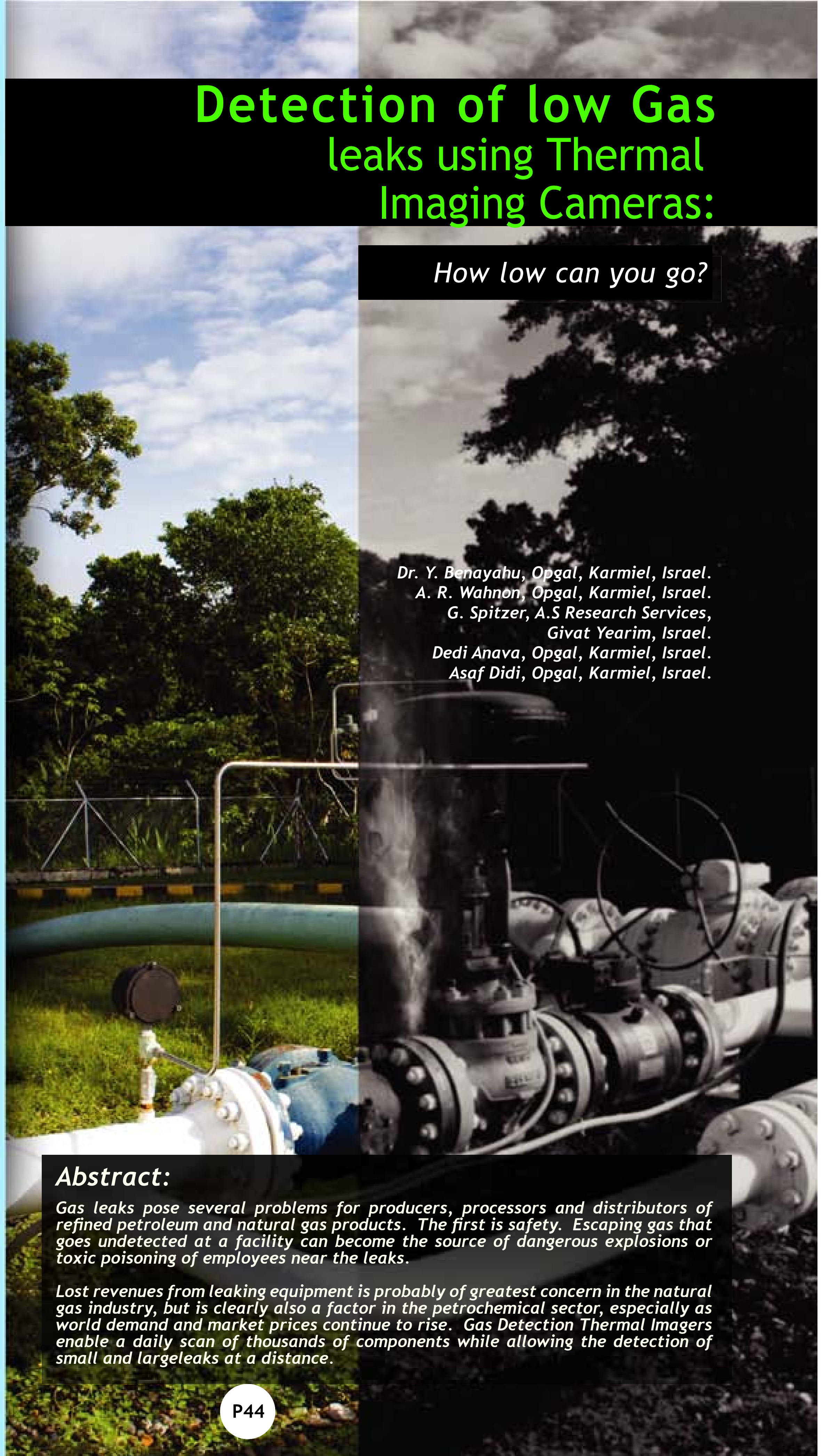
Casos de ÉXITO

*El secreto de permanecer siempre vigente, es comenzar a cada momento.* ***Agatha Christie, escritora británica.***

