LOW SULPHUR DIESEL AND REFINING PROCESS, TECHNICAL AND FINANCIAL IMPLICATIONS FOR TEMA OIL REFINERY (TOR) LIMITED

By: Emmanuel K. Darko
Mark Quist
PRESENTATION OUTLINE

- Brief Overview of TOR, Capacity & Facilities
- Sulphur in Fossil Fuels, Crude Characterization, Refinery Choices & Implication
- Why low Sulphur Refinery Products
- Diesel Specification
- Sulphur Removal Strategies
- National Diesel Demands / TOR’s Response
- Conclusion
Tema Oil Refinery (TOR) Limited, formerly Ghanaian Italian Petroleum (GHAIP) Limited was commissioned on 12\textsuperscript{th} December 1963.


MISSION
To provide clean energy products to power Ghana’s economic growth in an environmentally sustainable manner.

VISION
To be the preeminent refinery, a pride for Ghanaians - A Blue flame.
**INSTALLED CAPACITY**

- **Crude Distillation Unit (CDU):**
  - 45,000 bpsd (2,000,000 tpa)

- **Residue Fluid Catalytic Cracker (RFCC):**
  - 14,000 bpsd (685,000 tpa)

- **Premium Reforming Unit (PRF):**
  - 6,500 bpsd (315,000 tpa)
UTILITIES SYSTEM

- **BOILERS**
  - 41-H5: 70ton/hr
  - 41-H6: 70ton/hr
  - 41-H7: 70 ton/hr
  - RFCC: 55 ton/hr

- **Boiler Fuel (Dual)**
  - Residual fuel oil
  - Fuel gas
POWER GENERATION CAPACITY

- **41 TG4**
  Condensing Steam Turbine Generator
  Capacity : 5.5 MW

- **41 TG5 (Under Construction)**
  Condensing Steam Turbine Generator
  Capacity : 5.5 MW

- **Emergency Diesel Generator**
  Capacity : 1.2 MW
UTILITIES-AUXILIARIES

- Compressed Air System
- Compressed Nitrogen
- Plant Water
- Anti-fire / Sprinkler Water System
- Cooling Water System
Crude oil is imported via:
- 24" above-ground pipeline from the oil jetty to the refinery;
- 36" pipeline from the SPM.

For Import/Export:
- 10" and 14" pipelines for Kero, diesel and mogas
- 18" pipeline for residual fuel oil.

Two 6" pipelines run from the refinery to the Accra Plains storage depot for diesel/kerosene and gasoline transfer.
Total crude storage capacity is about 2 million barrels.

Sufficient liquid product storage.

Five (5) LPG spheres of total capacity 6,400 metric tonnes.
REFINED PRODUCTS

- Crude Distillation Unit (CDU)
  - FUEL GAS
  - LPG
  - GASOLINE
  - KEROSENE
  - AVIATION TURBINE KEROSENE
  - GAS OIL
  - ATMOSPHERIC RESIDUE
REFINED PRODUCTS

- Residue Fluid Catalytic Cracker (RFCC)
  - LPG
  - GASOLINE
  - LIGHT CYCLE OIL
  - HEAVY CYCLE OIL
  - CLARIFIED OIL
SULPHUR IN FOSSIL FUEL, CRUDE CHARACTERIZATION, REFINERY CHOICES & IMPLICATION
Sulphur compounds are always associated with Crude Oil.

Crude oil is a complex mixture of Hydrocarbons of varying proportions with compounds of Sulphur, Oxygen and Nitrogen including metallic constituents such as vanadium, Iron, Nickel, Copper and Sodium.
# Crude Oil Characterization

## By Specific Gravity (SG)

<table>
<thead>
<tr>
<th>Type</th>
<th>°API</th>
<th>SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>&gt; 35</td>
<td>&lt; 0.85</td>
</tr>
<tr>
<td>Medium</td>
<td>25-35</td>
<td>0.85 - 0.898</td>
</tr>
<tr>
<td>Heavy</td>
<td>10-26</td>
<td>0.898 - 1.000</td>
</tr>
<tr>
<td>Extra Heavy</td>
<td>&lt;10</td>
<td>&gt; 1.0</td>
</tr>
</tbody>
</table>

## By Sulphur (% wt) ppm

<table>
<thead>
<tr>
<th>Type</th>
<th>% wt</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>&lt; 0.5</td>
<td>&lt;5000</td>
</tr>
<tr>
<td>Medium</td>
<td>0.5-1.0</td>
<td>5000-10000</td>
</tr>
<tr>
<td>Sour</td>
<td>&gt;1.0</td>
<td>&gt;10000</td>
</tr>
</tbody>
</table>
## Types of Crudes Available to Refiners

<table>
<thead>
<tr>
<th></th>
<th>API (°)</th>
<th>SULPHUR (% wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Sweet</td>
<td>30-40</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Light Sour</td>
<td>30-40</td>
<td>0.5 - 1.5</td>
</tr>
<tr>
<td>Heavy Sour</td>
<td>15-30</td>
<td>1.5 - 3.0</td>
</tr>
<tr>
<td>Extra Heavy</td>
<td>&lt; 15</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

- **High Acid Crude (HACs)**
  - **TAN (Total Acid Number)** > 0.5 mg KOH / g of Crude Oil
PRIMARY CRUDE PROCESSING
Refinery Choice of Crude Oil, Based On:

- Crude Availability
- Crude Cost
- Desired Product Yield
- Refinery Configuration / Complexity
- Environmental Constraints
CRUDE TYPES IMPLICATIONS

- High value product content in crude is crucial. The value of the products decreases in the order: Generally, Gasoline > Kerosene/Diesel > Crude oil > Fuel oil. Now Diesel > Gasoline.

