with innovations in chemical processes playing a central role. From enhancing oil recovery and refining efficiency to minimizing the environmental impact of production, chemical innovations are reshaping the future of the petroleum industry. These advancements promise not only to improve operational efficiency but also to reduce the ecological footprint of oil and gas extraction and processing. In this article, we explore some of the most exciting and transformative chemical innovations currently at the forefront of the petroleum industry.

·Green Chemistry: Eco-friendly Additives and Solutions

In response to the growing environmental concerns surrounding the petroleum industry, green chemistry has emerged as a key field of innovation. Green chemistry aims to reduce the use and generation of hazardous substances in chemical processes, offering safer alternatives for both workers and the environment.
One area where green chemistry is making a significant impact is in the development of bio-based additives for fuels. Traditionally, fuel additives have been derived from petroleum, but the demand for renewable alternatives has driven the development of bio-based additives derived from plant or microbial sources. These bio-based additives are used to enhance the performance of fuels, improving combustion efficiency, reducing emissions, and increasing fuel economy, all while being environmentally friendly.

Another exciting innovation in green chemistry is the development of biodegradable drilling fluids. Drilling fluid is essential to the oil and gas extraction process, helping to lubricate the drill bit, transport cuttings to the surface, and maintain wellbore stability. Traditional drilling fluids often contain toxic chemicals that can harm the environment if they spill or leak. However, new biodegradable drilling fluids, made from non-toxic ingredients, offer an eco-friendly alternative. These fluids break down naturally in the environment, reducing the risk of contamination and environmental damage.
Moreover, green chemistry principles are also being applied to the creation of safer chemicals for hydraulic fracturing (fracking). Hydraulic fracturing is a controversial method used to extract oil and gas from shale formations. While it has revolutionized the oil and gas industry, it also raises environmental concerns due to the use of toxic chemicals. Today, companies are developing non-toxic, biodegradable fracking fluids that are less harmful to ecosystems and water supplies.

Ionic liquids (ILs) have gained significant attention in the petroleum industry due to their unique properties, such as low vapor pressure, high thermal stability, and tunable solubility. They are being used in a variety of applications, including as solvents for the extraction and purification of hydrocarbons, such as sulfur removal from fuels. Ionic liquids can also be utilized in petroleum refining processes, such as hydrotreating and hydrocracking, to improve efficiency and reduce environmental impact. Furthermore, their ability to dissolve both polar and non-polar compounds makes them useful in CO_2 capture and separation processes, contributing to cleaner and more sustainable energy production.

Nanotechnology: Revolutionizing Petroleum Production

The field of nanotechnology, which involves manipulating matter at the molecular or atomic scale, is having a profound impact on the petroleum industry. Nanotechnology is being used in a variety of applications, from drilling and extraction to refining and environmental remediation.

In oil extraction, nanoparticles are being used to improve the efficiency of hydraulic fracturing by optimizing fluid recovery and reducing the risk of wellbore damage. These nanoparticles are designed to alter the properties of fracking fluids, making them more effective at breaking apart rock formations and improving the flow of oil to the surface. Nanoparticles can also be used to reduce the formation of scale in pipelines and reduce the need for harsh chemicals.

Nanomaterials are also enhancing the efficiency of refining processes. Nano-catalysts, for example, are being developed to speed up chemical reactions, allowing refineries to produce cleaner fuels with lower emissions. Nanomaterials are also being used in the development of membranes for separating gases, such as hydrogen, during refining processes, leading to more efficient and cleaner fuel production.

In addition to these applications, nanotechnology is playing a crucial role in environmental remediation. Nanoparticles are being developed to help clean up oil spills by breaking down hydrocarbons more quickly and efficiently, reducing the environmental impact of petroleum production.

Nanohybrid polymers are increasingly being used in the petroleum industry for their enhanced properties, such as improved mechanical strength, thermal stability, and chemical resistance. These materials, which combine nanoparticles with polymers, are particularly useful in applications like drilling fluids, enhanced oil recovery (EOR), and corrosion protection. In drilling, nanohybrid polymers help improve the performance of fluids, providing better lubrication and reducing friction. In EOR, they can enhance the efficiency of oil extraction by increasing the viscosity of fluids, aiding in better displacement of oil. Additionally, nanohybrid polymers are used in coatings to prevent corrosion of pipelines and equipment, extending the lifespan of critical infrastructure.

·**Biochemical Innovations: Turning Waste into Energy**

As the petroleum industry faces increasing pressure to reduce waste and improve sustainability, biotechnology is providing innovative solutions. Biochemical processes, such as the use of microbial agents and enzymes, are being explored to optimize petroleum production and reduce its environmental impact.

Microorganisms are already being used to break down hydrocarbons in oil spills, a critical aspect of environmental clean-up. Advances in biotechnology are expanding the use of microorganisms in other areas, such as bioremediation, where microbes are used to clean contaminated water and soil in the vicinity of oil extraction operations.

Additionally, biochemical processes are being explored to convert petroleum waste and by-products into useful resources. For instance, waste oils and organic by-products from refineries can be processed by microbes to produce biogas or other forms of renewable energy.

This approach not only helps reduce waste but also opens new pathways for sustainable energy production, contributing to the industry's ongoing efforts to transition toward greener solutions.

·Smart Materials: Improving Equipment Performance and Longevity

The development of smart materials is helping the petroleum industry improve its operations by enhancing the performance and longevity of critical equipment. Corrosion-resistant materials are increasingly being used in pipelines, offshore platforms, and drilling rigs to ensure they can withstand the harsh conditions of the petroleum industry.

