Direct Hydrocarbon Leak Detections based on Nanocomposite Sensors
Contents

• Needs for Leak Detection Sensors
  – Review of Leak Detection Systems
• Platform Technology
  – Nanocomposite Sensors: direct hydrocarbon detections
• Direct-C Products
• Strain Sensing
Situation: Pipeline Leaks

- **Average pipeline has a 57% probability of experiencing a major leak in 10 year period***
  - Estimates that a leak detection systems would reduce the impact by 75%
  - Benefit of leak detection is $600,000 per 1,000 km


Extreme environmental impact & Safety

Causes negative public perceptions
Leak Detection Monitoring

• Current pipeline leak detection is a compromise
  – Internal Systems (ILI)
    • Limited accuracy – indirect detection
    • Affected by operational changes
  – External Systems
    • Higher accuracy – direct hydrocarbon detection
    • Immune to operational changes
    • Capable of continuous real time monitoring
    • Relatively new
    • Stand-alone – higher cost for implementation

EXTERNAL SYSTEMS hold greater promise for accurate leak detection
Leak Detections

Existing External Detections

- Visual & Air monitoring
- Mass flow/Pressure differences
- Fibre optic (temp & strain)
- Acoustic sensors
- IR Camera

Extremely difficult to directly detect SMALL & SLOW LEAKS

Leak Detection Study – DTPH56-11-D-00001. For the U.S. DOT PHMSA. December 10, 2012
Our Solution

- Proprietary, *polymer-based* “paint” *substance mixed with nanoparticles* capable of detecting oil leaks.

- Deployed to monitor oil pipelines using 3 techniques:
  1. **Ground probes** (existing pipes)
  2. **Wrap/patch** (new or existing pipes -- high consequence areas)
  3. **Coating** (new pipes)
Our Solution

• Uses carbon nanotubes, admixed with proprietary polymer, to form a nanocomposite.

• As polymer swells upon absorption of HC’s, the increased volume augments the distance between adjacent nanotubes, thereby increasing sensor resistance.

• Ability to determine hydrocarbon types (light, medium, heavy). Insensitive to methane (biogenic or thermogenic).

• 2 patent applications for sensor composition and methods of deployment.
Addressing Limitations in Existing LDS

Direct-C LDS Advantage
(What limitation does it address in each LDS alternative)

- More accurate location detection
- Detects very small leaks (SCADA, CPM cannot detect leaks <1% of flow)
- More reliable (fewer false alarms)
- Directly detects hydrocarbons (SCADA, CPM uses product flow to infer leak)
- No specialized modeling (algorithms and numerical techniques)

- Easier to install & maintain (lower cost, no need to trench and run cables)
- More reliable (Lower risk of false alarms)
- Directly detects hydrocarbons (not relying on a proxy such as sound/vibration, temp.)
- Lower operating costs

Source: Leak Detection Study - U.S. Department of Transportation PHMSA
Market Applications

Broad applications within the entire oil supply chain.
Exposure – Sensitivity tests

- Purpose of test: determine the relationship between amount of exposure and response of the sensor element

- Increased exposure to small amount of motor oil (100, 200 and 300 micro liter)

- Saturation at 5 ml exposure

<table>
<thead>
<tr>
<th>Amount of Exposure (µl)</th>
<th>% increase (ΔR/R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>31</td>
</tr>
<tr>
<td>200</td>
<td>61.5</td>
</tr>
<tr>
<td>300</td>
<td>145</td>
</tr>
</tbody>
</table>

*Increase in sensitivity with respect to amount of exposed hydrocarbon*
Produced water tests

- Use of industrial produced water (contains hydrocarbon contaminated water)

- Three liquid portion were taken out from the solution
  - Top layer oil, bottom layer water and mixture

*Capable of sensing hydrocarbon contamination in Water*
Selective Hydrocarbon Detection Capability

**Liquid Phase**

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Instantaneous Slope (in degrees first 10 seconds of response)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentane</td>
<td>89.3</td>
</tr>
<tr>
<td>Octane</td>
<td>88.8</td>
</tr>
<tr>
<td>Diesel</td>
<td>73.4</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>9.3</td>
</tr>
<tr>
<td>Motor Oil</td>
<td>6.3</td>
</tr>
</tbody>
</table>

**Gas Phase**

<table>
<thead>
<tr>
<th>HC</th>
<th>% resistance change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>0</td>
</tr>
<tr>
<td>Ethane</td>
<td>4.3%</td>
</tr>
</tbody>
</table>