En Colombia, el Departamento Administrativo de Ciencia, Tecnología e Innovación COLCIENCIAS, trabaja para fortalecer la competitividad de los sectores productivos y de servicios, a través de apoyo a programas estratégicos sectoriales y/o proyectos de investigación, desarrollo tecnológico e innovación (I+D+I), que impliquen el mejoramiento o desarrollo de nuevos productos, servicios, y procesos productivos u organizacionales. Esta sección destaca entidades que han desarrollado potencialidades en torno a los avances de la ciencia y tecnología, en unión con grupos de investigación de universidades, centros de desarrollo tecnológico o centros de desarrollo productivo.



# Detection of low Gas leaks using Thermal Imaging Cameras:

*How low can you go?*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## Abstract:

*Gas leaks pose several problems for producers, processors and distributors of refined petroleum and natural gas products. The first is safety. Escaping gas that goes undetected at a facility can become the source of dangerous explosions or toxic poisoning of employees near the leaks.*

*Lost revenues from leaking equipment is probably of greatest concern in the natural gas industry, but is clearly also a factor in the petrochemical sector, especially as world demand and market prices continue to rise. Gas Detection Thermal Imagers enable a daily scan of thousands of components while allowing the detection of small and largeleaks at a distance.*








Gas leaks pose several problems for producers, processors and distributors of refined petroleum and natural gas products. The first is safety. Escaping gas that goes undetected at a facility can become the source of dangerous explosions or toxic poisoning of employees near the leaks.

The second is environmental. The fossil fuel industry, both by virtue of its own commitment to improved environmental protection and by the ever present threat of regulatory citation and fines, has placed increasing emphasis on detecting and repairing leaks. Finally, there is the lost revenue that escapes into the atmosphere with the leaking product. Lost revenues from leaking equipment is probably of greatest concern in the natural gas industry, but is clearly also a factor in the petrochemical sector, especially as world demand and market prices continue to rise. Gas Detection Thermal Imagers enable a daily scan of thousands of components while allowing the detection of small and large leaks at a distance.

The tests shows that a Thermal Imager camera can visualize methane mass flow of 0.35g/h at temperature differences of 2˚C and Butane mass flow of 0.86 g/hour at temperature differences of 1˚C. The results shows a much lower mass flow compared to the required threshold of 60 g/h in the Alternative Work Practice (AWC) for EPA method 21 in the US.

The Figure 1 shows a leak image, which is unnoticed to the naked eye in the color picture (left) and well viewed in the Normal (center) and Enhanced (right) modes. The images are part of the footage of the movie recorded. The leak is coming from a pin hole in a small pipe corner.

## 1. INTRODUCTION

Volatile organic compounds (VOCs) that are mostly emitted from leaking components in the petroleum refining and petrochemical processing facilities; these hydrocarbon emissions are tightly regulated by the U.S. Environmental Protection Agency -EPA under the LDAR program. The relevant regulation prescribes a precise work practice to detect and repair any leaks found within refineries, storage and conveyance systems and emanating from a catalogued equipment component (as opposed to those not catalogued and targeted by EPA). Each component must be inspected quarterly. The work practice is known as Method 21. Under M21, crews utilize a gas detector with a wand-like probe and physically "sniff" every valve, flange and fitting at a regulated facility. The leak detector, known as an organic vapor analyzer (OVA), measures only the concentration of the leaking gas, not the volume. Thus a tiny leak, while it may emit a high concentration of gas may generate only a low total volume of gas. Regardless of the volume, any detected leak above a specific concentration (which varies by type of gas) must be repaired. Such inspections and repairs cost a typical refinery as much as $1M per year. This work practice is known as the current work practice (CWP). Organic or toxic vapor analyzers are used to monitor emissions at each possible point, which in the case of a typical chemical plant or oil refinery can be in the tens of thousands.

