Way forward In IOR/EOR Processes

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Sub-Surface Manager N & H
Outline

- Global Scenario
- Setting the scene: Why IOR/EOR
- EOR / IOR ... Today: The Game Changer
- Simple mathematics
- IOR/ EOR ... Way forward
- Conclusions
Global Oil Discovered

trillion barrels

- More than 40,000 oil and gas fields discovered (Onshore & Offshore)
- 94% of the oil is coming from 1500 fields only.

**DISCOVERED**
- Light oils (>25 API) 9.4
- Medium/Heavy (11-25 API) 1.5
- Xtra Hvy (<11 API) 3.0 _______ 14 Tbo

**PRODUCED** 1.1 .......................... 10%

**STILL IN THE GROUND** 90% !!!!!

**Current Avg. World Recovery Factor** 22%
- US Recovery Factor 39%
- North Sea Recovery Factor 46%
- Tech. attainable Recovery Factor 70%
Worldwide EOR Production

<table>
<thead>
<tr>
<th>Process</th>
<th>Prodn, bbl/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 Miscible</td>
<td>268983</td>
</tr>
<tr>
<td>CO2 Immiscible</td>
<td>16735</td>
</tr>
<tr>
<td>H/C Miscible</td>
<td>755622</td>
</tr>
<tr>
<td>Polymer</td>
<td>57327</td>
</tr>
<tr>
<td>Steam</td>
<td>1326802</td>
</tr>
<tr>
<td>Combustion</td>
<td>34185</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2459654</strong></td>
</tr>
</tbody>
</table>

3 % of production is from EOR
“Half of the world’s production which comes from the 100 biggest fields, almost all of these are more than 25 years old”

Source: The G forces of Energy Insecurity; C D Ruppel, 2006
Most of the oil and gas will not come from new fields

Primary Sources of Oil and Gas

- To 1960: 50-60% from new fields
- To 1990: 20-25% from new fields
- Today: 12-15% from new fields
- Tomorrow: 7-10% from new fields

Most of the oil and gas will not come from new fields.
The Importance of Mature Fields

- To date, we have produced approximately 1 trillion barrels of oil from existing fields.
- About 10% has Recovered with an average worldwide recovery of 22% of oil in place.
- If we increase our recovery rate in these existing fields to 35 - 40%, we will add another trillion barrels of recoverable oil reserves to the global inventory.
- The same is true for natural gas.
**Future challenges**

1. Identify bypass oil
2. Increased oil recovery in existing fields
3. Development of smaller fields
4. Induction of State of Art technologies
Enhanced Oil Recovery (EOR) is ...

- Oil recovery by injection of fluids not normally present in reservoir.
- Excludes pressure maintenance or water flooding.
- Changes the intrinsic properties of oil by using chemical thermal, Gas etc.

Improved Oil Recovery (IOR) is ...

- EOR Plus additional technologies dealing with drilling, Production, Operations and reservoir Characterization for reducing reservoir heterogeneity effect and capture bypassed oil to improve flow and recovery of liquid hydrocarbons.
What is EOR/IOR

PRIMARY Recovery

Natural Flow

Secondary Recovery

Artificial lift, Stimulation

Water flooding, Infill drilling etc.

Redevelopment

Pressure maintenance

Tertiary Recovery

Thermal

Gas miscible/immiscible

Chemical & other
The Real EOR - IOR Challenges

Recovery Factor = 22 %

1 % increase in Recovery Factor = 100 billion barrels added reserves of traditional light oils

= 4 years of current production

= 10 years of exploration efforts for new reserves
EOR...

Today
Concepts & Methodologies...

Gas Injection ($CO_2$)

Denver Unit Production / Injection History

- **Primary**
- **Secondary**
- **Tertiary**

- **Water Injection**
- **Oil**
- **$CO_2$ Injection**
- **Water Production**
- **EOR**

BBL/D, MCF/D

Year: Jan-38, Jan-43, Jan-48, Jan-53, Jan-58, Jan-63, Jan-68, Jan-73, Jan-78, Jan-83, Jan-88, Jan-93, Jan-98
Daqing Polymerflood....

