FIPI

Federation of Indian Petroleum Industry

R&D CONCLAVE 2021

Summary Report

March 24-26, 2021


FIPI
R&D CONCLAVE 2021
MARCH 24-26, 2021
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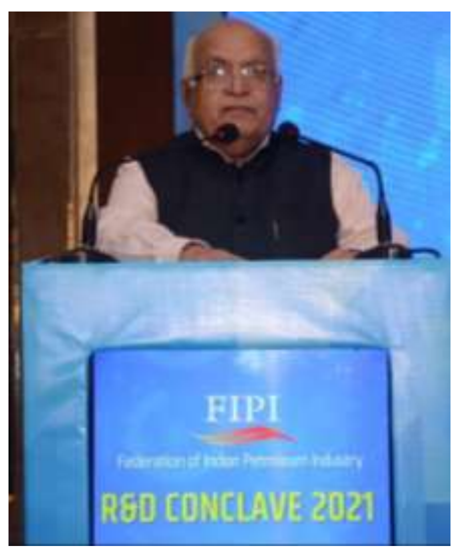
Contents

Summary

The Federation of Indian Petroleum Industry (FIPI) organised the fourth edition of its flagship event, R&D Conclave 2021 in a hybrid mode due to the ongoing COVID-19 pandemic from 24th – 26th March, 2021 at Shangri-La Eros Hotel, New Delhi, with appropriate COVID-19 protocols in place, with limited physical attendance and a much larger presence on the virtual platform. The conclave witnessed a wide participation of companies across the upstream, midstream, downstream, and technologies domain.

Shri Tarun Kapoor, Secretary MoP&NG graced the inaugural session as the chief guest at the conclave and delivered the inaugural address. Dr. Anil Kakodkar, Chairman, Rajiv Gandhi Science and Technology Commission and Former Chairman, Atomic Energy Commission was the guest of honour and delivered his talk virtually during the session. The conclave was attended by Ms. Vartika Shukla, Director(Technical) – EIL, Dr. S.S.V. Ramakumar, Director (R&D) - IOCL, Dr. P. Chandrasekaran, Director (E&D) – Oil India Ltd, Dr. Ajit Sapre, Group President (R&D) – RIL, Mr S. Bharathan, Head R&D - HPCL, Dr. V. Ravikumar, Head (R&D) – BPCL, Dr. M.O. Garg, President – Refining & Petchem R&D – RIL, Dr. Anjan Ray, Director, CSIR-IIP and Dr. Sanjeev Katti, Director General, ONGC Energy Centre among other eminent personalities and experts from the sector.



The Welcome Address at the inaugural session was delivered by Dr R.K. Malhotra, Director General, FIPI. Dr Malhotra welcomed the delegates and mentioned that this year's R&D Conclave is being organised in a hybrid format due to the ongoing COVID-19 pandemic. He highlighted the fact that climate change and global warming have become very urgent issues at this point of time and needs to be tackled on priority. The R&D community is tasked with the responsibility to integrate renewables into the system and advance towards zero-carbon operations. The R&D segments of all major oil and gas companies in the country are working towards making India's energy mix greener. India has successfully transitioned to BS VI fuels in 2020, which has been made possible due to the backing of strong R&D work done by Indian oil refining and marketing companies. Many of the Indian oil refining and marketing companies have been able to achieve this transition by making use of indigenously developed technologies. He further stressed that the energy sector presents plethora of opportunities for the R&D sector. The Government is providing many incentives on development of indigenous technologies and their commercialization.

Shri Tarun Kapoor, Secretary, MoP&NG in his inaugural address highlighted the role played by Indians across the world in the R&D field and appreciated the efforts of Indian companies for providing importance to R&D activities. He further said that the R&D community in India is tasked with the responsibility of finding new technologies which would be path breaking and take the country towards energy security. Energy sector is crucial to the economy and any ground breaking developments have the capability of touching billions of lives. He also emphasised the importance of identification of right research areas and sharing of knowledge to give further impetus to R&D activities.

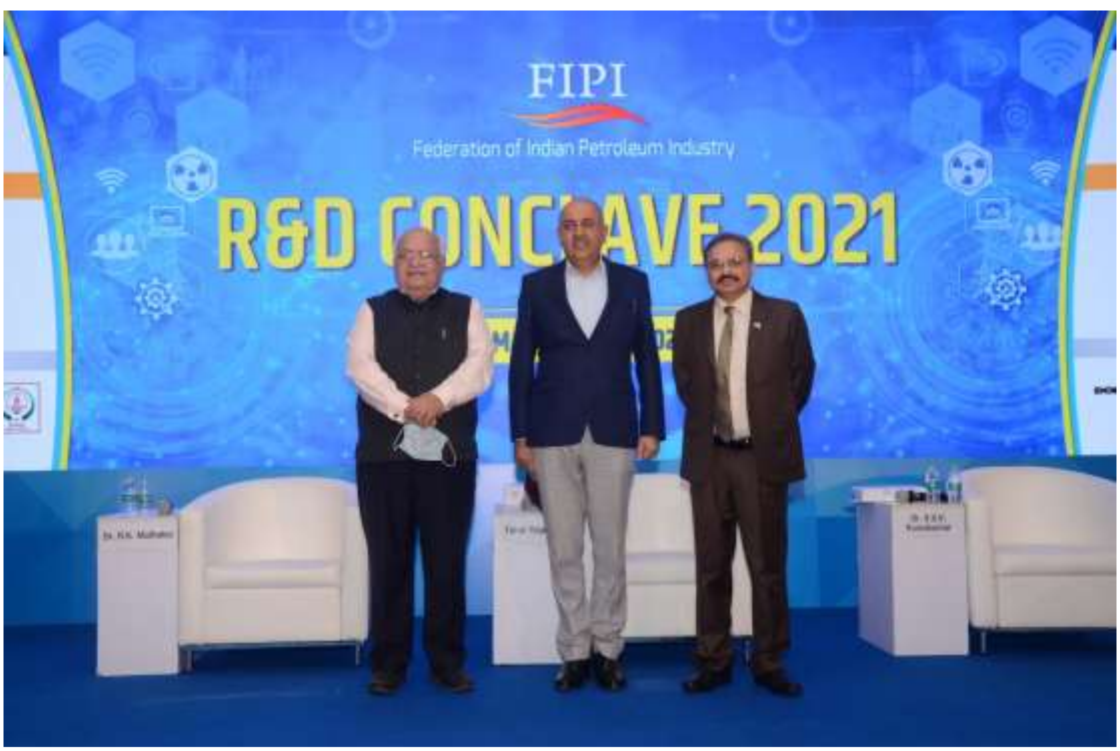
Dr. Kakodkar, in his invited talk, mentioned that India is one of the fastest growing countries in terms of the research publications. However, our ability to convert the research into commercially marketable technology and products is still not comparable to some of the other countries. Some smaller countries with much lower outlay are performing better than us in this respect. He said that Oil and gas sector has heavily invested in R&D for last many years and as an industry has been doing better than other sectors in terms of R&D activities. He further stated that since energy transition is well in motion, refineries should be looked at more from the perspective of petrochemicals business. India should aim to emerge as a net exporter of petrochemicals in the future. In terms of alternative fuels, Hydrogen and Bio fuels have a significant potential for growth in India.

In his special address, Dr Ajit Sapre highlighted the challenge of climate change and stressed on the role that hydrogen can play in decarbonising the energy sector as well as stabilizing the power grid. RIL has been working on the fuel cell technology for past several years, has deployed it for backup power at telephone towers. He said that, India would need the renewable liquid fuels despite the unprecedented push for EVs as aviation cannot be electrified and the fleet will require hydrocarbon fuels which are zero carbon. In this direction, RIL has developed the Reliance Catalytic Hydro thermal liquefaction. This converts organic waste into light crude that can be used directly in combustion, power generation and to make aviation fuel. Dr Sapre stressed on India's need for taking leadership position in technology development and commercialization.

Dr S.S.V. Ramakumar spoke about the emerging trends in the post COVID world that is in the middle of a historic energy transition towards low carbon technologies. In this regard, the major challenge for India is the CO_2 emissions from the power sector. He highlighted the efforts of

Indian Oil on carbon capture and utilization, and pursuing all pathways, to move towards a net zero future. The other focus areas for Indian Oil is building sustainable refineries including bio-refineries, working on waste to energy and plastic neutrality.

After the inaugural session on 24th March 2021, over the next two days, R&D Conclave 2021 witnessed dedicated technical sessions on various research areas related to upstream, midstream, downstream segments along with discussion on upcoming technologies, which will revolutionize the industry in the short to medium term. Going on with the trend and need of the hour, the commitment of oil & gas companies was clearly visible in their R&D activities with focus on various aspects of energy transition such as efficiency, low carbon technologies, carbon capture, alternative fuels, and energy conservation. The conclave came to its culmination with a panel discussion on 'R&D and deployment of indigenously developed technologies', where leaders from various major Indian Oil & Gas companies talked about game changing technologies developed by their companies and their far reaching impact on the sector. The details of each session of the conclave is captured in the sections below.



R&D Conclave 2021

Day 1, 24 March, 2021

Inaugural Session

Dr R K Malhotra
Director General
Federation of Indian Petroleum Industry (FIPI)

Welcome & Opening Address

- R&D Conclave 2021 is being organized in a hybrid format due to the ongoing COVID-19 pandemic. Physical presence of the participants is crucial for the R&D conclave to serve its purpose of sharing of ideas and best practices across the industry.
- The oil and gas sector has been among the worst hit due to the pandemic. The profits of the oil and gas operators suffered during this period. This alongside climate change and global warming have become very urgent issues at this point of time and needs to be tackled on priority.
- Further, the Government of India has given a challenge to the industry to reduce import dependence by 10 per cent by 2022. To achieve this ambitious target, a range of interventions in the upstream side of the industry have already been introduced.
- On the alternative energy side, newer sources such as bioenergy, hydrogen and renewables have received ample focus and push from the Government over the years.
- Keeping pace with the ongoing energy transition, the R&D community needs to look for ways to integrate renewables with fossil fuels and making them affordable to the common man in the country.
- Many countries and companies globally have announced their net-zero commitments with target of 2050. Indian Industry is also very well positioned to successfully surmount these challenges. RIL has already taken up a challenge to become zero carbon by 2035, well ahead of the global targets of 2050.
- Today, Hydrogen is being looked as the fuel of future. India should also explore Blue Hydrogen in addition to green Hydrogen. If CO2 produced from Blue Hydrogen could be captured and put to constructive uses, there will be no difference between blue and Green Hydrogen.
- In 2020, India transitioned to BS-VI quality fuels. This has been made possible through strong R&D work done by Indian NOCs. Many of the Indian oil refining and marketing companies have

	been able to achieve this transition through developing indigenous technologies ▪ The energy sector presents plethora of opportunities for the R&D sector. With the necessary support extended by Government of India we will soon witness successful commercialization of many indigenously developed technologies.
 **Dr Ajit Sapre** Group President (R&D) Reliance Industries Ltd (RIL)	**Special Address** ▪ Climate change is a common challenge and responsibility of both developed and developing countries. India needs to do its part and stay on the right trajectory through implementation of necessary technologies while growing the economy. ▪ To meet the inherent challenges over affordability, India need to work towards reducing the green premium of RE technologies to as close to zero as possible. In this direction, Government of India has played an instrumental role in promoting indigenous technologies under the Aatmnirbhar Bharat programme. ▪ Over the last few years, Hydrogen has emerged as the energy source for a cleaner future. Splitting of water using green electricity will produce green Hydrogen. However, the green premium for splitting water is about USD 3/KG. To ensure a successful transition to Hydrogen, the country must focus on bringing down the Green Premium to zero. India also need to work on the storage of Hydrogen and its transportation and some solution needs to be worked out. ▪ In the Northern States of the country, agricultural residue, which is presently being burnt, leads to wastage of this resource. This burning of biomass has raised serious concerns over the air quality in neighboring major cities such as Delhi. We should aim to convert the biomass into green Hydrogen and make the premium to zero. ▪ This can be achieved through biomass catalytic gasification through a system developed by RIL. This technology produces higher volumes of Hydrogen without any tar formation. Hydrogen as a fuel has significant appeal for many industries including power, steel and transportation. ▪ RIL believes that while the EVs will be successful in the two and the three wheeler segment, the heavy duty vehicles will be fuelled by Hydrogen fuel cells in future. ▪ RIL has been working on the fuel cell technology for over last ten years and have developed both low and high temperature technologies. The Hydrogen fuel cells are already being deployed as the back-up power source for the Jio Towers. This technology

	will soon be commercialized for mobility and transportation purposes. ▪ India would need the renewable liquid fuels despite the unprecedented push for EVs as aviation cannot be electrified and the fleet will require hydrocarbon fuels which are zero carbon. In this direction, we have developed the Reliance Catalytic Hydro thermal liquefaction. This converts organic waste into light crude that can be used directly in combustion, power generation and to make aviation fuel. ▪ Indian Government has provided a big push to convert agricultural waste and municipal waste into bio-ethanol. If India could convert its entire organic waste from cities and towns to biofuel, it would save the country almost 20 per cent of the total oil imports ▪ Significant efforts are going on around the world to recycle plastics. To this end, RIL has adopted an approach to educate, collaborate and innovate for its plastic business. In this direction, RIL has developed a technology to produce mixed plastics. This technology is presently being commercialized ▪ RIL has developed a fluid bed technology CO2 to capture CO2. This technology is far superior to the conventional CO2 capture technologies. The technology captures diluted CO2 from the flue gas. ▪ The captured CO2 also finds usage in developing the RIL's algea to oil programme. In this technology, all parts of the process have been developed indigenously in India. Today, RIL has the most advance algea to oil programme in the world ▪ To achieve India's coveted USD 5 trillion objective, India needs to take leadership position in technology development and commercialization. India's R&D expenditure is larger than most countries in the world. Yet, many smaller countries with their targeted research programmes are more competitive in the R&D space than India. ▪ Linkage between industry and academia is imperative to ensure the research work in the country is focused and to ensure that we develop competitive technologies