The LDAR Method 21 current work practice (CWP), instructs the operators the way the monitoring should be made with the appropriate instrument, normally TVA (PID, FID) (See Fig. 2). Measuring a leakage at a regulated component, first the background emission level must

*Fig 1. View Mode*

be measured. The head of the analyzer probe should be located at the monitoring component while covering its circumference in a slow movement. When a higher concentration measurement is read, the movement is stopped until the reading comes to a steady state, then resuming the monitoring around the component. The leakage rate results will be then the highest reading subtracted from the background emission level. This process is repeated for all regulated components Refineries and

*Fig. 2 Monitoring with TVA*

petrochemical plants have hundreds of thousands of regulated components which under the CWP must be inspected every quarter. Hence monitoring for regulatory compliance is a very major effort in human resources as well as monetary ones. The EPA introduced in December 2008, the Alternative Work Practice to Detect Leaks from Equipment (AWP) to be done in parallel to the existing CWP Method 21. While the number of screened components in CWP is around 700 per day, the number of screened components while operating in AWP is around 3000 a day.

**Alternative Work Practice**

An American Petroleum Institute study found that 0.13% of components in a typical refining facility accounted for 93% of the mass emissions of that facility. It was further shown that these components were leaking at rates of 10,000 ppm or more, well beyond the leak definition or allowable levels.

The trigger of releasing the Alternative Work Practice as an option to the existing method 21 was for the EPA, the existence of the technology which provides fast detection and exact location of the leaks. This technology although new to the petrochemical and oil & gas industries, is well known for many years in the military and security fields for night vision purposes. The thermal imagers, manufacturers seek for different applications to expand their field of use and markets mainly in the commercial and the industrial. These search, turned into a very useful application while the primary input came from a service provider who explore the possibilities and turned them into a successful product. Although it was proved that the heavy leakers are the most relevant in terms of amount of emissions overall, the EPA still requires an annual method 21 CWP, while if a site is planning to use the AWP must declare it in writing and keep the records. A site also must declare the conduction of surveys every 30, 45 or 60 days accordingly to the sensitivity level of the thermal imager used. Surveys must be conducted every 30, 45 or 60 days, depending upon the selected sensitivity level of the monitoring instruments, which also must be documented. After repair, a component must be checked regularly for leakage, and all video records of daily instrument checks and survey results must be retained for five years.

It has been found, that applying AWP more leaking equipment will be found than in CWP within a given timeframe, although CWP will find more leaks in given area. It is also common to find that CWP will tag a "leaking component" while the real source is found meters from there down wind.

A Thermal Imager dedicated for gas leak detection allows operators to say *"I see gas"*, and see gases that are invisible to the human eye without the use of the camera (See Fig. 3)

*Fig. 3 Monitoring with IR Camera*

**2. Thermal Imagers can detect gases plumes**

Thermal Imagers are sensitive to the IR spectrum which is a band in the electromagnetic spectrum as it is shown in Fig. 4. Gases have their own characteristic absorption lines in the IR spectrum;





