Vision 2030

Emerging Global Energy Basket – Challenges & Opportunities

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As Chairman Steering Committee for Petrotech 2014 it gives me immense pleasure to have you all here for Petrotech 2014 - the 11th edition of the biennial International Oil & Gas Conference and Exhibition series scheduled January 12 through January 15.

I welcome you all to the event and I assure you that the time and efforts that you will invest here are going to be well used in developing a better and more evolved understanding of the shape of things to come in energy industry of the future. You presence is an ample proof of your commitment to the continuous growth and development of the industry as each of us is keen on a strong future for the industry. So, I thank you all for registering your presence with us for this flagship energy event of India.

On behalf of the host organization ONGC and in my personal capacity as the Chairman of the Steering Committee, I would also like to place on record our indebtedness to our administrative Ministry, the Ministry of Petroleum & Natural Gas, for having extended unstinted support to all our efforts and initiatives pertaining to Petrotech 2014. Most significantly, the unqualified support and guidance that we have received from the Hon’ble Minister of Petroleum & Natural Gas, has gone a long way in instilling confidence and belief in our ranks.

The global oil & gas industry, and by extension the entire gamut of energy, is undergoing a remarkable flux. New frontiers of energy have emerged accompanied by rapid advances in technology even as global economic, political or geopolitical developments continue to temper the industry dynamics. And Petrotech 2014 is situated well to negotiate and deliberate over these changing terms and the conference theme - “Vision 2030: Emerging Global Energy Basket – Challenges & Opportunities” – has been carefully chosen to provide intent and direction to the discussions around this issue of the evolving energy market and the accompanying shuffle that is happening in the energy mix.

It is critical to do so as conclusions made and decisions taken during this event, about our energy strategies, will have a bearing even beyond the next 10-15 years. Energy has fundamental linkages with the economic aspirations of countries worldwide. And as the world at large starts to come out of what has been a recessionary economic phase of the last 4-5 years in the aftermath of the global financial meltdown of 2008, the demand for energy is only going to pick up going forward.

Before I go any further, here are some projections that will well contextualize the need for an exhaustive and well-rounded debate on the future of energy –

- The world population will increase to 8.5 billion by 2030 about 20% higher than what it is now, and will be more prosperous and energy hungry.
- While population is a key to projecting energy demand, demographics matter too. Of particular importance is a country's working-age population (people between 15-64 years old) because this group is the engine for economic growth and energy demand.
- India is forecasted to see significant growth in its population and its working-age group as well as the Middle East, Africa and Latin America. These demographic trends will help India and the regions I have just mentioned become areas of the strongest of growth of GDP in the world.
- The OECD economies are expected to expand by about 2% a year, while non-OECD economies will grow much faster, at almost 4-5% a year through 2030.

In this unfolding scenario, it is all the more significant for our country to commit adequate resources to and undertake the necessary intellectual inquisition into the evolving global energy framework since our international engagement is only going to progressively increase as our energy demand keeps in step with our growing economic outlook. Even a conservative estimate of 6 per cent growth in the Indian economy is expected to approximately double India’s per capita energy consumption over the next 20 years. The Indian oil and gas sector, which provides the country with a significant portion of its energy requirements, has been identified as a key metric that will drive future GDP growth. But our limited domestic resource base means that we have a high degree of international exposure when it comes to sourcing our energy supplies. As significant players of the country’s energy setup, we have the mandate to ensure that the country has access to a stable energy supply while at the same time undertaking major steps to enhance our energy self-reliance.

In the context of this globally inter-connected energy map, Petrotech 2014 is geared to explore possibilities to strengthen national, regional and global partnerships to promote active collaboration and mutual assistance in matters of common interest in the energy business in general, and Oil and Gas in particular.
Like already mentioned, the global appetite for energy is not abating anytime soon but encouragingly there are also enough resource plays that are continually being discovered and this will ensure that the world stays well away from facing a severe energy crunch. Here, a strong R&D and technology bias will be a key enabler in the energy industry of the future. New technologies that have come up in the horizon over the last few years have meant that resources that were hitherto inaccessible or commercially unproducible are now very much the part of the energy mix. And the fact that most of the ‘big finds’ of the last few years have been made in more difficult and challenging locations makes the focus on R&D and continuous innovation imperative. World oil & gas is a dynamic environment and only through the adoption and integration of ‘a serious R&D ethic and technology-centeredness’ in our operating models can provide us with the greater agility and adaptability necessary to stay relevant and highly competitive in this arena.

Finally, energy is a universal pursuit so must our strategies to tap energy opportunities also reflect global practices and realities while at the same time furthering national priorities of economic growth and development and providing energy security. India, in particular, will have to develop an energy model after having comprehensively reassessed its current business and financial models, technological framework, project management approach, regulatory and fiscal structures, and governance mechanism if it has to make the new model robust, resilient and one that can efficaciously address the energy imperatives of the country.

I firmly believe that with the discussions and deliberations in the various sessions of this three day Petrotech-2014, there shall emerge meaningful propositions of redefining our existing energy matrix, and takeaways that are practicable and relevant takeaway.

Wishing a great time and greater satisfaction to each participant of Petrotech-2014

Sincerely,

Sudhir Vasudeva
Chairman, Petrotech
Chairman Steering Committee: Petrotech 2014
CMD ONGC
The business of Petroleum Industry is Knowledge driven and the Petrotech series of International Conference and Exhibition serves as a congregation of globally acknowledged scientists, technocrats and professionals to ponder on concurrent issues and future challenges in hydrocarbon industry. To this effect, I believe, the release of special issue of the Journal of Petrotech (Jop) being brought out during the forthcoming Petrotech-2014, is an apt move.

Each Petrotech conference and exhibition held biennially has an enviable reputation in international circles as one of the leading platforms for the global hydrocarbon industry by giving an impetus to pioneering technology in this field. Each of the ten conferences and exhibitions held since 1995 have set higher standards, uniting the upstream and downstream sectors in helping to secure India’s energy needs as well as promoting the drive towards energy independence.

The expanding demand for energy, coupled with tight supplies has emphasized the urgency for optimal use of available resources in India and collaborating with global players in adoption of latest technology. The emerging importance of shale gas and gas hydrate from Indian point of view requires critical inputs from global players for ongoing R&D in these fields as well as smooth technology transfer. The increasing roles that solar and nuclear energy are poised to play, demands in depth deliberations and exchange of ideas in congregations like Petrotech.

Knowledge sharing is crucial to managing the conventional and unconventional hydrocarbon resources and Petrotech Conference and Exhibition provides unique opportunities to Oil & Gas companies and professionals to exchange their innovative ideas and showcase their capabilities.

Publications like JoP act as mouth piece of International Conference and Exhibition like Petrotech through articles it carries from Oil & Gas Companies, Research Institutes, Academia and Process Licensors etc. the journal serves as a link pin between the hydrocarbon professional working in India and rest of the world and therefor, has a significance in providing a churning ground for nucleating new ideas. I am sure that this special issue of Journal of Petrotech will showcase India’s capabilities in Oil & Gas sector besides disseminating crucial information and knowledgebase on key developments of recent past. The dedicated efforts by the team behind the successful publication of this journal in successive Petrotech conferences deserve appreciation of highest order.

I wish the special issue of JoP a great success and sincerely cherish that it will continue its efforts towards eliciting the Vision and Mission of Petrotech in years to come.

Narendra K. Verma
Director (Exploration)
Chairman Organising Committee: Petrotech 2014
Dear Friends & Benefactors,

Before I dwell on the subject, let me take this opportunity to welcome you all to the 11th international oil & gas conference and exhibition, Petrotech-2014: Vision–2030: Emerging Global Energy Basket – Challenges & Opportunities being held from 12-15 January, 2014.

The event is a biennial platform for national and international experts in the oil & gas industry to exchange views and share knowledge, expertise and experiences. Petrotech-2014 is being organized by Oil and Natural gas Corporation Limited and Petrotech under the aegis of Ministry of Petroleum & Natural Gas, Government of India. The event showcases the Indian oil & gas industry and provides a global networking opportunity to participants in addition to providing a platform to display cutting edge technology and scientific innovation by service providers and vendors at the exhibition. The event also aims to explore areas of growth in the oil & gas sector. As the prime showcase of India’s hydrocarbon sector, this mega event attracts scientists, technologists, planners, policy makers, management experts and entrepreneurs to solicit their views in order to catalyze achievement of global energy security. I whole heartedly welcome you all to this grand event of India’s oil & gas sector and wish you have a fruitful time. On this occasion, we are bringing out a directory “Human Capital – the Experience Pool” which is compilation of superannuated professionals of Indian Hydrocarbon Industry. These professionals are still very active in their respective field.

Coming to the subject, in contrast to the availability of experience pool of human capital on one hand, keeping the human resources engaged at work on the other hand is one of the biggest challenges for any organization. One of the ways to achieve this is to win the heart and mind of the employees. Winning the Hearts & Minds by engaging the work force is the need of the day particularly when the life is so fast moving, competitiveness has become the order of the day, technology is fast changing, economic conditions are so complex which industry need to adjust itself.

Like anyone else, employees in any organization have their own needs. Once their lower order needs are fulfilled, the higher order needs come into play. Similarly employees also have intellectual and emotional needs and if an organization can fulfill their basic intellectual and emotional needs, the employees will be self motivated to perform at their best. Minds and hearts of the employees will be fully engaged. Employees will be full of life with new ideas to keep the internal & external customers of the company satisfied, loyal and committed. However, if their intellectual and emotional needs are not fulfilled, they will always be on the lookout for other organizations to satisfy their basic intellectual and emotional needs.

You must have come across many examples in the organizations where an employee who generally seemed to be happy suddenly resigns one day citing no complaints but simply saying that the new employer offered him better perks and better salary. Studies, however, show that such employees leave the organization not because they were not being paid well but because they were not fully engaged and rather were disengaged. Their basic intellectual and emotional needs were not fulfilled which caused them internal frustration and this made them to look for opportunities in other organizations. Therefore, it is true that the most difficult challenge for any organization is to capture the hearts and minds of sincere, good and reliable employees who may not be the extra ordinary brain but are significantly more productive when engaged. Paul R. Lawrence and Nitin Nohria in their 2002 book Driven: How Human Nature Shapes Our Choices explain that people are guided by four basic emotional needs, or drives, that are the product of our common evolutionary heritage and these are:

♦ the drives to acquire (obtain scarce goods, including intangibles such as social status);
♦ bond (form connections with individuals and groups);
♦ comprehend (satisfy our curiosity and master the world around us); &
♦ defend (protect against external threats and promote justice).

These drives underlie everything we do.

Intellectual needs have been defined as the desire to learn, to communicate and to upgrade our skills for different objectives like career progression, doing the job in a better way or to know the client’s likes and dislikes etc etc.

It is easier said than done. Simply reading these lines will not help the employees to contribute to their maximum. To do this, each organization need to evolve its own practical tools to keep the employees engaged at all levels which can ignite in them the fire of “Passionate Performance”. Therefore, there is need to build passion and performance through employee engagement. This will be possible when the management of an organization is prepared to ask itself the following questions:

♦ Do their employees feel proud and passionate about the work they do?
♦ Are the employees in tune with the actual objectives of the organization?
♦ Do they come out of their comfort zone to walk an extra mile to satisfy their customers? And
♦ Do the employees believe that their survival is linked to the survival of their company?

If answer to any of these questions is in negative, rest assure we are in for trouble and we need to immediately take remedial steps.

New Year has just begun and may the dawning of this New Year bring Happiness & Prosperity to you all!

Have A Happy Reading!

Ashok Anand
Director General, Petrotech
Dear Patron of Petrotech,

The year 2013 has left behind an admirable footprint on the Indian Oil & Gas industry; of liberalization of gas prices, gradual deregulation of Diesel prices, total deregulation of gasoline prices, fixing number of subsidised LPG cylinders and direct disbursement of subsidy on LPG cylinders. It has set the process of deregulation, and liberalization; which should continue in the New Year. We look forward to greater activity in the New Year, towards realization of India’s Energy Vision 2030 of self reliance and creating its own energy basket. With this hope and aspiration, we welcome the New Year with our flagship International Oil & Gas Conference and exhibition: Petrotech-2014.

Welcome you to the Petrotech-2014 – the biennial confluence of the global oil and gas people in New Delhi. This four days event starting from 12th January; filled with numerous plenary sessions, technical sessions, and digital poster sessions and with over 400 exhibitors to meet around, is bound to keep you engaged and enthralled all the time. With your active participation in the sessions will inhibit our work on realizing the “Vision 2030: Emerging Global Energy Basket – Challenges & Opportunities”, which is theme of Petrotech-2014.

Having realized the need for intense collaborative R&D, for realizing the vision, we bring to you, on this occasion, a special issue of JoP, highlighting some of the major initiatives of R&D establishments and institutions of Indian oil and gas industry; and their plan for overcoming the challenges posed by the energy of future, which should be clean and affordable to meet the energy needs of ever increasing global population. With its huge Indian population yet to get access to the basic energy supplies, there is great potential for developing technologies to generate energy at affordable price and make them available at places they are required, which certainly a great opportunity for India specific R&D in energy sector, both, in areas of basic and applied research. Demographically India is a country with large young population, with good quality institutions of higher education and numerous R&D organizations, with large pool of academia and scientists, functioning under the public and private sectors. It is for this reason that many of MNCs have, recently, set-up their R&D facilities in India.

The Govt. of India has already announced first phase of its Shale Oil & Gas policy and soon it shall bring out its Shale Oil & Gas policy opening doors for large players in this field. But India has to overcome many technical and technological challenges before fully establishing its Shale Oil & Gas reserves and exploiting the same. This calls for large investment in related R&D, to overcome the challenges specific to the Indian conditions. There is vast tract of onshore and offshore areas yet to be explored, which is great opportunity for R&D in the up-stream oil and gas industry. Expanding oil exploration activity shall pose many safety issues and R&D in HSE is unavoidable for sustainable growth of this industry. Numerous R&D facilities set-up by the ONGC have great potential for carrying out futuristic and collaborative research in various areas of upstream.

The downstream R&D establishments like, IndianOil-R&D, Indian Institute of Petroleum, BPCL-R&D, HPCL-R&D etc., have developed and commercialized some of very robust and highly competitive technologies, catalysts and additives, which are presented in this issue, for your ready reference. You shall find that IndMax—one of highly efficient, robust and versatile RFCC technology developed by IndianOil-R&D is there for the new and old refiners to adopt it and include in their refinery processing scheme. This technology is offered by IndianOil in association of CBI Lummus Technologies, USA. IndianOil has also developed and commercialized DHDT and Isomerisation technologies, which are on board along with the EIL. The catalysts and additives developed by IndianOil-R&D have proven their robustness and beneficial economics, which can easily compete with the best in the class.

The Petrotech-2014, also, offers an opportunity to create a conceptual energy basket for 2030, which would, call for developing and commercializing cleaner technologies for generating more efficient green energy from renewable as well as fossil sources. The Govt., in this regard, has to play a significant role in modulating the energy demand for facilitating suitable technological developments in meeting the challenges, posed in way of creating a balanced energy basket for the year 2030. It calls for greater investment in R&D.

The Indian investment in R&D has remained stagnant at 0.9% of its GDP for over last three years and is likely to remain same in 2014 also; whereas, China’s R&D budget is likely to outpace even that of USA. In 2014, Ten countries, alone, will spend about 80% of the total $1.6 trillion invested on R&D around the world; of which, more than 50% will come from U.S., China and Japan. India needs to catch-up fast, for realizing its Vision-2030. It shall not only in the area of energy production, transportation and efficient conversion and utilization is important area for R&D, but the environmental impact of energy production calls for greater emphasis on R&D. At the same time, R&D in the areas of developing right material and chemicals that support and promote clean and sustainable energy technologies and improved energy efficiency, must find right place on our R&D agenda and investment. In general, the energy R&D heavily relies on a combination of in-house development and collaboration, therefore, an eco-system of R&D has to be created by investing more and more on basic and applied research institutions, and in building infrastructure and scientific talent and research oriented human capital.

I am sure that the Petrotech-2014 shall be great opportunity for identifying right partners for collaboration and right technologies to work with.

Wishing you highly enriching time at Petrotech-2014, and a very Happy New Year,

(Anand Kumar)
anand.iocl@gmail.com
info@petrotechsociety.org
Team Petrotech
Wishes you
Happy New Year
2014
Shri S.C. Pandey has taken over the charge as Director (Projects), NTPC with effect from forenoon of 1st October 2013.

Shri S.C. Pandey (56 years) is B.E. in Instrumentation. He joined NTPC in November, 1978 as (3rd batch) Executive Trainee. He has about 34 years of comprehensive experience in management of large size power project in the areas of engineering, project construction and power plant operation and maintenance. He has a strong background in managing, operating and maintaining few of the largest stations of the country and has a rich experience and exposure of entire life cycle from concept to commissioning of Greenfield project.

As Executive Director (Project Planning & Monitoring), he was responsible for planning and implementation of pre-award and post-award activities related to Thermal, Hydro, Coal mining, Renewable Energy, R&M and international JVs, analyzing and identifying bottlenecks and critical issues and suggesting corrective actions for their timely resolution.

Mr. S C Pandey  
Director (Projects), NTPC

He joined GAIL as Manager in December 1990 and served at various levels across different departments including Business Development, Marketing and Projects. Prior to his assignment as Executive Director (BD), he was incharge of Marketing for various products of GAIL including natural gas, petrochemicals, liquid hydrocarbons and telecom bandwidth at Ahmedabad Zonal Office. He also headed the Petrochemicals Marketing Department at Corporate Office as General Manager (Marketing). He was part of the core team that worked on the development and implementation of GAIL’s first gas based petrochemical complex right from its conceptualisation to commissioning.

Mr. S Venkatraman  
Director (Business Development), GAIL (India) Ltd.

Shri S. Venkatraman has done B.Sc. (Physics) from University of Madras, Madras in 1973. In 1976, he completed Diploma in Instrumentation from Madras Institute of Technology, Madras and thereafter Diploma in Management from All India Management Association, New Delhi in 1989. He started his career in 1976 with Instrumentation Ltd., Kota and worked there at various levels till December 1990.

Ms. R S Borah  
Director (Finance), OIL

Ms. Rupshikha Saikia Borah has taken over as Director (Finance) of Oil India Limited (OIL) October, 2013. She is the first ever lady functional director in the Board of OIL. Ms. Borah has to her credit over 27 years of rich experience in diverse fields of Financial Management, Audit and Strategic Planning. She had been honoured with the ‘Best CA Professional Woman Achiever Award’ by The Institute of Chartered Accountants of India and had also received a special commendation “Petrofed Woman Executive of Oil & Gas Industry Award” by Petrofed, India.

Ms. Borah is a post graduate in Commerce from Delhi School of Economics and has the distinction of being the first lady Chartered Accountant from the North-East India. Her laurels include the prestigious Fulbright Hubert Humphrey Fellowship, USA. She is a keen golfer and loves travelling.

Mr. Kulamani Biswal  
Director (Finance), NTPC

Shri Kulamani Biswal has taken over as Director (Finance) NTPC on the Board of NTPC Limited with effect from 09.12.2013.

Shri Kulamani Biswal (52 years) has rich experience of 28 years both in coal and power sector. He was Director (Finance) in Mahanadi Coalfields Limited (MCL) since October 2010 managing finance, accounting and corporate governance functions of the Company. He played a pivotal role in making MCL as second largest coal company in India in terms of production and profitability. He was Chief (Finance) at Central Electricity Regulatory Commission and contributed to drafting of various regulations and policies for smooth functioning of the power sector from year 2004 to 2010.
M. Veerappa Moily said in an interview that oil prices will remain subdued in 2014 and due to new discoveries, oil and gas will become a buyer’s rather than a seller’s market.

Edited excerpts:

The automobile industry runs on fuel, what is your own assessment? What are your advisers telling you? How do you see global fuel prices moving? We saw a lot of activity around Iran recently. Do you see fuel prices remaining subdued or 2014 could throw some more shocks?

According to the assessment made by a number of agencies including McKinsey, I think in the future days the fuel prices will come down for various obvious reasons. In fact, shale gas is the biggest contributor today to the gas sector. Canada and the US could do it within five to six years. Forty percent to 50% of the gas requirement is provided by them.

We have also found that in many areas where we had not seen oil or gas, we did find the oil fields. For example, the Barmer desert in Rajasthan. Everybody had ruled it out. When I convened a meeting of our companies and experts that I would like to have a big refinery in Barmer, the prompt reply was, “No, we can’t go for 100% import and establish a refinery of the capacity of 9 million metric tonnes. “I called the next meeting, the third meeting.

Your will be surprised to know that it is totally 45% of the contribution of the indigenous oil but ultimately when the refinery well be commissioned within 2-3 years, the oil found will be more than enough to sustain 9 million metric tonnes. Ultimately, you may have to plan for the next

INTERVIEW

Level, that is 15 million metric tone. This is it. I had gone to the northeast the other day for a review and I found that the northeast is abundant in gas and oil.

we have plenty of resources of shale gas and there are new players coming up like Mozambique, Nigeria and there are new players that are coming out of Antartica. Iran is also likely to open up now which will provide that kind of quality crude. That’s why I’m telling you now that in the years to come, within a decade or so, oil products will become the buyers’ market instead of the sellers’ market which has been for so many decades.

Do you believe that oil prices will remain subdued for a better part of 2014? Is that your assessment? That is not only our assessment but it is also the assessment of many of the people which I have mentioned already, like McKinsey and other agencies.

When we last spoke you told me that the fall in the rupee upsets you as much as it does anyone else. What is your own understanding? I’m sure this is an issue which has been discussed at the various levels of government and I know you don’t run the finance ministry, but do you believe the worst is over as far as the rupee is concerned?

I feel so because it is because of the extraneous factor, like the US Fed taking some abrupt decisions. Despite that our country has got its own strength but at the same time, oil is an important factor for the rupee appre-
You all know that for every one rupee which depreciated, India lost Rs 9,000 crore. This is the casualty which we had to suffer, face and combat.

I think we need to build our own exploration: we need to build our own stock. That is why we are working on strategic reserves in the country. For the first time, we are planning this in Asia. We have commissioned it in Vizag, cavern. The other two will be in Udupi and Mangalore.

You addressed one of the very contentious issues about hiking the gas prices. You just did it just the other day. What are the implications of that?

You know affordability and accessibility, these are the questions before the country because ours is an inclusive economy. When we increase the gas price of the fertilizer, price of the power and of course fertilizer is totally subsidized. When power is not extended. When power is concerned that subsidy is not extended but at the same time, suppose we need to invite the investors both within the country and outside the country.

Even in the PSG (production sharing contract), which is the agreement we had in the NELP (New Exploration and Licensing Policy) procedures, we had promised that ultimately, we are going from the gas to the market price. We have now taken the weighted average of our import and also our domestic production and we have the hope that in the days to come, prices of the petroleum products may stabilize and even come down and to that extent the benefits will be passed over to the consumers.

We need to produce oil and all the gas. When gas will be produced within our country. It will be about $13-14 whereas production now is $4.2 and then when it’s increased as on today, if we take the weighted average, it will be around $6.5 Maybe that will get stabilized because now the gas resources are available in the country and outside the country it will get stabilized.

Let’s talk about your passion, which has been deregulation and decontrol. By when do you think you are going to decontrol diesel?

I think the complete process may be over may be within 5-6 months time. I would have done it by December, as I told you. But for rupee depreciation, I came down to Rs2.45, then suddenly it went up to Rs14. Now, as of today it may have come up to Rs 7.50.

But you are very clear that the diesel prices will go up going forward?

Our total capacity in the refinery is 217 million metric tonnes. Within 2-3 years time, it will go up to 275 million metric tonnes. Instead of becoming the net importer, we are becoming net exporter as well as far as the petroleum products are concerned. We are capable of producing our own diesel out of the crude.

The only question is that we need to go for the competitive rates in our crude purchase.

Now we have only one country that is Qatar where we have a longstanding agreement. That is also going to expire by the end of this month. Thereafter we are left with no long-standing agreements, and we only have to go in for sport purchases.

Sport purchases is a debatable point sometimes because of the competitive reservoirs and exploration in various countries across the globe. Possibly, tomorrow the gas and the oil prices are likely to come down.

With that hope perhaps, we don’t want to get into long range agreement immediately. We need to watch for January and ensure that whether we can go in for long range agreement with various countries.

Source: Livemint
IndianOil, is the largest commercial enterprise of India and aspires to be a global energy company. It’s world class Research & development Centre at Faridabad, established in 1972, has state-of-the art facilities and has delivered pioneering technological solutions in the areas of lubricants technology, refining process, pipeline transportation, petrochemicals, alternative and renewable energy sources. Development of innovation culture in the organization and adopting the mantra of innovation is the only way ahead to counter the ever increasing global competition. IOCL has recognized the need for innovation in the organization and hence leaving no stone unturned for creating a culture supporting innovation in all the verticals of the organization. IndianOil’s R & D technology investments span the full cycle - from strategic research through technology development to demonstration and deployment.

Technological Innovations from IndianOil-R&D

Refining Technology

In the refining sector, IndianOil-R&D Centre has been providing technical support to IndianOil refineries spread across India and also engaged in development and commercialization of some novel process technologies. Concerted efforts from basics to commercialization including setting up of laboratory facilities, pilot plants, modeling and scale up have resulted into development of globally competitive refining technologies and catalysts. The major Process/Catalyst technologies developed and commercialized as well as under commercialization by IndianOil R&D, which address the emerging scenario are summarized below:

As technology development is a continual process, IndianOil R&D has been engaged in further improvement of the already developed and commercialized processes to remain competitive in the market. Recently developed new technologies, which are ready for commercialization, are summarized below:

**INDMAX**

4.17 MMTPA INDMAX unit at IndianOil Paradip Refinery (Figure 3) is nearing mechanical completion and refractory, process and mechanical inspection have already been completed. The unit is expected to be commissioned in 2014.

The excellent metal tolerance of the multifunctional catalyst accompanied by better selectivity of Dry gas and Coke have made INDMAX technology more competitive and attractive especially with metals contaminated heavy feed. Recently, concerted efforts have resulted in enhancement of propylene yield (>26%) from paraffinic VGO feedstock using INDMAX technology. INDMAX technology is under active consideration by an Indian refinery outside IOCL, for maximizing the yield of light olefins using heavy feed with high Ni content (>80 ppm).

**INDAdeptG**

Demonstration unit of 35000 TPA INDAdeptG at Guwahati refinery for desulphurization of heavy Indmax gasoline based on technology developed by IndianOil R&D was approved by IOCL Board in Nov,12 with a completion schedule of 36 months. The technology can reduce sulfur content in treated gasoline to less than 10 ppm level and compared to presently employed technology in Indian refineries, consumes 20-30% lower hydrogen.

**Diesel Hydrotreating (DHDT)**

1.2 MMTPA DHDT unit at IndianOil Bongaigaon refinery (Figure 4) which was commissioned in Aug, 2011 and has
been running successfully for production of diesel meeting BS-IV specifications (Figure 5) at much lower operating severity than design operating condition. Prior to commissioning of DHDT unit, all the diesel components from Bongaigaon refinery were being sent to other refineries for upgrading.

Technologies for BS-IV Gasoline
Demand of BS-IV gasoline is increasing in India and refineries are looking for alternate processes to meet the specification. For augmenting both gasoline quality and quantity, IndianOil R&D has developed a process for upgrading of C4 hydrocarbons from refinery LPG stream to high-octane (RON>100) gasoline blending stock employing a solid catalyst in fixed bed reactor, much simpler as compared to Alkylation technology for production of gasoline blending component employing hazardous liquid acid catalyst.

IndianOil R&D jointly with EIL has already developed and successfully commercialized Light Naphtha Isomerization technology named Zeosom (Figure 6). The process is based on robust catalyst, capable of tolerating more feed contaminants, thereby eliminating elaborate feed pre-treatment. The process is being improved further by employing higher activity catalyst.

Hydrogenation based Food/Polymer Grade Hexane (FGH/PGH)
FGH/PGH technology has been licensed to HMEL, Bhatinda refinery and a unit of 20,000 MTPA capacity (Figure 7) has been commissioned successfully in May 2012, producing product with benzene content of <100 ppmv from feed benzene of 2.0-2.5 vol%.

Needle Coke
Needle Coke is a high value petroleum coke used for manufacturing graphite electrodes of very low Coefficient of Thermal Expansion (CTE) for the electric arc furnaces in the steel industry. The technology developed by IndianOil R&D has been successfully demonstrated in two refineries employing existing hardware for conventional Delayed Coking and premium quality of coke with CTE. Study on the feasibility of setting up a Dedicated Needle Coke Plant in one of the IndianOil refinery through sourcing of feed from nearby refineries is currently in progress aiming towards reduction of imports of high value Needle coke.

LPG Deasphalting
Heavier crude oil generates as high as 25% vacuum residue (VR), therefore, VR upgradation is crucial for GRM improvement. Deasphalting of VR is emerging as better option compared to delayed coker as Deasphalted Oil (DAO) can be further upgraded in secondary processes like FCC and hydrocracker.

Conventional deasphalting process employs propane as solvent, which
IndianOil - R&D: Expanding Horizons

IndianOil, the India’s flagship national oil company, way back in 1972 realized the importance of Innovation and set up the corporate Research and Development Centre at Faridabad, with the prime objective to Indigenize lubricant technology for import substitution & to meet the strategic needs of defence. Along the journey, Innovation – one of the cornerstones of our corporate Vision, is playing a significant role in shaping our past, present and future. With an eye on emerging as a “globally admired company’, IndianOil continues to foster research, development & deployment of technologies. Thus, in a relatively short span since 1972, IndianOil R&D Centre has emerged as one of the well recognized research institutes in this part of the world.

IndianOil – R&D has now reached a stage when technologies produced in-house are amply proven and globally recognized. In the year 2012–13, a record 52 patents were filed – one per week on an average – which reflects in ample measure the innovative zeal and commitment of Team R&D to corporate business. Our current patent portfolio of 262 Indian and international patents speaks volumes of our commitment to develop new innovative technology solutions for the growth of our company. We believe that our thrust on innovation is not only providing competitive advantage but also helping in the growth of our company.

Based on the IndianOil R&D developed INDAdaptG technology for desulphurization of gasoline, the foundation stone of its demonstration unit was laid by the Hon’ble Governor of Assam at Guwahati Refinery early 2013. The ongoing 4 MMTPA Indmax unit, based on our in-house technology, is shaping up well at Paradip Refinery. We have also licensed our catalysts and additives which will generate royalties for IndianOil in times to come.

Lubricant technology continued to pay rich dividends in terms of new generation product development resulting in many OEM approvals that included Nissan Motors, Japan, which granted this approval for the first time to an Indian lubricant manufacturer after intensive joint work. In conjunction with SAIL R&D, we developed roll bite lubrication system which helped us in garnering hot rolling oil business in steel plants. Ultra low viscosity oil, developed by us, won OEM approval from Maruti Suzuki.

Recent R&D efforts in the field of Petrochemical and Polymers have given rich dividends to our corporation with continued technical support to our manufacturing and marketing operation leading to greater acceptability of our polymer grades. IndianOil R&D’s joint initiatives with BARC, Mumbai have resulted in the development of 12”, 14”, 18” and 24” size of IPIG tools. Using these indigenous tools and technology, more than 2000 Kms of pipelines sections of IOCL pipeline as well as other Oil companies have been successfully inspected.

In the area of Biotechnology, IndianOil R&D has developed expertise and knowledge base for solving the critical scientific and technical problems and devising new and alternate bio–assisted products and processes to add value to our existing and future business operations. In order to leverage Biotechnology for energy research, we have recently set up a DBT–IOC Bio–Energy Research Centre to undertake R&D in the areas of lignocellulosic bio–mass to ethanol, algal based biofuels and bio–hydrogen etc.

Similarly, at IOC–R&D, Nanotechnology has evolved as a frontier area of research & development with a focus to develop commercial / industrial applications. Applications in energy sector, especially relating to fuels and lubricant formulations and catalyst/additives etc by adopting nanotechnology methodologies are being attempted.

In addition to the above developments in our core business areas, we continued to cover important ground in alternative energy in keeping with our corporate vision to emerge as the Energy of India. We recently commissioned India’s first integrated ligno–cellulosic biomass–to–ethanol pilot plant in association with the National Renewable Energy Laboratory of USA. Further, an agreement with L&T has been signed for production of gasifiers based on our patented integrated gasification concept. IndianOil has joined the consortium on National Mission on Clean Coal Technologies (NMCCCT) under Govt. of India for collaborative research in gasification along with DRDO, CII, L&T and Thermax. We have also successfully developed and commercialized a technology to co–process non–edible vegetable oil in the existing Diesel Hydrotreating (DHT) units of a petroleum refinery. This is the first time in India when Jatropha oil has been used for co–processing in a petroleum refinery. We have also entered into Solar Research area and have drawn up comprehensive Master–plan for R&D Activities in Solar Energy, particularly in areas like Solar Hydrogen, Solar Thermal & Solar Photovoltaics, etc.

With a view to consolidate research in renewable and other alternative energy areas at a single location, we plan to set up a separate centre – “IndianOil Centre for Alternative and Renewable Energy” (i–CARE).
Indian Oil: India’s flagship national oil company. Fostering research, development and deployment of cutting edge technologies. Pursuing research in alternative energy and cleaner technologies. Developing competencies that are amply proven and globally recognized. Patent portfolio includes 271 Indian and international patents.

**Our Patent Portfolio**

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<tr>
<th>Country</th>
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<tr>
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<td>Total</td>
<td>271</td>
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- Patents filed (since 1972) - 458
- Patents applications filed in 2012-13 - 52
- Patents applications filed in 2013-14 - 24 (Till 30.11.2013)

IndianOil’s R&D Centre – one of the country’s foremost commercial centres of research excellence. Playing a key role in developing economical, environmentally and socially responsible technology solutions. Honing IndianOil’s commitment to be future-ready through innovation.

**Key Research Areas**
- Refining Technology
- Lubricant Technology
- Petrochemicals & Polymers
- Fuel Additives
- Bio Technology
- Nano Technology
- Alternative Energy

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produces high quality DAO suitable for LOBS but with lower yield. IndianOil R&D developed dual mode LPG deasphalting process provides the flexibility of producing DAO, meeting LOBS specification as well as opportunity to maximize DAO quantity for upgrading through secondary processing only by change in operating conditions. DAO yield is found to increase by 7% in the RFCC mode without any change in hardware at IOCL Haldia Refinery and also RFCC mode asphalt, being heavier than that of LOBS mode, can be used for production of bitumen meeting export grade specification. This novel process is patented in India and PCT application has already been published.

### Synergistic Simultaneous Cracking

IndianOil R&D has developed another novel process on FCC platform for simultaneous cracking both lighter and heavier hydrocarbon streams in a single unit with synergy in heat integration. The process employs two reaction zones with single catalyst system, precisely designed to crack both lighter and heavier feedstock’s under tailor-made optimized process conditions. Besides reducing the capital cost significantly, the process offers wide flexibility in terms of feed and also very high product selectivity for light olefins as petrochemical feedstock, especially propylene and ethylene.

Considering the demand gap in Propylene and lower propylene to ethylene ratio in Ethylene cracker, the process is envisaged to be in great demand due to its ability of converting surplus low value feedstock to valuable products at lower cost.

### Dimerisation Technology

#### Low PAH rubber process oil

Low PAH rubber process oil is a requirement for export bound tyre industry wherein PAH content should be <10 ppm without compromising aromatics content. An innovative process of production of low PAH rubber process oil has been developed by optimizing vacuum distillation deasphalting and extraction units. Field trials have also been conducted at various tyre manufacturing industry. A process patent is filed in India and also published by PCT.

### Co-processing of Non-edible vegetable oil

Co-processing of vegetable oil in refinery is found as a better option than biodiesel as additional infrastructure as well as methanol are not required and does not produce byproduct, and above all can be transported in petroleum pipeline unlike biodiesel. IndianOil R&D has developed technology for co-processing of non-edible vegetable oil in DHDS/DHDT unit. As co-processing requires removal of metals from oils, de-metallization and de-gumming technology has also been developed and patented.

The technology has been demonstrated in a hydrodesulfurization unit at CPCL, Manali refinery by processing 6.5% Jatropha oil in diesel feed. Jatropha oil was pre-treated for de-metallization (<5 ppm) and de-gumming. Considerable energy saving was achieved due to lowering of Reactor inlet temperature by 10°C and product cetane number improved by ~2.0 units.

### Catalyst Research

Advances in catalysts will continue to play a dominant role in shaping the evolution of technologies for the oil industry. IndianOil R&D has been in the forefront for developing innovative catalyst systems in the country, like Lotus series FCC catalyst, i-MAX series ZSM-5 additives, high active INDICAT-DH-IV series DHDT catalyst, metal passivator additive, those are proven commercially and licensed for commercial offering on royalty sharing.

Following are some recent advancements/initiatives taken by IndianOil R&D:

- Keeping in view of the limitations of currently available FCC catalyst/additives to produce iso-butylene beyond 34%, a unique additive formulation has developed that can enhance the iso-butylene selectivity to over 40%.
- A novel CO promoter additive developed through an environment friendly process having CO conversion above 90%.
- New series of DHDT catalyst INDICAT-DH-V developed using low density carrier with improved dispersion.
- A novel additive capable of reducing the coke by over 1 wt% in FCC
Integrity & Reliability Assessment

IndianOil R&D has developed expertise for providing vital technical assistance through systematic on site and laboratory investigations to address the need for:

a) Fitness for service assessment,
b) Remaining life assessment of high temperature components,
c) Advanced Non destructive testing for equipment health assessment as well as process optimization / troubleshooting

d) Corrosion prediction and mitigation.

The centre is equipped with state-of-the-art facilities such as Accelerated stress rupture test machines, instrumented impact tester, servo hydraulic UTM etc. The life assessment methodologies are being developed for various damage mechanisms encountered in refining. Through extensive research work, a technology has been established for estimation of mechanical properties of materials through testing of miniature samples obtained from in service components (Figure 8 and 9). This will pave the way for Pseudo non destructive assessment of equipment health without cutting and retrofitting requirements thereby avoiding extended shutdowns. Development of component specific automated NDT tools for remaining life assessment is being pursued in collaboration with other centers of excellence such as NML, Jamshedpur, IIT Madras etc.

Pipeline Inspection & Transportation

Instrumented Pipeline Inspection gauges (IPIG) are devices used for inline inspection of long distance buried pipelines for their health assessment and reliability. Inline inspection helps in identifying the locations of potential failure, residual strength of pipelines and efficacy of corrosion internal/external corrosion mitigation programmes.

IndianOil R&D’s joint initiatives with BARC, Mumbai have resulted in the development of 12”, 14”, 18” and 24” size of IPIG tools (Figure 10). The design specification of these indigenously developed tools is at par with that of international tools. Also, through collaborative efforts with IIT Madras, automated software for quick and accurate data analysis of the extensive IPIG data has been made. Using these indigenous tools and technology, more than 2000 Kms of pipelines sections of IOCL pipeline as well as other Oil companies have been successfully inspected and the vulnerable corrosion locations identified by the inspection have also been physically verified (Figure 11). At present, IOCL has planned inspection of 2500 kms of its own pipelines using these indigenous tools. Similar services are being provided to other Oil companies as well. The technology is currently available for licensing.

With the changing demography of crude sourcing, there is an emerging need for transportation of opportunity crudes that are heavy/viscous or waxy. IndianOil R&D has developed the methodology for identification of
pumping feasibility and constraints of transportation of such crudes in existing pipeline infrastructure through rheological evaluation and simulation. Using this methodology, the blending strategy for pumping waxy Mangla crude to inland refineries has been studied and optimum blends have been suggested considering the pipeline terrains and the seasonal soil temperature variations.

**Lubricant Technology**

IndianOil R&D Centre plays a pivotal role in satisfying the diverse lubrication needs of entire gamut of Indian industries covering sectors such as automotive, railways, steel, power generation etc., in addition to the strategic needs of Indian defence services. The SERVO product line of 4000 lubricant formulations covering 800 brands is widened each year with innovative, high performance, eco-friendly and energy efficient products (Figure 12). Commensurate with the higher growth trajectory of Indian industry in the last few years, special efforts were undertaken by IndianOil R&D because of which, SERVO could not only maintain its market leadership domestically but also spread its tentacles in 17 overseas destinations. Customer satisfaction and product differentiation have been the watchwords that guided Indian Oil’s research efforts. Capability in designing of lubricants through component approach that uses the basic understanding of the chemistries to built-up an appropriate synergy for a specific application and/or a combination of applications has resulted in formulating of state-of-the-art railroad and marine lubricants.

Some of the recent technological advancement in this area are detailed below:

**Automotive Lubricants**

Automotive lubricants account for ~60% of the lube market segment. A recognizable shift towards high performance and high-end product line has been the hallmark of the automotive oils development programs in recent years. The superbrand status of Servo Brand primarily comes through the automotive lube segment attributes. The brand strength is consolidated through brand approval from major OEMs.

With a view to achieve fuel efficiency, major car manufacturers are shifting to low viscosity grade engine oils. However this has added challenges for India specific operations. In this series, ultra low viscosity Passenger Car Motor Oil PCMO Servo XEE SL 0W-20 has been approved by Maruti Suzuki India Ltd (MSIL) after an exhaustive evaluation protocol and final validation test program.
at Suzuki Motors Corporation (SMC) Japan. Similarly, new generation passenger car motor oil (PCMO) Servo XEE SM 10W-30 was approved by NISSAN Motors after rigorous endurance tests at Nissan Motors, Japan followed by field trials. Approval for products Servo Technic ol SAE 5W-30 and Servo Technic ol Plus 5W-30 from Volkswagen (VW), Germany has put IndianOil into an enviable position for Service Fill business segment for this European major for not only Volkswagen but also Skoda and the high end Audi cars. In the Commercial Vehicle Segment, Servo Pride ALT Plus 15W40 has been credited with an approval from Ashok Leyland for a drain interval of 80,000 kms, thus marking the advent of a new segment of the product line. Servo Pride Supreme Plus was approved by Tata Cummins, both for Factory fill and Service fill for Cummins B series BS III Mechanical Engines. Re-approval of Volvo VDS-3 on Servo Pride XL 15W-40 strengthened the brand position has been strengthened by not only the re-approval by Volvo Sweden for VDS-3 category but also by additional MACK EO-N and Renault VI RLD-2 approvals.

Driveline lubricants has also witnessed an upward movement in specification and approach for fuel efficiency and long life both for transmissions and axles resulting in customized product line based on conventional group I to the premium group IV base stocks with appropriate performance additive systems. Successful performance of the premium transmission oil “Servo Gear MTXL 80W90 for future VECV (Volvo Eicher Commercial Vehicles) segment was obtained. This would help IndianOil not only the current but also future business consolidation.

In the railroad oil segment, fundamental approval of Servo Magnum RR 510, Generation 6 lubricating oil from General Electric Company USA for use in GE Diesel Engine would consolidate IndianOil’s position with this major Locomotive manufacturer.

Roll Bite Lubricant (RBL) for hot steel rolling mills
In a hot steel rolling mill, steel sheets are deformed plastically at elevated temperature (>850°C) using two or more rotating rolls for finishing them to the desired thickness, shape and metallurgical properties. Due to arduous tribological condition at roll bite, roll wear out at faster pace and necessitate their frequent change causing loss of production besides their reduced life. The roll bite is also having high friction level, which increases roll force and energy consumption in the rolling mill. In order to overcome these issues, new Roll Bite Lubricant (RBL), “Servosteelol H2” was designed to achieve reduction in friction at roll bite during hot rolling of steel. This oil was evaluated in “RBL system (Figure 13)”, which was designed by SAIL RDCIS, in a commercial hot rolling mill at Rourkela Steel Plant. New oil had showed reduction in average roll force (5-10%), in specific power consumption (6-8%), in roll wear (~50%) and increase in campaign size of rolling (~20%). In addition to the above, there is remarkable improvement in surface of work roll (retention of original finish) after completing one rolling campaign (Figure 14).