Dr. S.S.V. Ramakumar
Director (R&D)
IndianOil

Special Address

- There are three major emerging trends in the post COVID world:
    - The demand for oil products is back online since the lows seen in the first half of 2020.
    - Electricity and Hydrogen will emerge as the dominant forces in the energy landscape
    - Fossil fuel peak is now sooner than later
- Despite COVID pandemic the investment flows in the energy sector have continued uninterrupted and this is not going to dry soon.
- Today, the world is in middle of a historic energy transition towards low carbon technologies. In this regard, the major challenge for India is the CO2 emissions from the power sector. The transport sector is still in far third position as far as CO2 emission are concerned.
- Keeping pace with the transition, the world and India is working towards developing new low carbon sources of energy. The essence of all these developments is that the country needs to create a veritable mix of energy basket.
- Carbon as an input is still the cheapest and the richest. There is pressing need to make use of the emitted carbon in intelligent and smarts usages. IndianOil R&D is focusing its efforts on carbon capture and utilization, pursuing all pathways, to move towards a net zero future.
- Net zero for IndianOil is first and foremost energy efficiency. Energy efficiency is the lowest hanging fruit in the fossil fuel domain. One of the most neglected areas to gain efficiency is lubricants. Transport sector is heavy diesel guzzler and here any avenue that can lead to incremental fuel efficiency is more than welcome. IndianOil has demonstrated that the use of right combination of lubricants we can increase the fuel efficiency by 4 per cent.
- Another aspect of gaining efficiency in transport sector is boosting of Octane number. OCTAMAX technology developed by IndianOil has already demonstrated 100 Octane fuels for the first time in the country.
- Another focus area for the company is sustainable refineries including bio-refineries. Refiners should think of integrating bio-refinery concept into the existing fossil fuel refinery and not just stand alone bio refinery.
- IndianOil is focusing on waste to energy including the plastic neutrality. Plastic neutrality is one of the key imperatives for achieving net zero goals. IndianOil is also pursuing 10 pathways

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- for plastic neutrality. At least four of these have already been demonstrated.
- Use of Solar energy in refining operatioons will prove a stride towards the net zero goals in otherwise Carbon intensive processes. Refineries today contribute to 6 per cent of global air pollution. In today's world, refiners must look at every possible way to cut carbon.

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Dr. Anil Kakodkar, Chairman, Rajiv Gandhi Science & Technology Commission and

Former Chairman, Atomic Energy Commission

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Invited Talk by Guest of Honour

- India is one of the fastest growing countries in terms of the research publications. However, our ability to convert the research into commercially marketable technology and products is still not comparable to some of the other countries.
- Oil and gas sector in India has heavily invested in R&D activities for last many years. That is a very good sign for the sector. The industry also maintains a strong connect with the academia in the country. Researchers, in the sector, are now looking at solving important industry problems rather than academic issues.
- India is among the countries looking to net zero carbon emissions by 2050. This means that the country needs to put very aggressive timelines for R&D and needs to collectively deliberate on ways to achieve this ambitious objective.
- India is today heavily dependent on imports for its oil and gas requirements. Import reduction is a serious challenge for the country. A large part of our import bill is oil and gas and are the largest item of foreign exchange outlay for the country.
- With an objective of reducing imports, Government has launched a very supportive policy for 2G biofuels alongside the SATAT initiatives. The new policy introduced in 2018 offers significant subsidies for biofuels producers. However, there is still a viability issue that needs serious attention from the R&D community.
- We must look for ways to make use of the energy sources available in the rural area to fuel the energy needs of the region. In this direction, conversion of the biomass, available locally, into Compressed Bio Gas (CBG) or Biogas could serve as a local alternative for imported fossil fuels.
- Today, Hydrogen is being seen as the ultimate clean fuel. The Hydrogen fuel cells powered heavy vehicles are expected to be much cheaper than diesel based heavy vehicles in the future.
- With energy transition now well in motion, the time has come to look at refineries more from the perspective of petrochemicals business. Refinery technology capability is India's stronghold and the country must continue its R&D efforts to develop the

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	necessary technology and processes to increase its petrochemicals produce. ▪ There is a huge demand for petrochemicals in the international market and India is still an importer. India should aim to emerge as a net exporter of petrochemicals in the future. This will save the balance of payment issue and will also contribute to developing flexible processes. ▪ Another area to focus R&D efforts is gas hydrates. India is blessed with huge resources of gas hydrates and may prove a single point solution to service all India's energy requirement. India should emerge as a leader in this technology since the energy challenge faced by the country is more severe.
 **Shri Tarun Kapoor** Secretary Ministry of Petroleum & Natural Gas (MoPNG)	**Inaugural address by Chief Guest** ▪ India is known all over the world for producing the best minds in the field of R&D. Indians are today working across countries in their R&D programmes. With right environments, facilities and opportunities, India can develop strong indigenous R&D capability ▪ It is very encouraging to see that large oil companies and PSUs in the country are providing high importance to the R&D activities in India. These companies have created a good and supportive infrastructure in the country, which will ensure the growth of the sector in the long run ▪ Some of the companies in the oil and gas sector have successfully commercialized their findings and are yielding great benefits to the companies in this sector. ▪ The oil and gas companies in India must ensure that the R&D community is given enough importance and growth opportunities to attract the best minds. ▪ The sector participants must look for the niche areas they could do research and benefit. Targeted research areas need to be identified and worked upon. There should be ample opportunities for knowledge sharing among the R&D communities for knowledge growth. ▪ Today, the R&D community in India is tasked with the responsibility of developing new technologies, which would be path breaking and take the country towards on road to energy security. ▪ Energy sector is crucial to the economy and any ground breaking developments have the capability of touching billions of lives. Increasing efficiency and cleaner use of fuels should be the two main focus areas for the R&D community in this sector.

Day 2, 25 March, 2021

Invited Talk on Geothermal Field Development for Carbon Neutral Ladakh

Dr. Sanjeev Katti
Director General,
ONGC Energy Centre

- Geothermal energy is the only renewable source of energy that is available 24*7. 1 MW of geothermal plant gives out the same amount of energy as a 5MW solar PV. Geo-thermal energy is also the lowest cost renewable energy that is being produced commercially today all over the world.
- To develop geo-thermal energy resources, we need to locate the fault lines where the two plates collide. In India vast resources of geothermal energy are found where the Indian and the Eurasian plates collide. Such places are mostly located in the Himalayan region.
- Advantages of geothermal energy are no emissions, continuous source of energy and a reliable base load power. It is also sustainable, re-useable as the water coming out could be reused as hot water for various purposes. There is also no requirement for major land acquisition compared to other sources of renewables.
- One of the challenges faced while developing geo-thermal resources is how to use the hot water which is between 100 and 180 degree Celsius. In Ladakh, this water could be fully utilized for space heating, radiators, snow melting, in swimming pools and so on.
- While there are multiple examples internationally where Geo-thermal energy is being used for power generation for over 100 years, in India, ONGC is working on one project in Ladakh. ONGC is also looking for sources of geo-thermal energy in Cambay Basin in Gujarat and Tatapani in Chhattisgarh.
- Development of geothermal resources in Ladakh may lead to employment generation, reverse migration and may also attract steel industry to the region.
- Hydel power generation in the Ladakh region falls by 10-15 per cent during winters and most of the water resources freeze. The hot water produced from the geothermal resources could be used to melt the ice in rivers and increase the power generation.
- Residual heat from the geo thermal resources could be used for room heating purposed. This will be helpful for the defense personnel posted in high altitude difficult conditions. ONGC is working closely with DRDO to explore more uses of the geothermal resources for the betterment of defense personnels in the region.

Day 2, 25 April, 2021

Session I: Advances in Refining, Technology & Catalysts – I

Session Chair: Mr. S. Bharathan, Head (R&D) HPCL

Mr. Pramod Kumar
DGM-FCC
HPCL

Innovation in Fluidized bed technology

- Advantages of Fluidized Bed Process includes High heat transfer, high mass transfer; good solid mixing; and easy scalability.
- The Fluidized Bed Process is divided into two parts: a. Reactive Chemicals Process and b. Non-reactive Chemicals Process. Reactive Chemicals Process includes: FCC; FT synthesis; Pyrolysis; Calcining; Coking; Gasification; and Combustion. Non-reactive Physical Process includes: Drying; Coating; Granulation; and Gas Purification via absorption.
- In the fluidized bed process, as the velocity of gas is increased, the process moves from packed bed to pneumatic transport. The various types of the FCC process are as under: Primary Conversion Unit; Employs catalyst for cracking; Feedstock : VR, RCO, VGO, Naphtha, C4s, C3s; Flexibility of operation – Diesel, Gasoline, LPG/Olefins mode; Contribute > 50% of refinery gasoline; Produces feed for Petrochemical Unit; Useful products (Propylene, LPG, Gasoline, Diesel); > 400 FCC worldwide.
- FCC configuration: Components in R-R Section: Feed Nozzles; Cyclones; Striper Internals; Air Distributor; Spent Cat Distributor; Riser design; Catalyst cooler.
- Innovation in FCC: Downer- Dry gas reduction; Two Stage Regenerator- High CCR feed; Recycling of spent catalyst – Increasing olefin yield; Multiple Risers- Different Severities; Riser with varying diameter- Optimization of Product/Quality; Dense bed cracking- Higher conversion; High Severity – Higher Conversion; Higher Zeolite Containing Catalyst; Mesoporous Zeolite.

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- HPCL has developed the [HP]2FCC Technology. This technology is a combination of hardware and the catalyst. It has already been granted patent for development of this technology. The advantage of this technology is that the bottom is quite low and the swing mode of operation that provides the flexibility to move from fuel to petrochemicals.
- This technology is a low cost solution to increase propylene, RON and reduce bottoms. It can be used as an additive/Co-catalyst in conventional FCC Units.
- Innovation in Fluidized Bed Technology by HPCL: Naphtha to olefins; Natural Gas to H2 and CNT; Natural Gas conversion to H-CNG; Biomass to fuel; Bio-oil Co-processing in FCC; Process Intensification in FB Process; Spouted Fluidized Bed; Process Intensification – Multizone Reactor

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Dr. Mayuresh Sahasrabudhe,
Lead Research Scientist
Reliance Industries Ltd (RIL)

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Composition modelling for Refinery optimization: Naphtha reformer - a case study

- Main goal of this modelling is to use the molecular information to support feedstock valuation, plant trouble shooting optimization, planning scheduling, new process development and compatibility. This could be achieved through molecular reaction model, molecule based process model as well as composition to molecular models.
- There are three types of kinetic models: Lump groups (these are feedstock dependent); Pathway Model and mechanistic model. Molecular level pathway model: Understanding of the reaction chemistry is essential; next step is developing feed and product molecular slate. This could be done by molecular identification using analytical techniques or property to composition model.
- After molecular model is developed and the reaction chemistry is known, the next step is to develop reaction network. Naphtha reforming typically has dehydrogenation reaction that is highly endothermic reaction to convert the naphtheses into aromatics.
- Paraffin ring isomerization is the conversion of cyclo-pentane to cyclo-hexane. This model was validated against the data from the pilot plant and real plant.
- Molecular naphtha reforming model can be used for plant monetary optimization. It can also be integrated in the LP utility for LP operations. These models can also be integrated into excel based platform for developing monitoring systems. These could also be used for process model application.