- Generally, light & low sulphur crudes cost higher than heavy & high sulphur crudes.

- This is due to ease in processing, minimum impact on Plant & Machinery and minimum in the cost in products treatment to meet quality specification and environmental targets.

- Sulphur compounds in crude are distributed in the various fractions of products that require different technology for treatment. The sulphur level increases down the bottom of the Barrel.
WHY LOW SULPHUR REFINERY PRODUCTS?
THE NEED FOR LOW SULPHUR REFINERY PRODUCTS

SULPHUR POLLUTION HAS IMPLICATIONS ON:

- **HEALTH**: Sulphur pollution creates respiratory & heart diseases, skin diseases and sometime premature loss of life.
- **ENVIRONMENT**: Affects plants & Biodiversity as well as the degradation of the Ozone layer.
- **PLANT & MACHINERY**: Creates corrosion effects in Plant & Machinery resulting in breakdowns and high equipment maintenance cost.

THE WORLD HAS EVERY THING TO WIN FOR LOW SULPUR FUEL!!!
DIESEL SPECIFICATION
## Diesel Specification Summary

### National Spec

<table>
<thead>
<tr>
<th>Specification</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur, ppm, max</td>
<td>5,000</td>
</tr>
<tr>
<td>Cetane</td>
<td>&gt;42</td>
</tr>
<tr>
<td>Density @ 15 °C, kg/m³</td>
<td>830-880</td>
</tr>
</tbody>
</table>

### Tor Average

<table>
<thead>
<tr>
<th>Specification</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur, ppm, max</td>
<td>1000-3000</td>
</tr>
<tr>
<td>Cetane</td>
<td>&gt;48</td>
</tr>
<tr>
<td>Density @ 15 °C, kg/m³</td>
<td>855-870</td>
</tr>
</tbody>
</table>

### Afri Spec

<table>
<thead>
<tr>
<th>Specification</th>
<th>AFRI 1</th>
<th>AFRI 2</th>
<th>AFRI 3</th>
<th>AFRI 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur, ppm, max</td>
<td>8000</td>
<td>3500</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Cetane</td>
<td>42</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Density @ 20 °C, kg/m³</td>
<td>800/900</td>
<td>800/900</td>
<td>800/900</td>
<td>820/880</td>
</tr>
</tbody>
</table>

### Euro Spec

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur, ppm, max</td>
<td>2000</td>
<td>350</td>
<td>50/10</td>
<td>-</td>
</tr>
<tr>
<td>Cetane</td>
<td>49</td>
<td>51</td>
<td>51</td>
<td>-</td>
</tr>
<tr>
<td>Density @ 15 °C, kg/m³</td>
<td>820-860</td>
<td>845</td>
<td>845</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: ARA
### WORLD FUEL CHARTER (“ADVANCED FUEL SPEC”)  

### DIESEL:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur Max PPM wt</td>
<td>350 (50)</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Density, kg/m³</td>
<td>820 - 845</td>
<td>820 - 845</td>
<td>820 - 840</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>&gt;51</td>
<td>&gt;51</td>
<td>&gt;55</td>
</tr>
<tr>
<td>Cetane Index</td>
<td></td>
<td></td>
<td>&gt;52</td>
</tr>
<tr>
<td>Aromatics, wt%</td>
<td></td>
<td></td>
<td>&lt;15</td>
</tr>
<tr>
<td>PNA, wt%</td>
<td>&lt;11</td>
<td>?</td>
<td>&lt;2</td>
</tr>
<tr>
<td>T95 °C</td>
<td>&lt;360</td>
<td></td>
<td>&lt;340</td>
</tr>
</tbody>
</table>
SULPHUR REMOVAL STRATEGIES
SULPHUR EXISTENCE IN DIESEL:

- Mercaptans : R-SH
- Sulphides : \( R_1-S-R_2 \)
- Disulphides : \( R_1-S-S-R_2 \)
- Thiophenes : (Aliphatic & Aromatics)
- Cyclic Sulphides
- Polysulphides, etc.

Removal of sulphur products in Diesel gives cleaner fuel with less soot, low emissions (VOC’s, NOx’s, Sulphur Particulates, etc).
HYDROTREATING

Reaction carried out with \( \text{H}_2 \) at temperatures around 290-430 °C and pressures ranging from 7 bar (Naphtha) to about 140 bar for Diesel.