High performance greases
Sugar industry is traditionally using bitumen based product for lubrication of journal bearings of crusher rollers. New non-bituminous and environment friendly, Servogem Super JB2 grease was developed and field trial conducted at M/s Dnyanayogi Shri Shivakumar Swamiji Sugars ltd, Bijapur and M/s Indian Cane Power Ltd., Karnataka. This product had given extremely good performance and reduced consumption of lubricant to 1/8th of in use bitumen based lubricant. The use of this newly developed product will change the scenario of lubrication in sugar industry in near future.

A new class of water resistant grease, Servogrease TPMG was developed with superior extreme pressure, corrosion resistance and exceptional mechanical stability. This
grease is specially developed for steel and paper industries where water ingress in bearings is unavoidable. The use of this grease in these applications being planned for performance evaluation in steel plants w.r.t., improved lubrication, reduction in bearing failures and decrease in frequency of re-lubrication. The department, in the short time since inception in 2010, has been able to create impact in the Polyolefin field. Technological pathway has been laid for in-house Polyolefin catalyst development including development of REACH compliant Internal Donor technology. Ziegler-Natta class of catalysts have been developed for Polypropylene and Polyethylene with achievement of targeted activity, bulk density, hydrogen & donor response and comonomer incorporation (Figure 17). The scientific endeavor has been provided Intellectual Property Protection and four patents have been filed.

Fuel Additives

Over the years, IndianOil R&D has indigenously developed and commercialized various types of fuel additives, usage of which results in enhanced performance characteristics, reduced emission, cost effectiveness, foreign exchange savings besides better mileage etc.

The IndianOil R&D technology basket in the area of fuel additives is depicted in Figure 15.

Petrochemicals & Polymers areas – Technology Development for Catalysts and Niche Products (Figure 16).

The department has developed Ultra high molecular weight Poly(α-olefins) which find extensive application as Drag Reducing Agents (DRA) in pipe line transportation. Process and catalysts has been developed for synthesizing Poly(α-olefins) having a molecular weight of about 20 Million Dalton (Figure 18).

Extensive bench marking studies have helped IndianOil to develop few new grades which were not in the original grade slate of the licensors e.g. HD Tarpauline grade, HD Mono filament grade and HD large blow molding PE grade for 250 L drums (Figure 19)

Industrial Biotechnology

Biotechnology is the science of future and its potential in petroleum and energy sector is vigorously explored worldwide. As a proactive approach IndianOil R&D initiated research in this emerging field during 1993. Since then, IndianOil R&D has developed expertise and knowledge base for solving the critical scientific and technical problems and devising new and alternate bio-assisted products and processes to add value to our existing and future business operations. Some of the noticeable developments are:

‘OiliVorous’ Technology for Bioremediation of Oily Sludge

The environmentally sound disposal of petroleum waste oils/sludge has been the problematic area for oil industry since long. IndianOil R&D in association with TERI has developed a microbial blend consisting of natural isolates for bioremediation of oily sludge. The development of ‘OiliVorous’ bioremediation technology has provided a cost-effective route for bioremediation of petroleum wastes. The ‘OiliVorous’ technology has now been fully commercialized and even has been found suitable for bioremediation of oil spills in the sea.

Bio-inoculants for Refinery ETPs

To comply with the new standards notified by the Government oil and grease content (5 ppm from 10 ppm)
in effluent discharge from refineries, a specialized bacterial combination and the process of its manufacture in large scale have been developed. This microbial bio-inoculant helps in reducing O&G content in refinery ETP’s without any revamping/modification and has emerged as excellent import substitute. These are already in use in IOC Refineries (Figure 21).

Microbiologically Influenced Corrosion (MIC)
Corrosion leads to staggering losses to oil industry assets. The microbiologically influenced corrosion (MIC) is localized corrosion resulting from presence and activities of microorganisms including bacteria and fungi and encountered in oil and gas pipelines, tank bottoms, and cooling water systems etc. IndianOil R&D has developed capability for detection, monitoring and mitigation of microbial corrosion problems in IOCL refineries and pipelines.

Carbon Dioxide Capture and Utilization Research:
The rising concentration of carbon dioxide (CO$_2$) has led to global warming and several undesirable environmental consequences. As a sustainable solution, R&D on CO$_2$ capture and its utilization as feedstock for value added products is essential and Indian Oil (R&D) has created a dedicated “Centre for Excellence of CO$_2$ Utilization” to undertake research in this area. The major research projects in this area include enzymatic CO$_2$ capture and electrobiocatalysed conversion of CO$_2$ to fuels and chemicals.

Microalgae Based CO$_2$ Utilization
Microalgae are considered as a potential option for CO$_2$ utilization and its conversion to value added products. Extensive laboratory studies for strain development and growth condition optimization has been carried out. Recently, a demonstration facility for one of the power company has been created by IOC-R&D for cultivation of microalgae and utilization of power plant flue gases at its Faridabad Gas Power plant. Under this facility, two open raceway ponds each of 12 & 35 Sq Meter have been constructed and cultivation of in-house algal strains using flue gas from the power plant is underway (Figure 20).

Nanotechnology research
Over past few years, nanotechnology has evolved as a frontier area of research & development with commercial / industrial applications. Applications in energy sector, especially relating to fuels and lubricant formulations by adopting nanotechnology methodologies are being attempted by IOCL R&D Centre. The department has acquired capabilities of doing small molecule surface modification and preparation of stable nanodispersions in both polar & nonpolar hydrocarbon matrix. The department is equipped with facilities for synthesis of the active nanomaterials at bench/pilot scale, specialized characterization and evaluation facilities for nanomaterials & nanodispersions. All the present activities are aimed at applications in many areas of operations for efficiency improvement, better heat management, new and improved processes and products.

A simultaneous functionalization and reduction route to prepare stable dispersion of reduced graphene oxide (rGO) from graphene oxide (GO) has been established with Diethanol amine (DEA). Thermal diffusivity studies of such dispersions in water suggest nearly 60% increase in thermal conductivity of the dispersion in comparison to...
Multi layered graphene (MLG) dispersion has been prepared in hydrocarbon oil medium in a mechano-chemical process. Thermal conductivity of the formulated lubricant composition with MLG dispersion has shown higher thermal conductivity and comparable tribological properties at relatively lower dose.

The multi-metal nanodispersion (MMD) developed by IOC-R&D acts as vanadium incapacitator in fuel oil; and also in-situ neutralizes the formed acidic components. Removal of “S” content from the flue gas reduces the acid dew point; plant operator can run the boiler at lower temperature thus resulting in energy saving to the corporation. Further the developed nanodispersion promises better combustion which lead to overall fuel efficiency.

**Alternative and Renewable Energy Sources**

**DBT- IOC Centre for Advanced Bio-Energy Research**

The Advanced Bioenergy Research Centre, located at IndianOil-R&D Campus, has been funded equally and jointly by Department of Biotechnology (DBT), Government of India and Indian Oil Corporation Limited (Figure 21). The Centre has made a significant progress, addressing second and third generation biofuel in the last one and half years since its inception.

**Cellulosic ethanol pilot plant**

Pretreatment removes biomass recal-

citrant and destruct the biomass cell wall. For the pretreatment of biomass a cellulosic ethanol pilot plant has been installed and commissioned (Figure 22). This facility was built up with the help of National Renewable Energy Laboratory, Department of Energy, USA and is the first of its kind in India which will help to generate data for commercialization of cellulosic ethanol. This plant is capable of handling multiple feed stock which includes forestry waste, agricultural residue with the processing capacity of 250 Kg/day of biomass on bone dry basis. More than fifty batches of pretreatment on wheat straw, rice straw have been conducted successfully and the conditions like pressure, temperature, residence time and catalyst concentration has been optimized for scale-up. Further studies are being carried out using other feed stocks which are non-feed and non-fodder in nature like cotton stalk, jatropha prunings.

**Steam explosion digester**

Steam explosion is one of the pretreatment methodologies based on the explosion of biomass from high pressure to atmospheric pressure leading to destruction of biomass cell wall matrix making the biomass amenable for enzymatic hydrolysis. For this purpose, 10L capacity of steam explosion digester has been designed in-house, installed and commissioned (Figure 23). This pilot plant is equipped with digester attached with cyclone collector 200 L and shock absorber. Number of experiments have been carried out using hydrothermal varying temperature and residence time. Impact of various acid catalysts on the pretreatment of biomass has also been studied. This facility has proven a potent tool for pretreatment of biomass which requires much lesser amount of catalyst than cellulosic ethanol pilot plant, whereas, temperature requirement in the steam explosion is slightly higher than the cellulosic ethanol pilot plant.

Other areas of research focused at DBT-IOC Centre are:

- Characterization of biomass.
- Saccharification enzyme development
- Fermentation
• Algal biofuel and Gas Fermentation
• Life cycle assessment

Bio-Fuels
In Bio-fuels, besides spearheading commercialization of Ethanol-Blended Petrol i.e E5 & E10 in the country, IndianOil has been in the forefront of technology development for Bio-diesel production from various edible and non-edible oils and its application in vehicles.

IOC R&D is also pursuing research activities in area of application of biojet fuel in aviation sector for net reduction of aviation emissions. In this regard, collaborative project with various consortium partners from India and Canada is being carried out to obtain approval from ASTM. IOC R&D has also developed a novel process for degumming and demetallation of non edible vegetable oils for processing to biojet and high cetane diesel.

Further, IndianOil R&D has also explored production of renewable bio-oil/pyrolysis oil by pyrolysis (thermochemical cracking) of biomass. The application of bio-oil thus produced in fuel oil and DCU has also been developed to upgrade bio-oil for refinery application.

Expanding the Horizon
In future due to environmental benefits, efficiency and feed flexibility, gasification is likely to be integrated with refinery operation. Besides, upgradation of Petcoke, residues, it also provides flexibility to diversify refinery input utilizing bio-derived feedstocks and also upgradation of shale oil.

Gasification
Gasification is gaining renewed interest due to the benefit of higher efficiency, flexibility in processing variety of feeds like municipality waste, biomass, refinery residues/petcoke, coal etc and environment friendliness. The syn-gas produced during gasification could be converted to hydrogen, power, liquid fuels and chemicals/urea etc. Due to these advantages, gasification is a technology option for producing energy from sources other than normal fossil fuels and likely to be integrated with petroleum refining.

Keeping this in view, research has been initiated in gasification of coal, petcoke, biomass, petroleum residue etc. A pilot plant facility of 1-2 kg/hr based on fluidized bed gasification has been installed (Figure 24). IndianOil R&D has developed a novel concept on integrated Gasification for optimal Gasifier design by segregation of feedstock according to reactivity and ash content. Extensive kinetic data has been generated with various coal samples for carrying out basic design of Gasification prototype. IndianOil R&D has entered into MoC with M/s L&T for development of gasification technology based on the Integrated Gasification Concept. IndianOil R&D is also associating with National mission on Clean Coal Technologies by the Government of India.

Hydrogen-CNG
IndianOil R&D has set up a demonstration unit (Figure 25) for in-house developed single step compact reforming process for production of Hydrogen-CNG mixture in a single step from Natural Gas. Scale up data has been generated and Basic engineering and cost estimate has been prepared along with M/s L&T for 250 Nm3/hr H-CNG commercial unit for setting up at R.O. of CNG retailer.
Solar Energy Research

IOC-R&D has drawn up a comprehensive Master-plan for “R&D Activities in Solar Energy” which was approved in October 2010. The master plan is synergistic with IOC’s existing & future path of progression well in line with global oil industry directions. Short, medium & long range goals and objectives in areas of Solar Hydrogen, Solar Thermal & Solar Photovoltaics, revolving around three-pronged R&D approach of infrastructure creation & expertise development; product development & technology evaluation; and areas of basic research has been envisaged.

Though, IOC-R&D Solar Energy Master-plan envisages efforts in PV as well as in solar thermal technologies, special focus has been laid on solar thermal or CSP technologies owing to many synergistic areas common with the company’s present strength. Further, within Indian context, CSP has several advantages over PV by having higher efficiencies, lower investment costs, proven dispatch ability, inherent thermal storage capacity that enables power generation during cloud cover or after sunset and a better hybrid capability. The main objective of IOC-R&D’s efforts in solar thermal energy area is to make it a profitable business option of IOCL by development, deployment and marketing of efficient, market competitive and low cost solar products & processes worldwide.

Some of the activities envisaged as part of this is development of heat transfer fluid (HTF), Solar thermal storage materials/concepts, Solar collector & reflector research, Solar thermal electricity generation technologies, development of solar based products/processes such as novel heat storage concepts & materials, anti-reflective/anti-dust/super hydrophobic coatings, desalination plants, etc and Solar hydrogen generation. Detailed research feasibility plan has been prepared by M/s. Fraunhofer Institute, Germany.

IndianOil-Centre for Alternative & Renewable Energy (i-CARE) at Manesar

It is proposed to shift the alternative and renewable energy (A&RE) research activities from present location of IOC-R&D at Faridabad to an alternate location and set-up a dedicated IndianOil Centre for Alternative & Renewable Energy (i-CARE). The main objective of i-CARE would be; working towards energy security, sustainable development, reducing carbon footprint, alternative business and revenue generation. i-CARE will also catalyze as well as provide technical support to the corporate business plans in AE&RE areas. i-CARE shall be taking up studies in the areas like; bio-energy, pyrolysis, hydrogen & fuel cell, gasification, solar energy etc.

Main objectives of i-CARE are:

- Energy security of the country
- Development of sustainable energy sources & environmental protection
- Improving efficiency of AE&RE technologies, processes and products
- Generating revenue for the company through newer businesses
- Sustained leadership and image of the company

Intellectual Property Rights (IPR)

In order to support the prevailing innovative culture in IOCL, IOCL also fol-
lows a robust system of identification & capturing of innovation and their protection through filing patent etc. As of now, IOCL has filed more than 454 patent applications and last year (2012-13) was remarkable when IOCL achieved filing of 52 patents i.e. filing of a patent every week, which is highest patent filing rate by any Oil PSUs in the country.

Over the next 5 years, it is expected to increase patent filing rate by IOCL to more than 100 patents per year. Besides filing of patents and protecting intellectual property, commercialization of the potential patents, either for company’s own internal consumption or for outside commercialization is equally important. Sustained efforts are being made by its scientists to evaluate, demonstrate and deploy the developed technologies within & outside company. With continuous efforts, today; more than 45 technologies have already been commercialized till date from its patent portfolio. The success rate of commercialization is quite high and it is surpassing national average commercialization rate of the patents.

Further, in order to encourage the innovations, IndianOil implemented an IndianOil Intellectual Property Right (IPR) Incentive Scheme effective FY 2012-13 for the inventors. This incentive Scheme of IOCL has been intended to reflect a fair credit and reward approach to motivate employees to invent/innovate and enhance the intellectual capital of the corporation.

The success rate of commercialization is quite high and it is surpassing national average commercialization rate of the patents.

IndianOil-R&D management strongly believe that in today’s competitive world, collaboration is the key to success and has strong faith in enhancing Industry-Academia interaction, wherein expertise available in Academic Institutions and industrial experience available in the Industry can be leveraged to develop some path breaking technologies.

In line with the above philosophy, IndianOil-R&D has number of collaborations with various academic institutions and research labs. MOUs have been signed with prestigious institutes to collaborate for promotion of education, research and innovation and provide model for academia-industry partnership for directing Research and Development on projects which are relevant to the industry and have high prospects of commercialization. In order to attract the best talent, IndianOil-R&D offers a fellowship amount which is 25% more than the standard CSIR/DST/UGC rates under the IndianOil Research fellowship Scheme. This scheme aims to provide an opportunity to Research Scholar for undertaking their Ph.D. research works on a project of mutual interest.

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**National and International Awards (Recent)**

In recognition for development and commercialization of many novel products and processes, IndianOil-R&D has received number of National and International awards. Some of the recent ones are:

- The World Petroleum Congress (WPC) Excellence Award-2008 in the technical development category for “Hydroprocessing Technology for Green Fuels”.
- Petrofed Innovator of The Year- Team Award Diesel MFA (2009) and for DHDT catalyst (2010)
- CSIR Award for development of environment friendly, ‘Servo Agrospray Oil’ for agricultural crops under S&T Innovations for Rural Development category (Conferring by Prime Minister of India)
- Technology Award-2010 from De-
department of Science and Technology (DST), Govt. of India for successful commercialization of indigenous technology of multifunctional additives.

- Hart Energy Global Award: Refining & Energy Company of the Year award (first time to an R&D Organization of a Company)
- SCOPE Meritorious Award for the year 2010-11 in the category of “R&D, Technology Development & Innovation”
- IAHE Rudolf A. Erren Award to Dr. R.K. Malhotra, Director (R&D), IndianOil, for contributions in Hydrogen Research
- “Global Excellence Award” to Dr. R.K. Malhotra, Director (R&D), IndianOil, for vision, leadership, outstanding contribution and for demonstrating excellence in Renewable energy sector.
- “FICCI Chemical and petrochemical Awards-2013” in “Process Innovator of the year in Petrochemicals” category for ‘Development and Commercialization of Food Grade Hexane Technology’.
- Petrofed Award 2012 in “Innovator of the Year-Team”-Special Commendation Award category, for Development and Commercialization of Diesel Hydrotreating and Light Naphtha Isomerization Technologies for Production of Clean Transportation Fuel’ delivered in June, 2013.

Figure 24: Fluidized bed gasification pilot plant

Figure 25: H-CNG Demonstration Unit at IndianOil R&D
Continuing Innovation at CSIR-Indian Institute of Petroleum: A Preview

M O Garg, Director IIIP, CSIR
Email: director@iip.res.in

ABSTRACT

The current hydrocarbon value chain – from oil exploration, production refining to marketing has become a highly integrated process and is being increasingly expected to deliver fuels at reasonable cost to drive economies. The industry is currently faced with several challenges and undoubtedly is expected to face unprecedented challenges in future. None the less, it contributes a significant portion to the GDP of a nation.

The challenges, which this industry is currently facing and is likely to face, are unstable crude prices, significant price differential between light and heavy crudes, shifting product demands, reducing fuel oil uptake etc. In addition, there is a moving target for purity of petroleum products and need to synergistically utilize other energy sources, particularly, bio-resources.
The future refineries would have to be necessarily smart in terms of understanding these challenges and to be able to adopt their designs and operations to take advantage of the above. For example, high conversion processes would be needed to take advantage of low price of heavy crudes, maximize energy efficiency, minimize CO2 footprint and thus encourage use of hydrogen free technologies. There is also a need to synergistically integrate current operations with petrochemical production while allowing for the high volatility of this market.

Lastly, in any refining operation, there are several by-product streams, which are considered to be of low value. These streams need to be looked at for value addition as they can bring significant impact to the refinery bottom line.

**Challenges Faced by Hydrocarbon Sector**

Global energy demand currently is around 225 million barrels oil equivalent per day (Fig.-1), with an average annual increase during the last 25 years of about 1.5 %. At a global level, crude meets about a third of this demand, with natural gas and coal satisfying 50 % in about equal proportion, and the rest being met by biomass, nuclear, hydroelectric, wind and solar energy. The general trend for product demand is significant growth of the overall transportation fuel market together with a shrinkage of the gasoline market in parallel with a remarkable increase in the demand for distillates particularly for automotive diesel and reduction in consumption of heavy fuel oil. As far as product specifications are concerned, the petroleum refining industry is experiencing a sea change in production environment since last decade. Due to increased environmental awareness the product specifications as well as emission standards from refinery are becoming more and more stringent and refineries are also becoming conscious towards emissions of green house gases. On the other hand the crude quality is deteriorating particularly with respect to sulphur and API gravity. Thus to meet the low sulphur specifications there is increasing dependence on hydrogen which in turn is making the refining more and more expensive and the margins will not only depend upon the crude price but also be governed by hydrogen production price. With the existing infrastructure, the refineries are taking efforts to meet these new product specifications which needs substantial investment for up gradation. Unfortunately, the returns on these investments have generally been low, or sometimes negative.

Coming to future refining scenario, it is envisaged that over the next 20-30 years, competitive pressures and changing societal requirements will dramatically reshape the refinery. It will become more like a chemical plant. This refinery conversion will require development of innovative technologies and more in-depth knowledge of the existing technologies. For each application, several alternative technologies are available; each having advantage or disadvantage over other. It is very difficult to find a single optimum solution for all the refineries. Moreover, international prices of crude and products, the tariff structures and the domestic demand/supply balance are outside the control of the Indian refiner. The refiner can only improve his competitiveness and margins by optimizing the other factors which are under his control. To meet the above challenges continuous efforts are being made at CSIR-IIP to develop innovative technologies to be implemented in hydrocarbon sector. The key achievements are summarized below:

**Value Addition to the Refinery Streams**

Value addition is of paramount importance in the current context and it is therefore not surprising that refiners are looking at options to upgrade their product slates by optimal utilization of their existing assets. To survive in this competitive market refiners can also look at all possibilities of value additions to such streams. Few examples of such streams are presented in Table-1. Some examples of value addition to refinery streams are presented below:

Light naphtha cannot be blended in to the gasoline pool due to its low octane and high RVP values. This naphtha stream can be converted in to LPG and aromatic rich stream by using innovative technologies. One such technology is NTGG process which is jointly developed by CSIR-IIP and GAIL. Figure 2 shows the NTGG unit of GAIL Vaghodia, Gujrat. The typical product yields are 40% LPG and 45% superior quality gasoline blend stock with sulphur content less than 75 ppm and RON about 95.

Owing to its high aromatics content its cetane number is low whereas PAH and sulphur content are high. Upgradation of LCO by hydrotreating is a cost intensive option due to requirement of high hydrogen pressure as well as high hydrogen consumption. Recent studies carried out at CSIR-IIP indicated that use of aromatics extraction process to remove these aromatics is better option. In this scheme either neat LCO or LCO mixed with the SR gas oil is treated with selective solvents like sulpholane or NMP, The solvent being polar selectively extract aromatics without compromising much on yield. An improvement in about 20 cetane
units is observed with about 66% sulphur reduction. The aromatics extract obtained as a by product is a valuable feedstock for the production of 2, 6 Dimethyl napthalene.

Recently CSIR-IIP-EIL-HPCL have demonstrated on HPCL lube extraction unit, successful valorization of CLO into low aromatic raffinate for recycle as FCC feedstock and high Bureau of Mines Correlation Index (BMCI) extract for making Carbon Black Feed Stock (CBFS) at HPCL lube extraction unit (Figure 3).

To process off spec naphtha, one innovative approach is to extract pure aromatics and use raffinate as naphtha cracker feedstock. Although aromatic extraction technology exist for aromatic rich feedstocks with aromatic content more than 65% and napthenic content less than 2% such as reformate and hydrogenated pyrolysis gasoline(PG) whereas in case of off spec naphtha, the aromatic content is around 10-15%, and the napthenic content is more than 25%. The ratio of aromatics to napthenes (impurities) is 15 to 20, in the conventional feedstock such as reformate while in the naphtha cracker feedstock this ratio is less than 1. This makes the process to produce pure BTX from the said off spec naphtha highly challenging and needs innovations. Innovative process was developed at CSIR-IIP to tackle these challenges (Figure-4). In the proposed process, naphtha feed before going to cracker will be routed to extraction column wherein it will be contacted with polar selective solvent to extract pure aromatics. The raffinate (dearomatized naphtha) produced will now send to cracker as an improved feedstock due to its low (<3 wt.%) aromatic content. The recovery of pure aromatics from the extract phase can be carried out in the existing pyrolysis gasoline extraction unit as most of the naphtha crackers are already have their own dedicated aromatic extraction unit. The envisaged benefits of the technology are as follows:

- Feasibility of processing off grade naphtha with simultaneous production of pure aromatics.
- Increase in the capacity of existing naphtha cracker due to reduction of refractory aromatic compounds
- Decreased coke lay down in the furnace

**Use of alternative technologies for desulphurization and dearomatisation**

To meet an ever increasing demand of hydrogen in today’s refinery, effective management of expensive hydrogen resources is essential. One option to reduce hydrogen consumption in the refinery is to supplement the existing hydrotreating technologies with alternative technologies. The drawback with the hydroprocessing technologies are that they are cost intensive as well as operating cost is also high particularly for meeting stringent specifications with respect to sulphur & aromatics and also results in increasing emissions of green house gases eg. CO₂.

A novel vapor phase adsorptive desulphurization process has also been developed for sulphur removal from gasoline and diesel in the collaboration with SINTEF, Norway High throughput combinatorial screening technique was used for the screening of adsorbents and selection of the novel sulphur selective adsorbant. The adsorbants were also screened out and tested at Pressure Swing Adsorption Unit (Figure 5) for optimization of process

<table>
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<tr>
<th>Table 1: Maximizing Value Addition to Refinery Stream</th>
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<tr>
<td>FCC Offgas</td>
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<tr>
<td>FCC Olefins</td>
</tr>
<tr>
<td>Reformate</td>
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<tr>
<td>Naphtha</td>
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<td>Gas Oil</td>
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<td>FCC LCO</td>
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![Figure 2: NTGG unit of GAIL Vaghodia, Gujrat](image-url)
conditions. This technology has many salient features such as minimum octane loss for gasoline, sulphur can be removed to less than 30 ppm, hydrogen requirement is 6 times lower than the conventional hydrosulphurization process, significant lower operating pressure, unique feature of seamless process integration with existing hydrid-sulphurization facilities etc

**Synergistic Processing of Biodiesel and Bio-Jet Fuel**

Renewables are going to make up an increasing share of the future fuels pool. First generation biofuels, mostly bioethanol and fatty acid methyl esters (FAME) from ‘food’ crops, though raw material limited, were an important first step to creating a biofuels infrastructure. Second generation feedstocks, from ‘non-food’ sources, cellulosic waste, algal oils, and inedible-oils have the potential to make significant contributions. Refiners are well positioned to play a major role in the production of biofuels. It is necessary to identify and utilize processing, composition, and infrastructure synergies to leverage existing refining/transportation infrastructure to lower capital costs, minimize value chain disruptions, and reduce investment risk. Processing of bio-diesel in refineries can also be a rational approach as the refinery infrastructure can be used for the transesterification/hydrotreating process and the bio-diesel thus produced can be blended with the petroleum diesel to produce high quality diesel. The advantages of blending in the refinery are use of existing infrastructure and eliminating the possibilities of adulteration.

Majority of commercial processes currently used to produce biodiesel employ base and acid catalysed transesterification of vegetables and fats. Both base and acid catalysts are associated with several inherent problems. Free fatty acid (FFA) present in the vegetable oil / fat and moisture interfere with transesterification, deactivate the catalyst leading to loss of catalyst and biodiesel yield. FFA reacts with base catalyst to form soaps which leads to emulsions and foam. Due to emulsion the purification and separation of glycerin and biodiesel becomes difficult. CSIR-IIP has developed heterogeneous catalyst based continuous process for biodiesel which is free from these difficulties. Main Features of the process are followings.

- Flexibility for processing variety of vegetable oils separately or mixed. Tolerance of higher levels of free fatty acids. Requires no pretreatment or removal of FFA.
- Conversion of free fatty acids present in feed oils to biodiesel
- Tolerance of water in alcohol
- No emulsion or soap formation
- Catalyst is recycled when operated in batch mode and is not deactivated either with water or FFA.
- Biodiesel produced meets the standard specification (ASTM, European or proposed BIS).
- Glycerin produced is ~95% pure
- Process can be adapted to wide range of production capacities.
- The process is ecofriendly with almost zero effluents.

CSIR-IIP Dehradun has made a breakthrough by developing a catalyst and single step process for the production of biojet fuel from plant oil sources (Figure 6). The biojet fuel produced is a drop-in fuel and meeting most of the specification. The process can be well implemented in the current refinery infrastructure (hydrocracker unit) without any modification. Moreover the byproducts of the CSIR-IIP process are green gasoline, green diesel and this makes the process further more marketable.

In this process the catalyst is tailor made and the process conditions are so tuned that plant-oil triglycerides are hydrodeoxygenated, selectively hydrocracked and hydroisomerized to get the desired range of the products.

Catalyst life study by continuous plant operation is going on at CSIR-IIP. The catalyst can be regenerated and resulfided for reuse which makes the process more viable. Bulk production of the biojet fuel on existing pilot-plant is going on smoothly for real time engine
testing, 15 liters of biojet has already been supplied in two batches to IOCL and HPCL for further testing.

**Waste to Wealth**

Plastics have inherent advantages over competing materials like paper, glass, tin etc. and hence have been able to displace them from common use. The worldwide consumption of plastics is in excess of 300 MMT and is increasing at a rate of 10-12% annually consuming about 5-7% of fossil fuels for its production and processing. Polyolefinic plastics like polyethylene and polypropylene account for 65-70% of the total. Their increased consumption has also resulted in simultaneous generation of enormous amount of wastes. These wastes are obtained mainly from process industry, production industry and municipal solid wastes (MSW). Around 9-10% of the (MSW) consists of plastic materials and it is estimated that in India more than 10 thousands tonnes per day of plastic wastes are generated as part of MSW.

These plastics wastes being non-biodegradable are environmental hazards and pose a serious disposal problem. The present means of waste plastics disposal like mechanical recycling, landfilling, incineration etc have certain limitations and hence are not suitable for disposal of the this increasing amount of waste. Chemical recycling of waste plastics i.e the conversion of waste plastics to value added products in an environment friendly way has the potential to be a feasible solution for the utilization of waste plastics.

Since last decade intensive R & D efforts have been undertaken worldwide to develop an economically viable and environmentally friendly process for chemical recycling. Most of the processes developed worldwide up to now produce a type of plastic crude which requires further processing in refineries and blending with refinery streams and hence have not found wide acceptability. CSIR-IIP has developed a technology to convert the waste plastic in to fuels (Euro-III diesel and gasoline) and aromatic depending upon the requirement (Figure 7). The salient features of the technology are listed below:

- Exclusive production of either gasoline or diesel or aromatics along-with LPG
- Liquid fuel (gasoline and diesel) meeting standard fuel specifications (Euro III)
- Environment friendly process
- Scalable in batch and continuous mode
- All polyolefinic wastes, accounting for 65-70% of total plastic wastes, can be used
- 5 TPD demo plant is being set up

Used lube oil disposal problem can be tackle by its re-refining for its reuse. CSIR-IIP, Dehradun has developed NMP based technology which is offered to United Lube Oil Company (UNILUBE) Jubail Industrial City, Kingdom of Saudi Arabia to improve the color and color stability of used lube oil. In this process solvent extraction of used wide cut oil followed by its fractionation into light, medium and...
heavy base oils (LBO, MBO and HBO) showed improvement in color as well as stability in color for a period extending up to 6 months (Figure 8).

**CO2 capture and utilization**

Petroleum refining is an energy intensive process, and consequently contributes significantly to green house gases emissions. With the world refining capacity exceeding 85 million barrels per day (12.88 million tons/day), CO₂ emitting out from a refinery is approx. 5.0 million tons/day (i.e. almost 0.25 to 0.5 tons CO₂/ton of crude to be refined). Strict environmental regulations, increasing effects of green house gases and growing concerns of global warming have generated a strong need to estimate and reduce CO₂ emissions.

A novel technology based on zeolite type adsorbent has been developed for CO₂ recovery from Power plant flue gas in the collaboration NEERI, Nagpur, CSMCRI, Bhavnagar, and IIT, Mumbai. This technology provides CO₂ purities more than 90% with recoveries > 80%. Based on this technology, 100Kg/hr Pilot plant is coming up at NTPC.

Metal organic frameworks (MOF) which have high adsorption CO₂ capacity are being tested in the collaboration of SINTEF, Norway for PSA/VSA technology development for CO₂ recovery from flue gas. Moreover, CO₂ removal from Bio gas to improve its calorific value using the zeolite based adsorbents is also under progress in the collaboration with Monash University Australia.

A hindered amine based novel solvent (AGSL 69Abs) to be used in absorption processes for CO₂ capture from the flue gas has been developed by screening and equilibrium measurements of more than 90 solvents/blended solvents formulations. This solvent offers highly improved characteristics compared to the conventional MEA solvents. Higher rate of absorption, easy regeneration and high absorption capacity for this solvent are bound to decrease the investment and operating cost of the process for CO₂ recovery.

**Energy Conservation and Processes Improvement**

The key to maximizing energy efficiency is to capture and reuse waste heat within the processes and total sites, cutting the need for additional heating and cooling, thereby savings in hot and cold utilities. Pinch Analysis is a systematic procedure, based on fundamental thermodynamic principles (first and second law of thermodynamics), that guarantees optimum solution for energy conservation. Prime objectives of pinch analysis are to achieve financial saving and green environment by better process heat integration (Maximizing process-to-process heat recovery and reducing the external utility load).

In pinch analysis area, CSIR-IIP has got immense expertise and has already carried out a large number of projects in this area. Out of those, a list of major projects along with benefits achieved is given below.

**Studies on DME**

With the main objective of ‘Production of DME from small stranded NG reserves, or NG associated with oil production and its utilisation both in engines and domestic burners for cooking and heating’ studies are taken up with AISRF funding. Six R&D organizations, three from India, CSIR-IIP, IIT Roorkee and BPCL & three
from Australia, CSIRO, University of Melbourne and RMIT are participating in the project.

**Human Resource Development:**

Developing human resource for hydrocarbon and related industries has been one of the major activities of CSIR-IIP since its establishment and has maintained its leading role in imparting training to personnel from petroleum refining, petrochemical and related industries and government bodies. CSIR-IIP has already imparted training to more than 7000 personnel since its inception. During the last fourteen years, CSIR-IIP has organized more than 200 training programs.

**Conclusions**

The Indian refining industry is currently faced with several challenges. These challenges are both with respect to maintaining production margins as well as to address both environmental issues and stringent quality product specifications. Coupled with this is the challenge to adopt alternative fuels. There are several opportunities with the refiners to exploit in short term, medium term and long term basis. Understanding the refinery processes, value addition with various components can bring the use of new and innovative technologies that would help the refiners to survive in the future. The successful would be those who anticipate the changes and work towards implementing the schemes to meet such changes, particularly with respect to the need to reduce greenhouse gas emissions and thus large scale introduction of alternative fuels from renewable resources. CSIR-IIP has already developed and committed to maintain its leading role in developing large number of innovative technology to meet the challenges prevailing in hydrocarbon Industry.
The necessity of intensive R&D in the knowledge field of petroleum sector is well recognized. With stagnating new finds, smaller finds and logistically difficult finds becoming more common, challenges are enormous before the E&P industry. Besides expanding conventional oil & gas horizons shifting focus to gas from unconventional resources require new approaches and workflows. Strengthening of R&D has been adopted as a viable way by many globally recognized companies. In the recent times, the pace of technological innovation is transforming the fast-changing business environment. Research & Development (R&D) is widely recognized to be the key driver for technological advancement and plays a central role in E&P industry. It plays a crucial role in determining the competitiveness of oil companies engaged in E&P business activity in the marketplace, nationally and internationally. While R&D activity is highly capital intensive, at the same time, it is absolutely essential to achieve long term self-reliance and competitive edge. With the increasing significance of technology today, it becomes apparent that R&D has to take into account not only customers and business economics but the environment and society at large. Innovative activity and capabilities are essential for new discoveries and enhanced recovery from existing Fields with minimum environmental footprints. Being a non renewable resource, R&D in oil & gas exploration and production and hence, the technology has an important role to play in exploring and extracting the resource in an economic and sustainable manner.

R&D function in ONGC is catered through eleven Institutes (Nine R&D Institutes + two for knowledge support) dedicated to different domains of hydrocarbon sector, but de facto, these institutes have been engaged in solving the operational needs of ONGC thereby pursuing adaptation/customization and applied research rather than indulging in primary or fundamental research. Historically, KDMIPE was established as the first Institute for training and E&P research and as ONGC expanded its activities dedicated facilities in geophysics, reservoir, production technology, engineering solutions, proficiency development etc. was felt to be opened up leading to genesis of other Institutes. Of
late, the necessity of R&D in acquiring edge over competitors, opening up new domains, self-sufficiency in core sectors, enhancing the organizational capabilities has increased manifold which ONGC has been managing through these array of institutes.

The ‘2012 EU Industrial R&D Scoreboard’ has listed ONGC at the 36th position in the list of oil and gas companies based on Research and Development (R&D) expenditure. It is to mention here that ONGC is the only company in this list from India. The total R&D Expenditure as a percentage of total turn-over has increased from 0.43% in 2011-12 to 0.65% in 2012-13.

The Institutes which cater to the knowledge support and applied R&D for E&P activities in ONGC are as mentioned below:

a. Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE), Dehradun
b. Geo-data Processing & Interpretation Centre (GEOPIC), Dehradun
c. Institute of Drilling Technology (IDT), Dehradun
d. Institute of Engineering & Ocean Technology (IEOT), Panvel, Mumbai
e. Institute of Oil & gas Production Technology (IOGPT), Panvel, Mumbai
f. Institute of Petroleum Safety, Health & Environment Management (IPSHEM), Goa
g. Institute of Reservoir Studies (IRS), Ahmedabad
h. Centre for Excellence in Well Logging Technology (CEWELL), Vadodara
i. Institute of Biotechnology and Geotectonic Studies (INBIGS), Jorhat, Assam
j. School of Maintenance Practices (SMP), Vadodara*
k. ONGC Academy (ONGCA), Dehradun*

*knowledge support

In order to identify the gaps and overlaps and also to deliver the common issues, a common platform was created called COIN (Committee of ONGC Institutes) as an interconnecting body for effective R & D networking. The COIN was made as a platform to share knowledge base, identify gaps and overlaps for effective R&D networking among ONGC Institutes. KDMIPE, Dehradun is the Headquarter of COIN and Permanent Secretariat of COIN activities and HOI-KDMIPE is the coordinator -COIN. Director (E), ONGC is the Incharge of COIN activities on Board.

The various innovative & investigative projects done by the research institutes under COIN cater to the requirement of different Assets / Basins of ONGC as well as other upstream companies in India and abroad.

A brief description about the primary roles of all the Institutes under the umbrella of COIN is being brought out below:

**KDMIPE (Keshava Deva Malaviya Institute of Petroleum Exploration)**

It is the mother Institute out of which all other Institutes were carved out. The Institute carrying the legacy forward has aligned its roles and responsibilities according to the business strategies of ONGC. KDMIPE now primarily carries research activities in the various fields of geosciences, mainly basin research, basin modeling, structural analysis, geochemistry, high resolution gravity and magnetic data acquisition, magnetotelluric studies, remote sensing, petrography, geochronology, bio-stratigraphy, radiometric dating, petrophysical analysis, PVT studies, water shut off studies etc. The work carried out is broadly classified under Conventional Research Group and Unconventional Research Group. The institute has seven groups and twenty two divisions under which these studies are carried out.

**GEOPIC (Geo-data Processing & Interpretation Centre)**

Hived off from the Computer Services Division of KDMIPE, GEOPIC was set up in 1987. It is the largest computing facility of ONGC and one of the few centres around the world for integrated processing and interpretation of geoscientific data, from seismic to petrophysical, geological and reservoir engineering.

**IDT (Institute of Drilling Technology)**

The institute was setup in 1978 to render R&D services in the area of oil and gas well drilling technology. Over the years, the Institute has emerged as a premier R&D centre in South east Asia, capable of providing advance technical knowledge through training and offering plausible solutions to field problem. IDT is dedicated towards drilling engineering, which includes cementation & cementing materials & drilling fluid engineering. It also has the Well Control School for International Certification of Drilling Engineers.

**IRS (Institute of Reservoir Studies), Ahmedabad**

The Institute was founded in 1978 as a...
The institute was established in 1984 to meet the technological requirement of Oil & Gas production with an objective to improve the economics of operations and boost indigenous hydrocarbon production.

IEOT (Institute of Engineering and Ocean Technology), Mumbai

The institute was established in 1983 for innovation, development and acceleration of the future plans of ONGC to achieve self-reliance in technology. The Institute has developed expertise in the fields of concept evaluation and risk analysis, geo-technical engineering, structural engineering, materials and corrosion engineering.

IPSHEM (Institute of Petroleum Safety, Health & Environment), Goa

IPSHEM was established in 1989 with an objective of promoting standards of safety, health and environment in petroleum sector in India. It is totally dedicated towards exposing & providing training to the employees on Safety, Health & Environment Management, including survival in land & sea, disaster management & Safety audits.

The institute which was founded in 1989 is engaged in the innovative research of Petroleum Bio-technology and plays a vital role in geo-microbial prospecting, enhancing oil recovery from reservoir and environment protection by bio-remediation of oily wastes.

INBIGS (Institute of Biotechnology & Geotectonics Studies), Jorhat, Assam

The institute which was established in 2006 to develop and nurture competencies for providing best well logging solutions and services in domestic and

single source and multi service reservoir engineering institute, contributing effectively in the development of new concepts and innovative techniques for maximizing hydrocarbon recovery at minimum cost.

IOGPT (Institute of Oil and Gas Production Technology), Mumbai

It was founded in 1983 for innovation, development and acceleration of the future plans of ONGC to achieve self-reliance in technology. The Institute has developed expertise in the fields of concept evaluation and risk analysis, geo-technical engineering, structural engineering, materials and corrosion engineering.

IEOT (Institute of Engineering and Ocean Technology), Mumbai

The institute was established in 1984 to meet the technological requirement of Oil & Gas production with an objective to improve the economics of operations and boost indigenous hydrocarbon production.

CEWELL (Centre for Excellence in Well Logging Technology), Vadodara

This institute was established in 2006 to develop and nurture competencies for providing best well logging solutions and services in domestic and
Key to Energy Security of India - for the last 57 years

**ONGC, in its glorious journey thus far, has**
- discovered 6 of the 7 oil & gas producing basins
- added 8.5 billion (88% of total) tons of oil & gas reserves
- produced 1.55 billion (83% of total) tons of oil & oil equivalent
- contributed over ₹ 6.71 lakh crore to the exchequers
- 32 projects operational in 16 countries

**By 2030, ONGC is committed to**
- add 4 billion more tons of oil & gas reserves
- double oil & gas production to 130 million tons per year
- increase overseas production six fold
- produce 6500 MW of power from renewable sources (nuclear, solar & wind)
- grow non-E&P business to 30% of the Group Revenue
• Assessment of Disproportionate
• Identification of suitable chemi
• High Resolution Molecular Stra
Some of the important areas in which R&D was carried out by ONGC Insti-

ONGCA (ONGC Academy), Dehradun

Established in 1982, the institute provides training to the employees in various Management Development & Technology Programmes. The institute also takes up customized Functional trainings & Induction trainings.

School of Maintenance Practices (SMP) Baroda

School of Maintenance Practices has been set up with the aim to provide comprehensive technical development of maintenance engineers under “Single Window”. The motto of SMP is “Safer, Better, Cheaper & Easier Operations”.

