Rapid Crude Oil Assay:
Upstream and Downstream Applications of the AI-60 Crude Analyzer
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The Process Industry is undergoing a revolution: The 4th Industrial Revolution

Using cutting edge technologies such as: Big Data and data-driven process
On-line real-time data collection
IIoT (Industrial Internet of Things)

Today’s refineries cannot afford to ignore the benefits of on-line analyzers that significantly minimize their environmental footprint, reduce safety hazards and maximize profits

This new generation of precision analyzers is used for: process control, custody transfer, quality assurance and environmental protection
The Technology

The NMR phenomena provides picture or spectra of the hydrocarbon structure, which enables the determination of physical and chemical information. The NMR spectral specificity/resolution provides a complete, quantitative depiction of all hydrogen bond types (C-H, O-H, N-H, S-H, etc.) in the intact sample matrix. This specificity allows both direct and “simple” correlations to multiple physical and chemical properties of petroleum materials.
NMR Integrated Refinery Control Since 1997

Tank Farm → Crude Oil Blending → Crude Desalting → Gas Processing

Atmospheric Distillation
- Naphtha → Hydrotreater → Light Naphtha → Isomerization → Isomerate
- Heavy Naphtha → Catalytic Reforming

Vacuum Distillation
- Kerosene → Meroks Treater → Jet Fuel Kerosene → Reformate
- Diesel Oil → Hydrotreater → Diesel Oil

Visbreaking
- Vacuum Residuum → Delayed Coker

Asphalt Blowing
- Asphalt

Hydrotreater
- FCC Feed Hydrotreater
- Fluid Catalytic Cracker
- Naphtha → Hydrocracker → Hydrocracked Gasoline
- FCC Gas Oil
- Fuel Oil
- Coker Gas Oil
- Coker Naphtha

Crude Adjustment

Blue line represents the predicted yield curve using only an off-line LP program based on historical crude properties of the blend.

Red line is the actual yield curve for the same crude blend obtained using the reconciliation function of the optimizer. The triangles are the feed forward NMR predicted yield curve demonstrating the NMR accuracy compared to the LP.
Differences in the Composition of Crude Oil
True Boiling Point - Actual vs NMR Predicted

Actual Crude TBP Curves

NMR Predicted TBP Curves for Crudes

Marib Light Crude TBP Curves
(Actual and NMR Predicted)

Dulang Crude TBP Curves
(Actual and NMR Predicted)
Crude Blending

• To keep pace with changes in regulatory and market forces refineries must be flexible responding to crude oil changes and deviations in product demands.

• Rapid monitoring of the quality of the incoming crude and the outgoing products facilitate efficient operation and increased margins.

• Optimizing “in-house” crude blending strategies can make significant contributions to achieving these goals.
Crude Blending – AI-60 Optimization

On-line NMR measurements of critical LP crude oil properties:
- TBP (True Boiling Point)
- Distillation Curve
- IBP, T(10), T(50), T(90), FBP
- API Gravity
- Water
- Viscosity
- Sulfur
- TAN
## Savings by using NMR

<table>
<thead>
<tr>
<th></th>
<th>$/ Barrel</th>
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</thead>
<tbody>
<tr>
<td>Brent</td>
<td>85%</td>
</tr>
<tr>
<td>Maya</td>
<td>15%</td>
</tr>
<tr>
<td>Blended Crude Cost</td>
<td></td>
</tr>
<tr>
<td>Saving from Light</td>
<td></td>
</tr>
<tr>
<td>Safety margin without NMR</td>
<td>10 %</td>
</tr>
<tr>
<td>Safety Margin Reduction by NMR</td>
<td>5 %</td>
</tr>
</tbody>
</table>

**Saving for typical refinery of 250K BPD capacity**

\[(0.15\times250,000\times300=11,250,000)\]

**$11,250,000 USD per Year**

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The table above illustrates the cost savings achieved by using Nuclear Magnetic Resonance (NMR) technology in crude oil blending. The savings are calculated based on the blending of Brent and Maya crude oils, with respective weights of 85% and 15%, and their respective costs of $55 and $35 per barrel. The blended crude cost is $52 per barrel, which is $3 lower than the cost without using NMR, providing a safety margin of 10% or $0.3 per barrel. With an additional 5% reduction in safety margin through the use of NMR, the savings for a typical refinery with 250,000 barrels per day (BPD) capacity amount to $11,250,000 USD per year.
Custody Transfer
Monitoring system at the pipeline point of entry

- Verifies that the pipeline tender is fully intact and meets receipt/delivery specifications.
- Mitigates supplier liability by reducing tender changes/contamination during pipeline transmission to the end user.
- Provides “early-warning” details of:
  - Stratification of product while in delivery storage tanks prior to shipment
  - Detrimental co-mingling with tank heels from previous tender
  - Asphaltene precipitation (plugging)
  - Water Separation which typically causes corrosion
- Insures proper tender delivery to the End User.
Custody Transfer Critical Properties