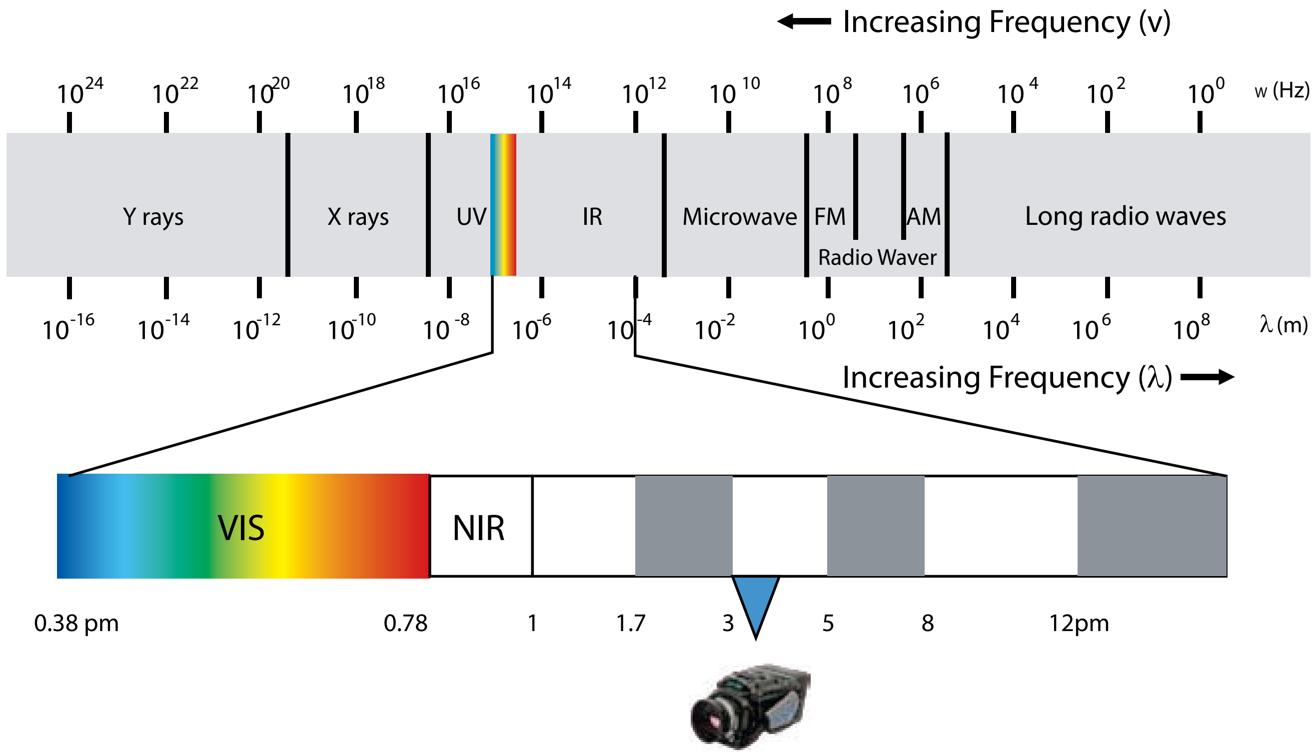



*Fig. 4 Electromagnetic Spectrum and IR camera*

VOC's and others have these lines in the region of the MWIR. The use of an IR imager adjusted to the region of interest will allow the gases to be visualized by the imager and displayed to the observer.

In the following figures, the spectrum in MWIR for Butane (Fig. 5) and Methane (Fig. 6) are shown, while the horizontal axis shows the spectrum in microns and the vertical axis shows the transmittance of the gas in the atmosphere, the lower percentage is the higher absorption for the gas.

Thermal imagers are sensitive to the absorption lines spectrum of the gases and designed to have the optical path sensitivity in correspondence with the gases in the spectrum area of interest. If acomponent is leaking, the emissions will absorb the IR energy, appearing as smoke black or white on the LCD screen.

The leaking gas temperature differs from the background temperature. The camera spectral band coincides with the absorbance spectra of the leaking gas. As shown in Fig. 7, the radiation getting to the camera is the background radiation from the background and the radiation from the gas area which obscures the background visualizing the existence of the gas.