Some of the important areas in which R&D was carried out by ONGC Institutes in recent past are as follows:

• Integrated geological and geophysical studies for depositional framework and hydrocarbon prospectivity of Cretaceous and older sediments to the south of Podurru-Draksharama high in Vygreswaru North Pasar-
• Depositional architecture and Sediment dispersal pattern in the deep and ultra-deep-water in KG Basin and its integration with shallow wa-
• Sedimentation pattern, morphology and their distribution within different stratigraphic levels in Mahanadi Basin based on understanding of interpretation of 3D & 2D data.
• Gravity atlas of India has been prepared for onshore and offshore areas consisting of one integrated map and 82 smaller maps.
• 2D & 3D Move-based structural modeling along key profiles in Kutch Offshore.
• 2D-Move based structural modeling of Chambal and Son Valley sectors of Vindhyan Basin.
• Petroleum systems modeling in western NELP-VIII Blocks west of Accretionary Prism in Andaman Basin.
• Tectono-Sedimentary evolution of Kutch-Saurashtra Basin involving onshore and offshore areas depicting relationships to Cambay rift & Nagar Parkar fault.
• Software development using CUDA-GPU Technology.
• Evaluation of thin pays/invasion for better productivity with the application of log-data recorded in four wells of HP/HT regime of KG Basin using UTAP WeLS Simulation software.
• Development of methodology for resistivity independent saturation computation using NMR log of Charali Field.
• Field application of various MEOR processes in the different fields like Mehsana and Ankleshwar area. Jobs included Paraffin Degrading Bacterial (PDB), mitigation of Wax deposition problem and field trial of high temperature (96ºC) microbial system for enhanced oil recovery.
• Developing specifications for composite material down hole casing for highly corrosive wells in onshore Assets.
• Specifications for fibre glass pipelines for oil field applications in onshore - Revision 2012.
• Studies on Binary Hydrates for application in storage and transportation of methane gas.
• Studies on the effects of gas hydrate dissociation on sea floor stability.
• Studies on the thermodynamics and kinetics of Carbon Dioxide Hydrate formation and dissociation and its structural characterization.
• Nonlinear dynamic analysis of flexible risers in shallow waters of Indian western offshore.
• Soil classification from PCPT DATA with special reference to Indian offshore areas.
• Evaluation of soil design parameters using PCPT data with emphasis on application in Indian waters.
• CPT/PCPT based methods for pile capacity.
• Sampling and characterization of calcareous sands.
• Development of Viscoelastic Surfactants Based Self-diverting Acid (VSDA)
• Application of new Well bore cleaning system in Horizontal wells.
• Indigenous development and installation of Venturi type Surface Chokes for stabilized flow in Oil & Gas wells.
• Development of Low Temperature Demulsifier.
• Eco-friendly solvent for removal of organic deposits for production enhancement.
• Well design for STP – 1 well in Kazakhstan for OVL.
• Well bore stability and Mud weight window for Balol / Santhal Field.
• Ultra High Density Cement Slurry Designing for HT/HP oil & gas Wells.
• Solution for improving ROP in Marl Section of Parh Formation in Jaisalmer Basin.
• Identification of suitable shale stabilizers and lubricants for HTHP mud system in Rajahmundry Asset.
• Formulation of Baryte free NDDF system for low permeability/HT/HP reservoir.
• Baryte free NDDF for drilling of fractured/Low permeability Rohtas limestone of Vindhyan basin (Sone valley).

Some of the important Technology ab-
sorption and adaptation in recent past are as follows:

- FPSO technology implemented at N.B. Prasad field (D-1) and is under implementation for Cluster-7 field development.
- Twin Screw Horizontal Surface Multiphase Pump was implemented at a platform in NB Prasad field (D-1).
- Visco-elastic foam acid system was implemented in Heera field.
- Field trial for H2S scavenger in gas lift lines of MH Asset is under implementation.
- Modified acid fracturing system implemented in 3 wells of Heera field.
- Developed innovative structural concepts for minimum facility platforms for marginal fields through analysis of guyed tower platform.
- CPT/PCPT based methods used for estimating pile capacity.
- The state of the art Gas Hydrate Cell System for Gas Hydrate prediction and characterization has been acquired and put in use after extensive training of engineers.
- Advanced Portable Simulator for Well Control School.
- “Sodium/ Potassium Format & Non Damaging Drilling Fluid (NDDF) System” developed by Institute of Drilling Technology(IDT) has been successfully implemented in Mumbai fields like - B149-A-1H & 1H, WI- 4#2ZH, N-18#2H, NTP-2#1H, NTP-2#2H wells.
- A new state-of-the-art dating facility Sm-Nd (Samarium-Neodymium) has successfully been setup at KDMIPE. It will be used to date hard rocks (Igneous and metamorphic) and to ascertain the provenance age in sedimentary rocks and correlation of reservoir lithology.
- H2S generation problem mitigated for wells in Mumbai High fields.
- Microbial consortium (NJS4-96) developed for high temperature reservoirs (above 900 °C) in carbonate environment.
  - Use of slow release fertilizer in bioremediation of oil.
  - Technologies like - Converted wave processing, 3D beam processing, CGG, Quantum Technology, Seismic Guided Drilling, Q-technology, Low frequency passive seismic, ROTOR, Passive Seismic Tomography (Landtech), Amplified Geochemical Imaging, M/s GORE, Pore pressure prediction (drill work), Micro CT scanner, OBM, Well Shuttle, Resistivity Imager, Sonic scanner, Flow Scan Imager, MR Scanner, Sea Bed Logging, Airborne EM survey, Fugro Airborne survey and Controlled Source EM, Rock Source –adopted for better G&G imaging.
In addition to the above mentioned R&D efforts, ONGC has set up the ONGC Energy Centre (OEC) for research in renewable and alternate energy sources beyond hydrocarbons, which can be brought to market. The objective is in line with the vision of ONGC to become an integrated energy company and not just restrict itself to oil and gas. The Centre was pioneered by former-CMD Late Mr Subir Raha with motto “Mind to Market”. The ONGC Energy Centre aims to conduct research in alternate energy specifically focusing on projects which have the potential to make an impact on India’s energy scene. The Centre does not stop at just R&D, but pursues beyond to “demonstrate for commercialization”.

The IPR Management in ONGC is carried out through a centralized cell recently opened at KDMIPE. The cell facilitates the entire process of IPR from sensitization, identification of training needs, hiring of agencies, filing of patents, generation of important documents and record maintenance etc. The following is the list of patents obtained and filed by ONGC Institutes:
Institute of Oil and Gas Production Technology (IOGPT)

Introduction

The Institute of Oil & Gas Production Technology (IOGPT) was established in 1984 with assistance from United Nations Development Program (UNDP) and Asian Development Bank (ADB) to meet the production and processing related technological requirement of Oil and Gas fields and processing plants. The institute is located amidst picturesque surroundings at the Technology Park in Panvel, Navi Mumbai, about 50 km from Mumbai on the Mumbai-Pune highway.

IOGPT is the first Institute in the country to provide an integrated R&D support to the entire spectrum of Oil and Gas production, which begins at the well bore and culminates at the consumer point.

It is a centre of excellence for applied R&D and offers consultancy services in the areas of; Well completion, intervention & completion plan, Sand control, Water & gas control, Well stimulation, Conceptual and feasibility studies for surface facilities, Studies related to value added products, Preparation of process package for surface facilities, Field development facilities, Debottlenecking studies, Optimization of surface facilities, Crude characterization studies, Pipeline network optimization, Flow assurance studies, Artificial Lift System Design & Optimization, Static & Dynamic testing of Gas Lift Valves, Integrated production modelling, Well bore Hydraulics and Analysis, Material selection for tubing, wellhead, X-mas tree, pipelines, Material failure analysis, Internal & external corrosion protection, identification & evaluation of corrosion inhibitor, Corrosion rate determination, Pitting tendency prediction, Prediction of scaling tendency, Formulations and techniques for scale mitigation, Deep-water completion, production and Subsea Technology, Conceptual studies for Offshore Field Development, Specialized Trainings in Artificial Lift, Well Completions,
Hands-on Simulator Training & IADC course on well control.

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Apart from catering to the needs of the Assets, Basins & Plants of the parent organization, IOGPT’s clientele includes Joint Venture companies, OVL and other commercial entities in the Oil & Gas sector.

The major strength of IOGPT lies in its highly qualified, trained and experienced technical manpower which has a harmonious blend of youth and experience, who are equipped to take up any challenge in the field of hydrocarbon production and processing.

The infrastructure at IOGPT includes state-of the-art laboratories with sophisticated equipment to support the applied R&D to achieve high quality experimental results. IOGPT has the following well equipped laboratories like Stimulation laboratory, Process laboratory, Analytical laboratory, Corrosion laboratory, Water and Gas shut-off laboratory & Artificial Lift laboratory.

Till March’2013, IOGPT has completed more than 1900 projects related to various aspects of petroleum production and processing and has more than 200 research paper publications in various national and international seminars, conferences and journals. It has patented 4 technologies and techniques and another 15 applications are under examination for grant of patents.

The institute is equipped with the latest and the most advanced information technology tools to keep pace with the ever-changing technology. It has Sophisticated advanced computing facilities based on work station concept and latest softwares for each domain function catering to their computational needs.

Information Centre of IOGPT is a specialized technical library that supports the learning and research goals of ONGC and also serves as a centre for information in entire field of technology and applied science. It is equipped with a comprehensive range of collections covering specialized books, academic journals, reference materials, standards and databases.

IOGPT is one of the four locations that have the OCC (Onshore Control Centre for Offshore Control) set-up. The system implemented is used for initiating Emergency Shut Down (ESD) commands to well platforms as well as 13 process platforms in case of an emergency for ensuring the safety of offshore operations and operating crew. It could also be used for disaster recovery in case of natural calamities.

The whole project involves state-of-the-art control centers and collaboration rooms for 24x7 hours operation and monitoring, video conferencing with offshore process complexes and drilling rigs and monitoring of rotating equipment data from process platforms, Integrated with various third party systems like: SCADA (production, drilling, lift optimization and ESP data), VRC (sub-surface data), VATMS (logistic data) & IAM (integrated asset management) Monitoring status feedback of critical shutdown valves on process platforms and running status of all critical rotating equipment.


Mission

To provide reliable services through up-gradation, development and assimilation of technologies

Vision

To be the foremost among the companies providing consultancy and support
services to the Hydrocarbon Industries.

**Objectives**

- To ensure customer satisfaction by providing reliable, cost effective and timely services
- To develop scientifically oriented and technically competent employees through motivation and training
- To equip with eco-friendly and state-of-the-art technologies.

**Core functional areas**

IOGPT has the following core functional areas:

- Production Engineering
- Surface facility & Process Engineering
- Corrosion & Scale Control
- Artificial Lift & Well Analysis
- Deep-water & Field Development
- Training & Business Development

Laboratory facilities are attached to these groups for necessary R & D back up.

**Production Engineering**

Production engineering department deals with the core areas of oil and gas production technology in various types of reservoirs viz. sandstone, carbonate, CBM, shale gas, etc. The major areas of interest are:

- Well stimulation
- Acid Fracturing & Hydro fracturing
- Matrix acidization
- Basement Stimulation
- Sand control
- Water and gas control

**Capabilities**

The department has the capabilities for design and development of various chemical formulations, selection of techniques, customization of treatment methodology, candidate well selection, well specific treatment design and post treatment evaluations in the areas of well stimulation, well intervention, well completions, well testing, sand control and water & gas control.

**Technology developed/customized**

The department endeavors for the solutions of field problems related to the critical operational issues and production enhancement from matured fields both Onshore and Offshore. With continuous R&D efforts and based on the field requirement, the department developed / customized various formulations and techniques in the field of well stimulation, well services, water and gas control. Some of such formulations and techniques developed are mentioned below:

1. Viscoelastic surfactant based self-diverting acid (VSDA) for stimulation of heterogeneous carbonate reservoirs.
2. Multistage acid fracturing for tight carbonate reservoirs.
3. Multistage Stimulation of horizontal wells using deep penetrating retarded acid system (DPRAS) and chemical diversion.
4. Emulsified acid system for stimulation of carbonate as well as sandstone reservoirs with high carbonate content.
5. Self-diverting acid system for stimulation of carbonate reservoirs.
6. Mineralogy based acid systems for stimulation of sandstone reservoirs
7. Enzyme technology for wellbore cleaning of horizontal wells.
8. Particulate pill fluid system for sub hydrostatic wells.
9. Foam fracturing fluid with Coco Diethanol-amide surfactant as foamer.
10. Viscoelastic surfactant based (VES) based fracturing fluid.
12. VES Foamed Acid system (VFA) for stimulation of relatively low pressure wells in carbonate reservoirs.
13. Gelled Emulsified Acid (GEA) system for acid fracturing and stimulation of horizontal wells.
14. IPT R-1 biopolymer gel for water control.
15. IPT S-1 gel for water and gas control.
16. Micro fine Oil Cement (MOC) for water control.
17. Eco-gel for combined stimulation and water control of high water cut wells.

**Contributions in terms of value addition**

1. Patented “the process for preparing relative permeability modifier bio-polymer gel for blocking/limiting water production in oil sand”.
2. Patent obtained for “the process for preparing X-linked polymer gel for Water & Gas shutoff in HT oil wells”.

**Capabilities**

- Conceptual/Feasibility studies for Surface Facilities including Value Added Products.
- Preparation of process package for Surface Facilities.
• Optimization & trouble shooting of surface Facilities.
• Field Development Plans.
• Pipeline design & optimization for single phase/multiphase transportation.
• Fluid Characterization.
• Rheological properties of fluid at high temperature
• Evaluation of crude oil, natural gas and condensate.
• Carbon Profiling of wax and crude oil.
• Saturates, Aromatic, Resins and Asphaltene (SARA) Analysis.
• Study the effect of pressure and temperature changes on organic solids deposition in live oil.
• Saturation pressure (Psat), Viscosity and Density determination of live oil.
• Asphaltene onset pressure (above Psat) and offset pressure (below Psat).
• Reversibility Test: Isothermal repressurization (above Psat)
• Isobaric cooling for live oil Wax Appearance Temperature.

Contributions in terms of value addition

Corrosion & Scale Management
This department studies corrosion and scale problems of oil and gas field and offer remedial measures. The department provides R&D back-up to study the corrosion behavior of metal in corrosive environment of flow / process system.

Capabilities
• Material selection for tubing and down hole equipment, wellhead and X-mas tree, pipelines and surface facilities
• Internal and external corrosion protection: Selection of coatings and linings, corrosion inhibitor evaluation
• Corrosion monitoring: Electrochemical & Gravimetric method, Wall thickness monitoring by UT Gauge, Corrosion monitoring using hydrogen patch probe in H2S environment
• Failure Analysis: Onsite observation, Laboratory evaluation for compositional analysis of water & metal, corrosion rate prediction, Pitting tendency, mechanical testing, metallographic study
• Evaluation of scale problems: Identification of scales, evaluation of scale inhibitors, evaluation of scale removal techniques.

Technology developed/customized
DTPA (diethylene triamine penta acetic acid) based SrSO4 (Srkill) scale removal formulation (patent filed) has been developed in house for successful removal of down hole strontium sulfate scale deposition. Two variants with concentration 0.5M & 0.05M for tubing and near well bore area are designed for better cleaning efficiency. It is successfully implemented in 16 wells in MH and N&H Assets and resulted in a liquid gain of 2769 bbl/day and oil gain of 597 bbl/day.

Contributions in terms of value addition
1. Implementation of DTPA based SrSO4 (Srkill) scale removal formulation in total 16 wells of Mumbai offshore has resulted in gain of 2769 BLPD (liq) & 597 BOPD (oil).
2. The recommended metallurgy for the wells (L-80, 13 Cr. SS tubing for Neelam & Heera Asset) to result in saving of life cycle cost: Rs 1.36 crs/well (Neelam field) & Rs 1.04 crs. /well (Heera field) due to reduced work over costs.
3. Recommended metallurgy (L-80, 13 Cr SS tubing) for the wells in Mumbai High to result in savings of life cycle cost of Rs 5.43 crs. /well due to reduced work over costs.

Lift & Well Analysis
This department provides complete solutions for Artificial Lift including conceptualization, selection, designing, trouble-shooting, optimization of Artificial Lift systems, Quality Control Testing of Gas Lift Valves and undertakes applied R&D works and technology scouting.

Capabilities
• Conceptualization, Selection, designing & Review of Artificial lift schemes.
• Trouble-shooting & optimization
• Integrated Production Modelling
• Nodal system analysis
• Training on Artificial Lift Systems, Gas Lift optimization, SRP Optimization
• Quality Control testing of Gas Lift Valves
• Technology development
• Study of well performance for problem(s) identification and understanding of overall performance and trends through diagnostic plots, production performance plots etc.
• Layer-wise study by integrating well production history.
• Identifying the reasons for under-performance of the wells i.e well bore damage etc.
• Suggestion for suitable remedial measures to improve /sustain the production.

Technology developed/customized
1. Improved device for separation of gas from petroleum liquid in the well bore.
2. Improved Gas Lift Valve with modified seat.
3. Venturi type Surface Choke for stabilized flow.
4. Slim-hole gas lift completion with macaroni tubing carried gas lift valves.

Contributions in terms of value addition
1. Analyzed more than 2000 wells across all the Assets, both Offshore & Onshore, during the last 10 years.
2. The envisaged gain from the recommendations is more than 38,000 bopd of oil and 0.7 MMSCMD in terms of gas savings/ incremental gas production.
3. Implementation of the in house developed Venturi chokes(patent applied), which has been conferred with the Innovation Award at the Petrofed Awards 2012, has resulted in 15% incremental gas production from the wells it was installed.
4. Patented Modified poorboy Gas Anchor for SRP wells, which differs from the conventional gas, anchors as the holes provided in the gas anchor for fluid entry are slotted type instead of round. Staggered and overlapping slot design is a completely new concept for better separation of gas from the petroleum liquid. The improved Gas Anchor design may be coupled with a tubing pump or top hold down insert type sucker rod pump. Implemented in more than 30 SRP wells of Assam & Ahmedabad Assets resulting in 10 to 30% incremental oil production.
5. Patent obtained for Improved Gas Lift Valve with modified seat, which incorporates an improved, the flow geometry of the GLV so that critical flow can be achieved even with small pressure differential across the Gas lift valve port. This results in improving the stability in gas lift wells, resulting in reduced injection gas consumption, enhancing production and conserving injection gas pressure energy to achieve deeper depths of injection.

Deep water & Field development
This department carries out conceptual, feasibility and flow assurance studies for development of offshore fields in shallow and deep water. This involves screening and optimization of various development options for finalization of development plan.

Capabilities
Conceptual Studies for Offshore Field Development covering
• Stimulation needs
• Artificial Lift selection
• Flow assurance studies-steady state and transient analysis
• Pipeline network design
• Production optimization
• MDT support in preparation of field development

Technology evaluated and recommended
The following Technologies were proposed as part of field development:
• Inflow Control Tools
• Multiphase Pumps
• Pigg-able WYE technology for Optimization of Risers

Contributions in terms of value addition:
During the last ten years conceptual development & flow assurance studies were carried out for 78 fields resulting in monetization of Reserves of 73.97 MMT oil and 238.80 BCM gas.

Training & Business Development
IOGPT offers specialized training courses in all the areas of oil and gas production, processing and transportation for technologists and engineers. The training division has all facilities of modern class rooms, conference rooms, hardware and softwares, Simulators & visualizations tools to which the trainees have a full access. IOGPT has trained more than 4000 personnel in almost all specialized areas of Production Engineering since inception.

The Institute has a full-fledged Training Division and imparts specialized trainings, through its highly experienced in-house faculty, in the areas of Artificial Lift, Well Control and Well Stimulation etc. to professionals from other Assets and Work Centres of ONGC. Customized training modules are also designed for clients outside ONGC.

IOGPT has the accreditation of International Association of Drilling Contractors (IADC), USA, for conducting the training programme on Work over Well Control. The IADC accreditation has added repute, quality and importance to the training program and entailed participation of trainees from other private E&P companies apart from ONGC employees. IOGPT has so far imparted training to 44 batches. Every year 5 programs are being conducted. IOGPTs accreditation of IADC was renewed in 2011 and is valid up to 2018.

A special training module for the Graduate Trainees of Production discipline is also conducted regularly under the aegis of the ONGC Academy. It covers all the topics from Well Completion, Work over Operations, Stimulation, Hydro fracturing, Water/Gas control, Onshore & Offshore operations, Value Added Products, Process Control & Instrumentation, Artificial Lift, Corrosion & Scale Treatment problems, Deep water field Development, Flow Assurance etc.

Business Development:
Proactively, IOGPT ventured in marketing of its services way back in 1994. This helped IOGPT to reinforce the quality of services and prepare for upcoming challenges with different service providers. IOGPT has been offering services on commercial basis to many E&P companies operating in India and overseas. Some of the clientele includes Hardy Oil, Cairn Energy India Ltd., OIL, GSPC, BG India, FOPA, Jubilant Oil & Gas Pvt Ltd., etc. During the last 15 years IOGPT has earned revenue of more than Rs. 60 million from the commercial projects undertaken. The standard and quality of projects completed by IOGPT for various customers have been rated at par with international standard by the outside companies. A few of the important projects and their customers are as mentioned below;
Infrastructure

The infrastructure at IOGPT includes a fleet of advanced software and state of the art laboratories with sophisticated equipment to support the applied R&D to achieve high quality experimental results. IOGPT has the following well equipped laboratories like Stimulation laboratory, Process laboratory, Analytical laboratory, Corrosion laboratory, Water and Gas shut-off laboratory & Artificial Lift laboratory.

Laboratory facilities

a) Production Labs

There are three laboratories in this group as stimulation, water and gas shut-off and sand control laboratories and, equipped with state of the art laboratory equipment like:

1) Linear core flow set up: To determination of core permeability under simulated reservoir conditions, Acid response studies and evaluation of suitable acid formulation, Studies on organic solvents and customize effective formulation, Studies of effectiveness of various gels for water control & Estimation of formation damage.

2) Rheometer: To evaluate rheological properties of various fluids/gels used in well stimulation, water control, sand control, completion & work over

3) Proppant conductivity set up: Determination of proppant conductivity at various stress conditions, used as input in design of hydraulic fracturing treatments

4) Atomic absorption spectrometer: Analysis of metallic ion concentrations of spent acids used for evaluation of problems related to precipitations in acid treatments

5) Set-up for Core Dressing: Core slabbing, plugging, cleaning and saturation

6) Sieve shakers: Dry sieve analysis for sand size distribution, used as input in gravel size selection in gravel pack/frac pack jobs

7) Linear flow set up for sand control: Study of gravel pack efficiency in various flow conditions

b) Process & Analytical Lab

This Lab is equipped with state of the art laboratory equipment and facilities like:

- Natural Gas Analyzer
- SIMDIS Analyzer
- Detailed Hydrocarbon Analyzer
- Solid Detection System
- Electromagnetic Viscometer
- Flow Assurance Laboratory

c) Corrosion Lab

The corrosion lab is equipped with state of the art laboratory equipment and facilities like:

1) HP/HT corrosion test apparatus: Determination of corrosion rate of materials subjected to high pressure and high temperature under dynamic conditions

2) Wheel test apparatus: Determination of corrosion rates of metal specimen under static and dynamic conditions and evaluation of corrosion inhibitors under simulated conditions

3) Liquid ion chromatograph: Quantitative analysis of produced water to predict water chemistry i.e. cations, anions and heavy metals based on the principle of ion chromatography

4) Analytical balance: Weighing of materials for various corrosion & scale test

5) Thermostatic Oven: Used in the process of drying of glassware & other equipment and preheating

6) Static water bath: To heat & main-
tain samples at a certain temperature to determine corrosion rate in static condition

d) Artificial Lift Lab
The Artificial Lab is equipped with state of the art laboratory equipment and facilities like:
1) Static Test Set-up: Performed under static conditions for valve leakage test, hydrostatic ageing tests, valve stem travel test, shelf test and probe test
2) Dynamic Test Set-up: For obtaining the dynamic valve performance characteristics of a GLV with a given set pressure

Software
a) Production Engineering
The state of the art softwares for treatment optimization, design and evaluation of well stimulation and sand control jobs are:
• Fieldpro Suite: Database and design of Hydraulic fracturing & matrix stimulation jobs
• Fracpro: Simulator for hydraulic fracturing design, optimization and post job evaluation
• Fraccade: 3 D Simulator for Design of proppant hydraulic fracturing and acid fracturing
• Sandcade: Simulator for Design of gravel pack, high rate/water pack & frac pack

b) Process Engineering & Surface Facilities
The state of the art softwares available are:
• PRO-II: Process Simulation software for petroleum processing.
• HYSYS PLANT: Steady state and dynamic process simulation.
• PIPESIM: Steady state single/multiphase flow in pipeline & pipeline networks.
• DESIGN-II: Process simulation & design of process facilities
• FlareSim: Heat radiation analysis
• INPRO: Process equipment sizing

c) Corrosion & scale management
The department is equipped with following softwares:
• PREDICT 6.0: Prediction of corrosion of carbon steel in multiphase oil & gas production or transmission systems
• SOCRATES 9.1: Comprehensive material selection system for corrosive oil & gas applications
• SCALECHEM: Prediction of scaling tendency.

d) Artificial lift & Well Analysis
In addition to having the latest softwares used in the industry, Artificial Lift department has also developed a number of softwares in house:

a) In house developed:
• GLIDE: Gas lift design
• PLUNGER: Plunger lift design and optimization
• DYNA: Sucker rod pumping system design & analysis.

b) Acquired:
• PIPESIM: Single, multiphase pipeline, nodal analysis, ESP and Gas Lift design & analysis, well flow simulation
• PROSPER: IPR-Single & multilayer, multiphase, flow (vertical), Gas lift, ESP & hydraulic pump design & analysis
• GAP: General allocation & Production Network modelling
• SUB PUMP: Design and analysis of Electrical Submersible Pump
• PC PUMP: Design and analysis of
Progressive Cavity Pump
- **RODSTAR**: Design and analysis of Sucker rod pumping system.
- **MBAL**: Reservoir simulation

e) Deep water & field development

The softwares available with the department are:
- **QUESTOR**: Cost estimation of offshore & onshore field development concepts for evaluation.
- **INPRO**: For sizing / designing of surface facility equipment.
- **PIPSIM**: Steady State flow assurance study and sizing of flow line.
- **ReO**: Integrated production modelling & Optimization.
- **OLGA**: Steady state & transient flow simulator for flow assurance studies.
- **OGM**: Oil and Gas Manager - field development costing software

**Intellectual Property Right (IPR)**

Till date, IOGPT has taken 08 copyrights and 04 patents and several are in pipeline:

**Copy rights**
3. PC based software for designing electrical submersible pump-Gaslift combination lift. ESP-GL (2001)
4. PC based software for design of jet pump JET-DES (2001)
5. PC based software for advanced gas lift design GLIDE(2001)
6. PC based software for SRP design and Diagnosis DYNA(2002)
7. PC based software design of Intermittent gas lift and chamber lift INFLOW(2001)
8. Probe testing of G/L valve and its significance in field application. PROTEST(2001)

**Patents obtained**
1. An improved device for separation of gas from petroleum liquid in the well bore. (Modified poorboy Gas Anchor for SRP wells) (No.184622 17.1.1997)
2. Improved gas lift valve with modified seat (No:207291 dt 04-06-2007)
3. A process for preparing relative permeability modifier bio-polymer gel for blocking/limiting water production in oil sand (No.198188,
4. A process for preparing X-linked polymer gel for W&GSO in HT oil wells (No.213178 dt 25.01.2008)

**Patents filed & under examination**

1. Composition and method for dissolution of Strontium Sulphate scales.
2. Visco Elastic Surfactant based Self diverting Acid (VSDA) for Stimulation of Carbonate Reservoirs.
3. Quaternary Ammonium Surfactant Based Fracturing Fluid for Improving oil well fracture efficiency
4. Deep Penetrating Retarded acid System (DPRAS) for stimulation of carbonate reservoir
5. In-situ Cross linking Acid Diverting System
6. Improving solvent Efficiency by doping polymer dispersant to mitigate Asphaltene precipitation.
7. Enzyme application for well bore cleaning to remove mud cake in oil/gas wells
9. Optimization for recovery of rich gas from CSU.
10. Slim-hole Gas Lift completion with Macaroni tubing carried Gas Lifts Valves
11. Polymer based Scale Inhibitor for Oil field produced brine in Calcium stressed environments.
12. Eco-gel for water control and acid diversion during stimulation of carbonate reservoirs
13. Venturi type surface chokes for stabilized flow
15. Gelled Acid Emulsified system for Carbonate Reservoir

**Collaborative/Joint Industry Projects (JIPs)**

In continuation & in conformance with the aspirations of PP2030, IOGPT is actively pursuing various industry/academia collaborations.

- Signed an MOU & NOA placed on M/s NCL, Pune for development of Low Temperature Demulsifier.
- MOU has been signed with M/s Halliburton Offshore Services Inc. for R&D collaboration in the areas of Stimulation, Sand Control and Conformance Control.
  - M.Tech dissertation projects with reputed universities like ISM-Dhanbad, Andhra University etc. are taken up regularly in our areas of interest.
  - Further, consultations are also in process for taking up joint academia projects with like IIT, UDCT, and other national & international institutes of repute.

**Awards and Accolades:**

The work carried out by IOGPT over the years has been recognized and rewarded at various forums both within ONGC & outside. A few of the awards and accolades bagged by IOGPT are:

1. Chairman’s Award (citation & cash award of Rs.10000) for contribution towards MDT on supply of gas to Palatana Plant, Tripura
2. Director (Offshore)’s best research paper Award for paper titled “Celestite scale removal through innovative chemical formulation – Indian Western offshore wells study”
3. NPMP award for innovative well stimulation jobs for Mumbai offshore fields - 2002
4. Golden peacock national training award for excellence in training -2003
5. Accreditation from IADC for work over well control simulator – 2003
7. Golden Peacock National Award for Innovation in well stimulation- 2010
8. Corrosion Laboratory has been conferred award for Best laboratory by NACE International Gateway India Section (NIGIS), during 17th CORCON held at Mumbai in Sept 2011 IOGPT
10. Golden Peacock National Award for Eco Gel System- Innovation in well stimulation- 2011
11. Innovator of the year – Team award to IOGPT for the year 2011 for the innovation - Viscoelastic Surfactants Based Self-diverting Acid (VSDA) awarded at the PetroFed Oil & Gas Industry Awards Ceremony, in New Delhi on Jun 08, 2012.
12. Golden Peacock Innovative Product/ Service Award’ for the year 2012 for Eco Gel System - Innovation in well stimulation
### Patents obtained:

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Institutes/ RGL’S</th>
<th>Patent No.</th>
<th>Application No.</th>
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<tr>
<td>1</td>
<td>KDMIPE</td>
<td>209854 / 07.09.2007</td>
<td>848/del/ 2001</td>
<td>A process for the treatment of the oily effluent produced by the petroleum upstream oil industries</td>
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<td>2</td>
<td>KDMIPE</td>
<td>215703 / 11.03.2008</td>
<td>1330/del/1999</td>
<td>A new mathematical representation of rock eval hydrogen index(HI) vs T_max profiles</td>
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<td>3</td>
<td>IRS</td>
<td>197554 / 27.09.2006</td>
<td>892/del/2003</td>
<td>A process for enhanced recovery of crude oil from oil wells using novel multi-microbial strain</td>
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<td>4</td>
<td>IRS</td>
<td>225118 / 07.11.2008</td>
<td>1463/mum/2005</td>
<td>Three–Dimensional core holder for performance evaluation of oil well configurations</td>
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<td>5</td>
<td>IDT</td>
<td>218262 / 14.05.2008</td>
<td>2564/del/2004</td>
<td>Synergistic cement slurry composition for EOR wells and its process thereof</td>
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<td>7</td>
<td>IOGPT</td>
<td>184622 / 17.01.1997/22.01.2002</td>
<td>305/ bom/1995</td>
<td>An Improved device for separation of gas from the petroleum liquid in the well bore</td>
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<td>8</td>
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<td>196188</td>
<td>98/mum/2003</td>
<td>A process for preparing relative permeability modifier bio polymer gel for blocking/limiting water production in oil sands</td>
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<td>9</td>
<td>IOGPT</td>
<td>213178 / 25.01.2008</td>
<td>897/mum/2004</td>
<td>A process for preparing cross linked polymer gel for water and gas shutoff in high temperature oil wells</td>
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<td>10</td>
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<td>207291 / 04.06.2007</td>
<td>956/mum/2002</td>
<td>Improved gas lift valve with modified seat</td>
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<td>11</td>
<td>RGL Chennai</td>
<td>209597 / 12.09.2007</td>
<td>872/che/2004</td>
<td>A Synergistic cement slurry composition and process thereof</td>
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### Patents Filed by ONGC:

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<th>Sl. No</th>
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<th>Year</th>
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<tr>
<td>1</td>
<td>IRS</td>
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<td>A novel multi microbial strain for enhanced recovery of crude oil from oil wells</td>
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<td>Non carcinogenic corrosion inhibition for oil and gas well completion and packer fluids</td>
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<td>Composition &amp; method for dissolution of strontium sulfate scales</td>
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<td>DPRAS (Deep Penetrating Retarded acid System)</td>
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<td>9</td>
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<td>Improving solvent Efficiency by dropping polymer Dispersant to mitigate Ashphalitene Precipitation</td>
<td>1225/MUM/2010</td>
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<td>12</td>
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<td>Polymer Based Scale Inhibitor for Oil Field Produced brine in Calcium stressed environments</td>
<td>1272/MUM/2010</td>
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<td>13</td>
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<td>2010–2011</td>
<td>Optimization for recovery of rich gas from CSU</td>
<td>1378/MUM/2010</td>
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<td>14</td>
<td>IOGPT</td>
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<td>Enzyme application for well bore cleaning to remove mud cake in oil/gas wells</td>
<td>1379/MUM/2010</td>
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<td>15</td>
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<td>Slim hole Gas lift completes with Macaroni Tubing Carried Gas lift vs Valves</td>
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<td>16</td>
<td>IDT</td>
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<td>Cementitious slurry for oil and gas well cementing applications</td>
<td>2944/DEL/2010</td>
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<td>20</td>
<td>IEOT</td>
<td>2011–2012</td>
<td>Punch through prevention during preloading of offshore Jack up rig in 80m water depth by breaking hard seabed overlying soft clay”</td>
<td>3405/MUM/2011</td>
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<td>21</td>
<td>KDMIPE</td>
<td>2012–2013</td>
<td>A Composition and method to control Retriever infestation in micro algal cultural systems (Joint Patent of CSIR CFTRI, Mysore &amp; KDMIPE)</td>
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<td>22</td>
<td>IOGPT</td>
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<td>Gelled Acid Emulsified system for Carbonate Reservoir</td>
<td>659/MUM/2013</td>
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<td>23</td>
<td>IEOT</td>
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<td>Fiber reinforced plastic fencing system for oil and gas well head areas in on land</td>
<td>1144/MUM/2013</td>
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<td>25</td>
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<td>2011–12</td>
<td>Eco–gel for water control and acid diversion during stimulation of carbonate Reservoir</td>
<td>2928/MUM/2011</td>
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<td>26</td>
<td>WSS</td>
<td>2013–14</td>
<td>Fracturing Fluid for Horizontalfracturing Utilizing sea water</td>
<td>2558/DEL/2013</td>
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</table>
Holistic Reservoir Engineering Solutions by Institute of Reservoir Studies (IRS), Ahmedabad

R K Sharma, ED–Head of Institute
Email: 43660@ongc.co.in

The Institute of Reservoir Studies (IRS) is the in-house R&D institute of ONGC providing Reservoir Engineering Tools, Techniques & Technologies to maximize/ optimize recoveries from oil & gas fields for more than three and half decades. Over the years, IRS has emerged into a premier institution providing complete reservoir engineering solutions to both ONGC operated fields in India and OVL (overseas arm of ONGC) operated fields abroad. The prime areas of expertise are development of oil & gas fields ranging from brownfield to greenfield and enhanced oil recovery methods for various types of crude, light/medium gravity to heavy oils backed up with various laboratories for basic data generation to specialized studies for reservoir engineering descriptions, all under one roof, performed by team of experienced Geoscientists and Engineers using industry standard hardware and software, laboratories with state-of-art equipments.

IRS works on the philosophy that high value services can be provided through the advanced technology and collaboration. The institute has technology transfer agreement with M/s Computer Modeling Group (CMG), Calgary, Canada, Technical collaborations in the area of Enhanced Oil Recovery with University of Calgary, Canada, University of New South Wales, Australia and Institut Francais du Petrole, France. It has also collaboration with important national institute like Indian Institute of Technology, Mumbai for complex modeling of heat transfer process, The Energy Research Institute (TERI), New Delhi for development of high temperature microbes, paraffin degrading bacteria, Agharkar Research Institute (ARI), Pune in the field of Microbial applications.

The institute has qualified and skilled manpower from various G&G disciplines having varied work experience from laboratory, simulation studies and field operations enabling the institute to carry out comprehensive field development exercise from seismic to simulation including all secondary and tertiary recovery processes, keeping in view the field implementability and cost effectiveness in terms of project returns. The computational support for G&G, Simulation, Enhanced Oil Recovery and Production Analysis is provided by the state-of-the-art hardware & software.

IRS has provided services to many international clients like PDVSA, Venezuela, Petronas, Malaysia, Iraq National Oil Company and GNPOC, Sudan. The Institute has been evaluating fields of Russia, Vietnam, Kazakhstan, Yemen, Tunisia, Indonesia, Iraq, Venezuela, Sudan, Columbia, Iran etc. for ONGC Videsh Limited, the overseas arm of ONGC.

Field Development Activities

IRS possesses the experience of over three decades for building development strategies for fields having different characteristics ranging from clastics to carbonates containing volatile to heavy oil hosted in single and/or multi-layered reservoirs.

It carries out around 100 R&D projects every year ranging from Reservoir Characterisation and reservoir mapping, field development planning, laboratory studies for basic data generation for rock characterization (core, mineralogical studies, SEM & X-Ray diffraction), fluid characterization, tracer injection and monitoring, laboratory studies for various EOR processes (thermal, chemical, gas injection methods, WAG etc), solutions for well productivity enhancement by designing chemicals for water shut off, Microbial EOR processes for bringing life to stripper wells, improving flow efficiency in surface flow lines and paraffin degradation in tubular.

Rolling development plan concept for offshore giants has been adopted in view of large investment and large returns. Also IOR schemes have been initiated, implemented and re-visited in Onshore fields. For fast track exploitation of new discoveries or greenfields, innovative concept introduced through cluster development in Offshore is paying rich dividends.

Rolling development plan concept for offshore giants has been adopted in view of large investment and large returns. Also IOR schemes have been initiated, implemented and re-visited in Onshore fields. For fast track exploitation of new discoveries or greenfields, innovative concept introduced through cluster development in Offshore is paying rich dividends.

By adopting a multi-disciplinary approach, expertise of all disciplines are integrated to construct realistic reservoir models for field development. All major investment decisions of ONGC on hydrocarbon exploitation strategies are based on recommendations of this institute. By adopting an IOR-EOR programme in 15 major fields at one go some 10 years back, a substantial
trend reversal in performance could be established.

Through an integrated approach from data generation from laboratories to field implementation and monitoring of development plan, IRS is able to know the reservoir with time. For example, the learning curve generated with time for the giant offshore gas field ‘Bassein’ in the Western Offshore Basin of India and its effective use in field development in phases ensuring uninterrupted gas supply as per commitments for the last three decades demonstrates the worthiness of the concept.

**Enhanced Oil Recovery**

IRS has the infrastructure facilities related to EOR studies under a single roof with expertise in applying various EOR processes to almost all types of oil i.e. heavy, medium, light and volatile. EOR projects are built-up from essential laboratory experimentation and simulation studies for tailor made EOR process. Thereafter, it is monitored through a robust workflow during the entire pilot and field scale implementation.

The successful commercialization of In-situ combustion in heavy oil fields, miscible hydrocarbon gas injection in a sand after forced reservoir closure to attain miscibility pressure, polymer flood to improve mobility ratio are field proven with established high rate of returns both commercially and in terms of recoveries.

Some of the milestones of IRS in EOR:

**In-situ Combustion Process:** ONGC is successfully operating one of the largest commercial in-situ combustion projects in the world at a depth of 1100 m involving OIIP of about 100 MMt. This has resulted in significant realization of EOR oil over conventional water flood. In-situ combustion processes in Balol and Santhal fields in heavy oil belt of Gujarat have yielded rich dividends in exploiting heavy crudes. The proven Balol process and effect of air injection in Lanwa from adjoining Balol has led to yet another commercial ISC scheme in Lanwa field. Based on the experience from similar fields operated by OVL elsewhere in the foreign countries, the feasibility of strengthening the ISC process by cyclic steam stimulation is also studied. Having the experience in exploiting heavy crudes, air injection is extended for applications in light oil reservoirs. Air injection in Gamij field envisaging high end Recovery Factor due to favourable dipping reservoir at 8 degrees. The entry of Air Injection for light oil, if successful will open up a new horizon for Thermal EOR process based recoveries for all light oil sands/fields of ONGC, subject to techno-economic acceptance.

**Polymer Flooding:** ONGC has the success story of reservoir management by polymer flooding in a heterogeneous reservoir having moderately viscous
crude of 20 cp, not suitable for plain water flooding due to very adverse mobility ratio. In view of low estimated primary recovery of about 14%, polymer flooding appeared a suitable EOR process based on extensive laboratory studies. The process first applied on pilot scale showed encouraging results and consequently field scale implementation is expected to yield in significant enhancement in recovery of oil.

IRS has in its kitty, a series of successful ASP EOR pilots in fields of Ahmedabad Asset. Based on encouraging pilot results, their field expansion has been planned to realize larger oil gain.

**Miscible Hydrocarbon Gas Injection:** Miscible hydrocarbon gas injection has proved to be a game changer for the main sand of a major oil producing field in western sector of ONGC resulting in large oil gains. The process was implemented after taking the bold decision of suspending oil production for about one year to attain miscibility pressure necessary for higher efficiency of the process.

**Field scale WAG application:** IRS has spearheaded WAG pilot implementation in many sands in the multilayered reservoir of Gandhar field with encouraging response. Field scale WAG implementation holds promise for incremental recovery of 7%. Accordingly, field scale WAG programmes have been designed and their implementation is under commencement.

**Microbial EOR:** MEOR Laboratory is focused with the objective to identify and develop bacterial consortium capable of releasing residual oil from pores and grain surface of the rocks with the help of useful metabolites such as biosurfactants, biopolymers, solvents gases etc. MEOR laboratory at IRS has developed, through collaborative project with premier institutions, anaerobic, thermophilic, halophilic and barophilic bacterial consortium active upto 90°C. Bacterial culture active upto 96°C has also been developed and tested in field. The bacterial consortia have been successfully applied in several wells in fields of Ahmedabad, Mehsana and Ankleshwar Assets. This has brought life to stripper wells leading to realization of oil gain.

Another useful consortium has been applied for paraffin degradation in well tubular and has tremendously helped in reducing the scrapping frequency of wells leading to improved productivity. MEOR applications have also been developed for improving flow efficiency in surface flow lines.

IRS has also developed MEOR applications for improving mobility of ultraviscous oil (viscosity about 100000 cp). Such application has been field tested and reduction in oil viscosity from 900000 cp to about 6000 cp along with reduction in pour point from 63°C to 24°C have been achieved. IRS is also actively pursuing in expanding MEOR applications viz. in treatment of produced water for re-injection, miti-
gation of H2S in carbonate reservoirs, application of MEOR in wells of heavy oil reservoirs etc.

**Laboratory Set up**

**Air Injection Laboratory:** Air Injection Laboratory has been set up at IRS in collaboration with University of Calgary, Canada, with the objective to widen the domain of application of air injection process to enhance recovery from heavy to medium and light oil reservoirs. IRS is now the second institute in the world (next to University of Calgary, Canada) to have such facility. Studies have been carried out to see the efficacy of AI process in many fields of ONGC. Lab studies have also been carried out for PDVSA, Venezuela on contract basis. PDO, Oman also has shown interest in the setup at IRS for studies on HPAI.

**Micro CT Scan Center:** The micro CT scanner facility has been set up at IRS with the help of University of New South Wales (UNSW), Sydney, Australia which has state of the art technology for virtual core analysis.

Institute of Reservoir studies, Ahmedabad has developed expertise and established state of the art laboratory facilities for the following EOR/IOR processes:

**Laboratory Investigation, Pilot Design, Analysis, Fieldwide Implementation, Monitoring and Surveillance of EOR/IOR processes:**

**Water Flooding**
- Water quality aspects of injection water, physico-chemical characterization, rock & fluid compatibility tests, and designing treatment scheme for injection water.
- Generating relative permeability/ROS data under simulated reservoir conditions.

