Understanding Filter Methods for Uncooled Optical Gas Imaging

Infrared (IR) cameras have long been a valuable tool for detecting gas leaks at facilities such as natural gas power plants and many locations across the natural gas supply chain, using a technique known as optical gas imaging (OGI). By capturing the contrast between background energy and energy that’s been absorbed or transmitted by gas, such cameras make it easy to identify leaking components. The most common OGI cameras available today offer a cooled imaging sensor. While these cameras provide users with sophisticated capabilities, they may be out of reach for some potential users due to the price point. Now, new advancements in uncooled detector and spectral filter technology are expanding the options for OGI to include a more cost-effective option.

Filtered, uncooled IR cameras are not as sensitive as their cooled cousins. For example, the uncooled cameras may not have enough sensitivity to meet the Environmental Protection Agency’s (EPA) standard to comply with the O000a rule, which requires natural gas well pads and compressor stations to check for gas leaks. (Fig. 1) Fortunately, for companies that don’t have to meet those requirements, the substantially lower price of an uncooled camera opens up new options. For instance, companies that liquefy natural gas for shipping across the ocean, then return it to its gaseous state after unloading it, could

**Figure 1:** A leak in a natural gas compressor is easily visible using optical gas imaging.

**Figure 2:** OGI allows users to spot the source of leaks, such as in this valve.
benefit from being able to detect methane leaks. Even though they’re not bound by the same EPA regulations, using OGI for leak detection and repair would improve their safety and reduce the amount of product lost to the atmosphere, increasing their profits.

Looking for Contrasts
The idea behind OGI is straightforward. When energy passes through a plume of gas, the gas both absorbs and emits energy at particular wavelengths, depending upon the type of gas. If the temperature of the gas and the background differ, the strength of this absorption and emission will also differ, creating a contrast in the image. On a detector optimized for the correct wavelengths, the gas will appear as a smoke-like cloud against a bright background. While other technologies such as electrochemical “sniffers” can also detect gas leaks, they only register the presence of the gas. An IR camera makes it easy to see not only the size of the gas plume but also where it’s coming from. (Fig. 2)

But to achieve the sensitivity to pick out the contrast between background and gas, IR cameras have traditionally been cooled to cryogenic temperatures of 70 Kelvin, or minus 203 degrees Celsius. That helps cut out stray energy and thermal noise from the camera equipment itself and makes the gas easier to spot. Such cameras have relatively complex designs, including the cooling system and a spectral filter inside the dewar, where it too can be cooled to prevent it from causing any thermal noise. These systems require sophisticated manufacturing processes and the coolers include moving parts built to tight tolerances, which require periodic service to maintain optimal performance. Other characteristics to consider: the helium gas used to cool the system may slowly leak and the coolers, due to regular use, need to be rebuilt after approximately 30,000 hours in the field. For optimum use, these cameras require operators to wait approximately seven minutes for the system to cool to the correct temperature.

To provide customers with an option other than a cooled system, FLIR Systems introduced a new type of gas detection camera that uses a bolometer to see infrared. Bolometers are made of materials such as vanadium oxide or amorphous silicon—which respond in the 7 to 14 µm range—and they work differently than the cooled IR cameras. While cooled detectors count the number of IR photons striking them, bolometers heat up when the IR radiation hits them, causing a measurable change in their electrical resistance. Because they don’t require cooling, bolometer-based cameras are simpler to design and build and therefore are more affordable than their big brother, the cooled camera.

Uncooled cameras don’t require any start-up time, meaning operators can get straight to work. While they’re not as sensitive as cooled cameras, bolometer-based uncooled cameras are improving with upgrades such as improved pixel pitch for higher sensitivity.

Adding a Filter
Typical uncooled infrared cameras aren’t designed to see gases, so some new models are fitted with spectral filters relevant to specific gases. For example, a camera meant for use in the oil and gas industry might have a spectral filter range of 7–8.5 µm, because methane absorbs energy in that range. Another gas of interest, sulfur hexafluoride, is visible between 10.5 and 11 µm. (Fig 3)

Filtering out other wavelengths reduces the energy that might otherwise overwhelm the gas signal, making it easier to see. The narrower the wavelength range of the filter, the higher the contrast between the radiation from the gas and the background energy.