These smart materials are designed to adapt to environmental changes, resist extreme temperatures, and self-heal when damaged. By using these materials, companies can reduce maintenance costs, improve safety, and extend the lifespan of expensive infrastructure.

Conclusion:

A Sustainable and Efficient Future The petroleum industry is facing unprecedented challenges as it navigates the complexities of global energy demands, environmental concerns, and regulatory pressure. However, through innovation in chemicals and materials, the industry is making significant strides toward a more sustainable and efficient future. Green chemistry, nanotechnology, and biotechnology are all contributing to a transformation that promises to make petroleum production more efficient and environmentally friendly.

As these innovations continue to evolve, the petroleum industry will play a crucial role in meeting the world's energy needs while minimizing its impact on the environment. The future of petroleum is not just about extracting and processing oil; it is about creating a more sustainable, cleaner, and greener energy landscape for future generations.

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Cost Modeling for CCS Projects in India

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Carbon Capture and Storage (CCS) is a crucial technology for reducing greenhouse gas emissions in hard-to-abate sectors, including the upstream petroleum industry. As India seeks to achieve net-zero emissions by 2070, CCS offers a practical solution to decarbonize oil and gas operations while addressing the country's increasing energy demands. CCS captures CO_2 at the source, transports it to storage sites, and sequesters it in geological formations such as depleted reservoirs and saline aquifers.

Globally, over 40 million tons of CO_2 are captured annually by operational CCS projects (Source: Global CCS Institute, 2024). In India, CCS is still in its infancy but has significant potential due to abundant geological storage capacity and the economic benefits of integrating CCS with enhanced oil recovery (EOR). Here, we would try to define the key cost components, data-driven analysis, and strategies to optimize CCS deployment in India's upstream petroleum sector.

Key Cost Components of CCS Projects

The costs of CCS projects are broadly divided into three components: CO_2 capture, transportation, and storage. According to the International Energy Agency (IEA, 2023), the distribution of these costs is typically as follows: capture (60–80%), transportation (10–25%), and storage (10–15%).

1. CO_2 Capture Costs

Capture is the most expensive component of CCS projects. Costs vary based on CO_2 concentration in the gas stream and the chosen technology. For example:
·Post-Combustion Capture: Widely applicable for retrofitting facilities, costing $40–$90 per ton of CO_2.
·Pre-Combustion Capture: Suitable for new projects; costs $30–$70 per ton.
·Oxy-Fuel Combustion: Highly efficient but expensive, costing $50–$100 per ton.
A study by the MIT Energy Initiative (2023) highlights those facilities processing high-CO_2 natural gas, such as fields in the KG Basin, could achieve capture costs as low as $45 per ton due to concentrated CO_2 streams.

2. CO_2 Transportation Costs

Transportation costs depend on distance, terrain, and the volume of CO_2 transported. Pipelines are the most economical for large volumes. According to the U.S. Department of Energy (DOE, 2023), pipeline costs range from $2–$8 per ton per 100 km, while truck transport costs $20–$30 per ton for short distances.
India's Western Offshore and onshore fields in Gujarat have several potential CO_2 clusters with storage sites within a 200 km radius, enabling pipeline transport costs of approximately $6 per ton.

3. CO_2 Storage Costs

Storage costs are influenced by the type of geological formation and monitoring requirements. Storage in depleted oil and gas reservoirs is more cost-effective ($5–$15 per ton) compared to saline aquifers ($10–$20 per ton) due to the need for additional site characterization. Long-term monitoring adds $3–$7 per ton.

The Deccan Traps in central India are being explored for basaltic rock storage, which involves mineralizing CO_2. Pilot projects suggest potential costs of $15–$25 per ton, with significant scalability (Source: Geological Society of India, 2024).

Data Summary and Total Costs for CCS Projects

Based on recent global and Indian data, the total cost of CCS in India is estimated as follows:
·CO_2 Capture: $40–$90 per ton (contributing 60–80% of total costs).
·CO_2 Transportation: $2–$10 per ton (10–25% of total costs).
·CO_2 Storage: $5–$20 per ton (10–15% of total costs).
For a typical CCS project capturing 1 million tons of CO_2 annually, the overall cost ranges between $50–$120 million.

Factors Influencing CCS Costs in India
Several factors directly affect CCS costs in India, including:

- Scale of Operations: Economies of scale reduce costs for large projects.
- ·Proximity to Storage Sites: Shorter distances to storage sites minimize transport costs.
- ·Geological Suitability: High-capacity reservoirs with existing infrastructure lower storage costs.
- ·Policy Incentives: Carbon credits, subsidies, or carbon taxes can offset high upfront costs.
- Strategies to Optimize CCS Costs
- To reduce costs and improve CCS viability, India must adopt strategies such as:
- ·Leveraging existing oil and gas infrastructure for CO_2 transport and storage.
- ·Integrating CCS with EOR in fields like Bombay High, which can enhance oil recovery by 10–20%.
- ·Developing regional CO_2 clusters, such as a Gujarat cluster for shared transport and storage infrastructure.
- ·Promoting research in advanced technologies like membrane-based CO_2 capture to lower capture costs.
- ·Strengthening regulatory frameworks and introducing carbon pricing mechanisms.

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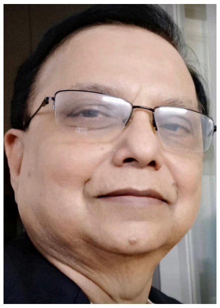
Culture and Behavior - Important aspects in Oil and Gas Operations Safety



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Upstream Oil and Gas Industry has witnessed improved HSE performance over the years, by adopting the latest technologies and standards, implementing engineering improvements and emphasizing safety through robust processes and management systems. Global Energy Risk Engineering Companies collate accident data worldwide, which reveals that despite improved HSE performance, accidents are still happening. Studying the ”culture and behavior in Safety” within Offshore Oil and Gas Operations is an important aspect for enhancing safe operations.

