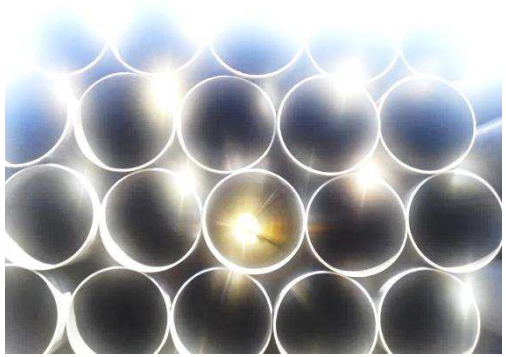
November 2017



Direct Hydrocarbon Leak Detections based on Nanocomposite Sensors

DIRECT-C
LEAK DETECTION SYSTEMS

Contents

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

DIRECT-C LEAK DETECTION SYSTEMS

TECH TO BUSINESS INNOVATE CALGARY

UNIVERSITY OF CALGARY

Situation: Pipeline Leaks

Nexen Leaks, 2015
(Edmonton Journal)

- **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

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

Kaohsing, Taiwan explosion 2014

www.democracynow.com

Extreme environmental impact & Safety

Causes negative public perceptions

Leak Detection Monitoring

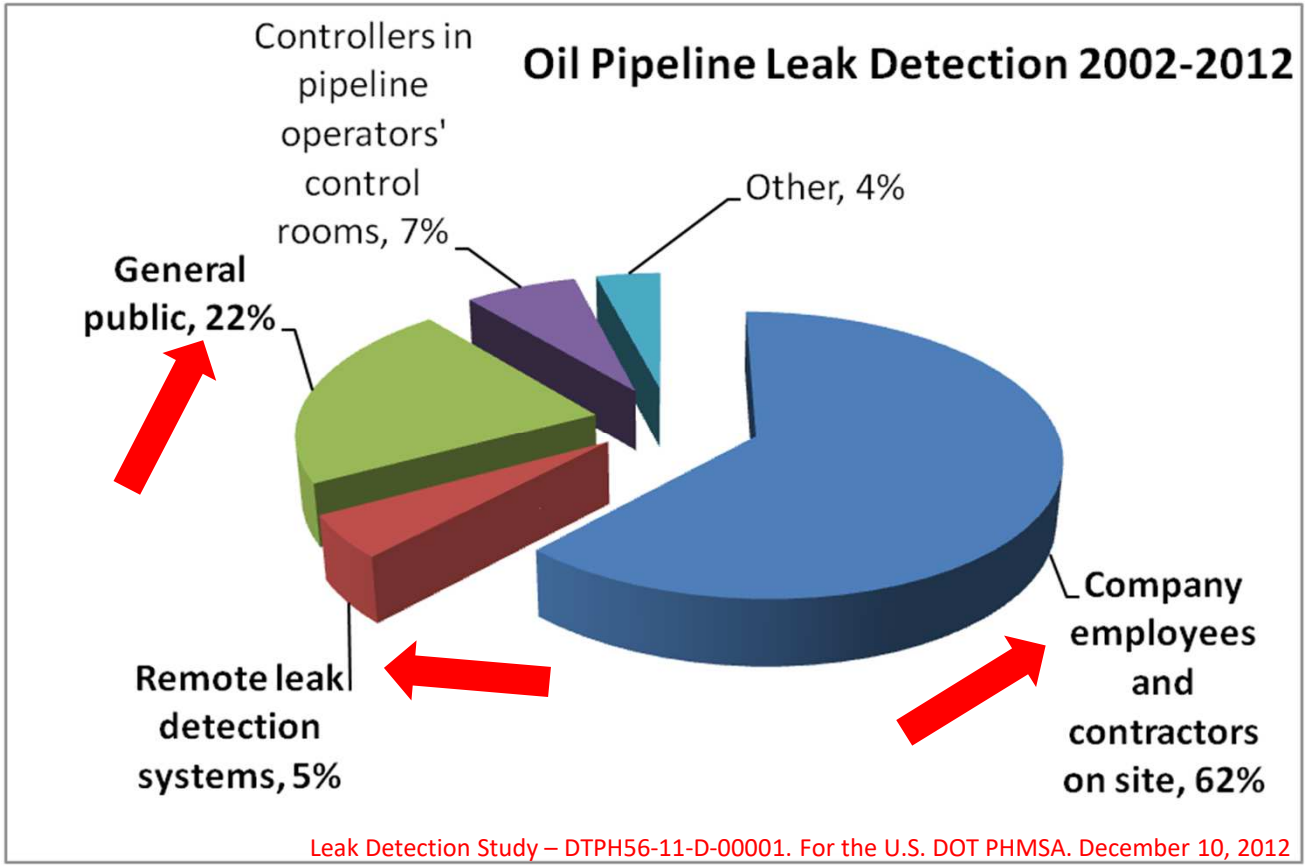
- Current pipeline leak detection is a compromise
  - Internal Systems (ILI)
    - Limited accuracy – indirect detection
    - Affected by operational changes
  - External Systems
    - Higher accuracy – direct hydrocarbon detection
    - Immune to operational changes
    - Capable of continuous real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

