HELPCOS – THE HELICOPTER BASED PIPELINE CONTROL SYSTEM OF VNG - VERBUNDNETZ GAS AG

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ABSTRACT

In recent years, VNG - Verbundnetz Gas Aktiengesellschaft, Leipzig, GKSS Forschungszentrum GmbH, Geesthacht and Fachhochschule Bochum have been testing a helicopter-based leakage detection system to be used during routine flights above long-distance pipelines. With an innovative laser measuring system the position as well as the strength of leaks are identified by determination of absorption due to methane in the near infrared wavelength range. The mechanical components of this optical system are able to follow the route of the long-distance pipeline to a high degree of accuracy on base of the “Differential Global Positioning System (DGPS)” data and the known coordinates of the pipeline. Thus time-intensive gas detection work at the ground along the long-distance pipeline can be optimized. The goal is to have all time a full automatic system on board of a helicopter in order to check all pipelines for leaks during a flight.
1 INTRODUCTION VNG

VNG - Verbundnetz Gas Aktiengesellschaft is a wholesale gas merchant company and service provider for the energy sector in the eastern part of Germany. Its customers and partners are regional and local distribution companies, power stations and major industrial users.

The company operates a modern high-pressure gas pipeline system with a total length of approx. 7,300 km. The system includes 6 underground gas storage facilities with a total work capacity of $2.2 \times 10^9$ m³, 2 compressor stations and 36 metering and pressure regulating stations.

2 BACKGROUND

Over 1 million kilometres of high-pressure gas pipelines are in operation worldwide. In Germany, DVGW - process sheet G 466-1 dictates that regular monitoring of pipelines be performed to guarantee a constant, high level of safety in both supply and technical aspects when operating delivery systems for gas supply companies.

In addition to these statutory requirements, maintaining the technical integrity and usage potential of pipelines, as well as efficiently protecting them from risks and hazards, is in the interest of any pipeline operator.

To fulfill these tasks, VNG - Verbundnetz Gas Aktiengesellschaft Leipzig, together with the GKSS - Forschungszentrum Geesthacht GmbH (national laboratory) and Fachhochschule Bochum (technical college) have developed the Helicopter based Pipeline Control System - HELPCOS. The main objective was the application of a full automatic helicopter-based leakage detection system to be used during routine flights above a pipeline to identify leaks in long-distance pipelines.

The leakage detection subsystem which uses laser beam scanning to locate a gas leakage has been tested by VNG for a while. Further tests are planned to show the reliability and robustness of the system.

3 METHODS

3.1 PHYSICAL BASICS

Leaks of underground pipelines cause higher methane concentrations at the ground and in the air above it. Similar to many other gases, methane absorbs light at certain wavelengths, and a system for detecting methane-induced light attenuation should distinguish this effect from an undesirable but existing absorption by other gases. Trace concentrations can be determined by adjusting the wavelength of a laser to the spectral absorption characteristics of the gas to be detected which, in the case of gas utilities, is mostly methane.

To give sufficiently sensitive readings, the laser should emit a wavelength at which the absorption of the gas in question is strong and preferably reaches a maximum. In addition, care in the wavelength selection should be taken to avoid not only saturation effects from the finite background concentration of methane (approx. 1.8 ppm), but also overlaps with absorption lines of water vapour which is invariably contained in the atmosphere (Figure 1).
Figure 1: Physical basics of methane absorption
**Picture a)** in Figure 1 summarizes atmospheric absorption by methane and water vapour in the 1.5 - 3.6 µm range. In view of the great atmospheric variability of water vapour, such cross sensitivity should be avoided where possible, or minimized to ensure the safe detection of methane. Shown is the optical thickness of the atmosphere due to methane (red) and water vapour (black) depending on wavelength.

Clearly visible are three vibrational bands of methane in the 1.65, 2.4 and 3.33 µm regions with a multitude of absorption lines. The measured spectral solar radiation density $S$ of the sun (green) is diagrammed at the upper margin of atmosphere and shows a decline toward longer wavelengths. For a passive methane detection, as much solar radiation as possible should reach the ground.

A more detailed view of **Picture a)** at higher spectral resolution is depicted in **Picture b)** for the 1.645 - 1.655 µm range. Clearly seen are individual absorption lines of methane, water vapour and carbon dioxide.

**Picture c)** in Figure 1 shows the absorption cross section of the methane absorption line at 1.6509 µm. The dotted lines indicate the electrical adjustment range of a diode laser suitable as a light source for an active procedure.