It has been observed that people in general are poor at assessing risk as they become used to it and start living with small failures. These failures may ultimately lead to Catastrophic Disasters (Dominoes effect). This is because overconfidence and complacency may gradually creep amongst operating personnel. Also, ignorance or lack of knowledge is another reason for increasing the likelihood of any incident/accident. It has been observed that on-site hazards are generally due to human behaviour, in addition to flaws/ deficiencies in technical decision or planning.

A study had been conducted by the author on behavioral issues of offshore operating crew based on data / feedback collected from operating personnel working offshore amongst a number of Indian companies. The

- results align with Industry perceptions. Some key highlights from the study are summarized below:

- Overconfidence causes accidents: 90% agreed while 10% disagreed.
- Complacency may cause accidents: Majority agreed with this.
- Shift-change/crew change is a very serious activity: Majority agreed that this is the “golden hour” for accident occurrence. The crew tries to hurry up the job and/or used short cuts before the shift-change.
- Teamwork and good safety culture is the highest motivating factor, while the next motivating factor was growth followed by salary.
- Monotony of work with increasing number of days offshore, causes decline in performance: Majority agreed to this.
- Extending extra days after normal shift days is a demotivating factor: In many cases, the crew responded that it heightens stress/ anger.
- Inexperienced person can cause accident: Most agreed to this. Also, the team needs training or re-training to improve their skills continuously.
- More automation or human intelligence or both: Majority answered that they need both.

The culture and behavior in HSE are very important aspects that require to be studied thoroughly and should become part of any accident analysis. The learnings from such an exercise needs to be subsequently implemented at worksite after comprehensive evaluation. Linking People (Acts) and Processes (Conditions) to the culture and behavior of operating crew is essential for significantly improving safety in offshore operations.

Residual Oil Saturation (S_{ro}) and Its Impact on Recovery Factor

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A significant amount of hydrocarbons remains unrecovered or trapped in the reservoir, resulting in a recovery factor far below 100%. The oil that remains in the porous media after water or gas flooding is referred to as residual oil saturation (S_{ro}). S_{ro} is a critical parameter influenced by factors such as lithology, pore size distribution, permeability, wettability, fluid characteristics, and the recovery method employed. Determining S_{ro} precisely is one of the most challenging tasks in reservoir engineering due to the high degree of heterogeneity present in reservoirs. Despite its complexity, S_{ro} is a key parameter for recovery estimates and plays a vital role in forecasting oil production.

Residual oil saturation depends on several factors and has different definitions. It is contingent on the rock type and properties, wettability, initial oil saturation (1 – Swi), the type of test and the test conditions.
In most cases, S_{ro} is determined through core flood experiments conducted under reservoir conditions. However, these experiments often face notable limitations:

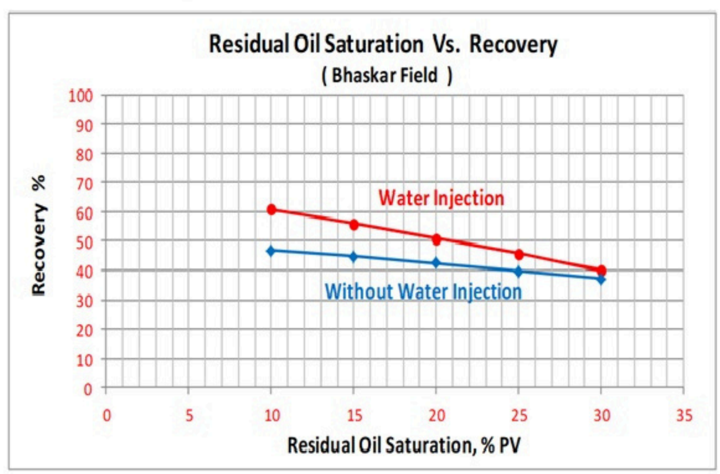
1. The core samples used may not accurately represent the heterogeneity of the actual reservoir.
2. The crude oil used in experiments often differs from the reservoir oil, leading to non-representative results.

S_{ro} is also estimated through centrifuge imbibition tests, which provide values closer to true residual oil saturation than conventional waterflood tests. This occurs because the higher displacement forces in centrifuge tests overcome capillary forces, allowing rocks to drain to lower oil saturations. The discrepancy between waterflood residual oil saturation (S_{ro}) and true residual oil saturation (S_{rot}) can be significant, particularly in high-permeability rocks where capillary forces dominate over viscous forces.

Additionally, wettability plays a fundamental role in defining S_{ro}. For similar rock types, intermediate-wet rocks generally yield lower S_{ro} values than strongly water-wet rocks, maximizing recovery efficiency by maintaining a continuous oil phase at low saturations. Obtaining reliable S_{ro} data is essential for estimating remaining oil in place and identifying target oil volumes for enhanced oil recovery (EOR) methods.

Case Study: Impact of S_{ro} on Recovery Factor in Bhaskar Field

The sensitivity of S_{ro} to the recovery factor is best illustrated by a case study from the Bhaskar Field, where direct S_{ro} measurements are unavailable. The impact of S_{ro} on overall recovery is significant, particularly in water injection or secondary recovery scenarios.



The impact of S_{ro} on overall recovery is clearly visible in the above sensitivity analysis. The plot was obtained by simulating the sensitivity scenarios on S_{ro} in reservoir simulation variants of the Base Case (without water injection) and with water injection. As observed, in the base case (no water injection), reducing S_{ro} from 30% to 10% increases the recovery from 37% to 47%, a significant 10% increase. With water injection, reducing S_{ro} from 30% to 10% increases the recovery from 40% to 61% which is a massive 21% increase in the overall recovery.