EXTERNAL SYSTEMS hold greater promise for accurate leak detection

Leak Detections

Existing External Detections

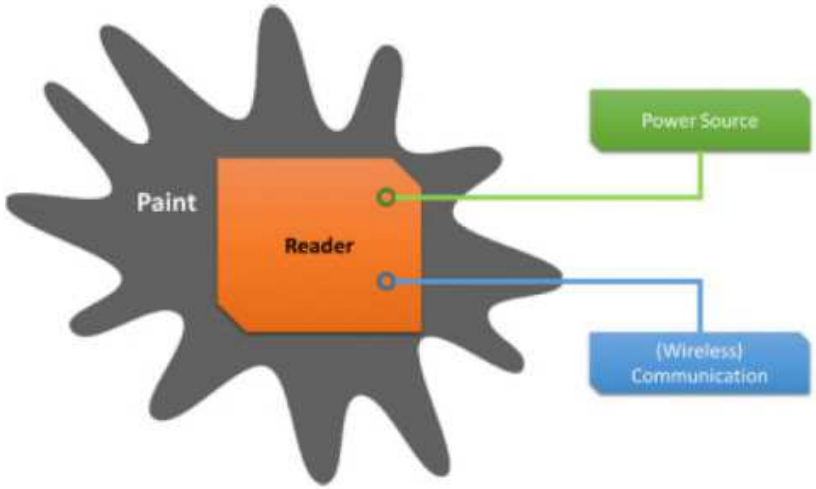
- Visual & Air monitoring
- Mass flow/Pressure differences
- Fibre optic (temp & strain)
- Acoustic sensors
- IR Camera

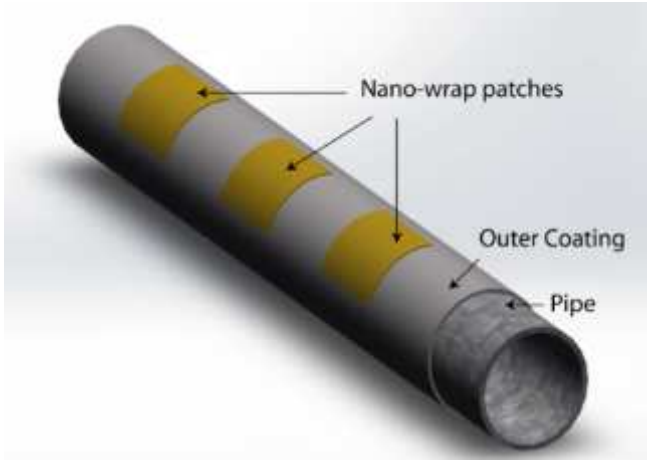


Extremely difficult to directly detect SMALL & SLOW LEAKS

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)





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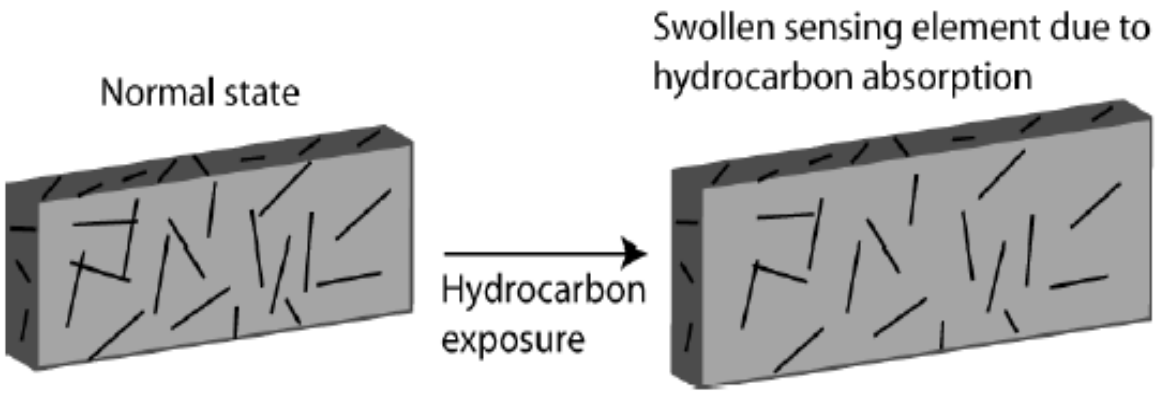
Our Solution

- 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 deployme



Addressing Limitations in Existing LDS

		Direct-C LDS Advantage (What limitation does it address in each LDS alternative)
Internal LDS	SCADA (Pressure & Flow) CPM using material balance Negative pressure wave monitoring Real-Time Transient Modeling (RTTM)	▪ **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)
External LDS	Acoustic Fiber Optic Cable	▪ **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.

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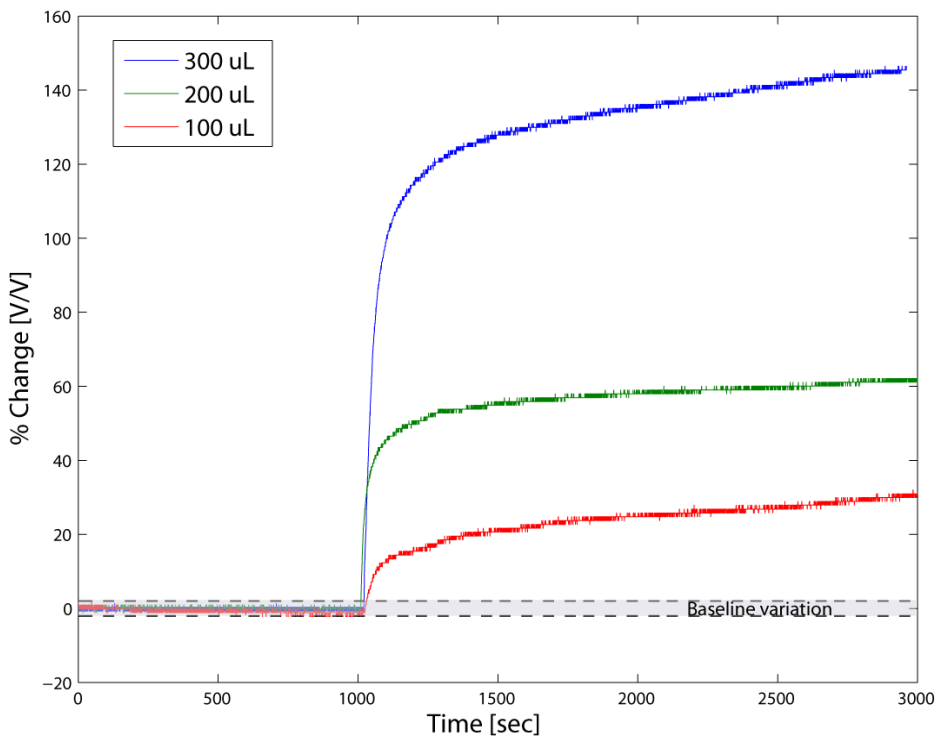
Exposure – Sensitivity tests

