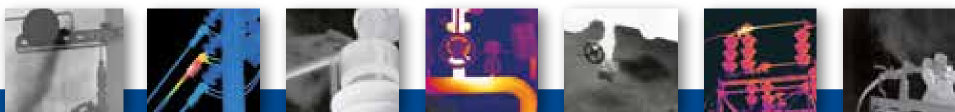
Aerial photo of a gas compression station of ©GASCADE Gastransport GmbH

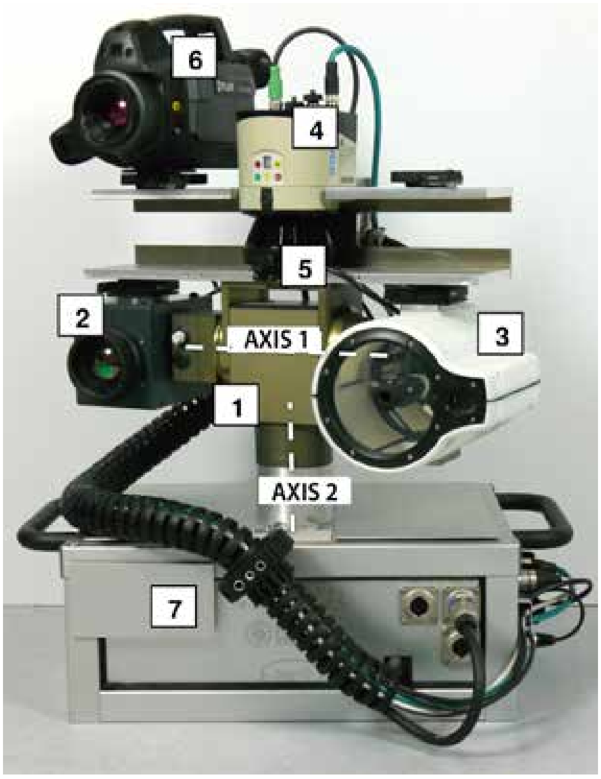
Remote detection and localization of gas leaks with autonomous mobile inspection robots in technical facilities

Detection of gas leaks in industrial facilities cannot only be dangerous and time-consuming; it is also susceptible to human error and interpretation. In order to provide a safer, more efficient and more reliable detection solution, RoboGas^{Inspector} was conceived. This innovative robot system for remote detection and localization of gas leaks was developed by a range of German companies and institutes, and uses a FLIR GF320 optical gas imaging camera.

As part of the German technology program AUTONOMIK, a consortium of nine companies and research institutes developed a prototype of an autonomous mobile robot for gas leak detection and localization in large industrial facilities. The consortium came up with a system that is able to perform inspection tasks in industrial facilities without having to access hazardous areas directly - and without requiring any human presence. The robot can be used for routine inspections of facilities or for targeted inspections of specific system parts. The independent mobility of the system was implemented with various navigation sensors and the option of manual intervention via remote control at any time. The system is also equipped with video and optical gas telemetry, which enables it to inspect system parts that were previously difficult to inspect due to restricted accessibility.

The RoboGas^{Inspector} consists of three modules: a chain-driven mobile platform, a navigation module and an inspection module. Note the FLIR GF320 on top of the unit.





The multi-sensor inspection module: The pan-tilt unit (1) is equipped with a thermal imaging camera (2), an active TDLAS measuring device (3), a laser rangefinder (4), a video camera (5) and the FLIR GF320 thermal imaging camera for gas visualization (6). The computer and other electrical/electronic modules are housed in a switching cabinet (7).

The development of innovative monitoring processes that make the most of state-of-the-art measuring and automation technology as well as robotics promises improvement in the reliability, efficiency and cost-effectiveness of inspections. At the same time, it relieves technical personnel of monotonous, time-consuming and labor-intensive tasks.

This was the starting point for a collaborative research project headed by Dr. Andreas Kroll and Dr. Ludger Schmidt at the Mechanical Engineering Department of the University of Kassel and subsidized with € 2.4 million from the Federal Ministry of Economics and Technology.

