Desulphurization of Gas Oil and Fuel Oil

4th Annual Platts Asian Refining Summit
(9-10 March 2017, Singapore)

Presented by:
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General Manager - Technical
IndianOil, New Delhi
Agenda

• GasOil Desulphurization
  – Policy on ‘S’ limit
  – Technology landscape
  – BS-VI preparedness by Indian refineries

• Fuel Oil
  – Latest MARPOL Specifications
  – Challenges for Refineries
  – Technology Landscape
  – Refinery Cost Economics for Producing Fuel Oil
  – Alternate Fuel Options for Marine Propulsion
Indian Auto Fuel Policy

Primary cause:
- Overwhelming concern for public health: Worsening Air Quality
- Vehicular emissions – considered a large contributor to air borne pollution.

<table>
<thead>
<tr>
<th>Year</th>
<th>BS-1</th>
<th>BS-2</th>
<th>BS-3</th>
<th>BS-4</th>
<th>BS-5</th>
<th>BS-6</th>
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<td>2000</td>
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<td>Select Cities</td>
<td>Nationwide</td>
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<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
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<tr>
<td>2010</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
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<tr>
<td>2017</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
</tr>
<tr>
<td>2020</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
<td>Nationwide</td>
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</tbody>
</table>

BS-I: Nation-wide from 2001
BS-II: Select Cities from 2001
BS-III: Nation-wide
BS-IV: Select Cities
BS-V: Select Cities
BS-VI: Select Cities

Indian Diesel Fuel Standard
Bharat Stage (BS)

<table>
<thead>
<tr>
<th>Norm</th>
<th>'S' ppm</th>
<th>Equiv</th>
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<tr>
<td>BS-1</td>
<td>2500</td>
<td>EU-1</td>
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<tr>
<td>BS-2</td>
<td>500</td>
<td>EU-2</td>
</tr>
<tr>
<td>BS-3</td>
<td>350</td>
<td>EU-3</td>
</tr>
<tr>
<td>BS-4</td>
<td>50</td>
<td>EU-4</td>
</tr>
<tr>
<td>BS-6</td>
<td>10</td>
<td>EU-6</td>
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India’s Demand Growth

High Fuel Demand Drivers
- GDP Growth
- Industry Growth
- Automobile Growth
- Population Growth
- Demographic Dividend
- Rapid Urbanization
- Favourable Govt Policies
  - Make in India
  - Ease of doing business
  - Infrastructure Development

Oil Demand Outlook

<table>
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<tr>
<th>Year</th>
<th>Million barrels per day</th>
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<tr>
<td>2015</td>
<td>3.9</td>
</tr>
<tr>
<td>2020</td>
<td>4.7</td>
</tr>
<tr>
<td>2030</td>
<td>6.9</td>
</tr>
<tr>
<td>2040</td>
<td>9.6</td>
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</tbody>
</table>

Source: India Energy Outlook WEO 2015, OPEC Oil Outlook 2015

HSD Domestic consumption, MMT

- HSD Sales
- Future HSD demand

Source: IOCL Projections

Refining Growth, MMT

- Yr 2017: 230
- Yr 2030: 350
- 120 TMT addition!

Source: IEA, BP
TECHNOLOGY LANDSCAPE-GAS OIL

Existing Refineries units for meeting Current Spec
- Diesel Hydro Treatment (DHDT)
- Diesel Hydro De-Sulphurization (DHDS)
- Hydro Cracker & Once-thru Hydro Cracker (OHCU & HCU)
- Vacuum Gas Oil (VGO) - Treaters

Technological interventions for further reduction of ‘S’
- DHDT / DHDS Revamp/Catalyst changes/New Unit
- OHCU/HCU Revamp/Catalyst changes/New Unit
- Revamp/New Hydrogen Generation units
- Revamp/New Sulphur recovery & associated units
- Revamp of VGO HDT
- Ebullated Bed/Slurry Hydrocracker
Gas Oil Desulphurization Technologies

• Major commercially established Global players
  – UOP
  – Axens
  – Chevron Lummus Global
  – Shell
  – Halder Topsoé/ENI
  – ExxonMobil

• Established Indian technology
  – IOC(R&D)-EIL indeDiesel
First indeDiesel Unit @ IOCL Bongaigaon Refinery

- **Capacity:** 1.2 MMTPA
- **Unit Commissioned:** Aug’ 11
- **PGTR Completion:** Dec’11

- **S = < 10 ppm**
- **CN increase = 12.7**
- **Feed:** Cracked components
  - (CK+HCN+CLGO+ CHGO) in feed mix:
    \[ \sim 32 – 40 \text{ wt\%} \]

### New unit and Revamps

<table>
<thead>
<tr>
<th></th>
<th>Gujarat DHDS</th>
<th>Gujarat DHDT</th>
<th>Bongaigaon DHDT</th>
<th>Haldia NEW DHDT</th>
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<tbody>
<tr>
<td>Capacity</td>
<td>1.7</td>
<td>2.2</td>
<td>2.2</td>
<td>1.2</td>
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<tr>
<td>MMTPA</td>
<td>2.2</td>
<td>2.9</td>
<td>1.2</td>
<td>1.6</td>
</tr>
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</table>