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



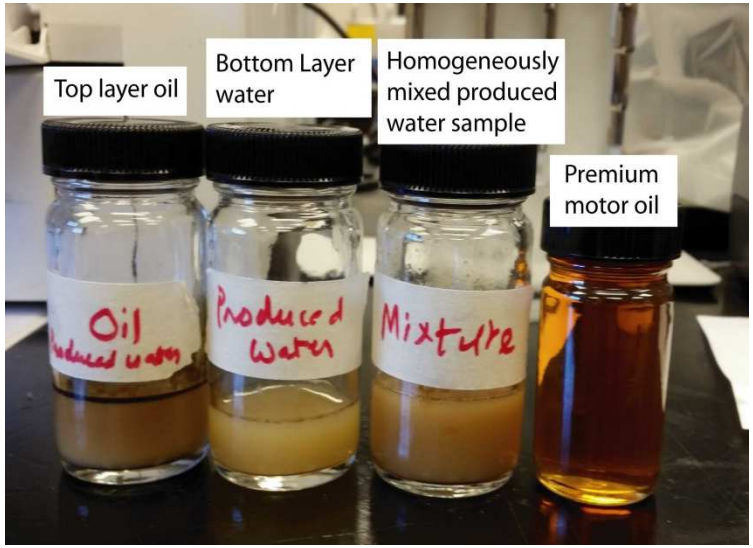
- Increased exposure to small amount of motor oil (100, 200 and 300 micro liter)
- Saturation at 5 ml exposure

Amount of Exposure (µl)	% increase (ΔR/R)
100	31
200	61.5
300	145

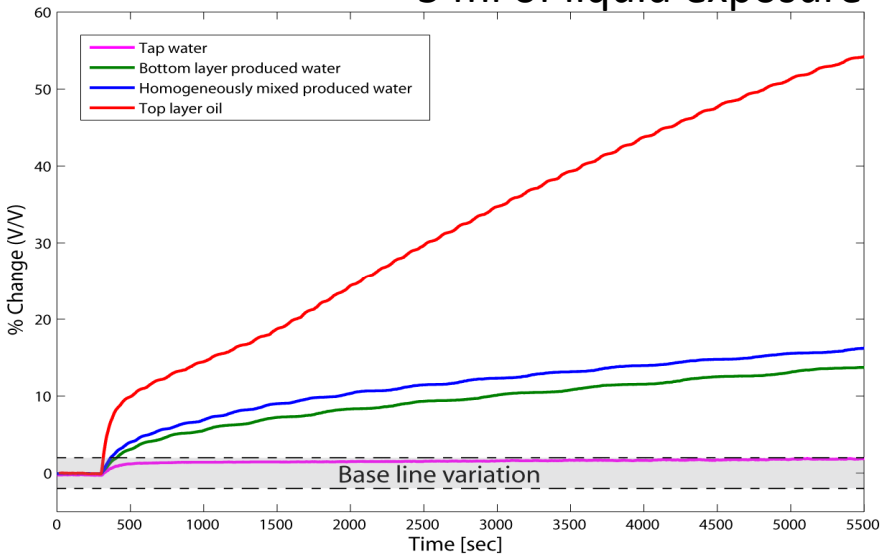
Increase in sensitivity with respect to amount of exposed hydrocarbon

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



5 ml of liquid exposure



Capable of sensing hydrocarbon contamination in Water

Selective Hydrocarbon Detection Capability

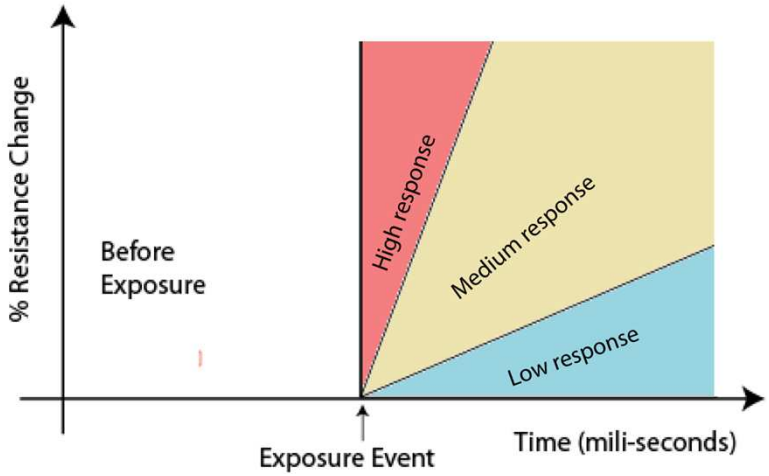
Liquid Phase

Hydrocarbon	Instantaneous Slope (in degrees first 10 seconds of response)
Pentane	89.3
Octane	88.8
Diesel	73.4
Crude Oil	9.3
Motor Oil	6.3

Gas Phase

HC	% resistance change
Methane	0
Ethane	4.3%

Capable of Selectively identifying the leaked hydrocarbons



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

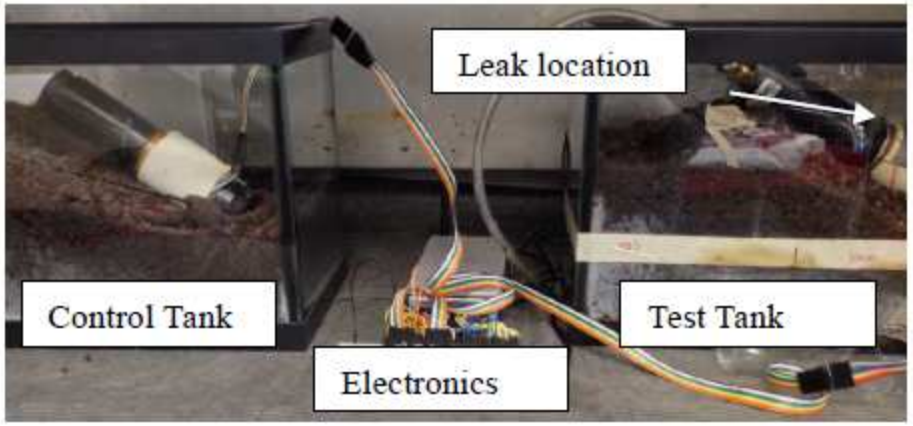
Low level: Detection of heavy hydrocarbons, refined hydrocarbons, and non-volatile hydrocarbons