![Graph showing water cut and oil production vs. amount of polymer injected.](image)
Surfactant flood - FIELD PERFORMANCE

Glenn Pool Field, OK

Oil Rate, B/D or WOR


10  100  1,000

OIL

WOR
Indian perspective

EOR - Game Changer Technology
Polymer Flood: Sanand Field

Water Flood Vs Polymer Flood

Water Cut SCTR - %

Time (Date)


0 20 40 60 80 100

His_102005.irf
His_102005_water.irf
Summary........

- Oil Recovery 22.5% till date against 14.7% with water-flood
- Reduced water cut as compared to water flood.
- Possibility of enhancing recoveries with higher polymer concentration
Miscible Gas Injection: GS-12 Sand, Gandhar

Miscible HC Gas Injection, Gandhar
Waterflood Recovery: 36%
HC Miscible Gas Injection recovery: 58%
Gas Injectors: 13 (6.7 Lakh m3/d)
Avg Res Pressure: 235ksc
Oil rate / water cut: 650 m3/d / 7%
Recovery as on Jan-10: 40%
WAG Process: GS-11 sand, Ganghar

Oil contribution from pilot & offset producers

Oil rate - WAG Pilot performance
GS-11 sand, Gandhar field

Oil gain - 74248 T

WAG Pilot Started

Month
In-situ Combustion: Balol

- Commercial application
  - Phase-II: 2000-01
- Strategy: Updip line drive
- Primary Recovery: ~ 13%
- Envisaged additional recovery: 36%
Indian perspective

IOR - Game Changer Technology
IOR Programme

- ONGC, National Oil Company of India launched Improved Oil Recovery (IOR) programme in 1999

- The aim to augment declining domestic production

- 15 major fields including 3 offshore around the country, holding 85% of total reserves identified
**Offshore**
- MHN Redevelopment
- MHS Redevelopment
- Addl. Dev. Heera Pt-I
- IOR - Neelam
- Addl. Dev. Heera Pt-II

**Onshore**
- IOR - Gandhar
- IOR- Kalol
- IOR- North Kadi Ph-I
- IOR- Sobhasan
- IOR- Jotana
- IOR- Santhal
- IOR - Lakwa Lakhmani
- IOR - Geleki
- IOR - Rudrasagar
- IOR North Kadi Ph-II

**IOR Projects**
IOR/ EOR Campaign yielding results

- 15 major fields: Producing 60% of country’s total oil for more than 30 years put on IOR/ EOR. Natural decline of these fields @ about 7% per year arrested
- Recovery Factor of these 15 fields rises from 27.5 in 2000 to 32.5 in 2009
Location of Mumbai High
Mumbai High field

IOIP, MMt  1659
Cumulative Oil Prodn, MMt  396
Recovered, %  23.9
Water Cut, %  65
Number of platforms  110
Strings on Production  721
Strings on Injection  238
Number of Gas producers  35
Re development’s Focus Areas

• Improve oil recovery
  • Locate by-passed / un-drained oil pockets
  • Hi-tech infill wells
  • Surveillance on health of reservoir

• Offset declining production

• Modernize and re-engineer ageing surface facilities.

• Assimilate Cutting Edge Technology

• Reduce cost and add value

• Dynamism to learn and use during the project
Drilling & Completion: Conventional to high tech

- New technology in Drilling – Horizontal sidetracks, Multilateral and Fishbone to reach by-passed oil.
- Drain hole to increase Reservoir contact and productivity.
- Advanced non-damaging Drilling fluid
- Application of new logging systems - LWD, MWD, CHFR, MDT, DFA …

- Segmented Completion
- Multilateral Level-3 Completion
- Surface controlled Intelligent completion
- Use of Swell Packers.
Performance of Mumbai High Field
IOR / EOR ...

