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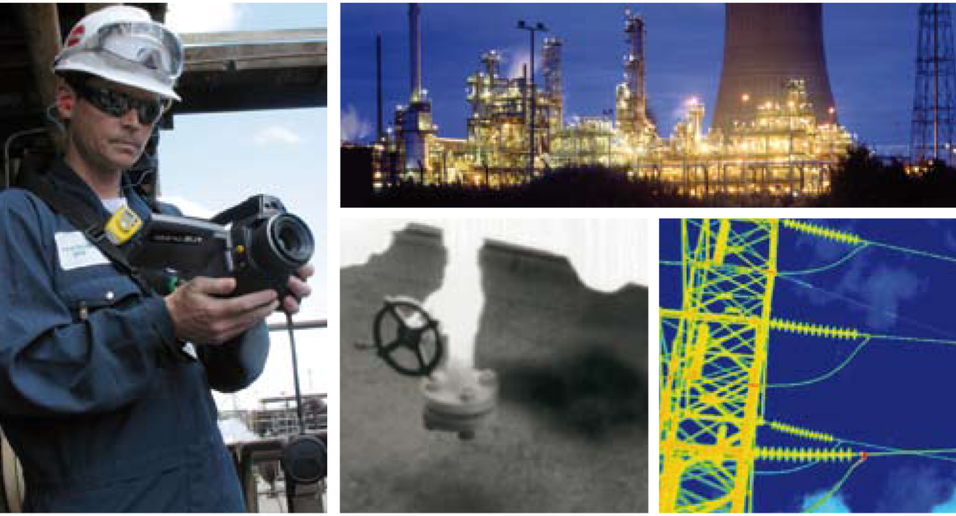


GAS DETECTION

The Professional Guide

Content

This booklet is produced in close cooperation with the Infrared Training Centre (ITC).

INTRODUCTION

Over the decades infrared cameras have revolutionized maintenance in many industries, proving to be the most superior technology for finding electrical and mechanical hidden faults – even before they occur. The clear benefit has been substantial cost savings, increased worker safety and enhanced product/process quality.

Infrared cameras can also play a major role in helping to decrease environmental damage. They are successfully used for detecting insufficient insulation in buildings, identified as one of the highest opportunity areas for decreasing the greenhouse effect, as well as detecting environmentally dangerous gas leaks.

Not only do some of the gases harm the environment but the leaks also cost companies substantial amounts of money. Against this background FLIR has introduced a range of gas detection cameras capable of detecting many gases including SF_6 - a gas 24,000 times more environmentally dangerous than CO_2.

1. INFRARED VISUALIZES GAS LEAKS

Many chemical compounds and gases are invisible to the naked eye. Yet many companies work intensively with these substances before, during and after their production processes. Strict regulations govern how companies are to trace, document, rectify and report any leaks of volatile gaseous compounds, and how often these procedures are to be carried out.

Earlier methods of gas detection required close or near contact using "sniffer" technology and probes. The limitations of these methods are that they are time consuming and run a risk of missing gas leaks. They may expose inspectors to invisible and potentially harmful chemicals, and do not allow for wind and weather factors that can produce inaccurate measurements. In addition, they can only tell us something about the test points that have been identified beforehand and only give readings within the immediate vicinity of the inspector.

The FLIR Gas Detection cameras are infrared cameras which are able to visualize gas by utilising the physics of fugitive gas leaks. The camera produces a full picture of the scanned area and leaks appear as smoke on the camera's viewfinder or LCD, allowing the user to see fugitive gas emissions. The image is viewed in real time and can be recorded in the camera for easy archiving.

The key success factors for businesses today are safety, efficiency and profitability. When carrying out maintenance, it is of vital importance that maintenance engineers are able to obtain as complete a picture as possible of the condition of the plant. An infrared camera is an extremely important tool for tracing potential faults.

The examples below demonstrate a wide range of applications that can be served with IR cameras. Potential applications are limited only by the imagination of the system designer.

Greatly Improved Efficiency
Experience shows that up to 84 percent of leaks occur in less than 1 percent of the plant. This means that 99 percent of what are expensive, time-consuming inspection tools are being used to scan safe, leak-free components.

Using a Gas Detection camera you get a complete picture and can immediately exclude areas that do not need any action. This means you can achieve enormous savings in terms of time and personnel.

Another advantage is that systems do not have to be shut down during the inspection, measurements can be carried out remotely and rapidly and – most important of all – problems can be identified at an early stage. An inspector using an infrared camera system can get through an inspection regime of more than one hundred objects an hour.

Safe Scanning
A Gas Detection camera is a quick, non-contact measuring instrument that can also be used in hard-to-access locations. It can detect small leaks from several meters away and big leaks from hundreds of metres away. It can even show leaks on moving transport vehicles, greatly improving the safety of both the inspector and the plant.

Preserving the Environment
Fugitive gas emissions contribute to global warming, cost industry billions of dollars in regulatory fines and damages, and pose deadly risks to both workers and people living close to these facilities. FLIR Gas Detection cameras detects dozens of volatile organic compounds, including the "greenhouse gas" Sulfur Hexafluoride (SF_6), efficiently contributing to a better environment.

2. THE MID WAVE GAS DETECTION CAMERA

Applicable Industries

The mid wave gas detection camera is particularly suited to the following industries:

Oil Refining – The typical refinery consists of two types of process, separation and conversion. The separation processes split crude oil into useful 'fractions' to be sold as fuel or used as feed for further processing. The conversion processes modify molecules to provide products with suitable characteristics for blending into finished fuels. The camera has an excellent response to most of the 'light end' products and intermediates found in fuels processing refineries. The general rule of thumb is that the camera can detect crude oil fractions from gas down to the kerosine part of the barrel.

