Improve Safety and Quality while Reducing Failures with XRF, LIBS and OES
Agenda

• Overview of technologies
• Minimizing global supply chain risks
• Saving money and increasing efficiencies
• Avoiding process failures
• Using different technologies in:
  • Metal production
  • Metal fabrication
  • Failure analysis
• Summary
  • Wrap-up
  • Selecting the right technology
Introduction of Technologies

- Microspot X-Ray Fluorescence (XRF)
- Handheld X-Ray Fluorescence (XRF)
- Handheld Laser-Induced Spectroscopy (LIBS)
- Optical Emission Spectroscopy (OES)
## Technology Overview

<table>
<thead>
<tr>
<th></th>
<th>XRF</th>
<th>LIBS</th>
<th>OES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NDT</strong></td>
<td>Non-destructive</td>
<td>Virtually non-destructive</td>
<td>Destructive</td>
</tr>
<tr>
<td><strong>Form factors</strong></td>
<td>Bulk, microspot, handheld</td>
<td>Benchtop, handheld</td>
<td>Stationary, mobile</td>
</tr>
<tr>
<td><strong>Portability</strong></td>
<td>Excellent with handheld</td>
<td>Excellent with handheld</td>
<td>Mobiles designed with wheels or can be carried</td>
</tr>
<tr>
<td><strong>Purge</strong></td>
<td>Vacuum, helium, air in analysis path or chamber</td>
<td>Not required</td>
<td>Argon (spark) Not required (arc)</td>
</tr>
<tr>
<td><strong>Elemental range</strong></td>
<td>Na – U (EDXRF) Be – U (WDXRF)</td>
<td>Entire periodic table</td>
<td>Similar to XRF + C, N, B, Li, Be</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Fast measurements, may require minimal sample preparation</td>
<td>Fastest measurements</td>
<td>Sample preparation takes longer than measurements</td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td>Empirical and theoretical</td>
<td>Empirical</td>
<td>Empirical</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>As good as calibration standards</td>
<td>As good as calibration standards</td>
<td>As good as calibration standards</td>
</tr>
<tr>
<td><strong>Detection limits</strong></td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$ - $$$$</td>
<td>$ - $$</td>
<td>$$ - $$$$$</td>
</tr>
</tbody>
</table>
Minimize Global Supply Chain Risks
Supply Chain Management

Manufacturing

Can you control all your incoming material?

Who is responsible for goods that leave your facility?

Can you control your process?

YOU!
Supply Chain Management

Potential concerns

- Unknown suppliers
- Unknown raw material
- Negligence
- Deception
- Counterfeit parts

…but you’re responsible for product going out your door
Supply chain and XRF

- RoHS

- CPSIA

- Packaging directive

- ASME Boiler and Pressure Vessel Code

- Manufactured goods are a combination of the above
Supply Chain Management

Raw materials supply

- Mineral ore
- Polymers
- Chemicals
- Un-formed metal alloys
Supply Chain Management

Component-level manufacturer

- Fasteners
- PCB manufacturer
  - Component manufacturer
  - Solder manufacturer
- Fabricator
OEM

- Aerospace assembler
- Children’s products manufacturer/retailer
- Electronics manufacturer
What can you do?

- Trust your suppliers, but **verify**
- Request certificates of compliance
- Test incoming materials
- Test outgoing product

A combination of ALL of the above
Metal Producers
Metal Producers

- Metal life cycle
Metal Producers

- Ensure melt chemistry
  - Verify incoming scrap matches specifications
  - Detect poison elements
  - Test raw ores, ferrometallic additives
- Outgoing QC
  - Verify target chemistry was achieved
  - Certify batch chemistry
  - Warehouse screening
- Test internal scrap
  - Re-use
  - Sell
- On-site supplier vetting
<table>
<thead>
<tr>
<th>Metal Producers</th>
<th>HHXRF</th>
<th>LIBS</th>
<th>OES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incoming material inspection, internal scrap</strong></td>
<td>Scrap metal</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Scrap metal</td>
<td>Rapid, non-destructive testing</td>
<td>Fastest metal sorting for high volume</td>
</tr>
<tr>
<td></td>
<td>Scrap metal – poison elements</td>
<td>Most elements available</td>
<td>Picks up some elements XRF can’t</td>
</tr>
<tr>
<td></td>
<td>Minerals</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Outgoing QC</strong></td>
<td>Batch certification</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Warehouse screening</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>On-site supplier screening</strong></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Metal Fabricators
Metal Fabricators

Fabricator/Manufacturer
Metal Fabricators

- Start with metals and finish with different shape or size, or create completed assembly
- Outgoing products are built to customer specifications
- Best (or only) chance to verify composition is incoming inspection
- Metals should arrive with material test report (MTR) but…
  - May be incorrect or incomplete
  - Residual elements may not be included or tested
• In oil & gas industry:
  • Mechanical integrity is biggest source of “large property damage losses”
  • Per API 578 “Mill test reports should not be considered a substitute for a PMI test.”
  • Installing equipment with an erroneous MTR could result in catastrophic release of hazardous chemicals or energy
  • Fabricators may be required to test before shipping products
Metal Fabricators

- Verify incoming materials
  - Reject off-spec material
  - Additional information to MTR
  - Ensure they go into right warehouse location
- Quality control
  - Last check before goods leave the production line
  - Create certificate
- Welding inspection
## Metal Fabricators