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- Molecular models provide better knowledge of various reaction pathways and chemistry, reactor conversion can be tracked, provides better insights for optimization and what-if case study analysis and accurate prediction based on better crude chemistry.

Mr. K D P Lakshmee Kumar
Indian Institute of Petroleum (IIP) Dehradun

Single-step dimethyl ether synthesis from syngas over Cu-Zn/Boehmite hybrid catalysts

- EIA projects that world energy consumption will grow ~50% by 2050. Global liquid fuels consumption increases more than 20% by 2050. Total oil consumption would reaches to ~240 quadrillion Btu by 2050 as per EIA. World would need twice the energy as it produces today. Global energy demand emphasizes the energy transition from fossil fuels to sustainable or alternate fuels
- Synthesis gas (H_2+CO) is a substantial intermediate product that can produce many alternate fuels and chemicals. Global production of syngas is around 6Ej/year. Syngas reduces the world energy demand by almost 2% of the current primary energy consumption. Syngas derivatives Fischer-Tropsch fuels Methanol Dimethyl ether Ammonia Oxo chemicals Power generation
- Dimethyl ether (DME) is a non C-C bonded, non-sulfur and oxygenated fuel. DME is the secondary energy material & ozone-safe aerosol propellant. DME can be used as an alternative to LPG and diesel due to its: a. Similar physical properties; b. High cetane number (55-60); c. Reduced NOx, SOx and zero particulate emissions; d. Superior combustion properties
- Challenges to Direct STD Process: Testing and validation of more efficient catalyst for one step process; Designing of new reactor configurations such as slurry, membrane & fixed bed reactors; Efficient distillation process through columns for DME purification; Higher CO_2 emissions while using coal as feedstock for direct DME route; No commercial catalyst & technology available for direct DME route; JFE has started its slurry reactor based 100 TPD demonstration plant in 2002; KOGAS also constructed a 3000 metric tons/yr DME demonstration plant in 2004 at Incheon, Korea.
- Synthesized hydrotalcite derived nanostructured (Cu-Zn-Al)/γ-Al_2O_3 hybrid catalyst via kneading extrusion process. The CuO/Al_2O_3 ratio plays key role in obtaining the active precursor phase derived methanol synthesis catalyst such as hydrotalcite (Htl) and zincian malachite (ZM)
- Phase transition of boehmite to γ-Al_2O_3 improved the Lewis acidity of Cu-Zn hybrid catalyst along with high thermal stability.

	The STD-1 hybrid catalyst with low CuO/Al2O3 ratio derived from pure Htl phase showed high DME selectivity 71% with CO conversion of 60% ▪ The ZM phase rich derived STD-4 hybrid catalyst showed lower DME selectivity than STD-1 catalyst. The factors responsible for the higher catalytic activity of STD-1 hybrid catalyst: a. Large number of medium acidic sites with high amount of surface acidity; b. High metallic Cu surface area with nano size Cu particles; c. High degree of Cu metal dispersion
 **Dr. Alex C Pulikottil** CGM (Catalyst) IndianOil	**INDICAT-Prime: Catalyst for Ultra-Low Sulphur Diesel – Concept to Commercialization** ▪ Mandatory dependence on high severity Hydro-treating (DHDT) process to meet diesel specification. Catalysts are at heart of the DHDT process and hence a strategic component to the refiners. High performance DHDT catalyst improves unit performance. ▪ Hydro-treating catalyst technology forte of multi-national companies, Indian refineries fully dependent on import. DHDT catalyst indispensable for BS VI diesel production ▪ Indigenous catalyst technology is the need of the hour: a. Make in India and Aatmnirbhar Bharat initiatives; Guidelines for tapping domestic market for manufacture ▪ Evolution of Hydro-treating catalyst: a. Understanding of the reaction path; b. Active site of hydro-treating catalysts are now better understood; c. Advances in synthesis methodologies and manufacturing process ▪ Science Behind INDICAT Prime: a. High dispersion of nano-crystalline intrinsically super active Type II NiMoS sites; b. Higher hydrogenation ability for aromatic saturation and deep desulphurization; c. Optimized metal support interaction; d. Higher degree of sulfidability to enhance active site density ▪ INDICAT DHDT – A major milestone: a. Commercial validation of high end DHDT catalyst; b. IndianOil in select group of multinational companies in knowledge intensive domain of DHDT catalyst; c. Strategic importance of self-reliant in line with Make in India and Atmanirbhar Bharat initiatives of Government of India; d. Potential of lower cost of DHDT catalyst in the country with economy of scale of production

Dr. T. Chiranjeevi,
DGM (R&D), BPCL

Bharat-GSR: An innovative, Cost Effective Gasoline Sulfur Reduction Additive for FCC Operation

- Due to the ongoing energy transition all refiners are forced to introduce petrochemicals to fuel based refining. In this transition, catalysts will have a huge role to play. According to a recent report 90 per cent of all molecule feedstock undergo changes in presence of catalyst.
- Whether it is a fuel based refinery or an integrated refinery, catalysts have paramount importance and caters to the changing needs of the fuel and the petrochemicals industry. Challenges of present FCC process: a. Cannot process other feedstock than VGO; b. Cannot process renewable feedstock; c. Cannot change production based on market demand; d. Environmental issues
- The role of catalysts have increased from 40 per cent in the initial years of refining to almost 80 per cent in the present day, marking a tremendous growth. Riser model has changed the course for FCC. Refiners started using additives also to meet the specific objectives of operations
- Additives are base catalyst used for refining operations. Additives are used to meet the specific objectives of FCC. The clear advantage of additives is that it is easy to add and easy to withdraw, providing a big operational flexibility. There are different catalyst additives being used in FCC. They can be divided into environmentally driven and performance improvement additive
- There is today immense scope for the catalyst scientists to work and come up with new formation of catalysts. With objective of reducing cost of the GSR catalyst and increasing the flexibility and to develop in house expertize, the work on gasoline sulphur reduction catalyst was started
- The approach followed is only as good as for any other catalyst development followed by the catalyst scientist. This product the main properties to achieve for gasoline sulfidation catalyst attrition of paramount importance. Hydrogenation capability and Sulphur reaction capability are very important to develop
- Properties of the catalyst developed are as good as the commercial catalysts and surface area. Other properties are also in the acceptable range. The developmental work on the catalyst is now over and the commercialization of the catalyst will be shortly started. As we commercialize, maintaining the quality and performance at the vendor location will be a crucial challenge going forward.

Session II: Advances in Refining, Technology & Catalysts – II

Session Chair: Dr M.O. Garg, President – Refining & Petchem R&D, RIL

Dr. A. Selvamani
Indian Institute of Petroleum (IIP) Dehradun

Catalytic Process for Production of Aromatics from Unconventional Feedstocks

- Aromatic are very important for refining and petrochemicals intermediates. Aromatics are generally produced through catalytic refining and steam refining of petroleum Naphtha. There is a need for alternative feedstock to produce aromatics. Such feedstocks are called unconventional feedstock.
- We are working on novel catalytic process for generation of aromatics from low value hydrocarbons derived from biomass and waste plastic. In regard, IIP has prepared bi-functional catalysts which are studies for production of aromatics from unconventional feedstock.
- Adopting the sodium route we can directly produce the H-Aluminium Silicate. Zinc Aluminium silicate also has the same properties as aluminium silicate, which indicates that the involvement of zinc does not affect the aluminium silicate section. From this result we can conclude that the successful formation of aluminium silicate through the Sodium Silicate method.
- Aluminium silicate has uneven source while the Zinc aluminium silicate source has even pores. Zinc aluminium silicate dissolves at higher temperature compared to strong acids. IR spectrum results prove that the loading of the metals does not affect the structure.

Mr. Vijay Yalaga
Senior Manager
Engineers India Ltd

Hydrodynamic Aspects of DHDT/DHDS Reactors, Operational Feedback and Up-gradation

- Diesel Hydro-treating is a major thrust area today with legislations enforcing improved diesel quality specifications for meeting environmental norms on fuel emissions. This technology is closely guarded by a few international licensors.
- To achieve self-sufficiency in this area, IOCL (R&D) and EIL jointly developed indigenous technology and implemented it in various

(EIL)	Indian refineries. The technology offers the ability to upgrade middle range straight run distillates, coker gas oil streams and light cycle oil from catalytic cracking to low sulphur, high cetane diesel suitable for meeting ULSD pool requirement. ▪ Trickle Bed type Reactors (TBR) are mainly used in such processes which involve gas-liquid flow in presence of fixed bed solid catalyst with complex hydrodynamics. ▪ The major technological components in this are the catalyst and reactor internals. Apart from the highly active catalyst, reactor internals are very important for ensuring fullest extent of catalyst utilisation through providing proper hydrodynamics (uniformity of fluid distribution, pressure drop, liquid holdup, gas liquid mixing etc.) in such multiphase systems. ▪ EIL has developed the reactor technology with state of-the-art proprietary reactor internals which were tested in pilot plants and subsequently incorporated in commercial designs of various DHDT/DHDS units. ▪ The key features of these internals are: Proprietary novel and efficient gas-liquid distributors (modified chimney type) and reactor internals; The novel distributor has high distribution element density and functions efficiently over a wide range of gas-liquid flow rates; Reactor design based on in-house hydrodynamic models for predicting pressure drop and liquid holdup; Effective at high turndown with good mechanical integrity. ▪ Post implementation of the reactor technology at multiple locations in India, the units are operating successfully. ▪ Further, the performance of these units is being monitored by collecting the feedback and operating data and its analysis on a regular basis. These internals are being continuously upgraded with respect to hydrodynamic aspects.
 **Dr. Satish Vats** Lead Research Scientist Reliance Industries Ltd (RIL)	**A Novel Plug in Technology for Clean-up of Sulpholane Solvent in Aromatics Extraction** **Use of Sulfolane in Industries** ▪ It is a colorless liquid commonly used in chemical industry as a solvent for extractive distillation, especially in extraction of aromatic hydrocarbons (Shell/UOP sulfolane process). It is one of the most efficient solvents as it operates at a relatively low solvent-to-feed ratio, making sulfolane relatively cost effective. ▪ Acid gas treatment (sulfinol process) and was first implemented by Shell Oil Company in 1964. This process sweetens the natural gas

	using a mixture of alkanolamine and sulfolane. The worldwide market for sulfolane is expected to grow at a CAGR of roughly 1.2% over the next five years, will reach 106 m **Problems faced in Sulfolane degradation** ▪ Sulfolane is highly stable & can be reused, it does eventually degrade into acidic by products. Degraded sulfolane also has reaction products of materials conventionally added to mitigate their corrosive effect, such as amines. The main products of oxidative degradation of amines are acetates, formates, oxalates, succinates. **Sulfolane Purification Processes and their limitations** ▪ Vacuum & steam distillation, back extraction and ion exchange resin techniques are used to purify sulfolane. In vacuum distillation only high boiling materials are removed and has relatively high capital cost. ▪ Steam distillation is relatively low cost but has limitation of removing only high boiling materials. Acidic impurities with similar boiling point of sulfolane cannot be removed. ▪ Regeneration by back-ex- traction can removes both light and heavy degradation products. However, it is the most expensive regeneration process. Regeneration by ion exchange is satisfactory, but to remove impurities of trace level two column system is required. Thus, it is costly process. It works well at ambient to 80 0C, poor performance at high temperatures. ▪ Adsorption technique singly column packed with adsorbent is sufficient to ensure the complete removal of impurities and can works well at high temperature as well (120 C) **Global Impact of RIL's Sulfolane Purification Technology** ▪ 1st time in the world, adsorption process for the online purification of sulfolane. Economically viable technology with low CAPEX and OPEX to install the technology worldwide. This technology purifies the solvent (sulfolane) online without disturbing the normal operation of the plant contrary to the conventional techniques. ▪ The worldwide market for sulfolane is expected to grow at a CAGR of roughly 1.2% over the next five years, will reach 106 million USD in 2024, from 100 million USD in 2019, at CAGR of 9.3%. The major user of this magic solvent are oil and natural gas industries.