Petrochemical – The industries that make hydrocarbon substances using base feedstocks from the oil refining processes either by conversion processes or further separation that is not normally carried out at an oil refinery. Most of the chemicals used or made in these industries have good visibility using the mid wave gas detection camera.

Chemical – The production of non-hydrocarbon or inorganic chemicals from base feed stocks. These are often a mixture of batch and continuous processes that yield very high purity products. The mid wave gas detection camera has a good response to some chemicals found in this sector of industry.

Power Generation – The production and distribution of electric power. Gas fired power stations often use natural gas as fuel. The mid wave camera is therefore very suitable for leak detection in this industry.

Natural Gas – The production, storage, transportation and distribution of natural gas. Natural gas consists mainly of methane and ethane, both of which are clearly detectable with the mid wave camera. The camera can be used for leak detection in all parts of this industry from the gas production field right through the distribution network to the end consumer.

Service Providers – Increasingly companies are contracting out services for leak detection and repair (LDAR). LDAR service providers currently using non-imaging gas detection methods will see a dramatic improvement in productivity and gas detection capability using a gas detection camera.

Regulators – Enforcement of statutory regulation by government agencies rather than industry is common in many countries. The gas detection camera enables these agencies to monitor industry ensuring their compliance with regulations and auditing their performance in emission reduction.

APPLICATIONS

Leak Location

The camera can be used to detect gas from many different sources in the petrochemical industry but some of the most common leak paths are from:

- Flanges
- Plugs and Caps
- Couplings
- Holes
- Drain covers
- Valve stems
- Machinery
- Pump seals
- Passing valves
- Instrument Connections

Level float switch

In a complex petrochemical facility there may be many thousands of potential leaks paths. Some may be leaking but most will not. Using the Gas Detection camera allows the user to examine many potential leaks sources in a short time and from a distance. Conventional leak detection methods such as a Volatile Organic Compound meter (or sniffer) mean that the operator must visit and test each potential leak site. Each item must therefore be accessible or made accessible to be tested. A full survey by this method would clearly be significant longer and more expensive than with the gas detection camera.

Corrosion Under Insulation (CUI)

Occasionally leaks are found in unexpected locations. Equipment that is thermally insulated is susceptible to water penetration into the insulation if the sealing of the outer cladding is poor. If the equipment temperature is suitable, the water heats up and can create a region of very high corrosion out of sight under the insulation. The shell of the equipment can rapidly corrode to such an extent that it starts to leak and this leakage can be detected by the camera at considerable distance, sometimes several hundred metres away from the leak source.

Improving Plant Start-Up Safety

The reasons for conducting a survey may vary from site to site but also from time to time. Most petrochemical facilities are now required to examine their process plant for leaks to reduce the emission of volatile compounds (VOCs) to the atmosphere. This forms the bulk of the use of the mid wave camera in this industry but there are other advantages that are not so readily apparent. The camera has had proven success in leak detection surveys during the start up of process plants following both planned and unplanned shut-downs. The thermal cycles associated with shut-down and start-up can initiate leaks in equipment that was previously leak free and components that have been disturbed due to maintenance activity may also leak. Performing a leak detection survey using a gas detection camera during this critical phase in the operating cycle of a process plant can help to achieve every owner's aim of a safe, leak free start up.

Lost Product Opportunities

Leaks from process equipment, no matter how small, not only constitute a potential damage to the environment, they also represent lost product that could otherwise be sold to customers. There may be many very small leaks that have been in existence for many years in locations that are difficult to access or test that all add up to considerable lost profit. Frequently surveying the process plant can help to eliminate these leaks and maximise the owner's profit.

Incorrect Fault Location

Items of machinery may sometimes be shut-down for maintenance unnecessarily. It has been known for leaks to be detected with VOC meters only to find that subsequent examination with a camera proves that the source of the leak is in a different location that does not require an expensive shut-down to rectify. The camera shows in real time the leak plume and allows it to be traced back to its true origin.

Regulation

Statutory regulation, laws and external audits are all driving owners of petrochemical plants to monitor, report and reduce their emissions of Volatile Organic Compounds (VOCs). Some countries rely on the company to reduce their emissions by repairing the leaks of their own free will; others use fines or the threat of fines as an incentive.

In the USA the Environmental Protection Agency requires companies to follow the 'Method 21' process for their LDAR (Leak Detection And Repair) programmes. This method is less common outside the US but there is still a requirement to carry out leak detection surveys by a method that is acceptable to the regulator. The use of the gas detection camera is permitted as an 'Alternate Work Practice' under Method 21 and is becoming accepted as a suitable method in the EU. In the EU, industry bodies such as CONCAWE have reviewed the performance of the gas detection camera method and have found that it is an acceptable alternative to the conventional VOC meter or sniffer method for point source emissions.

Infrared image of a process furnace

Spectral Response and Detectable Gases
The mid wave gas detection camera has a detector response of 3-5 µm which is further spectrally adapted to approximately 3.3 µm by use of a cooled filter. This makes this particular model of camera most responsive to the gases commonly found in the petrochemical industries. The camera can detect many gases but it has been laboratory tested against 19 which are:

- Benzene
- Butane
- Ethane
- Ethylbenzene
- Ethylene
- Heptane
- Hexane
- Isoprene
- MEK
- Methane
- Methanol
- MIBK
- Octane
- Pentane
- 1-Pentane
- Propane
- Propylene
- Toluene
- Xylene

A leaking pressure gauge

Conclusions
The gas detection camera technique has a wide range of potential uses in the petrochemical industry, all of which have positive benefits for the owner of the plant. It is an accepted Alternate Work Practice in the Method 21 leak detection procedure and has clear time and cost benefits over the conventional VOC meter or sniffer method. Although limited to a certain extent by environmental conditions, the camera has proven many times that it can identify leaks at some distance thereby reducing the cost of surveys by removing the requirement to provide access to every potential leak path.