Under Organic Soil (Compost) Tests

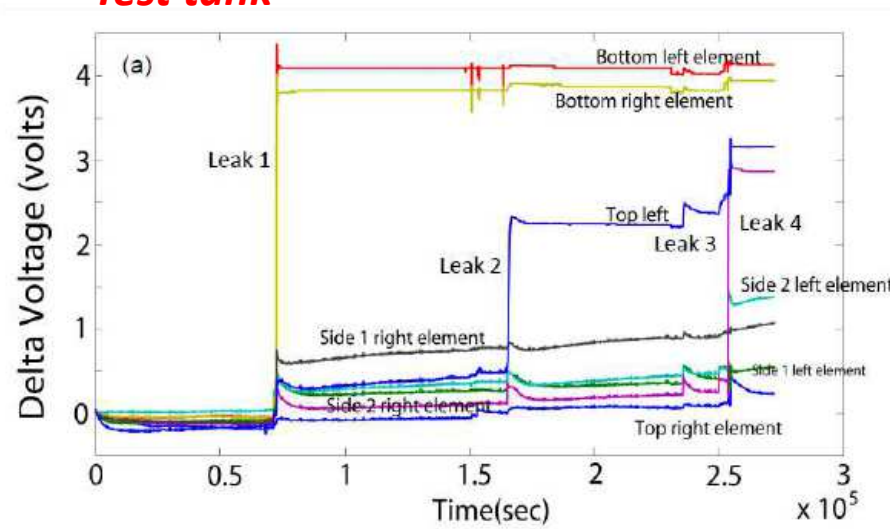
Two tanks with buried pipe wrapped with a prototype sensor

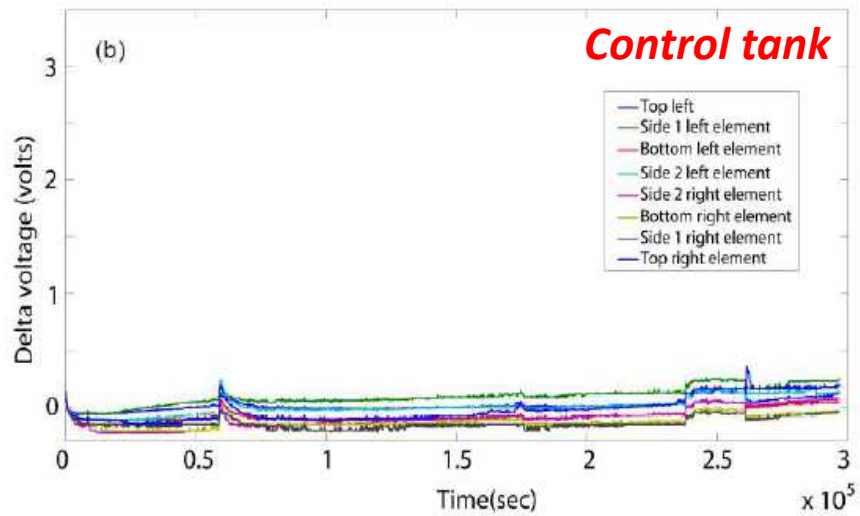
a) Control tank: No oil leakage

b) Test tank: with controlled oil leakage



Test tank

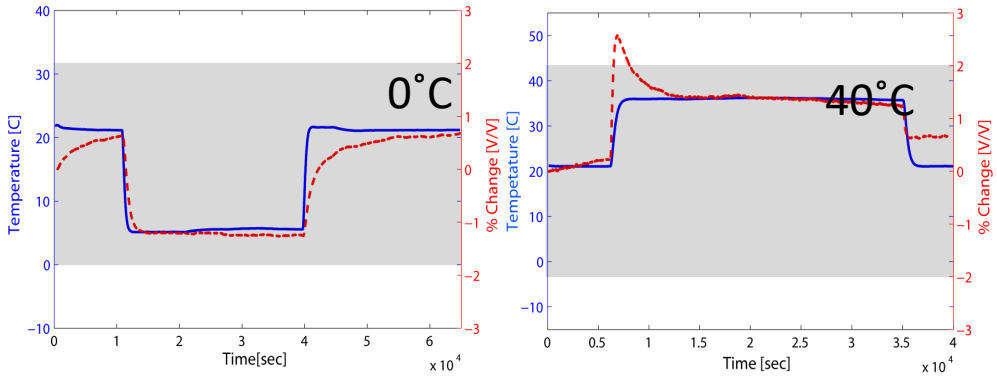




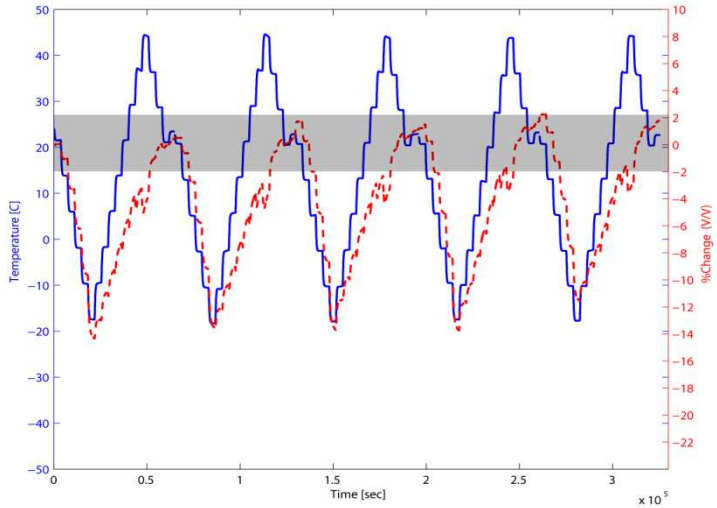
Capable of working under organically rich soil – No False Alarms