Mr. B Neelam Naidu
Senior Scientist
Indian Institute of Petroleum (IIP)
Dehradun

Syngas Production by Methane Tri-reforming Over Ni-Based Supported Catalyst

- Aggressive investments taking place in the low carbon and sustainable technologies across the globe. The present tri-reforming process is related to some of the key pillars such as gas based economy and cleaner use of fossil fuel, biofuels and Hydrogen
- The chemical route to conversion of CO_2 to various polymers reforming through syn gas or methanol. Photochemical and electrochemical routes too have great potential to utilize this CO_2
- Tri-reforming of methane and steam reforming are highly endothermic processes in nature. Main advantage of the process is the utilization of gases such as methane and CO_2. It also produces a range of Syn Gas ratio, which can be a source for various
- Major challenges associated with this process are: Finding a stable catalyst to produce higher CO_2 conversion; Resources to convert methane and CO_2; Point resources for methane and CO_2
- Catalyst are mainly Nickle based oxides. Final catalyst formation is dependent on higher surface area. This increases the oxygen storage capacity at high temperatures. With increase in temperature the concentration of methane and CO_2 increases
- Syn Gas ratio is maintained at 1.4. For this process three catalysts chosen are: TRM 1, 2, 3. comparatively a lower coating is deposited in the catalyst in the range of 5 per cent. TRM 3 is a high resistance catalyst. One of the promising qualities of this catalyst for CO_2 reforming is to raise capacity
- Methane conversions are not severely changed by varying the percentage of CO_2 and H_2O. CO_2 conversion is dependent on the concentration of CO_2 and the H_2O
- Syngas ratio is increase decreasing the water concentration. A variety of syngas ratios can be obtained by varying the concentration of the CO_2. Bench scale studies were also carried out for syn gas production. Here similar Syn-gas ratios were achieved as the lab scale studies.
- CO_2 consumption rate is high in the process. Since a variety of syngas ratios are achieved during the process, this syn-gas could be applied in variety of processes. The tri-reforming process has not been commercially reported yet but the KOGAS has reported a plant.

Dr. Pranab Rakshit
Chief Manager
(R&D), BPCL

K-Model-A Versatile Tool for GRM Improvement

- Crude oil cost constitutes more than 85-90% of input costs of a refinery e.g., For a 50 MMT capacity refinery, processing of crudes costing USD 1 less would make over USD 40M/Annum additional profit.
- Implications of K Model for the refinery: a. Quick and reliable prediction of crude blend compatibility is critical to maintain good health of refinery equipment and operation; b. Currently, there is no standard practice to check the compatibility in advance; c. Excess demulsifier, antifoulant chemical dosage is done to prevent incompatibility issues; d. Are we ignoring the health of refinery equipment by feeding incompatible diet.
- Chemical characterization of Asphaltene: a. The chemical characteristics of asphaltene molecules derived from different sources are different; b. To determine the quality of the Asphaltene, CPMAS 13C-NMR analysis is used along with other analytical techniques such as FT-IR, TGA and XRD, TLC-FID, CHNS etc. c. NMR characterization revealed the behaviour of asphaltene molecules in the oil systems for inhomogeneity / incompatibility; d. It was also correlated with desalting & fouling characteristics of crude oil blends processing.
- K Model: a. For smooth refinery operation, every refinery operator would like to run it before choosing the crude blend; b. K Model predictions are in line with OCM and Spot Test methods for Ratawi/Saharan Blend & Ras Gharib/Saharan Blends; c. K Model predictions are validated with 16 different blends for SCP method as depicted above; d. K Model predicts the composite results of all nine experimental test methods with the accuracy of ±1 wt%.
- Major features of K Model: a. K Model predicts the composite result of all nine compatibility test methods. The accuracy of K Model is ± 1.0 wt%; b. K Model is applicable to any number of known or unknown crude oils for blend compatibility. It is because, K Model requires only four physical parameters data of the participating crude oils in the blending as input; c. K Model provides the complete optimized blending solution of N number of crude oils within compatible region; d. Two crude oils blending – 2-5 minutes; e. multiple crude oils blending: 1 hour.

Day 2: Thursday, 25, March 2021

Session III: Petrochemicals & Polymers – I

Session Chair: Dr. G.S. Kapur, Executive Director (CT & TPF), IOCL

Dr. V. K. Gupta,
Head R&D – Polymer &
Senior Vice President,
RIL

Presentation: Key talk on Polyolefin Science & Technology: Successful Commercial Technology Development

- Global polymer requirement is about 335 MMT and it is going to reach 1,000 MMT in next 30 years. In this 56% of the contribution will be from Polyolefin based material. Current Polyolefin requirement in 189 MMT and it shows the importance and its demand.
- According to 2035 technology vision, India's polymer CAGR over 10%, highest across the globe.
- It is essential to create the fundamental understanding of the catalyst support, as well as a catalyst polymerization process.
- These fundamental understandings at a macro micro and nano scale are very essential to design the high-performance catalyst.
- To create a highly disruptive technology in the area of polymers, one has to compete globally with the all the major players in this area. Reliance in 2001, developed the catalyst which was non morphological catalyst and sustained for 10 years a continuous production.
- Catalyst gets consumed in polymerization process and therefore, it is essential to improve the process and performance characteristics of catalyst. A suitable catalyst development technology is required to be sustainable.
- Easter based catalyst is second generation process which has the potential to produce homopoly propylene grade polymers. This process took time to get progressed from pilot stage to commercial stage. It is currently in a gas phased process. Non phthalate catalyst system is next level process.

	▪ This polypropylene based catalyst has better rubber content and is highly used in automobile sector where criticality of polymer is higher. ▪ Polyethylene is also in highly demand in the market. LLDPE is produced using the Ziegler - Natta Catalyst technology and silica supported Ziegler - Natta Catalyst technology is most preferred in the gas-based process. ▪ As a company, Reliance has established a strong platform in production of Polyolefin and the company will continue to deploy indigenously developed technology for the same. Specialty Polyolefin will have a major role in the future product markets across multiple sectors.
 **Mr. Bennet C,** Sr. Manager, Petrochemicals & Polymers, HPCL	**Presentation: ‘Circular economy of plastics for a sustainable future’** ▪ Circular economy of the plastic is the need of hour to remove all the negativity that goes around the plastic. It involves recycling of plastic through chemical or mechanical process in a closed loop. ▪ Circular economy of plastic started in 1970s, where people started thinking about recycling of plastic. In 1980, waste management became a part of process and by 1990s, government regulations came in. ▪ Benefit of circular economy is polymer will not be produced again and again; energy is saved in producing new polymer. It improves economic growth, job growth etc. ▪ 8.3 billion tons of plastic consumed across the globe every day and only 9 % is recycled and rest goes in landfill. In India, consumes 15.5 MMT of plastic across the year and 43% of this is single usage. 16 % is recycled, 19% is unmanaged and 40% goes to landfill. ▪ China has a regulated system for plastic collection and recycling and in years going ahead china will have large recycling of plastics. ▪ Recycling of plastics can increase the input stock for monomers by around 29% and will have a greater impact on polymer production. Fundamental redesigning of plastic is needed. Economic factor and quality factors also must be considered. Circular activity by recycling is used by the most companies across the globe. ▪ Improving sorting of different types of plastic is key towards recycling of plastic. Single use plastic is difficult to separate.

	Digital tools can be deployed for this. Chemical, Thermal and mechanical recycling can improve % of recycling plastics. ▪ Mechanical and Molecular recycling are two major types of recycling. Mechanical has finite processing and molecular recycling has infinite processing. Ease to use and solution-oriented plastic can be produced. ▪ India's plastic consumption is 13 kg per capita and it is expected to grow more. 40% of this will end up in landfill. Emerging trends are recycling into virgin plastic, conversion of low value plastic into fuel etc. ▪ Technology is viable for sorting and recycling. There is need to create awareness among people in segregating the different types of plastic. Stringent regulations must be implemented towards recycling. There is need to develop comprehensive policy towards plastic. ▪ Global companies are recycling plastics into fuel, naphtha and other useful products through molecular and mechanical recycling. Companies also use cracker units in converting these plastics.
 **Mr. Thomas Mallet,** Market & Tech, Development Manager, Axens	**Presentation: 'Axens solution to unlock low carbon plastics and circular economy'** ▪ The worldwide plastic production is growing exponentially and it has two main challenges. The first one is regarding the environment. Today we have produced something like 9 billion tons of plastics worldwide. ▪ More than 50% or more than half of the plastics has ended up in non-field or dumped into land. This is a real problem. As per Ellen MacArthur foundation estimates, there are 250 million tons of plastics that may be recovered in the ocean by 2025, so we need to address this challenge and the challenge is regarding the resources. ▪ Today, plastic represents about 8% of the oil consumption, but if we continue to produce plastic like we do today, it will represent up to 20% by 2035. Even if a very small amount of plastic is refined, there is a need to develop innovative solution for plastic recycling. ▪ 2G sugars technology will be opening the door to new plastics that could be biodegradable. Compostable like the PDF, PLA etc. are most promising to treat those plastics, the gasification.

	▪ This technology that converts the plastics into Naptha and this Naptha, is a very good to be sent to steam cracker to make polyolefin. ▪ PT is one of the most commonly used plastic for packaging and today it recycles through mechanical recycling. But this mechanical recycling has two main imitations. The first one is that only 30% of this recycle PT can be used for food application. ▪ IFPEN PT solution can help in overcoming these challenges. Purification step removes dies pigment and all impurities. Global companies are recycling plastics into fuel, naphtha and other useful products through molecular and mechanical recycling. Companies also use cracker units in converting these plastics.
 **Dr. M O Garg,** President – Refining & Petrochem R&D, RIL	**Presentation: 'Development of ionic liquid as a catalyst for petrochemical production: a case study from concept to commercialization'** ▪ Ionic liquids are molten salts formed with anions and cations. If anions and cations are symmetric, ionic material is in molten form. They have high melting points. ▪ If the anions and cations are asymmetric, they are not strong and they are loosely formed. It is called as room temperature ionic liquids. ▪ Major application of ionic liquids is in separation and conversion process, diesel fractionation, carbon capture and bio-oil recovery. ▪ Ionic liquid can be used as electrolyte for Co2 utilization. Ionic liquids can be used as catalyst for C02 conversion, it is also used for separation and for aromatic extraction. ▪ Ionic liquids are used for making vinyl chloride monomer by dehydrogenation of 1-2 dichloroethane. ▪ Ionic liquids are also used in desalination by directional solvent extraction. Ionic liquids are also used as catalyst for biofuels. ▪ Large number of chemical companies are active in this and the topic is of key interests in academia. It is very stable at high temperatures. ▪ As a company, Reliance has got large portfolio and very large number of patents and all the activities carried out on this subject can be pocketed into five categories.

Day 2: Thursday, 25, March 2021

Session IV: Petrochemicals & Polymers – II

Session Chair: Dr. G.S. Kapur, Executive Director (CT & TPF), IOCL

Dr. Sangeetha Karthikeyan
Senior Research Scientist, RIL

Presentation: Reliance Silica Supported Ziegler - Natta Catalyst Technology: Commercialization for Linear Low Density Polyethylene Grades

- Linear Low Density Polyethylene Grades (LLDPE) has a market size of 45.62 MMT, 30% of the PE market size. Indian market size is 2.4 MMT. 50% LLPE contributes towards the manufacturing of PE film and sheet.
- Market growth rate forecast in India is 8 % and global growth rate forecast is 5.5%.
- Production process involves continuous improvement, hence there is a rise in demand for LLDPE. New supply addition all over the world is aimed at meeting the rising demand for LLDPE. China and US are the two major suppliers.
- There are three major catalyst production technologies LLDPE production and the most preferred one is Ziegler - Natta Catalyst technology.
- Other technologies are metallocene based catalyst technology and phenoxy amine single side catalyst technology. By volume phenoxy amine catalyst technology is most preferred.
- Production process involves three major types and gas-based process is mostly adopted (43%). Other process types are Slurry based process contributes to 42% and solution-based process which contributes to 15%.
- Properties of resin is dependent upon the quality of catalyst used. In the gas-based process and slurry-based process, Heterogenization of catalyst is preferred as it helps in better fluidization and improves stability of catalyst.