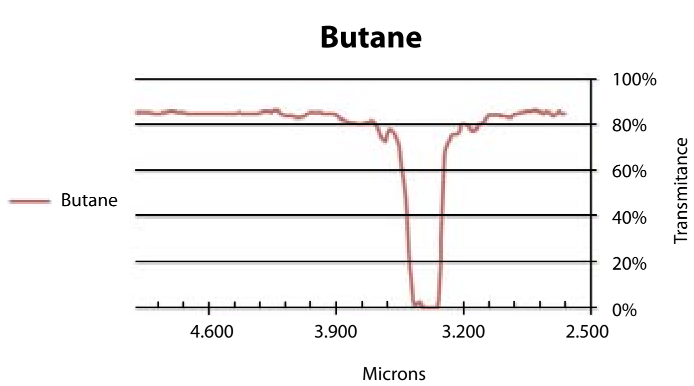



*Fig. 5 Butane IR Spectrum in MWIR*

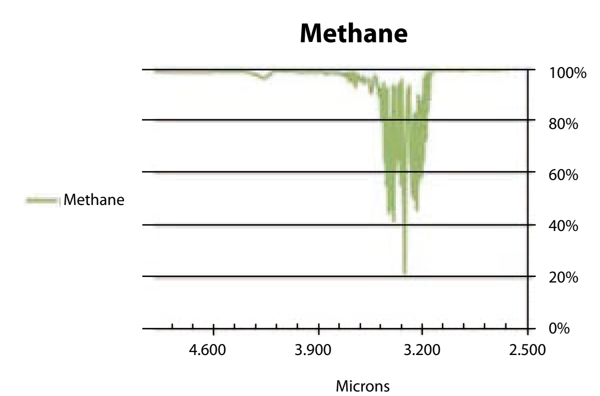



*Fig. 6 Methane IR Spectrum in MWIR*

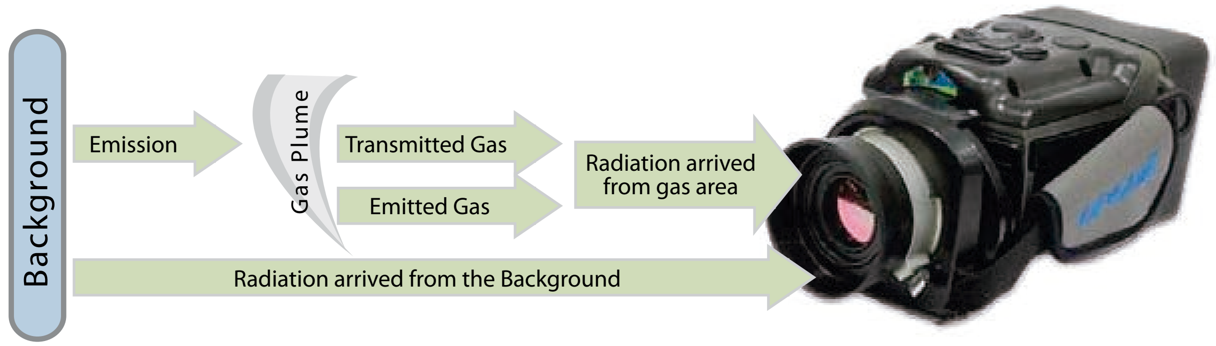



*Fig. 7 Detection path of the gas*

## 3 Test setup

The test was performed by placing two cameras model EyeCGas, side by side as a matter of redundancy to get results from similar cameras and proof of minimum leak rate detection (see Fig 8). The cameras were set in front of a calibrated Blackbody radiation instrument (Fig. 9 (1)) at a distance of 2 meters. A flexible gas tube with an inner size dimension of 6mm was attached in front of the blackbody; the gas flow through the tube was controlled via a flow controller (Fig. 9 (2)) verified and measured with a flow meter (Fig. 9 (3)), the ambient temperature and humidity were measured at all times with an electronic thermometer (Fig. 9 (4)). The gas was supplied from an equipped cart with methane cylinder with gas at 99.995% purity and a butane cylinder with gas at 99.995% purity.

During the tests was found, especially in the lower values set to the flow controller that there was a discrepancy between the measurement of the flow meter and the flow set in the flow controller. In order to get certainty of the measurements another calibrated flow meter was utilized to confirm the measured results and found correct.

Both cameras gave the same results proving repeatability of the product. The operators chose to use both modes of the camera during the whole test to verify the detectability at such extreme conditions, as a result was found that the enhanced mode of operation provides better detection for worst case scenarios. The procedure of the test also revealed that at given low thermal differences between the gas and the background the camera can detect very small leaks.

*Fig. 8 Test Setup with two cameras*





Test Equipment used for the setup:

(1) Black Body CI SR80 calibration date 31/8/2010

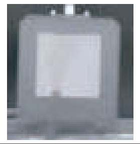
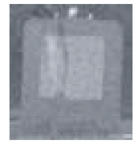
(2) Mass Flow Controller C100L Sierra Instruments for propane 0-3000 SCCM and C100L Sierra Instruments Methane 0-0.04 g/m. calibration date 20/9/2010.