Way forward
Today

- Majority of our producing fields have produced through their peaks
- 80% of total indigenous production coming from such mature fields
- Cost-intensive IOR/ EOR processes are required to keep them flowing
### Indian Scenario

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially In-place</td>
<td>5895</td>
<td>3239</td>
</tr>
<tr>
<td>Ultimate Reserves</td>
<td>1646</td>
<td>1755</td>
</tr>
<tr>
<td></td>
<td>(27.9%)</td>
<td>(54%)</td>
</tr>
</tbody>
</table>

As on 1.4.2008
IOR/ EOR (NOC Perspective)

Total

Offshore (2675~61 %)

4397 MMT

Onshore 1722~ 39 %
IOR/ EOR  (NOC Perspective)
Total ~ 4397 MMT

Majors (65%)

Small, Isolated / Marginal Fields ~ 20%

Others 15%
IOR/ EOR (NOC Perspective) Offshore

Majors (73%)

Small, Isolated / Marginal Fields ~19%

Others 8%
IOR/ EOR (NOC Perspective)
Onshore

Majors (53%)
Small, Isolated / Marginal Fields ~ 16%
Others 31%

IOR/EOR
Simple Mathematics (India)

Aim: 40% Recovery factor ~ 800 MMt of oil

With current production rate ~ 25 year

NOC Perspective

Offshore

Majors .... 33% >>> 40% >>>>> 136 MMt - IOR-2nd phase

Others.... 30% >>>>> 35% >>> 11 MMt - IOR-1st phase

Marginal.... 16% >>> 83 MMt - Put on production

Total... >>> 236 MMt
Simple Mathematics

NOC Perspective

Onshore

Majors .... 31.8% >>> 40 % >>>>> 75 MMt - IOR-2\textsuperscript{nd} Phase/ EOR
Others....27% >>>>> 40 % >>> 69 MMt - IOR - 1\textsuperscript{st} phase / EOR Pilot
Marginal....16 % >>> 45 MMt - Put on production
Total... >>> 189 MMt

Initial target  IOR / EOR by 2025  ~  325 MMt
Redevelopment / Additional Development of Fields through

- integrated schemes of IOR/ EOR
- Fast track development of new finds
- Drilling of Hi-Tech and Side track wells
- Put the marginal and small pool on production
Extracting the last drop

- Continuous review and foresightedness has the potential to extend the life of a field
- Anticipating the future performance by monitoring; surveillance; and diagnostics holds the key to a long producing life
- Pinpointing the residual oil reserves area is another aspect to extend the life of field

Technical challenges to counter the natural decline in production
Tools, Equipment & Technology
Induction
Improved Oil Recovery In Brown Fields- A Game Changer
Western Offshore India
40% RECOVERY

- Conceptual road map based on redevelopment experience
- Main strategy: 40% path by 2025
- Broad framework for long term development
  - Type of development
  - LT commitments required
- Rolling plan, next 10 years following the redev
- Frame work 2006-09
  - Planning
  - Monitor, course correction, review and upgrade the road map
- Areas for future focus
- Frame work plan 2007-12
- Continue to develop as understanding improves

Conceptual exercise of disintegration into reasonable activity specific targets so that strategies can be worked out and implemented for achieving them systematically. Specific projects have to be worked out with details for investment purpose.
Rolling plan target for next 10 years

- **Periods of low investment**
- **1.2 Billion bbls to be produced under approved schemes**
- **1 billion barrels additional oil**
- **13.5-14 MMt**
- **40% Rec plan**
- **Projects before MHRD**
- **FR MHRD**
- **% recovery**
- **Water Cut %**
New Technologies

Drilling:
- Long Distance Sidetracks (LDST)
- Medium Radius Drain Hole (MRDH)
- Short Radius Drain Hole (SRDH)
- Ultra Short Radius (USR)

- ERD wells
- Use of
  - Expandable tubulars
  - SOBM
  - Autotrack
- Level-3 completions in wells where more than one pay is promising
- Massive Hydraulic Fracturing
- Profile Modification
Well Completions

Improved well completions
Segmentation for Layer Control with Swell packers

Level-3 Completion in HZ# 7
**North Kadi : IOR**

**N. Kadi (Kalol sands)**
- Use of Geocellular model
- Mapping of heterogeneity (phi, k)
- Revisit to ROS (24%) and Rel. Perm.
- Oil gain envisaged by high liquid withdrawal in flank wells

**Extending Plateau**

**Cum oil 26.4 MMM3 (by 2030)**
- 26 wells (incl 10 horizontal)
- RF 36.3 % >>> 45 %
- Peak Qo 1570 m3/d
EOR .... 
Way forward
**EOR : CO2 Flooding**

- Carbon dioxide flooding (continuous or alternating with water-WAG) is the dominant EOR process in US.
- This is due to the high availability of low-cost CO2.
- In simple terms, if CO2 is available it will remain the most sound choice for EOR.