**Chemical Flooding**
- Screening and detailed evaluation of chemicals (Alkali, surfactant and polymers) for use as EOR agents – compatibility, solubility, thermal and mechanical stability, static adsorption, emulsion formation, and change in interfacial tension.
- Core flood displacement studies on long cores under simulated reservoir conditions.
- Designing and analyzing chemical EOR pilot.
- Field wide implementation, monitoring and surveillance of chemical
EOR process.
- Low salinity and low tension water injection.

Gas Injection processes
- Minimum miscibility pressure (MMP) determination for hydrocarbon and non-hydrocarbon gases.
- Miscible & immiscible hydrocarbon and non-hydrocarbon gas injection experiments.
- Laboratory core flood experiments for Water-alternate gas (WAG), Surfactant alternate gas (SAG) and simultaneous water & gas injection (SWAG).

Thermal Recovery Processes
Laboratory experiments to investigate applicability of thermal EOR processes upto 3000 psi pressure for heavy, medium and light oil reservoirs.
- Thermal analysis system
- Dry & Wet in-situ combustion.
- Steam injection
- Designing in-situ combustion/high pressure air injection pilot and its analysis.
- Field wide implementation, monitoring and surveillance of in-situ combustion process.

Microbial Enhanced Oil Recovery Laboratory
- Identification, isolation and characterization of bacterial system for MEOR application
- Identification of bacterial system for improving flow assurance of oil in the tubing/surface flow lines

Monitoring & Surveillance of field EOR schemes through Tracer Surveys
- Designing and monitoring Inter well tracer tests (IWTT) for flood front tracking.
- Designing and analyzing single well tracer Test (SWTT) for estimation of residual oil saturation in water flooded areas/zones.

Treatment Design for Water Injection System: The water flood laboratory at IRS addresses the challenge of improving water injection quality and also recommends suitable measures for treatment design of water injection system. Such studies have been carried out for many of the in-house fields where quality and quantity of water injection is an issue. Such studies have also been carried out for other companies on revenue generation basis.

Deposition of scale in various pipelines is also an issue of concern especially in old installations. IRS has the capability to carry out studies for scale prediction and scale forming tendency of produced water samples and identification of suitable chemical formulation as scale inhibitors.

Detail analysis of the composition of the scale by XRD including its chemical analysis is carried out and the suitable acid formulation to remove the deposition is optimized. Field implementation of such formulations has been carried out in some of the installations/pipeline/effluent lines and the results are highly successful.

Patenting R&D Work
Although applied R&D work is the major focus area of IRS wherein it provides Reservoir Engineering solutions to the operating Assets and Basins, a significant amount of R&D efforts is also put in Basic Research mainly through collaborative approach to bring out innovations in E&P arena. These provide opportunities for patenting the R&D work and some of the main patents by IRS are as under:

Patents Received
- Indian Patent: No. 197554 awarded on September 22, 2006 for “A Process for Enhanced Recovery of Crude Oil from Oil Wells Using Novel Multi Microbial Strain” It provides a novel microbial consortium (deposited with Institute of Microbial Technology, Chandigarh) which is used for in situ application in the reservoir, by proliferating the microbial consortium in Nutrient media and thereby enhancing the crude oil recovery from wells, making the residual oil mobile and producible.

The technology can be used for (a) Improving productivity of low producing & stripper wells.
30x30x10 cm has been designed for Core-Flood Studies in three dimensional. It has multiple inlet and outlet points where pressure-temperature readings can be recorded and monitored. There is provision of placing/modeling vertical as well as High-Tech wells (inclined and horizontal). Combination of injector and producers can also be configured for Core Flood studies.

ISO 9001:2008 Certification

Institute of Reservoir Studies, Ahmedabad is an ISO 9001:2000 accredited institute since March 04, 2005 by M/s Bureau Veritas Certification (I) Pvt Ltd. IRS conducts regular internal audits and management reviews as per IRS QMS procedures. Surveillance audits by certification body are also conducted annually. IRS cleared all surveillance audits and was re-certified in March 2008, as well as in February 2011. With effect from March 3, 2010 the ISO certification has been renamed as ISO 9001:2008. The certification agency Bureau Veritas Certification (India) Pvt. Ltd conducted 2nd Surveillance Audit in March, 2013 after 2nd re-certification of IRS in Feb 2011 for its quality management system. The audit was carried out as per ISO 9001:2008 standard and the current certificate of IRS is valid up to March 2014.

Collaborative Research

The Institute has been pursuing collaborative research work in different E&P arena with some of the premier National and International Institutions to gain from advancement in technology and new developments. Some of the notable collaborative projects carried out in the recent past are listed below:

- University of Calgary, Canada - Long term collaboration, participation, maintenance and service of High Pressure Air Injection set-up for studying EOR processes in heavy, medium and light oil reservoirs.
- University of New South Wales (UNSW) Australia - Hydrocarbon prospect evaluation of Basement Reservoirs.
- University of New South Wales (UNSW) Australia - Establishment of micro CT scan centre for Reservoir Characterization
- ARI, Pune - Development of microbial consortium active above 90°C for EOR.
- BHU, Varanasi - Isolation, identification and development of methanogens for in-situ generation of methane from oil reservoirs
- ARI Pune - Development of microbial consortium for enhanced oil recovery from heavy oil reservoirs
- Agharkar Research Institute (ARI), Pune - Development of microbial system for treatment of oil field produced water to make it suitable and re-injection into oil reservoir.
- TERI, New Delhi - Development of microbial process for enhanced oil recovery from heavy oil reservoirs
- TERI, New Delhi : Development of reservoir and crude specific thermophilic, anaerobic bacterial culture bank for enhanced oil recovery.
- TERI, New Delhi - Microbial system for improving flow efficiency of oil in surface flow lines
- IFP France (Beicip Franlab) : Fracture Modeling
- Skochinsky Institute of Mining, Russia : Agreement of Collaboration for Underground Coal Gasification (UCG)
- The Energy Research Institute (TERI), New Delhi - Isolation, identification and development of methanogens for in-situ generation of methane from coal seams
- TERI, New Delhi : Development of reservoir and crude specific thermophilic, anaerobic bacterial culture bank for enhanced oil recovery.
- University of New South Wales (UNSW) Australia - Establishment of micro CT scan centre for Reservoir Characterization

(b) Long term improvement of recovery factor of reservoir through microbial flooding.
(c) The process is applicable in reservoirs having temperatures in range of 70° to 90° C.
Introduction

Background

Engineers India was established in 1965 to develop indigenous capabilities in the area of Hydrocarbon to provide technical services for establishment of Hydrocarbon processing units in India. Over the years, EIL has evolved into a highly reputed technical organization providing complete range of services which include process design, basic and detailed engineering, procurement and inspection services, construction management, plant commissioning, plant operation and project management of hydrocarbon complexes. It has emerged today as one of the South East Asia’s leading design, engineering and EPC organization.

The major revenues of EIL come from the core activities related to Engineering & Consultancy. However, numbers of these assignments are the outcome of front end technical studies, feasibility reports, basic design & engineering packages etc. Clients approach EIL because of technical competence and experience that reside in the organization. It gives them the comfort of adequate technology support at all stages of project implementation. A sound technical base, with an expanding technology portfolio is therefore essential for EIL’s continued growth.

New product design and development is more often than not a crucial factor in the survival of a company. In a progressing organization, design capabilities, range of products and newer portfolios must be added on continuous basis. This is necessary due to continuous technology upgrade and changing preferences of the clients. Without a R&D program, organization has to rely on the innovation of others. It is seen that organizations with a persistent R&D strategy outperform those with an irregular or no R&D investment program. Therefore, an organization with higher R&D intensity has an edge over the other organizations. EIL is a live example of such a strategy.

Strategic Initiative for R&D Centre

In order to keep up with the technological innovations, developing capabilities indigenously and to support process engineering, EIL established Research and Development (R&D) Division in 1970. Initially this Division started building in-house capability through desk top research, literature survey, process modeling and simulation. During this time the major initiatives taken by R&D were in the following areas:
• Development of in-house modeling capabilities for process simulation and hardware design, thus augmenting the capabilities and extending support to other EIL technology divisions.
• Development of processes based on in-house know-how, literature information and through experimental back up provided by research organizations like IIP, NCL, and RRL.

At that time, foreign exchange was not readily available and import/licensing of technology as well as hardware had to be assessed vis-à-vis the availability of indigenous options, the developmental activities were taken up by R&D with a view to develop indigenous capabilities. This provided an additional impetus to R&D for developing indigenous capability. A number of technologies were, in fact, successfully developed at a time when EIL did not have its own facilities for carrying out bench scale/pilot plant testing and relied on collaborative work with NCL, IIP and RRL.

In the eighties, Hydrocarbon Industry was highly dependent on the foreign licensors. Therefore, there was a need to have a world class R&D facility that could provide services to Hydrocarbon industry. Therefore, MOP&NG and the Scientific Advisory Committee recommended that EIL must set up a world class R&D facilities as a part of their R&D initiative. A grant of INR 2 crores was given by OIDB to EIL for taking up this initiative. Accordingly, EIL’s R&D Centre was set up in 1988-89.

The objectives underlined while setting up the R&D centre was to;
- Provide a national facility for process development and equipment design improvement
- Facilitate absorption and adaptation of technologies to meet indigenous requirements, i.e., following a reverse engineering concept
- Carry out collaborative research
- Identify new areas in line with diversification plan of EIL
- Develop scale up methodology
- Provide hardware testing and diagnostic services

The perspective of R&D with respect to developing newer technologies has changed over the years. It is not mere development of a technology, but also to ensure that the technologies developed at R&D centre are technically as well as commercially competitive with the world’s best available technologies.

Research & Development Policy

Considering the Corporate Vision, Company’s areas of operation and R&D objectives, following R&D policy has been adopted:
- Focus on enhancing the intrinsic core competitive edge in hydrocarbon and emerging areas.
- Develop technologies having differentiating attributes aligned with organizational goal of delivering value to all stakeholders.
- Develop energy efficient solutions for conventional, non-conventional and renewable energy systems to limit operational impact on the environment and society as a whole.
- Establish a collaborative framework for development of technologies with common vision, mission and goal.
- Sustain the innovative legacy of EIL and foster creativity & novel practices with the objective to make EIL a global technology resource centre.

Research & Development Model

Considering EIL’s primary areas of operation (i.e., Engineering and Consultancy in Hydrocarbon sector) and expected role of R&D in the working structure of EIL, an optimum and efficient model for the R&D Operations is necessary. EIL (R&D) functions as a technology division with an emphasis on developing newer technologies, upgrading available technologies and developing specific products with or without collaborating partners. Developed technologies are further taken up for implementation by Process Development Division while R&D continues to provide technology package support to them. In addition R&D also provides support to vendors to manufacture / fabricate products being developed by R&D. This model has been adopted because it provides seamless interface with downstream technology divisions of EIL, other research organizations and vendors / manufacturers. Adoption of this model necessitates forging newer tie ups, formation of Joint Ventures and collaboration with other R&D organizations to develop an integrated collaborative approach to R&D.

Plant and Laboratory Facilities

EIL R&D Centre was established in 1988 at Gurgaon. The R&D Centre is

Mr Ganesh Prasad is at present General Manager (R&D), responsible for management of Research & Development Division and ensuring research activities of EIL. Some of these projects are collaboration with major operating refineries.

Prior to the current assignment, he was heading HMTD where he was responsible for design and engineering of Process Equipments-Column internals, Heat exchangers and Fired Heaters for Refinery/Petrochemical and Gas plants. He also has to his credits process design experience of off shore –Well Head and Process Platforms. He has been instrumental in development and commercialization of various Indigenously developed technologies namely:

♦ FGH technology indigenously developed by EIL and IOCL has been adopted by Guru Gobind Singh refinery (HMEL). The unit was commissioned in May 2012 is producing food grade hexane (IS 3740-2002).
♦ Developed basic design and engineering package for flue gas Desulphurization for Demonstration of SO2 Recovery Process (SOR) Technology at NRL.
♦ First Indigenous DHDT Unit for Greening of Oil and Gas Business.

He has been regular contributor of papers in national/international journals/technology meet etc.
located in a 33 acres plot situated on the NH-8. In addition to R&D Centre, this plot also houses a training centre and lush green gardens. The facilities in the R&D Centre were selected considering the development plan, which was focused on enhancing EIL’s capabilities in mainly refining industry including Process design and Heat & Mass transfer equipments. Over a period of last 25 years, EIL has built a unique research infrastructure comprising industrial size pilot units, which are unparalleled in the country. These facilities include:

- Laboratory Building: In addition to large routine laboratory facilities, the centre has
  - 100 mm dia distillation column (LABODEST)
  - Oldershaw column (AUTODEST), operable up to vacuum of 0.1 torr
  - High pressure phase equilibrium still
  - HPLC, GC, Simulated distillation etc.
  - Particle size analyzer
  - Ion chromatograph
- Pilot plant facilities, e.g. distillation columns, vacuum system, Gas liquid separator etc.
- Pilot building consisting of TBR Pilot facility, Extraction facilities, packed column facilities, FCC cold flow model, PSA unit and Slurry bubble column reactor facilities.
- Coal to Liquid Pilot Plant
- Utility Units e.g. cooling tower, boiler, instrumentation, etc.

The Pilot Plants at R&D Centre are comparable to some of the best available globally and is supported by a well equipped Analytical Laboratory to provide substantially reduced scale up uncertainties. This helps in generating more reliable data for efficient design of specialized hardware and processes. Pilot plants have been set up to study various units encountered in a refinery.

Some new facilities are also planned to be set up in the R&D Centre in order to meet long term vision of the organization. All these facilities shall be located in an eight (8) acre plot within the R&D Complex. The new R&D facilities shall include:
- Steam-water related studies block.
- Bioremediation Pilot Block.
- Renewable Power Pilot Block.

**Manpower**

EIL R&D has about 55 employees on its rolls. It comprises of about 35 engineers with minimum educational qualification being bachelor’s degree in engineering. Most of these are chemical engineers. We have two PhDs in chemistry for manning our laboratory facilities. Around 20 are support staff for pilot plant operation and laboratory work. In addition EIL has one of the most diversely skilled workforces comprising of engineers, technologists and specialists who are available for any engineering support required by R&D either for designing and setting up pilot facilities or for commercialization of developed technologies.

**Technologies Developed and Commercialized**

EIL has today positioned itself as an organization with an Independent Research Center and has developed analytical, evaluative, and experimental and scale up capabilities. The concepts developed are integrated to prepare a complete knowledge package, which is directly transferable to user for commencement of Detailed Engineering / Implementation.

EIL has developed several technologies which have formed part of EIL’s present technology portfolio. Some of these include:
- Visbreaker (Coil & Soaker) Technology for Petroleum residual fractions
- Distillation
- Trickle bed reactor
- Facility to Test Mass Transfer Internals in 400 and 1200 mm column.
- Two cold flow reactors of dia 150 mm and 300 mm for the hydrodynamics and scale up studies
- Two cold flow slurry bubble column reactors of dia 200 mm and 450 mm for the hydrodynamics and scale up studies as a part of Coal To Liquid (CTL) technology development suitable to handle Indian coal in blends with pet coke.
• Delayed Coking Technology
• Diesel Hydro treating (DHDT) Technology
• Technology for production of Food Grade Hexane (FGH) / Polymer Grade Hexane (PGH) by Hydrogenation process
• Spent caustic Treatment
• Sulphur Recovery using Claus Process
• Oxygen enrichment process for Sulphur recovery
• Regenerative SO\textsubscript{2} process for Tail gas treatment unit
• Liquid Sulphur Degassing process
• Reactive Adsorption Process (INDAdept) for deep desulphurization of Diesel and Gasoline
• Light Naphtha Isomerization Technology
• Inde treat and Inde sweet technologies
• CFC technology for LPG treatment
• Ammonia Recovery from Sour Water Stripper ammonia rich stream by converting to ammonium sulphate.
• CO\textsubscript{2} Recovery from flue gas by Amine solvent

Some of these Technologies have been developed in association with other Research Institutions and Operating Companies. EIL R&D maintains a close association with various National Laboratories & R&D centers, academic institutions like Indian Institute of Technologies (IIT) and International Research Institutes like Fractionation Research Institute (FRI), Process Science and Technology Center (PSTC), Process Integration Research Consortium (UMIST), International Flame Research Foundation (IFRF), etc. to supplement its efforts at continuously pushing the frontiers of knowledge for the benefit of EIL’s clients.

**Patents and Awards earned by R&D**

**Status of Patents**

Based on the innovative work carried out by R&D, EIL has been filing patents to protect its intellectual property from unauthorized usage. The first patent entitled “A process for the vapour phase catalytic oxidation of hydrocarbon xylene / naphthalene and homologues thereof for the production of corresponding hydrides” was filed by EIL in, as early as, 1981. Since then, a total of 41 patents, covering new processes, catalyst formulations and hardware devices have been filed. Out of these 41 applications filed by EIL, 22 patents have been granted till date and 15 patents are awaiting grant.

In addition to above, R&D has been filing at least one Patent application every year. Almost all the technologies including those, for which patents are yet to be granted, have been commercialized by EIL.

**Awards Earned by R&D**

Based on the achievements and innovation work carried out by the R&D, EIL has been conferred with more than 15 patents are awaiting grant. EIL in, as early as, 1981. Since then, a total of 41 patents, covering new processes, catalyst formulations and hardware devices have been filed. Out of these 41 applications filed by EIL, 22 patents have been granted till date and 15 patents are awaiting grant.

In addition to above, R&D has been filing at least one Patent application every year. Almost all the technologies including those, for which patents are yet to be granted, have been commercialized by EIL.

**Awards Earned by R&D**

Based on the achievements and innovation work carried out by the R&D, EIL has been conferred with more than

**DHTD technology, indigenously developed by IOCL and EIL, has been adopted by Bongaigaon Refinery (IOCL-BGR).**

The unit was commissioned and Guarantee Test Run accomplished successfully to produce EURO-IV Diesel and ATF fuels.

**FGH technology, indigenously developed by IOCL and EIL, has been adopted by HMEL.**

The unit have been commissioned and successfully to produced on specification product.

Sheo Raj Singh is a Deputy General Manager with R&D division of Engineers India Limited. He received B. Tech. Degree from IIT Kanpur in 1981 with first rank in Chemical Engineering and joined EIL in the same year as a management trainee. His main areas of interest include Process simulation and modeling, advanced process control, Pinch technology and process integration, simulation of separation systems, reaction systems like FCC, Catalytic reforming, hydro-cracking and dynamic simulation. During his long Association with EIL(R&D) he has been responsible for development of several in-house software, notable among them are process simulator SIMSYS, Data Reconciliation Software RAGE, Heat Exchanger Network Synthesis software HENSEN, Heat Exchanger Network Simulation and optimization Software HENOPT, Cast Air pre-heater simulation software, Software for simulation of FCC, Catalytic reforming and hydro-cracking units, software for scheduling of multipurpose batch processing units, Software for Steam – Power Network optimization for refineries. He has also been responsible for developing and implementing online software for crude pre heat train optimization and fouling estimation using in-house software RAGE and HENOPT. Currently he is working towards development of complete capability for water management studies, Desalination of sea water using waste heat from flue gas, Dynamic Simulation and Process Intensification.

Sheo Raj Singh is a member of Board of studies (BOS) University Department of Chemical Engineering, Thapar University Patiala, India, member Technical Advisory Committee (TAC) for Technology Management, Department of Scientific and Industrial Research, Ministry of Science and Technology Government of India, Member of Committee for Development of Glossary for Technology Management (MSD-4), Bureau of Indian Standards, Government of India. He has contributed about 26 papers to international journals, seminars and conferences.
twenty prestigious awards including Petrotech 2012 for first Indigenous DHDT Unit for Greening of Oil and Gas Business and ICC PSE Excellence Award-2012 for R&D, Technology Development & Innovation in the Mini Ratna Category. List of major awards earned by EIL (R&D) is given below:

- NRDC Meritorious Invention Award for development of Technology for Removal of H2S & Mercaptans from LPG through Continuous Film Contactor” for the Year 2007
- PSE Excellence Award 2011 for R&D, Technology Development & Innovation.
- PETROTECH 2012 – for First Indigenous DHDT Unit for Greening of Oil and Gas Business.
- ICC PSE Excellence Award-2012 for R&D, Technology Development & Innovation in the Mini Ratna Category
- SCOPE meritorious award for best practices in R&D, Technology Development and Innovation for the year 2011-12

Recent achievements

Light Naphtha Isomerization Technology
In recent years, Light Naphtha Isomerization has become increasingly important to help refiners in meeting the stricter gasoline specifications. Isomerization is the best light naphtha octane boosting process, which produces Isomerate free from sulfur, olefins and aromatics. This process converts the straight chain light paraffinic hydrocarbons (pentane and hexanes) to the corresponding branched isomers, having higher octane number.

Sulphur Technologies
Over the years, EIL R&D has developed many technologies in the field of sulphur recovery (SR) from various sour gas streams. EIL’s SR Technologies are capable of treating sour gases containing H2S in ppm level to as high as 92%v. The technologies are capable of providing sulphur recovery in range of 96% to 99.9%. In refinery applications where the sour gas contains H2S in the range of 50%-92%v, EIL also have capability to provide Claus based Technology for 96% recovery, which along with indigenously developed Tail Gas Treating Technology provides 99.9% recovery of sulphur.

Engineers India Limited (EIL) and Chennai Petroleum Corporation Limited (CPCL) have jointly developed and commercialized a low cost and highly efficient indigenous process called - OXYENRICH (Oxygen Enrichment) Process.

Highlights of OXYENRICH Process
- Process ensures enhancement of the capacity of SRU by 15% - 35% by using oxygen-enriched air.
- Process gives better conversion of H2S to sulphur in main combustion chamber
- Oxygen enrichment process improves overall sulphur recovery by 0.5%.
- Process uses liquid oxygen after vaporization for enrichment of combustion air.
- Process can alternatively use waste nitrogen if refiner generates sufficient waste nitrogen in their nitrogen plant . Use of waste nitrogen is highly economical.
- High temperature (1350-1500 oC) at the main combustion chamber ensures complete destruction of ammonia.
- Process ensures stable flame in main burner even at low H2S concentration (<50%v) in feed gas.
- Process does not call for any major modification of sulphur recovery unit for implementation.
- Implementation of process in a running plant needs minimum investment and minimum shutdown period (15 days).

New design and revamp of SRU based on OXYENRICH Process ensures dual mode operation of SRU i.e., normal operation with the plant air and operation with oxygen enriched air.
Preamble

In the past two decades, India has certainly developed significantly to become the fourth largest economy in the world. This has mainly been due to a consumer based economy. To cater to the projected growth India’s petroleum refining capacity is expected to rise to 265 million tonnes per annum (MTPA) by 2016 from the current capacity of 215 MTPA. Admittedly, there is less innovation in various sectors including petroleum refining. It is important that India innovates in various sectors including petroleum refining to accelerate growth. In the current dynamics with competitive growth only learning organizations that create and innovate can sustain and have a cutting edge. A factor that works in favor of India is its young population with some of the brightest minds brimming with enthusiasm.

BPCL has been working diligently towards creating a world class Corporate R&D centre. Through this centre the Company is encouraging innovation through interaction with academia and industries. The R&D Centre is also working towards foreign collaboration & sponsorships besides attracting new talent. The Investment in R&D has been planned to build infrastructure, and install state-of-the-art facilities that would attract and nurture the best scientific resources at all levels. The blends of exploratory research projects and tech-support have been prioritized for sustainable business growth and have been actively integrated with all the business units like Lube, Aviation, Gas, LPG, Retail and Refineries for providing technological solutions and development of niche products. The core research areas are broadly divided into four categories namely Refinery processes up-gradation / optimization, Development of novel energy efficient technologies, Product development and Alternative fuels & energy.

BPCL (R&D) centres intend to work intensively in the areas of improving performances of their existing business units and will focus aggressively on in-house product/process technologies and their commercialisation. The overall objective would be secure the burgeoning energy demand of the country there by achieving sustainability.

Genesis of R&D Centres

Research and Development centre is the pulse of sustained business growth of the company. BPCL established its first R&D Centre at Sewree, Mumbai in 1983; followed by one at Kochi and then the corporate R&D Centre at Greater Noida, New Delhi, in 2001. Today, these R&D centres are recognized by the
Research and Development – Corner Stone of Sustainable Growth

S. Varadarajan, Chairman & Managing Director
Bharat Petroleum Corporation Ltd, Mumbai

The statement “there is no more easy oil” is commonplace in the oil & gas industry across marketing, refining and exploration. Besides upgrading technology, it is just as critical to nurture human resources and equip them to explore the new frontiers in the oil sector.

To reduce dependence on fossil fuels as the main source of energy it is inevitable that alternate renewable energy forms are introduced that would ensure sustainability in the long run. While there have been many forays to introduce these renewable forms of energy the challenge for R & D teams is to ensure that these are commercially viable options.

Globally the challenge in Oil & Gas exploration has been to introduce technology to facilitate ultra deep water drilling and also to streamline the process of shale gas extraction. The introduction of new processes and technologies will considerably improve the efficiency of exploration, enhance safety standards and provide safeguards from environmental disasters.

In refining the emphasis has always been to produce environment friendly fuels at reasonable cost so that these can be made available to consumers at affordable prices. This would have a major relevance in the context of India going in for introducing Bharat Stage V and more advanced fuels in the near future.

In Marketing, the introduction of high performance fuels and lubricating oils to cater to the burgeoning growth of new generation vehicles will be important areas that the R & D teams would have to focus on. In addition, the automation of Retail outlets, supply locations and transportation system would provide end users with an assurance of guaranteed quality and quantity of petroleum fuels. The use of nano technology in the areas of exploration, refining and marketing could see quantum improvements in efficiencies.

In pursuit of its vision, BPCL has been leveraging both technology and people to achieve leadership in the market place. Research & Development has been a key focus area to drive growth and the company now has three strategic R & D Centres at GREATER NOIDA, Sewree & Kochi. The Investment in R&D has been towards building infrastructure, installing state-of-the-art facilities and nurturing the best scientific resources at all levels.

BPCL has undertaken several projects in the area of non-conventional energy and alternative fuels to support the sustainable development activities in this pertinent area. R&D has been working in the area of nanotechnology in collaboration with IISC Bangalore and CSMCRI Bhavnagar for development of materials for storage of hydrogen and methane. A technology for gasification of coal and petroleum coke to produce value added liquid fuels is being developed jointly with Engineers India Ltd under the sponsorship of Centre for High Technology (CfHT), India. High selectivity catalysts for Fisher-Tropsch process are being tested and developed for production of liquid fuels from synthesis gas.

Exchange of scientific information with national and international scientists is essential for the cross fertilization of ideas which is being achieved through various activities such as Sponsored/ Collaborative research. Some of the institutes and industries with which BPCL is working on collaborative research programs include, Indian Institute of Technology, Kanpur, Indian Institute of Petroleum, Dehradun, Korean Institute of Energy Research, Alternate Petroleum Technologies, USA with many more to follow.

India today stands on the threshold of becoming an economic super power and the Oil and Gas sector will play an important role in fuelling the growth of the country. The role of R & D would be of immense significance in the context of providing innovative solutions to meet the challenges of the future.

R&D centre at Kochi Refineries which is equipped with state-of-the-art circulating FCC pilot plant for optimization of commercial plants has several successful new product developments to its credit, like Rubber Solvent, Mineral Turpentine Oil, Rubber Spray Oil, Natural Rubber Modified Bitumen (NRMB), Polymer Modified Bitumen, Bitumen Emulsion, and High Performance Diesel Additive.

On similar lines, Sewree R&D has been actively working on lube oil development for automotive and industrial applications. It is continuously engaged in new superior lube formulation development through better understanding of lubrication mechanism. Till date,
Sewree R&D has successfully developed numerous lube oil formulations and is constantly supporting Lube business development. New products developed include Passenger Car Engine Oil, Fully Synthetic Gear Oil, customer specific Metal Working Fluid, High Performance Grease, MAK all season HMO (Horticulture Mineral oil) and LLPO (Light Liquid Paraffin Oil) for the cosmetic industry. Furthermore, field trials and condition monitoring, the testing of lubricants, greases and fuels form an extensive part of R & D activities.

We give here a brief insight to BPCL R&D’s Core Purpose and Vision Statement.

Core Purpose Statement

“We are a vibrant team providing cost-effective technological solutions and innovative products through research and development to achieve business excellence”.

Vision Statement

- We contribute to business growth through innovative, cost effective, sustainable and environment friendly technological solutions.
- We are a renowned Research Centre attracting brightest minds across the world.
- We promote green energy solutions for societal benefit.
- We have state-of-the-art facilities for advanced research.
- We operate in a cordial collaborative and transparent environment with mutual trust and respect for each other.

R & D Infrastructure

Analytical Sciences

Strong analytical sciences support is a prerequisite for the success of R&D projects. R&D laboratories are equipped with state-of-the-art facilities to provide analyses support for the new processes and product developments by scientists with specialization in spectroscopy, chromatography and other advanced analytical techniques who work in association with other divisions, refinery operations and marketing groups to achieve the results and advance the expertise in vital areas.

Crude Oil Evaluation and Crude Oil Blend Compatibility

R&D has acquired competency in the areas of Crude oil evaluation and crude oil blend compatibility. Till now more than 70 types of crude oils traded world over have been evaluated in detail and various blend options have been studied for opportune crude oil processing. BPCL has also provided these services to external agencies like PI, OIL, Cairn Energy and Nigerian Petroleum Company (NNPC).

Catalysis and Catalytic Processes

Catalyst forms the heart of secondary refinery operations. Activities in catalysis and catalytic processes area are largely directed towards development of improved catalysts, monitoring of catalyst performance, evaluation, and selection of catalysts & additives for fluid catalytic cracking (FCC), reforming and hydroprocessing are some of the critical areas that R & D specialises in.

Modelling, Simulation and Optimization

“Modelling, Simulation and Optimization” is one of the core areas of R&D Centre at BPCL. Its agenda covers development of rigorous simulation and optimization tools for refinery processes which include FCC, reforming, hydrocracking and separation processes. The objective of these models is to facilitate effective interpretation, scale up of in-house bench scale units/ micro reactors experimental data and simulation of commercial refinery units. Rigorous models for FCCU, DHDS, and Hydrocracker have been developed. These simulation models are in extensive use for catalyst and additive selection, trouble shooting, scale-up and design. Energy efficiency improvement studies for crude preheat trains, Crude distillation Units and FCC main fractionator have been carried out using Aspen Plus and Pinch Analysis tools. The group is well equipped with state-of-the-art tools for steady state as well dynamic simulations. Necessary software packages for molecular modelling for the new material development and computational fluid dynamics are also envisaged in future.

Fuel Characterization

Product quality up gradation has assumed tremendous importance due to customer awareness and highly demanding competitive environment. New environment regulations for ambient air quality are leading to very stringent specifications for fuels necessitating use of advanced fuel testing equipment.

Bitumen

To cater to the growing demand for high quality bitumen Corporate R&D Centre took a major initiative to develop improved bitumen, Polymer Modi-
fied Bitumen (PMB), Crumb Rubber Modified Bitumen (CRMB), Bitumen Emulsions, Colored Bitumen and Performance Grade Bitumen (PG). To achieve these goals, the R&D centre is well equipped with a bitumen blowing pilot plant and bitumen testing equipments. R&D centre has also developed a cost-effective process for bitumen packaging in polymer bags.

**Corrosion and Fouling**
A state-of-the-art Corrosion Test Laboratory has been established for monitoring corrosion rates, developing corrosion inhibitors, antifouling chemicals and providing services to abate corrosion related problems in refinery and allied areas. Certain activities have been initiated to study the effect of corrosion in handling ethanol blended gasoline. Synthesized filming amine for imped ing the corrosion in process vessels and this will be commercialized in the future. R&D has provided support to the product-pipeline team in handling various issues relating to corrosion.

**Alternative Fuels & Renewable Energy**
We have undertaken several projects in the area of non-conventional energy and alternative fuels to support the sustainable development activities in this pertinent area. As an initial step to develop infrastructure for hydrogen generation, storage and its application, a CNG three wheeler modified for running on hydrogen stored on-board & a hydrogen refuelling platform have been developed. Certain projects for development of efficient hydrogen generation are also initiated. R&D has been working in the area of nanotechnology in collaboration with IISC Bangalore and CSMCRI Bhavnagar for development of materials for storage of hydrogen and methane. A technology for gasification of coal and petroleum coke to produce value added liquid fuels is being developed jointly with Engineers India Ltd under the spon sorship of Centre for High Technology (CHT), India. High selectivity catalysts for Fisher-Tropsch process are being tested and developed for production of liquid fuels from synthesis gas.

**Biotechnology**
A state-of-the-art Biotechnology Laboratory has been established in view of emerging importance of biotechnology in hydrocarbon processing, biofuels development and other applications. One of the biotechnology areas of great importance to refinery is in the application of Bio-desulphurisation of petroleum products.

**Human Resources**
BPCL is a fortune 500 oil refining, exploration and marketing Public Sector Undertaking with a Navaratna status. For Bharat Petroleum, commitment of its employees is a critical resource. Fully realizing that only a satisfied employee will put his best foot forward with the customers, Bharat Petroleum has taken many steps to make the organization a ‘Great Place to Work’. Bharat Petroleum fosters effective value-based HR processes for development of people and their organizational capabilities with a view to provide them with a competitive edge and also to realize their personal vision in tandem with the corporate vision.

BPCL has been recruiting scientists and engineers having experience and exposure of working in national and international research institutions. The present strength of research personnel at all three R&D centres is 66 with an average age of 36 years. The centre plans to attract young and fresh M. Techs and PhDs from various scien-
tific and engineering disciplines.

**Library and Information**

Access to precise and reliable information is of utmost importance for gaining a competitive edge while developing technologies. R&D has established a well-equipped library. The library is subscribing to a number of international and national periodicals, and is continuously adding books & journals in the relevant areas. To keep abreast with the latest developments, Library and Information Division has subscribed to online chemical abstract services viz. “Scifinder” and STN host with access to 200 international data bases including Elsevier and ACS Journals.

**Linkages with External Institutions**

Exchange of scientific information with national and international scientists is essential for the cross fertilization of ideas. This is being achieved through various activities such as Sponsored/ Collaborative research. Collaboration with academia by offering facilities and expertise to students for their post-graduate & doctoral programs, participating in Symposia/ Conferences/ Workshops, lectures by and discussions with distinguished scientists from India and abroad are some of the initiatives that form part of these collaborative efforts.

Some of the institutes and industries with which BPCL is working on collaborative research programs are:

- Indian Institute of Science, Bangalore
- Indian Institute of Technology, Kanpur
- Indian Institute of Petroleum, Dehredun
- National Chemical Laboratory, Pune
- Indian Institute of Technology, New Delhi
- Indian Institute of Technology, Kharagpur
- Indian Institute of Technology Roorkee
- Osmania University, Hyderabad
- The Energy Resources Institute, New Delhi
- UICT, Mumbai
- Indian Institute of Technology Chennai
- CSMCRI, Bhavanagar
- Institute for Plasma Technology, Gandhinagar
- Tamil Nadu Agricultural University, Coimbatore
- EIL, Korean Institute of Energy Research, Stockholm University, Sweden
- SINTEF, Norway
- Alternate Petroleum Technologies, USA

**Major R&D Achievements**

Substantial progress has been achieved on major research projects in the emerging areas of coal to clean liquid fuels, bio-fuels, hydrogen storage and refinery processes. R&D programmes from the past one decade have continued to provide a competitive advantage to its business operations through development and commercialization of cost-effective and niche products, process improvements, development of catalysts, lubricants, alternate products, processes in the areas of Refining, renewable energy, etc.

**New Offerings and Initiatives**

In a recent development, an Indian and Australian consortium won the AISRF Grand Challenge Project, “Mini DME: A custom designed solution to bring stranded gas to the energy markets”. This is funded by the AUSTRALIA-INDIA STRATEGIC RESEARCH FUND (AISRF). The Australian side consists of CSIRO, RMIT University and University of Melbourne, while Indian side includes IIT Dehradun, IIT Roorkee and BPCL (R&D).

BPCL R&D is also a consortium partner in an International project “Environmental due diligence of CO, capture and utilisation technologies” (EDDiCUT) along with Norwegian University of Science and Technology (NTNU).

BPCL R&D has taken initiative to promote industry-academic research collaboration through “Petrotech Research Fellowship” scheme, as well as various new initiatives and research programs on Refining Processes, New Product / Catalyst Development, Alternate Energy, Environment Protection and technological development.

**Accolades /Awards**

The Corporate R&D Centre has filed sixteen (16) Indian and forty-five (45) foreign patent and applications (two Indian and seven foreign patents have been granted ) to protect the intellectual property resulting from innovative research of past one decade. Along with this, one hundred forty one (141) research articles/publications in the related areas of renowned petroleum journals and symposia have been published. In catalysis area, our scientists are recognized as Editorial Board Member in the science journals like The Open Catalysis Journal, Bentham Open and Journal of Catalysts, Hindawi Publishing Corporation and J. Porous Materials.

Scientists/engineers of BPCL (R&D) are receiving special invitations from renowned journals for contributing articles in the areas of refining, process improvements, and product development like Hydrocarbon World, Hydrocarbon Processing and Petroleum Technology Quarterly (PTQ). On invitation by ASTM, two special chapters have been written by CRDC scientists in ASTM Hand Book in the areas related to hydro-isomerisation and FCC.

BPCL Corporate R&D Centre has bagged many accolades/awards for their research efforts in the areas of product development & commercialization and process improvements implementations, some of them can be mentioned like Ocean Tex Award, 2010, best paper awards in ISIF 2006 & 2012, Catalyst Symposium (2010) & Petrotech (2003 and 2009), CORCON (2007 & 2009) and best laboratory awards (NACE 2010). Dr. T. Chiranjeevi was conferred the “SISTLA KAMESWARI YOUNG SCIENTIST AWARD” for the year 2012 by the Catalysis Society of India.” from PetroFed 2012. The Team comprising of Dr. P S Viswanathan, Dr. Jaya Rawat, Mr. V S Dhaneesh and Dr. Sudha Tyagi won the PetroFed 2012 Award named “Innovator of the year- Team for developing an efficient multi-metal corrosion inhibitor for ethanol to be used in gasoline blends developing the product namely BEIC.

**BPCL (R&D) – The Pulse of Sustained Business Growth of the Company**

Competent, vibrant and talented BPCL (R&D) team firmly believes that the strategy of making world class R&D Centers through developing core competencies and visionary leadership for developing in-house products/process will cater to the increasing demand of oil industries and help BPCL sustain market leadership. With this approach, R&D would endeavor to bring paradigm shift in the area of technological innovations.
HPCL is a Government of India Enterprise with a Navratna Status, and a Fortune 500 and Forbes 2000 company, with an annual turnover of Rs. 1,90,048 Crores and sales/income from operations of Rs 2,15,675 Crores (US$ 39.726 Billions) during FY 2012-13, having about 20% Marketing share in India among PSUs and a strong market infrastructure. HPCL’s Crude Throughput and Market Sales (including exports) are 15.78 Million Metric Tonnes (MMT) and 30.32 MMT respectively in the same period.

HPCL operates 2 major refineries producing a wide variety of petroleum fuels & specialties, one in Mumbai (West Coast) of 6.5 Million Metric Tonnes Per Annum (MMTPA) capacity and the other in Visakhapatnam, (East Coast) with a capacity of 8.3 MMTPA. HPCL holds an equity stake of 16.95% in Mangalore Refinery & Petrochemicals Limited, a state-of-the-art refinery at Mangalore with a capacity of 15 MMTPA. In addition, HPCL has constructed a 9 MMTPA refinery at Bhatinda, in Punjab, in a joint venture with Mittal Energy Investments Pvt. Ltd.

HPCL also owns and operates the largest Lube Refinery in India producing Lube Base Oils of international standards, with a capacity of 335 TMT. HPCL’s Lube Refinery accounts for over 40% of the India’s total Lube Base Oil production. HPCL’s vast marketing network consists of 13 zonal offices in major cities and 101 Regional Offices facilitated by a Supply & Distribution infrastructure comprising Terminals, Pipeline networks, Aviation Service Stations, LPG Bottling Plants, Inland Relay Depots & Retail Outlets, Lube and LPG Distributorships. HPCL, over the years, has moved from strength to strength on all fronts. The refining capacity steadily increased from 5.5 MMTPA in 1984/85 to 14.8 MMTPA presently. On the financial front, the turnover has grown from Rs. 2687 Crores in 1984-85 to an impressive Rs 1, 69,011 Crores in FY 2011-12.
HPCL has also signed an agreement with Government of Rajasthan for setting up a state-of-the-art 9 MMTPA refinery-cum-petrochemical complex in Barmer District of Rajasthan. The project is being setup in partnership of HPCL, Government of Rajasthan and others.

Presently hydrocarbon industry is passing through a challenging phase. Increasingly stringent environmental regulations and fluctuating crude oil prices have thrown up both challenges and opportunities to Indian oil industry. Other than this, Petroleum Refining Companies are facing major challenges in increasing complexity of refinery configuration more towards dieselization, striving for energy efficient processes which have direct influence on the GRMs, etc. In these circumstances, refiners are investing more on technology development, technology improvement, more intense process scheme development to meet product specification, minimize the bottoms and increase the more valuable middle distillate yields through resid upgradation options. To meet the high demand of fuel, refinery configuration should handle the changing quality of crude oil which is becoming heavy and sour over the years. Feedstock characteristics are also changing rapidly in terms of heavy crudes, high TAN crudes, shale oil, and tar sands, so that it is going to be a major technological challenge for refiners in future.

Refiners are also need to focus on integration of more downstream processes like petrochemical plants for increasing prof−its. Difficulties of processing crude oil like variable pricing, changing characteristics, refiners are more interested in investigating new alternative renewable energy sources, namely solar, bio-energy, gas hydrates, hydrogen, wind, etc offer viable potential options to address the energy security concerns. Concept of bio-refinery or processing of bio-oils in existing units is gaining momentum in recent years with examples such as processing of vegetable oils in hydrotreating units for producing green diesel and green jet fuel. The rising cost of energy and the growing concern over climate change and global warming has led industries to carry out research and development for new green technologies for reducing the environmental impact. Major thrust is on achieving energy efficiency, securing alternate modes of energy, development of novel technologies and carbon capture and conversion to high value chemicals and fuels. To address the above challenges and to achieve energy security for sustainable growth, it is felt that R&D in the energy sector is critical.

In view of the above, there is an urgent need for in-house technical strength backed by strong R&D to face the market challenges which can give several direct and indirect benefits. Therefore, HPCL has taken up R&D initiatives in a significant way as one of the company’s major strate−gies. HPCL believes R&D as a major enabler for the corporation’s sustainable growth in the years to come.

HPCL’s R&D initiatives comes through two−way approach i.e., through setting up of a full−fledged state−of−the−art R&D center at Ban−galore to cater to the future research activities and through taking up collaborative R&D in fundamental and applied research areas with national/international academic institutes & industrial R&D centers.

**R&D Objectives**

The main objective of HPCL R&D Centre is to provide support to the Refineries and Marketing divisions for operational improvement, absorb new technologies, develop innovative & path breaking technologies and on the long run license technologies and be−
Petroleum refining companies are now facing serious challenges in terms of increasing crude oil prices, increasing complexities in refinery configuration, meeting stringent fuel norms and increasing environmental regulatory compliance costs which have direct influence on the refinery profitability.

As a part of our long term strategy, HPCL is giving a large thrust to R&D to meet these challenges. HPCL management has decided to set up a world class Green R&D Centre at Bangalore. It is being set up with state of the art infrastructure facilities and shall comprise of energy efficient green buildings and eco-friendly design norms. The objective of HPGRDC is to support various areas of refinery operations, development of efficient refining catalytic processes and also developing newer and greener technologies such as solar and bio-energy. This article brings out the salient aspects of HPGRDC facilities, activities and the way forward for making it a world class R&D centre.