The trick is to design the filter correctly. While a narrower bandpass increases the contrast, it also means less energy gets through to the detector overall, changing the signal-to-noise ratio for the worse. Much of the noise comes from the detector itself, so it remains constant even as the filter reduces the amount of signal.

There are systems that do not use filters. Some cameras are essentially wide open, picking up energy over the entire wavelength range of the detector. Operators need to use software to perform image subtraction, taking out the parts of the image they don’t need.
in the hopes of seeing any gas leaks more clearly. While such software can improve the visualization of the gas image, they do not work as well as filters.

Measuring Noise
The quality of the signal is often characterized in noise equivalent temperature difference (NETD). NETD, measured in millikelvins, represents the temperature difference that would produce a signal in the image equal to the noise from the camera. In other words, it provides the minimum temperature difference a camera can resolve.

For example, an uncooled camera with no filter would collect energy across the entire range of 7 to 14 µm. The NETD in such a system would be low, perhaps 20, so the signal-to-noise ratio would be good. On the other hand, the contrast between the gas and the background would also be low, so the image would be harder to see. Adding a filter that transmits between about 9 and 12 µm improves the contrast, but the NETD more than doubles, making the noise worse and degrading the image. A filter that operates between 10.5 and 11 µm—the wavelength range for sulfur hexafluoride—provides a very high contrast image, but the NETD becomes roughly 10 times worse, nearly drowning out the signal from the gas.

Essentially, then, the contrast and the noise move in opposite directions. The key to getting the best image is to pick a filter narrow enough to provide good contrast, but not so narrow that the signal vanishes in the noise.

The quality of the image is also affected by the volume of gas that energy is passing through, which is described in terms of concentration length.

The quality of the signal, therefore, can also be characterized in terms of noise equivalent concentration length (NECL), a parameter similar to NETD. A camera with lower NECL has greater sensitivity. Concentration length is the average amount of gas in the air over a given distance, measured in parts per million per meter (ppm x m). If you had a one-meter long tube filled with 100 percent methane, the concentration length would be 1 million ppm x m. If the gas were diluted to 50 percent, the concentration length would be 500,000 ppm x m. The greater the concentration length, the more energy is absorbed or transmitted, leading to a higher-contrast image. Larger gas plumes, in other words, are easier to see whether the filter is wide or narrow, so the choice of filters also plays a role in how big a leak is detectable.

Temperature Changes
IR cameras are not only useful for OGI, of course. Owners of natural gas processing facilities also use them to inspect equipment for temperature anomalies. For instance, if a connector in a gas line is a lot hotter than it should be, that could be a sign of imminent failure. Many facilities use IR cameras for such dual-purpose imaging and require accurate temperature readings. (Fig. 4) For these dual-applications, a cooled OGI camera may be a more appropriate choice.

Just as the addition of a spectral filter degrades signal-to-noise and image quality, the filter also reduces the accuracy of temperature measurements. If it’s important to be able to both detect gases and gather precise measurements, a cooled IR camera would be preferred.

A Range of Options
The introduction of uncooled cameras equipped with spectral filters has opened up new options for the people who handle gas and need to perform leak detection and repair. Cooled cameras are still the best choice for companies that need to comply with OOOOa regulations or gather accurate temperature measurements along with finding gas plumes. However, uncooled bolometers could be ideal for companies that don’t have such stringent requirements but would still like to turn to OGI to improve their safety profile and reduce losses. The less expensive uncooled IR cameras, when fitted with the correct spectrally filtered lens, can prove a valuable tool for detecting leaks.

For more information about thermal imaging cameras or about this application, please visit www.flir.com/ogi

The images displayed may not be representative of the actual resolution of the camera shown. Images for illustrative purposes only.