3. THE LONG WAVE GAS DETECTION CAMERA

Applicable Industries
The long wave gas detection camera is particularly suited to the following industries:

Electrical Utility – A large amount of the equipment used in the distribution of high voltage electrical power uses Sulphur Hexafluoride (SF_6) as an insulating gas. This allows the equipment to be more compact and protected from the elements inside substations. The long wave gas detection camera is extremely sensitive to SF_6.

Petrochemical – The industries that make hydrocarbon substances using base feedstocks from the oil refining processes either by conversion processes or further separation that is not normally carried out at an oil refinery. Some of the chemicals used or made in these industries have good visibility using the long wave gas detection camera.

Chemical – The production of non-hydrocarbon or inorganic chemicals from base feed stocks. These are often a mixture of batch and continuous processes that yield very high purity products. The long wave gas detection camera has a good response to some chemicals found in this sector of industry.

Service Providers – Increasingly companies are contracting out services for leak detection and repair (LDAR). LDAR service providers currently using non-imaging gas detection methods will see a dramatic improvement in productivity and gas detection capability using a gas detection camera.

APPLICATIONS

SF_6 Detection

The primary market for the long wave gas detection camera to date is the electrical distribution industry and specifically the detection of Sulphur Hexafluoride (SF_6). SF_6 is used extensively in the electrical distribution industry as an insulating gas in high voltage switchgear and transformers. It is a potent greenhouse gas with a 'global warming potential' (GWP) of 23,900 and an atmospheric lifetime of 3,200 years. The GWP means that a release of 1kg of SF_6 into the atmosphere has the same impact as a release of 23,900 kg or 23.9 tonnes of CO2. To put this in perspective a company that purchases 1 tonne per year of SF_6 as top-up gas is releasing 1 tonne per year through leaks. This is the equivalent of 23,900 tonnes of CO2. To produce this amount of CO2 you would have to drive an average sized car just over 149 million miles (239 million km). That's the equivalent of driving 311 times to the moon and back or 5964 times round the equator! Conversely, a company that reduces its emission of SF_6 to the atmosphere by using a gas detection camera to locate and fix leaks is improving the environment by the same amount as taking 11,950 average cars off the road.

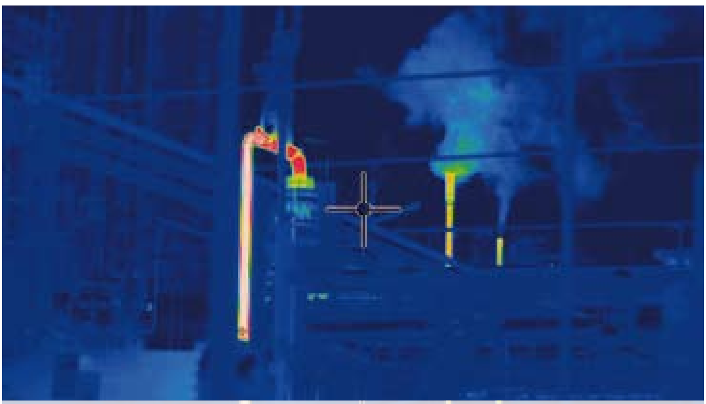
Typical SF_6 Filled Substation Equipment

Leak paths found on electrical distribution equipment are fewer than in the process industries. The most common are flanges, bushings, bursting discs and valve stems. Leaks may be due to poor installation, disturbance during planned maintenance or failure of the sealing parts due to age.

The long wave gas detection camera has proved to be highly effective at detecting very small leaks. The pressures used in switchgear and transformers are relatively low which results in very small leak rates. In addition, the operating temperature of the equipment is generally close to ambient. The result is a low thermal contrast between the leak and the background. Despite this, the camera is capable of detecting leaks as small as 0.25 kg/year and has had success in both indoor and outdoor substations. As with the mid wave camera, the long wave camera is effective at some distance which not only removes the requirement to provide access to all potential leak paths it also permits leak surveys to be completed when the equipment is energised.

Chemical Industries

The applications for the long wave gas detection camera in these industries are very similar to the applications for the mid wave gas detection camera in the petrochemical industries but the reasons for the surveys may be slightly different. In the petrochemical industry the main drivers for leak detection surveys are the protection of the environment, reduction in lost product and the elimination of potentially flammable leaks. These priorities also apply in the chemical industries but the chemical compounds visible with the long wave gas detection camera are generally more toxic. Protection of personnel may therefore become an additional reason for performing leak detection surveys.



Vent pipes on a petrochemical plant

Refrigerant Gases

The long wave camera is also ideal for detecting several refrigerant gases. These include gases that are used for domestic and commercial refrigeration and automotive air conditioning. The gas camera is most effective when used at the manufacturing stage for these items rather than the maintenance stage. New product design testing and production sample testing can lead to reduced failure rates improving reliability of the finished product and reducing the emission of potentially harmful gases to the atmosphere.

Co-workers identify the location of a gas leak

Regulation

Governments are becoming more aware of the risk posed to the environment by release of SF_6. There is a general increase worldwide in the use of gas filled substation equipment and no alternative substance is currently known or used. Consequently they are providing a combination of reward and punishment for the reduction of losses and the release of gas respectively. Some governments are enforcing reduction in SF_6 release by means of fines; some are advocating encouraging the reduction of leaks by giving financial incentives such as tax breaks for demonstrated reduction in consumption. The cost of SF_6 is also increasing which further increases the financial motivation to eliminate leaks.