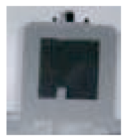
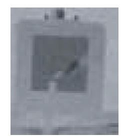
(3) Gas Flow Bios International corporation Defender 520

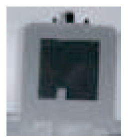
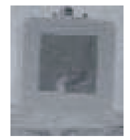
(4) Humidity & Temperature Recorder EXTECH RH520 calibration date 7/10/2010.

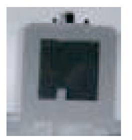
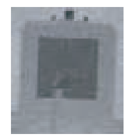
*Fig. 9 Instruments used for the set.*

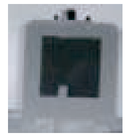
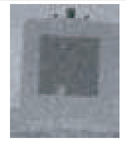
| Test #1 | No Gas | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  | N/A |
| Ambient °C | 26.63°C | | |
| Relative Humidity | 35% | | |
| Flow Mass ml/m | N/A | | |
| Flow g/h | N/A | | |

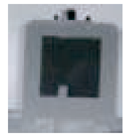
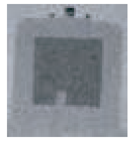
| Test #2 & 3 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 26.8°C | | |
| Relative Humidity | 37% | | |
| Flow Mass ml/m | 1588 | | |
| Flow g/h measured | 62.27 | | |
| Detection | | YES | YES |

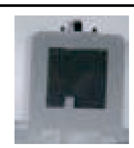
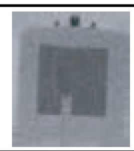
| Test # 8 & 9 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 27.9°C | | |
| Relative Humidity | 37% | | |
| Flow Mass ml/m | 63 | | |
| Flow g/h measured | 2.47 | | |
| Detection | | YES | YES |

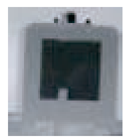
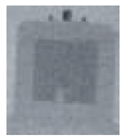
| Test # 10 &11 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 27.9°C | | |
| Relative Humidity | 32% | | |
| Flow Mass ml/m | 31 | | |
| Flow g/h measured | 1.22 | | |
| Detection | | YES | YES |

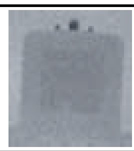
| Test # 12 &13 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.2°C | | |
| Relative Humidity | 32% | | |
| Flow Mass ml/m | 19.3 | | |
| Flow g/h measured | 0.76 | | |
| Detection | | YES | YES |

| Test # 14 &15 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.2°C | | |
| Relative Humidity | 34% | | |
| Flow Mass ml/m | 12.8 | | |
| Flow g/h measured | 0.50 | | |
| Detection | | NO | YES |

| Test # 16 &17 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.7°C | | |
| Relative Humidity | 31% | | |
| Flow Mass ml/m | 9.73 | | |
| Flow g/h measured | 0.38 | | |
| Detection | | NO | YES |

| Test # 19 & 20 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.7°C | | |
| Relative Humidity | 31% | | |
| Flow Mass ml/m | 8.8 | | |
| Flow g/h measured | 0.345 | | |
| Detection | | NO | YES |

| Test # 23 & 24 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 2°C |  |  |
| Ambient °C | 28.7°C | | |
| Relative Humidity | 29% | | |
| Flow Mass ml/m | 8.8 | | |
| Flow g/h measured | 0.345 | | |
| Detection | | NO | YES |

| Test # 26 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 1°C | N/A |  |
| Ambient °C | 28.8°C | | |
| Relative Humidity | 29% | | |
| Flow Mass ml/m | 15.74 | | |
| Flow g/h measured | 0.62 | | |
| Detection | | | YES |

## TEST RESULTS

Methane Test Data - The tests were numbered and those who were repeated or irrelevant were not introduced in the results (See Table 1).