"The objective of this project was the development and testing of an innovative human-machine system with inspection robots equipped with remote gas measuring technology and local intelligence," explained Dr. Andreas Kroll of the Department of Measuring and Control Technology at the University of Kassel. "The detection and localization of gas leaks should be performed largely independently by mobile robots. During this process, the mobile robots should also analyze the measured data and document the inspections."

Safety and efficiency

Operators of industrial plants (e.g. chemical plants, refineries, gas compression stations) give top priority to the safety of their staff and their production facilities.

Exercising the utmost care wherever toxic or explosive gases are used is absolutely essential. That's why rigorous inspection specifications apply to the chemical industry, biogas facilities and gas suppliers. Usually, preventive inspection programs require personnel to perform time-consuming routine inspection procedures on a daily basis.

During these regular inspections, staff members check the system for proper functionality and therefore he or she usually relies on perceptions and experience without making use of measuring technology.

For professors Andreas Kroll and Ludger Schmitt, a top requirement for the new system was that it should allow for automated, hazard-free inspection and monitoring and that it should be able to respond independently to problems.

Technical detection options: Toxic Vapor Analyzer (TVA)

To prevent harm to people, the environment and investment goods, gas leaks from systems and infrastructure facilities must be detected and located quickly and reliably, as they can form toxic and/or explosive mixtures. Today, various methods are used to accomplish this. The conventional method of detecting Volatile Organic Compounds (VOCs) in plant fittings is based primarily on Toxic Vapor Analysis (TVA) or "sniffing" technology.

During the search for gas leaks, an inspector checks all relevant system parts at sites marked in advance. According to a study carried out by the American Petroleum Institute, 84% of all leaks occur in 1% of the equipment. That means that companies have to dedicate the majority of their inspection procedures to the 99% of functioning, reliable and leak-free areas - a possible source of inattention due to monotonous routine and a considerable expense.

Moreover, TVA technology has a number of disadvantages. First, it exposes the employees searching for leaks to invisible and potentially dangerous chemicals. Working from a safe distance is not possible with TVAs. Furthermore, wind or other weather factors can scatter gas and vapors, so that the accuracy of the measurements is impaired.

The FLIR GF320 thermal imaging camera visualizes more than 20 for the naked eye invisible, organic gas compounds.

FLIR GF-Series: visualization of invisible gases

With the GF-Series, FLIR Systems has developed a thermal imaging camera that can optically visualize gas leaks from medium-range distances, including methane, benzene derivatives and other Volatile Organic Compounds (VOCs) that cannot be recognized with conventional camera technology or the naked eye. These chemicals are transported and processed in large quantities every day.

Optical imaging with thermal imaging cameras such as those in the FLIR GF-Series offers numerous advantages, as larger areas can be covered significantly faster than with conventional methods and detection also succeeds in sectors that are difficult to access with contact measuring devices. Leaks are shown as plumes of smoke in the thermal image. When a leak is found from a safe distance with the GF camera, a TVA can be used to quantify the gas concentration.

During routine procedures such as repeat inspections, there is always a risk of inadvertently overlooking possible sources of danger due to inattention.

Therefore, the development of innovative inspection technologies and focusing the flexibility and performance of human operators on managing the technological systems makes sense not only for economic reasons, but also with regard to relieving humans from repetitive routine tasks and improving coverage of the wide range of inspection tasks.

First demonstration

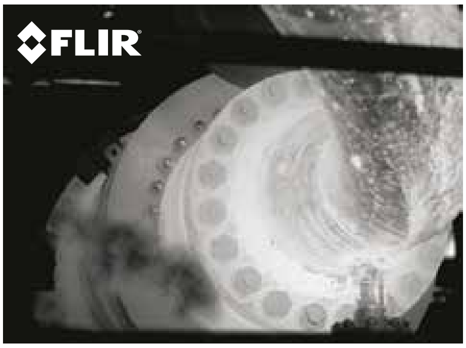
The RoboGas^{Inspector} was demoed for the first time in a hall at the University of Kassel. The robot independently completed an inspection route, successfully overcoming obstacles and a ramp in the process.