The key areas of research identified by HPCL R&D are:

- Providing support to do trouble-shooting for refinery operations
- Novel catalyst development for key refining operations
- Energy efficient process / technology development
- Residue upgradation for more valuable products
- Exploration of alternate energy sources - bio-fuels/ hydrogen/ solar
- Studies in modeling & simulation of various refinery processes
- Process Intensification

R&D Plans and Activities

HPCL has two functional R&D centers, one located at Vashi, Mumbai and another at Devanagonthi, Bangalore named as “Hindustan Petroleum Green R&D Centre” (HPGRDC). The Vashi R&D was set up in 1989 and was duly recognized by the Department of Scientific and Industrial Research (DSIR), New Delhi and it mainly focuses on lube product development and primarily engaged in new product development, development of cost effective lube formulations, develop import substitution whenever necessary and develop ecologically responsive technologies. The center is well equipped with spectroscopic, chromatographic and tribological equipment, bench/rig/field simulation test to serve the demands from OEM’s and industry customers. The lube R&D center develops high performance, economically viable and eco-friendly lubricating oil products and additives. Some of the products such as engine oils, greases, turbine oil, radiator coolants and wire rope lubricants developed in Lube R&D have approvals of several leading OEM’s and major industry users including core sectors.

The corporate R&D center at Bangalore is being set up to make HPCL a technology leader through continuous innovative R&D efforts in supporting existing business of refinery operation and developing, adapting and assimilating competitive, energy efficient and eco-friendly technologies for producing cost-effective, profitable and customized quality products/processes. The Corporate R&D center is focusing its research activities in various areas of refinery operations, crude oil evaluation and catalyst testing, bioprocesses, alternate energy sources such as bio-fuels, hydrogen etc.

The HPGRDC is being set-up in 2 phases in around 100 acres plot in Bangalore. Phase I is being executed with a budget of around Rs 312 crores having a total built up area of three lakh square feet consisting of 9 research labs viz., Crude Evaluation and Fuels, Hydroprocessing, FCC/RFCC, Catalysis, Bio-processes, Process Modeling and Simulation, Standard Testing, Analytical labs and Centre for Excellence in Nanotechnology.

Phase II of R&D would be taken up after completion of Phase I with overall investment of about Rs.700 crores for both the phases. The estimated man-
MILCY Turbo 15W 40

A – असली 15W 40

द्रुक चलाने की A, B, C की शुरुआत होती है आपके टर्बो द्रुक के लिए सही इंजन ऑयल की जानकारी के साथ.
power for Phase I is about 108 and for the Phase II is additional 185 making the total manpower strength for both phases about 300. In second phase additional Labs will be built for research in the areas of Petro chemicals & Polymers, lubricants & additives, Residue processing, Applied Metallurgy & Corrosion Studies, Alternate energy studies, Adsorption & Membrane separation, process intensification.

In short term, HPCL R&D focus would be in the areas of FCCU, hydro-processing, crude evaluation and testing, catalysis and bioprocesses.

In the long term, R&D focus will be in the areas such as novel separation processes such as process intensification, adsorption and membrane, resid up-gradation, hydrogen, solar energy, biomass conversion.

To accelerate the research activities, HPCL R&D has commenced a DSIR recognized lab facility in June’12 at Devanagonthi HPCL installation on fast track basis. About 60 equipments have been installed. Major bench scale units like Acer Mat, TBP & Potstill, Stream Deactivation Unit, Hydrotreating pilot plant have been successfully installed in the last financial year.

Research projects on Catalysts/additives development in progress in the areas of FCC, Hydroprocessing, Diesel maximization, resid upgradation, valorization of naphtha and other refinery streams and effluent treatment.

HPCL R&D Centre is also providing advanced technical services to its refineries in the areas of FCC through initiatives such as catalyst evaluation, reduction of CLO yield, maximization of diesel yield, processing heavy feed stock in FCC, catalyst additives for bottom of barrel upgradation in FCC. HPCL R&D also has a membership in Particulate Solid Research Institute (PSRI), USA and is taking up projects like improved Air Grid design and Cyclone design.

HPCL R&D is also active in giving support to Refineries in other process areas also for trouble shooting and optimizing plant performance. Simulation software are being used extensively for this activity.

HPCL R&D is also focusing in the development of rigorous kinetic models of different units such as hydproprocessing, FCC, Visbreaking etc. The aim of this activity is to replicate plant performance for doing further research to predict plant yield by changing different operating conditions.

Bioprocesses engineering is another important thrust area, where HPCL R&D is working. Research is going on in the areas of effluent treatment for zero discharge and development of bioprocess for bio-fuels production from lingo-cellulosic biomass. For improving the effluent characteristics and for recycle, a number of biochemical blends at lab scale have been developed and evaluated for R&D is also doing collaborative research work with different IIT’s, institutes, foreign research institutes and universities in the areas such as nanoparticles based lubricating oils, bio-energy, development of efficient catalyst formulations for hydrogen production from natural gas, storage of hydrogen in special adsorbent materials, development of catalyst & support systems for CO2 conversion, and refinery process modeling, etc.

A brief overview of the major R&D collaborative projects taken up by HPCL with renowned organizations/ institutes is given below:

- Development of efficient catalyst systems which produce hydrogen from natural gas and generate valuable by-product, carbon nano-fibers with no CO2 generation in collaboration with IIT Delhi and Centre for High Technology (CHT). The project is funded under the Hydrogen Corpus Fund (HCF) of MoP&NG.
- Development of Integrated artificial photo catalytic systems’ for efficient
conversion of CO₂ & water to hydrocarbons (e.g. methane, methanol, formic acid was undertaken along with IIT Madras.
- Research program with IIT Bombay on adsorptive separation and purification.
- Joint research is being carried out along with Chevron and IIT Kanpur indifferent areas of fundamental and applied research such as:
  • Development of novel and efficient nanocatalysts for hydrodesulphurization reaction.
  • Studying & analyzing the performance of reactor internals using Computational Fluid Dynamics (CFD) simulations.
  • Developing chemically activated ionic liquid based absorbents for enhanced CO₂ capture.
  • Hydrodynamic studies in high pressure slurry bubble columns.
- Development of efficient biocatalysts for fermentative butanol production with JNCASR, AQUA-CAT visbreaking process with CIMFR, Dhanbad, development of shape selective modified zeolite catalysts for different hydrocarbon conversions with PPISR, Bangalore, process/catalyst development of residue hydrotreating with IIP Dehradun are in progress.
- Fundamental research on physical & mechanical behavior of nanoparticles in lubricants with IISc, Bangalore.
- Collaborative research program with GITAM University, Visakhapatnam
  a) for increasing the tribological performance of automotive engine oils and gear oils using nanoparticles.
  b) Enhancing the performance of automotive coolants by heat transfer enhancement through addition of nanoparticles.

Indo-US Joint Energy Research Projects:
  a) ’Development of Novel materials and approaches’ for solar energy to reduce the cost/watt of delivered power through improvements in conversion efficiency’
  b) ’Advanced bio-fuels production from renewable biomass’.

HPCL has also signed an MOU with Korean Institute of Energy Research (KIER) for collaborative research in various areas such as novel separation and purification processes, hydrocarbon conversions, bio-fuels, etc. A Research project on adsorptive separation has already been initiated under this program.

HPCL R&D Center has been successful in completing some of the above projects leading to filing of 7 Indian Patents of which 3 have been filed under PCT also.

Way Forward

HPCL Green R&D Center facilities will be fully functional from 2014-15 enabling R&D group to leverage additional capabilities to meet future challenges and to sustain business especially in the context of highly volatile crude oil market and shrinking refining margins.

Thus R&D will be an enabler for the sustainable growth of the corporation by addressing technical needs of refineries and marketing in respective domains.

Top 500 Global firms may create 200,000 jobs in India by 2018

The world’s top 500 research and development (R&D) companies will create over 200,000 jobs in India by 2018 and about 45% of these spenders already have centres in India, according to a report by technology advisory firm Zennov Management Consulting Pvt.Ltd.

The Deccan Triangle (Bangalore, Hyderabad, and Pune) alone has over 200 established R&D centres, making it the innovation engine of India, said the report released on Friday. However, it also pointed out that only 11% of the companies with centres in India had any global roles in engineering, product management and support functions. While only 15% of the Indian leaders were proactive, influential and had a global impact, clearly indicating a need to grow strong a leadership pipeline.

Pari Natarajan, chief executive officer, Zinnov, said, “To move to the next level R&D centers in India must work on charters that impact the top-line objectives of the company – the ones that create architectural and business impact, for which higher maturity of product teams is a must. In order to cross this ‘value’ chasm, companies should pick focus areas, create point of views and socialize with stakeholders, develop architectural and leadership capabilities, create innovation programs, manage pipelines and measure and reward value metrics.”

In 2012, 26 companies increased their global R&D spend by at least 20% and contributed over $19 billion. Of them, 14 that have a presence in India increased their global R&D spend by $1.29 billion, but invested only $1.29 million in India.

Nonetheless, companies with a higher R&D spend find India an attractive destination for investments, and there is a clear opportunity to create additional 200,000 R&D jobs in India over the next five years, added the report.
Introduction

GAIL (India) Ltd, the Youngest Maharatna Company, has been constituted in 1984 to exploit the Natural Gas resources by creating necessary infrastructure in the country for the transportation, processing and distribution of natural gas from source to the consumers for their effective utilization. From a natural gas transportation & marketing (mainly a midstream) company at its inception, GAIL has grown in to a fully integrated Oil & Gas company by firmly establishing its presence in entire Natural gas value chain comprising of Exploration & Production; LNG/ natural gas sourcing; transportation; distribution; marketing services and with gas based integrated Petrochemical & LPG plants; thereby energizing the trillion dollars Indian economy during the last three decades.

GAIL through its business operations in India & abroad contributes immensely to the development of the Nation. Currently, 3/4th of India’s natural gas transmitted through GAIL’s pipeline network & more than 50% of Natural gas sales are effected by GAIL thus contributing towards 50% fertilizer production and 50% of gas based power production in India. Through its integrated petrochemical complex, GAIL produces 1/5th of Polymer in India. As a pioneer of spreading green energy in India, GAIL operates nearly 2/3rd of country’s CNG stations thereby enormously contributing to reduction of urban pollution & mitigation of GHG emissions.

GAIL’s Vision & Mission Statements

GAIL’s Vision and Mission statements reflect the belief on India’s sustained economic growth that will continue to drive the demand for energy and the challenge is to meet this demand supply gap under various constraints like energy security, affordability and environmental concerns. To convert these challenges into business opportunities, GAIL’s concerted efforts continue to be on scouting for more diverse sources of energy supply, with emphasis on lower carbon footprint, enhanced efficiency and demand-supply management.
Vision
“Be the Leading Company in Natural Gas and Beyond, with Global Focus, Committed to Customer Care, Value Creation for all Stakeholders and Environmental Responsibility”

Mission
“To accelerate and optimize the effective and economic use of Natural Gas and its fractions to the benefit of national economy.”

R&D initiatives at GAIL (India) Ltd
During its long journey, GAIL (India) Ltd. has consistently weathered many challenges posed by the emerging global economic and business scenario. These challenges are proactively dealt through selection & utilisation of appropriate technology in all of GAIL’s areas of operation. However, in today’s world, the rate of substitution of alternative technologies is very high due to shortening of the technology development cycle. Therefore, R&D is a focus area in the company to keep track of the evolving technological advancements & innovations and to assimilate the same at the appropriate levels to remain competitive.

As India is an energy deficit country and also nearly 3/4th of its energy requirement are met through imports, importance of R&D in energy sector in general and Natural gas sector in particular will go a long way for making clean and modern sources of energy available and affordable for majority of population.

The challenges and opportunities provided by the increased competition, reduced margins in operations, stringent environmental compliances and the regulatory regime can only be met through significant improvements and technology innovations with required emphasis on R&D. Thus, investment in R&D has become a strategic importance to the organisation. GAIL’s R&D programmes on natural Gas are focused to develop technologies, tools and strategies that increase energy efficiency, reduce energy cost, reduce air pollutants/ greenhouse gas emissions and improve the safety of pipeline infrastructure.

Technology Leadership through R&D
S. Venkatraman, Director (Business Development), GAIL

GAIL (India) Limited is India’s youngest Maharatna PSU and India’s principal Natural Gas Company with diversified activities in various facets of Processing, Transportation, Distribution and Marketing of Natural Gas and its fractions. GAIL has extended its presence in the energy value chain by entering into Petrochemicals, Liquefied Natural Gas, Power, E&P, CNG etc. and is moving towards becoming a global integrated energy company.

GAIL is a technology driven company and employs the latest and state-of-the-art technologies in all its areas of operation. However, in today’s world, the rate of obsolescence of technologies is very high. Therefore, it is a focus area in the company to keep abreast of the latest technologies and innovations and to incorporate necessary changes to remain competitive.

GAIL recognizes that Research & Development (R&D) plays an important role in the company’s quest to remain competitive. Therefore, GAIL has given a renewed impetus to R&D activities and has spent an all-time high of over Rs.50 Crore on R&D in last fiscal year.

We have divided our R&D activities into various Thrust areas relevant to our Business and follow a focused approach in pursing R&D Projects. We have constituted a Research Advisory Council (RAC) with external members having the requisite domain expertise to advise us in our R&D projects. We have also put in place a R&D Policy and Manual to streamline the process of selection, award and monitoring of the R&D Projects.

GAIL is presently pursuing over 20 projects through reputed Engineering Institutes/Laboratories which are in different stages of execution. It is expected that the successful outcome of these projects would generate good value in due course of time.

GAIL has recently implemented a unique first-of-its-kind Project in India on capturing Landfill Gas (LFG) from an active Landfill Site. In the 1st phase of this Project carried out at Ghazipur, Delhi the LFG is being collected and flared. This is a small step in mitigating Global Warming as LFG contains about 40% Methane which is 25 times more potent than CO2 as a Greenhouse Gas. The Project is being registered as a Clean Development Project with UNFCCC and should earn Carbon Credits for GAIL from next fiscal. This innovative Project has demonstrated that it is possible to extract LFG from an un-scientific and active landfill site.

Natural gas being an environmentally benign fuel is the preferred choice for various industries. Coupled with the growth of the Indian economy, this has led to an ever increasing demand for natural gas. While GAIL has been pro-actively laying the infrastructure for its transportation and wider usage but the supply of natural gas is lagging behind. GAIL has now increased its focus on tapping unconventional sources of natural gas like Coal gasification.

UCG, Gas Hydrates, Shale gas etc. so as to increase the availability of natural gas to meet the energy requirements for fuelling India’s growth.

R&D is widely recognized to be the pivotal of technological advances and plays a crucial role in a modern economy. GAIL would continue to pursue a focused R&D strategy to further its competitiveness and also help increase the availability and accessibility of clean energies in the country.
GAIL’s R&D initiatives put emphasis on identifying and addressing emerging natural gas technology related trends that are important to India’s energy security. These include opportunities for use of non-traditional alternatives to natural gas and other renewables.

**R&D Policy, Vision & Mission Statements**

R&D policy objectives of GAIL are formulated to carry out R&D projects that are in synchronisation with the company’s basic objective of becoming a leading company in Natural gas and beyond. The main objectives of R&D in GAIL are to develop, integrate & assimilate the new and indigenously developed technologies; enhance system flexibility, improved throughput and reliability of existing operations; improve the capability of cost effectiveness in O&M; Identify and mitigate environmental issues etc. Accordingly, GAIL’s R&D Policy, Vision & Mission statements were incorporated capturing the very essence of carrying out the business in a sustainable manner.

**R&D Policy Statement**

R&D department is committed to development of new or improved materials, fuels, products, processes, systems or devices through research findings. Design, construct and test through Pilots & models the new technologies prior to their commercialization. Provide information on latest technological advancement to maintain the technological edge of GAIL in all its businesses.

**R&D Vision**

To be a leading R&D establishment in Natural gas, its derivatives & beyond, driven by values of Innovation, Integrity, Customer centricity with focus on Technology assimilation and Talent nurturing.

**R&D Mission**

Strive to develop and assimilate Innovative and Cutting-edge technologies to meet the business requirements of GAIL.

This R&D Policy and Manual shall provide an overarching enabling framework for selection of suitable projects for furthering GAIL’s business & technology objectives. GAIL has also constituted a Research Advisory Council (RAC) comprising of various external domain experts for providing valuable guidance in selection of the R&D projects, for review of existing projects against their intended goals etc. The RAC meets at least 4 times in a year for the above purpose.

**Thrust Areas for R&D**

Based on the above objectives, thrust areas in which GAIL has to embark upon are formulated. At the corporate level, R&D thrust is recommended through new business development strategy and vision while at unit level R&D efforts are focused on improvement of productivity, capacity utilization, energy efficiency, safety & environmental aspects.

Accordingly, GAIL’s R&D focus is towards the following broad thrust areas:

- Natural Gas Transportation and Storage
- CO₂ Conversion/ Utilization
- Fuel Cells & Nano-composites
- Unconventional Energy Sources

**Current R&D Efforts in GAIL**

Current R&D efforts are focused towards promoting Basic / fundamental,
CO2 in causing Global Warming. It is a potential Green House Gas (GHG), ppm level apart from few micro constituents. These efforts shall lead to sustainability through resource conservation, GHG mitigation and may reduce the cost of energy and thereby making it affordable in the days to come. Some of these research efforts are enumerated below:

Landfill gas (LFG) Pilot Project

Nearly 210 Millions of Tons of Municipal Solid Waste (MSW) per annum is generated across India and most of them are dumped in Landfill sites without processing. This MSW generates Landfill gas under anaerobic condition. The LFG principally contains Methane (40-50%) and CO2 (50-60%) and other minor constituents like H2S in ppm level apart from few micro constituents. The Methane in the LFG is a potential Green House Gas (GHG), considered 25 times more potent than CO2 in causing Global Warming. It is estimated that nearly 75 MMSCMD of LFG is generated in urban landfills and is the second largest source of methane emission after coal mining in India. Thus capturing & destroying of methane may immensely reduce the fugitive emissions (GHG). GAIL, as a part of its R&D activities, took an initiative to implement the Pilot project to ascertain the recovery of LFG from an unscientifically managed open active MSW dumping site to enable upgradation of the LFG to Natural gas quality to utilise it as CNG.

GAIL entered into an MoU with MCD (now EDMC) for implementation of LFG Pilot project. MCD earmarked 4 hectares of Landfill site out of 29.6 Hectares at the Ghazipur landfill site for the Pilot project. The objective of the Pilot project was to assess the potential of LFG recovery from an active Landfill site (in Phase-1) and study the suitability of its use as an alternate renewable fuel source by purifying it for use as CNG (in Phase-2).

The Phase-1 of the Project (comprising of landfill closure as per MSW rules LFG extraction & flaring) was completed during April 2013. As per the field results of operation, about 120 m3/hr of LFG flow rate is established with CH4 concentration of 24-28 mol%. Techno-economic feasibility of converting LFG to CNG is being worked out for this quantity & quality of LFG. On successful demonstration of this project, it may pave the way for integrating the waste to energy concept in GAIL’s business model.

R&D Project on Conversion of Waste Plastics to Valuable Hydrocarbons (Diesel, Gasoline & Aromatics)

The consumption of plastics, particularly polyethylenes and polypropylenes, are increasing at rapid rate, which simultaneously results in the generation of enormous amount of plastic waste & 80% of these plastic wastes are ending up as landfill or remain littered in the urban areas. Due to their nature of low biodegradability, these waste plastics remain longer in the ecosystem and affect the environment. Among these plastics, waste polyolefin has the potential to be degraded in to various low molecular weight (MW) hydrocarbons like gasoline, diesel, LPG, BTX etc.

GAIL in collaboration with IIP, Dehradun had developed a two stage process consisting of pyrolysis followed by catalytic conversion for chemically recycling the waste plastics by producing value added products like gasoline, diesel and aromatics. Lab-scale & Bench-scale studies (involving catalyst selection, process optimisation) were completed successfully and encouraging results were obtained with respect to Product quality (diesel & gasoline which meets the Euro-III norms). Through this unique process, any of the specific fuels i.e. gasoline or middle distillates or aromatics along with LPG can be exclusively produced in the same experimental setup by selecting appropriate process parameters. Now, GAIL is in the process of setting up a pilot plant, with a feed capacity 10 TPD (Tonnes per day) of waste plastic, for demonstration & technology development in collaboration with IIP, Dehradun. The invention was also applied for Indian Patent.

Research in the area of Hydrogen

Hydrogen is promising to be the next generation ultra clean fuel with no carbon emission during its combustion. But for the advancement of Hydrogen economy, the problems associated with its high cost of production, issues in safe and efficient storage for transport has to be overcome. As a pioneer of Natural gas economy in India, GAIL’s efforts are to find solutions for the above problem areas and propel the country towards hydrogen economy.

One of the major obstacles to the diffusion of hydrogen as an energy carrier is the lack of safe, efficient and cost effective storage systems, suitable for the various stationary and mobile applications. In this regard, GAIL is carrying out collaboration research with IIT, Chennai for the ‘Development of Novel nano-composite materials’ for safe storage of hydrogen at low pressure. Further, GAIL’s research efforts are also directed towards the ‘Development of light weight composite cyl-
inders for high pressure storage’ with immediate application in CNG storage.

**Research in the area of Fuel Cells**

Fuel cells are electrochemical devices that convert chemical energy in fuels into electrical energy directly, promising power generation with high efficiency and low environmental impact. GAIL is participating as an Industrial partner in the indigenous development of Solid Oxide Fuel Cell (SOFC) under the prestigious New Millennium Indian Technology Leadership Initiative (NMITLI) programme under the aegis of Ministry of Science & Technology. Under this programme, efforts were primarily made to develop and demonstrate a working SOFC stack based on the planar anode-supported SOFC design.

**Research on Natural Gas Storage, Transportation & Safety**

Development of Technologies for efficient low pressure storage of Natural Gas would enhance the acceptability and wide spread use of NG in transport sector by reducing the cost of compression as vehicles require gas at only 1.5 bar pressure. In this regard, GAIL’s research efforts are directed towards development of Metal Organic Framework (MOF) based Adsorbents for storage of methane at moderate pressure and ambient temperature.

GAIL is currently maintaining a vast network of Natural gas & LPG Pipelines across the length and breadth of the country. The safety and integrity of these assets is of paramount importance for GAIL’s business operations. The health of these vast networks is adequately monitored through dedicated fixed line communication, SCADA system, cathodic protection, foot/ helicopter patrolling etc. In addition to above existing systems, to improve the reliability in monitoring of the system, GAIL is in the process of development and deployment of wireless sensor network based condition monitoring system for these underground pipelines. GAIL is also exploring the possibility of using remote sensing and GIS technology for monitoring Right of Use (ROU) of its pipeline.

Safe distribution and use of Natural gas as CNG in Vehicles & PNG at household is an important concern to all. Currently, natural gas leak detectors are not found wide spread use in vehicles & households due to their high cost. This has prompted GAIL to intensify its research efforts to develop low cost Nano-composite & Metal Oxide based sensors. Prototype of Metal oxide based sensors has been developed and is in testing phase. Successful development and deployment of such sensors shall immensely promote the safe use of Natural gas in its application.

In addition to the above projects, GAIL is also implementing Research projects pertaining to LNG technologies especially with respect to cold energy utilization of LNG for sea water desalination.

**Other R&D Projects**

GAIL is carrying out collaborative research projects with premier research Institutes in the area of CO₂ separation from natural gas & mitigation of CO₂ emissions. Here, the focus is on development of new & effective solvent for CO₂ removal and to develop novel ionic & nanocatalysts for dry reforming / tri-reforming of CO₂ in to synthesis gas for producing useful chemicals.

**GAIL Polymer Technology Centre (GPTC)**

GPTC is entrusted with the main activity of new polymer grade development and extending technical services and offering technical guidance to various petrochemical customers. The centre is equipped with state-of-the-art polymer testing facilities for raw materials, additives and end products. It acts as the interface between the valued customers and the plant.

**Patents & Awards**

GAIL’s invention related to a fixed bed Hypersorber has been granted both Indian Patent (No: 254118) & US Patent (No: US 7,771,510 B2). The Fixed bed Hypersorber is a counter current gas separating unit having moving ports for injecting and withdrawing fluids which can be used for fractionation of gaseous mixtures in a fixed bed filled with absorbents/adsorbents. Many other patents are in various stages of application.

GAIL along with IIP has been awarded National Award for ‘Technology Innovation in Petrochemical and Downstream, Plastic Processing Industry’ from Ministry of Chemicals & Fertilizers for innovation in Polymer waste Management & Recycling Technology for ‘Technology to Convert Waste Plastics (Polyolefins) to Automotive Grade Fuel and Petrochemicals’.

At the outset, GAIL is fully geared up to meet the upcoming challenges by adopting a right mix of collaborative, cooperative and in-house research efforts as enumerated above.
Chennai Petroleum Corporation Limited (CPCL), formerly known as Madras Refineries Limited (MRL) was formed as a joint venture in 1965 between the Government of India (GOI), AMOCO and National Iranian Oil Company (NIOC) having a share holding in the ratio 74%: 13%: 13% respectively. At present it is a group company of Indian oil.

CPCL has two refineries with a combined refining capacity of 11.5 Million Tonnes Per Annum (MMTPA). The Manali Refinery has a capacity of 10.5 MMTPA and is one of the most complex refineries in India with Fuel, Lube, Wax and Petrochemical feedstocks production facilities. CPCL's second refinery is located at Cauvery Basin at Nagapattinam.

It is one of the key refining players in southern region and supplies feed stocks to many downstream industries in the region.

CPCL has taken several initiatives towards energy conservation, environment protection, technology upgradation and research and development. As part of its Corporate Plan, in order to face the competitive challenges, the Company has taken various strategic actions to achieve excellence in competitive performance and emerge as a world-class energy company as envisioned in its Vision statement.

**CPCL R&D**

In line with CPCL's corporate objective to remain in the technological forefront in all aspects of the company’s operation, CPCL R&D centre was established in July 1984.

A modest beginning was made in the year 1986 by establishing facilities such as TBP distillation unit, FCCU pilot plant & petroleum testing laboratory to start R&D activities
at CPCL. Subsequently CPCL invested around Rs 50 crores over the past 20 years towards setting up various pilot plant units and sophisticated analytical and petroleum testing laboratories.

Today CPCL R&D has established itself as one of the premier petroleum research institutions in the country. Over the years R&D continues to provide technical support to refinery operations by evaluating catalysts, feed stocks, process options and new crude selection, absorption and development of new technologies.

**R&D Policy**

CPCL as a group company of Indian Oil adheres to the parent company’s R&D policy including its vision statement.

However as an in-house R&D established with the emphasis of supporting refinery operations, CPCL has the following mission:

- Provide technological inputs to meet the corporate objective of technical excellence in all aspects of refinery operations
- Promote indigenous technologies for refinery processes in association with national laboratories/academic institutions
- Develop new products and upgrade the quality of the existing petroleum products

**DSIR recognition**

CPCL R&D centre is a recognized centre of DSIR since 1989.

**Brief on Existing Infrastructure:**

- CPCL R&D has Micro reactor pilot plants for various processes such as Catalytic reforming, Hydro treating, extraction, state of art ACER MAT Unit (for supporting commercial FCC unit) besides Crude fractionation facilities (TBP Unit)
- CPCL has established extensive analytical facilities including state of the art Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) and Mass Spectrometer (ICP-MS) for trace element analysis of refinery process streams and finished petroleum products
- CPCL R&D has laboratory and testing facilities for detailed Physico Chemical characterization of various catalysts and in evaluating its activity
- A new Hydrocraker Pilot Plant has been commissioned recently

**Major contributions**

- The CBR refinery (1 MMTPA) was designed jointly with EIL based on Crude Assay data of various available crudes in the CBR region
- In collaboration with IIP and EIL CPCL (R&D) centre developed NMP based extraction technology for the production of Lube base stocks which formed the basis for implementation of Lube unit in IOCL Haldia in 2003
- The centre developed the RO membrane technology in collaboration with CSMCRI Bhavnagar for recovery of process water from secondary treated sewage and a demonstration unit of capacity 1 million litre per day was installed to process secondary treated sewage in 2004
- A Process for up gradation of FCC recycle oil to high BMCI carbon black feed stock (CBFS) was developed in collaboration with IIP, HPCL and CHT. The technology was implemented in HPCL Mumbai in 2008
- Development of the high activity lube hydro finishing catalyst in collaboration with Sud Chemie India Pvt Limited completed in 2010
- Pilot plant data based reformer & ISOM process models were developed for supporting the commissioning and subsequent operation of CCR and ISOM units

**Improvement in operational efficiency/value additions:**

- Introduction of new generation...
high activity catalyst in commercial DHDS unit to achieve ULSD was based on R&D pilot plant studies. This eliminated the necessity of re-vamp of the unit with additional reactor

• R&D pilot plant studies confirmed suitability of NMP extraction for light distillates
• Monitoring the assay of KG basin crudes and optimizing the crude mix enhanced the profitability of CBR unit
• Co processing of CBR RCO (upto 10%) with UCO was implemented in FCC unit based on R&D studies
• R&D studies established the optimizing of rare earth content in base catalyst for improving olefinicity of LPG

Industry-Academia interaction

CPCL R&D is closely associated with Academia institutions for promoting research activities. CPCL research facilities are made available for PG students of IITM and Anna University.

Major Collaborative Projects Completed with Academic Institutions/National Laboratories

• Development of FCC catalysts – IIT Madras
• Development of Catalyst/Process for Catalytic Dewaxing (NCL Pune)
• Development of Catalyst for Isode-waxing (NCL Pune)
• Simulation and Modelling of Diesel Hydrodesulphurisation – IIT Madras
• Development of ULSD Catalyst – NMITLI Project
• Catalyst for Reduction of Sulfur in FCC Gasoline (IIP)
• Development of Polymer Modified Bitumen (IIP)
• Upgradation of FCC Recycle oil to High BMCI CBFS (IIP/HPCL)
• Adsorptive Desulphurisation of Diesel (IIT Madras)
• Development of Catalyst for End Point Reduction of Diesel (IIT Madras)
• Development of Performance Grade Bitumen with Feedstocks such as PDA pitch and fluxes like heavy extracts (NAC, IIT Madras)

Synergy with IOCL R&D

Synergy is established with IOCL R&D centre for carrying out collaborative studies for mutual benefit.

Commercial trial of IOCL R&D developed catalyst for Ultra Low Sulfur Diesel was held at CPCL. The catalyst was evaluated at the Pilot Plant before successfully completing the commercial trials using 35 tonnes of IOCL R&D developed ULSD catalyst in Plant 13.

CPCL R&D also carried out Pilot Plant studies on Co Processing of Vegetable Oils developed by IOC R&D and commercial trials were successfully completed using vegetable oil upto 7% along with Diesel in Hydro treating unit to produce EURO IV diesel.

Current projects

CPCL R&D besides supporting refinery operations has been working on development of new processes and catalysts for refinery operations. The Projects currently in progress, include the following:

• Upgradation of residual fuel oil using Non HDS route such as oxidation and solvent extraction in collaboration with IIP
• Development of suitable catalyst for the production of food grade hexane using hydrotreating route instead of solvent extraction
• Development of non noble metal (zeolite based) catalyst for light naphtha isomerization in collaboration with IITM
• Study on conversion of Algae to bio crude in collaboration with ABAN

The In house R&D centre at CPCL is providing technical support to refinery operations in terms of selection of feedstocks and catalysts for various process units and also collaborates with National Laboratories and Academic Institutions for development of new processes for Petroleum Refining industry.
Research and Innovation at Reliance Industries Limited (RIL)

Dr. Peter Hanik, Reliance Industries Limited
Email: peter.hanik@ril.com

Summary

Reliance Industries Limited (“RIL”), as part of its continuous quest for robust growth, has embraced a “business transformation” within its business model. This paper describes its parallel “technology transformation”, a step change in commitment to Research and Development, along with a pinpoint focus on Innovation. While Reliance is already a regional business leader, these fundamental changes will enable RIL to move into the ranks of business and technology world leaders.

Introduction

The Reliance Group, founded by Dhirubhai H. Ambani (1932-2002), is India’s largest private sector enterprise, with businesses in the energy and materials value chain. Group’s annual revenues were about US$ 68 billion in the year 2012-13. The flagship company, Reliance Industries Limited (“RIL”), is a Fortune Global 100 company. In the last financial year, RIL contributed 14% of India’s total exports and 4.8% to the total indirect tax revenue collected by the government of India. Backward, vertical integration has been the cornerstone of Reliance’s evolution and growth. To ensure full integration along both the materials and energy value chains, Reliance pursued vertical integration from textiles and polyester in the 70’s to fiber intermediates, plastics and petrochemicals in the mid 80’s and, later, petroleum refining, oil & gas exploration and production.

Today, the Group’s major activities span from exploration and production of oil and gas, petroleum refining & marketing, petrochemicals (polyester, fiber intermediates, plastics and chemicals), textiles, retail, infotel and special economic zones. RIL is the world’s largest producer of polyester fiber and yarn, fifth largest producer of paraxylene, fifth largest producer of polypropylene and eighth largest producer of MEG and ninth largest producer of PTA. Most significantly, it has created the benchmark in petroleum refining by creating our Jamnagar complex - - the world’s largest refining capacity (1.3 million B/D) at a single location.

Reliance’s motto (“Growth is Life”) reflects the basic philosophy of its leadership as well as its core strategy. Aside from sterling business acumen, technical excellence is a key requirement to realize this never ending goal. Reliance does many things exceedingly well, such as (i) understand and optimize the “economy of scale” principle, (ii) execute capital projects flawlessly and quickly, realizing early financial returns, and (iii) read the markets well and invest in
high-growth areas, thereby minimizing market risk.

While its engineering prowess and business astuteness keep Reliance moving forward, worldwide competitiveness demands more. To respond to this challenge, RIL has sought to leverage its strengths by fostering innovation - using creativity to expand more broadly into previously uncharted territory. This innovation and major commitment to expand its technical footprint represent a “new Reliance”. This “technology transformation” also complements the company’s ongoing “business transformation”.

Reliance recently announced several major projects like pet coke gasification, off gas cracker with downstream polymers, para-xylene, PTA and polyester expansion, which collectively are multi-billion dollars in scope. These are just the “tip of the iceberg” of things to come.

**Reliance Innovation Council (“RIC”)**

RIL aspires to be one of the most innovative companies in the world. The Reliance Innovation Council (RIC) steers programmes in realizing this vision. The RIC comprises global science and business leaders such as Mr. Mukesh D. Ambani, Dr. R. A. Mashelkar, Dr. William A. Haseltine, and Dr. George M. Whitesides and Nobel Laureates: Prof. Jean-Marie Lehn and Prof. Robert H. Grubbs.

The Reliance Innovation Leadership Centre (RIL-C) in Pune under the aegis of the RIC, implements the innovation agenda throughout the organization. Its primary focus is to design and deploy innovation programmes and tools that will help make us one of the world’s most innovative companies. The Leading Expert Access Programme (“LEAP”) initiative, as per RIC’s activity, strives to inspire our human resource through talks and lectures by global innovation leaders. These leaders share their work, life and experiences-which leave indelible marks on the minds of our people. From Nobel Laureates to corporate leaders and from social crusaders to policy makers- LEAP speakers have enthralled and inspired our people.

Research & Development, coupled with Innovation, intertwine as the key focus areas to drive Reliance’s growth; this strategy also ensures sustainability and enables the company make major inroads in rural transformation - part of its corporate social responsibility. To sustain and enhance profitable growth in its existing businesses as well as to spearhead new ventures in India’s and the world’s growing markets; RIL’s added commitment is to discover and develop many new technologies, expanding our base to (i) deliver high performance products to the customer, (ii) explore breakthrough fields to dramatically enhance the life of Indians and society in general, and (iii) identify and develop value-added products in our core areas.

Consistent with the above aspirations, Reliance Research & Development Group, acts as a hub for R&D activities with research facilities, including pilot plants, at our various manufacturing locations. We have recently operationalized a world-class R&D center at Reliance Corporate Park (“RCP”), Navi Mumbai besides the R&D centers at manufacturing sites. The centre is built with two goals: invention and discovery. These two attributes are the fundamental aspects in the R&D pipeline: (i) discovery, (ii) scoping and pre-development, (iii) development, and (iv) commercialization.

To facilitate a productive laboratory, two basic elements are kept in mind: ambition and ambience. Ambience is to give our talented scientists and engineers an environment that is fully conducive for achieving the ambition, i.e., “making the impossible possible” and delivering cutting edge, world-class technologies. The target is to evolve from an embryonic concept to commercial reality.

Creation and protection of intellectual property (“IP”) for the Company continue to be a dominant area of focus. RIL’s portfolio of national and international patents is rapidly increasing in existing as well as new technology areas. In this paper, we will share some of the recent success stories. Unfortunately, several of the most exciting projects are so new that we’ll have to wait until next year to reveal them in detail.

**R&D Goals**

To be the most innovative, globally connected technology organization in our industry; fully aligned with our manufacturing / business partners and recognized for creating unique opportunity and value through development of technology for Reliance and society.

“Grow from licensing technology to developing technology.

Evolve from being an intellectual property user to an intellectual property creator.”

**Reliance Research and Development Group**

Reliance R & D consists of two types of technical teams: (i) Breakthrough Research Team looking at creating new businesses through breakthrough technologies. (ii) R&D groups focusing mainly on existing business with new product, process and catalyst development for the businesses e.g. refining, polymer, polyester, petrochemicals etc. Besides the Mumbai R&D centre located at Navi Mumbai, the R&D groups are located in their respective plant areas e.g. (i) Refining R&D at Jamnagar, (ii) Polymer R&D at Hazira and Application R&D at Chembur, (iii) Petrochemical and Elastomers R&D and Application R&D at Vadodara, (iv) Polyester R&D at Patalganga, etc.. These R&D groups operate laboratory facilities and pilot plants in their respective areas, which are supported by their respective plants to provide easy access to samples, plant data etc., thereby permitting rapid transfer of R&D ideas and technologies for implementation in the plants.

RIL is the sole industry partner in the New Millennium Indian Technology Leadership Initiative (“NMITLI”) project on indigenous Fuel Cell technology development. The R&D group will continue to address the needs of
the organization to identify, develop, and implement technology-related opportunities for fueling RIL’s future growth.

Here is an overview of the several research facilities in Reliance. The text gives a flavor of our recent activities, accomplishments, and accolades.

**Mumbai R&D Centre**

The Corporate R&D Centre at RCP (Reliance Corporate Park), Navi Mumbai houses advanced analytical and evaluation facilities and various interdisciplinary groups to carry out cutting edge research in the entire material and energy value chain, covering both existing business as well as entirely new business areas – true departures from the Reliance of the past. This also provides the platform for synergy and integration among various R&D groups which in turn enables development and assimilation of technologies from cross sector ideas. The facilities include analytical equipment for sophisticated characterization of hydrocarbons and catalytic materials, laboratory/bench scale facilities for synthesis and evaluation of catalysts, product synthesis lab, process development facilities, an advanced separations lab, etc. The facilities also include advanced material synthesis and evaluation lab, lab facilities for electrochemistry and advanced areas of biotechnology for the material and energy sectors. To support the above research areas, there are three major central facilities to cover the following:

- Advanced analytical facilities for molecular-level characterization of hydrocarbons, materials and catalysts
- High Throughput Experimentation for Micro-scale, parallel testing in catalyst/product formulation and evaluation planned
- Advanced Computing for high speed computation such as CFD, Micro Kinetic Modeling, molecular and ab initio modeling and big-data analysis

The Mumbai Lab also has state-of-the-art technical, shared services such as infrastructure and utility/safety management, knowledge management including library, IP/Legal, learning and development centre, conferencing facilities etc. In the initial phase, ~120,000 sq. ft. of laboratory space is created to house all these facilities.

**Jamnagar R&D Centre**

The Centre, located at Jamnagar manufacturing site, is focused on R&D activities in the Refining sector with an overall objective to create value through innovative solutions and cutting edge technology development. Jamnagar R&D Centre had a modest beginning in 2006 with an initiative to setup FCC research facilities and pilot plant for maximizing propylene yields and conversion in our commercial FCC plants. Today, the centre consists of an energized team of ~50 people (15 PhDs) covering both Engineering and Science backgrounds, having technical skills in experimental as well as modeling research. The activities at the R & D Centre are broadly classified into FCC, Coker, Crude, Hydroprocessing and process modeling/simulations. The projects are targeted to develop new processes, new catalysts as well as new schemes and concepts for improvement in the commercial plants. The experimental facilities are spread throughout the R & D Centre, housing an FCC pilot plant, and demonstration-scale spray dryer for making FCC catalyst/additive and FCC catalyst testing/characterization facilities. With the establishment of a 2 bbl./day FCC pilot plant, the Jamnagar lab is now able to perform various process and catalyst development studies in FCC. These efforts have led
to major improvements in enhanced propylene production in RIL FCC units while also reducing the cost of catalyst/additive. The Jamnagar lab has developed several breakthrough technologies in a short period of 2-3 years’ time.

The advanced crude lab covers facilities in crude-related studies and process development. The team also has state-of-the-art CFD (Computational Fluid Dynamics) facilities for flow simulation of actual process plant/reactors in the refinery.

The Jamnagar R & D Centre has received recognition from DSIR (India’s Dept. of Scientific & Industrial Research) in 2011. It has filed 26 patent applications during the last four years. Two projects have been commercialized, and two other projects will be implemented soon. Within the Group, Jamnagar R&D has received the “Best Vertical Award” among all RIL R&D Centers in both 2011 and 2012 for its significant contributions in value generation and technical projects completion. Several individuals of the R&D team have also received many national awards, e.g. DSIR award, DST award, NPMP award, etc. for their contributions in technical excellence and innovations.

Reliance’s Jamnagar refinery complex has earned one of the highest refining uplifts ($/B) in the world; and, along with the talent and commitment of the entire refining team, technology plays a key role in this achievement.

Hazira R&D Centre

The Hazira R&D Centre is located at
Hazira manufacturing site which is the hub of petrochemical, polyester and polymer manufacturing of RIL. This Centre was established in October 1999; with manpower strength of 20. Also, the pilot plant operation is managed by the PP plant personnel. The major focus of the Hazira lab is to create value through Research and Technology development across the polyolefin manufacturing and business value chain such as polyolefin catalysis, polymerization processes, additives and polymer products/ applications for bringing self-sufficiency in RIL polypropylene production.

RIL is a major producer of polypropylene and polyethylene - approximately 4 million tonnes per annum. Our infrastructure facilities include a synthesis lab for handling moisture sensitive compounds, characterization lab, polymerization lab, multipurpose pilot plants and gas-phase PP pilot plant. It also has advanced analytical instruments including Scanning Electron Microscope (SEM), Nuclear Magnetic Resonance (NMR) and Wide angle X-Ray Diffractometer ("WAXD") for carrying out research in the field of polyolefins catalysis. In addition to in-house developmental work, the R&D Centre actively involves external research institutions, in order to leverage intellectual as well as infrastructure resources. Active collaboration and sponsored development work has been taken up with Polymer Char-Spain, PIB – Brno, NCL- Pune, CSMRI- Bhavnagar, ICT- Mumbai, GOL- Ankleshwar, Excel- Mumbai, Sanmar- Chennai, Degussa-Germany, and the Chinese Academy of Science-Beijing. The development process involves close interaction with Business, manufacturing, and the product application center to successfully convert R&D ideas into commercialization. The Hazira lab received Lab of Year - Special mentioned award by R&D magazine USA. It is the only research facility in Asia to receive this prestigious award.

Hazira R&D Centre has received DSIR recognition in 2000. It has filed 28 patent applications since 2002, and five US patents have been granted. Three trademarks have been granted to HZ lab for developed research products. The group has published 31 research publications in peer-reviewed journals since 2002. The team has received several international and national Awards such as the Golden Peacock Award, ICC (Indian Chemical Council) PC Ray Award, FICCI Award, Indira Innovation Award, FGI (Federation of Gujarat Industries) awards, National Technology Award, ICC award for plant design, and the SGCCI Award for development of indigenous technologies.
**Product Application and Research Centre (PARC) - Chembur**

The Product Application and Research Centre (PARC) caters to RIL customers across India and the world for more than 20 years. PARC was instrumental in establishing Reliance's polymer grades in various sectors and applications.