| Test # | Mode | ΔT ºC | Ambient ºC | Relative Humidity | Flow Mass ml/m | Flow g/h | Detection |
|---|---|---|---|---|---|---|---|
| 1 | Test no gas | 3°C | 26.63°C | 35% | N/A | N/A | |
| 2 | Normal | 3°C | 26.8°C | 37% | 1588 | 62.27 | yes |
| 3 | Enhanced | 3°C | 26.8°C | 37% | 1588 | 62.27 | yes |
| 6 | Normal | 3°C | 27.9°C | 37% | 63 | 2.47 | yes |
| 7 | Enhanced | 3°C | 27.9°C | 37% | 63 | 2.47 | yes |
| 10 | Normal | 3°C | 27.9°C | 32% | 31 | 1.22 | yes |
| 11 | Enhanced | 3°C | 27.9°C | 32% | 31 | 1.22 | yes |
| 12 | Normal | 3°C | 28.2°C | 32% | 19.3 | 0.76 | yes |
| 13 | Enhanced | 3°C | 28.2°C | 32% | 19.3 | 0.76 | yes |
| 14 | Normal | 3°C | 28.2°C | 34% | 12.8 | 0.50 | no |
| 15 | Enhanced | 3°C | 28.2°C | 34% | 12.8 | 0.50 | yes |
| 16 | Normal | 3°C | 28.7°C | 31% | 9.73 | 0.38 | no |
| 17 | Enhanced | 3°C | 28.7°C | 31% | 9.73 | 0.38 | yes |
| 18 | Normal | 3°C | 28.7°C | 31% | 8.8 | 0.35 | no |
| 19 | Enhanced | 3°C | 28.7°C | 31% | 8.8 | 0.35 | Yes |
| 22 | Normal | 2°C | 28.7°C | 29% | 8.8 | 0.35 | No |
| 23 | Enhanced | 2°C | 28.7°C | 29% | 8.8 | 0.35 | Yes |
| 24 | Enhanced | 1°C | 28.8°C | 29% | 8.8 | 0.35 | No |
| 25 | Enhanced | 1°C | 28.8°C | 29% | 15.74 | 0.62 | Yes |

*Table 1. Methane Test Data*

A temperature difference of 3°C between the gas and the background was enough to visualize a methane mass flow of 0.76 g/h in normal [NOR] mode; in enhanced [ENH] mode, a temperature difference of 2°C between the gas and the background was enough to visualize a methane mass flow of 0.35 g/hr. After setting the temperature difference to 1°C the minimum detectable leak rate was measured to be 0.62g/h in the ENH mode of the camera. The instruments used for these tests didn't allow getting to lower flow rates.

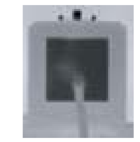
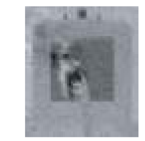
**Butane Test Data** - The tests were numbered and those who were repeated or irrelevant were not introduced in the results. (see Table 2)

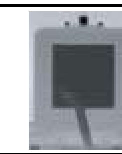
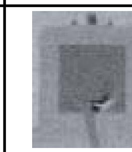
| Test # | Mode | ΔT ºC | Ambient ºC | Relative Humidity | Flow Mass ml/m | Flow g/h | Detection |
|---|---|---|---|---|---|---|---|
| 1 | Normal | 3°C | 28.6°C | 33% | 100 | 14.27 | yes |
| 2 | Enhanced | 3°C | 28.6°C | 33% | 100 | 14.27 | yes |
| 3 | Normal | 3°C | 28.6°C | 33% | 111 | 15.83 | yes |
| 4 | Enhanced | 3°C | 28.6°C | 33% | 111 | 15.83 | yes |
| 5 | Normal | 3°C | 28.6°C | 33% | 19.9 | 2.84 | yes |
| 6 | Enhanced | 3°C | 28.6°C | 33% | 19.9 | 2.84 | yes |
| 7 | Normal | 3°C | 28.6°C | 33% | 12.9 | 1.84 | yes |
| 8 | Enhanced | 3°C | 28.6°C | 33% | 12.9 | 1.84 | yes |
| 9 | Normal | 2.5°C | 28.6°C | 33% | 6 | 0.86 | no |
| 10 | Enhanced | 2.5°C | 28.6°C | 33% | 6 | 0.86 | yes |
| 11 | Normal | 2°C | 28.6°C | 33% | 6 | 0.86 | no |
| 12 | Enhanced | 2°C | 28.6°C | 33% | 6 | 0.86 | yes |
| 13 | Normal | 1°C | 28.6°C | 33% | 6 | 0.86 | no |
| 14 | Enhanced | 1°C | 28.6°C | 33% | 6 | 0.86 | yes |