Spectral Response and Detectable Gases
The long wave gas detection camera has a detector response of 10-11 µm which is further spectrally adapted to approximately 10.5 µm by use of a cooled filter. This makes this particular model of camera most responsive to Sulphur Hexafluoride (SF_6) as well as many gases used in the chemical industry and several common refrigerant gases. The camera can detect many gases but it has been laboratory tested against 8 which are:

- Sulphur Hexafluoride
- Anhydrous Ammonia
- Ethyl Cyanoacrylate ('Superglue')
- Chlorine Dioxide
- Acetic Acid
- FREON-12
- Ethylene
- Methyl Ethyl Ketone (MEK)

SF6 leak from a high voltage insulator

In addition to the laboratory tested gases there are **18 additional gases that the camera is known to detect**. These are:

- Acetyl Chloride
- Allyl Bromide
- Allyl Chloride
- Allyl Fluoride
- Bromomethane
- FREON-11
- Furan
- Hydrazine
- Methylsilane
- Methyl Vinyl Ketone
- Propenal
- Propene
- Tetrahydrofuran
- Trichloroethylene
- Uranyl Fluoride
- Vinyl Chloride
- Vinyl Cyanide
- Vinyl Ether

Conclusions

The gas detection camera technique has a wide range of potential uses in the electrical distribution and chemical industries, all of which have positive benefits for the owner of the plant. It is an accepted Alternate Work Practice in the Method 21 leak detection procedure and has clear time, safety and cost benefits over the conventional VOC meter or sniffer method. Although limited to a certain extent by environmental conditions, the camera has proven many times that it can identify leaks at some distance thereby reducing the cost of surveys by removing the requirement to provide access to every potential leak path and permitting surveys to be completed on energised electrical equipment.

4. APPLICATION STORIES

Read how our customers are using FLIR Gas Detection cameras.

Tracing gas leaks: maintenance and safety problems highlighted

With more than 160,000 kilometres of piping of every imaginable kind, Shell Nederland Raffinaderij in Pernis (Rotterdam) is the largest oil refinery in Europe. Safety and environmental considerations are firmly embedded throughout the company, its quality systems and its production management processes. Shell has also adopted a stringent safety policy in which preventive maintenance is uppermost.

Many chemical compounds and gases are invisible to the naked eye. Yet many companies work intensively with these substances before, during and after their production processes. Strict regulations govern how companies are to trace, document, rectify and report any leaks of volatile gaseous compounds, and how often these procedures are to be carried out. The most commonly used technology is the 'ToxicVaporAnalyzer (TVA) or 'sniffer technology'. "When searching for potential gas leaks, we check all systems at points that may or may not have been identified beforehand. These checks are carried out regularly, and are particularly important following a shutdown. At a refinery like the one we have here, this means carrying out tens of thousands tests on piping, stopcocks, seals, valves, torches, etc. Before we had the FLIR GasFindIR, an inspector using the TVA could carry out around five hundred inspections per day.

Rutger Zoutewelle, research analyst at Shell Pernis.

An inspector using this infrared camera system can, on the other hand, get through an inspection regime of more than one hundred objects an hour. The most important reason for using the system is to minimise discharges of gas and other volatile organic substances from our pipework, particularly (potential) leaks around flanges and other gaskets", explains Rutger Zoutewelle, research analyst at Shell Pernis.

Safe scanning
The key success factors for businesses today are safety, efficiency and profitability. When carrying out maintenance, it is of vital importance that maintenance engineers are able to obtain as complete a picture as possible of the condition of the plant. A thermal imaging system is an extremely important tool for tracing potential faults. Experience shows that up to 84 percent of leaks occur in less than 1 percent of the plant. This means that 99 percent of what are expensive, time-consuming inspection tools are being used to scan safe, leak-free components. Using the FLIR GasFindIR in this sector allows us to achieve enormous savings in terms of time and personnel.

The technologies currently in use may expose inspectors to invisible and potentially harmful chemicals, and do not allow for wind and weather factors that can produce inaccurate measurements. In addition, they can only tell us something about the test points that have been identified beforehand and only give readings within the immediate vicinity of the inspector. The infrared technology used by the FLIR GasFindIR shows gas emissions as a plume of smoke. When a leak has been identified from a safe distance using the device, the Toxic Vapor Analyzer can be used to determine the concentration percentage of the substance. Rutger Zoutewelle: "We heard about FLIR GasFindIR through our colleagues in Houston. Compared to how we did things before, using the camera for testing offers many advantages over more conventional technologies. The camera is a quick, non-contact measuring instrument that can also be used in hard-to-access locations. It also offers benefits in terms of safety and the environment".

Benefits

The core of the FLIR GasFindIR is a cooled Indium Antimonide (InSb) detector. This detector produces clear images with a high level of detail. The camera, which weighs only 2.5 kg, has been designed for use in harsh industrial environments and operates within a wide temperature range of -15° C to +50° C. It produces infrared images in real-time in the widely used PAL format. It has an industrial shock rating of 40G. The camera can detect twenty different types of gas in real time; these appear on the screen as 'black smoke'. These characteristics mean that miles of piping can be scanned from a safe distance. Rutger Zoutewelle: "Most pipes, flanges, valves and other connections in petrochemical operations are free of faults. However, certain factors that are beyond our control could result in a small number of components not being hundred percent. The positive experiences of our colleagues at the plant in Houston in using the system to trace leaks resulted in Shell Pernis deciding to introduce the technology here as well." Anyone using the system has to go on a short training course and then needs a few days of on-the-job familiarisation to become fully conversant with the system. But, once you have got the hang of it, the camera offers many benefits. The camera is in constant use at the refinery and is always used following a shutdown. It's an invaluable tool and a great preventive solution".

