LEOS
Leak Detection and Localization System
LEOS Detection and Localization of smallest Leaks

Key element of risk management
Tardily detected chronic leaks on pipelines and tanks with hazardous media constitute one of the highest operational risks. LEOS provides a central tool for efficient risk management, since its variety of detectable media such as crude oil, CO, chlorine gas, etc. offer attractive safety benefits for operators of pipelines, tank farms and chemical facilities.

Avoidance of expensive secondary damages
Chronic leaks mostly remain undetected by conventional methods (mass balance, pressure difference). However, this limitation collides with increasing needs for the protection of humans and nature. While conventional methods require a leak rate of at least around 1% of the throughput for online detection, the LEOS system will alert already at leak rates as low as 1 Liter per hour – and even independent of the throughput of the pipeline!
An early-stage detection of leakages by LEOS significantly supports the operator in avoiding expensive secondary damages, production downtimes and environmental contamination.

Reduction of erection costs
Numerous clients were already successful in achieving a more cost-effective pipeline route by selecting our LEOS system. This measure allowed more direct and hence less expensive routes through e.g. water protection areas.
In addition, the gain in safety from a LEOS installation can also contribute to reduce public concerns against disputed pipeline projects. In particular in densely-populated urban areas, LEOS makes a valuable contribution to an efficient crosslinking of individual chemical facilities via underground pipelines.

LEOS - over 30 years of experience in the field of leak detection

LEOS features at a glance
- Extremely high detection sensitivity (typical 1 l/h liquids, 100 l/h gases)
- Fast response time (typical 2 - 24 h)
- High accuracy of leak localization (0.5 % of monitored length: e.g. 50 m on 10 km)
- Automatic integral self-test
- Very low operation and maintenance costs
- Identification of leak substance possible (by use of special gas analysers and air sampling)
- Large variety of detectable media (gases and liquids)
- Each system can monitor up to 2 x 25 km of pipeline
- Works under & above ground and submerged in water
- Up to date no leak remained undetected (including leak simulation field tests)
- 100% reliability of installed tubes (275 km of LEOS tubes installed by 2009)
- General license by German supervisory authority for civil works (DIBt) and UL certified equipment
- Complies to German technical guidelines for pipelines (TRFL)
**LEOS – Technical Description**

**Diffusion method**
The physical principle of operation is based on the air-tight so-called “LEOS sensor tube” that is permeable to gases and vapors within a certain diffusion period. The sensor tube is laid alongside the monitored pipeline and is purged with clean air in periodic intervals. Between these measuring cycles the tube remains at normal pressure. If there is a leak, the medium carried by the pipeline gets in contact with the wall of the sensor tube, **diffuses** (=penetrates) through the **tube wall** after a certain time, and forms a locally high vapor concentration inside the tube at the point of contact. This works regardless of whether the leakage medium gets in contact with the sensor tube as **liquid** or gas (=vapor) – and it even works when the leakage medium is **dissolved in water** (for example if sensor tube and pipeline are buried below groundwater level or in the seabed/riverbed). Since the described diffusion process occurs with most chemical substances, there forms an **expanded long air sample** inside of the sensor tube that represents the atmosphere outside the tube.

**Periodic measuring cycles**
In adjustable time periods, this air column is being purged through out of the tube and passed through several gas sensors. The signals of these gas sensors are recorded as a function of the purge time (see Figure below). At the same time during this purge process, there flows filtered air into the tube line in order to fill it with pure air for the next diffusion period.

**Leak localization**
When the vapors from the leakage pass the Measuring Station, its gas sensors show a clear signal peak (**leakage peak**), that will trigger a "**leak alarm**" when exceeding an alarm threshold. **Before each purge process**, a small amount of test gas (Hydrogen, Butane or Propane test gas, etc.) is also injected at the end of the tube and is transported along with the air flow through the entire sensor tube line. The resulting so-called **“test peak”** will also be detected by the gas sensors and its travel time marks the total length of the tube line. The location of the leak along the tube line (and thus also on the pipeline) can be determined accurately from the **travel times** of test peak and leakage peak, as well as the measured air **flow velocity**.

**Automatic integral self-test of the system**
The correct operation of all LEOS components is being **integreally checked** with every measurement by means of the test gas. Amplitude and arrival time of the test peak normally stay within a small variation range (so-called **“test peak window”**). In case of deviations a "**system alarm**" is automatically triggered.