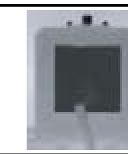
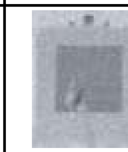
*Table 2. Butane Test Data*

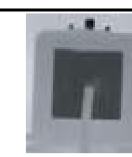
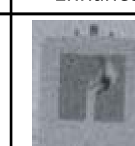


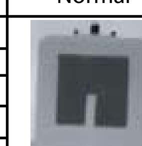
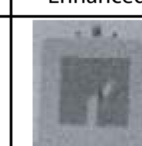
A temperature difference of 3°C between the gas and the background was enough to visualize a Butane mass flow of 1.84 g/h in NOR mode. In ENH mode a temperature difference of 1°C between the gas and the background was enough to visualize a butane mass flow of 0.86 g/h.

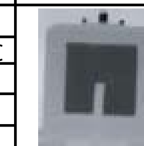
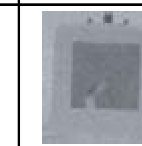
| Test # 1&2 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 462 | | |
| Flow g/h measured | 65.9 | | |
| Detection | | YES | YES |

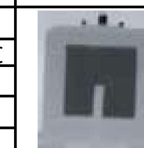
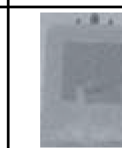
| Test # 3&4 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 111 | | |
| Flow g/h measured | 15.84 | | |
| Detection | | YES | YES |

| Test # 5&6 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 19.9 | | |
| Flow g/h measured | 2.834 | | |
| Detection | | YES | YES |

| Test # 7&8 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 3°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 12.9 | | |
| Flow g/h measured | 1.84 | | |
| Detection | | YES | YES |

| Test # 9&10 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 2.5°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 6 | | |
| Flow g/h measured | 0.86 | | |
| Detection | | NO | YES |

| Test # 11&12 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 2°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 6 | | |
| Flow g/h measured | 0.86 | | |
| Detection | | NO | YES |

| Test # 13&14 | | Normal | Enhanced |
|---|---|---|---|
| ΔT °C | 1°C |  |  |
| Ambient °C | 28.6°C | | |
| Relative Humidity | 33% | | |
| Flow Mass ml/m | 6 | | |
| Flow g/h measured | 0.86 | | |
| Detection | | NO | YES |

## 4 Summary

The tests shows that Thermal Imagers for gas leak detection can visualize methane mass flow of 0.35 g/h at temperature differences of 2°C and Butane mass flow of 0.86 g/hour at temperature differences of 1°C. The results shows a much lower mass flow compared to the required threshold of 60 g/h in the Alternative Work Practice (AWC) for EPA method 21 in the US.

The tests were performed for Methane and Butane for minimum detectable leak rate for convenience while the Thermal Imagers tuned for detection of VOC's are well capable for the detection of other materials as it is specified herein: Ethylene, 1-Hexane, Propanal, 1,3-Butadiene, 1-Butene, Methane, Propylene 1-pentene, Styrene, Toluene, Acetic acid, Xylene, 1,2-dimethyl-Benzene, Isobutylene , Isoprene, Benzene, Ethyl benzene, Ethylene oxide, Hexane, Methanol, Propylene oxide, Propylene, Ethane, Octane, Heptane, Isopropyl alcohol, MEK Methyl Ethyl Ketone 2-butanone, Propane, Butane, Pentane.

*Thermal Imager* can detect Methane @ 0.35g/h at 2°C ΔT.*
*Thermal Imager* can detect Butane @ 0.86g/h at 1°C ΔT.*
*Thermal Imager* can detect at much lower flows than the required by the EPA for Method 21, AWP (0.35g/h vs. 60g/h)*

* The Thermal Imager used for the test was EyeCGas by Opgal.
For more information please visit the website:
http://www.eyecgas.com/