Examining potential leak paths

A Smart Solution

Using thermal imaging techniques 'in the field' can place high demands on the equipment and the user: often a safe distance has to be maintained from the object being tested or, in other cases, the problem might be how to get close enough. Then you have to remember that the work may involve climbing, or hours at a time spent inspecting a major plant. Therefore, the size and weight of the equipment that inspectors have to carry around with them are important factors. "The FLIR GasFindIR contributes to the safety and the effective operation of our plants. It provides direct, tangible results and gives peace of mind", concludes Rutger Zoutewelle. "It's particularly useful when inspecting high pressure systems, as these are at the greatest risk of developing leaks. Here, the camera has become virtually indispensable".

A modern complex petrochemical facility

The camera can be used in a number of different ways to inspect plant safely. There are several major benefits to using thermal imaging techniques. These include the fact that systems do not have to be shut down during the inspection, measurements can be carried out remotely, rapidly and at relatively low cost and – most important of all – problems can be identified at an early stage.

Using the FLIR GasFindIR, an inspector can get through an inspection regime of more than one hundred objects an hour. The most important reason for using the system is to minimise discharges of gas and other volatile organic substances from our pipework.

FLIR GasFindIR™ infrared camera spots methane leaks, prevents uncontrolled gas venting and keeps air clean at Norwegian landfill

Economic and environmental concerns push for an increasingly streamlined waste disposal, treatment, neutralization and recycling process. Waste treatment companies increasingly turn into energy suppliers. The GasFindIR gas detection infrared camera supports these trends by providing immediate and tangible results.

Lindum Ressurs og Gjenvinning AS, based in Norway, specializes in waste treatment solutions. Lindum follows a consistent waste-to energy conversion by composting, recycling, as well as extracting landfill gas for power production and residential heating. The company's main site at Drammen, one hour drive from Norway's capital Oslo, has a biogas production plant and a huge landfill consisting of selected solid waste covered with clay layers.

The methane gas produced by the landfill is extracted and used for power production and residential heating. Methane is an odourless, environmental harmful gas which is created as a result of pressure formed in the landfill. Moreover, the landfill discharges hydrogen sulphide (H2S) a malodorous gas that at times annoys surrounding residential areas.

Covering and sealing a landfill site with clay

To detect relevant leaks, Lindum decided to procure a FLIR GasFindIR, an infrared camera that traces and visualizes about twenty Volatile Organic Compound gases including methane.

The landfill, with a surface of approx 10 hectares, is inspected twice a week at dawn for about one hour. The GasFindIR instantly shows gas leaks, visualized in black or white smoke. Landfill workers then cover the leaks with clay and an ironed mass to neutralize the sulphide odours.

Gas leak on land fill surface

The FLIR GasFindIR is also used for inspection of the biogas production piping on a weekly basis. And the Lindum company, convinced of the camera's benefits is offering inspections with its GasFindIR to other landfill companies, as imagery can be easily recorded by a standard video recorder and stored.

"The FLIR GasFindIR's efficiency can be measured easily: we find some four to five leaks per week and we have been able to reduce the foul odour development considerably", says operations manager Aud Helene Rosenvinge.

"We consider the GasFindIR both a maintenance and a safety instrument that has become indispensible", says Rosenvinge, adding that she estimates cost savings at a minimum of EUR 12,000 per year.

To access more application stories, please visit www.flir.com/thg/applicationstories

5. THE GAS DETECTION CAMERA – WHY IT IS DIFFERENT?

Detectors
The construction of a thermal imaging camera is similar to the construction of a digital video camera. There is a lens, a detector, some electronics to process the signal from the detector and a viewfinder or screen for the user to see the image produced by the camera. The detectors used for the Gas Detection cameras are quantum detectors that require cooling to cryogenic temperatures (around 70K or -203°C). The MW camera uses an InSb detector and the LW camera a QWIP detector.

In materials used for quantum detectors, at room temperature there are electrons at different energy levels. Some electrons have sufficient thermal energy that they are in the conduction band, meaning the electrons there are free to move and the material can conduct an electrical current. Most of the electrons, however, are found in the valence band, where they do not carry any current because they cannot move freely. (See left-most views of Fig 1.)

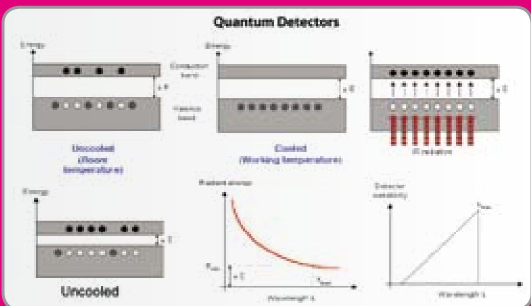


Figure 1. Operating principle of quantum detectors

When the material is cooled to a low enough temperature, which varies with the chosen material, the thermal energy of the electrons may be so low that there are none in the conduction band (upper centre view of Figure 1). Hence the material cannot carry any current. When these materials are exposed to incident photons, and the photons have sufficient energy, this energy can stimulate an electron in the valence band, causing it to move up into the conduction band (upper right view of Figure 1). Thus the material (the detector) can carry a photocurrent, which is proportional to the intensity of the incident radiation. There is a very exact lowest energy of the incident photons that will allow an electron to jump from the valence band into the conduction band. This energy is related to a certain wavelength, the cut-off wavelength. Since photon energy is inversely proportional to its wavelength, the energies are higher in the SW/MW band than in the LW band. Therefore, as a rule, the operating temperatures for LW detectors are lower than for SW/MW detectors. For an InSb MW detector, the necessary temperature must be less than 173 K (-100°C), although it may be operated at a much lower temperature. A QWIP detector typically needs to operate at about 70 K (-203°C) or lower. The lower centre and right views of Figure 1 depict quantum detector wavelength dependence. The incident photon wavelength and energy must be sufficient to overcome the band gap energy, ΔE.