### 3.2 FIELD APPLICATION

The light sources for HELPCOS may be either sunlight (passive method) or a laser (active method). For the first measuring scheme sunlight reflected from the ground is examined for attenuation (absorption) with a polychromator by comparison with a previously taken reference spectrum. The active part uses a laser diode and a differential absorption method, i.e. the diode wavelength is adjusted to maximum absorption and then to the wing of an absorption line of methane. The concentration reading results from the comparison of the two measured signals.

Dependent on soil conditions and soil structure, natural gas may escape from a leak not just vertically but also at some distance away. At a typical flying height of 100 m and a flying speed of 80 km/h, the passive method therefore covers a corridor which is 20 m wide along the pipeline route so that highly diffuse sources of methane can be detected (**Figure 2**).

The measuring points on the ground formed by the laser beam of the active part are 10 cm in diameter and are guided by a scanner along a corridor with a width of ± 5 m from the pipeline axis, ensuring a max. spacing of 0.6 m for any two measuring points over the area covered (**Figure 2**).

The diagram in **Figure 3** shows the scanning scheme of the active measuring system which results from the circular motion of the laser beam and the movement of the helicopter, with the shading at the centre indicating an area where methane escapes. Two adjacent points correspond to a time lag of 1 msec. For the sake of clearness the plot colour is changed from black to red for the second half of the simulated measurement.
Figure 2: Principle of remote measurement with HELPCOS
4 PRACTICAL APPLICATION

4.1 COMPONENTS

Figure 4 shows the detection components of the combined HELPCOS system. The telescope unit is accommodated outside the helicopter and the coupling to the processing units is accomplished by optical fibres. The optical axes of the telescope and of the passive system fibres, respectively, are precisely aligned collinear.

Both procedures - the passive and the active laser measurement are possible. In the former case, an optical fibre cable transmits the accumulated light direct to a spectrometer. Due to restricted space and load capacity of the helicopter a compact 1/4m polychromator is used to determine the absorption by methane between 1.60 µm and 1.68 µm.

The active procedure is similar, the only difference being a sensor which consists of a transmitting and receiving fibre cable and a stabilization system (stabilized platform) for the telescope to assure the overlap of the much smaller scanning range of the active system (Figure 3) with the pipeline.

Stabilization adjusts the scanner to a preset angle relative to the ground surface at all times, even during erratic helicopter manoeuvres. Furthermore the electronic of the stabilized platform yields information for the pilot thus to navigate precisely the aircraft along the pipeline vector within the laser scanning range tolerance. The adjustment takes place with the position of the helicopter and the known pipeline coordinates from GIS.

The steering accuracy of the platform is ± 1 m at the ground and the maximum deflection angle is approx. 18 ° corresponding to ± 30 m from the pipeline at a flight height of 100 m.
4.2 STABILIZATION OF HELPCOS

Apart from these technical aspects, a major problem is to make the optical system “look” at a point on the ground which is exactly above the pipeline at all times, regardless of helicopter movement and attitude.

Therefore the Differential Global Positioning System (DGPS) is used to determine the helicopter’s position more than 50 times per second as well as an inertial navigation system (INS) thus creating the basis for precise measurements to be taken.
The detection system data are continuously stored together with the corresponding position data for documentation and quality assurance purposes. Once a leak has been found, an appropriate message is sent to the helicopter’s onboard leak detection system.

The software of the data acquisition was extended to record in addition to the actual measured values simultaneously the pictures of a digital camera. So a clear temporal and spatial allocation of measured value and picture information is guaranteed.

4.3 INTEGRATION HELPCOS IN VNG’S PIPELINE MONITORING

VNG carries out monthly aerial patrols of the entire pipeline system, including loop lines and third-party pipelines inspected under service contracts. The main tasks of the flights are:
- To observe any third-party activities, that might have impact on the pipeline,
- To report any changes in pipeline status, such as soil settlement or erosion and
- To check correct routing.

To ensure air surveillance within precise coordinates, VNG and the air service operator AirLloyd have developed and introduced the DMP – Digital Messaging system Pipeline monitoring since 1998 which simplifies the inspection process and optimizes its efficiency.