This centre, comprised of polymer engineers and various scientists, is the key link between end users and our polymer manufacturing plants, R&D and the polymer business. PARC is instrumental in new product applications developments, tailoring to suit the customers' specific needs. We benchmark the industry, continuously optimize cost/performance, and provide technical support for obtaining national/international certification for RIL products. Our customer technical service has contributed commendably towards customer satisfaction and the growth of India’s thermoplastic industry.

PARC, in collaboration with end-use sectors and processors, works towards creation and sustenance of Indian/ international standards related to polymers and related end products and takes an active part in BIS and ISO committees.

PARC employs its full-fledged laboratory facilities where processability and performance properties of polymer resin and end-products are evaluated as per national/international standards.

**Vadodara R&D Centre**

In the petrochemicals area, R&D is providing technology support to olefin crackers, polymers, fiber intermediates, linear alkyl benzene (“LAB”), and polyester. The R&D Centre at Vadodara has a total technical strength of 75, including more than 35 PhDs. The research areas cover: catalysis and catalytic processes, polymers and elastomers research, organic synthetic chemistry, chemical engineering and process development, environmental science, adsorption separations and analytical spectroscopy. The facilities include lab/bench scale and pilot plants for various petrochemical and polymer processing. The focus areas in petrochemicals include efficient asset utilization, development of specialty grades/materials, development of catalysts/additives for cost reduction, value addition to byproduct streams, and leveraging opportunities at the chemicals/oil refining interface.

**Patalganga R&D Centre**

The Polyester R&D Centre is focused on research and technology activities in the polyester sector. The mission of this group is to consistently develop & deliver polyester product and process technologies through ideation, understanding, investigative research and implementation to create sustained, measureable, business value.

The R&D activities in the Polyester Sector were initiated in 1996. The state-of-the-art research centre was inaugurated at RIL’s Patalganga (PG) complex in 2003. Today, the PG lab consists of a motivated team of nearly 65 people (10+ PhDs) having technical skill in experimental research, process modeling and pilot plant operations. This team is focused on technology, product & process innovations for all polyester businesses of RIL.

In the last 9 years, Polyester R&D has received 11 patents and has filed 26 additional patent applications.

The facilities at R&D Centre Patalganga are: a) Polyester synthesis and analysis lab b) Laboratory reactor assemblies for new polymers c) Melt spinning for bi-component yarns d) Polymer processing facilities e) Advanced mechanical testing for polymers / fibers f) Tribological testing g) Dyeing & textile processing h) Pilot plants for master batch, melt polymerization & solid state polymerization i) Advanced Chemical analysis, microscopy and j) Advanced process simulation and modeling.

**Key Projects**

- Enhanced Propylene Recovery Technology
- Olefinic Feedstock Co-cracking Technology
- LVGO chloride removal
- Computational Fluid Dynamics (“CFD”) Simulation of Refinery processes and equipment
- Design and indigenous fabrication of FCC pilot plant

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• FCC Catalyst with high metals tolerance
• Processing of olefinic streams in FCC products
• PP odor-related studies and process for efficient, adsorbent regeneration in the propylene treater
• Process for upgrading slurry oil to high value products
• New IR method for fast crude characterization
• Modeling of catalyst attrition in FCC
• Improving VGO recovery in VDU columns – design of internals
• Basic polypropylene catalyst technology for gas phase polymerization
• Shape-controlled catalyst technology for polypropylene
• Precursor technology development for high performance polypropylene catalyst
• Latest external donor technology for raffia grade polypropylene
• Latest external donor technology for Injection and TQ (tubular quenched film) grade polypropylene
• High performance, external donor for BOPP grades
• High performance, external donor for impact copolymer grade
• Improved solvent recovery process of polypropylene catalyst
• Process of converting polypropylene catalyst waste to value-added byproduct
• Process for nucleating agent for random grade polypropylene
• Alkyl benzoate synthesis process as external donor for polypropylene
• Catalytic process for slurry and bulk phase production of PP
• Process for morphology-controlled polyethylene catalyst for slurry PE process and ultrahigh molecular weight polyethylene (“UHMWPE”)
• Plant for morphology-controlled precursor production
• Plant for advanced generation, external donor plant for homo and impact PP grades
• Pilot scale plant for advanced catalyst developments
• Antipolymerant process development for controlling fouling in naphtha cracker caustic tower
• Antifouling chemical development for DM water plant of captive power plant
• Novel antipolymerant synthesis process for controlling aldol condensation of aldehyde
• Improvement in process capability of NG-3 process for PE production
• Analytical support for developing titanium dioxide value added product
• Study of surface properties of PVC and VCM catalysts that improve process performance.
• Collaborative new catalyst development for Addipol PP process with external catalyst supplier
• High melt strength polypropylene for light weight appliances and containers
• Heat sealable grade of polypropylene for BOPP application: Uses for specialty packaging, tear-able films
• Linear Low Density Polyethylene (LLDPE) for lateral pipe: Uses for Agricultural applications and water conservation
• Degradable films for environmentally friendly pickup bags / carry bags
• Sound dampener PVC pipes for building & construction: For reducing noise levels
• 1-butene comonomer from Ethylene
• Process for production of para-DEB from EB
• Catalyst for dehydrogenation of C10-C14 n-paraffins
• Oxidation catalyst for purification of nitrogen
• Molecular sieves adsorbent for cracked gas drying
• Cyanide removal from ACN waste
• Defluoridation process for PBR water
• Catalytic process for “on-purpose” alpha-olefins from ethylene
• Catalyst and products for specialty ultra-high molecular weight polymers
• Functionalized and self-healing polymers
• Chlorination processes for polymers
• Superabsorbents
• Bio filtration process for effluent water treatment
• Para-xylene isomerization catalyst
• CCR-type catalysts for naphtha reforming
• Catalyst for selective oxidation of ethylene to EO
• Adsorbents for separation of paraxylene from other C8 isomers
• Additives for ethylene cracker coking passivation
• Cationic dyeable polyester POY & Low pill fibre, both through a continuous polymerization route.
• R3S fibre for construction and wet laid applications
• Specialty bi-component yarns for apparel applications
• Advanced Reliance Spinning (“ARS”) with 15-30% increased productivity for apparel & home furnishing end use
• Black and coloured master-batches for dope-dyed yarns and fibres
• Proprietary spin finishes for FDY yarns
• Co-catalyst for 5-8% productivity enhancement in PET resin manufacturing

Some polymer grades recently commercialized by PARC:
• A Linear Low Density Polyethylene (“LLDPE”) grade with excellent properties for drip lateral applications (Relene E19010)
• High Density Polyethylene (“HDPE”) grade produced and specially formulated to manufacture stained tape products like tarpaulin/wrapping fabrics with a good combination of tenacity and elongation (Relene HD53EA010)
• A medium flow propylene random copolymer designed to give high clarity for injection molding and injection stretch blow molding applications like hygienic food containers, e.g. milk bottles (Repol SRX100)
• A highly crystalline PP impact copolymer grade for making automobile and appliance parts where a combination of high flow is required with very high stiffness. (Repol B300MN)

Awards

Team Awards
Individual Dr. V K Gupta

Other awards:
• Golden Peacock Award – 2005 & 2011
• Mark Patent Visionary Inventor Award - 2006
• Vasvik Awards - 2005, 2006, 2010
• IICHE’s Bhagirathi Award for water effluent treatment process, 2009

Internal Rewards & Recognition (R&R) program

Every year the R&R event is held to recognize the dedication & talent in Technology and R&D and influence everyone to learn by examples. The Reward & Recognition Program encourages the contributions by talented fellow colleagues and acknowledges their accomplishments.

This year the event was held at Hotel Ramada, Navi Mumbai on 19th October, 2013 with high tea and was attended by huge gathering of employees, including from the sites and other senior members from business and sites (around 300 nos.).

RTG Rewards and Recognition event was broadly categorized into Individual and Team Recognition.

Individual Award Categories
• Best Innovator Award
• Out-of-the-box Idea Award
• Technical Excellence Award

Team Award Categories included
• Best Project Team
• Best Services Team
• Best Technology Developed
• Edison Award which is a new category of awards for exceptional efforts.
• Special Recognition Award
• Best RTG Vertical Award – R&D and Technology

Looking Ahead

RIL recognizes that innovation holds the key to sustain the rapid growth that Reliance has achieved in its first four decades of its existence and successfully compete globally. The “business transformation” being implemented across all major activities of RIL will ensure that the process-centric approach for innovation will take deeper root within the organization. As Reliance strives to grow into a leadership position in the national and global market, this vision will not only require significant enhancement in R&D commitment but at the same time building seamless teams for rapid commercialization of R&D developed products, processes and technologies. In this “technology transformation”, Reliance continues to pursue cutting edge research in both existing as well as new areas of business with a focus to develop breakthrough technologies which are “first of its kind”. The growth envisioned will be toward new products - especially high margin, high performance products. Strong collaboration, including our business units as well as various national and international labs and academia, will also help to accelerate the innovation drive at RIL.
For further characterization of crudes, we are equipped with an S-Value instrument which indicates the compatibility of various crudes and its blends. The equipment acts as a pilot plant to simulate conditions in CDU and VDU columns in the refinery and predicts the potential of each cut and properties. We have conducted characterization of about 190 crudes some of which are repeated to check its potential periodically.

When processing crudes, and in particular heavy/tough, there is a tendency for the preheat exchangers to get fouled over a period of time. In order to predict fouling in exchangers, normally researchers use HLPS. With our internal talents, we could design and develop indigenous Fouling Potential Analyzer (FPA) at a cost less than 1/5th of HLPS. The FPA will predict the heat exchanger fouling during processing of various crudes. The data from FPA enable us to decide on the compatibility of blends for smooth performance. Till now we have studied more than 75 crudes.

We have an S-Value instrument which indicates the compatibility of various crudes and its blends. The S-value has helped in transporting and unloading high viscous crudes by off-shore blending with other crudes. Till now we have studied more than 90 crudes.

For further characterization of crudes, we are equipped with SARA analyzer; the correlation between SARA, S-Value and fouling potential of crude blends shall broaden the horizon for tougher crude processing.

While processing some of the crudes, a typical phenomenon of colour deterioration when exposed to sunlight was observed during manufacture of ATF. Through literature survey, suitable resins were identified and various lab and field trials were conducted. The trials successfully improved colour of the ATF. However, due to high cost of resins it was not feasible.

Other studies: Besides crude characterisation, opportunities for improvement in product quality, production of value added product, alternate processing scheme etc were also explored as part of the R&D activities. Some of these are:

- Development of bitumen with modified sulfur based binder. The modified sulfur based binder shall have equivalent binding potential as bitumen and can be sold as a new binder for road pavement. This shall be economically benefited due to the value addition to sulfur.
- Development of acid treated clay to enhance the efficiency of kerosene colour removal. This technology can be used in-house or transferred to clay supplier to enhance the quality of clay.
- Wax extraction from Vacuum gas oil (VGO) derived from certain crudes. The trials indicated that VGO has a very good potential for Wax production. The wax properties were found to meet the BIS specifications and can be sold as a new product. After preliminary trials at our end, the project was awarded for further development at IIP, Dehradun.
- Development of analytical technique/method for Arsenic content at low levels in FCC streams.
- Refinery is using caustic soda lye in various treaters for sweetening of hydrocarbon streams. The major component which is absorbed is hydrogen sulfide. The spent caustic goes to ETP where it is further treated before disposal. As a part of optimizing the use of caustic in refinery, through various study and trials, various alternatives were established to minimize its consumption. Some of the options identified are reuse of gasoline spent caustic in Isomerisation unit, reduction of caustic strength for kerosene treating etc.
- Another innovative thought of replacing de-sulfurised naphtha in Merichem treating units with low sulphur straight run naphtha. This reduced the processing cost of naphtha hydrotreating unit and was implemented after several lab trials.
- Extraction of spent oil from spent caustic and using it as Lubricity additive has been experimented on lab scale. Few field trials have also been conducted and have been successful. Further study is in progress. This shall reduce the cost of lubricity additive in Diesel product.
A Study on Application of Nanotechnology in Oil Field Chemistry

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Abstract

With the introduction of nanotechnology, energy industries envisage a potential revolutionary change in the field of exploration, development and production. The most significant advantage with Nano particles is its ultrafine nature which provides very high specific surface area resulting in larger areas of interaction. Nanoparticles can enhance the additive properties by tuning particle characteristics to meet certain operational and technical requirements.

In current scenario largest impact of Nano-materials and Nano-techniques, within the upstream business is expected in subsurface applications. There are numerous areas in which nanotechnology can contribute to more efficient, less expensive, and more environmentally sound technologies.

This paper showcases some important Nano materials developed so far in the field of oilfield chemistry, including drilling fluids, completion fluid, stimulation fluid, profile agent control, Surfactant Structure Fluids, Novel sensors, prevention of fine migrations Effluent treatment material and their application to the upstream viz. exploration and production business.

Introduction

The worldwide demand for energy is anticipated to continue to increase over the next few decades with the expectation that the world’s energy consumption will increase by as much as 50% in next 20 years. Although the use of alternative energy sources, such as nuclear and renewable energy will increase in coming years, the increase will be relatively small and main role of alternative energy sources, at least four to next two decades, will be two complement and supplement, rather than replace, the use of hydrocarbon’s. Accordingly, meeting the world growing energy demand will be the major challenge in coming decades and will only be possible with revolutionary breakthrough in oil and gas industry course science engineering. Breakthroughs in nanotechnology have potential to move industry beyond the current alternative for energy supply by introducing technologies data more efficient and more environmentally sound.

Nanotechnology has the potential to introduce revolutionary change in the field of oil field of oil field chemistry (Kristamoomdi et al. 2006; Mokhatab et al. 2006; sensoy et al. 2009). Currently, Nano-materials are considered to be the most promising matter of choice for designing and develop-
migrate-able fines should keep or fixated as far away from near wellbore region as possible.

In this paper propose the use of nanoparticle treated fracture of propagant as a mechanism to fixate and distribute migrated formation files the nanoparticles employed in this method have sufficiently high surface forces including Vander wall forces and electrostatic force and readily attracted to the surface of propagant particles during the propagant stages of fracturing treatment. During production when formation finds move through the nanoparticle treated propagant bed, surface forces of the nanoparticle capture and prevent the fines from moving to the near wellbore region. Laboratory testing of the propagant bed and sand packs treated with low concentration of nanoparticle demonstrate that nanoparticles are capable of fixing formation fines such as colloidal silica, charged and non-charged particles, expandable and non-expendable clays.

**Novel Sensors (Zhang et al; 2011)**

Nanoparticles, when synthesized in a specific size range and with a special surface coating tailored to achieve certain desired functionalities, exhibit unique properties. This is because they are almost of molecular size but still retain many useful colloidal characteristics. Recent developments on novel potential upstream applications of nanoparticles are reviewed with focus on research at our laboratory. Oil-water emulsions and CO2 foams that have long-term stability under harsh down hole conditions could be employed as alternatives for surfactant-stabilized emulsions and foams for drilling and other applications. Nanoparticles that show minimal retention can be employed as sensing-capability carrier to detect fluid and rock properties of the producing zone. For example, paramagnetic nanoparticles delivered to the target formation could evaluate fluids saturations there, with application of magnetic field and measurement of response.

**Heavy oil recovery (Wang et al 2013)**

With the increasing consumption of world oil market and scarcity of the fast decrease of conventional oil reserves, more attention is paid to huge unconventional oil resources such as heavy oil, mainly due to their enormous volume and worldwide distribution. However, the viscosity of heavy oil is very high, and it is difficult to be produced from the wellbore, so a suitable heating technique to reduce its viscosity and decrease the cost of energy should be developed. In other words, the reduction of heavy oil viscosity should be achieved in an economic way.

Prama et al. (2010) proposed Nano-Ferro-fluid and graphite fluid as stimulants for heavy oil recovery processes using electromagnetic induction heating. The heat generation in the stimulants would be used for reducing the viscosity of heavy oil. The results showed that the temperature of the stimulants increased with the presence of electromagnetic induction, and thus they could transfer the heat to the heavy oil, so the viscosity of heavy oil decreased significantly, and large quantities of heavy oil could be extracted at low pressures. Compared with graphite fluid and brine, Nano-Ferro-fluid was more rapidly heated, so it had more efficiency improvement of electromagnetic induction heating for heavy oil recovery. The combination of the electromagnetic induction heating and Nano-meter stimulant fluids was economically and practically optimum.

Shokrlu et al. (2010) investigated the effect of different metal types with different sizes on heavy oil viscosity in the absence of electromagnetic fields. The viscosity of oil samples added by these metal particles was measured, and the effect of the metal particles on heat transfer enhancement was tested. The experimental results indicated that heavy oil viscosity could be reduced even at room temperature or without steam stimulation. Additionally, due to the stronger effect of the aqua-thermo-lysis reactions catalysed by metal particles, the efficiency of heavy oil viscosity reduction would be more with applying steam stimulation. More importantly, Nano-sized particles caused an improvement in heavy oil recovery, mainly due to the combination of viscosity reduction effect and heat transfer enhancement.
of nanoparticles, so they had a remarkable effect on heavy oil viscosity, which was very useful in further studies and applications as to the efficiency improvement of the thermal applications for heavy oil recovery.

**Prevent Fines Migration** *(Paternostro et al; 2010)*

Formation fines are the loose solid materials present in sandstone reservoirs. Generally they can be classified as clays and non-clays (quartz, amorphous silica, feldspar, zeolite, carbonates, salts and micas), which occur in all sandstone reservoirs (Hibbeler et al., 2003). Apart from natural deposition over geologic times, formation fines can be introduced through complex drilling and completion processes. The negative charges on these clay particles cause them to dissociate among themselves, thus forming matrix sands. These matrix sands are susceptible to migration under hydrodynamic drag forces. Other factors that contribute to the migration of these formation fines can be drawn down above the critical flow rate, multiphase flow, changes in water salinity, pH imbalance, organic adsorption from crude oil, and stimulation/work overs. This fines migration process can create severe formation damage and production impairment (Blauclh, et al., 1998; Ezeukwu, et al., 1998; Gruesbeck, et al., 1982). Chemical treatments with clay stabilizers are the most popular methods for clay control. Clay stabilizers can be divided into the following classes: simple inorganic salts, cationic inorganic polymers, cationic organic polymers, anionic organic polymers, and non-ionic organic polymers. A comprehensive discussion on the advantages and disadvantages of these clay stabilizers are discussed elsewhere (Zhou, et al., 1995). An array of acid systems are also used to remove the formation fines in gravel packs, sand control screens, and the near-wellbore region (Hibbeler, et al., 2003; Huang, et al., 2008).

**Ca-DTPMP Nanoparticle Suspension** *(Zhang et al; 2008)*

Di-ethylene-tri-amine-pentakis (methylene phosphonic acid) (DTPMP) is commonly used in oilfield for scale inhibition. In this study, Ca-DTPMP submicron-sized particles were prepared directly by chemical precipitation with the assistance of phosphino-poly-carboxylic acid (PPCA). The influences of adsorbed PPCA, KCl concentration and sonication on the transport and deposition kinetics of Ca-DTPMP particle suspensions in calcite and sandstone matrix were investigated. Adsorption of PPCA to Ca-DTPMP particles increases their negative surface charge and decreases particles deposition in a porous media. The mobility of PPCA-coated Ca-DTPMP particles decreases with increasing KCl concentrations. Using sonication treatments the mobility of Ca-DTPMP particles at high KCl concentration in porous media increased significantly. The retention and long term flow back performance of Ca-DTPMP particles were tested in Frio sandstone columns after 18 hours shut-in time to allow deposition. The results show that enhanced retention of Ca-DTPMP particles and slow dissolution of DTPMP are highly advantageous in slowing the phosphate release from porous media, and ensuring successful inhibitor treatments in oil fields.

**Viscoelastic-Surfactant Stimulation Fluids** *(Crews et al; 2007)*

Viscoelastic surfactant (VES) fluids have been widely used in the oil industry as completion and stimulation fluids. The surfactants structurally arrange to form rod-like micelles that increase VES fluid viscosity for regular fracturing and frac-packing fluids. However, high fluid leak-off and low viscosities at elevated temperatures have limited VES fluids for hydraulic fracturing and frac-packing applications. This paper will introduce a nanotechnology application for maintaining viscosity at high temperatures and controlling the fluid loss of VES fluid, without generating formation damage. The nanometer-scale particles studied display unusual surface morphologies and have high surface reactivity. These nanometer-scale particles, through chemisorption and surface charge attraction, associate with VES micelles to: 1) stabilize fluid viscosity at high temperatures; and 2) produce a pseudo-filter cake of viscous VES fluid that significantly reduces the rate of fluid loss and improves fluid efficiency. When internal breakers are used to break the VES micelles, the fluid will dramatically lose its viscosity and the pseudo-filter cake will then break into nanometer-sized particles. Since the particles are small enough to pass through the pore throat of producing formations, they will be flowed back with the producing fluids, and no damage will be generated. The results of rheology leak-off and core flow tests will be presented for the VES fluid systems at temperatures 150°F and 250°F.

**Treatment of Effluent**

A substantial amount of oily wastewater has been generated from oil and gas exploration and production activities, and it contains a great number of harmful substances such as suspended solids, organics, heavy metal ions, and so on, which will cause severe environmental pollution when discharged arbitrarily without any treatment (Wen et al. 2008). Therefore, it is necessary to purify this wastewater so that it can be reused to save water resources. However, conventional oily wastewater treatment methods have several disadvantages, including low efficiency, high cost, and corrosion and recontamination problems. Additionally, they are not effective in removing smaller oil droplets and emulsions (Mondal et al. 2008). So a new technique for wastewater treatment should be developed.

A tubular UF module equipped with poly-vinylidene fluoride membranes modified by inorganic Nano-sized alumina particles was used to purify oily wastewater, and the membrane water permeations of the UF process were analysed (Li et al. 2006; Yan et al. 2009). The experimental results showed that the oil content was reduced to less than 1 mg/L, suspended solids content was reduced to less than 1 mg/L, and the median diameters of solid particle were less than 2 µm, which indicated that the quality of the permeation water could meet the requirement for oilfield injection or drainage. The retentions of chemical oxygen demand were more than 90%, and the total organic carbon was more than 98%. The SEM images showed that the nanometre alumina
particles could improve the performance of membrane antifouling, and the modified membrane flux recovery ratio reached 100% when washing with 1% of OP-10 solution (pH 10), which indicated that the modified membrane had a better antifouling performance, better flux recovery and less contaminant adsorption in comparison with unmodified membrane. As a result, this modified Nano membrane had excellent permeation performance, and it would have a broad application in oily wastewater treatment.

**Nano-Sized Shale Inhibitor**

Maintaining wellbore stability is the most critical aspect of petroleum drilling operations. But most of conventional water-based mud can easily generate fluid invasion into shale formations, and subsequent cause swelling and sloughing of wellbore. The basic reason is that conventional filtration additives do not form mud cakes to plug Nano-sized pore throats in shale’s, and thus do not stop fluid invasion. Six brands of commercial and non-treated silica nanoparticles with sizes varying from 5 nm to 22 nm were added to the drilling fluids, and water-based inhibitive drilling fluids were formulated for the first time (Cai et al. 2011). The experimental results demonstrated that all 6 non-modified nanoparticles could reduce the Atoka shale permeability by a significant amount, and thus stop fluid invasion and increase wellbore stability. In addition, these nanoparticles with size varying from 7 nm to 15 nm had better plugging performance than those with size greater than 20 nm, so they were more effective plugging agents. The reason for this was that these nanoparticles were small enough to enter and plug the pore throat in shale’s, and built an effective mud cake on shale surface, therefore, minimized fluid invasion into shale. Using these water-based inhibitive mud containing non-modified nanoparticles to seal the shale was a very powerful and economical approach to address borehole instability problems in troublesome shale formations. As a result, these water-based fluids were suitable for the drilling of long sections of horizontal laterals. In the future, these non-modified nanoparticles based drilling fluids might hold great promise to resolve shale instability problems.

**Nano-Sized Fluid Loss Agent**

The filtrate invasion into formations may cause formation damage and increase the difficulty of filter cake removal, resulting in the reduction of oil well productivity. Hence, the filtrate losses to the formation should be properly controlled. Sized silica nanoparticles were added to drilling fluids, and their fluid loss properties were tested (Srivatsa et al. 2012). The experimental results showed that the nanoparticles had better reduction in fluid loss in comparison with the standard polymer-based fluid loss additive, because the nanoparticles could seal the pores and form an effective filter cake than the internal filter cake formed by the polymer. Moreover, the addition of nanoparticles did not raise the mud weight, so they could be used as a new class of bridging agent that did not increase the solid content of drilling fluids, which could play an important role in drilling in high angle wells, horizontal and directional wells. Therefore, the application of nanoparticles in drilling fluids was mainly to form a thin and impermeable membrane on the borehole wall, which could plug the pores of the shale formation, minimize filtrate-induced damage, strengthen borehole stability, and maximum well conductivity.

**Nanoparticle-Based Drilling Fluid**

Novel oil-based drilling fluid system was formulated for the first time by adding in-house prepared nanoparticles (NPs) to commercial oil-based drilling fluid (Zakaria et al. 2012). The experimental results indicated that there was no effect on the viscosity of commercial drilling fluid, and the oil-based drilling mud containing NPs could maintain its stability for more than 6 weeks. The NP-based drilling fluid produced an ultra-thin, tight and relatively impenetrable mud cake deposited on the borehole wall, which could reduce filtrate invasion into formations and hence minimized fluid-induced damage. In addition, NPs could also possess the small sized pores to block throats and interact with the clay particles, and consequently provided an excellent sealing effect and hence increased borehole stability. As a result, the application of NP-based drilling fluid might offer high potential for reducing the differential pipe sticking in highly permeable formations, formation damage and contamination while drilling, and also could enhance ROP in hard rock formations greatly, and thus lower drilling costs significantly.

**Nano-Enhanced Drilling Fluids**

Abdo et al. (2012) reported an approach to overcome drilling problems by controlling the rheological properties of drilling fluids by using nanoparticles. New nanomaterial ATR was added to drilling fluids, and the rheology of drilling fluids was investigated. The results demonstrated that ATR could reduce viscosity without compromising the requirement of density. Additionally, the obtained drilling fluids had high gel strength, which was very essential for eliminating severe drilling problems such as poor hole cleaning, high torque and drag, pipe sticking, wellbore instability and formation damage. Compared with regular bento-nite, ATR nanoparticles could offer better functionality. In order to improve the functionality of bento-nite, a certain number of ATR nanoparticles were added to bento-nite-based drilling fluid system. The results showed that the obtained drilling fluid system had excellent properties and shear thinning behaviour mainly due to the combination of the characteristics of high density of bentonite and low viscosity and high gel strength of Nano-sized ATR, which could not be achieved by bento-nite or ATR alone. Therefore, the use of ATR could play an important role in developing versatile drilling fluid recipes to suit particular drilling conditions.

**Smart Fluid Development (Tahini et al; 2009)**

Current as well as future drilling and production operations are likely to face greater technical challenges due to a change in the operational depth, nature of subsurface geo-hazards with increasing depth, length of horizontal departure to maximize produc-
tion, complexity of drilling operation, shape of wellbore profiles or number of laterals from a mother bore to maximize reservoir contact. The industry also faces a range of material related challenges due to a significant change in the physical, chemical and thermal conditions of deeper horizons along with the increasingly strict environmental regulations enacted by different governing bodies. Current experience shows, it is often impossible to fulfill certain functional tasks that are essential in challenging drilling and production environments using conventional macro and micro type fluid additives due to their inadequate physical, mechanical, chemical, thermal and environmental characteristics. Hence, the industry is looking for mechanically strong, physically small, chemically and thermally stable, biologically degradable, environmentally benign chemicals, polymers or natural products for designing smart fluids to use virtually in all areas of oil and gas exploration and exploitation. Due to totally different and highly enhanced physio-chemical, mechanical, electrical, thermal, hydrodynamic properties and interaction potential of Nano materials compared to their parent materials, the Nanos are considered the most promising material of choice for smart fluid design for oil and gas field application. Moreover, due to the scope of manufacturing of tailored made Nano-materials with custom made functional behavior, ionic nature, physical shape and sizes, charge density/unit volume, nanotechnology opened the door to the development of a new generation of fluids defined as the smart fluids for drilling, production and stimulation related applications.

**New Nano-Cement Slurry**

The Nano-sized particles such as SiO2, 2CaO·SiO2, 3CaO·SiO2, Al2O3, and phosphorous/calcium were selected as additives to improve the properties of the resulting cement (Mercado et al, 2010). The experimental results showed that these Nano-additives could enter the interstitial areas and other areas of high porosity in the cement. Therefore, a much less permeable structure could be formed, and the strength and other desirable characteristics of the cement could be improved. In addition, these Nano-particles could raise the mechanical, thermal and chemical properties of the resulting cement, which was particularly useful in solving such problems as low mechanical property; gas and fluid migration of oil and gas well cement system, and reducing the erosion of sour gas.

**New Nano-Spacer Fluids**

Nano-emulsions, the droplet size of which was between 20 and 500 nm, were obtained by a low energy cost method, so they could be prepared readily in great amounts (Maserati et al, 2010). In addition, the Nano-emulsions could be directly obtained in the field or transported on site. Due to their small droplet size, they had a high surface area, very particular characteristics, and high stability, and thus had potential applications in oil and gas industry. With the help of Nano-emulsion technology, a new Nano-spacer was prepared by adding commercial gelling and weighting agents to the Nano-emulsions. Compared with the traditional spacers, the Nano-spacer had better performances in mud removal, reverse wettability, and casing-bore adhesion of the concrete. Moreover, the experimental results demonstrated that the fresh and aged Nano-spacers had the same effect, so the Nano-spacer could be applied at complex field conditions. The innovative spacer fluid had very high cleaning properties, was totally compatible with drilling fluid as well as slurry systems, and could improve the cement sheath bonding, so it would have a broad prospect in well cementing operations.

**Nano-scale Work over Fluids**

Low permeability oil and gas well reservoirs are commonly characterized by high content of argillaceous cements, small pore throats, poor permeability, severe heterogeneity, and large oil and gas flow resistance. The reservoirs are extremely sensitive to working fluids such as drilling fluids, completion fluids, stimulation fluids, and so on. Therefore, the fines invasion into reservoirs can result in pore throat blockage, and thus create severe formation damage and produce impairment (Davies et al, 2009). As a result, novel work over fluids should be developed to repair the damaged reservoirs. A new work over fluid had been developed by a unique blend of biodegradable solvent, surfactant, co-solvent and water (Penny et al, 2005). The experimental results demonstrated that this work over fluid was efficient in remediating damage and promoting well clean-up following stimulation. The work over fluid could result in lower pressures to displace frac-fluids from propped fractures resulting in lower damage and higher production rate. Field applications indicated that the addition of the work over fluids to drilling fluids could result in greater fluid recoveries and higher production rates, the addition of the work over fluids to fracturing treatments could result in improved load recoveries and enhanced gas and oil production, and the squeeze jobs with the work over fluids had restored productivity to wells damaged by frac-fluids, water blocks and heavy oils. Meantime, the work over fluid system was naturally occurring, non-synthetic, non-hazardous, non-carcinogenic, and contained no volatile organic solvents. The work over fluid was effective in remediating damaged wells, and was highly effective in fluid recovery and relative permeability enhancement when used in drilling and stimulation treatments, and thus it would have a wide application future in work over operations.

**New Profile Control Agents**

CO2 channelling is a serious problem for enhanced oil recovery with CO2, which has serious influence upon oil displacement efficiency of CO2, and thus it will reduce oil recovery drastically. Therefore, to control CO2 channelling during CO2 injection process is an important part in oil displacement process. It is particularly necessary for petroleum scientist to develop an environmental friendly and highly effective CO2 plugging agent. Utilizing sodium silicate as starting materials, acrylamide as initiator and crosslinking agent, Hou et al. (2010) prepared a new type of organic-inorganic Nano-composite gel at high-pressure acid environment
generated by CO2. The experimental results demonstrated that the high-pressure acid environment generated by CO2 injection could not only accelerate the formation of composite gel, but also have positive influence on gel properties. The composite gel system had good resistance to high temperature and high pressure, and high elasticity. The core plugging tests showed the plugging rate of the composite gel could reach up to 95%. Additionally, the gel system flowed freely, and could be pumped into the formation easily. As a result, the new Nano-composite gel was a kind of environmental-friendly CO2 plugging agent, and it would have good potential for plugging CO2 channeling. Using diesel oil, sorbitan mono-oleate, polyethylene glycol sorbitan monoo-stearate, acrylamide, N-N'-methylene-bis-sacryl-amide as raw materials, Wang et al. (2010) synthesized a new kind of polyacrylamide micro-gel Nano-sphere by inverse micro-emulsion polymerization method. The experimental results demonstrated that the Nano-spheres after water absorption could expand from the original 50 nm to several microns in diameter, which showed that they had good water absorbing capacity and excellent swelling property. Meantime, the Nano-spheres had good elasticity and deformability, too. The micro-gel Nano-spheres were not water soluble, and they had high stability in water. The core flood tests demonstrated that the Nano-spheres could enlarge the sweep efficiency, so they were suitable for deep profile control. The sand packs tests showed that the Nano-spheres could improve enhanced oil recovery (EOR) with incremental oil recovery over 20% OOIP after primary recovery. Therefore, the Nano-spheres had great potential in profile control and oil displacement.

Discussion

With the rapid development of nanotechnology, Nano-materials have been gradually infiltrating to every respect of oilfield chemistry, and they will play an essential role in the preparation of new oilfield chemistry agents. Unfortunately, there are many problems in the applications of nanotechnology and Nano-materials in the field of oilfield chemistry. (1) It is very easy to generate agglomerates for Nano-materials during use, and the grain sizes will increase greatly. Only by stirring can hardly disperse these agglomerated particles into Nano-meter scale again, so these Nano-materials will lose their unique properties, even resulting in failure of preparation of novel oilfield chemistry agents. Therefore, the agglomerate problem of Nano-materials remains to be solved in future, and the stability of Nano-materials should be improved.

(2) There are few researches on the mechanism of Nano-materials in oilfield chemistry, and some aspects are seldom involved. A breakthrough in their application cannot be made until the fundamental research of Nano-materials is appreciated.

(3) Nowadays, the cost effectiveness of most Nano-materials is too low. In the field application, the desired results cannot be achieved with only a little dosage of Nano-materials, but excessive dosage will raise the cost. So, low cost and industrial production are the key factors for extensive application of Nano-materials in the field of oilfield chemistry. With the development of nanotechnology, many potential solutions will emerge for the above problems, and Nano-materials will be applied in broader field of oilfield chemistry. Meanwhile, further development of nanotechnology and oilfield chemistry technique will be promoted.

Conclusions

Different types of applications of nanotechnology in oilfield chemistry have been emerging such as Surfactant Structure Fluids, Prevent fine migrations, drilling fluids, completion fluids, work over fluids, environmentally friendly stimulation fluids, profile control agents, heavy oil thinner, oily Effluent treatment materials etc. So it shows great promise for upstream sectors of petroleum industry. The cost effectiveness of most Nano-materials is too low. In the field application, the desired results cannot be achieved with only a little dosage of Nano-materials, but excessive dosage will raise the cost. So, low cost and industrial production are the key factors for extensive application of Nano-materials in the field of oilfield chemistry. With the development of nanotechnology, many potential solutions will emerge for the above problems, and Nano-materials will be applied in broader field of oilfield chemistry. Meanwhile, further development of nanotechnology and oilfield chemistry technique will be promoted.

References


Unlocking Value Potential from Naphtha Cracker By-product Streams

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Steam cracking of hydrocarbons to produce ethylene is the work horse of the global petrochemical industry. The capacity of steam crackers in a country is an indicator of its level of economic development. Growth in global economy will increase demand for petrochemicals & plastics, that would necessitate increase in cracker capacity.

In view of varying types of gas or naphtha feed stocks available in different regions and at different prices this industry faces increasing challenges of remaining competitive. Now there is the threat of very cost competitive petrochemicals from low cost shale gas feedstock and from the already existing low cost gas in the Middle East. For naphtha crackers to be competitive in the global ethylene business, more emphasis must be placed on upgrading the byproducts generated from the liquid crackers.

This article presents the global disparities of gas and naphtha crackers and ways to mitigate the impact through the up-gradation of byproducts generated in larger volume from naphtha crackers.

Introduction

Demand for petrochemicals has been growing exponentially particularly in growing economies like India and China. Overall, Asia is responsible for much of the new demand. In the present scenario of diverse regional requirements and varying availability of feed stocks, it is imperative to explore different innovative solutions to unlock the value potential from existing naphtha crackers and implement strategies to maximize recovery of secondary co-products.
Global Scenario of Naphtha Cracking

World ethylene production capacity has grown from about 120 million tonnes in 2008 to 141 million tonnes\(^1\). Geographic split of this production capacity is given in Figure 1 as percent share of the world cracker capacity.

The growth in cracker capacity from 2008 to 2012 was mainly in the Far East and Middle East regions.

This trend is obviously in line with the availability of cheaper gas based raw material in the Middle East and growing demand of petrochemical products in the Far East which includes India and China. The European Union, which also includes crackers in Russia in the present analysis, has not only shown decline in the capacity share but also withdrawal of some capacities. North America and the rest of the world continued with by and large stagnant capacity during this period. The region wise capacity split for gas and naphtha (liquid) based crackers in 2012 is portrayed in Figure 2.

In the Middle East, ethylene production capacity is dominated by gas crackers while in the Far East it is dominated by liquid crackers. Globally, liquid feed stocks provide more than half of the ethylene production capacity. In the European Union, it is liquid feed stocks that dominate ethylene production capacity. Germany, France, Benelux and UK have significant liquid feedstock based ethylene capacity. During 2008-12 there was no additional capacity mainly due to stagnant demand for petrochemical products in the region and availability of lower cost feed stocks in other regions e.g. Middle East and North America.

In North America, gas based capacity dominates the current scenario, even though there is significant capacity of liquid based crackers. In the past, flexible fuel crackers were built to take advantage of the periodic price swings between NGLs and naphtha. Now with the shale boom, the US is ramping up production of gas crackers with plans to build approximately seven new crackers in addition to expanding existing plants. This could add almost 10 million tonnes of ethylene capacity, (+37% of the total US capacity today) by 2017-18.

Challenge for Far East Naphtha Crackers

As evident from Figure 1 capacity in Far East region crackers is highly skewed towards liquid feed stocks which is about 84% of the regional ethylene production capacity. This is exactly reverse of that in the Middle East region which has 87% of its crackers based on gas feed stock. Furthermore, additional capacities based on cost competitive feedstock planned in the Middle East will target the same growing market of Far East.

This poses a challenge for naphtha crackers in the Far East, mainly in India and China. Obviously the higher yields of by-products from naphtha feed stock require a greater value addition through the adoption of the right technological options. Unlocking the value potential from naphtha crackers is the key to limit the disparity from gas based crackers in the Middle East and the impact foreseen due to new crackers in North America in view of the shale boom.

Potential Premier Products from Naphtha Crackers

Gas crackers primarily produce ethylene and smaller amounts of co-products, whereas liquid crackers produce a broader range of coproducts, olefins and aromatics including propylene, butenes, benzene, toluene and a variety of other co-products in smaller quantities. These production yields are presented in Table 1.

Downstream processing of cracked gasoline from liquid feed stocks (naphtha and gas oil) is also more complex than processing of NGL feed stocks because of the heavier components and...
increased number of potential impurities that are present, which impact the quality of recovered co-products. The primary fractionators upstream of the compressor produce considerable fuel oil and a gasoline stream, called pyrolysis gasoline or ‘pygas’, which is rich in aromatics (benzene, toluene, xylene and other C8 aromatics). This pyrolysis gasoline portion of the cracker product contains a host of valuable petrochemicals that can be recovered provided:

1. they are available in sufficient quantity,
2. a suitable recovery method is chosen (this is often plant specific and requires a technology provider to integrate with other co-product units),
3. product quality requirements are known and addressed, and
4. product off-take or other supply arrangements can be made.

The increasing size of cracker projects and the decreased production from traditional supplies strongly support a strategy of maximizing secondary co-products when possible.

Figure 3 gives the potential products and broad guideline about which products may be economically recovered as a function of the ethylene rate based on liquid feed. With today’s typical increased cracker size, many of these products are economical to produce in new world scale cracker projects.

At ethylene rates exceeding 400 KTA, butadiene, benzene, toluene and xylenes production becomes economically feasible. After ethylene and propylene, butadiene, benzene, toluene and xylenes are the next most widely produced steam cracker petrochemicals. Toluene has petrochemical uses or can be used as a premium gasoline blend stock. Recently GTC has developed technology to alkylate benzene and toluene with methanol to produce xylene. Xylene production continues to grow to support global polyester demand growth at levels of greater than 7% per year. In order to maintain competitiveness in the ethylene business, more emphasis must be placed on upgrading all of the byproducts that are

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**Table 1: Influence of Feedstock on Steam Cracker Yields** (wt%) *(Values obtained at high severity and with recycling unconverted E/P stream. (Chauvel & Lefebvre 1989 [2])*

<table>
<thead>
<tr>
<th>Product</th>
<th>Ethane</th>
<th>Propane</th>
<th>Butane</th>
<th>Naphtha</th>
<th>Atmospheric Gas Oil</th>
<th>Vacuum Gas Oil</th>
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<tbody>
<tr>
<td>Hydrogen 95% Purity</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<td>Methane</td>
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<td>7</td>
<td>19</td>
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<td>2</td>
<td>5</td>
<td>18</td>
<td>25</td>
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</tbody>
</table>

---

**Figure 3. Economical products as a function of ethylene rate (liquid feed)**

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Joseph C. Gentry is Director - Global Licensing for GTC Technology US, LLC. He is a specialist in GTBtx and GT-Styrene, working in all area of technology, licensing and business development.

Charlie Chou is Manager - Petrochemical/PTA for GTC Technology US, LLC. He is a co-inventor of the PTA process.
available in the value chain of liquids crackers. At 600 KTA and above, styrene extraction, production of C9 resin feed stocks, xylenes, benzene derivatives and C4 derivatives become economic.

Cracker C5s are interesting for a variety of end uses. At 800 KTA ethylene from liquids cracking, DCPD (dicyclopentadiene) and piperylene (cis & trans 1,3 pentadiene), and optionally isoprene becomes economical. Polyisoprene is a substitute for natural rubber, which is being constrained by land use in Southeast Asia that has been set aside for palm oil plantations. The supply/demand balance for isoprene has tightened in recent years, resulting in sometimes sharp upward shifts in pricing. Piperylenes are used as a reactive monomer in the manufacturing of plastics, adhesives and resins. DCPD is used for resins in printing inks and as a precursor to unsaturated polyester resins.

At rates of 1000 KTA or greater, naphthalene recovery from the C10s and aromatic solvents can be recovered from the C11 and C12 in the pyrolysis gas (PGO) fraction. One significant use of naphthalene is as an admixture flow property enhancement to concrete.

Technologies to Tap Value Potential from Naphtha Crackers

Figure 3 is not exact for every producer, but it is a useful guideline to highlight what typical commodity products could be recovered. Individual plant sites will have different economies based on local supply/demand, logistics of product movements, and construction costs. Sections following present the key technologies which can be exploited to tap value potential from a naphtha cracker depending upon the local scenario.