Cooling Method

The Detectors in the Gas Detection cameras are cooled using Stirling Coolers. The Stirling process removes heat from the cold finger (Figure 2) and dissipates it at the warm side. The efficiency of this type of cooler is relatively low, but good enough for cooling an IR camera detector.

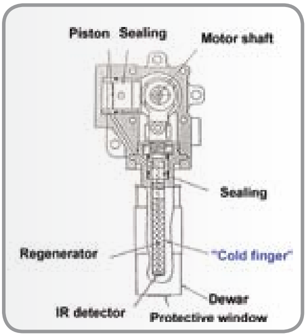


Figure 2. Integrated Stirling cooler, working with helium gas, cooling down to -196ºC or sometimes even lower temperatures

Image Normalization

Another complexity is the fact that each individual detector in the FPA has a slightly different gain and zero offset. To create a useful thermographic image, the different gains and offsets must be corrected to a normalized value. This multi-step calibration process is performed by the camera software. The final step in the process is the Non-Uniformity Correction (NUC). In measurement cameras, this calibration is performed automatically by the camera. In the Gas Detection camera, the calibration is a manual process. This is because the camera does not have an internal shutter to present a uniform temperature source to the detector.

The ultimate result is a thermographic image that accurately portrays relative temperatures across the target object or scene. No compensation is made for emissivity or the radiation from other objects that is reflected from the target object back into the camera (reflected apparent temperature). The image is a true image of radiation intensity regardless of the source of the thermal radiation.

Real-time image of the gas cloud displayed on the built in LCD screen

Spectral Adaptation

The gas detection camera differs from measurement cameras. In addition to the lens, detector, cooler and image processing electronics there is a filter mounted on the front of the detector. This filter is cooled with the detector to prevent any radiation exchange between the filter and the detector. The filter restricts the wavelengths of radiation allowed to pass through to the detector to a very narrow band called the band pass. This technique is called spectral adaptation. The filter band pass wavelengths for the different gas detection cameras are shown in Table 1.

Camera Model	Detector Spectral Range	Filter Waveband
Mid Wave	3-5 µm	approx. 3.3 µm
Long Wave	10-11 µm	approx. 10.5 µm

Table 1. Spectral Response for Gas Detection Cameras

Gas Infrared Absorption Spectra

For many gases, the ability to absorb infrared radiation depends on the wavelength of the radiation. In other words, their degree of transparency varies with wavelength. There may be IR wavelengths where they are essentially opaque due to absorption. Physical property databanks exist containing infrared absorption data for many substances. To determine the infrared absorption spectrum for a gas a sample is placed in an Infrared Spectrometer and the absorption (or transmission) of infrared is measured at different wavelengths. These spectra are normally published as graphs and the absorption spectrum of benzene and sulphur hexafluoride are shown in Figures 9 and 10. One source for IR spectrum data is the American National Institute of Standards and Technology (NIST). Their web based data book http://webbook.nist.gov/chemistry/name-ser.html is a very useful (and validated!) resource. Selecting a filter that restricts the camera to operating only in a wavelength where a gas has a very high absorption spike (or transmission trough) will enhance the visibility of the gas. The gas will effectively 'block' more of the radiation coming from the objects behind the leak in the background.

Why Do Some Gases Absorb Infrared Radiation?

From a mechanical point of view, molecules in a gas could be compared to weights (the balls in Figure 4 below), connected together via springs. Depending on the number of atoms, their respective size and mass and the elastic constant of the springs molecules may move in given directions, vibrate along an axis, rotate, twist, stretch, rock, wag, etc.

The simplest gas molecules are single atoms, like Helium, Neon or Krypton. They have no way to vibrate or rotate, so they can only move by translation in one direction at a time.

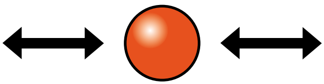


Figure 3. Single atom

The next most complex category of molecules is homonuclear, made of two atoms such as Hydrogen H_2, Nitrogen N1 pt and Oxygen O1 pt. They have the ability to tumble around their axes in addition to translational motion.

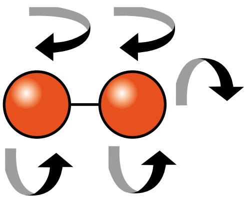


Figure 4. Two atoms

Then there are complex diatomic molecules such as carbon dioxide CO1 pt, methane CH_4 sulphur hexafluoride SF_6, or styrene $C_6H_5CH{=}CH_2$ (these are just a few examples).

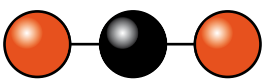


Figure 5. Carbon dioxide 3 atoms per molecule

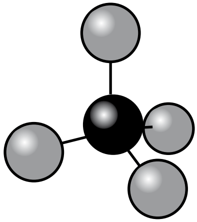


Figure 6 Methane 5 atoms per molecule

This assumption is also valid for multi-atomic molecules.