As a major improvement, the system is able to pinpoint a defect using GPS coordinates. Any defects found are now stored with their coordinates in digitised network plans on board and transmitted online to maintenance units immediately after helicopter touchdown. A specifically modified onboard GPS system then makes it possible for VNG’s maintenance supervisor to drive his vehicle precisely to the point concerned (Figure 5).

![Figure 5: Operating mode of the Digital Messaging system Pipeline monitoring (DMP)](image-url)
Air surveillance in practice works as follows: the position stabilizing platform imports the vector of the desired pipeline from the DMP system and displays an image on the pilot’s navigation surface which accurately guides him along the line within the laser scanning corridor.

At the same time, the exact laser position on the ground is calculated from sensor readings of the position stabilizer which is linked online to the high-precision DGPS (Digital Global Positioning System), and from 3D coordinates of the pipeline vector. The required laser coordinates are continuously transmitted to the measuring system which blends them with the laser position, and then classifies and transmits them back to the DMP system.

5 CONCLUSIONS

5.1 RESULTS

After extensive preliminary studies, components were laboratory tested and integrated into an overall system. The actual detection limits obtained so far are 800 ppm x m for the passive procedure and 80 ppm x m for the active system. Prototype test flights have shown that the system detects leaks and measures methane concentration. Further test flights are essential to get reliable data for sufficient and well-defined detection limits.

The test flights with HELPCOS on board of a BELL 206 / R 44 helicopter showed that on the base of the above outlined remote detection principle simulated gas leakages could be evidenced and estimates of methane concentration could be derived. The compact system is small in size (0.2 m³) and can be carried even on light helicopters due to its low weight (total approx. 70 kg) and low power consumption (700 W). Integrated into a weatherproof housing such a system can easily be attached to the load hook of a small helicopter (Figure 6).

Figure 6: The HELPCOS system installed in the helicopter BELL 206
5.2 CHALLENGES

Before HELPCOS can be used for a durable application in line with the continuous pipeline surveillance some challenges have to accomplish to optimise the laser measuring hardware and software. Current difficulties and influencing variables are:
- Interference / impact of the measurement data due to strong methane drifts as a result of wind
- Interferences during measuring and processing the data in the helicopter at the aerial flights and
- Temporarily unknown interfering signals in the measuring data.

Further testing is planned to increase the accuracy of the sophisticated measuring system for future use. The goal is to have a fully automatic system on board a helicopter every time so that all pipelines can be checked for leaks during a flight. This "fully automatic" system can use stored line data to find a specific pipeline corridor and stores the coordinates of any trouble spots. A maintenance supervisor can then evaluate this data at ground.

6 SUMMARY

A new laser scanning procedure is currently being tested and further developed by VNG prior to entering series production. In future, it will detect leaks in gas pipelines during surveillance flights in line with the legal requirements of pipeline monitoring. The advantages for using HELPCOS are obvious:
- **Optimization** by integrated detection of gas leakages in line with general monitoring flights
- **Cost reduction** by compensation of time-consuming gas detection operations at the ground along the long-distance pipelines
- **Safety** by rapid reaction and responding in case of emergencies by interconnection to the Digital Messaging system Pipeline monitoring (DMP) in combination with a fleet management
- **Efficiency** by a compact design with a little size (approx. 0.2 m³), low weight (approx. 70 kg) as well as a low power consumption (approx. 700 W) thus searching for leaks is even possible from small-sized helicopters.

The complete system solution HELPCOS encompasses all significant monitoring activities on gas pipelines via helicopter. As a basic component within is used the DMP - Digital Measuring System Pipeline Monitoring developed by VNG and AirLloyd. DMP is a modular software system that provides effective, economical management and reporting of the monitoring flights.

The methane detection from the air is based upon the principle of selective absorption of laser light of a specific wave length. With an innovative laser measuring system (active system: radiation source: diode laser) the position as well as the strength of leaks are identified by determination of absorption by methane in the near infrared wavelength range. The combination of the laser measurement with a passive spectral process (passive system: radiation source: sunlight) guarantees the redundancy of the measurement.

The HELPCOS system offers a modular design of all methods of monitoring gas pipelines from the air via optimal system components as well as quick and precise pipeline control and failure elimination via GPS-assisted recording, distribution and documentation. This economical efficient solution meets the legally-prescribed monitoring directives.

The use of HELPCOS for regular monitoring of gas pipelines for leakages significantly reduces the time and money required for leakage searches, as well as further raising the safety of gas supplies, thus reinforcing the positive image of natural gas as an environmentally friendly energy source.