**BTX Recovery**

The first priority for component recovery from the pygas is benzene, toluene, and xylenes (BTX). Most plants already have or are familiar with aromatics extraction units, or sell the BTX cut to other units that recover the aromatics. Two methods are traditionally used for BTX recovery:

- Liquid-liquid extraction
- Extractive distillation

Highly selective new generation solvents like Techtiv-500 make it possible to achieve excellent process performance with BT or BTX containing feed stocks which can also process wide-cut feeds instead of benzene- only in the ED configuration. Previous generations of solvents could be used only with fractionated narrowcut feeds, or with very high aromatic content to avoid the situation of 3 phase distillation. The new generation Techtiv solvents can economically handle 15 to >99% aromatics in the feed. These are higher boiling, low corrosive and thermally stable solvents which significantly reduce the operating costs, for recovering naphtha cracker co-products.

The flow sheet schematic of GT-BTX process is given in Figure 4.

In the last few years nearly all new units have been designed using extractive distillation technology, which offers a simpler design and better process performance.

GTC’s extractive distillation technology for aromatics recovery from pygas, GT-BTX, operates by alteration of the relative volatility of key components in the presence of a highly selective solvent, selected from our Techtiv family of extraction solvents. Pygas contains a mixture of aromatics and non-aromatics. By using a highly aromatic selective solvent system, the relative volatility of the nonaromatic components is enhanced. This enhancement allows the non-aromatics to be distilled overhead in a conventional distillation column, while the aromatics are recovered in the column bottoms.

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**Figure 4. Process flow scheme for GT-BTX**

**Figure 5: Conceptual arrangement for GT-Styrene**
fairly simple involving only two main columns – Extractive Distillation and Solvent Recovery columns. This makes it easier to design and operate than the conventional liquid-liquid extraction processes. On the other hand in liquid-liquid extraction systems, the solvent makes an incomplete separation of the components at both ends of the extraction column, thus requiring the additional steps of extractive stripping and water washing of the raffinate.

**Styrene Recovery**

The next profitable component to recover is styrene, extracted from the C8 fraction of raw pyrolysis gasoline. Conventionally, in a typical pygas operation, the styrene is hydrogenated to ethyl-benzene in the pygas hydrotreater units in order to reduce the gum-forming potential of the gasoline. Unfortunately, this downgrades the component value, consumes valuable hydrogen, limits capacity in the pygas hydro treating unit, and decreases the potential value of the remaining xylenes. Styrene cannot be purified by conventional distillation because of the presence of many other components or isomers with close boiling points.

New units that GTC has started up in the Asia region now demonstrate the advantages of recovering styrene from pygas. GT-Styrene is the most cost-effective process for recovering the styrene from untreated pyrolysis gasoline. The economics are good for reasonably-sized crackers using liquids feedstock.

This extraction technology is applied to upgrade the styrene to petrochemical value and to improve the quality of the mixed xylenes. Figure 5 shows the conceptual arrangement and GTC’s Techativ 200 extraction solvent system is used to change the relative volatility of the pygas components and allow the styrene to be selectively extracted. A prospective economic analysis indicates that the extraction technology provides profitable production of styrene at relatively small capacities. The cash cost of production will always be lower than styrene produced from benzene plus ethylene feedstock. Prime candidates for the technology are ethylene producers that can generate sufficient pygas feedstock to produce at least 15,000 t/yr of styrene. This would include major naphtha-based steam crackers in India, China, Europe, as well as in the CIS, Asia and the Americas.

The process also provides other advantages by upgrading the xylenes (by lowering the EB content), reduced hydrotreater operating costs, hydrogen consumption, and increased hydrotreating capacity/catalyst life in exist-

<table>
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<th>Carbon Number</th>
<th>Technological Option</th>
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<td>C4 to C8 Olefins</td>
<td>GT-Aromatization</td>
</tr>
<tr>
<td>C5</td>
<td>Piperylene/DCPD (GT-C5), Isoprene GT-Isoprene HCR</td>
</tr>
<tr>
<td>C6</td>
<td>Benzene (GT-BTX)</td>
</tr>
<tr>
<td>C7</td>
<td>Toluene (GT-BTX), GT-STDGP</td>
</tr>
<tr>
<td>C8</td>
<td>Styrene (GT-Styrene), xylenes (GT-BTX, DX*)</td>
</tr>
<tr>
<td>C9</td>
<td>Resin Oil, HCR, solvents</td>
</tr>
<tr>
<td>C10</td>
<td>Naphthalene, compressor wash oil, solvents</td>
</tr>
<tr>
<td>C11-C12</td>
<td>Aromatic Solvents</td>
</tr>
</tbody>
</table>

*Alliance with Toray

Anil Khatri

Anil Khatri is Regional Licensing Manager with GTC Process Technology (India) Pvt Ltd. He is responsible for technology licensing and general business management.

Alok K Saxena

Alok K Saxena is Technology Consultant with GTC Process Technology (India) Pvt Ltd, based in India. He has more than 32 years of research and industrial experience in concept to commercialization of refining technologies through close R&D and process design interaction, modeling and simulation, scale-up from lab scale concepts to process packaging.
ing units. Styrene is produced at high purity, suitable for polymerization, at a significant upgrade over its alternate value as gasoline blending component.

### Upgrading Olefins to Aromatics

Other low value steam cracker products can be converted to additional BTX components with a novel aromatization technology. The technology exists to convert C4-C8 range olefins into a mixture of C6-C9 aromatics. Typical feedstocks are the mono-olefin C4 or C5 fractions or the olefinic C6-C8 fractions from partially hydrotreated pygas. C4s usually come from the raffinate after BD extraction, the raffinate after i-butene extraction for MTBE or the mixture of the above. C5s include raffinate after isoprene and cyclo pentadiene (CPD) extraction, partially hydrotreated C5s, or a mixture of the above. C6–C8s are the olefins from partially hydrotreated pygas. Another feed source is from refinery fluid catalytic cracked (FCC) gasoline after removal of the aromatics. In the aromatization process, olefins and naphthenes convert at approximately a 1:1 ratio into aromatics. The products are rich in xylene and xylene precursors, and therefore useful for feeding into a paraxylene complex. Figure 6 highlights the aromatization process.

The aromatization takes place in a single-stage adiabatic fixed bed reactor, which operates in a cyclic mode of regeneration. The operation is very simple with no hydrogen required. The reactor is operated at 460-540°C and the pressure is 1-4 bars. Catalyst life time is greater than 2 years. The liquid yield of aromatics is approximately 47-55% depending on feedstocks. By-products are dry gas and LPG with yields of 15-20% and 30-35%, respectively. Separation of liquid aromatics products may be accomplished by simple fractionation.

### EB dealkylation

Further down the C8 chain, pygas xylenes can be selectively dealkylated to produce isomer-quality material. Typically, pygas C8 streams have high EB (ethylbenzene) content and are not desirable for use as paraxylene plant feed. The EB dealkylation process was developed for increasing PX production capacity by converting ethylbenzene into the benzene plus ethane. Benzene is produced at high purity (99.8% wt) without extraction. The ethane can be combined with cracker feed to produce additional ethylene. The technology features a proprietary catalyst with high activity, low ring & xylene loss, very high conversion and superior long catalyst cycle length.

Highlights of the EB dealkylation process are:

- Simple, low cost fixed-bed reactor design
- Flexible feedstocks and operation
- Low hydrogen consumption
- Moderate operating parameters

### Naphthalene and Aromatic Solvents

Other specialty chemicals and aromatic solvents exist in the higher boiling point tail of pyrolysis gasoline. When a cracker size approaches 1000 KTA, naphthalene recovery is economically feasible. Naphthalene is a component in the heavier cut of Pyrolysis Gas Oil (PGO). The production method of choice is a static-melt crystallization process. This operation produces refined naphthalene with MP of 80°C, along with aromatic solvents and specialty fuel products. Various product derivatives can further increase profitability of naphthalene recovery. Naphthalene recovery technology is available in three grades (melting point based): 78°C, 79°C and 80°C. Refined naphthalene from PGO feedstock is clear, with low levels of sulfur. The process involves pre-fractionation and crystallization.

### Summary of Upgrade Options

The above suite of technological options available from GTC Technology addresses the entire carbon range of pyrolysis gasoline to provide value addition and address the challenge of economic disparity which naphtha crackers face. Carbon number wise available options are summarized in Table 2.

### Conclusion

Depending on feedstock positioning, naphtha crackers that are disadvantaged on the basis of pure ethylene and propylene production can reduce their ethylene cash cost and improve their global competitive position if additional by-products are strategically upgraded. Many of the secondary products are economical to produce at ethylene rates as low as 600 kta, or lower depending on local supply chain considerations. The key to realizing this value is understanding the range of products that are possible to produce and utilizing the latest process technology for the petrochemical upgrades.

In summary, there are a number of new existing processes which are applicable to the C4 – C12 spectrum of by-products from naphtha based steam crackers. In order to maintain a competitive position, a cracker operator should take advantage of all the reasonable upgrade opportunities that are available.

### References

Introduction

The global refining industry has experienced radical changes over the past decade due to variations in regulations, emerging and changing market forces such as fluctuating crude rates, strict regulations on product quality and refinery emissions, varying crude quality and fundamental changes in fuel demand. These forces are highlighted in the North American market where crude quality has become heavier due to higher amounts of lower cost heavy, sour Canadian bitumen and where regulations became tighter by limiting fuels sulfur level to 15 wppm in diesel and 30 wppm in gasoline. In addition to those feed and product quality changes the demand for transportation fuel is shifting from the traditional gasoline-oriented to an increasingly diesel-oriented market.

The gasoline and diesel pool regulatory specifications, which are constantly evolving, have been the main challenge faced by refiners for the last ten years. More specifically, the gasoline sulfur and benzene regulations have been the driving force behind the recent remodeling of the refinery configuration. This transformation was witnessed worldwide but was emphasized in Europe, Asia and North America. Other countries have followed suit and a shared global gasoline specification is now in sight. Indeed the overall gasoline sulfur content is likely to level off at 10 ppm across the globe. As a consequence most refiners will once again be challenged to meet the new Ultra Low Sulfur Gasoline (ULSG) specifications. However, emerging market forces may also develop into new opportunities for refiners.

This paper will point out these new opportunities by reviewing the processing options and effects of such regulation focusing mainly on North American refineries and the European and Asian understanding of meeting the 10 ppm ULSG regulations. The implications of each option will be presented and discussed.

Gasoline Sulfur Specifications

There has been a steady downward trend in the sulfur content of fuels to reduce the emissions from cars and trucks. Many countries mandated the production of Low Sulfur Gasoline (LSG) some time ago, but in recent years regulations in Western Europe, some Asian countries and California in the USA have brought in even tighter specifications to lower the gasoline sulfur to 10 ppm.

The different regional approaches to gasoline sulfur specification are illustrated in the Table 1 showing a clear trend towards ULSG.

As shown in Figure 1, other countries are following the same path to either meet their domestic regulatory specifications or be able to export and sell on the international ULSG market.

Although the majority of countries still have gasoline sulfur specifications well above 10 ppm, the overall trend clearly shows that in the near future ULSG production will become the norm worldwide.

A Closer Look at Refinery Configuration

Refinery configurations vary widely depending on crude availability, local demand, export markets and regulatory constraints. In the same way each market has its own set of dynamics and means of complying with the new fuel regulations.

In Europe regulations for ULSG were adopted early and somewhat influenced by a market demand which is more heavily skewed toward diesel than gasoline. The options for ULSG compliance were influenced by:

- Processing of relatively light and low sulfur crude oil
- Relatively good quality FCC feed (little cracked gasoil such as heavy coker gasoil)
- Undercutting of FCC gasoline to maximize diesel production.

The EU 10-ppm ULSG is produced mainly by using moderate severity FCC post-treatment.
Many CFHT units installed in Asian refineries were designed to meet modern fuels and emission regulations. As such, many are designed for high desulfurization level to meet refinery and SOx regulations from the FCC flue gas resulting in low sulfur FCC gasoline. Consequently, most refineries in Japan have met the new ULSG limit of 10 ppm by adding low severity post-treatment units.

In the US, the refinery configuration was influenced by a large gasoline demand coupled with limited fuel-oil outlet resulting in the installation of bottom-of-the barrel conversion units and high FCC feed sulfur. The US Tier 2 gasoline sulfur and CARB regulations led to a sharp increase in the number of FCC feed pre-treatment and FCC gasoline post-treatment units over a short period of time as shown in Figure 2. Essentially all of the US refineries now have pre and/or post treatment units to ensure compliance with gasoline sulfur regulation.

Choosing Between FCC Pretreatment and Post-treatment

When the Tier 2 regulations were proposed, many were convinced that Cat Feed Hydro Treating or CFHT would be the solution of choice due to the resulting large improvement in FCC performance. However, the high capital cost requirement for the FCC pretreatment option coupled with low refinery margins resulted in the widespread application of FCC post-treatment to reduce gasoline sulfur.

Another factor that can influence the decision between the pre-treatment and post-treatment is FCC flue gas emissions. Limits on refinery emissions and in particular those from the FCC have led to refinery-specific regulation via consent decrees with the EPA resulting in much lower SOx and NOx emissions. The ‘preferred’ refinery configuration may well have been different had the limits on emissions and product sulfur been regulated in concert.

More recently there has been an important trend toward processing of increasingly heavier crudes in particular heavy Canadian crude or bitumen. By the year 2015, there is an expected increase of about 2 Million BPD of Canadian bitumen which will be largely exported to the US as raw bitumen (DilBit) or synthetic bitumen (SynBit) after partial upgrading at the production site. These very heavy crudes are a challenge for processing in existing refinery assets due to a high acid content (TAN), high aromaticity and low hydrogen content along with very high contaminant content: S, N, Con Carbon, and metals. A sampling of heavy crude components which may be considered potential FCC feed are shown in Table 2 to highlight the challenges of processing Bitumen derived materials.

As a result of these feedstock trends and renewed focus on cleaner fuels, lower emissions and even a shift in the gasoline / diesel production, the topic of pre-treatment vs post-treatment is upon us again. More specifically we will focus on the pre-treat and post-treat issues around the FCC as it relates to FCC performance, emissions and level of product gasoline post-treatment required.

FCC Pretreatment Overview

The benefits of FCC feed pretreatment in a CFHT are well known and extend beyond simply reducing the sulfur level in the FCC feed. The reduction in sulfur and other contaminants is helpful in terms of reducing the FCC product sulfur level and lowering the flue gas emissions from the FCC, but the interaction with improved feed quality and increased FCC performance is also very important as will be discussed. Environmental regulations and in particular the need to produce very low sulfur gasoline have put increased emphasis on the CFHT performance and reliability.

Co-currently, the lower demand for fuel oil coupled with the processing of heavier crudes has resulted in the installation of residue conversion units such as delayed cokers. These conversion units produce significant amounts of hydrogen deficient, heteroatom rich (N and S) Vacuum Gasoils (VGO, HCGO) which need to be deeply hydrotreated.
prior to conversion in the FCC unit.

As a result, modern CFHT units need to process increasingly more refractory feedstocks while achieving high desulfurization levels to meet gasoline sulfur specifications. The increased contaminants also make it more difficult for the CFHT to upgrade the quality of the FCC feed to maintain the required yield of gasoline and LPG. In addition to the objective of hydrodesulfurization, hydrodenitrogenation and polynuclear aromatics (PNA) saturation, processing of cracked stocks in a CFHT, often with high end-point to maximize refinery economics, require a careful selection of the catalytic system to take into account the potential for higher metals (Ni, V, As, Si...), asphaltenes along with the higher fouling propensity of these aromatic rich feeds.

On the other hand, this problem can turn into an opportunity to increase the severity of the CFHT not only to meet sulfur targets but also to change the refinery Diesel/Gasoline ratio by operating in the Mild Hydrocracking (MHC) mode and taking advantage of low cost natural gas to further increase volume swell. These adjustments will require some modifications to the operating conditions, selection of optimum catalytic system and distributor internals, increased hydrogen consumption and likely upgrades throughout the unit. One of the challenges of operating in the MHC mode is the ability to meet Ultra Low Sulfur Diesel (ULSD) specifications throughout the MHC cycle. Moderate pressure MHC units generally do not meet the required diesel specifications therefore post treatment is required. One attractive option to meet this challenge is the HyC-10™ technology developed by Axens to integrate the diesel upgrading within the MHC high pressure loop while decoupling operating conditions 12. Another important factor in MHC/CFHT design is the ability to maintain desulfurization targets while meeting optimum VGO quality throughout the cycle length.

In conclusion, a deep understanding of the feedstock type and the chemical reactions involved in a CFHT (kinetics, thermodynamics, contamination/poisoning) coupled with their impact on the FCC operation is paramount to selecting the optimum CFHT operating conditions and design of the optimum catalyst system. The following section will examine the influence of the CFHT operation on the FCC unit performance.

**Understanding CFHT Impact on FCC Performance**

The FCCU has long been the workhorse in the refinery to achieve, relatively low cost conversion of heavy crude components (VGO, HCGO and some atmospheric residue) into; gasoline, butenes for high octane alkylate production, propylene and LCO diesel blend components. Although the chemistry and catalyst systems can be complex, generally speaking the FCCU is a hydrogen redistribution system with some carbon rejection as coke that is consumed in the process. The performance of the FCC and yield of valuable products is therefore linked to the hydrogen content of the feed. This trend is shown in Figure 3 where the conversion potential and gasoline yield increase sharply with the hydrogen content of the feed.

The CFHT therefore has a vital role in improving the FCC feed quality to enhance the yield and overall refinery profitability. As the feed contaminants of sulfur and nitrogen are reduced to improve product quality and reduce FCC emissions, multi-rings aromatics are saturated and the crackability

<table>
<thead>
<tr>
<th></th>
<th>Canadian Bitumen</th>
<th>Coker HCGO</th>
<th>Syn. Bitumen</th>
<th>Mexican Blend</th>
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**Table 2 FCC Feed Quality from Heavy Feeds**

![Conversion vs. Feed Hydrogen Content](image_url)
of the feed increases. As seen in the figure below sharp gains in conversion and gasoline yield result from the first incremental increase in hydrogen and there is some degree of diminishing returns. When propylene yield is of interest the increased hydrogen input is always beneficial and in many cases high hydrogen input can be justified, particularly when hydrogen is relatively inexpensive.

As the severity of the CFHT increases there is also the opportunity of co-produced diesel in the CFHT via mild hydrocracking to shift the overall refinery balance between gasoline and diesel. Defining the optimal balance between severity, hydrogen input, cracking, and FCC mode of operation within the existing constraints of a refinery configuration is therefore very complex.

Within the context of ULSG, the more traditional role of the CFHT to consider is that of desulfurization and the impact on the FCCU gasoline produced. As the sulfur content in the FCCU feed decreases and the extent of feed hydrotreating increases, the types of sulfur left in the FCC feed alter and the amount of sulfur found in the gasoline decreases. Figure 4 demonstrates this general trend for feeds that are hydrotreated and for non-hydrotreated feeds of varying sulfur content.

If one were to target the new ULSG pool sulfur level of 10 ppm, then the CFHT must reduce the feed sulfur to about 200 - 300 ppm, considering a ratio of between 20:1 and 30:1 of the hydrotreated feed sulfur to the gasoline sulfur. This will be true even if we consider that the FCCU gasoline is only about 1/3 of the pool and the other blend stocks are nearly sulfur-free as refiners will leave some margin below 10 ppm to ensure compliance.

When looking at the sulfur in the FCC gasoline one needs to be very clear about the gasoline cut point and the distillation tail on the produced gasoline product. In Figure 5 we can see a carefully analyzed commercial FCCU gasoline and the cumulative full range gasoline sulfur vs. TBP.

The above figure clearly demonstrates the importance of defining the gasoline boiling range when discussing the sulfur level. In the US market, gasoline has been traditionally ‘over-cut’ relative to the standard 430°F (221°C) cut and often extended to 450-480°F thereby including not only benzothiophene but also some methyl-benzothiophenes in the gasoline. These compounds enter the gasoline cut just at the standard cut point and complicate accurate measurement of gasoline sulfur from non-ideal industrial samples. With the increased interest in distillate production, undercutting the gasoline to less than 430°F will significantly help control the sulfur level when producing ULSG – as is done in Europe.

Considering the dependence of FCC gasoline on both CFHT performance
and precise fractionation of the gasoline product, meeting ULSG targets through CFHT alone is possible but challenging. There will be little room for error or deterioration in CFHT performance over the course of a production run or cycle.

**FCC Post-treatments: Complying with ULSG**

In order to comply with low sulfur gasoline regulation, a majority of refiners in North America and across the world have already invested in a FCC post-treatment unit. However, processing schemes vary greatly from one site to another depending on the sulfur specification, overall refinery configuration and crude diet as described earlier in this paper and as illustrated in Table 3.

Most refineries in California and Japan are equipped with FCC Feed pre-treaters which explain the low sulfur level in the FCC naphtha. Conversely, FCC naphtha sulfur tends to be high in the Americas and high severity post-treaters will be required to meet 10 ppm gasoline sulfur target.

The Prime-G+ process selectively desulfurizes the FCC Full Range Naphtha (FRCN) while ensuring minimal octane loss. It is by far the most widely used cracked gasoline desulfurization technology with over 190 Prime-G+ licensed units throughout the world 4. The technology has proven to be the most flexible process on the market with several Prime-G+ processing schemes offered according to the targeted severity of the unit - Figure 6.

**Benefiting from Existing Prime-G+ Units**

Depending on the existing Prime-G+ configuration, meeting new ULSG regulations at 10 ppm while using the existing assets could be achieved in different ways.

First, one potential solution which does not require any additional investment would be to simply increase severity (essentially reactor temperature) to lower the existing Prime-G+ product sulfur. The increased HDS level would lead to higher octane loss and hydrogen consumption coupled with a potential cycle length reduction. Switching to higher selectivity and activity Prime-G+ catalysts may help mitigate these drawbacks but could prove insufficient in many cases.

Another solution would involve the co-processing of other sulfur rich streams in the Prime-G+ unit that previously did not require any treatment to meet the earlier sulfur specifications. The streams could be light streams such as Light Coker Naphtha or Visbroken Naphtha that can be handled in the Prime-G+ first step (Selective Hydrogenation Unit – SHU - and Splitter section). Light straight Run Naphtha, Natural Gasoline could also be co-processed either in the SHU upstream of the splitter or directly into the HDS section. One of the drawbacks of co-processing is possible hydraulic limitations in the unit. In addition, adding sulfur rich streams could lead to a higher HDS level coupled with higher octane loss and again potential for cycle length reduction.

An alternative option would be to decrease the Prime-G+ feed sulfur to maintain a similar HDS level across the unit to ensure constant octave loss and cycle length. Lowering the feed sulfur could be achieved in different ways. The short term solutions would be to use sulfur reduction additives in the FCC or process low sulfur crudes. Both of these options have limitations and are generally not practical for significant sulfur reduction without a heavy penalty on refinery flexibility. More realistically, a reduction of the FCC Naphtha end point or changes in the CFHT could be envisioned to reduce the sulfur in the FCC Naphtha. In Western Europe, it is common to reduce the FCC Naphtha end-point as it also maximizes the diesel production to meet the market demand.

**Upgrading FCC post-treatment units**

As most refineries are equipped with a FCC post-treatment unit to control gasoline sulfur, it is instructive to take a closer look at the revamping options around the selective FCC Naphtha desulfurization unit to meet the new ULSG requirements. There are a number of possibilities to revamp an existing selective FCC Naphtha desulfurization unit to meet tighter sulfur specifications that display different

![Figure 6 Prime-G+ Processing Schemes](image-url)
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levels of complexity and associated cost:

1. Option 1: Install a Prime-G+ 1st step if not existing
2. Option 2: Add a SHU (Selective Hydrogenation Unit) or HDS reactor if the cycle length is a limitation for the new product sulfur target
3. Option 3: Route the Medium Cat. Naphtha (MCN) cut to the NHT/Reformer
4. Option 4: Process the Medium Cat. Naphtha (MCN) and the Heavy Cat. Naphtha (HCN) streams separately
5. Option 5: Install a second stage HDS section

In option 1, the installation of a FCC naphtha splitter downstream of the existing (or new) SHU is the Prime-G+ 1st step. The SHU operating conditions and SHU catalyst design allows for the selective hydrogenation of the diolefins which may foul the desulfurization section and also the conversion of light sulfur species such as mercaptans to heavy boiling sulfur compounds. As a result of the chemical reactions taking place in the SHU, the downstream splitter produces a sweet, low-sulfur Light Cat Naphtha (LCN) stream rich in olefins and a Heavy FCC Naphtha (HCN) which is routed to the HDS section. Such a HCN stream with its lower olefins content can be selectively desulfurized through the use of tailored catalysts to meet ULSG target while controlling the olefins saturation and thus octane loss. The addition of the splitter reduces the throughput to the HDS section and hydrogen consumption. This solution also allows the co-processing of other streams containing sulfur such as coker naphtha, visbroken naphtha, straight run naphtha or natural gasoline.

For option 2, the addition of a SHU upstream of an existing splitter will produce a sweet low-sulfur LCN stream and provide similar benefits as described in option 1. In case cycle length becomes limited, implementation of an additional HDS reactor in series with the existing one can be envisioned.

Option 1 and 2 are easy to implement and lead to moderate capital expenditure.

The typical block flow diagram of Option 3 is presented in Figure 7.

This option involves revamping the existing splitter into a 3-cut column in order to withdraw a heart cut (MCN) rich in olefins and which contains some sulfur and exhibits a moderate octane number (especially MON). The MCN is then mixed with the normal feed to the NHT unit and reformer unit. Sending the MCN to the reformer will lead...
to a gasoline octane gain. However, there may be limitations in terms of capacity for both NHT and reformer sections that need to be carefully assessed and taken into account for the evaluation of the overall revamp cost. In addition potential increased benzene production in the reformer could lead to issues in meeting the MSAT II gasoline benzene specifications. The addition of an integrated reformate splitter/benzene hydrogenation (BenfreeTM) solves this issue 5.

While this solution offers some advantages in terms of octane, the decreased gasoline yield should also be considered. Overall, this option may be attractive but has more implications than just making modifications to the existing FCC post-treatment section.

Decoupling of the MCN and HCN can also be utilized to treat these two streams in two separate selective HDS sections. This is option 4 and is illustrated in Figure 8.

This innovative and patented scheme by Axens has the additional advantage to offer greater flexibility to route the desulfurized HCN either to the Mogas or Diesel Pool according to the economics of the refinery. Both MCN and HCN selective HDS sections are designed to minimize octane loss while achieving 10 ppm product sulfur. Compared to the previous option, option 4 incurs more revamping cost as a new MCN HDS section needs to be installed. But the additional cost could be easily offset by the improved octane retention compared to treating the combined MCN and HCN in a single one-stage selective HDS section at ULSG levels and by the additional flexibility that this option offers.

The last option explored in this paper is the inclusion of a second stage HDS section to minimize octane loss and maintain or even increase the catalyst cycle length. The typical block flow diagram is presented in Figure 9. Although shown below with the splitter upstream of the HDS section, Axens also has experience of designing a two-stage HDS section on full range FCC Naphtha with no upstream splitter.

In a typical one-stage HDS configuration, the olefins saturation, and thus octane loss, increases rapidly above 98% HDS. At high HDS level, the addition of a second-stage HDS section helps improve octane retention and minimize hydrogen consumption.

Several Prime-G+ units have been designed for two-stage operation and many are in operation. Although this option requires additional capital investment, there is a real incentive to pursue this solution when the refinery is octane-tight or hydrogen constrained.

These options provide commercially proven solutions for refiners to meet new ULSG specifications with existing or modified post-treatment units. In view of the low refinery margins and octane-long position resulting from the ethanol mandate, the debottlenecking of a selective FCC Naphtha desulfurization unit will likely be the preferred solution for many refiners assuming no significant changes in their crude diet.

A number of refiners are however envisioning the processing of heavy crudes such as those derived from Canadian Oil Sands due to their lower cost coupled with geopolitical reasons. Processing of these heavy crudes require a complete refinery reconfiguration with bottom of the barrel conversion units such as coking or ebullated bed hydrocracking. As described earlier, the resulting VGO and HCGO streams are very refractory with high levels of sulfur and nitrogen and very low hydrogen content. Such feeds require deep pre-treatment prior to feeding the FCC unit to maintain acceptable yields. Since FCC pre-treatment (CFHT) is mandatory in those cases, one may wonder whether a post-treatment unit is required or not. In a second article, the economic evaluation will illustrate the pros and cons of FCC pre-treatment only or in combination with post-treatment.

North American refineries need to adapt to tightening sulfur specifications and the prospect of ULSG at 10 ppm and the challenge will be exacerbated by the increased proportion of heavy crudes and the gasoline/diesel imbalance. This article has presented commercially proven configurations that are available to meet these constraints and maintain profitability. A combination of pre and post treatment may be necessary depending on the initial refinery configuration, the local market demands, emissions regulations and the crudes processed.

Axens’ experience in implementing solutions to meet 10 ppm specifications and our global offer in both pre and post treatment means we can select the best option to match each refinery’s circumstances.

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1. J. Bonnardot et al, Direct Production of Euro-IV Diesel at 10 ppm Sulfur via the HyC-10 Process, ERTC 9th Annual Meeting, Nov. 2004
5. D. Largeteau et al, Benzene Management in a MSAT 2 Environment, AM-08-11, NPRA Annual Meeting, March 2008
Enhancing product yields by improving catalyst circulation rate of Flexi cracker unit

Pramod Kumar, Madan Kumar K, Shirsendu Ghosh, Poonam Parab, Peddy V C Rao, N V Choudary and Gandham SriGanesh
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Abstract

Fluidized catalytic cracking (FCC) unit is the most important secondary processing unit in a refinery for producing high octane gasoline and LPG from gas oil or residual feed stocks. Product yield from any FCC depends on many variables viz. Reactor temperature, feed preheat temperature, catalyst circulation rate, catalyst properties, feed quality etc. FCC unit is considered as the workhorse of a refinery and its best operation is always desirable in order to improve refinery profit margin.

HPCL is having a Flexi-cracker FCC unit of 1.0 MMTPA capacity in one of its refineries. This unit has a riser-reactor-stripper-regenerator configuration without having slide valve operation. Reactor and regenerator are connected by J-bends for enabling transfer of spent and regenerated catalyst, and the catalyst circulation is mainly controlled by reactor-regenerator pressure difference and by lift air in spent catalyst standpipe. This unit was operated at catalyst circulation rate of 7.3 MT/min and producing bottoms make of 15 wt%, which seems to be on higher side for the kind of feed processed in the unit.

Thus, a study was undertaken to improve the conversion by increasing catalyst circulation rates based on comprehensive approach which consists usage of kinetic model, pressure survey, and aeration flows optimization at different points in J-bend/standpipe etc. Subsequently, a field trial was taken in the unit, which resulted in reduction of bottom yield by 5 wt%. The present paper outlines the different approaches used for improving the catalyst circulation rate upto 9.3 MT/min and the field trial results.

Introduction

FCC unit is an important secondary processing unit referred as the workhorse in refining industry which majorly produces gasoline and LPG from various feed stocks such as vacuum gas oils, atmospheric/vacuum column residual materials or their combination. Even a marginal increase in conversion in FCC unit will increase the margins to a great extent in any refinery.

Hence, generally FCC unit is operated beyond the design limit. HPCL is having a Flexi-cracker unit licensed by M/s ExxonMobil Research and Engineering Company, USA in one of its refineries and this unit was commissioned in the year 1999. The Reactor-Regenerator(R-R) section of the unit is shown in Figure-1. This unit has a riser-reactor-stripper-regenerator configuration like FCC. However, unlike other FCC units, there are no slide valves in the spent and regenerated catalyst standpipes. Instead, two on-off valves are there in these lines. Therefore, process control philosophy for this unit is different compared to that of conventional FCC units. Here, feed pre-heat temperature is varied to control the reactor outlet temperature. Reactor and regenerator are connected by J bends for enabling transfer of spent and regenerated catalyst. Also, lift air is provided in the spent catalyst standpipe from Control air blower (CAB), which controls the catalyst circulation rate. Thus, catalyst circulation is controlled by reactor-regenerator pressure difference and by the air, which changes the catalyst head in the lift pipe by changing the density. Moreover, unlike conventional FCC, catalyst level in regenerator of Flexi-cracker is constant. Therefore, this
unit lacks flexibility to independently change the catalyst circulation rate or reactor outlet temperature depending on the process requirement.

**Approach for Performance Improvement**

For improving the catalyst circulation rate in the Flexi cracker unit, following approach were followed:

- Single gauge pressure survey for understanding the pressure profile of the R-R section
- Optimization of stripping steam flow
- Optimization of aeration flows in J-bends for reducing the pressure drops
- Optimisation of aeration flow in standpipe so as to build-up pressure in standpipes
- Optimisation of differential pressure set point between Reactor- Regenerator
- De-choking of some of the aeration injection points
- Increase of catalyst bed level in Reactor-stripper vessel in order to increase the driving force for catalyst movement from reactor to regenerator. This was done while operating the unit within the constraints to the possible extent calculated from Transport Disengagement Height (TDH) correlations mentioned in M/s Particulate Location Unit Base Case Test Run:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Base Case</th>
<th>Test Run#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed density @ 15°C</td>
<td>gm/cc</td>
<td>0.8810</td>
<td>0.8969</td>
</tr>
<tr>
<td>Feed Sulfur</td>
<td>wt%</td>
<td>0.21</td>
<td>0.84</td>
</tr>
<tr>
<td>Feed CCR</td>
<td>wt%</td>
<td>0.28</td>
<td>0.25</td>
</tr>
<tr>
<td>Total feed rate</td>
<td>m3/hr</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Stripping steam flow</td>
<td>kg/hr</td>
<td>2590</td>
<td>1796</td>
</tr>
<tr>
<td>Feed preheat temperature</td>
<td>°C</td>
<td>385.0</td>
<td>350.7</td>
</tr>
<tr>
<td>Riser outlet temperature</td>
<td>°C</td>
<td>492.6</td>
<td>508</td>
</tr>
<tr>
<td>Regen. Dense bed temp.</td>
<td>°C</td>
<td>680.7</td>
<td>664.3</td>
</tr>
<tr>
<td>Regen. Dilute bed temp.</td>
<td>°C</td>
<td>681.3</td>
<td>660.0</td>
</tr>
<tr>
<td>Reactor-Reg. Diff. Press.</td>
<td>psi</td>
<td>3.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Reactor catalyst level</td>
<td>%</td>
<td>70.8</td>
<td>76.4</td>
</tr>
<tr>
<td>MAB air rate</td>
<td>SCFM</td>
<td>22158</td>
<td>23507</td>
</tr>
<tr>
<td>CAB air rate</td>
<td>SCFM</td>
<td>3500</td>
<td>3708</td>
</tr>
<tr>
<td>WGC gas rate</td>
<td>SCFM</td>
<td>6857</td>
<td>9007</td>
</tr>
<tr>
<td>Catalyst Circulation rate</td>
<td>MT/min</td>
<td>7.3</td>
<td>9.7</td>
</tr>
</tbody>
</table>

# Test Run at improved catalyst circulation rate

---

**Table-1: Pressure Profile in Standpipe/J-bend**

<table>
<thead>
<tr>
<th>Location</th>
<th>Unit</th>
<th>Base Case</th>
<th>Test Run#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regen. Cat. Standpipe Pr. gain (OFW bed top to R–8)</td>
<td>PSI</td>
<td>9.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Regen. ‘J’ bend Pr. drop (R–8 to Feed entry)</td>
<td>PSI</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Riser Pr. drop</td>
<td>PSI</td>
<td>3.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Stripper Pr. gain (Reactor bed top to point –SA)</td>
<td>PSI</td>
<td>9.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Spent ‘J’ bend Pr. drop (point–SA to d/s of SPSOV)</td>
<td>PSI</td>
<td>6.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Spent catalyst riser Pr. drop</td>
<td>PSI</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Rx–Rg Pr. differential</td>
<td>PSI</td>
<td>3.8</td>
<td>4.5</td>
</tr>
</tbody>
</table>

# Test Run at improved catalyst circulation rate

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**Table-2: Feed quality and operating conditions**

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Pramod Kumar is a Manager in Corporate R&D Center of Hindustan Petroleum Corporation Ltd, Bangalore. He has more than 12 years of experience in process design, research, engineering and technical services in the area of FCC, Vis-breaking and Delayed coking. He holds a M Tech degree in chemical engineering from IIT, Kanpur.

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Mr. Shirsendu Ghosh – B.Tech (Chemical Engg.) working with Hindustan Petroleum Corporation Ltd., for the past 13 years. Currently, he is holding the position of Manager-Technical, Mumbai Refinery. He has 13 years of experience in both Operations and Technical department. He was involved in UOP FCCU commissioning and during this tenure carried out monitoring, troubleshooting and yield improvement program in FCCU.

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**Dr. P. V.C. Rao**

Dr. P.V.C. Rao holds Ph.D. in Chemistry from Indian Institute of Technology, Bombay. He has over 25 years of experience in R&D in Refining and Petrochemicals. Presently he is working as Deputy General Manager (R&D) at the Hindustan Petroleum Green Research & Development Centre at Bangalore. He is working in the areas of Catalytic Processes, Biofuels and alternate Energy areas. He has 16 patents and 70 Research publications in national & international journals.


Field Trial Results

Pressure survey was conducted in the R-R section to understand the bottleneck for increasing the catalyst circulation rate and based on that aeration flow was adjusted in the standpipe/J-bends. Other options like increase in catalyst inventory and optimization of stripping steam flow was done to have more catalyst circulation. In-house developed FCC model was used for predicting the plant performance at higher catalyst circulation rate.

Based on the study, the approaches indicated in section 2 above were implemented in the FCC unit. And subsequently a test run was conducted for 24 hrs at improved cat circulation rate. The following section details about the observations made during the test run at improved catalyst circulation rate vis-à-vis the base case conditions:

Field Trial Results

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Based on the study, the approaches indicated in section 2 above were implemented in the FCC unit. And subsequently a test run was conducted for 24 hrs at improved cat circulation rate. The following section details about the observations made during the test run at improved catalyst circulation rate vis-à-vis the base case conditions:

a. Pressure Survey data
The pressure survey details of the R-R section during the test run as compared to base case is indicated below:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Base Case</th>
<th>Test Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT wt%</td>
<td></td>
<td>73</td>
<td>74</td>
</tr>
<tr>
<td>Surface Area m²/gm</td>
<td></td>
<td>171</td>
<td>173</td>
</tr>
<tr>
<td>Ni+V ppm</td>
<td></td>
<td>1514</td>
<td>1464</td>
</tr>
<tr>
<td>CRC wt%</td>
<td></td>
<td>0.04</td>
<td>0.22</td>
</tr>
<tr>
<td>APS micron</td>
<td></td>
<td>92</td>
<td>97</td>
</tr>
<tr>
<td>PSD &lt;40 µ wt%</td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

#: Test Run at improved catalyst circulation rate

The above table clearly shows that during the test run the pressure gain was more in the standpipe and there was less pressure drop in the spent cat J-bend. This helped in improving the catalyst circulation rate.

b. Feed quality and Operating Conditions
Feed properties and the major operating conditions (test run vis-à-vis base case) are indicated below:

With the improved pressure profile in R-R section, the catalyst circulation rate has increased from 7.3 MT/min to 9.7 MT/min. This helped in increasing riser outlet temperature increased from 492.6°C to 508°C and reducing feed preheat temperature from 385°C to 351°C, which resulted in significant increase in product yield pattern. The feed density was higher during test run. Further during the test, it was seen that the dense bed temperature was much lower (664.3°C) compared to base
The above data shows that the catalyst properties are nearly comparable during base case and test run case. The catalyst make-up rate was kept same.

d. Product Yield Pattern

Comparison of the product yield pattern in base case and test run is shown in Figure-2. The broad observations are as follows:

- LPG and Naphtha yield increased by 2.1 wt% and 0.4 wt% respectively in the test run as compared to base case.
- Light cycle gas oil (LCGO) yield increased by 1.27 wt% during test run.
- Bottoms (HCGO + Resid) reduced by 4.9 wt% during test run as compared to base case.

During test run, the overall conversion has increased from 56.32 wt% to 59.95 wt%.

Conclusions

Following is the conclusion:

- Based on optimization of aeration flow in standpipe/J-bend in combination with increase in catalyst inventory and modeling study resulted in increasing the catalyst circulation rate in the Flexi-cracker unit increased from 7.3 MT/min to 9.7 MT/min.
- Test run was successfully completed at 120 m³/hr feed rate without any disturbances in the unit.
- Torch oil and CO promoter addition was not used during the test run period.
- Bottom yield (HCGO + resid) was reduced from 15.2 wt% to 10.3 wt%.
- LPG make has increased from 19.58 to 21.68 wt%.
- During test run, feed preheat was 350 °C and ROT was 508 °C. There exists a possibility to further increase the ROT and reduce the bottom yield. However, same was not done due to limitation in WGC Amps and potential flaring apprehension.

Expected Economic Benefit

The potential economic benefit works out to be Rs 40 crores/anum as compared to base case operation, provided the unit is operated at the conditions demonstrated during the test run.

References

a) “Chapter-3: Entrainment in Fluidized beds”, PSRI Design manual
b) http://www.refiningonline.com/engelhardkb/crep/TCR1_5.htm
Bioremediation of Oil

Rajiv Kumar, S Pahari, L C Bora, Naren Das and B S Neog, Institute of Biotechnology & Geotectonic Studies (INBIGS), Oil & Natural Gas Corporation
Email: kumar_rajiv@ongc.co.in

Abstract

Exploration & production operations in petroleum industries may cause oil spillage due to leakages, accidents etc. Spilled oil in ocean, river or in any other water body cuts off oxygen to the underneath flora & fauna, therefore harmful to the environment. In international scenario, to remove oil from water bodies, there are different practices like- booms, adsorbents, chemical dispersants, microbes etc. Booms and adsorbents are very useful to contain and collect free oil floating on the surface. Spraying of chemical dispersants breaks the spill/oil film into smaller droplets which disperse into larger volume of water, thus fighting the pollution aesthetically.

Bioremediation of spilled oil is an environment friendly technology which is effective & economical. As per international best practice, free oil of the spill is first removed from the surface of the water body by booms or adsorbent, collected in a tanker/container and sent to refinery. The remaining oil is subjected to bioremediation by spraying a mixed consortium of oil-degrading microorganisms which eat up oil and convert it into water & carbon dioxide. INBIGS has carried out field studies of bioremediation after removing free oil by a natural adsorbent. Rate of remediation varied between 72 to 93% in 2 to 5 months depending upon the quantum of initial oil pollution. Results with use of fertilizers to enhance the degradation and economics shall be presented.
Introduction

The global environment has been changing day by day due to different natural and artificial phenomena occurring in the ecosystem. The quality of life on earth depends upon the overall activities of living and non-living organisms and their interdependent environment. Therefore, it is a serious concern for all of us to act decisively to protect our environment. Release of hydrocarbons into the environment whether accidentally or due to human activities is a main cause of water and soil pollution. In most of the oil exploration/exploitation regions of the world, oil contamination is more or less common phenomenon and is a matter of serious concern.

Bioremediation is an emerging biotechnological approach, utilized to degrade and detoxify the hydrocarbon contaminants in a cost effective manner with minimum threat to environment. It is defined as the use of microorganisms to detoxify or remove pollutants owing to their diverse metabolic capabilities. Bioremediation by natural population of microorganisms represents one of the primary mechanisms by which petroleum and other hydrocarbon pollutants are removed from the environment. This method has the advantage of treating oil waste at the site itself, reducing the risks that are involved in transporting the oily sludge and waste to a dumping site. Moreover it is an effective and inexpensive clean-up technology. Bioremediation of petroleum hydrocarbons is a complex process that depends on the nature and on the amount of the hydrocarbons present. One of the important factors that limit biodegradation of oil pollutants in the environment, is limited availability of microorganisms. Bioremediation exploits the genetic diversity and metabolic versatility of microorganisms for the transformation of contaminants into less harmful/harmless end products, which are then assimilated into natural biogeochemical cycle.