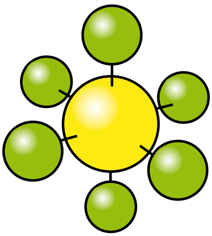


Figure 7.SF_6 7 atoms per molecule

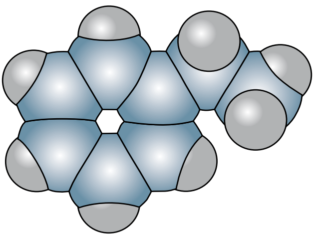


Figure 8.Styrene 16 atoms per molecule

Their increased degrees of mechanical freedom allow multiple rotational and vibrational transitions. Since they are built from multiple atoms they can absorb and emit heat more effectively than simple molecules. Depending on the frequency of the transitions, some of them fall into energy ranges that are located in the infrared region where the infrared camera is sensitive.

Transition type	Frequency	Spectral range
Rotation of heavy molecules	10^9 to 10^{11} Hz	Microwaves, above 3 mm
Rotation of light molecules & vibration of heavy molecules	10^{11} to 10^{13} Hz	Far infrared, between 30 µm and 3 mm
Vibration of light molecules. Rotation and vibration of the structure	10^{13} to 10^{14} Hz	Infrared, between 3 µm and 30 µm
Electronic transitions	10^{14} to 10^{16} Hz	UV - Visible

Table 2. Frequency and Wavelength Ranges of Molecular Movements

On order for a molecule to absorb a photon (of infrared energy) via a transition from one state to another, the molecule must have a dipole moment capable of briefly oscillating at the same frequency as the incident photon. This quantum mechanical interaction allows the electromagnetic field energy of the photon to be "transferred to" or absorbed by the molecule.

Gas Detection cameras take advantage of the absorbing nature of certain molecules, to visualize them in their native environments. The camera focal plane arrays and optical systems are specifically tuned to very narrow spectral ranges, in the order of hundreds of nanometres, and are therefore ultra selective. Only gases absorbent in the infrared region that is delimited by a narrow band pass filter can be detected.

Below are two transmittance spectra of gases:
Benzene C_6H_6 – absorbent in the MW region
Sulphur Hexafluoride SF_6 – absorbent in the LW region.

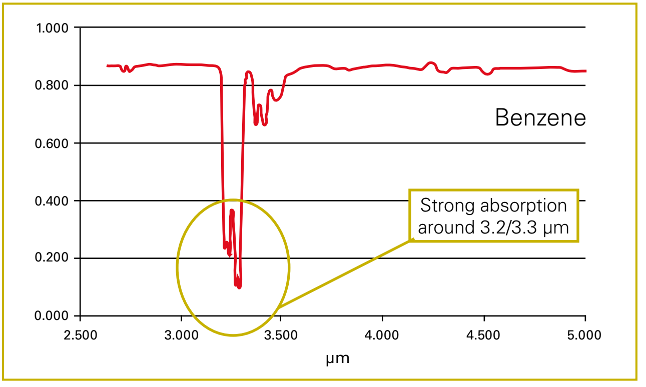


Figure 9. Benzene C6H6 – absorbent in the MW region

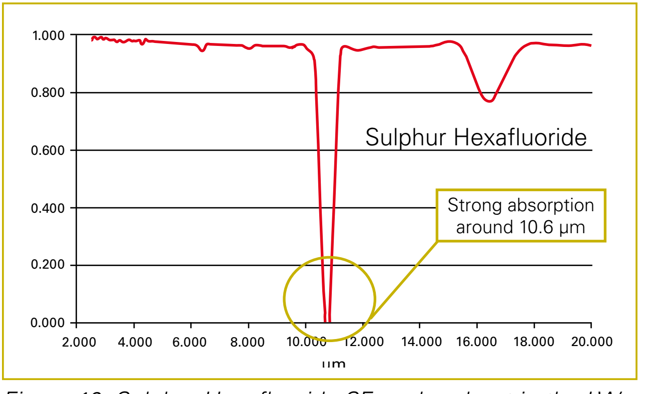


Figure 10. Sulphur Hexafluoride SF_6 – absorbent in the LW region.

Visualising The Gas Stream

If the camera is directed at a scene without a gas leak, objects in the field of view will emit and reflect infrared radiation through the lens and filter of the camera. The filter will allow only certain wavelengths of radiation through to the detector and from this the camera will generate an uncompensated image of radiation intensity. If a gas cloud exists between the objects and the camera and that gas absorbs radiation in the band pass range of the filter, the amount of radiation passing through the cloud to the detector will be reduced (Figure 11)

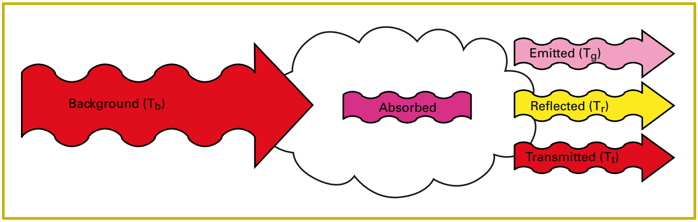


Figure 11. Effect Of A Gas Cloud

In order to see the cloud in relation to the background, there must be a radiant contrast between the cloud and the background. That is to say, the amount of radiation leaving the cloud must not be the same as the amount of radiation entering it (Figure 12). If the blue arrow in Figure 12 is the same size as the red arrow, the cloud will be invisible.

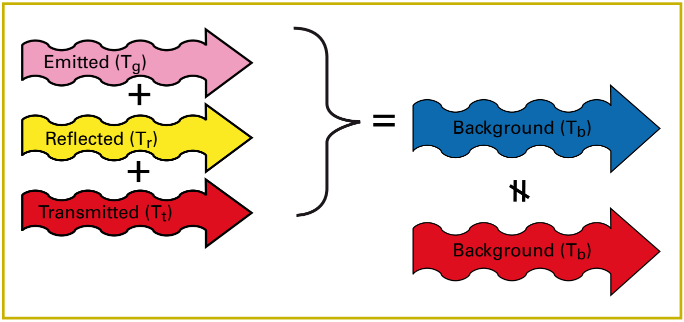


Figure 12. Radiant Contrast Of Cloud

In reality, the amount of radiation reflected from the molecules in the cloud is very small and can be ignored. So the key to making the cloud visible is a difference in apparent temperature between the cloud and the background (Figure 14).

