Magnetic Resonance Technology For Process & Quality Control

By Uri Rapoport

2005 CPAC Fall Sponsor Meeting
ASPeCT Magnet Technologies Ltd.

PROCESS CONTROL

QUALITY END PRODUCT

MAXIMIZED YIELD

INCREASED REVENUES

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Design Criteria for Industrial Use

• 1.5 Tesla
• Efficient Gradients
• Field Of View Optimized for the Application
• Zero External Magnetic Fields
• Portable, Transportable
• Fits ANY Existing Production Environment
• On-line
• No Expert Operation, Fully Automated
• Industrial Grade System Technology
• Industrial speed for Sample Handling
• 24/7 Operation
• Low Maintenance – Short Downtime
• Cost Effective
ASPeCT’s Technology

1. Permanent Magnet
   - 1.0 - 1.8 Tesla
   - Large Field Of View (FOV)
   - Zero field outside = safety
   - No maintenance
   - No power required to operate

2. MRI – Magnetic Resonance Imaging
   - High resolution
   - Micro MRI down to 20 micron
   - The inside of the tested product revealed
   - Specificity

3. MRS – Magnetic Resonance Spectroscopy
   - Chemical composition analysis
4. Non-Invasive Advanced RF Sensor
   • Monitoring chemical reaction
   • Measuring Viscosity
   • Measuring Humidity
   • Measuring Acidity and pH
   • Sample handling monitor
   • Fast continuous measurements < 50 millisecond

5. Software
   • MRI & NMR Sequences – Dedicated for the application
   • Post processing for fully automated operation
ASPeCT’s Technology – On-Line

3 MODALITIES

- MR Imaging
- MR Spectroscopy
- Advanced RF Sensor

ASPeCT System
MR Imaging On-Line - Modality # 1

Room Size Full Body MRI

Brain MRI
MR Imaging On-Line - Modality # 1

One 30 mm MRI slice

30 mm - Slice By Slice

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MR Spectroscopy - Modality # 2

60 MHz 1H Spectrum of a wide range of Crude Oils (0-10 wt% water)

CRUDE OIL AT 80° – 100° C - NOT A PROBLEM ANYMORE

Points 67 and 79 are linearly connected to remove water peak and the data is re-normalized
MR Spectroscopy - Modality # 2

CRUDE OIL AT 80° – 100° C - NOT A PROBLEM ANYMORE

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MR Spectroscopy - Modality # 2

Spectra of plum and avocado

Oil, Fat, Sugar Acidity and more Chemical Structure and Information
Advanced RF Sensor - Modality # 3

NaOH + Cl₂ ----> NaOCl + HCl (hypochlorite)

Fast Continuous Measurements < 50 millisecond
## Advanced RF Sensor – Example Applications

<table>
<thead>
<tr>
<th>Active chemical in sample stream</th>
<th>reagent</th>
<th>Reaction/product</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOH</td>
<td>Water</td>
<td>dilution</td>
</tr>
<tr>
<td>HCl</td>
<td>Water</td>
<td>dilution</td>
</tr>
<tr>
<td>CH3CH2OH (Ethanol)</td>
<td>Water</td>
<td>dilution</td>
</tr>
<tr>
<td>NaCl</td>
<td>Water</td>
<td>dilution</td>
</tr>
<tr>
<td>NaOH (water)</td>
<td>HCl</td>
<td>NaCl/titration</td>
</tr>
<tr>
<td>NaOH (water)</td>
<td>Cl2 (gas)</td>
<td>NaOCl</td>
</tr>
<tr>
<td>NaCl</td>
<td>Milk</td>
<td>dilution</td>
</tr>
<tr>
<td>NaCl</td>
<td>Cheese</td>
<td>salinity</td>
</tr>
</tbody>
</table>
## Advanced RF Sensor – Example Applications