Due to the complexity of oil products, combinations of bacterial strains with broad enzymatic capabilities are required to achieve for extensive degradation. Most of the crude oil degradation studies have been carried out with mixed bacterial strains isolated from the native soil and grown in specific mineral salt media with crude oil as the only carbon source. Since alkanes are the most abundant compounds, these strains are usually alkane degraders that in some cases are able to oxidize selectively the alkyl chains of certain alkylated PAHs, which are common in crude oil. The rate of microbial degradation of different components in crude oil is found to be in the order of n-alkanes > branched alkanes > low-molecular weight aromatics > cyclic alkanes > NSOs > resins > asphaltenes. However, factors controlling the biodegradation rate depend on composi-

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Broad range</th>
<th>Optimal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moisture</td>
<td>25–90%</td>
<td>25–35% of water holding capacity</td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.5–8.8</td>
<td>6.5–8.0</td>
</tr>
<tr>
<td>Oxygen content</td>
<td>Aerobic, minimum air–filled pore space of 10%</td>
<td>10–40%</td>
</tr>
<tr>
<td>Nutrient content</td>
<td>N and P for microbial growth</td>
<td>C:N:P=100:10:1</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>15–45</td>
<td>20–30</td>
</tr>
<tr>
<td>Contaminants</td>
<td>Not too toxic</td>
<td>Hydrocarbon &lt;10% of dry weight of soil</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>Total content 2000 ppm</td>
<td>&lt;700 ppm</td>
</tr>
<tr>
<td>Type of soil</td>
<td>Low clay or silt content</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Conditions of optimum environment for degradation of contaminants

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Ingredients</th>
<th>Quantity/lt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urea – NH₂CONH₂</td>
<td>2.00 gm</td>
</tr>
<tr>
<td>2</td>
<td>Magnesium sulphate – MgSO₄.7H₂O</td>
<td>0.20 gm</td>
</tr>
<tr>
<td>3</td>
<td>Ammonium sulphate – (NH₄)₂SO₄</td>
<td>2.00 gm</td>
</tr>
<tr>
<td>4</td>
<td>Calcium chloride – CaCl₂. H₂O</td>
<td>0.05 gm</td>
</tr>
<tr>
<td>5</td>
<td>Disodium hydrogen phosphate – Na₂HPO₄</td>
<td>3.61 gm</td>
</tr>
<tr>
<td>6</td>
<td>Potassium dihydrogen orthophosphate – KH₂PO₄</td>
<td>1.75 gm</td>
</tr>
<tr>
<td>7</td>
<td>Ferrous sulphate – FeSO₄.7H₂O</td>
<td>0.01 gm</td>
</tr>
<tr>
<td>8</td>
<td>Copper sulphate – CuSO₄.5H₂O</td>
<td>50 µg</td>
</tr>
<tr>
<td>9</td>
<td>Boric acid – H₃BO₃</td>
<td>10 µg</td>
</tr>
<tr>
<td>10</td>
<td>Manganese sulphate – MnSO₄.5H₂O</td>
<td>10 µg</td>
</tr>
<tr>
<td>11</td>
<td>Zinc sulphate – ZnSO₄.7H₂O</td>
<td>70 µg</td>
</tr>
<tr>
<td>12</td>
<td>Molybdenum oxide – MoO₃</td>
<td>10 µg</td>
</tr>
<tr>
<td>13</td>
<td>Distilled Water</td>
<td>1000 ml</td>
</tr>
<tr>
<td>14</td>
<td>Crude oil</td>
<td>2.00 ml</td>
</tr>
</tbody>
</table>

Table 2: Composition of mineral salt medium (MSM) : pH=7.0

Dr. Rajiv Kumar is Deputy General Manager (Chemistry) and working in ONGC since last 32 years. He is presently posted at Jorhat in a R & D institute namely- Institute of Biotechnology & Geotectonic Studies. He is M.Sc., D.Phil, MBA, Post-graduate Diploma in Ecology & Environment. More than 40 technical papers has been presented/published by him in national & international journals & conferences. He has one patent to his credit.
tion of the waste, presence of suitable microorganisms, presence of adequate oxygen, temperature, pH, presence of available inorganic and organic minerals etc.

Optimal conditions for bioremediation are summarized in Table 1. Research is progressing at rapid speed to reduce the time taken by microbes to degrade the oil. Field applications of bioremediation of oil with addition of nutrients to enhance rate of biodegradation, were carried out at various oil contaminated effluent pits by INBIGS and the results are presented.

### Materials and Method

INBIGS collected soil samples which were contaminated with crude oil long back in ONGC oil fields. Different microbial strains were then isolated which grew in Mineral Salt Medium (MSM) having crude oil as sole carbon source (Table 2). A mixed microbial consortium of oil degrading bacteria was thus developed and maintained by regular activation & reactivation in INBIGS laboratory. In a 5000 ml conical flask, 3000 ml of the medium was taken and sterilized in autoclave at 121°C & 15 psi for 20 minutes. This medium was inoculated with mixed consortium under aseptic condition in laminar flow equipment. Many such sets were prepared so as to get sufficient seed culture required for the preparation of large quantity of bulk culture. Crude oil (0.2%) is added to each flask as a sole carbon source. All the flasks were placed in a shaker incubator at 180 rpm and 37°C temperature for constant mixing & aeration for 48 hrs. Growth and presence of the microbes in the flasks was confirmed visually and also under microscope. Developed microbial consortium from these flasks were then transferred into fresh medium for further growth and thereafter the process was repeated periodically to develop & maintain an active mixed microbial consortium. Developed consortium was used for preparation of bulk culture.

Bulk culture was prepared In an aerobic tank (capacity 500 litre) by taking 200 liters of distilled water by mixing the nutrient chemicals (Table 2). The ingredients were thoroughly mixed with the help of stirrer. The fully grown 2.0 % active seed culture of isolated oil degrading microbes is transferred to the tank by maintaining aseptic and aerobic conditions. The crude oil from the respective site is added as the sole carbon source to acclimatize the microbes to the crude type. The bulk

### Table 3: BIOREMEDIATION JOBS IN EFFLUENT PITS OF # KHAV

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Effluent sample</th>
<th>Pit no.</th>
<th>pH</th>
<th>Oil content (ppm)</th>
<th>Remarks</th>
<th>Appearance of effluent</th>
<th>Aquatic life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Before bioremediation</td>
<td>Pit-1</td>
<td>8.4</td>
<td>113</td>
<td>Bioremediation was recommended</td>
<td>Hazy and turbid effluent with patches of oil layer floating on surface.</td>
<td>Absent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pit-2</td>
<td>8.23</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pit-3</td>
<td>7.8</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>After bioremediation</td>
<td>Pit-1</td>
<td>7.43</td>
<td>10</td>
<td>After 5 months (Oil degradation rate 91%)</td>
<td>Effluent became clear and patches of oil layer vanished.</td>
<td>Growth of aquatic flora and fish observed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pit-2</td>
<td>7.45</td>
<td>9</td>
<td>After 5 months (Oil degradation rate 93%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pit-3</td>
<td>8.6</td>
<td>8</td>
<td>After 2 months (Oil degradation rate 89%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: BIOREMEDIATION JOBS IN EFFLUENT OF # NOAA PIT-1

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Effluent sample</th>
<th>pH</th>
<th>Oil content (ppm)</th>
<th>Remarks</th>
<th>Appearance of effluent</th>
<th>Aquatic life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Before bioremediation</td>
<td>8.48</td>
<td>14.3</td>
<td>Bioremediation was recommended</td>
<td>Hazy and turbid</td>
<td>Absent</td>
</tr>
<tr>
<td>2.</td>
<td>After bioremediation</td>
<td>7.9</td>
<td>4.00</td>
<td>After 03 months (Oil degradation rate 72%)</td>
<td>Effluent became clear and patches of oil layer vanished.</td>
<td>Growth of aquatic life observed</td>
</tr>
</tbody>
</table>

Figure-1: Oil Degradation in # KHAV Effluent Pit-1

Figure-2: Oil Degradation in # KHAV Effluent Pit-2
Triental minerals (Urea, DAP & NPK). Samples were collected periodically from water below the surface of the effluent pits. Oil content of samples from effluent pits was analyzed in the laboratory by thoroughly mixing its 10 ml sample with 10 ml of carbon tetra chloride in a separating funnel. After gravity separation of about 15 minutes, CCl4 layer was transferred to a cuvette and then oil in ppm is determined using Spectroscan UV-2600. The bioremediation process was carried out at different sites and continued on monthly application of fresh bulk culture till the oil content came down to safe environmental limit i.e. less than 10 ppm for effluent pits.

Results and Discussion

INBIGS has carried out bioremediation job in the effluent pits of # KHAV, ONGC, Jorhat. There were 3 effluent pits having patches of oil which were floating on the effluent covering about 1/4th pit area. Free oil was first removed using an adsorbent which was of vegetative origin. The adsorbent after adsorption of free oil was physically removed (Photo 1 & 2). The water of the pit was also very dirty and brownish in colour. All the three # KHAV Effluent Pits (1, 2 & 3) were measured to be approx. 29 m x 29 m with depth of effluent 1.5 m and hence each pit was having about 1261 m3 effluent. Thus total volume of effluent in these pits was ≈3783 m3. Neither aquatic flora nor fauna was visible in the pits. The pH of effluent water was 8.4, 8.23 & 7.8 for Pit-1, Pit-2 & Pit-3 respectively in initial stage (Table 3). Oil content was observed to be 113 ppm (Pit-1), 130 ppm (Pit-2), & 72 ppm (Pit-3) before the bioremediation job. The job was carried out with bulk culture of mixed microbial consortium (200 lts/pit/application) along with urea, DAP, NPK (in the ratio 10:1:1). The oil content was measured in the INBIGS lab periodically. After the last bioremediation job in the effluent pits of # KHAV, the oil content came down to 10 ppm in 5 months, 9 ppm in 5 months & 8 ppm in 2 months for Pit-1, Pit-2 & Pit-3 respectively (Table 3 and Figure 1-3). Rate of oil degradation varied between 89-93% in 2-5 months (Table 3). The pits were observed to have clear water.
ppm with pH 8.48 (Table 4 and Figure 4). Rate of bioremediation was 72% which brought down the oil content to 4 ppm in 3 months. Growth of aquatic life was also observed (Photo 9-10).

Thus total about 4658 m³ of effluent contaminated with oil was bioremediated. Growth of flora and fauna was seen in the bioremediated effluent pits. Algae and fish were observed in the cleaned pits. Field work immensely helped in removal of oil from effluent controlling oil pollution in an inexpensive and environmentally friendly manner. The results establish bioremediation as best practice which will play an important and bigger role in future to control oil pollution.

**Economics**

Bioremediation of oil using microbes is a very cheap technology. The cost of procured inputs i.e. fertilizers and labour charges are as follows –

1. Input cost per application of bioremediation in site –
2. Number of applications depended upon field conditions/oil quantity in effluent pit. The number of applications were 2-3 times only and hence cost of field inputs was approx. Rs.2000/- per pit. ONGC manpower cost is not included in present economics. Mass culturing at laboratory and visit to site etc. were managed from existing facility/lab stock of INBIGS.

**Conclusion**

Bioremediation proves itself as best treatment practice that can be used in oil-contaminated environment. The jobs were carried out in various oil contaminated effluent pits of the Basin with great success. Total 4658 m³ of effluent of 3 pits of # KHAV and 1 of # NOAA was successfully bioremediated. Above is achieved in an inexpensive manner and the growth of flora and fauna was observed in the bioremediated effluent pits. The field jobs have achieved the goal of timely control of pollution. With growing awareness of safe environment, the bioremediation shall be the foremost
practice in future in combating oil pollution in most environment friendly manner.

Acknowledgement

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References

Storage Tanks – Duplex for a Sustainable Future!

C Tigerstand, M Willför, C Canderyd, Chang–Ching Sun
Avesta Research Centre, Outokumpu Stainless AB, Avesta, SWEDEN

Abstract

Modern duplex stainless steels have been commercially produced for over thirty years, with an increase in both number of available grades and usage in recent years. Today there are duplex grades ranging from the lean duplex grades suitable for less corrosive applications, in the same range as 304 and 316-type stainless steels, to the superduplex grades for the most aggressive environments such as sea water. The characteristics of the duplex grades are well documented, which make it possible to choose the material most suitable for the specific application. One of the advantages of using duplex grades is their high mechanical strength, which can be clearly utilized in storage tank applications.

The results presented in this paper clearly show the benefits of both high mechanical strength and corrosion resistance to the design of storage tank shells in duplex stainless steel, as well as how it can provide better life cycle cost efficiency in comparison with both austenitic stainless steel and coated carbon steel. The thinner gauges which can be used because of the higher strength of the duplex grades result in lower material costs, less welding and easier handling which improves fabricability, although the welding costs per unit of weight is higher. The great combination of high resistance to both corrosion and wear, without any protective surface coatings, improves the durability with potentially prolonged service life and minimized need for costly maintenance and repair throughout the life cycle.

The advantage of using duplex grades in storage tanks is the combined value of cost-efficient structural design and more sustainable use of resources, regardless of whether material, financing, time requirements or environmental impact is considered.

Introduction

The development of modern duplex stainless steels

Duplex stainless steels were originally developed about 80 years ago, i.e. during the late 1920’s. The oldest test results recorded at Avesta Research Centre are dated December 23rd 1930, the protocol is shown in Figure 1. However, these old grades were not designed as structural materials, the metallurgical processes available were not suitable to produce grades with the right austenite-ferrite balance and alloying with nitrogen was not feasible, so fabrication was limited to cast products and possibly forgings [1].

Figure 1. Protocol from 1930 describing a test with stainless steels, including the 25%Cr-1.5%Mo duplex grade 453 S, a forerunner to ASTM 329 (left), and a reactor vessel for production of gun powder, made of the same grade, supplied to a Belgian chemical industry in August 1933 (right).
The introduction of the AOD-process (argon-oxygen-decarburization) in the late 1960’s and early 1970’s opened up possibilities to produce modern duplex grades, i.e. duplex grades with a low carbon content in combination with a high chromium content, a high content of nitrogen, and a favorable balance between austenite and ferrite. The first commercial such grade, today mainly known as 2205, was developed and introduced by the German steel producer Stahlwerke Südsütwesfelden in the mid-1970’s, and the success of this grade encouraged other steel producers to continue with lower alloyed duplex grades, often referred to as lean duplex grades, and higher alloyed, superduplex, grades.

Today, modern duplex grades such as LDX 2101 are excellent and widely used as engineering materials, examples of applications can be seen in Figure 2.

### The family of modern duplex stainless steels

#### Chemical compositions

The chemical compositions and other technical data for the duplex family of grades as well as for some austenitic reference materials are presented in Table 1. Worth noting is that if one compares an austenitic grade and a duplex grade with similar PRE and CPT values, the duplex grade is higher in chromium and nitrogen but lower in molybdenum and nickel. As a consequence, the duplex grades are more price-stable in situations when the prices for nickel and molybdenum are high and fluctuating, the variations of the nickel price with time can be seen in Figure 3.

#### Corrosion properties

**Uniform corrosion**

Attack by uniform corrosion on stainless steels occurs mainly in acidic and hot alkaline solutions. The influence of alloy composition may vary significantly between different environments, but in overall, the duplex grades have good to excellent resistance to uniform corrosion due to their high chromium contents. However, it is very dependent on the specific grade and environment. The performance of different stainless steel grades in various corrosive environments is well documented and available in the form of corrosion tables and iso-corrosion diagrams [3, 4].

**Localized corrosion**

Localized corrosion may occur in solutions containing halides, mainly chlorides, and the resistance to this type of corrosion is very often the limiting factor for the suitability of any stainless steel grade. One common way to roughly rank different grades in chloride containing environments is to calculate the PRE-numbers, pitting resistance equivalent, using the chemical compositions of the materials, the values are listed in Table 1. To validate a ranking obtained by using the PRE-numbers, laboratory tests are usually made. Normally, the so-called critical pitting and crevice corrosion temperatures, CPT and CCT respectively, are measured in standardized chloride solutions. CPT-values are given in Table 1, confirming the PRE-ranking – For each austenitic grade, there is a duplex alternative with similar resistance to localized corrosion. An overview of the CPT values for both duplex and austenitic stainless steels is shown in Figure 4. The critical temperatures can normally not be regarded as engineering design data, but they can still give valuable information when combined with reliable service experience.

### Mechanical properties

The duplex grades have approximately twice the proof strength (Rp0.2) of the corresponding austenitic grades, as seen in the overview in Figure 4. This can for certain applications, e.g. storage tanks, imply a considerable reduction in gauge, weight and thereby costs, this will be described in more detail in 2.2 Shell design of a tank case.

### Fabricability

#### Formability

Stainless steel is in general excellent for forming. When changing from an aus-

---

**Table 1. Typical chemical compositions, PRE-numbers and CPT-values of duplex stainless steels and standard austenitic grades for reference.**

<table>
<thead>
<tr>
<th>Outokumpu steel names</th>
<th>UNS</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>PRE</th>
<th>CPT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDX 2101*</td>
<td>S32101</td>
<td>0.03</td>
<td>21</td>
<td>1.5</td>
<td>0.3</td>
<td>0.22</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>2304</td>
<td>S32304</td>
<td>0.02</td>
<td>23</td>
<td>4.8</td>
<td>0.3</td>
<td>0.10</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>LDX 2404*</td>
<td>S82441</td>
<td>0.02</td>
<td>24</td>
<td>3.6</td>
<td>1.6</td>
<td>0.27</td>
<td>33</td>
<td>43</td>
</tr>
<tr>
<td>2205</td>
<td>S32205</td>
<td>0.02</td>
<td>22</td>
<td>5.7</td>
<td>3.1</td>
<td>0.17</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>2507</td>
<td>S32750</td>
<td>0.02</td>
<td>25</td>
<td>7.0</td>
<td>4.0</td>
<td>0.27</td>
<td>43</td>
<td>84</td>
</tr>
<tr>
<td>4307 (304L)</td>
<td>S30403</td>
<td>0.02</td>
<td>18.1</td>
<td>8.1</td>
<td>--</td>
<td>--</td>
<td>18</td>
<td>&lt;10</td>
</tr>
<tr>
<td>4404 (316L)</td>
<td>S31603</td>
<td>0.02</td>
<td>17.2</td>
<td>10.1</td>
<td>2.1</td>
<td>--</td>
<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

1. PRE (Pitting Resistance Equivalent) = %Cr + 3.3x%Mo + 16x%N
2. Critical pitting temperatures according to ASTM G 150 [2], typical values

* LDX 2101 and LDX 2404 are registered trade names of Outokumpu.
handled by adjusting the parameters of the forming equipment. In the most demanding cases from a forming point of view, i.e. when there is considerable stretching in the material, austenitic grades need to be used. Still, duplex grades have sufficient formability in most cases, especially if comparing with carbon/mild steel.

**Weldability**

Duplex grades have in general good weldability and most common welding methods can be used [5]. However, their welding characteristics differ in some aspects from those of austenitic grades. This means that factors such as welding parameters, joint configurations, and fillers should be adapted to the duplex grade in order to fully utilize the great potential of the duplex family [6]. If doing so, it is not more difficult to weld duplex grades, but just somewhat different compared to welding austenitic ones.

**Machinability**

Duplex stainless steels are generally more demanding to machine than conventional austenitic grades such as 316L due to their higher hardness. The effect of this will often be less pronounced in cases where it is possible to utilize the higher strength of the duplex alternative and thereby be able to down-gauge, since this will often decrease the amount of joint preparation required before welding. However, an exception to this general trend is LDX 2101®, which shows excellent machining properties, with performance even better than 316L [7].

**Stainless steel in storage tanks**

Numerous storage tanks have been built in stainless steel over the years and nowadays duplex stainless steel is much appreciated as a construction material due to the possibility to decrease the wall thickness and thereby lower the costs compared to austenitic stainless steels. Examples of existing storage tanks are shown in Figure 5. The lean duplex grades LDX 2101® and 2304 have successfully been used to store liquids used within the food and drink industry, for example wine, honey and edible oils but also to store marble slurry and calcium carbonate slurry and fuels such as biodiesel. The commonly used duplex 2205 grade has been used for storage and transportation of a variety of chemicals due to its good resistance to uniform corrosion. In one

![Figure 3. Variation in the monthly average price of Nickel (USD/metric ton) based on input from London Metal Exchange (LME).](image)

![Figure 4. Mechanical strength, minimum proof strength values according to EN 10088, versus critical pitting temperature, typical CPT values according to ASTM G 150, of different duplex and austenitic stainless steel grades.](image)

![Figure 5. Examples of storage tanks for the duplex stainless steel grades LDX 2101®, 2205 and 2507.](image)
example from the end of the 1980’s, the duplex grade 2205 was chosen to store phosphoric acid. The tank has been used for different phosphoric acid media in almost 20 years and there are today no known problems with the tank. For even more aggressive conditions, for example the hydrometallurgy industry, the super duplex grade 2507 has been used.

**Life cycle cost analysis of storage tank**

The ultimate motive when selecting a material for a tank is to find the most cost-efficient solution that fulfills the design and corrosion requirements. Cost efficiency is here defined as how to reach the maximum performance of the investment. This could simply refer to just the material costs or, of more interest for the end-user, the total initial investment cost for the fabricated structure or installation, i.e. both material and fabrication costs. However, when considering the total life cycle costs (LCC) “all” costs encountered during the entire life time are considered, i.e. implication of future maintenance costs and production losses due to maintenance stop etcetera are included, as well as the scrap value, depicted in Figure 6. The total life cycle cost will also be a measure of its sustainable value. However, the challenge with estimating the life cycle costs is how the future costs are predicted. Therefore, one should preferably look at different cost scenarios at different cost levels to get a broader and more trustful view of the cost estimation.

**Stationary welded storage tanks**

Carbon steel is the prevailing material for stationary welded cylindrical storage tanks. Presumably, the main reason is that carbon steels are considered the “low-cost alternative” to stainless steels for tank applications despite the high costs for the almost obligatory protective coating of the tank shells. Yet, having a closer look at initial costs as well as life cycle costs and scrutinizing several cases covering stainless and carbon steel tanks of different dimensions, this assessment does not necessarily hold up and even high material costs for stainless steel grades may not inevitably lead to a more costly stainless steel tank. This will be elaborated further on for the duplex grade LDX 2101® compared to the austenitic grade 304L as well as to the carbon steels A516-60 and A537-2.

**Shell design of tank case**

The design of a tank shell in accordance with the most common design code, the American standard API 650, allows for a beneficial use of the mechanical properties of duplex stainless steels, which most often have higher allowable design stresses than for both carbon steels and austenitic stainless steels. In Table 2 allowable design stresses of some duplex and austenitic stainless steels as well as carbon steels are depicted. The allowable design stress is derived from the minimum tensile strength Rm or yield strength Rp0.2 as specified in API 650. A516-60 is one of the most common carbon steel grades used in storage tanks, and A537-2 is a carbon steel with similar strength level as duplex stainless steel.

Basic shell design of the minimum required thicknesses to resist the internal hydrostatic pressure in accordance with API 650 may be calculated complying with the 1-foot method shown by equation 1 for SI-units. The equation below refers to stainless steels. For duplex and austenitic stainless steels, the joint efficiency E must be determined (0.7, 0.85 or 1 depending on weld inspection). The joint efficiency factor is excluded in the formula for carbon steel.

API 650 further specifies minimum allowable shell thicknesses depending on tank diameter as shown in Table 3. Figure 7 illustrates a tank case with required shell thicknesses for the duplex grade LDX 2101®, austenitic grade 304L, and the carbon steels A516-60 and A537-2.

\[
 t_d = \frac{4.9D(H - 0.3G)}{S_d E} + CA
\]

where

- \( t_d \) = tank shell thickness, in mm
- \( D \) = nominal tank diameter, in mm
- \( H \) = design liquid level, in m
- \( G \) = design specific gravity of the liquid to be stored, as specified by the purchaser (e.g. 1 for water)
- \( CA \) = corrosion allowance, in mm, as specified by the purchaser
- \( S_d \) = allowable stress for the design condition, in MPa
- \( E \) = joint efficiency 1.0, 0.85, or 0.70 (see Table X-3)

API 650 specifies that a corrosion allowance, CA, determined by the purchaser of the tank can be applied to the

**Table 2. Mechanical properties and allowable design stresses, in accordance with ASTM A 240 and API 650 respectively.** [8, 9]

<table>
<thead>
<tr>
<th>Grade</th>
<th>API 650</th>
<th>Min. ( R_{p0.2} ) [MPa]</th>
<th>Min. ( R_m ) [MPa]</th>
<th>Maximum allowable design stress ( S_d ) [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDX 2101®</td>
<td>Appendix X</td>
<td>450</td>
<td>650</td>
<td>260</td>
</tr>
<tr>
<td>304L</td>
<td>Appendix S</td>
<td>170</td>
<td>485</td>
<td>145</td>
</tr>
<tr>
<td>A516-60</td>
<td>Section 5.6</td>
<td>220</td>
<td>415</td>
<td>147</td>
</tr>
<tr>
<td>A537-2</td>
<td>Section 5.6</td>
<td>585*</td>
<td>234*</td>
<td></td>
</tr>
</tbody>
</table>
computed shell thicknesses in order to counteract corrosion and stretch the lifetime of the tank. Corrosion allowance is typically used for carbon steel tanks, and in rare cases a corrosion allowance may be added to stainless steel tank shells. The corrosion allowance used for this tank case is 25% of the thinnest plate thickness for the carbon steels, which results in 1.5 mm thicker material for each shell.

Obviously the high allowable design stress for LDX 2101® enables downgauging in tank shell thicknesses compared to 304L, A537-2 and A516-60. This in combination with no necessary corrosion allowance for the stainless steel grades leads to highest possible weight savings for the duplex grade.

**Cost data for tank analysis**

Background information to the input data used for this cost analysis follows below and considers material and fabrication costs for the initial investment cost analysis, and further on maintenance costs for the life cycle cost analysis.

**Material cost**
The material cost per unit of weight (metric tons) for the herein listed steels

<table>
<thead>
<tr>
<th>Nominal Tank Diameter [m]</th>
<th>Minimum Plate Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>5</td>
</tr>
<tr>
<td>15 to &lt; 36</td>
<td>6</td>
</tr>
<tr>
<td>36 to 60</td>
<td>8</td>
</tr>
<tr>
<td>&gt;60</td>
<td>10</td>
</tr>
</tbody>
</table>

**Basic shell design in accordance**

with API 650:

- Tank diameter $D = 20\,\text{m}$
- Tank height $H = 20\,\text{m}$
- Volume $= 6280\,\text{m}^3$
- Surface area $= 1260\,\text{m}^2$
- Density of content $G = 1\,\text{g/ml}$
- Temperature $= 20\,\text{°C}$
- Joint factor $E = 1$

**Corrosion allowance, $CA = 1.5\,\text{mm}$**
(for A516-60 and A537-2 only)

Min. allowed shell thickness $= 6\,\text{mm}$
Plate width $= 2000\,\text{mm}$

![Figure 7. Tank case with minimum required shell thicknesses and material weights for duplex grade LDX 2101®, austenitic grade 304L and the carbon steel grades, A516-60 and A537-2.](image)

**Table 3. Nominal tank diameter and minimum allowable plate thickness according to API 650 section 5.6.1.1.**

**Table 4. Input data for storage tank life cycle cost for a tank with dimensions according to Figure 7.**

<table>
<thead>
<tr>
<th>Material cost data:</th>
<th>LDX 2101®</th>
<th>304L</th>
<th>A516–60</th>
<th>A537–2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight of materials, mt</td>
<td>61.6</td>
<td>82.7</td>
<td>97.0</td>
<td>78.6</td>
</tr>
<tr>
<td>Average cost for hot rolled coil, 5–year–period (2005–2009), USD/mt</td>
<td>3200</td>
<td>3000</td>
<td>750</td>
<td>1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welding and assembly cost data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire consumption, kg</td>
</tr>
<tr>
<td>Welding and assembly time, h</td>
</tr>
<tr>
<td>Welding cost (High / Low), USD/kg</td>
</tr>
<tr>
<td>Labor cost welding and assembly (High / Low), USD/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface treatment cost data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell surface area, m²</td>
</tr>
<tr>
<td>Internal surface treatment cost (High / Low), USD/m²</td>
</tr>
<tr>
<td>External surface treatment cost (High / Low), USD/m²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance cost data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real interest rate, %</td>
</tr>
<tr>
<td>Life cycle duration, years</td>
</tr>
<tr>
<td>Number of complete maintenance surface treatment during life cycle (High / Low)</td>
</tr>
<tr>
<td>Internal maintenance surface treatment cost (High / Low), USD/m²</td>
</tr>
<tr>
<td>External maintenance surface treatment cost (High / Low), USD/m²</td>
</tr>
</tbody>
</table>
a lower level, welding costs may be substantially lower. Labor costs in European countries peak at around 72 USD/h including travelling, machinery and related inspections/maintenance and lodging. Minimum labor costs are set to 14 USD/h (20% of the high cost level) to represent countries where labor costs are at a lower level, e.g. China and South-East Asia, see Table 4.

Welding time needed per tank is estimated as function of the required shell thicknesses. The thicker the shells, the more hours need to be spent on welding the tank. In countries where labor costs are on a lower level, welding costs may be substantially lower. Labor costs in European countries peak at around 72 USD/h including travelling, machinery and related inspections/maintenance and lodging. Minimum labor costs are set to 14 USD/h (20% of the high cost level) to represent countries where labor costs are at a lower level, e.g. China and South-East Asia, see Table 4.

The material prices varies with time since important alloy element like nickel fluctuates heavily in time as discussed in the introduction and Figure 3. The total material cost is then calculated as the product of the material cost per unit of weight and the required weight of each material as given in Table 4.

Fabrication and assembly cost

Welding time and costs are very much related to tank size and consequent required shell thickness. The thicker the shells, the more hours need to be spent on welding the tank. In countries where labor costs are on a lower level, welding costs may be substantially lower. Labor costs in European countries peak at around 72 USD/h including travelling, machinery and related inspections/maintenance and lodging. Minimum labor costs are set to 14 USD/h (20% of the high cost level) to represent countries where labor costs are at a lower level, e.g. China and South-East Asia, see Table 4.

Welding time needed per tank is estimated as function of the required shell thicknesses. The welding method considered here for tank fabrication is flux cored arc welding (FCAW). The different cost levels high and low used in this analysis for welding reflect the regional cost differences more than the alloying cost volatility, where the high level represent northern Europe and the low level typically China and South-East Asia. The welding costs are based on data from a Swedish fabricator and a welding consumable manufacturer; the process cost per hour for LDX 2101® is estimated to be 25% higher than the carbon steels, and about 10% higher than 304L. The estimated welding speed is about 8% lower for LDX 2101® than for both the austenitic and the carbon steels. Thus, if
welding consumable cost, welding process cost and welding productivity cost are added together the total welding cost per kg consumed wire is 90% higher for LDX 2101® than the carbon steels, see Table 4. However, important to notice is the welding time for A516-60 is more than twice that of LDX 2101®, and about 60% longer than for 304L. The total wire consumption is based on the quantity of filler metal required to fill up a reinforced V-groove with FCAW considering deposition efficiency and wire losses during welding. An overview of the welding costs is shown in Table 4. Assembly time (other than welding) is estimated to be half of the total welding time.

Despite highly developed coatings and coating methods, inspection and maintenance is necessary on regular basis. After maximum of 10 years, a coating usually has to be maintained, repaired or, in most cases, completely redone. Maintenance cost is assumed to be only complete recoating. Costs for removing the old coating, and lost production time during maintenance shutdown, are excluded and the necessities of using spare tanks to reduce operation losses are not taken into account either. It must be mentioned here as well that epoxy coatings cannot be recycled and will hence cause environmental pollution upon removal. Maintenance costs have been discounted at an interest rate of 4%. Since lifetime of tanks is set to 30 years, maintenance costs occur twice during the lifespan of a carbon steel tank if the interval for complete recoating is set to 10 years. A more conservative case with only one recoating after 15 years is included as well.

Painting of the tank shell outer surface is less expensive than the more advanced inner epoxy coating. The cost of the painting is set to 90 and 30 USD/m² for high and low cost scenarios respectively. Painting can be considered as a necessity for carbon steel tanks from a corrosion resistance point of view and optional for stainless steel tanks depending on the aesthetic requirements.

Even though stainless steel surfaces in most cases are not protected by coatings the post fabrication surface treatment is very crucial for their performance. To maintain best possible corrosion resistance of the welds the surface is usually ground and pickled. For this cost case a pickling treatment is included for the welds of both inner and outer surface of the tank at a cost set to 22 and 7 USD/m² for high and low cost scenarios respectively (see further Table 4).

**Results of cost analysis**

Five different cost scenarios have been analyzed. The first two focus on the initial investment cost based on high and low fabrication and labor costs and are illustrated in Figure 8 and Figure 9 respectively. The third case is based on the low cost scenario but the surface treatment cost for the carbon steel is adjusted to level the initial investment cost with the LDX 2101® shell as shown in Figure 10. The last two scenarios are considering maintenance costs occurring during the life cycle as well; in Figure 11 one maintenance stop for recoating and repainting after 15 years and in Figure 12 for two maintenance stop after 10 and 20 years.

**Discussion of cost analysis**

The initial cost scenario – high fabrication cost level in Figure 8 – indicates that LDX 2101® could be more cost-efficient solution than the high strength carbon steel A537-2. This is apparent when the fabrication costs are on high level, i.e. in the high cost European re-
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gion. However, when fabrication costs are lower, i.e. low cost regions as in Asia illustrated in Figure 9, the high strength carbon steel A537-2 solution is, as one may expect, less expensive when only the initial investment is considered. The more commonly used A516-60 carbon steel for tanks is apparently less advantageous due to its lower strength. Important to notice for both the high and low cost scenarios is the strong impact of the surface treatment costs in the total initial costs for the carbon steel tank solutions, about 50-60%, due to the large surface area to cover.

Figure 10 also shows at what coating and painting cost levels in the low cost scenario the initial investment for the LDX 2101® shell becomes equal with the A537-2 shell. It equals at an internal coating cost of 85 USD/m², and external painting cost of 28 USD/m² (compared to 60 and 20 USD/m² respectively depicted in Figure 9. Thus, if a more advanced and more expensive coating system is selected the initial costs could level in the low fabrication cost scenario as well.

The savings by using the duplex grade LDX 2101® is not only about direct costs, the thinner shell thicknesses required for the case tank also reduces the welding and assembly time by more than 50% from 3000 hours to 1400 hours compared to for tank commonly used carbon steel A516-60.

When the net present value of future maintenance cost is taken into account in the analysis, as shown in the life cycle cost scenario depicted in Figure 11, the LDX 2101® tank shell is less costly than the high strength carbon steel A537-2 shell at just one recoating and repainting after 15 years. When considering two maintenance shutdowns after 10 and 20 years, the advantages of using stainless steel becomes even clearer, as illustrated in Figure 12. One should also bear in mind that large cost items such as for lost production etcetera is not considered in this analysis.

**Concluding remarks**

The results presented in this paper clearly show the benefits of both high mechanical strength and corrosion resistance to the design of storage tank shells in duplex stainless steel, as well as how it can provide better life cycle cost efficiency in comparison with both austenitic stainless steel and coated carbon steel.

- The thinner gauges provided by the higher strength of the duplex grades result in lower material costs, less welding and easier handling which facilitates fabricability, although the welding costs per unit of weight is higher.
- The great combination of both high corrosion and wear resistance, without any protective surface coatings, improves the durability with potentially prolonged service life and minimized need for costly maintenance and repair throughout the life cycle.

Altogether, the advantage of using duplex grades in storage tanks is the combined value of cost-efficient structural design and more sustainable use of resources, regardless of whether material, financing, time requirements or environmental impact is considered.

**Acknowledgments**

Stephanie Grote is greatly acknowledged for her work with shell design and input data for the LCC analysis.

**References**

[9] API 650 Welded steel tanks for Oil Storage
Activity Highlights

October - December 2013

26th Executive Committee Meeting

The 26th Executive Committee of Petrotech was held on 4th October 2013 at India Habitat Center, New Delhi. Mr Rahul Dhir President Petrotech Chaired the meeting. Various issues pertaining to further development & progress of Society and financial issues etc. were discussed during the meeting and a course of action was decided by the members.

Program on Best Practices in Training & Development

Petrotech organizes many workshops / seminars for mutual sharing of experiences, knowledge & best practices among oil & gas industry in many technical areas. This time Petrotech has taken another step forward and organized a program on “Best Practices in Training and Development” on 18th October 2013 at Hotel The Claridges, New Delhi.

Mr Ashok Anand, Director General Petrotech welcomed the august gathering during the program on Best Practices in Training & Development held on 18th October 2013 at New Delhi. Mr K S Jamestin, Chief Guest & Director (HR) ONGC addressed the gathering during the program on Best Practices in Training & Development held on 18th October 2013 at New Delhi.

Director HR of different companies were requested to chair the session on different topics. The sessions chaired by them are as follows

- Training And Development—Expectations And Reality
  - Session Chairman: Mr K S Jamestin, Director (HR), ONGC

- Challenges In Training Need Identification
  - Session Chairman: Mr Ashok Anand, Director General, Petrotech

- Measuring Effectiveness of Training
  - Session Chairman: Mr R P Singh, Director (HR& Legal), IFFCO

- Best Practices In Training And Development –I
  - Session Chairperson: Ms Veena Swarup, Director (HR), EIL

- Best Practices in Training And Development –II
  - Session Chairman: Mr P K Joshi, Director (HR) HPCL

- The way Forward—Innovative Approaches to Training and Development
  - Session Chairman: Mr N K Bharali, Director (HR & BD) OIL

5 Days Executive MBA Program for Oil/ Gas/Energy Industry at IIM Ahmedabad

Mr N K Bharali, Director (HR & BD) OIL India Ltd chairing the valedictory session of the program on Best Practices in Training & Development

Mr N K Bharali, Director (HR & BD) Oil India Ltd addressing the participants during the Valedictory Session of the program on Best Practices in Training & Development.
Challenges are being faced on the succession planning due to need of trained managers to take up higher positions. Therefore, for the first time, Petrotech organized a 5 days Executive MBA program, exclusively for the energy sector from 28th October–1st November 2013 at IIM Ahmedabad, one of the most prestigious Institutes. Program was suitable for middle management team around the crucial issues of strategy, structure and succession. The program offered powerful combination of foundational topics and advanced insight on the most timely and pressing issues. 27 participants from various oil companies participated in the program and appreciated the efforts of Petrotech.

During the program experts/faculty had covered various topics such as Business Strategy & Strategic Thinking—Meeting Strategic Personal and Organizational Goals, Environment Scanning, Managing Risk, Leading & Managing Future Workforce, Business Communication and Managing Change, Outlook and Trends in Oil & Gas Industry were also covered.

Mr Ashok Anand Director General and Ms Jatinder Peters, Secretary Petrotech attended the Inaugural Session of the program on 27th October 2013 and addressed the participants.

2nd Petrotech-Petronet LNG program

Petrotech in association with Petronet LNG organized the 2nd Petrotech–Petronet LNG program from 27th–29th November 2013 at Hotel Gateway, Kochi. 44 participants from various oil & Gas companies viz ONGC, IOCL, BPCL, OIL, EIL, HPCL, NRL, ESSAR, RIL etc attended the program. Mr Ashok Anand, Director General Petrotech welcomed the August gathering and expressed his thanks to Petronet LNG & especially Dr A K Balyan, CEO & MD Petronet LNG for acceding to the request of Petrotech for being partner in organizing LNG program which is 2nd in series. He also brought some important issues like LNG demand and supply in India and other parts of the world.

Mr Rajender Singh, Director (Technical) Petronet LNG Ltd gave a detailed introduction of the 3 days program and also said Petronet LNG is the 1st company to bring LNG in India and the program is designed in such a manner which covers maximum topics in 3 days program.

Dr A K Balyan, MD & CEO Petronet LNG addressing the participants during the 2nd Petrotech-Petronet LNG program at Kochi

Mr A K Balyan, MD & CEO Petronet LNG addessing the participants during the 2nd Petrotech-Petronet LNG program at Kochi

Mr K S Kim, CEO & Lead Country Manager, Exxon Mobil Gas (India) Pvt Ltd, Mr Rajinder Singh, Director (Technical) Petronet LNG, Mr Ashok Anand, Director General and Mrs Jatinder Peters, Secretary Petrotech during the inaugural session of 2nd Petrotech-Petronet LNG program

Participants during the 2nd Petrotech-Petronet LNG program

Mr K S Kim, CEO & Lead Country Manager, Exxon Mobil Gas (India) Pvt Ltd delivered the Keynote address and brought out LNG scenario and LNG chain in India and abroad in his presentation.

Dr A K Balyan, MD & CEO Petronet LNG appreciated Petrotech and Petronet for taking an initiative to organize a program on LNG for the benefit of hydrocarbon industry which is the need of the hour. He touched upon the following issues:

- Functional excellence to business excellence.
- Knowledge and value addition
- LNG is the Energy for future.
- Use of technology to improve quality of life at affordable price
- LNG scenario world wide and measures to be taken by India to overcome the LNG/ energy need of our country.

Mrs Jatinder Peters, Secretary Petrotech conducted the program and proposed a Vote of Thanks.

The topics covered during three days program were:

Introduction & Basics of Natural Gas & LNG

- Treatment of Natural gas
  - Liquefaction Processes

Speaker : Mr. Rajinder Singh, Director (Tech), PLL

Small scale LNG plants – Road/Costal Movements

Speaker : Mr. Alex P Verghese, Advisor : PLL
Domestic Gas scenario: Exploration & Production
Speaker: Mr. Yash Mallik, Chief Marketing ONGC

LNG Shipping: Latest Trends—FSRU & FSU
Speaker: Mr. A.K. Chopra, VP(HR), PLL

Regasification Terminals: Options & design
Speaker: Mr. Atul Kr. Verma, Dy. Manager (Mechanical): PLL
Mr J P Mishra, Chief Manager (LNG), Iocl

HSE in LNG Operations
- LNG Hazards – Spills, Dispersion, Fires, Roll over, etc
- Hazard Identification & Analysis
- LNG, Codes & Standards
Speaker: Mr. M.M. Ahuja, President (Technical), PLL

Development of Manpower for LNG Industry
Speaker: Mr. Pankaj Wadhwa, VP(Fin.& Commercial), PLL

World LNG Scenario and LNG Chain
Speaker: Mr. R.K. Garg, Director (Finance), PLL

LNG Contracts & Issues
Speaker: Capt Vikas Singh, Sr Manager (Port Operations), PLL

Comparative Study of LNG Vaporisers
Speaker: Ms. Hima Bharti, Engineering Officer, PLL

The three days program also covered a visit to Petronet LNG Kochi Terminal on 29th November 2013. Presentation on LNG Plant operations was given by Mr Pushp Khetarpal, Sr Vice President (O&M)—Kochi PLL. The program was a grand success.

Maiden Petrotech International Programme on “Complex Change Agents”

Mr Ashok Anand, Director General Petrotech welcomed the august gathering. Dr. Glenda Eoyang, speaker of the two days program, is the founding Director of the Human Systems Dynamics Institute (HSDI), USA. Dr. Eoyang is the founder of Human Systems Dynamics and has applied the principles of this discipline to help individuals and organizations around the world in managing change and adapting more effectively to the complex and uncertain—economic, political, social and diverse demographic environment. A renowned faculty and facilitator, Dr Glenda supports change for individuals and organizations around the world. She is also a prolific writer and her latest book Adaptive Action has just been published and released by Stanford University Press.

The programme was attended by 51 participants from major oil and gas PSUs and private organizations.

Maiden Petrotech International Programme on “Complex Change Agents”

Mr Ashok Anand, Director General Petrotech welcoming Dr Glenda Eoyang, founding director HSDI, USA during the programme on “Complex Change Agents”

Petrotech has organized the internationally acclaimed “Complex Change Agents Certification Program”, on December 18&19, 2013 at Hotel Le–Meridian, New Delhi, in partnership with MindShare HR Consultancy.
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