Thermal Imaging and District Heating Monitoring

Jessica Kodra 11/07/2025

1. Thermal Imaging

1.1 What is observed or measured by a thermal camera?

Thermal cameras measure infrared radiation emitted by objects. This relates to the surface temperature of the object. Visible light is only a small part of the electromagnetic spectrum and the only part that we can actually see. When directed at an object, a sensor on a thermal imagining camera allows us to view the infrared spectrum. The sensors integrate energy across a specific infrared bandwidth and captures a combination of emitted, reflected, transmitted and scattered radiation. The recorded temperature, however, does not equate to the internal temperature of the object but its surface radiance. (RS, n.d.)

What is recorded is then rendered onto a colour map in modern infrared cameras, but black-and-white displays are still used and preferred where more fine-detailed imaging is needed. For the colour thermographic display, warmer components show up as warmer colours (reds, oranges and yellows) and colder parts as cooler colours (purples and blues). Green is usually an indicator that an object is at room temperature. Thermal cameras are very useful for identifying heat sources in dark and obscure environments.

1.2 Differences between the Reflective and Emissive Domains

Emissivity measures the ability of a material to emit infrared energy and ensures accurate temperature measurements. It is defined as the ratio of infrared radiation emitted by a material to the infrared radiation emitted by an ideal blackbody at the same temperature. Emissivity ranges from 0 to1. A material with high emissivity (close to 1) mostly emits its own infrared energy which is what makes it ideal for thermal imaging. A material with low emissivity (0 – 0.2) reflect a lot of infrared energy and emit very little themselves which can often lead to inaccurate readings. An example of a material is polished metal

Reflectivity refers to how much radiation is being reflected from a material's surface. This becomes important when a material has low emissivity. Thermal cameras operate mainly in the emissive domain as they focus on radiation emitted by the object itself. Reflected infrared radiation tends to distort temperature readings. An example of this is tested by pointing a single wavelength infrared pyrometer at a stainless-steel cooking pot. The pot will yield a falsely lower temperature due to it being highly reflective. Advanced technologies have been developed to compensate for this effect by adjusting for reflectivity, allowing accurate measurements on low-emissivity surfaces. (What is Emissivity and Reflectivity?, n.d.)

1.3 Applications of Thermal Cameras in Energy-related Contexts

Thermal cameras can enable fast detection of heat loss, it can identify defects in mechanical systems, locate energy inefficiencies and monitor district heating networks. It is very useful as it is a non-invasive approach to ensure proper insulation and prevent wasting energy. In energy intensive industries such as oil and gas, manufacturing and construction, thermal imaging helps support machine maintenance and reduces the risk of breakdowns. This leads to improved efficiency, it extends equipment lifespan and helps save costs. Thermal cameras can also help reduce carbon emissions in plants by accurately monitoring the processes that emit greenhouse gases and supporting their maintenance. All these operations of thermal cameras help contribute to more sustainable operations and environmental responsibility. (Raytron, 2024)

1.4 Can Thermal Cameras See Through Objects?

Thermal cameras cannot see through solid objects like walls or glass as these materials are opaque to infrared radiation. Thermal imaging detects heat emitted from an object's surface, instead of penetrating surfaces. They cannot directly "see" through walls, but they can detect temperature variations caused by hidden elements like hot or cold pipes, as heat radiates to the outer surface. Materials that have low emissivity, such as concrete, do not emit much infrared energy but heat from internal components can alter the surface temperature. These can be interpreted to detect leaks, insulation failures or structural issues. (Gill, 2023)

2. District Heating

2.1 Difference Between Media and Energy Leakage

Both types of leakage result in reduced efficiency and increased operational costs, but they require different detection and repair strategies. There are two main types of leakage that can occur: media leakage and energy leakage. Media leakage is the physical escape of a heating medium, such as water or steam, leaving the pipe network. The medium functions to store or transport thermal energy- for example water in heating systems or air in ventilation systems.

In contrast, energy leakage is the loss of thermal energy to the environment through conduction, convection, or radiation, even when the medium remains contained. This is due to poor insulation, physical damage, and an unmanaged heat transfer process. Both types of leakage lead to reduced system efficiency, higher energy consumption and costs, environmental impact, and potential operational disruptions.

2.2 Thermal Camera Penetration Depth

Thermal cameras detect surface temperature changes caused by buried heat sources which makes them useful for identifying issues like underground pipe leaks. Its ability to detect these temperatures depends on various factors such as pipe temperature and insulation, soil composition and moisture, weather conditions and burial depth—typically up to 1 meter under ideal conditions. When a leak occurs, temperature variations may reach the surface and can be detected by thermal cameras.

2.3 Why Use Aerial Thermal Imaging Instead of Ground-based Methods?

Aerial platforms such as drones or planes provide several advantages such as:

- Comprehensive Coverage: offers a broader view and access to areas where ground vehicles cannot go.
- Efficiency: larger areas can be surveyed quicker with fewer interruptions.
- Data Quality: elevated vantage points reduce angular distortion and can detect anomalies better.

Flying comes with a higher cost initially, but it is more cost effective in the long run for its speed and accuracy. Ground vehicles are cheaper but are slower and not all areas are accessible.

Conclusion

Thermal imaging is a very beneficial tool that helps detect energy losses and helps with the maintenance of infrastructure systems, especially in district heating networks. By understanding the principles of thermal radiation, domain differences, and practical limitations, thermal technology can be used effectively to optimise energy and aid with public safety.

References

Gill, L. (2023, December 22). *How a Thermal Imaging Camera Can “See Through Walls”*. Retrieved from processparameters: https://www.processparameters.co.uk/can-a-thermal-camera-see-through-walls/#:~:text=Can%20Thermal%20Imaging%20Cameras%20See,data%20overlaid%20onto%20real%20images.

Raytron. (2024, September 25). *Energy Saving with Infrared Thermal Cameras: Key Role in ESG Initiatives*. Retrieved from https://en.raytrontek.com/news/news-detail-907.htm

RS. (n.d.). *Everything You Need To Know About Thermal Imaging Cameras*. Retrieved from RS: https://se.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/thermal-imaging-cameras-guide

What is Emissivity and Reflectivity? (n.d.). Retrieved from Willaimson: https://www.williamsonir.com/blog/what-is-emissivity-and-reflectivity/