<table>
<thead>
<tr>
<th></th>
<th>HHXRF</th>
<th>OES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incoming inspection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal sheet, coil, billet</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Warehouse screening</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Outgoing QC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDT verification</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Seal of approval</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Warehouse screening</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Internal scrap</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Weld inspection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>When C not needed</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>In situ</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Monitoring Process Equipment
Engine/Motor Failure

- Why engines and motors fail
  - Stress due to friction/contact
  - Excessive heat build-up
  - Wrong fuel blend
  - Neglect
- Engines and motors drive many industrial processes
- Failures result in down-time
Engine/Motor Failure

- Replace or repair?
- When the engine fails, what can you measure to determine root cause?
  - Analyze oils lubricant
  - Look at ratios of metals to determine particles
  - Analyze fuel to ensure proper fuel, compliance to regulations
- Test with laboratory XRF systems
Engine/Motor Failure

- Analyze 20+ elements in ~10 minutes
- No sample preparation
- Unattended instrument operation

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Calibration range</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>0 – 3500</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Al</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>P</td>
<td>0 – 0.40</td>
<td>% m/m</td>
</tr>
<tr>
<td>S</td>
<td>0 – 1.00</td>
<td>% m/m</td>
</tr>
<tr>
<td>Cl</td>
<td>0 – 4000</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Ca</td>
<td>0 – 0.40</td>
<td>% m/m</td>
</tr>
<tr>
<td>Sn</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Ti</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>V</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Cr</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Mn</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Fe</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Co</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Ni</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Cu</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Zn</td>
<td>0 – 0.40</td>
<td>% m/m</td>
</tr>
<tr>
<td>Pb</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
<tr>
<td>Mo</td>
<td>0 – 400</td>
<td>mg.kg(^{-1})</td>
</tr>
</tbody>
</table>
**Sample result:**

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration</th>
<th>Scaled to 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti</td>
<td>5ppm</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>8ppm</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>80ppm</td>
<td>16%</td>
</tr>
<tr>
<td>Fe</td>
<td>360ppm</td>
<td>72%</td>
</tr>
<tr>
<td>Ni</td>
<td>50ppm</td>
<td>10%</td>
</tr>
<tr>
<td>Mo</td>
<td>10ppm</td>
<td>2%</td>
</tr>
<tr>
<td>Sn</td>
<td>6ppm</td>
<td></td>
</tr>
</tbody>
</table>

UNS SS316
Engine/Motor Failure

- How XRF could have helped avoid the failure
  - Establish routine lubricant monitoring to develop working history
  - Develop predictive models to determine when the oil should be replaced
  - Test fuels before use

- Avoid costs from unexpected failure and costs of unnecessary maintenance
Inspecting Critical Components
• When the component fails, what can you measure to determine root cause?
  • Analyze metal components
    • FAC: was Cr value low
    • PMI: was the right alloy used

• Test with handheld XRF systems
• Flow Accelerated Corrosion (FAC)
  • Metals form a protective oxide layer inside carbon steel pipes
  • Oxide layer is removed by the high temperature and pressure process steam
  • Corrosion and erosion thin the walls of the components until they eventually rupture
  • Track Cr, Cu, Mo
Mihama-3 Accident

- August 9, 2004
- 200 miles west of Tokyo
- 5 workers killed, 6 injured
- Carbon steel pipe carrying 300°F degree steam ruptured
- Hole in the pipe measured nearly 2’ long
- Pipe wall thinned from 10mm to 1.5mm (less than 1/3 the minimum safety standard)
- Pipe had not been inspected since installation in 1976
• How XRF could have helped avoid FAC failure
  • Establish baseline for corrosion indicators
    • Cr < 0.1% indicates accelerated corrosion
  • Schedule routine inspections to monitor indicators
  • Develop predictive models to know when to remove component from production
Cr content = 0.07
Corrosion rate = 8 units/year

If the wall thickness today is 100 units, the component should be replaced in 6.25 years

Replace at 50 units
• Remove process equipment before failure
• Planned obsolescence saves money
• Improve process efficiency
In summary

- Microspot X-Ray Fluorescence (XRF)
- Handheld X-Ray Fluorescence (XRF)
- Handheld Laser-Induced Spectroscopy (LIBS)
- Optical Emission Spectroscopy (OES)
Conclusion

- As a producer or supplier, you are part of the supply chain
- Managing a supply chain requires internal and external focus
  - Enhance your production at incoming inspection
  - Ensure your quality at QC and shipping
- Increasing tests on supply chain will:
  - Improve your quality
  - Reduce failures
  - Improve safety
  - Save money
- XRF, LIBS and OES provide valuable information
Selecting the Right Instrument

- There are many choices
  - Technology
  - Manufacturer
  - Form factor
- Need to define how and where the instrument will be used
  - What elements are important?
  - What concentration range do you need?
  - What form are the samples in?
  - Will the instrument be stationary or mobile?
- There is no one-size-fits-all instrument
- Work with Applications team to make a good choice
## Selecting the Right Instrument

<table>
<thead>
<tr>
<th>Material Type</th>
<th>HH XRF</th>
<th>HH LIBS</th>
<th>OES</th>
<th>µ-spot XRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrap metal</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Metal finished goods</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Restricted materials</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fraudulent components</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Electronics</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Polymers</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Metal platings</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Oil Analysis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory testing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mobile testing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Thank you!

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