Temperature tests

Temperature stability tests



Temperature cycle tests



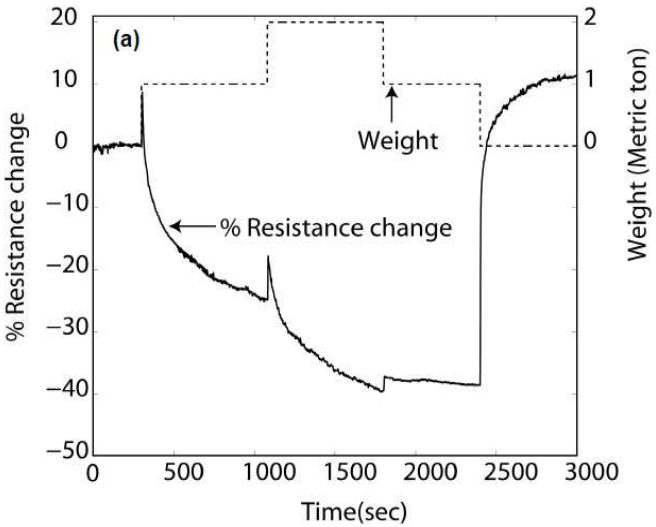
Less than baseline variation within the temperature range of (0 to 50 ˚C)