	▪ Globally, 76 % of LLDPE is produced using the Ziegler - Natta Catalyst technology and silica supported Ziegler - Natta Catalyst technology is most preferred in the gas-based process. Particle size distribution of Resin is narrow and it improves mechanical structure of the resin. ▪ Gas based trial was used for pilot projects and resulting were promising with Resins able to meet the requirement of characteristics. ▪ Catalyst performed well in the trial run and based on the success; company moved into the commercial stage of LLDPE production. Products of LLDPE produced in the facility are films and PE sheets.
 **Dr. G.S. Kapur** Executive Director (CT & TPF), IOCL	**Presentation: 'Achieving Plastic Neutrality – Concepts to Implementation'** ▪ India generates approximately 26 KTD of plastic waste, out of which 60% is recycled. 70% of the recycling is done at registered facilities and 20 % is recycled by unorganized sector. 9.4 KTD of plastic waste is left uncollected. ▪ IOCL is working on new plastic economy, where economics and quality is improved through recycling and leakage of plastics into natural system is drastically reduced. The resultant plastics from the process is used for composting and energy recovery through feedstock. ▪ Chemical recycling can create new outlets for waste plastics by enabling high end products to complement traditional mechanical recycling. Trials for this process was conducted in Digboi refinery and 60 MT of waste plastic was refined. 95% of the conversion was achieved with yield improvement. ▪ In the mechanical recycling, upscaling thru Rheology control is performed to produce bitumen filling, polybags etc, 16Mt of waste plastic in consumed in paving a stretch of approximately 850 meters of road. ▪ By organic recycling of plastic waste, biodegradable polymers and bio-plastics can be produced. Plant-biomass photosynthesis process can help in taking credit for C02 removal from the environment and incorporating into a polymer molecule in a time scale of 1-10 years. In the old carbon, it takes more than 100 years for the same. ▪ Biodegradable Polymers has ISO14855 and EN13432 test methods to determine biodegradability of plastics.

	Biodegradable polymers are not the one-point solution for the problem of pollution and littering.
 **Dr. Vivek Srivastava,** Lead Research Scientist, RIL	**Presentation: 'Novel Bullet and Stab Resistant Polymeric Materials'** ▪ Unlike Novel disentangled material, polyethylene is highly entangled polymer chain. Because of the disentanglement, the material has come up with unique properties. These polymers have high molecular weight and bulk density is very low up to 0.55. ▪ These polymers have extreme crystallitity up to 95% and because of the low bulk density high crystal density, this can be processed below melting temperature. ▪ Powder obtained from the polymerization process can be converted into solid state high molecular tape and this can be converted into fabrics. These fabrics in turn can be converted to high standard composite light weight material. ▪ Catalyst polymerization started with the lab process with 90 litre and 300 litre in batch and semi continuous mode. Process was scaled from 1 lite to 90 litre and 1.5 million tone of DPE tape was produced. ▪ High strength and high modulus DPE tape has a tensile strength of 3 GPA and module strength of 150 GPA. The composite material was tested in defence lab and the results have shown excellent bullet resistance. No perforation of bullet was observed and no bullet penetration was observed from automatic and self-loading rifles. ▪ This composite material has excellent properties for making body Armor and the same was verified in multiples tests in the defence lab. ▪ Hard composite DPE was tested in the laboratory for vehicles and no penetration of bullet was observed. Compared to glass & carbon protection, hard composite DPE is light and low arial weight with high DPE content. 55% of weight reduction and improvement in ballistic performance was also observed. ▪ The DPE composite material was also tested for stab resistance and the company worked with a university in India for detailed study. Fabric material used is light and doesn't add much weight to the body Armor. Improvement in inter-yarn friction helped in avoiding the bullet penetration.

Dr. S.A. Kishore Kumar,
Sr. Manager (R&D), BPCL

Presentation: 'Cyclohexylbenzene-A versatile niche petrochemical '

- Benzene content is less than 1% of the total volume in the gasoline pool. Benzene saturation is preferred because it consumes precious hydrogen and also goes through octane loss.
- Cyclohexylbenzene (CHB) is a possible option for benzene valorization while maximizing the profitability. The demand in India is expected to grow due to steady growth of EV in India and offer alternate route for Phenol.
- It has easy integration with refinery aromatic complex. Electronic grade CHB's price is 2.5 times more than that of the industrial grade CHB.
- Global Cyclohexylbenzene market was estimated to be around USD 360 Million in 2019 and it is forecasted to reach USD 485 million by 2026 with a CAGR of 4%. Rising demand for paints and coating across the industrial applications will drive the demand for Phenol & its derivatives.
- Some of the top global manufacturers of CHB are Eastman (18% of market share), Samsung (17% of market share), Basf (12% of market share) and Mitsubishi (11% of market share). These four constitute about 58% of the global market in CHB.
- Phenol production process has advantages like, avoidance of acetone production, non-requirement of propylene food and easy integration with refinery.
- This process produces high quality petrochemical intermediates. This also necessitates the need to develop highly selective catalyst and efficient process for conversion of benzene to CHB.
- Conventional process for CHB production has multiples drawbacks like, multi-step process, use of Sulfuric acid for alkylation, use of expensive corrosive catalyst system, and difficulties in integrating with the refineries process.
- Catalyst development is a key process in the CHB production. Some of the key development challenges in catalyst are metal loading, uniform distribution of metal nano-particles on the catalyst, catalyst sizing and shaping and identifying a competent catalyst with freedom to operate.
- BPCL is now currently in the stage of setting up demo plant design. Produced CHB samples are supplied to ISRO for possible application in Lithium-Ion Batteries. BPCL is working towards setting up bigger demonstration unit at BPCL Kochi refinery.

Day 3: Friday, 26, March 2021

Session V: Upstream

Session Chair: Dr. P. Chandrasekaran, Director (E&D), Oil India Ltd

Mr. Indrajit Barua,
Executive Director,
Frontier Basin, Oil India Limited

Presentation: Exploration in Frontier Plays: Dealing with the Need to Reduce Risk and Cost

- Energy transition has forced E&P companies to reduce greenhouse emissions and will increase adoption of renewables. Oil companies in Europe are faced with pressure to support decarbonisation. Companies are forced to look for low carbon technologies.
- In India, oil will be consumed in same way, however the percentage may change. Expected oil demand will need efficient exploration. Need for sustainable hydrocarbon replacement.
- Upstream companies have to expand to meet the future demand, companies focus more on near fields but it may not be sufficient to get new growth. Onshore discoveries were lower as compared to offshore. In India, demand gap is widening.
- For the frontier onshore plays, OIL India aims to shorten the production time. Challenges like logistics, not having service provider, project management issue, protection in sensitive environment, along with the subsurface difficulties and geology issues are increasing the exploration time.
- First year can take time and the time is not justified in the current situation. Therefore, area remain unexplored for long time. India too has unexplored areas and Assam Arakan basin is one. Elevation in Mizoram rise from 1500 to 5000 ft. Gorges,

forest, hull and difficult terrain and heavy rainfall. In 2007, drilling started and it took ten years for MWB. Company drilled two wells. DGH has given extension to explore the basin.

- Drilling took two years almost to complete and because climate is such, company has to wait up to dry time. Current exploration model must be changed. The return of geological tools and techniques are the key for exploration and it will improve the process.
- There is a need to change from prospect-based exploration to play based exploration. Prospect is a three-dimensional subsurface structure with a reasonable probability containing all the elements to form a hydrocarbon accumulation.
- Prospects are identified from the seismic data. Play- based exploration maps out where the play exists and where they exist. This approach demand prediction away from data control and it requires a deeper understanding of the geological history of the basin under consideration.
- Conventional exploration is for finding traps while Geochemical exploration is for finding hydrocarbons. New regime is very helpful for the exploration operation with a large availability of data. Companies must reduce cost and time for the exploration process. Companies must establish partnership with academia and research institutions.
- Provision of additional exploration time for logistically difficult frontier areas by 2 years can be helpful to the companies

Mr. Sheel Ranjan Prasad
DGM (Reservoir), IRS,
ONGC

Presentation: 'India's First Offshore Low Salinity Water flood-EOR In Mumbai High Unlocking oil from Mature Reservoirs'

- Low Salinity water Flood is more beneficial for the EOR process as compared to IOR. LSW flooding in basically a multi-complex ionic exchange between crude oil, the injection brine, formation brine and the surface rock which leads to change in wettability. In involves increasing reservoir affinity more towards water and less towards oil.
- Evaluation methodology includes laboratory studies, simulation studies and pilot implementation. Target for this is Bombay High field. The field is divided into North block and Southern block. South block was used for LSW.
- Recovery rate is now 30% and ONGC targets around 35%. There has been incremental production from the field. Implementation step includes evaluate, then simulate and then conceptualize.

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Target reservoir is a carbonate pack with a thickness of 40 meters and it has light to medium crude oil. The recovery rate was 28% under conventional water flooding.
Lot of studies was undertaken by ONGC for implementing EOR, however some of the challenge faced is pressure for conventional water injection. For chemical EOR, higher temperature is a challenge. Environment is also high saline. Therefore, it was planned to use the existing water flooding with modifications.
The reservoir has a very good mobility ratio of less than 1 and it has a good displacement between injection and reservoir liquid. The reservoir had a good pipeline infrastructure.
Decline in the southern block of the Bombay High field is 6% which is less than the global level for the mature field. Current production is around 80,00 barrels of oil per day. Produced water has a salinity of 32,470 ppm while the sea water has a salinity of 33,000 ppm. Formation water salinity is around 23,000 ppm.
Therefore, salinity of injection brine was modified. As the salinity of water is reduced, extra oil oozes out. It was done in a sequential way to achieve 6% of extra displacement. The same process was repeated with different levels of salinity. 8000 ppm of saline water gives best result for recovery. The process was simulated in the lab simulator and the result was showing significant recovery.
Water mobility can be reduced using Low salinity water. Based on the outcome, pilot project was implemented in the Western part of the Bombay High field. The test was matching the results of lab simulation. The well is producing around 20,000 barrels of oil and water level is not alarming. Water content was around 60%,
With 29% PVI under LSF, incremental oil recovery of 1.5% over the sea water. LSF injection requirement is about 1,25,000 bpd.

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Mr. S.K. Singh,
Executive Engineer
IRS, ONGC
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Presentation: ‘Spontaneous Ignition in High Pressure Air Injection (HPAI) PROCESS: LAB Studies’

Spontaneous ignition is the first step towards implementation of high-pressure injection. EOR helps in increasing the recovery factor and to maximise the oil reserves recovered.
HPAI is a process in which compressed air is injected into high-pressure oil reservoir with the expectation that oxygen in the injected air will react with a fraction of the reservoir oil to produce carbon dioxide and provide mobilization to the oil

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	downstream of the reaction region, sweeping it to production wells. ▪ Typically, there is an injection well and production well. When injection takes place, there is a formation of combustion zone where temperature for heavy oil goes from 500 to 600 degree C and for light oil it goes from 300 to 400 degree C depending upon the activity. Temperature profiling of the reservoir is done. ▪ Injection of air can be done with reservoir with low permeability. First step is LTO, in which oxygen gets added to hydrocarbons, resulted with higher viscosity and lower volatility than original oil. The temperature range us 150-200'c. ▪ Thermal cracking is significant in heavy oil. It is fuel deposition reaction and there is a coke formation. High Temperature is another type, where coke produced is oxidized and it realizes heavy amount of heat. Temperature range is 380- 800-degree C. LTO reaction must be avoided, because it makes oil heavier. ▪ Under DSC test, oil is taken in a small medium and the temperature is raised under oxidative medium. Under oxidative medium, when the temperature reaches up to where the reaction time takes place, the heat is being released and oxygen reaction rate gets added. In light oil, heat released is lower. ▪ During the DSC test, when air comes in contact with the crude oil, temperature is raised up to 200-degree c. Temperature is sustained. Main challenge is creation of combustion zone in the reservoir which needs artificial ignition and requires extra efforts. There is a need for spontaneous ignition. ▪ Spontaneous ignition test was performed in a one-dimensional reservoir in the laboratory with a set parameter. Reservoir temperature was increased up to 150-degree C. Because of the prolonged heating, oil gets moved from the reservoir and gets produced.
 **Mr. Shital Khot,** Managing Director, SNF Flopam India	**Presentation: 'Latest Advances in Polymer Flooding: A Cost Effective EOR Technique to Reduce carbon intensity'** ▪ Improving production from the existing fields is the key to reduce the import dependency of crude oil. EOR can help in improving the recovery factor. However, pressure and temperature are key challenges in executing the chemical EOR process.