**Three level of Hydrocarbon detection:**

**High Level:** Highly volatile hydrocarbons such as pentane, hexane, and other similar diluents

**Medium Level:** Detection of medium volatility hydrocarbons such as diesel, kerosene

**Low level:** Detection of heavy hydrocarbons, refined hydrocarbons, and non-volatile hydrocarbons

*Capable of Selectively identifying the leaked hydrocarbons*
Under Organic Soil (Compost) Tests

Two tanks with buried pipe wrapped with a prototype sensor

a) Control tank: No oil leakage
b) Test tank: with controlled oil leakage

Test tank

Capable of working under organically rich soil – No False Alarms
Temperature tests

Temperature stability tests

Temperature cycle tests

Less than baseline variation within the temperature range of (0 to 50 °C)

Stable behaviour (low hysteresis and no drift due to temperature)

Stable Temperature Behaviour

Private and Confidential
High Pressure (Compaction) Tests

Without leak - compaction

With leak - compaction

Capable of detecting leakage under HIGH COMPACTION
Long term Environmental Tests

- Sensor exposed to exhaust
- Tested over 6 months during July to February in Calgary (Temperature range of 30 to –30 °C)
- The sensors inside the exhaust are at high temperature (55 to 75°C)
- Sustained sun, rain, hail storm, snow during testing

Robust sensors, capable of withstanding extreme environmental conditions
SubSense LDS

- Leak detection sensor and communication system for existing pipelines
- *Off pipe;* easy retrieval of sensors for regular maintenance
- Economical; pipeline excavation not required
- Direct detection within +/- 10 meters
- Suitable for high consequence areas (water crossings or urban areas)
- 24/7 remote monitoring, response within one minute of oil detection
SubSense LDS

- Performed third-party controlled test at C-Core, summer 2017
- Tested with water, gasoline, diesel and crude oil under various soil moistures
- Results:
  - Stable even when fully *submerged* in water for long time
  - *Large response within one minute* for every Hydrocarbon tested as soon as the liquid HC contacted the sensor
SubSense LDS

Saturated Voltage Level

5% Water/Sand mixture

Oil held between sensor 2 and 3 for six minutes

All 3 sensors are saturated

Voltage [V]

Time [Minutes]
WrapSense LDS

• Patch/Wrap fixed *on pipe*
  – Can be installed as sleeve
  – Provides protection as well as leak detection
  – Ideal for *Field joints*
Intelligent Pipe Leak Detection System (LDS)
Nano Material-based Direct Leak Detection Coating

Three layers of coating:
1. Fusion Bonded Epoxy (FBE) – standard corrosion-resistant coating
2. Adhesive Coating – standard tie layer
3. Sensor Coating:
Surface Casing Vent Alarm for Well

- E&P companies responsible for monitoring oil leaks from **surface case vent flow (SCVF)** on oil wells.
- Failure to monitor/address such leaks can lead to substantial enviro/remediation costs and well bore damage.

*Schematic drawing of proposed Direct-C alarm fastened to SCVF pipe.*

- Direct, rapid, and accurate detection of oil leaks
- Continuous monitoring and data logging capabilities.
- Easy to install. Disposable.
- Able to withstand extreme temperature and operating conditions.
### Key LDS Performance Criteria & Direct-C LDS

<table>
<thead>
<tr>
<th>Performance Criterion</th>
<th>Optimal / Target</th>
<th>Direct-C Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>&lt; 1/Month *</td>
<td>High</td>
</tr>
<tr>
<td>Location Detection Accuracy</td>
<td>+ / - 10 meters *</td>
<td>High</td>
</tr>
<tr>
<td>Sensitivity / Scale of Leak</td>
<td>&lt; 5m³ / hour *</td>
<td>Very High</td>
</tr>
<tr>
<td>Speed / Response Time</td>
<td>Within a few minutes *</td>
<td>Instantaneous</td>
</tr>
<tr>
<td>Continuous Monitoring</td>
<td>Continuous monitoring</td>
<td>Yes</td>
</tr>
<tr>
<td>Direct Detection</td>
<td>Direct detection</td>
<td>Yes</td>
</tr>
<tr>
<td>Effective in Steady-state &amp; transient conditions</td>
<td>Steady-state &amp; transient</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Direct-C LDS satisfies each of the most critical factors with regard to effective leak detection:

- *Offers very reliable detection (few false alarms) in both transient & steady-state operation*
- *Instantaneous response*
- *Highly sensitive in detecting small leaks*
- *Able to precisely detect the location*
Thank you

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