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

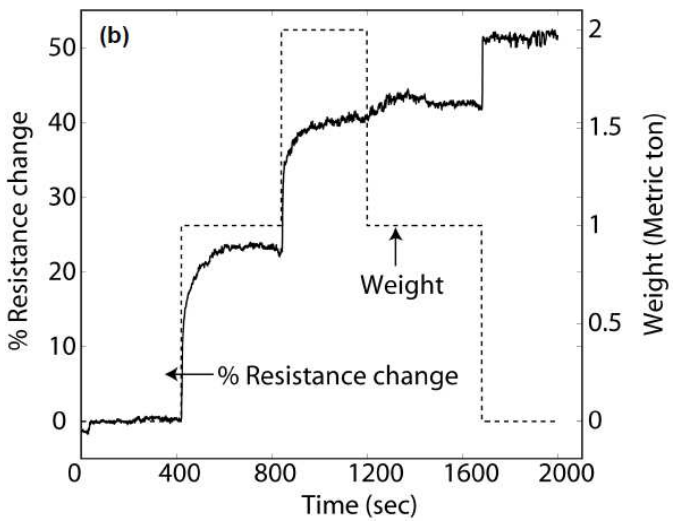
Stable Temperature Behaviour

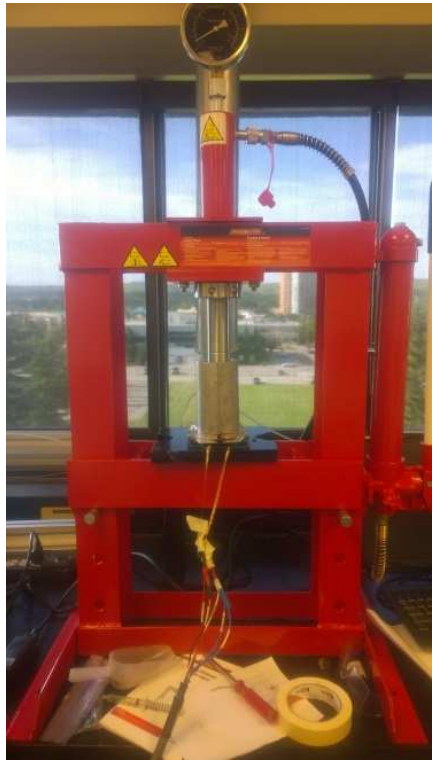
High Pressure (Compaction) Tests

Without leak - compaction



With leak - compaction

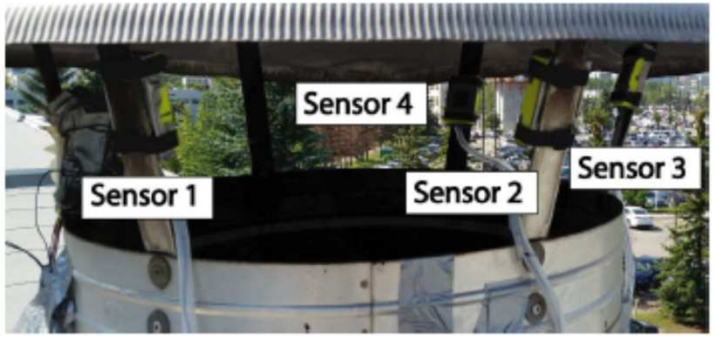


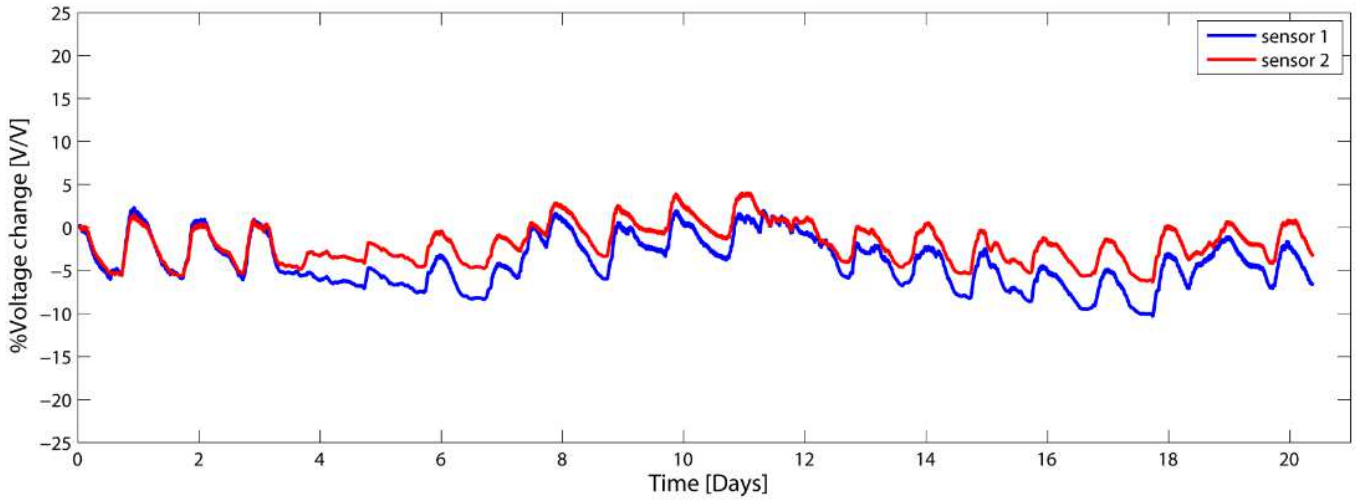


Capable of detecting leakage under HIGH COMPACTION

Long term Environmental Tests

- Sensor exposed to exhaust
- Tested over 6 months during July to February 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

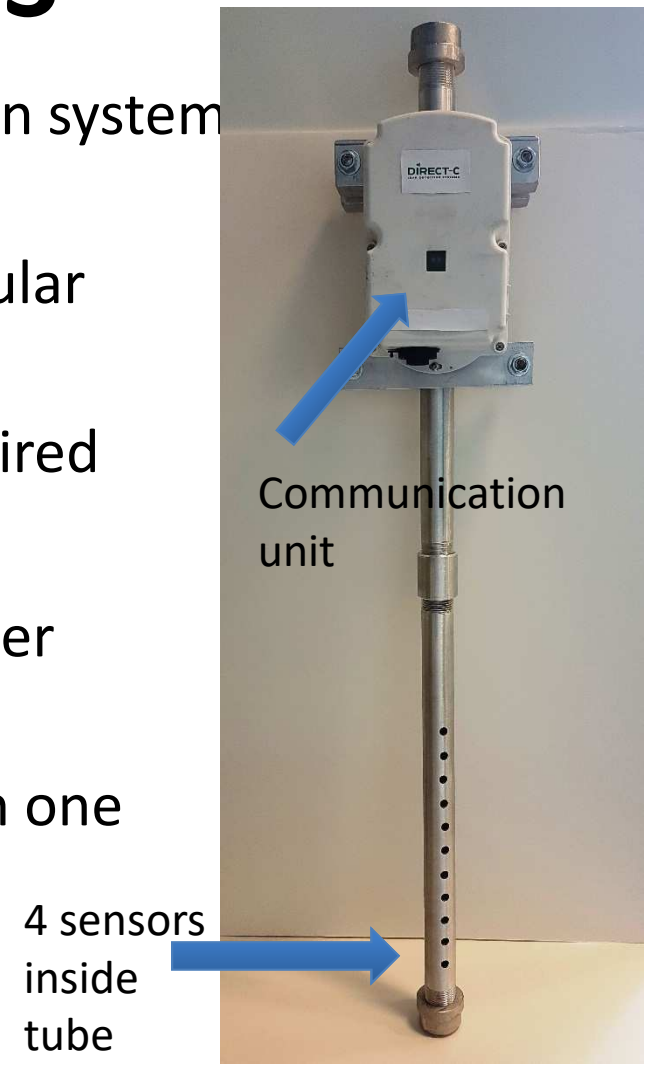




Robust sensors, capable of withstanding extreme environmental conditions

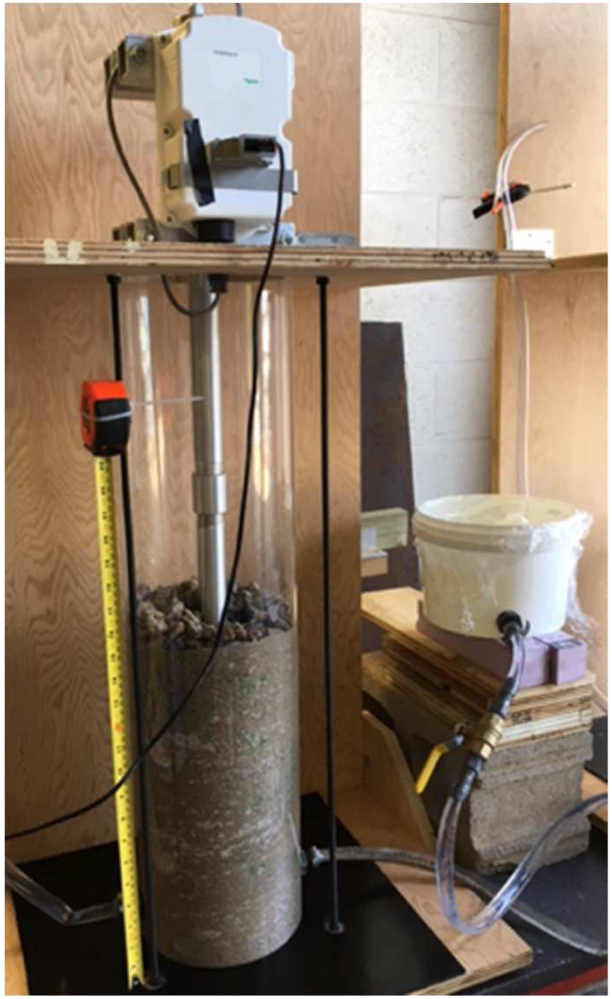
SubSense LDS

- Leak detection sensor and communication system for <u>existing</u> 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