	▪ A harsh environment can have high salinity, higher temperature and lower permeability. Developing a specific robust chemistry can improve the thermal stability and injectivity. SNF develops polymers based on the field requirement in discussion with the operators and are tailor made for respective fields. ▪ Partially hydrogenated Poly Acrylamide has temperature limitation up to 90-degree C. By introducing new monomers, temperature can be increased up to 130-degree C. Polymers are adapted to the harsh conditions with continuous improvement. Such projects are implemented in fields of ADNOC and Saudi Aramco. ▪ In offshore fields, there are some limitations in using powdered polymer, hence emulsion polymer is used. These has been implemented in North Sea fields. Some of the basic challenges in offshore fields are viscosity of the field, area of the platform etc. Emulsion polymers can improve the process and overcome all the limitations and challenges. ▪ Automatic cloud point measurement can be deployed which can measure the polymer deposition on production facilities on real time basis. These are mobile and compact solutions. ▪ Reducing carbon footprint is a key challenge for the oil producers. Polymer flooding can help in reducing carbon footprint by increase the oil recovery, reducing water consumption and economically viable. This offset the carbon produced in the entire process.

Day 3: Friday, 26, March 2021

Session VI: Carbon Capture & Oil to Chemicals

Session Chair: Dr. S.S.V. Ramakumar, Director (R&D), IOCL

Dr. S K Das
GM (Light End & Heavy End Processes), IOCL

Presentation: Crude Oil to Chemicals- Global versus Indian Imperatives

- Oil will continue to play a leading role in world's energy mix with the growing demand from commercial transportation and chemical industry. Share of coal in the energy mix will go below 20% due to emission reduction. By 2040, India's primary energy consumption will be around 1,924 Mtoe.
- Covid has impacted the energy demand across the globe with oil demand dropping by 8 % and natural gas by 4%. This is the largest decline in primary energy demand in seventy years, it decreased by 6%.
- India's gasoline will grow by a CAGR of 5.6 % and diesel will grow by 3.7% until 2045. There will be an increase in demand for middle distillate due to urbanization, aviation and road transportation. Petrochemical growth will contribute to 35-40% of increase in total oil demand
- In a conventional refinery configuration, 90-95% of the output is fuel while the rest 5-10% in the chemicals. Naphtha complex cracker will give olefins, while the aromatic complex will give BTX.
- Dedicated crude oil to chemicals refinery configuration can be configured to three schemes namely, modified steam cracker, crude to aromatic complex and crude to chemical complex.
- Modified steam cracker involves, direct steam cracking of light crude oil which gives 40-45$ olefins. Crude to aromatic complex produces PX up to 40% of the production.
- Crude to chemical complex is targeted towards 70-80% of the petrochemical production. This consists of a hydrocracker,

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distillation and steam cracking & separation unit which gives 70% petrochemical output.

In Indian perspective, demand for petrochemicals will reach 71 MMT by 2035. Several new petrochemical projects are underway and are announced in India to meet the rising demand. IOCL has different technologies like INDALIN, INDMAX, indResid, indLPet, IndCoker for crude to chemical conversion.
Refinery & petrochemical integration and molecular management are the key factors or higher ‘Crude to chemical’ conversion. There is a need for tailor-made process to achieve higher feasibility.

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Dr. Shobha Agarwal,
GM (Process), EIL
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Presentation: ‘Techno-Commercial Aspects of "Oil to Chemical" Configurations’

Crude oil -to-chemicals (COTC) technology allows direct conversion of crude oil into high value chemical products instead of traditional transport fuels. Petrochemicals see higher demand in house hold consumption.
India’s per capita polymer consumption will double from current level of 12 kg. Existing Olefin production capacity is 7,277 KTPA. Given the strong demand for petrochemicals several new projects are under execution and are announced.
Fuel markets growth is not expected to grow in line with the historical growth rate due to growing electrification of vehicles, reduction in Co2 emission, reduced demand for HSFO due to IMO regulation and need of vehicles with higher fuel efficiency.
Petrochemical growth rate is higher than global GDP growth rate. Government policy is aimed at reducing import dependency. Refiners are looking for alternate high value products due to strict fuel norms.
Better price stability is with the petrochemical products than fuels. Petrochemical integration gives better profitability and it comes with different configurations aimed at different levels of chemical production.
Crude oil fraction at different temperature ranges from 16 to 700-degree c for producing different carbon numbers varying from C1 to C4, C5 to C9 and up to C70 & above. Steam cracker and aromatic complex gives higher C2/C3 along with BTX.
Hydrogen addition and carbon rejection are two major technologies used for upgrading resid. Hydrogen addition gives maximum carbon conversion, removal of sulphur and metals

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and addition of Hydrogen and olefin yields. Carbon rejection gives maximum propylene and flexibility in operation.

Typical COTC flow scheme comes with RFCC option, Residue Hydrocracking option. COTC requires significant residue upgradation and hydrogen addition is favored over carbon rejection. Key performance indicators of COTC configurations are Hydrogen consumption, total utilities consumption and product yield.
EIL has executed studies on three different cases. They are 1. Resid FCC + ARDS+ Cracker + Petrochemical block, 2. HCU+ EbHCU + Cracker + Petrochemical Blocks 3. PFCC + DCU + Cracker + Petrochemical Block.
COTC complex requires additional units to convert and upgrade crude oil fraction into petrochemical feed blocks. Even though it requires high capital investment, the GRM and IRR of the project is much higher than the standalone complex.

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Mr. Clement Salais, Associate Group Manager, Axens
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Presentation: ‘Optimized CO2 capture solutions and development of new demixing solvent technology DMX™,’

IEA has projected three different scenarios for energy sector emissions namely Delayed Recovery Scenario (DRS), Sustainable Recovery (SDS, zero emission in 2070) and Net-Zero emissions Scenario wherein the emission level will be 0 in 2050.
There are 65 Carbon Capture & Storage (CCS) facilities across the globe with 26 in operation, 3 under construction, 13 in advanced development, 21 in early development and 2 on hold.
In steam Methane reforming (SMR) process, Hydrogen output is enhanced using PSA technology and CO2 is captured on SMR from the flue gas and it contain 90% of the Co2. C02 can be captured in Syngas and in Flue gas.
EnergizedMDEA is the technology used in Syngas for capturing Co2 and close to 55.8% of Co2 is avoided in SMR process with mature technology. Typical energy requirement is 1 – 2.5 GJ per ton of Co2.
MEA based chemical absorption is used for Flue gas. Co2 avoided is around 67% and energy required is 3.7 GJ per ton of Co2.
Axens has partnership with Total for AdvMine technology, where in Total is the owner of technology and Axens is the licensor. It is primarily for Syngas.

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	▪ In the DMX process, absorption of C02 on flue gas is 4 times higher than the MEA process with thermal stability and is less sensitive to Oxygen. C02 is absorbed in the DMX solvent. DMX process gives a OPEX saving of 30%. ▪ DMX Demonstrator project is in Dunkirk with a capacity of 0.5 t of Co2 captured per hour. The construction is in progress in Arcelor Mittal steel mill and the operation will begin in the start of 2022. ▪ Mature technologies like AdvAmine, EnergizedMDEA and DMX process can be implemented for carbon capture.
 **Mr. Puneet Puri,** Business Development Manager, Chevron Lummus Global	**Presentation: 'The Role of Residue Processing in the Optimization of Crude to Chemical Projects'** ▪ Growth of petrochemical sector is going to be higher than the GDP growth across the world and the sector will see a growth by 40% by 2040. Weaker demand for HSFO and Coke will result in conversion of oil to chemicals. ▪ Steam cracking will fuel the petrochemical demand growth. Liquid cracker is more suitable for the Indian context. Residue hydrocracking is the most ideal one and it maximizes the cracker fees stocks. Optimal refinery sees 50% + conversion of petrochemicals. ▪ Asphaltene molecules are difficult to convert full as it contains multi-ring aromatic plates which are loosely connected by Sulphur or carbonyl bridges. Managing sediment formation is the key to high conversion in residue hydrocracking. Sediment reduction improves hydraulic and solvency. ▪ Worst part of residues is not economically viable for conversion to distillates. This needs smarts CCR conversion technology. ▪ LC0 Fining technology meets all the requirement for higher conversion with high contaminants removals. The integrated design minimized the CAPEX and OPEX and gives superior performance with safety and reliability. Key advantages are low pressure drop, near isothermal temperatures, efficient catalyst utilization and results in maximum conversion. ▪ Profit pivot points for an integrated complex are hydro processing, mixed feed steam cracker and co-product selectivity. Hydro processing optimized cracker feeds. Mixed feed steam cracker feeds flexibility. Co-product selectivity maximized C2-C3-C4 product flexibility. ▪ For Olefin production, it needs light crude with API greater than 35. All crude oils cannot be cracked economically.

Day 3: Friday, 26, March 2021

Session VII: Bio-Technology for Conversion of Waste to Energy

Session Chair: Dr. Sanjeev Katti, Director General, ONGC Energy Centre

Dr. G Valavarasu,
DGM, Hydroprocessing, HPCL

Presentation: - Catalytic production of renewable transportation fuels through vegetable oil-based feed stocks

- ICAO's Carbon Offset Reduction Scheme for International Aviation (CORSIA) is a global carbon offsetting scheme, whereby airlines will offset growth in CO2 emissions above 2020 levels.
- The implementation of the scheme has been divided into three phases namely, initial phases, voluntary phases and a mandatory phase that will be effective from 2027.
- Under the scheme, the operators will be required to Purchase Carbon credits for the growth in CO2 emissions.
- Biofuels can be blended with transport fuels. Some of the raw materials used are Corn, Cereal, Sugars, waste and fats from food producing as well as vegetable oils.
- Jet fuel demand in forecasted to rise in India over the upcoming years. At high output growth scenario, it is expected to reach 10.1 MMT and per capita consumption will grow from 2.4 kg from 2003 to 7.1 Kg in 2030.
- Several nations in the Western Europe are working on scaling the Sustainable Aviation Fuel (SAF) and to improve the competitiveness. India has an annual potential of 11 MMT SAF output with 30 municipal solid waste plants and 80 plants based on agricultural waste
- SAF production can be achieved by Lipid conversion, Biochemical conversion and Thermochemical conversion. These processes can be used for producing sustainable road

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<td>transport fuel too. Several airlines across the globe have tested flight running with bio aviation fuel.
▪ Used cooking oil generated is around 20-32% of the total consumed vegetable oil. Global vegetable oil production is around 210 MMT and 42 MMT is used cooking oil.
▪ In HPCL, HP Trijet process has been used for converting used vegetable/cooking oil into Green propane, Green Naphtha and SAF. This process involves single step catalytic process for converting triglycerides to SAF and Renewable Diesel.
▪ This process can be used for maximising the jet fuel and renewable diesel in to different modes. Some of the key challenges are feed availability, contamination of feed, production yield etc,
▪ Products made use Trijet process meets the desired properties. In HPCL, pilot scale development is completed using the in-house catalyst. BDEP is in progress towards demonstration plant.</td>
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Mr. Ravi Kant Gupta,
Senior General Manager, EIL

Amarjeet Kaur,
DGM, EIL</td>
<td>Presentation: ‘Biofuels towards Atmanirbhar Bharat - An experience in implementation of Biofuels technology’
▪ Biofuels are transportation fuels such as Ethanal and biomass-based fuels that are made from renewable biomass material resources and Municipal solid wastes. Biofuels are important for meeting India’s growing energy demand.
▪ It also helps in mitigating global warming and in enhancing energy baskets diversity. India has biomass production potential of 670 MMT annually. Potential of surplus biomass in India is around 165 MMT.
▪ National Biofuel policy was formed in 2018 promoting usage of biofuels in transportation sector and an indicative target of 20% ethanol blending in Petrol and 5% in Diesel.
▪ EIL has developed unique expertise in the area of 2G Ethanol plants for HPCL, IOCL, BPCL and MRPL at different locations. EIL’s role in 2G Ethanol covered Technology Value Addition, vendor development and cost reduction.
▪ EIL faced challenges in Lignin based Boiler, Biomass feed pre-treatment Digester, Inorganic Salt/ Ash disposal, reactor scale-up time. Etc. Key technology challenges were in Scaling up, layout of equipment, Hydraulics, design and specification for Biomass digestor Packages
▪ EIL provided EPCM services for ABPRL’s Bio Refinery project in Assam. The plant has a processing capacity of 37.5 Tons/ hour of Bamboo on dry basis. 2G Ethanol production is 49,000 TPA.</td>
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<td>The area had high availability of Bamboo. This biofuel is burnt in power plant for power production.