Therefore, accurate estimation of S_{ro} becomes even more critical in case of water injection or secondary recovery. The extent to which overall recovery improves with water injection, will significantly influence the design of water injection and produced water handling facilities in the field.

With residual oil saturation (S_{ro}) of 30 % of pore volume and average oil saturation of 60 % of PV, the microscopic displacement efficiency (Theoretical recovery) may be up to 50 %. With horizontal and vertical displacement efficiency of 80%, a maximum recovery of around 40 % may be achieved with water injection.

With S_{ro} of 30 %, a good amount of oil will be left out after primary and secondary recovery techniques. To improve the recovery factor, EOR methods which reduce the residual oil saturation may be identified.
Furthermore, S_{ro} is one of the most important inputs for building reasonably representative dynamic reservoir models, which are crucial for future production forecasting. Simulation studies, as highlighted in related research, demonstrate the significant impact of S_{ro} on oil recovery, further emphasizing its importance in reservoir management and decision-making.

Microbial Menace: The Hidden Threat of Microbial Induced Corrosion

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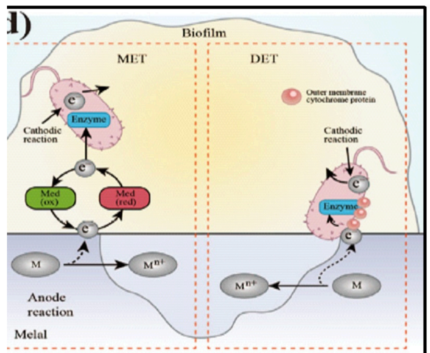
Microbial Induced Corrosion (MIC) is a severe form of corrosion caused by the metabolic activities of microorganisms in industrial environments. Estimates suggest that MIC accounts for up to 30% of all corrosion-related costs in the oil and gas industry. Oil and gas pipelines in particular are highly susceptible to corrosion from MIC, leading to substantial economic losses, environmental hazards, and safety concerns. MIC is responsible for 20–40% of internal pipeline corrosion failures worldwide, costing billions of dollars annually in maintenance, repairs, and replacements. Given its complex nature and underlying costs, the topic requires extensive study and industry-wide attention. This article explores its impact, mechanism, detection & monitoring strategies, current control measures, and the latest research trends.

The mechanism of any electrochemical corrosion requires three elements, an anode, the site from where the electrons are released, a cathode, where the released electrons are accepted, and an electrolyte, a medium that facilitates this ionic movement. MIC follows a similar electrochemical process, where microorganisms act as a cathode, pulling electrons from the metal surface (anode) via an electrolyte, typically water bearing medium present in the pipelines. Various microorganisms—bacteria, archaea, fungi, and algae—either individually or collectively contribute to MIC. These microbial actions lead to the formation of a 'biofilm', a protective slimy layer on the metal surface, under which corrosion occurs. (Figure 1).



The most studied microorganisms which are considered to be responsible for MIC include Sulphate-Reducing Bacteria (SRB), Iron-Reducing Bacteria (IRB), Methanogens, and Acid-Producing Bacteria (APB). Among these SRB's, which are widely present in marine sediments and water, have been identified as a leading cause of MIC. SRBs contribute to corrosion by metabolizing sulfate and producing hydrogen sulfide (H_2S) as a byproduct, which reacts with iron to form black iron sulfide (FeS) deposits. (Figure 2)

Reaction Type	Equation	Description
Metal Oxidation	$Fe \rightarrow Fe^{2+} + 2e^-$	Metal loses electrons (oxidation).
Sulfate Reduction	$SO_4^{2-} + 8e^- + 8H^+ \rightarrow H_2S + 4H_2O$	SRBs reduce sulfate to hydrogen sulfide.
Iron Sulfide Formation	$Fe^{2+} + H_2S \rightarrow FeS + 2H^+$	H_2S reacts with iron to form iron sulfide.

Recognizing and monitoring MIC requires a combination of visual, chemical, laboratory, and microbiological techniques. Analysing pit morphology, examining deposit samples, and measuring H_2S content along with ion composition in produced water can indicate the presence of MIC. However, confirming microbial activity necessitates identifying and quantifying microbial colonies through culture-based methods and microscopic analysis. More advanced techniques, such as DNA sequencing and Polymerase Chain Reaction (PCR), offer precise insights into the type and concentration of microbes responsible for MIC.

Since MIC is an eventuality in any metal surface exposed to the marine environment, especially fluid evacuation and water injection pipelines, control strategies should be implemented by the operators to prevent loss of assets. These strategies involve maintaining adequate liquid flow velocity, optimizing pigging frequency, applying biocides regularly, using coated pipelines, and enhancing the quality of injection water, among others. Each of these methods has its advantages and limitations, but achieving the best results often requires implementing multiple strategies simultaneously. Operators must exercise due diligence when implementing mitigation strategies, as certain applications can inadvertently worsen MIC instead of preventing it. For example, some biocides should not be used alongside specific corrosion inhibitors (CIs), as certain CIs may serve as a nutrient source for microbes, promoting their growth rather than suppressing it.