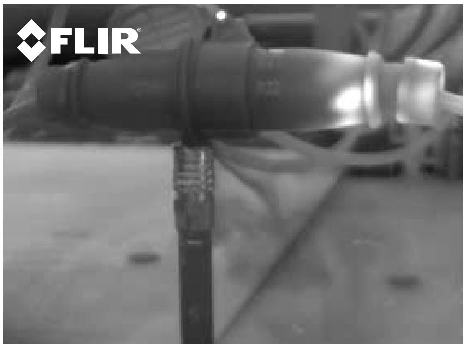
At specified inspection sites it inspected various pipelines and found a methane leak. In the following months, this success was expanded to several square kilometers of large industrial facilities under laboratory conditions, in which environmental factors such as wind and sun as well as confounding factors resulting from system operation were included.

Drive system and navigation of the RoboGas^{Inspector}

The RoboGas^{Inspector} consists of three modules: a chain-driven mobile platform, a navigation module and an inspection module, which incorporates the FLIR GF320 optical gas imaging camera. The chain-driven platform is equipped with an electric drive and conventional batteries.

The navigation module consists of 2D laser scanners (front and back, particularly important for navigation inside buildings) as well as a GPS for outdoor orientation. Continuous comparison of the area to be inspected with a digital map enables the chain-driven RoboGas^{Inspector} to determine its position at any time; obstacles and blocked areas (e.g. explosive zones) can be noted on this map. “Thanks to its 2D laser scanners, the RoboGas^{Inspector} also avoids unexpected objects such as parked cars, pallets, barrels, etc.," explained Professor Kroll. “This also includes persons. If the RoboGas^{Inspector} encounters obstacles, it moves around them, or stops until the path is clear again.”





The FLIR GF320 visualises invisible gases at leak sites as dark plumes of smoke.

Aerial photo of a refinery of the consortium partner © PCK Raffinerie GmbH

Panning range (view from above) and tilt range (side view from below) of the sensor system

The inspection module

The inspection module combines various metrological instruments on a pan-tilt unit, including a Remote Methane Leak Detector (RMLD), which is based on an active Turnable Diode Absorption Spectroscopy (TDLAS) instrument. It works by means of an infrared laser: when the laser beam hits a surface, it is reflected and its residual intensity is measured. In addition, a FLIR GF320 thermal imaging camera is mounted on the inspection module to visualize the gases.

To ensure that the RoboGas^{Inspector} itself does not pose a risk, it is also equipped with a built-in gas sensor that shuts down the entire system from 10% of the lower explosion limit (LEL) onwards in order to prevent possible danger to a flammable atmosphere.

Independent measurement

Processing of the measured data and pattern recognition are performed independently by the robot. The RoboGas^{Inspector} also carries out the inspection of the specified routes and performs measurements on its own. Despite this, it is continuously in contact with the control room and can be remotely controlled from there if necessary. A video camera is also incorporated in the pan-and-tilt measuring module for this purpose. However, in normal operating mode, the RoboGas^{Inspector} works independently and merely transmits all measured data to the control room via WLAN.

RoboGas^{Inspector} today and tomorrow

In the meantime, the system prototype has impressively demonstrated its use and capability in extensive series of tests. The drive unit, the navigation system and the complementary sensor systems performed beautifully during the tests. The RoboGas^{Inspector} facilitates independent gas detection and leak localization in sites that are otherwise difficult to access. Moreover, it helps to avoid using human inspectors in potentially dangerous environments. However, before deployment in industrial settings, further development is required (e.g. in explosion protection, software development, etc.), and of course legal issues must be clarified prior to deployment in commercial settings. Still, it is certain that an autonomous, mobile gas detection and leak localization robot is possible today and can significantly enhance safety.

The FLIR Systems GF320 is a vital part of the RoboGas^{Inspector}. It helps the system to detect sometimes harmfull gasleaks from a safe distance.

For more information about thermal imaging cameras and this application, please contact:

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