In this project, EIL faced challenges in conceptualising vendor packages, equipment specification issues for Engineering. This project was first of its kind and the scale up was challenging. Co2 produced is captured along with the Nitrogen.
EIL is also working with CSIR-IIP for Bio-jet process. Feasibility studies were performed for two different capacities namely 10 TPD and 31 TPD. It involved Single Step catalytic process for producing Bio-jet fuel, Naphtha, Diesel and Fuel gas,
EIL is working on scaling up the activities in the space of Bio-fuel. EIL is also working on developing Robust Domestic technical capacity and a manufacturing & fabricating base.

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Dr. Manoj Upreti
Sr. Research Manager, IOCL</td>
<td>Presentation: ‘Bio-ETP – A key step towards ZLD for refining Sector’

Water is an essential commodity and the world is faced with water scarcity. India has Water scarcity for more than 8 months in a year. There is nexus of Energy and Water is defined as link between energy efficiency and quantity of water needed to produce fuels.
Refinery sector uses about 1 to 2.5 gallons of water for every gallon of product. A lot of water is required for the refinery process and there is a need to reuse the water. Zero Liquid Discharge (ZLD) is based on the recovery of all the water by separating the contaminants as solid waste.
Doing so, 80-90% of the water can be reused. The system has pre-treatment system, brine concentrator and Crystallizer. Thermal and RO incorporated ZLD systems is the most widely used one.
Other ZLD system is based on membrane where electrodialysis, electrodialysis reverse, forward osmosis and membrane dialysis are used.
Role of Effluent treatment plant (ETP) plays a vital role in ZLD process. It depends on the quality of input water. The is need for treating the water before giving to ZLD system. Oil, greases, Phenols, Ammonia, Total Solids, Sulphides must be removed.
Pollutants interfere with ZLD system by damaging the membrane, corrosion of reactor and recovery of purified water etc.
Various set of chemicals are used for Chlorination, Ozonation, Neutralization, Coagulation, Adsorption, and Ion Exchange. Microbes eat all the oil mixed with the water.

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	▪ Biotechnology offers clean and green cost-effective and resource efficient treatment of wastewater streams, enabling zero liquid discharge and enhancing water re-use efficiency. Biological section has an Aeration Tank trickling filter. Water is then sent through Sequential batch reactor and Membrane bioreactor. A moving bed biofilm reactor is also used along with the Anaerobic treatment process. ▪ IOCL has developed few technologies which can be used for Biological treatments in the refineries, the technologies are, ETP-Bioinoculant, Los MLSS Advanced Biological Treatments, Bio-SR Technology for Sulphide rich effluent, Biological spent Caustic treatment and Microbial fuel cell. ▪ This technology is useful in meeting the prevailing MINAS standard in India refineries without altering the existing refinery ETP configuration. This cost 3-4 times less than the similar application and the system has long lasting characteristics. ▪ Achieving ZLD is one of the main targets for refinery ETP to meet the stringent regulations. Indian Oil has developed a 500 litres pilot plant in the IOCL R&D. ▪ IOC R&D developed various advanced biological methods for Enhancing the ETP performance, treating sulphide rich effluent and reducing bio-sludge generation.
 **Dr. Nimmi Singh** Chief General Manager, ONGC Energy Centre	**Presentation: 'Development of Biotechnology to convert unrecovered oil to methane gas'** ▪ India is the third energy consumer in the Globe and its energy consumption is forecasted to double by 2040. While addressing the energy needs, it is essential to keep the climate change threats in consideration. ▪ Methane gas is produced Biological way of microbial metabolism and Geological way in early stages of oil production. ▪ Bioconversion of oil to methane is significant. Oil recovery factor across the globe averages from 20% to 40%. Enhanced oil recovery process pumps large volume of produced water to the surface which also contains brine and other toxic chemicals. ▪ Biogenic methane recovery from Residual Oil remains in-place after additional oil recovery is considered a renewable energy alternative. ▪ Various research work has taken place on this on pilot and commercial stages across the globe.

	▪ ONGC’s oil field Ankleshwar has the potential for Bio-Methane. The field’s Oil Initially is place is 134 MMT. Ultimate recovery is 69 MMT. 66 MMT oil has been produced so far and oil yet to be recovered is 68 % with a recovery factor of 49-50%. ▪ ONGC’s R&D worked on the Biological Generation of Methane from Unrecovered oil. Gravimetric analysis of test samples after Column chromatograph was performed. ▪ GC fingerprints of saturate fraction showing range of n-alkanes from nC14 to nC35 with dominant peaks of Biomarker (Pristane, Phytane) and lighter molecular weight hydrocarbons (< nC17). ▪ In enrichment samples Components C9 to C14 are missing and all other peaks from C15 to C35 are of lower height as compared to saturates in control sample which may be taken up by microbes for the conversion to methane. This indicates Anaerobic biodegradation. ▪ Total Scanning Fluorescence (TSF) analysis of test samples indicated percent reduction in value of Aromatic. ▪ The core flood study for well sample conducted under the maintained reservoir conditions. The microbial actions resulted in Total 2 ml gas production from 3.2 ml of oil, 44 % methane concentration in total gas generated and 9.37% additional oil recovery. ▪ Metagenomic study revealed the presence of microbes involved in the process of conversion of oil to methane. It showed methanogenic microcosms along with oildegrading, fermentative microbes. Toxicity analysis revealed the non-toxic nature of microbial culture. ▪ Some of the key highlights are Enrichment of potent microbial consortia for methanogenesis, presence of fermentative, methanogenic and non-toxicity of enriched microbial consortia. ▪ OEC is continuing to optimize the process further and the technology will be licensed after optimization.

Day 3: Friday, 26, March 2021

Session VIII: Hydrogen Production, Storage, Supply & Utilization

Session Chair: Mr. K.K. Jain, Executive Director, CHT

Mr. Arun Kuniyil, Manager-R&D, Novel Separations, HPCL

Advances in hydrogen purification and storage technologies

- Hydrogen is a renewable energy source and it is environmentally friendly which burns with Oxygen releasing heat and producing water as exhaust. Hydrogen is a potential energy source for energy transition.
- Hydrogen as energy source can be used in multiple applications namely, Transportation, Heat and Power building & industries, and industry feedstock. In each of the areas, Hydrogen can be used in multiple sub-areas.
- Hydrogen can be produced in three ways namely, Methane Steam Reforming Co2 Emissions, Renewable Electricity Water (Green Hydrogen) Electrolysis and Methane Reforming Co2 Storage (Blue Hydrogen). However, these technologies come with higher cost and economically unviable.
- To meet the future energy demands, the energy must be sustainable and must be environmentally friendly with the use of technology for production, purification and Storage.
- Hydrogen purification techniques are of three types namely, Physical Purification, Chemical Purification and Selective Diffusion. These methods further have multiple ways of purifying Hydrogen.
- Pressure Swing Adsorption technology is the most widely used technology. In the process, purification is achieved by absorbing the impurity molecules on adsorbent materials. Depending on the type of impurities, different adsorbent material is used.
- Other widely used method is Metal Hydride based purification. This is done by dispersion of hydrate forming material in an aluminium based framework and gas is passed through the

	system. In this process, due to the formation of Metal hydrides, Hydrogen is captured. ▪ Cryogenic Purification is also one of the process used for Hydrogen production by cooling the feed gas which will lead to condensation of carrier impurities and condensed Hydrogen can be separated easily. By adjusting the temperature, the process can be altered. ▪ In Catalytic purification, Oxygen is removed from Hydrogen and this method is used to improve the purity of Hydrogen produced using Electrolysis method. It can reach purity up to 99.09 %. ▪ Diffusion bases Membranes can be used for producing Hydrogen using dense polymer membrane. In Polymer Electrolyte, water is split into Hydrogen and Oxygen through electrolysis process. ▪ Hydrogen storage is classified in Physical based and Material based. In Compressed gas storage system, Hydrogen is stored under high pressure. In liquid storage, Hydrogen is stored in liquid form, thereby increasing the quantity of storage. Hybrid method combines the both. ▪ HPCL has developed the PSA method of Hydrogen purification on commercial scale and the same is used in Vizag refinery.
 **Ms. Saroj Chaudhary,** Project Manager (Hydrogen Project), ONGC Energy Centre	**Production of Hydrogen as the ultimate carbonless fuel** ▪ Hydrogen, is the first element in the periodic table the lightest colourless doorless gas and anomalous condition, and it is a liquid at minus 250 degrees centigrade and it's a fuel with the highest energy density lowest and volume density. Hydrogen is an energy carrier. Hydrogen can be produced using Thermochemical Process, Electrolytic Process, Direct Solar Water Splitting and Biological process. ▪ In the global Hydrogen demand, 65% comes from the Chemical industry, 25% from the refining industry and the rest from Iron & Steel and general industry. ▪ 48% of the Hydrogen is produced from Natural Gas, 30% from Oil, 18% from Coal and 4 % through Electrolysis process. ▪ Green Hydrogen is made from renewable sources and no Co2 is emitted in this. Blue Hydrogen is produced from Methane, here the Co2 produced in captured and stored. ▪ Brown Hydrogen is produced from Coal and Co2 is emitted into atmosphere. Grey Hydrogen is produced from Methane wherein, the Co2 is emitted into atmosphere.

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- In ONGC Energy Centre, Hydrogen is produced on thermochemical water splitting process using closed-loop Copper Chlorine closed-loop/open-loop Sulfur cycles. This process was implemented in MRPL refinery with new sulfur-recovery process with a value addition.
- ONGC Energy Centre is also focused on thermochemical splitting of Water for Hydrogen generation. Cu-Cl cycle-lable scale metallic plant with a capacity of 25 litres per hour has been established.
- I-S cycle-closed loop in quartz system was established at 5 litre per hour capacity for Hydrogen generation. This has been operational since 2018. For I-S Cycle -Open loop, proof of concept in quartz system was established with a pilot plant set-up for H2S04 at 10-12 MT is planned to be set up in MRPL refinery.
- For alternative means of Hydrogen, OEC has initiated R&D on Sea water electrolysis, high temperature electrolysis, photo-electrolysis and Bio-Hydrogen.
- Production of Hydrogen can help in decarbonising the oil & gas industry. Transports & Storage cost will be significant. Pipelines are the most effective way of long-term Hydrogen distribution. Using existing gas pipelines can be used to improve Hydrogen supply.
- There is a need for supporting policies from the Government to boost the momentum in key value chains.

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Mr. Sachin Chugh,
Chief Research Manager, IOCL

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Presentation: 'Hydrogen in CNG – First Tryst with Hydrogen in India'

- IOCL is doing one of the most modern-day experiments of Hydrogen spiked CNG in Delhi for transportation fuel.
- An IC engine-based fuel car driving at 50 kmph consumes around 97,500 litres of air for an hour which is the quantity required by 9 people. Charging an electric vehicle requires 16-20 kWhr battery, wherein average household load in India is 2kWhr/day.
- Hydrogen comes with long term storage ability unlike electric vehicles. DNA of the Hydrogen supply chain remains similar to the oil & gas. Hydrogen can help in extending the life of existing IC engine vehicles.
- By blending Hydrogen with CNG, the mix can be used in mobility sector. However, using Hydrogen in the IC Engine is difficulty as this has very low sensitivity during the combustion process

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	▪ Fuel Cells are the best technology available as it no burning process takes place, but it is converting electrochemically. This area is one of the intense areas of research globally. ▪ Since the efficiency of the fuel cell is a novice, we can afford to have hydrogen at about four to $5 a kg to begin with and slowly reduce it to about three to $4 to make the entire value chain economical. ▪ CNG burns very slowly and it is much slower as compared to gasoline. Characteristics of the CNG makes the engine more sluggish leading to loss of power. Stability of combustion can be improved by blending Hydrogen with CNG. ▪ By using lean combustion, stability can be obtained with lighter modifications to the IC Engine. Carbon monoxide and Carbon dioxide emission can be reduced. Existing CNG infrastructure can be used for the same. ▪ On Life-Cycle emission comparison of CNG and H-CNG, there is a significant reduction in emission and unburned methane emission can be reduced considerably. H-CNG also helps in improving emission and fine tuning can help in reducing NO emissions. ▪ Indian Oil set up India's first commercial H-CNG dispensing station in Delhi and several vehicles are running under different demonstration projects. ▪ After multiples studies and research, 18% of Hydrogen volume in the CNG was found as the optimum one. IOCL has developed and patented single step compact reforming process to produce HCNG by varying the Hydrogen composition.