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<thead>
<tr>
<th>Active chemical in sample stream</th>
<th>Reagent</th>
<th>Reaction/product</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Hexane</td>
<td>Petroleum mix</td>
<td>distillation</td>
</tr>
<tr>
<td>Isophthalic acid</td>
<td>Nitric acid</td>
<td>5-nitoisophthalic acid/nitration</td>
</tr>
<tr>
<td>Mg(OH)2 (powder)</td>
<td>Water</td>
<td>Humidity measurement</td>
</tr>
<tr>
<td>FeCl2</td>
<td>Water</td>
<td>Fe(OH)3+dilution</td>
</tr>
<tr>
<td>Crude oil</td>
<td>Cracking/distilation</td>
<td>petrol</td>
</tr>
<tr>
<td>PBBMA</td>
<td>PBBPA</td>
<td>Polymerization</td>
</tr>
<tr>
<td>NaCl or NaOCl or Ethanol</td>
<td>Water</td>
<td>Temperature change</td>
</tr>
<tr>
<td>PIREX</td>
<td>Air</td>
<td>Glass (solid) width</td>
</tr>
<tr>
<td>Vax</td>
<td>Temperature</td>
<td>Viscosity change</td>
</tr>
</tbody>
</table>
ASPeCT’s INNOVATION

3 MODALITIES COMBINED or used INDIVIDUALLY

HOW DO WE DO IT?
MAGNET – Permanent Magnet Technology

- Magnet efficiency **4.1%** (considered very high)
- ZERO Field Outside – Null Fringing Magnetic Fields
- Self Shielded Passively – Magnetically and RF
- Mechanical Stability – Rugged Industrial Grade
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ASPeCT Technology

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MAGNET EFFICIENCY 4.1%

\[
E_{magnet} = \frac{1}{2} \int \int \int m \cdot B \ dv \quad \text{Integration over the volume of permanent magnet}
\]

\[
E_{FOV} = \frac{1}{2} \int \int \int H \cdot B \ dv \quad \text{Integration over the FOV}
\]

\[
\eta = \frac{E_{FOV}}{E_{magnet}} \quad \text{% of usable Energy (Magnet efficiency)}
\]

\[
\eta_{Odin} \sim 0.4\% \quad \text{(Head System)}
\]

\[
\eta_{Hitachi} \sim 1.3\% \quad \text{(Whole Body)}
\]

\[
\eta_{ASPeCT} = \frac{V}{0.21^2 \cdot 0.12 \cdot 390 \cdot 10^3} \cdot \frac{E}{1.4472 \cdot 10^{-3}} = 4.1\% \quad \text{(ASPeCT Industrial Magnet)}
\]
MAGNET - General Points to Remember

- FOV Size – Symmetrical and Nonsymmetrical - tailored for the Application
- Size of Opening
- Multiple Heads - Time Sharing - Modular
- Mobility
- Multiple Streams in One Single Head
- Temperature Shielding – Active and Passive

In Refineries – Multiple or Individual Stream In A Single Magnet
No More Sample Handling Headaches for Multi Stream Needs
Multiple Magnet MRI/NMR

Magnet size
40” X 40” X 35”

Weight
3500 Lb

Magnet Field
B₀=1.2T
Gap=5”
FOV=10” DIA x 5” H

Final Spec is Tailored for Each Application

Single Magnet MRI/NMR

9 - 12 object per second

Object
MAGNET SYSTEM VERSATILITY

Mobility
In Situ

Array of Magnets
Time Sharing
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ZERO External Magnetic Field
MAGNET – The Inside Flux

FEA – Finite Element Analysis
By: Infolytica Corporation

Boundary Elements Program for Design
By: Dr. Shimon Panfil & Dr. Ehud Katznelson

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**GRADIENTS**

- Slew rate 2500T/m/s (250 milli T/m at 0.1 millisecond)
- Gradient Strength 25 Gauss/cm
- Multiple gradient array
- Efficiency - Minimum Volume for the Application

Gradient coils designed in the presence of multi-iron plane

X or Y Gradient
Typical Users - 3 Modalities

- **POULTRY** – Incubators, Process Control and Energy Saving
- **FOODS** – Fresh and Frozen, 100% Inspection
- **PHARMACEUTICAL**
- **LABORATORY ANIMALS** – Desktop Instrument
- **REFINERIES**
- **DOWNSTREAM REFINERY**
- **POLYMERS**
- **GENERAL CHEMISTRY**
- **COSMETICS and PERSONAL CARE**
- **AGRICULTURE** – 100% Versatility
- **HOME LAND SECURITY**
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ASPeCT ASSETS

- CUSTOMERS
- DOZENS of PATENTS WORLDWIDE
- TECHNOLOGY
- KNOW HOW
- SUPERB TEAM

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