In India: Natural source of CO2 not established.

- Plan for a pilot in Ankleswar Field
- Offshore no Plan: Miscible Co2 not possible due to depleted Pressure. Limited Source.
In-Situ Combustion (Air Injection)

- Air injection into heavy and light crude oil reservoirs is known as ISC.
- Air injection may be one of the viable EOR process for offshore and onshore mature fields.
  - For heavy oil, NOC has good experience.
  - For light oil:
    - Onshore: Pilot under commissioning.
    - Offshore: Laboratory studies in progress.
    - Bottle neck: Old Surface infrastructure and well completions.
Hydrocarbon Gas Injection

- Miscible and immiscible hydrocarbon gas injection is still a viable recovery process used widely in the U.S. However, this recovery process has been applied mainly in sandstone reservoirs.

- If there is no other way to monetize natural gas, then a more practical use of natural gas would be to use it in pressure maintenance projects or in WAG processes.
  - Both Miscible and WAG Implemented Successfully in Gandhar.
  - Currently all the produced gas are committed.
EOR: Chemical Methods

CLASSIFICATION

CHEMICAL METHODS

- Alkali
- Surfactant
- Polymer
- Micellar
- ASP
EOR : Chemical Methods

Success of polymer flood projects are limited. High Temperature & High Salinity are the constraint.

In the case of carbonate reservoirs, most of the reported polymer floods used as part of a mobility control strategy to improve sweep efficiency and enhance the final oil recovery of water flood projects.

MP and ASP flooding hold the greatest potential for commercial success may play a key role in both mature and water flooded sandstone reservoirs in the near future.
EOR : Chemical Methods

• Sanand polymer commercialised in 1995, is a success: Since then no reservoir identified for Polymer:

• Encouraging Laboratory Results of ASP / AS/ SP flooding However Field test Failed.

• Research Shows EOR Chemical methods in Offshore carbonate reservoirs have made a relatively marginal contribution. No commercial success reported for offshore carbonate reservoirs with temperature more than 100 deg C and having formation water of high Mg++ & Ca ++.
EOR Observations...

• But still it moves
• EOR is a drag
• Don’t bank on it
• Size is important
• Gravity is our friend
• The more you inject, the more you get
Conclusions

- Multi-time development through infill drilling — major method to improve oil recovery by Exploiting un-swept areas of the reservoir.

- Foresighted pilot tests, technical preparation, and fit-for-purpose technique innovation are essential for maximizing oil recovery
Conclusions

Over the last decade, Enhanced Oil Recovery via gas injection has been the dominant recovery method for crude oil reservoirs, especially in carbonate reservoirs.

Widening the domain of air injection to encompass matured water flooded and light oil reservoirs

Chemical floods offer the only chance of commercial success in many depleted and water flooded reservoirs

Chemical flooding is here to stay because it holds the key to maximizing the reserves. The processes must be re-evaluated under the current technical and economic conditions.
Conclusions

- Integrated approach enhances Asset value
- Innovations and technology – key for Rejuvenation
- Identify bypass oil – “Fit for Purpose technology“
- Better Reservoir characterization
- State of art Drilling & Completion
- 24 * 7 Gas lift / ESP optimization thru Smart technology
The Bottom Line...

IOR / EOR in combination with...

More Wells
Improved Reservoir Characterization
Intelligent Wells
Real time monitoring
Decision analysis Procedures
Other Simulation technologies
And (Of course) a high oil Price

Will make Ultimate recoveries of 65 % Possible and even routine
We Must Bridge the Gap
Thank You