Despite advancements in MIC prediction modelling, accurately forecasting MIC remains the "holy grail" of MIC research, particularly for oil and gas pipelines. The intricate interplay between microbial communities, environmental conditions, and material properties makes it difficult to develop universally reliable prediction models. While numerous phenomenological, mechanistic, and risk-based models have been developed to explain specific MIC mechanisms and estimate corrosion rates, their accuracy and applicability remain limited. Operators must approach these models cautiously, relying instead on a proactive MIC control strategy that prioritizes robust monitoring, early detection, and effective mitigation. Until predictive models become more reliable, well-designed control strategies should remain at the forefront of MIC management. Nevertheless, the pursuit of a precise, real-time MIC prediction model continues to drive research, with advancements in artificial intelligence, machine learning, sensor technology, and microbiome analysis offering new possibilities for improving MIC forecasting and prevention.

The future of MIC management will bring together production engineers, corrosion specialists, data scientists, and microbiologists in ways never seen before, fostering cross-disciplinary collaboration to tackle this complex challenge. As new technologies and scientific breakthroughs reshape MIC prevention, exciting times lie ahead.

A Concise Review of India's Hydrogen Economy: Challenges, Alternatives, and Global Commitments

Rajib Roy
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A) Introduction

The hydrogen economy has gained global attention as a key driver of sustainable energy transition, offering a viable alternative to fossil fuels for reducing carbon emissions. With rising energy demands and its commitment to achieving net-zero emissions by 2070, India has recognized hydrogen as a crucial element in its clean energy roadmap. The National Green Hydrogen Mission envisions positioning India as a global leader in hydrogen production and utilization. However, despite its vast potential, various economic, infrastructural, and technological hurdles impede large-scale hydrogen adoption. This critical review examines the key challenges, explores alternative energy options, and assesses India's alignment with international sustainability goals while also analysing the cost-effectiveness of turquoise hydrogen and the hydrogen strategies of nations like Japan, the EU, and Australia.

B)Challenges of the Hydrogen Economy in India

1. High Production Costs and Energy Efficiency Concerns

Green hydrogen, produced via electrolysis powered by renewable energy, remains expensive due to the high costs of electrolysers and electricity. Despite India's abundant solar and wind resources, cost barriers persist (IEA, 2022). Currently, green hydrogen production in India costs approximately $5 per kg, significantly higher than grey hydrogen, which is derived from fossil fuels (TERI, 2021). Countries like Germany and Japan are working toward cost reductions through large-scale deployment and technological innovations.

Turquoise hydrogen, produced via methane pyrolysis, offers a cost-effective alternative as it generates solid carbon instead of CO_2, thereby reducing the need for carbon capture. The estimated production cost of turquoise hydrogen ranges from $2 to $3 per kg, making it a more competitive option compared to green hydrogen (IEA, 2023).

2. Storage and Transportation Limitations

Hydrogen has low volumetric energy density, necessitating complex storage and transportation infrastructure such as high-pressure tanks, cryogenic solutions, and chemical carriers like ammonia. India's existing gas pipeline network requires substantial modifications for safe hydrogen transport (MNRE, 2023). International efforts, including the European Union's hydrogen infrastructure investments, highlight the need for global standardization of storage and transport systems.

3. Infrastructure Development and Investment Gap

The development of hydrogen production, storage, and distribution infrastructure demands substantial financial investment. Although India has allocated resources through the Green Hydrogen Mission, private sector involvement remains limited due to high capital expenditure and uncertain returns (NITI Aayog, 2022). Countries such as the U.S. and South Korea have successfully implemented public-private partnerships to accelerate hydrogen infrastructure growth, serving as potential models for India.

4. Dependence on Fossil Fuels for Blue and Grey Hydrogen

Currently, most of India's hydrogen production relies on fossil fuels, leading to significant carbon emissions. Blue hydrogen, which integrates carbon capture and storage (CCS), is considered a transitional solution. However, India's CCS infrastructure is still underdeveloped (CSE, 2023). Nations such as Norway and Canada are pioneering CCS deployment, providing India with potential models for future adoption.

5. Renewable Energy Integration Challenges

Large-scale hydrogen production requires a stable and abundant renewable energy supply, which is challenged by grid stability issues, land acquisition constraints, and intermittent solar and wind power generation (IEA, 2022). The EU's Hydrogen Strategy emphasizes hybrid energy storage systems and smart grid technologies, which could provide a blueprint for India's renewable-hydrogen integration.

A)**Alternative Energy Solutions for India**

1. Turquoise Hydrogen as a Cost-Effective Alternative

Turquoise hydrogen, produced through methane pyrolysis, offers a middle ground between green and blue hydrogen. It does not release CO2 emissions and produces solid carbon, which can be repurposed in industries such as manufacturing and construction (IEA, 2023). Its cost-effectiveness makes it a compelling alternative for India's hydrogen economy.

2. Battery Electric Vehicles (BEVs) and Energy Storage
Battery electric vehicles (BEVs) are emerging as an efficient and cost-effective alternative to hydrogen fuel cell vehicles globally. India's Faster Adoption and Manufacturing of Electric Vehicles (FAME) initiative aligns with international trends seen in China and the U.S. (MoP, 2023). BEVs offer lower infrastructure costs, making them a more feasible alternative to hydrogen-powered transport. However, the true sustainability of BEVs depends on electricity generation from non-fossil fuel sources.

3. Direct Electrification and Smart Grid Expansion

Direct electrification through expanded grid capacity and smart energy solutions can reduce dependence on hydrogen. The International Renewable Energy Agency (IRENA) advocates for smart grids and energy storage integration to optimize renewable energy utilization (MNRE, 2023). India could adopt similar strategies to improve energy efficiency.

4. Biofuels and Green Ammonia
Biofuels, such as ethanol and biodiesel, play a key role in India's transportation and industrial sectors. Additionally, green ammonia is emerging as an efficient hydrogen carrier, mitigating storage and transportation challenges (TERI, 2022). Countries like Brazil and the U.S. have successfully scaled biofuel adoption, offering valuable lessons for India.