**Special applications**
The analysis capabilities of LEOS can be extended in a flexible way by implementation of additional gas analyzers in the air flow. This allows selective and sensitive detection of special toxic gases such as Chlorine or carbon monoxide. A detailed **chemical analysis** (such as gas chromatography, etc.) of the **air sample from the leak location** is also possible, since the LEOS system directly transports the leakage substance as vapor phase to the Measuring Station.
LEOS – System Components

**Sensors tube**
- perforated internal tube
- diffusion layer
- protective layer
- Ø approx. 16 mm

**Shipment packaging**
- small quantities: *carton spools* (330 m each)
- large quantities: *wooden spools* (max. 3500 m)

**Installation of cabinets:**
Pre-installed on mounting frame

**Measuring Station (MS)**
- **Basic cabinets**
- **External gas-analyzer (option)**

**Test Peak Generator (TPG)**
- **Test gas bottle (option)**
- **Compressed air unit (option)**
LEOS – Networking without limits

The modular system design of LEOS covers the full range, from the simple non-networked stand-alone system up to a complex LEOS network built of almost any number of subsystems, providing data through Ethernet to a central LEOS server which archives all of them in a database and provides them by means of a web interface for access with standard web browsers.

The decentralization of the monitoring task allows to use standard networks without real-time capabilities. All data relevant for the server are being buffered in the Measuring Stations for sufficient time.

Finally, there also exists the option of remote access for the LEOS experts at AREVA NP, in order to support the operating personnel on demand, perform software updates or do the regular supplier’s functional system checks that might be required by some regulations. As an alternative to the direct computer access via VPN (VPN = Virtual Private Network) as shown in the Figure below, there is also the option of “KVM over IP” (KVM = Keyboard-Video-Mouse), where only the KVM signals are transmitted between e.g. the AREVA computer and the LEOS client computer either over VPN-internet or ISDN modem link. In this case, the AREVA computer is not directly connected to the LEOS operator’s plant network.
LEOS – Alarm Outputs

LEOS User Interface (GUI):

LEOS web interface:
(optional LEOS server)

Operator console
LEAK ALARM
SYSTEM ALARM

2 alarm contacts
LEOS – Web Interface

Overview

<table>
<thead>
<tr>
<th>MS#</th>
<th>MS name</th>
<th>location</th>
<th>timestamp system state</th>
<th>system state MS</th>
<th>line#</th>
<th>monitoring line</th>
<th>timestamp last measurement</th>
<th>system state mon. line</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MS1</td>
<td>Duisburg Hafen</td>
<td>2008-08-13 17:11:51</td>
<td>system alert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Strecke 1_1</td>
<td>ok</td>
<td></td>
<td></td>
<td>2008-08-13 17:00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 Strecke 1_2</td>
<td>measurement blocked</td>
<td></td>
<td></td>
<td>2008-08-13 16:45:00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MS2</td>
<td>Bottrop</td>
<td>2008-08-13 17:11:52</td>
<td>ok</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Strecke 2_1</td>
<td>leakage alert</td>
<td></td>
<td></td>
<td>2008-08-13 17:00:00</td>
<td></td>
</tr>
</tbody>
</table>

Leakage details

- Tube pos: 2140.75 ft, PIPE D 818.57 ft, PIPE D 805.45 ft
- Position: low
- Date: 2008-08-13 17:11:51
- Time: 2008-08-13 16:30:00
- Alert: blocked

Position Calculator

- Measuring station: 2
- Monitoring line index: 2
- Tube position: 3000 ft
LEOS – Applications

Application range of LEOS
The flexible LEOS sensor tube can be installed on-shore both under and above ground, as well as submerged in water (in riverbed, seabed). This can be done both in a linear geometry for monitoring of pipelines, as well as in a planar manner e.g. for monitoring of tank farms and underground gas storage tanks. In general, there are no real limitations in respect to the topology of the monitored object (see illustration below).
The proven application range covers temperatures from -50°C to +80°C and water depths of up to 100 m.

Underground pipelines
The most common type of pipelines in Europe are underground (i.e. buried) pipelines. Continuous leak monitoring of long underground pipeline sections based on non-destructive or visual testing is neither technically nor economically reasonable. This applies in particular for those pipelines with inside diameters that are too small for standard pigging techniques.
LEOS – Applications

Pipelines above ground
In sparsely populated areas pipelines are often installed above ground and stretch over very long distances. Pipelines above ground are the best choice in regions where underground pipelining is not possible due to permafrost soil, swamps and spill-sensitive tundra.

Leak detection for pipelines above ground
External influences such as climate and wildlife, etc. require several technical solutions or adaptations when monitoring aboveground pipelines. In particular snow and ice can severely constrain visual inspections of the pipeline.