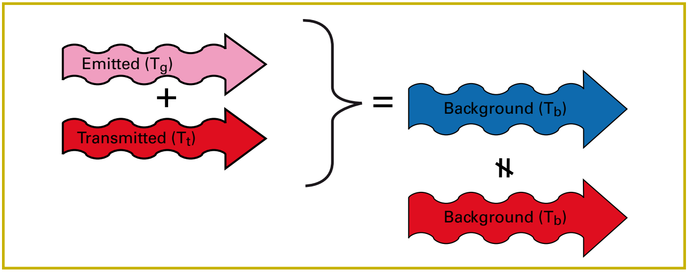


Figure 14. Difference In Apparent Temperature

Key Concepts To Make The Cloud Visible

- The gas must absorb infrared radiation in the waveband that the camera can see
- The cloud must have a radiant contrast to the background
- The apparent temperature of the cloud must be different to the background
- Cloud motion assists the visibility of the gas

6. TECHNIQUES TO MAXIMISE GAS DETECTION

Thermal Tuning

Thermal tuning is the term given to manual adjustment of the camera settings to display the colours of the colour palette across the target object. It is the most simple and common technique used to improve the visibility of a gas leak. Operating the cameras in automatic mode will do this for you but it may cause the operator to miss leaks. Good operating practice is to always thermally tune the image to optimise your chances of discovering a leak. It also allows the operator to determine if there is more than one leak in any particular location.

Figure 1.
Untuned Thermal Image

Figure 2.
Tuned Thermal Image

High Sensitivity Mode

High Sensitivity Mode or HSM is the name given to an image subtraction video processing technique that effectively enhances the thermal sensitivity of the camera. A percentage of individual pixel signals from frames in the video stream are subtracted from subsequent frames. The effect is somewhat similar to performing a Non Uniformity Correction with the lens cap off but there is a significant advantage in as much as the camera can be moved whilst in HSM. Using HSM gives the user control over the amount of compensation applied to the video stream and therefore the degree of increase in thermal sensitivity. HSM has particular advantages in the detection of SF_6 leaks using the long wave camera because of the low pressures used in the equipment and associated low leak rates. It also has benefits in the mid wave camera when very small leaks are to be identified.

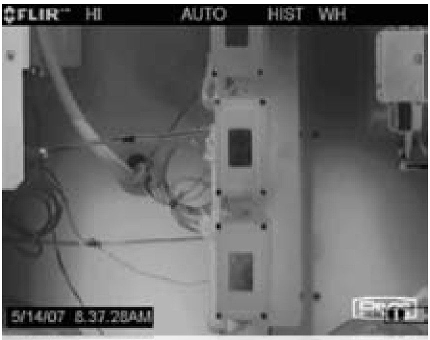


Figure 3.
HSM Off

Figure 4.
HSM On

Temperature Range Selection

The selection of the correct temperature range will improve the quality of the camera image. The temperature range needs to be set for the approximate temperature of the target object or of the object reflected in the target. Using the correct range removes noise and artefacts from the camera image and hence improves the visibility of any gas leaks. Just like a measurement camera setting the correct temperature range is essential. If the user selects the wrong temperature range they will not get an accurate temperature measurement. In fact they may not get a temperature measurement at all. In the gas detection camera setting the incorrect temperature range may eliminate any possibility of imaging a gas leak.

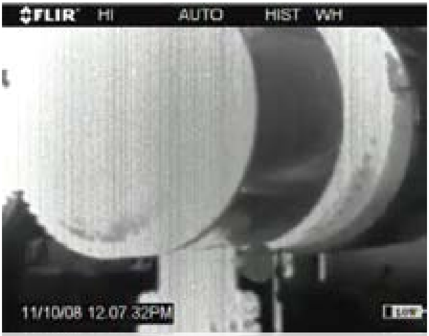


Figure 5. Incorrect Temperature Range

Figure 6. Correct Temperature Range

Positioning the camera to maximise the thermal contrast and improve gas visibility

Conclusions

Besides the simple automatic mode of operation there are several other techniques that further enhance the ability of the operator to detect gas streams. After suitable training the operator will be well equipped to maximise their chances of finding gas leaks. The tools are standard features, they are simple to use and make the cameras very flexible and powerful tools.

7. SAFETY

The areas where the camera is designed to be used are potentially dangerous unless you familiarize yourself with and follow local safety rules and regulations at the site where you are working. Below is some advice to keep in mind while using the camera on site:

- Change the battery outside operating areas only
- When climbing ladders or stairs, put the lens cap on and use the camera strap to free both your hands
- If you detect a large leak or potential serious condition, immediately stop your work, move upwind and quickly notify the relevant personnel
- When you detect a leak, make sure you are not “in” the leak when you make a video
- Keep the connector cover on the back of the camera closed when in potentially combustible atmosphere
- Make a quick scan from a distance before entering an operating unit to avoid entering a “cloud” of gas
- Take note of the wind directions and know your surroundings should you have to leave quickly

The gas detection specialist should always liaise closely with plant personnel

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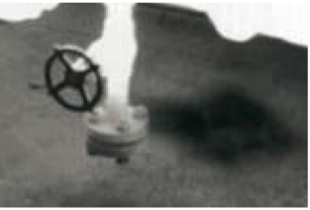

What's your application?
What kind of infrared camera is best for your needs?

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