Two catalysts of alumina base are used:

- Co/Mo - Effective for Sulphur removal
- Ni/Mo - Effective for Nitrogen removal and Aromatic Saturation.
HYDROTREATING SCHEME
BENEFITS OF EFFECTIVE HYDROTREATING

- **Major Benefit** - Removal of Sulphur

- **Associated benefit** - Removal of Nitrogen through Denitrification
  - Olefin Saturation
  - Aromatic Saturation
  - Removal of metals such as iron, nickel, vanadium etc.

NB: Hydrotreating is limited in removing sulphur and improving Diesel Cetane Number from Aromatic & Coker Distillates. Hydrocracking Technology is used.
HYDROCRACKING

 Accomplishes hydrotreating + breaking up of bigger diesel range molecules into lower-boiling low sulphur Diesel at Temp up to 425 °C and pressure up to 200 bar.

 Cracking promoted by acid sites on Zeolites (Silica–alumina).

 Hydrogenation promoted by Palladium, Molybdenum or Tungsten sulphides.

 Hydrocracking is very flexible but consumes more H₂ and very expensive.
HYDROCRACKER FLOW SCHEME
BENEFITS OF HYDROCRACKING

- As Refinery margins improve with the processing of cheaper heavier Crudes, Hydrotreating cannot achieve target sulphur reduction for the full diesel range.
- Hydrocracking becoming more popular due to an increasing demand on diesel vehicles for cleaner air.
- Upgrade low-grade diesel and cycle oil into high value Diesel and other lighter products.
EMERGING TECHNOLOGIES (LOW S- DIESEL)

- Fischer-Tropsch Process
  (Syngas production, conversion & hydro-processing)
- Adsorption Process
  (Using sorbent in fluidized bed reactors)
- Bio-desulphurization
  (Using bacteria enzymes for sulphur extraction)
- Chemical Oxidation of Sulphur with a catalyzed acid.

NB: BIODESEEL has zero sulphur with high cetane
NATIONAL DIESEL DEMAND / TOR’S RESPONSE
Diesel demand estimate currently stands at 1,200,000 T/year which is driven by:

- Haulage trucks
- Power generating applications
- Ever-growing mining operation in the country
- Revival of Railway industry
- Growing public transport sector
- The emerging Bus Rapid Transit (BRT) system
As Ghana’s population increases & GDP also increases, Diesel demand is projected to rise.

The need for investment in expanding refinery capacity cannot be over-emphasized.

TOR’s capacity limited

2005-2025 Projected Trend

Research Paper by E.K Asamoah, Univ. Dundee, Scotland
How does TOR respond?

- TOR to increase its processing capacity by 100kbpd to satisfy increasing fuel demand by 2017 in line with its Corporate Plan.
- Hydrotreaters to be installed to handle distillates.
- Hydrocracker to be incorporated.

How does TOR meet diesel Specs?

- By carefully selecting the right type of crude mix as there are no Hydrotreaters.
FINANCIAL IMPLICATIONS

TECHNOLOGY IS AVAILABLE.

INVESTMENT / FINANCIAL CAPITAL REQUIRED.

REFINERY CONFIGURATION UPGRADE CRUCIAL (PROJECTED BY 2017).
## TOR Configuration Upgrade & Estimated Capital Requirement

<table>
<thead>
<tr>
<th>Process Unit</th>
<th>Capacity (KPD)</th>
<th>Estimated Capital Cost US $ Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Distillation Unit (CDU)</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Isomerization</td>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td>Reformer</td>
<td>18</td>
<td>85</td>
</tr>
<tr>
<td>Resid FCC</td>
<td>35</td>
<td>280</td>
</tr>
<tr>
<td>Jet Hydrotreater</td>
<td>8.5</td>
<td>25</td>
</tr>
<tr>
<td>Hydrotreaters / Hydrocracker</td>
<td>37/12</td>
<td>400</td>
</tr>
<tr>
<td>Gasoline Merox</td>
<td>19</td>
<td>4.5</td>
</tr>
<tr>
<td>Saturation Gas Plant</td>
<td>10</td>
<td>2.8</td>
</tr>
<tr>
<td>Amine Treater, m³/h</td>
<td>16</td>
<td>2.5</td>
</tr>
<tr>
<td>Sulphur Recovery, mt/d</td>
<td>12</td>
<td>10.5</td>
</tr>
<tr>
<td>Wastewater Treatment Plant</td>
<td>250m³/hr</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>973.3</strong></td>
<td></td>
</tr>
</tbody>
</table>
TOR CONFIGURATION UPGRADE  PROJECTED BENEFITS

➢ Produce sufficient cleaner fuel to power, and sustain Ghana’s vibrant Public Transportation & Industrial growth whilst exporting surplus to neighbouring states.

➢ Complying generally with Euro IV Gasoline and especially low sulphur Diesel Specification.

➢ Environmental & Health sustainability

➢ Reduces financial expenditure burden due to emissions on Ghana’s economy.
CONCLUSION
CONCLUSION

- The role of TOR, Ghana’s only Refinery in the cleaner fuel project is crucial in terms of Fuel Security and Sustainability.
- The Refinery Configuration Upgrade project needs support from all stakeholders.
- TOR has the necessary expertise to deliver cleaner fuels for the benefit of all.