For these applications AREVA NP has developed a special installation method that allows a reliable and efficient installation of LEOS on both new and existing aboveground pipelines.

Leak monitoring of underground jet fuel pipelines at airports
On an increasing number of airports the aircrafts are nowadays fuelled directly from hydrant pits at the terminals via underground pipelines. This measure reduces stand-by times and increases operational safety. Potential chronic leaks underneath the concrete pavement would remain undetected for a long period of time. These would result in a long non-availability of the affected terminal during restoration work.

Reputable international airports in Central Europe have learned about the advantages of an online leak monitoring system for their underground jet fuel pipelines and thus installed AREVA NP's LEOS system.

Leak monitoring for tank farms and gas storages
Tank farms usually contain extremely hazardous or explosive substances used in the chemical industry. Leak monitoring systems in densely populated areas that are able to detect even smallest chronic leaks are a significant tool to reduce the operator’s risks.
The increasing use of Natural Gas requires more underground gas storage facilities. Their economic efficiency can be increased by using the surface area above for commercial purpose e.g. parking lots). LEOS can be used here for achieving the required safety level.
### LEOS Selected Projects

#### BP Northstar (Alaska)

<table>
<thead>
<tr>
<th>Type</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore pipeline, installed under water in sea bed</td>
<td>Arctic environment -40°C</td>
</tr>
<tr>
<td>Crude oil</td>
<td>Pipeline laying through a 3m ice crust</td>
</tr>
<tr>
<td></td>
<td>Zero error tolerance during pipelining</td>
</tr>
</tbody>
</table>

#### Chlorine pipeline Degussa (Germany)

<table>
<thead>
<tr>
<th>Type</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline crossing a river through dry culvert and buried under ground</td>
<td>Fast detection &lt;2 h</td>
</tr>
<tr>
<td>Liquid Chlorine (Cl₂)</td>
<td>Highest safety requirements</td>
</tr>
</tbody>
</table>

#### BP OT-21 (Prudhoe Bay / Alaska)

<table>
<thead>
<tr>
<th>Type</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline above ground</td>
<td>Protect the highly sensible ecosystem in the arctic tundra against consequential damages resulting from pipeline leaks; Extreme conditions (-50°C, ice, windblow); Ability to retrofit on existing pipelines</td>
</tr>
<tr>
<td>Crude oil (three-phase-flow)</td>
<td></td>
</tr>
</tbody>
</table>

#### CO Pipeline Bayer (Germany)

<table>
<thead>
<tr>
<th>Type</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline crossing river, under ground</td>
<td>Monitoring of entire pipeline over 70km</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>Highest safety requirements</td>
</tr>
<tr>
<td></td>
<td>Numerous HDD drillings</td>
</tr>
</tbody>
</table>
LEOS
Detectable Substances

Hydrocarbons and derivates
Methane, Ethane, Propane, Butane, Pentane, Hexane, Heptane, Octane, Decane, petroleum naphta, gasoline, jet fuel, petrol naphta, Acetylene, Ethene, Propene, Butene, Butadiene, Benzene, Toluene, o-Xylene, m-Xylene, Ethylene oxide

Nitrogen compounds
Nitromethane, Methylamine, Dimethylamine, Trimethylamine, Monoethylamin, Diethylamine

Inorganic gases
Chlorine, ammonia, carbon monoxide, carbon dioxide, Hydrogen, Hydrogen sulfide, Hydrogen cyanide

Halogenated hydrocarbons
Dichloromethane, Ethylene dichloride, Di-chloroethane, Trichloroethane, Vinylidene chloride, Trichloroethene, Bromomethane, Vinyl chloride, Tetrachloroethylene, chlorofluorocarbons (CFC – such as Freon, etc.)

Ketones
Acetone, methylacetone

Alcohols
Methanol, Ethanol, Propanol, Butanol

Esters
Methyl acetate, Ethyl acetate, Propyl acetate, Butyl acetate

⇒ Other substances on request
All over the world, AREVA provides its customers with solutions for carbon-free power generation and electricity transmission. With its knowledge and expertise in these fields, the group has a leading role to play in meeting the world’s energy needs.

Ranked first in the global nuclear power industry, AREVA’s unique integrated offering covers every stage of the fuel cycle, reactor design and construction, and related services. In addition, the group is developing a portfolio of operations in renewable energies. AREVA is also a world leader in electricity transmission and distribution and offers its customers a complete range of solutions for greater grid stability and energy efficiency.

Sustainable development is a core component of the group’s industrial strategy. Its 75,000 employees work every day to make AREVA a responsible industrial player that is helping to supply ever cleaner, safer and more economical energy to the greatest number of people.