The properties measured fall into three categories:

1. Quality/Value Measures:
   a. Distillation Cut Point: IBP; Cumulative Yields at 150°C, 220°C, 350°C, 520°C
   b. Density at 60°C
   c. Simulated Distillation: T10, T30, T50, T70, T90
   d. % Sulfur
   e. Chlorine (including organic chloride)
   f. Mercaptans
   g. Hydrogen sulfide

2. Performance Measures:
   a. TAN (Total Acidity Number)
   b. Asphaltenes
   c. Water

3. Integrity Measures:
   a. TAN (Total Acidity Number)
   b. Asphaltenes
   c. Water
## Measurement Accuracy Required

### Crude Oil measuring conditions:
- Temperature – 10 to 30
- Pressure – 0 to 0.5 Mpa
- Density – 800 to 900 Kg/m³

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Min</th>
<th>Max</th>
<th>Module</th>
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</thead>
<tbody>
<tr>
<td>Mass fraction of hydrogen sulfide</td>
<td>mn-1 (ppm)</td>
<td>0</td>
<td>100</td>
<td>4IR 400</td>
</tr>
<tr>
<td>Mass concentration of chloride salts</td>
<td>mg / dm³</td>
<td>100</td>
<td>900</td>
<td>4IR 410</td>
</tr>
<tr>
<td>Fraction of methyl and ethyl mercaptan</td>
<td>mn-1 (ppm)</td>
<td>0</td>
<td>100</td>
<td>4IR 430</td>
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<tr>
<td>Mass fraction of organic chlorides in fraction boiled to a temperature of 204°C</td>
<td>mn-1 (ppm)</td>
<td>0</td>
<td>10</td>
<td>4IR 420</td>
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<tr>
<td>Water content</td>
<td>%</td>
<td>0</td>
<td>1</td>
<td>AI-60</td>
</tr>
<tr>
<td>Saturated steam pressure</td>
<td>kPa (mm. Hg. v.)</td>
<td></td>
<td>66.7 (500)</td>
<td>AI-60</td>
</tr>
<tr>
<td>Oil density at 60°C</td>
<td>kg / m³</td>
<td>830</td>
<td>900</td>
<td>AI-60</td>
</tr>
<tr>
<td>Sulfur content</td>
<td>%</td>
<td>0.3</td>
<td>3.5</td>
<td>AI-60</td>
</tr>
<tr>
<td>Distillation Cut Point: IBP; Cumulative Yields at 150°C, 220°C, 350°C, 520°C</td>
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<td>Simulated Distillation: T10, T30, T50, T70, T90</td>
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<td>AI-60</td>
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<tr>
<td>TAN (Total Acidity Number)</td>
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<td></td>
<td></td>
<td>AI-60</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td></td>
<td></td>
<td></td>
<td>AI-60</td>
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</tbody>
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System Configuration

Control Unit

**Industrial PC** (Win 10 platform)
Operational Software (Server & Clients)
Communication
i-Model Software

**PLC**
Control peripheral devices
Communication
Alarms

**Communication to Control Room**
Modbus over TCP-IP or RS485
Ethernet (TCP-IP)
4-20mA (Analog)
Digital

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**AI-60 Industrial NMR analyzer**

**4IR 400 H₂S Module**

**4IR 410 Total Chlorides Module**

**4IR 420 Organic Chloride Module**

**4IR 430 Mercaptans Module**

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**Multi-Streams Switching (MSS)**

Sample Condition System (SCS)
Recovery System

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Sample Loop

Crude Oil Stream Loop
Typically organic chloride in crude sources is the result of contamination, unscrupulous dumping into transportation pipelines, tank contamination or refinery slop.

On-line ASTM D7536 technology can provide continuous chlorine (including organic chloride) analysis to monitor the corrosion of plant equipment.

Measurement of the mass concentration of Mercaptans and Hydrogen Sulfide
Sampling from the pipes, and switching between different process streams

Integrated Sample Handling Systems designed to maximize analyzer performance and insure reliable, available measurement.

All systems fully integrated and controlled through 4IR’s process software.
Offshore Production

• The processes in offshore treatment plants are generally rather simple compared to those seen in refineries and chemical plants.

• The AI-60 enables real time monitoring of live crude and offshore produced materials, even as mixtures/emulsions of hydrocarbons, water, dissolved gases, NGLs, etc.

Control Parameters:
- Specific Gravity
- TBP (True Boiling Point) yield
- Aromatic content %
- Olefin content %
- Pour Point
- Water %
- Sulfur %
4IR Solutions provides the ultimate toolbox for the process industry. With its comprehensive range of analytical products, supported by its solutions partners, the 4IR Group offers accurate on-line real time data for every stage of the process.