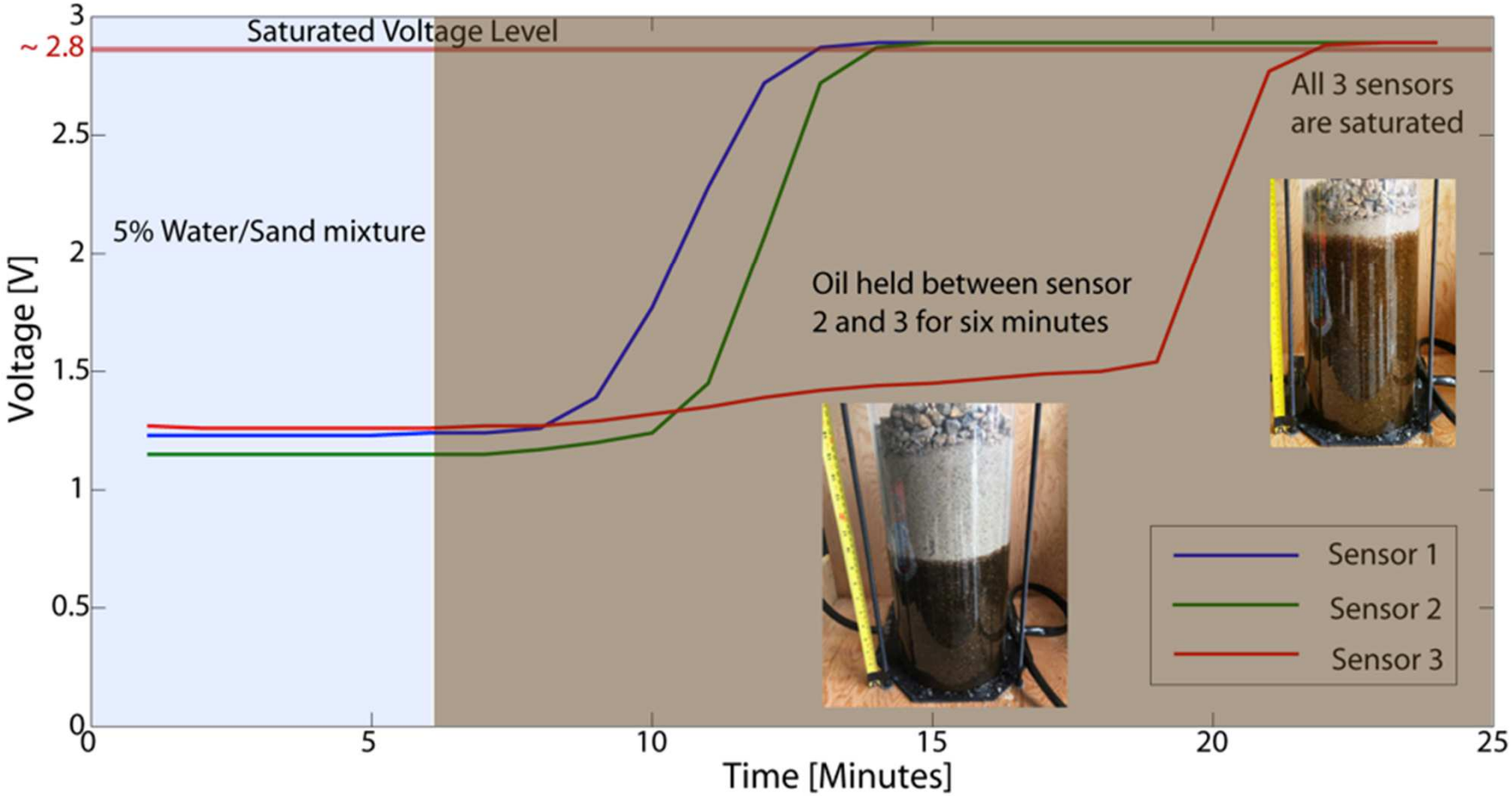


SubSense LDS

- 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

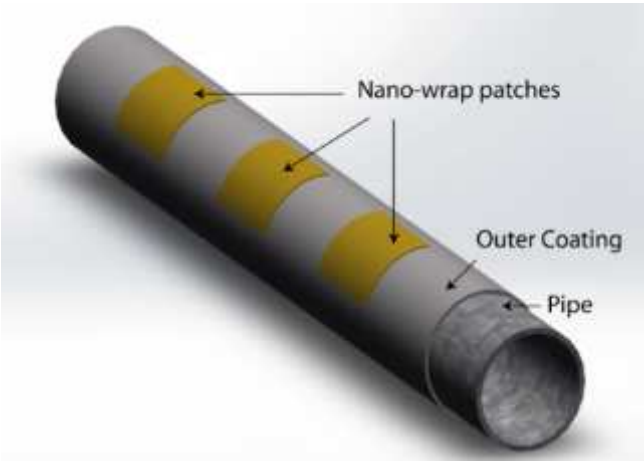


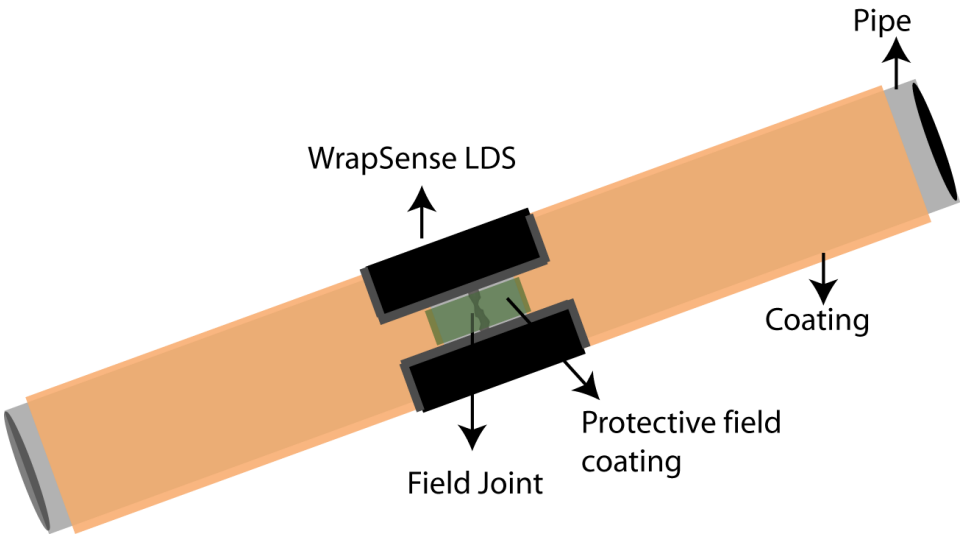
SubSense LDS



WrapSense LDS

- Patch/Wrap fixed *on pipe*
  - Can be installed as sleeve
  - Provides protection as well as leak detection
  - Ideal for *Field joints*





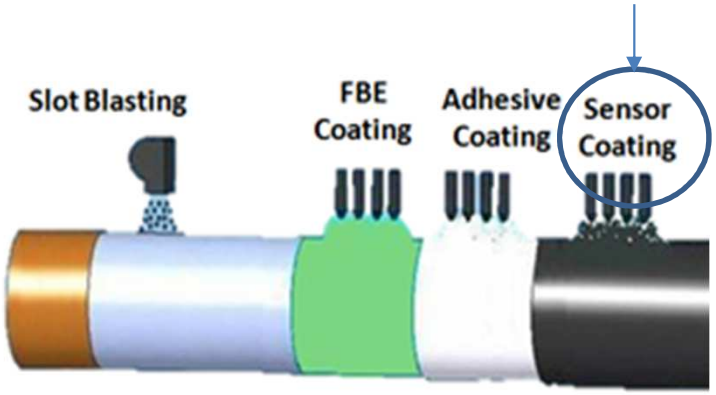
Intelligent Pipe Leak Detection System (LDS)

Nano Material-based Direct Leak Detection Coating

Three layers of coating:

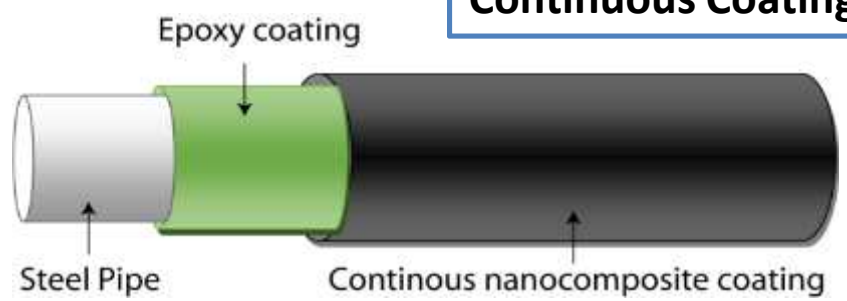
1. Fusion Bonded Epoxy (FBE) – standard corrosion-resistant coating
2. Adhesive Coating – standard tie layer
3. Sensor Coating:

Direct-C Technology

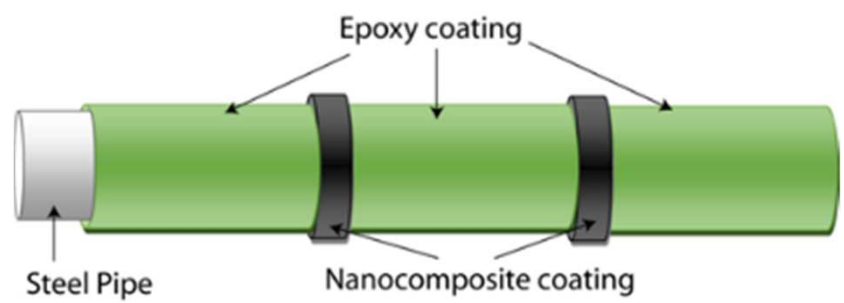


Fabrication process

Continuous Coating