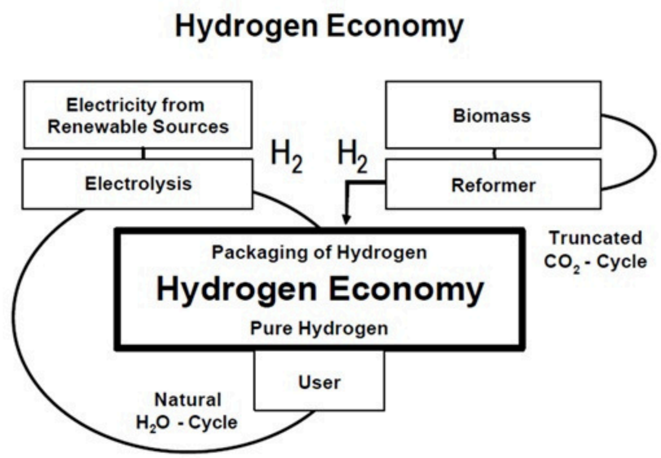
A) Global Commitments and India's Role in the Hydrogen Economy

1. Japan's Hydrogen Roadmap

Japan has committed to extensive hydrogen deployment, focusing on fuel cell vehicles and hydrogen-based power generation. Japan's strategic investments in international hydrogen supply chains position it as a leader in the hydrogen economy (METI, 2023). India could collaborate with Japan for technology exchange and supply chain development.

2. European Union's Hydrogen Strategy
The EU has set ambitious hydrogen deployment targets, backed by significant investments in green hydrogen production and infrastructure. Aligning India's hydrogen policies with EU standards could foster trade and technological collaboration (European Commission, 2023).

3. Australia's Hydrogen Investment Plan
Australia has emerged as a key player in hydrogen exports, particularly to Asian markets. Its focus on green hydrogen production using renewable energy makes it a valuable case study for India's hydrogen roadmap (Australian Government, 2023).



Conclusion
The hydrogen economy represents a transformative opportunity for India's clean energy transition, but challenges such as high production costs, infrastructure deficits, and renewable energy integration must be addressed. Turquoise hydrogen emerges as a cost-effective alternative, offering an intermediate solution between fossil-based and green hydrogen. Drawing insights from global leaders like Japan, the EU, and Australia can help India establish a robust hydrogen strategy. By aligning domestic initiatives with global sustainability commitments and fostering international collaborations, India can accelerate its transition to a cleaner and more energy-secure future.

Optimizing Waterflooding Strategies for Enhanced Oil Recovery: A Comprehensive Study

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1. **Introduction**

Reservoir simulation is a powerful tool in petroleum engineering that aids in predicting reservoir behavior under various recovery mechanisms. This study focuses on waterflooding, a widely applied secondary recovery method that involves injecting water to maintain pressure and improve oil displacement. The objective of this study is to compare different waterflooding injection patterns and determine the most efficient and cost-effective strategy for maximizing oil recovery. Additionally, the study aims to enhance decision-making in reservoir management through detailed sensitivity analyses and optimization techniques.

2. Methodology

A homogeneous reservoir model was created using CMG software, with the following parameters:

- Grid dimensions: 41 × 41 × 5
- Grid block size: 10m × 10m × 2m
- Reservoir depth: 1000m
- Reservoir porosity: 25%
- Permeability: 200 md (I, J direction), 100 md (K direction)
- Reservoir pressure: 22,000 kPa at datum level
- Bubble point pressure: 12,000 kPa
- Oil API Gravity: 18
- Gas Gravity: 0.7

The study investigated the impact of different waterflooding patterns (5-spot, 7-spot, and 9-spot) on oil recovery efficiency. Sensitivity analyses were performed to determine the optimal time for water injection, the appropriate injection rate, and the impact of grid resolution on simulation accuracy.

3. Grid Sensitivity Analysis

A grid sensitivity analysis was conducted to optimize simulation accuracy. Various grid configurations (5, 11, 21, 41, 47, 51, and 81 grids) were tested. The results showed that beyond 41 grids, additional refinement had negligible impact on accuracy. This finding justified the use of 41 × 41 × 5 grid dimensions for the study, ensuring computational efficiency without compromising accuracy.

4. Determining the Optimal Time for Water Injection

To determine the most effective timing for water injection, multiple scenarios were tested. Injection was initiated at different time intervals, and the resulting production rates were compared. The analysis revealed that commencing water injection in July 2027—when reservoir pressure approached the bubble point pressure—yielded the best results without incurring excessive costs. Early injection resulted in unnecessary operational expenses, while delayed injection led to undesirable reservoir pressure depletion.

5. Optimization of Injection Rate

Different injection rates were analyzed: 4.5 m³/day, 5 m³/day, 7 m³/day, 10 m³/day, 30 m³/day, and 50 m³/day. The results indicated that an injection rate of 10 m³/day per well (total 40 m³/day) provided an optimal voidage replacement ratio (VRR) slightly above 1. This ensured adequate pressure maintenance without excessive water handling costs. Higher injection rates led to early breakthrough, increasing water production and reducing overall efficiency.

6. Comparative Analysis of Injection Patterns

Three waterflooding patterns were evaluated:

- 5-Spot Pattern: Consists of one central producer surrounded by four injectors. It provided an incremental recovery of 7,780 m³ over six years post-injection. The simplicity and cost-effectiveness of this pattern make it a viable option for many reservoirs.