- **Commission**
  - 2017
  - 2019
  - 2019

### Advantages
- **Proven Technology with efficient Reactor Internal**
- **Can deploy best available Catalyst**
- **Cost Effective**
BS-VI (10 ppm ‘S’): Execution Plan

- All refineries across India, simultaneously undergoing Major Upgradation
- Implementation kick started by all Indian Refineries
- ~2.0 Billion USD investment for Gas Oil Desulphurization
  - Some Ref(s) completing BS-VI jobs along with BS-IV
- Expediting Execution:
  - Parallel job execution
  - Combined Tendering for multiple locations
  - Bulk procurement-Basket concept
  - Advance action-Standard design
  - Concurrent engineering by Licensor & EPCM
  - Leveraging existing refinery data

TIMELINE

Jun’19: Mechanical Completion of projects
Sep’19: Project Commission
Jan’20: Introduction of BS-VI fuel in Market
BUNKER FUEL OIL
New IMO regulations

MARPOL ratifying countries

As of Feb’17

- 155 countries, representing 99% of the world's shipping tonnage, are signatory to the MARPOL 1973/1978 convention.

- 88 countries representing 96% of world tonnage are signatory of MARPOL ANNEX VI

India is a Signatory

<table>
<thead>
<tr>
<th>Specification</th>
<th>Unit</th>
<th>RMG 380</th>
<th>RME 180</th>
<th>RMD 80</th>
<th>DMA</th>
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<tbody>
<tr>
<td>Kinematic Visc</td>
<td>cst max</td>
<td>380</td>
<td>180</td>
<td>80</td>
<td>6</td>
</tr>
<tr>
<td>Sulphur</td>
<td>%wt max</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>CCR</td>
<td>%wt max</td>
<td>18</td>
<td>15</td>
<td>14</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Bunker Sales and Projection

**Bunker Sales by Port-2015, MMT**

- Singapore: 45
- Fujairah: 24
- Rotterdam: 18
- Hong Kong: 9
- Antwerp: 8
- Houston: 6
- India: 2

Source: Sagarmala Report 2016, GOI

**India's Potential in Bunkering, MMT**

- FY15 Status: 2
- FY15 Potential: 8
- FY25 Potential: 15

Source: Sagarmala Report 2016, GOI

**Worldwide Production Projection (in MMT) as per CE Delft report**

- 2012 Prod'n: 64
- 2020 Proj: 36
- Total: 228

Even if production potential exists at Refineries, actual offer will depend on economics.

- Marine MGO
- Marine HFO(S > 0.5%)
- Marine HFO(S < 0.5%)
Challenges for Indian Refineries

- Domestic Distillate demand is growing fast while Fuel Oil demand is shrinking
- Large Investments made for Distillate Improvement
- Bitumen demand is projected to grow
- Significant Investment required to reduce ‘S’ in FO
- Low ‘S’ crude availability is limited

Source: IOCL projections

Source: PPAC
‘S’ management thru suitable Crude selection

**LS-HS Crude Spread**

Low Volumes of crudes having VR ‘S’ < 1%

LS & HS Crude spread: 4-6 $/bbl

Source: Landed Cost of HS Crude v/s LS Crude on East Coast of India
TECHNOLOGY LANDSCAPE - FO DESULFURISATION

Blend Stock Hydrotreatment

VGO Hydrotreatment

Residue Desulphurization

Axens (Hyvahl (H-Oil) Process)

Chevron Lummus Global (LC-fining of VR)

ExxonMobil (Residfining)

Shell Global Solutions (HYCON)

UOP (RCD Unionfining)

Alternative Pathways - Under Research

- Oxidative Desulphurisation plus extraction with Solvents
- Bio Desulfurisation: Aerobic and Anaerobic
- Desulphurisation using Alkali Metals
Refinery Economics for FO Production

• Margin Gain/Loss

- Distillate Blending
  7-8 $/bbl*

- FO 0.5%S Vs FO 3.5%S

- Coker Vs FO
  5-6 $/bbl*

- UCO in FCC vs FO
  8-9 $/bbl*

Large Gap between Gas Oil & FO price

*estimated at Current prices @ Indian Refinery
# Alternate Fuel Options

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **HSFO with Exhaust Gas Cleaning System (Scrubbers)** | - Ships can use cheaper High Sulphur FO  
- Waste disposal issue to be addressed |                                                            |
| **Liquefied Natural Gas (LNG)** | - Limited Refuelling Infrastructure  
- Large investment in Ship conversion |                                                            |
| **Distillate (MGO)**          | - Low capital investment for conversion  
- Higher fuel efficiency  
- Costlier than Fuel Oil |                                                            |
| **Low Viscosity FO**          | - Lowest capital investment for conversion  
- Price between FO and MGO |                                                            |
In Conclusion

- In sync with the world, India to switchover from present 50 ppm BS-IV to 10 ppm ‘S’ BS-VI fuels by 2020.
- All Refineries geared up for meeting execution challenge for completion within 3 years.

- Unfavourable refinery margins is a big challenge in meeting MARPOL grade FO production from 2020
- Both Refinery-based and Ship-based solution(s) to co-exist based on economics at various regions.
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THANK YOU