Day 3: Friday, 26, March 2021

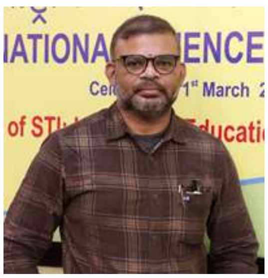
Session IX: Other R&D Activities

Session Chair: Dr. Anjan Ray, Director, CSIR-IIP

Mr. Abhishek Agrawal
Manager – Process Engineering
Lummus Technology

Transforming Low Value Gas Streams to Valuable Olefins with Siluria OCM Technology

- OCM is the Oxidation Coupling of Methane (OCM). Two molecules of methane react with one molecule of Oxygen to produce ethylene and water.
- Features of OCM reactor and catalysts: Fixed bed adiabatic design; OCM section loaded with proprietary catalyst which has high selectivity and low light of temperature; Conventional geometry; Conventional metallurgy; Conventional Catalyst shape and characteristics; Conventional catalyst loading/unloading procedures. OCM successfully provides polymer grade ethylene
- Procedure: a. Oxygen and natural gas comes from the preheater, enters the OCM reactor and gets heated. The process has ethane recycle and fresh ethane provision b. The hot effluent is recovered in the heat recovery unit and in the next stage heavy hydrocarbons are removed c. CO2 produces is removed else the gas will get trapped in the fractionation segment d. In the next stage it is dried and then goes for cryogenic separation followed by fractionation that produces the necessary products
- Advantages of cracker integration are: a. Potential to upgrade cracker offgas; b. Steam export to steam cracker. The main

	advantage of cracker integration is that the methane offgas produced can be used internally in the OCM ▪ The OCM is adaptable to various feedstock and varied composition. Enables monetization of natural gas, stranded gas or flare gas. Excellent overall economics of 3-5 years payback ▪ Enhanced process economics with 3-5 years payback. Enhanced process economics with ethane co-feed, reducing CAPEX by 38 per cent. Excellent economic opportunities by integrating with other technologies. OCM process can adopt to modularization maximizing capital savings
 **Mr. Nandakumar. T** DGM (R&D) GAIL (India) Ltd	**Covalent Organic Framework (COF) materials for Gas Storage Applications** ▪ Features of Covalent Organic Frameworks (COFs): a. COFs are a class of porous organic material with extended structures and were first synthesized in 2005 by Prof. Yaghi and his team; b. COFs are made by combination of organic building units covalently linked into extended structures to make crystalline materials; c. In COF organic units linked by strong covalent bonds: B-O; C-N and B-N ▪ COF Applications: Due to its turnable porous structure and high thermal stability, they have been investigated as potential material for various applications – a. gas storage; b. membrane separation c. heterogynous catalyst; d. energy storage; d. Photoconducting material; e. drug delivery ▪ There are largely three different types of COFs: Boron Containing COF; Imine based COF; and Triazine based COF ▪ **Boron containing – (B-O linked) COF:** a. Boronic acids were first used to synthesize COFs was by self-condensation of 1,4-phenylenebiboronic Acid (BDBA); b. COF 5 was synthesized reacting boronic acids with HHTP to produce boronate esters based linkages ▪ **Imine Based COFs**: These COFs can also be formed through the formation of C-N Bonds. Imine based COFs are synthesized via imine condensation of aldehyde and amine linkers eg. COF-LZU is synthesized reacting 1,3,5 Triformylbenzene and 1,4 Diaminobenzene. Hydrazone based COFs are synthesized via the condensation of aldehydes and hydrazide linkers ▪ **Triazine based COFs:** the covalent construction of CTFs is based on cyclotrimerization of nitrile building units in presence of

	ZnCl2 at 400 degree Celsius. For eg. Cyclotrimerization of 1,4 Dicyanobenzene (DCB) affords the CTF 1 ▪ C-N linked COFs: Imine/ hydrazone COFs possessed enhanced thermal stability. These COFs also possessed enhanced chemical stabilities. CTF are stable but suffer from lower Crystalanity ▪ Issues of Solvothermal method: High cost Pyrex or quartz tube; Inert atmosphere/vacuum conditions; Specific Solvents; High reaction temperature; Longer reaction time; difficult in monitoring the reaction; scaling up is a challenge ▪ Strategies and objectives of present work: a. Synthesis of chemically and thermally stable C-N linked COF through Schiff base reaction; b. Adopt facile methods of synthesis through Mechnochemical methods'; c. Use of Mixed linkers; d. Synthesized new COFs and evaluated its methane storage with respect to doe targets

Day 3: Friday, 26, March 2021

Panel Discussion on R&D and Deployment of Indigenously Developed Technologies

Session Moderator: Dr. R.K. Malhotra, Director General, FIPI

Dr. S.S.V. Ramakumar
Director (R&D)
IndianOil

New Projects for Commercialization

- Besides the flagship INDMAX and HCNG, IndianOil has over 20 new technologies in pipeline, which will soon be commercialized
- For crude oil to chemicals conversion, IndianOil has developed two new technologies, namely INDELPET and INDELENE, to boost petrochemical runs. INDELPET converts the lifecycle oil from the FCC units or INDMAX units to petrochemicals precursors.
- IndianOil is also developing a novel technology for Slurry resid hydro cracking that is also one of the key routes for crude to chemicals where all the vacuum residues of High CCR are converted into naphtha and diesel oil. The conversion rate in this new technology is more than 95 per cent. Indian Oil is shortly going to set up 1 MMT demonstration unit in its Panipat refinery.

Challenges in Commercialization

- At IndianOil, R&D department holds a board level position. This helps the company get its own indigenous technologies in getting scaled up and adopted. More oil and gas companies in the country must look at providing a board level representation to their respective R&D departments. This will also provide a big push to the Government's mission of Aatmnirbhar Bharat

	▪ Towards making India Aatmnirbhar in the Oil and gas sector, the Ministry of Petroleum and Natural Gas (MoPNG) has constituted a dedicated group of companies from the midstream and downstream sectors to synergise the R&D activities in the sector. After deliberations, nine projects have been shortlisted, cutting across company lines, affiliations and interests. ▪ Ministry has advised the collaborative group to look at the best practices in the core business areas to share and exchange these best practices. The group will be called 'Petroleum & Natural Gas R&D Think Tank'. The group will be responsible to execute the nine projects in a time bound fashion. Most of these projects are in downstream and alternative energy ▪ As a next step, the above mentioned group should be extended to include upstream operators, private players and research institutes such as IIP ▪ The companies in the Oil and gas sector are getting increasingly concerned over IP and mechanism sharing. To ensure uninterrupted flow of ideas, there is a need to settle these concerns amicably ▪ To become truly Aatmnirbhar, India should encourage indigenous development of technologies. Before importing new technologies from abroad, indigenously developed technology options must be explored.
 **Dr. Sanjeev Katti,** Director General ONGC Energy Centre	**New Projects for Commercialization** ▪ ONGC is soon going to commercialize H2S and SO2 sensors. These sensors will find extensive usage in refineries and natural gas producing fields. ▪ ONGC has also developed the superhydrophobic coatings for solar panels and non-solar usages like vertical buildings etc. These things reduce the frequency of water washing in buildings ▪ The ONGC Energy Centre is also working on the Hydrogen copper chloride cycle. It will take the company another two years to set up the pilot of 12 MTPA and subsequently a demonstration plant for the technology

Mr. S. Bharathan
Head (R&D), HPCL

New Projects for Commercialization

- HP PSA: HPCL is only the second refinery in the world to develop this technology. The company has also successfully replaced the absorbents of the Hydrogen generation plant PSA Units. HPCL is shortly going to commercialise this technology
- The company is also in advanced stage for implementation of HP-DAK, which will produce de-aromatized solvents. HPTSA (HP temperature Swing Absorber) has also been implemented in HPCL refineries and will soon be extended to buyer in petrochemicals and refining sector

Challenges for Commercialization

- While HPCL has sold a number of PSA technology, over the last few years, Indian companies could not compete for this technology because all Indian companies place a clause of Non-captive PTR.
- To start licensing and selling, there is a considerable amount of detailed engineering that is required, which requires a suitable partner. It is extremely time consuming to arrive at an agreement that is beneficial to both the parties.
- In order to smoothen the process from lab to commercial implementation of new technologies, HPCL has constituted a value addition committee, comprising of technical heads of the refineries and the heads of operations. The responsibility of the committee is to validate and endorse the technologies developed by the R&D department. After the benefits are seen, it is the responsibility of the committee to implement the technology in the refineries
- Refining is a sunset sector in most western countries today. In India, however, the sector is on a strong growth trajectory. To survive and thrive in this business, it is imperative for the country to now develop indigenous technologies in the sector

Dr. Anjan Ray,
Director
CSIR-IIP

New Projects for Commercialization

- IIP has numerous technologies in the pipeline, waiting for commercialization. IIP has a technology for direct desulphurization of crude oil at source. IIP is looking to commercialization of this tech soon

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Challenges for Commercialization

- Commercialization has emerges as a major challenge for research institutes in the sector such as IIP. For interim level scale ups, which is imperative for consumer confidence, IIP is forced to make investments by its own. Consequently, arranging for the necessary funds is a major challenge.
- Another challenge faced by the institute is that of process guarantee and first reference plant. The institute has seen more interest for the first reference plants from foreign parties than the Indian companies. For Eg. The Foxcat catalyst developed by the IIP is presently being used in only 10 Indian refineries while some of the largest refineries in the middle East are making use of this catalyst and benefiting from 30-50 per cent energy saving and through put. IIP expects greater support from Indian refining and petrochemical companies for commercialization of novel technologies
- Often, technologies being worked upon by IIP, are also seen to be developed in-house by some of the downstream companies in the country. This leads to duplication of national efforts. Hence, greater alignment among refiners and research institutes is required

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Ms. Vartika Shukla,
Director (Technical)
Engineers India Ltd

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New Projects for Commercialization

- EIL has a robust pipeline of new technologies waiting to be commercialised soon. There are more than 35 technologies and over 150 trains of various technologies running in Indian refineries that EIL has implemented.
- The Crude vacuum distillation unit developed by EIL is at par with the best in the world. In the cryogenic area, EIL has the largest trains of C2, C3 recovery running at GAIL's Vijaypur plant. The replacement for the imported technology for tail gas recovery unit for Sulphur recovery was put up by HPCL. The implementation of indigenous novel technologies developed by EIL has been made possible only through support from Indian PSU refineries.
- EIL is also working on technologies to put the waste generated during the processes back to use and increase the efficiency. There is also a technology for Hydrogen recovery from fuels gases, which are otherwise burnt in refineries
- EIL has won some technologies on competitive basis and plans to diversify into similar activities of scale up and diversify in the biofuels. EIL is looking towards more collaborative and

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complementary approach so that the entire research community in the oil and gas sector could move towards Aatmanirbhar Bharat

Challenges for Commercialization

- Often it is noticed that refiners do not want to take the risk of investing in new technology, which in turn pushes back the commercialization of these technologies. For any R&D activity or collaborative R&D, there is a need to build confidence among the industry members.
- In order to address the issue of finds for commercialization, there is a pressing need for the PSUs to put together a pool of fund and allocate the same towards risk mitigation of new technology deployment
- There is also a need for a mechanism where the leadership teams of Indian oil and gas PSUs must place greater confidence in their respective R&D teams and shield their credibility in case of a complete or partial failure of technology
- To ensure indigenous development of world class technologies, there should be a greater degree of handholding alongside necessary due diligence and all other supportive mechanisms. For this, leadership should make the efforts to mitigate the risk and encourage the best technological developments

Dr. V. Ravikumar
Head (R&D)
BPCL

New Projects for Commercialization

- BPCL has developed two game changing software: BPMark and K Model.
- BPMark is being continuously used in Mumbai refinery for optimization of CDU and ADU. This is a major achievement towards digitization of processes
- K Model finds usage for checking crude compatibility. The software enables the decision makers to select the most suitable blend for their refinery based on just the physical properties of the crudes
- BPCL has more technologies in the pipeline which are about to enter the demonstration phase

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