- 7-Spot Pattern: Features one producer surrounded by six injectors. It exhibited slightly better sweep efficiency than the 5-spot pattern but with marginal additional recovery. The added complexity and increased water injection costs should be considered in field applications.
- 9-Spot Pattern (1:1 and 10:1 diagonal/directional ratio):
  - The 1:1 diagonal/directional configuration resulted in a recovery of 76,990 m^3.
  - The 10:1 diagonal/directional configuration yielded the highest recovery at 78,440 m^3 but required significantly higher operational expenses.

7. Results and Discussion

- Sweep Efficiency: The 9-spot (10:1) pattern achieved the highest sweep efficiency, followed by the 7-spot and 5-spot patterns. However, diminishing returns were observed beyond the 7-spot pattern.
- Economic Viability: Despite the higher recovery of the 9-spot pattern, the increased injection and operational costs may outweigh the additional oil recovery. The 5-spot pattern emerged as the most cost-effective choice, balancing oil recovery with economic considerations.
- Reservoir Pressure Maintenance: The selected 10 m^3/day injection rate effectively maintained reservoir pressure above the bubble point, preventing gas breakout and ensuring stable production.

8. Conclusion

The study concludes that while the 9-spot (10:1 diagonal/directional) pattern provides the highest recovery, the 5-spot pattern offers the best balance between efficiency and cost-effectiveness. Implementing a 10 m^3/day injection rate at the optimal timing of July 2027 ensures sustained production and reservoir pressure maintenance. These findings can guide reservoir engineers in designing effective waterflooding strategies tailored to field-specific conditions.

These insights can guide field-scale waterflooding operations, optimizing oil recovery while minimizing operational expenditures. The study highlights the importance of a systematic approach to waterflooding, considering both technical and economic factors.

Famous Quotes on Oil & Gas Business

·Drill for oil? You mean drill into the ground to try and find oil? You're crazy! — Edwin Drake

·A smell of petroleum prevails throughout. — Bertrand Russell

·Electric power is everywhere present in unlimited quantities and can drive the world's machinery without the need of coal, oil, gas, or any other of the common fuels. — Nikola Tesla

·The secret of success is to get up early, work late and strike oil. — John D. Rockefeller

·The best business in the world is a well run oil company. The second best business in the world is a badly run oil company. — John D. Rockefeller

·The thing you have to remember is, oil and gas are commodities, and the more we use them the more the price goes up, like any commodity. Solar, wind - they are technologies, so the more you use them, the more the price goes down. — Thomas Friedman

·In 1859 the human race discovered a huge treasure chest in its basement. This was oil and gas, a fantastically cheap and easily available source of energy. We did, or at least some of us did, what anybody does who discovers a treasure in the basement - live it up, and we have been spending this treasure with great enjoyment. Kenneth E. Boulding

·The use of solar energy has not been opened up because the oil industry does not own the sun. -Ralph Nader

·Coal, oil and gas are called fossil fuels, because they are mostly made of the fossil remains of beings from long ago. The chemical energy within them is a kind of stored sunlight originally accumulated by ancient plants. Our civilization runs by burning the remains of humble creatures who inhabited the Earth hundreds of millions of years before the first humans came on the scene. Like some ghastly cannibal cult, we subsist on the dead bodies of our ancestors and distant relatives. - Carl Sagan

·We have become great because of the lavish use of our resources ... But the time has come to inquire seriously what will happen when our forests are gone, when the coal, the iron, the oil and the gas are exhausted. — Theodore Roosevelt

·The good Lord put oil and gas there for us to find and use, and we'd better do it. — Red Adair

·The profits of oil, coal, and natural gas companies will have to yield to the imperative of sustaining life on earth. — Robert Pollin

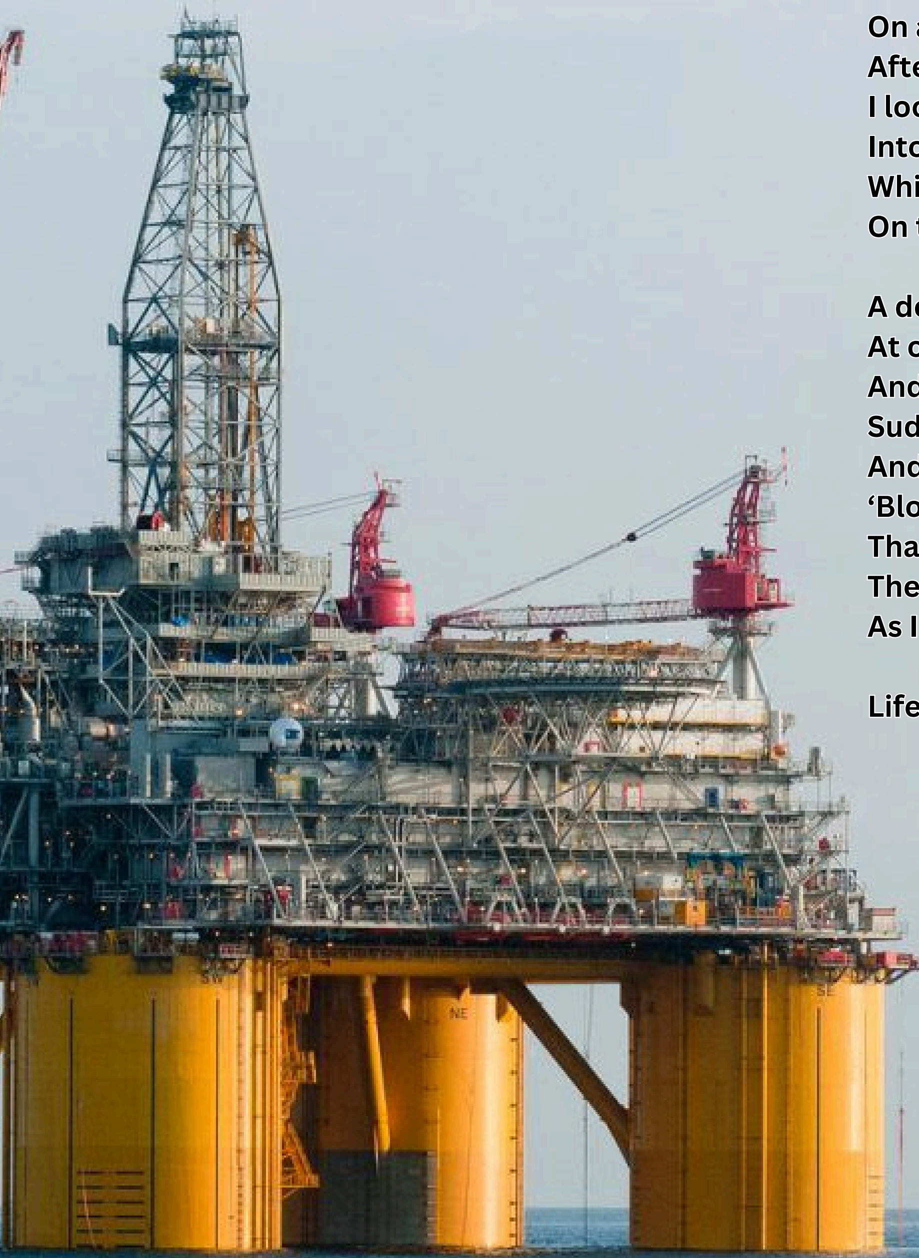
Well Test Blues.......