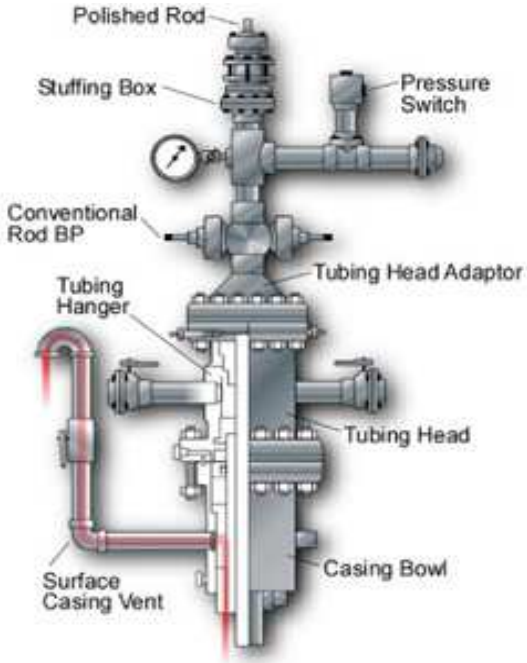


Discrete Sensor Coating



Surface Casing Vent Alarm for Well

- E&P companies responsible for monitoring oil leaks from <u>surface case vent flow (SCVF)</u> 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

Performance Criterion	Optimal / Target	Direct-C Capability
Reliability	< 1/Month *	**High** ✓
Location Detection Accuracy	+ / - 10 meters *	**High** ✓
Sensitivity / Scale of Leak	< $5m^3$ / hour *	**Very High** ✓
Speed / Response Time	Within a few minutes *	**Instantaneous** ✓
Continuous Monitoring	Continuous monitoring	**Yes** ✓
Direct Detection	Direct detection	**Yes** ✓
Effective in Steady-state & transient conditions	Steady-state & transient	**Yes** ✓

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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