- reflections of a tired petroleum engineer on an offshore rig

Standing on the deck
On a fine sunny morn
After a hard night, weary and worn
I look high
Into the cerulean skies,
While down below the wispy waves dance
On the crinkly cobalt expanse.

A dolphin flips over.
At once, a flock of noisy gulls rise up through the air
And a lone flier,
Suddenly stoops
And poops on me.
'Bloody hell,
That's a dead well',
The gull seemed to tell.
As I gawk, the roughnecks guffaw.

Life is shit.



Contributed by Prakash Swaminathan, Head-Reservoir, Adani Welspun Exploration

Quiz

1. What is the name of the world's deepest oil well, located in the Chayvo field off the coast of Sakhalin, Russia?

2. Which oil field is the largest in the world by reserves?

3. Which country has the largest proven oil reserves in the world?

4. Oil magnate Ellis Wyatt is one of the titans of industry who go missing in what 1957 novel by Ayn Rand?

5. “The Smartest Guys in the Room” is the byline of a 2005 documentary film about the collapse about what American company after it became embroiled in one of the biggest insider trading corporate scandals of all time?

6. In 1989, a ship hit a reef in the Prince William Sound and spilled more than 10 million gallons of crude oil over more than 1,000 miles of coastline. What was the famous, ill-fated two-word name of this ship?

7. Octan is a fictional company whose gas stations appear in the building sets of what Danish toy brand?

8. Upton Sinclair's 20th-century novel "Oil!" served as inspiration and a springboard for the screenplay of what Oscar-winning 2007 film following the life of a California oil man?

9. Daniel Yergin's 1990 book "The Prize: The Epic Quest for Oil, Money, and Power" was the winner of what annual award for achievement in writing?

10. What energy company describes its logo on its own website as follows? "The colors of the Helios – named after the Greek god of the sun – suggest heat, light and nature. It is also a pattern of interlocking shapes."

1.Z-44 Chayvo, reaching a depth of approximately 40,000 feet
2.Ghawar Field in Saudi Arabia, with estimated reserves of 70 billion barrels
3.Venezuela, with approximately 303 billion barrels
4.Atlas Shrugged
5.Enron
6.Exxon Valdez
7.Lego
8.There Will Be Blood
9.Pulitzer Prize
10. BP

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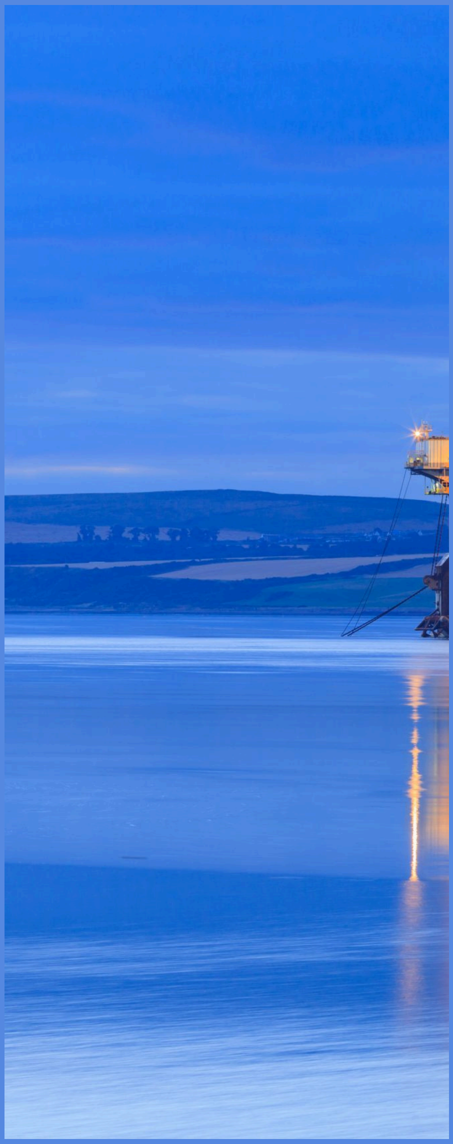


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