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# THERMAL IMAGING APPLICATIONS IN THE CONSTRUCTION INDUSTRY

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## ABSTRACT

Infrared radiation is one range of the electromagnetic spectrum that human beings have identified so far. The wavelength of this range is just larger than the visible light bundle that allow human eyes to perceive the surroundings and differentiate colors. On the other hand, infrared has been associated with carrying thermal energy from hot to cold bodies and has many applications in various industries due to this special nature. Through detection of infrared emitted from different bodies, thermal information can be collected and interpreted to serve in multiple important applications especially in the construction industry during the execution or the operation and maintenance of building projects. The objective of this paper is to present the background of utilizing this important radiation in the various construction applications and shed some light on potential future implementation.

**KEYWORDS**: Thermal Imaging – Infrared - Construction.

## INTRODUCTION

Within the field of technology, the advancements that continue to be made allow for more effective and efficient business practices. Of specific interest is that of thermal imaging, and its various applications in the construction industry. Within the electromagnetic spectrum is an array of various forms of electromagnetic radiation. Electromagnetic radiation occurs when a charged particle is accelerated or decelerated, in which electromagnetic waves are formed by the vibrations of magnetic and electric fields. These waves are thus temporary disturbances that despite progression through space, hold their shape (Vollmer & Mollmann, 2010). Furthermore, various forms of such radiation exist, including microwaves, ultraviolet light, and infrared light.

Of specific interest is that of infrared light. Infrared radiation is emitted through the rotations and vibrations of various materials. Therefore, while these wavelengths are often invisible to the naked eye, they can be detected as warmth through the skin. Furthermore, infrared light is often referred to as part of the "invisible" spectrum that comprises electromagnetic radiation of wavelengths from 800 nm to 1 mm. In an effort to understand this infrared light that comprises a portion of the "invisible" spectrum, there are a number of techniques used.

Infrared detectors can act as a transducer, in which the radiation emitted is translated into electrical signals (Vollmer & Mollman, 2010). Furthermore, infrared cameras utilize a number of different techniques in an effort to sense infrared light. Techniques such as multispectral and hyperspectral infrared imaging are used to gather image data through various wavelength bands across the spectrum. Furthermore, of specific importance is the use of thermal imaging and its ability to process infrared images. Due to the invisibility of infrared, thermal imaging technology allows individuals to perceive this part of the spectrum through the thermal energy emitted from various objects. Therefore, thermal imaging can be used to detect infrared energy and convert it into an electronic signal, which is then translated into a thermal image (Flir). While thermal imaging is a primary source for detecting infrared light, night vision goggles and low light imaging can also be used to sense infrared.

Despite the various mediums in which infrared can be detected, thermal imaging is of specific importance. With the existence of infrared radiation being discovered by William Herschel in 1800, the need to measure and understand infrared light has been a topic of interest for some time (Phillips, 2002). Prior to the inception of thermal imaging technology, various products were used, such as IR illuminators and intensified image devices. While these night vision products were efficacious, the limitations of the products often resulted in undesirable effects (Wimmer, 2011). However, thermal imaging, unlike the products above, were designed to not emit any kind of energy, but to merely detect infrared.

While an extension of William Hershel's discovery led to the production of the bolometer in 1880 by Samuel Langley to measure infrared radiation, the first thermal imaging camera was produced in 1929 in Britain (Wimmer, 2011). Thermal imaging cameras have the strongest connection to the military market, in which night vision was introduced and sought after to provide an advantage in battle (Phillips, 2002). For example, in 1970, the first naval thermal imager was developed to aid in shipboard firefighting. Despite the various military and security applications of thermography, thermal imaging is now being widely used in the construction industry, as a medium to identify the weak points in building structures, and to measure the amount of infiltration in a building (Woolaway, 2008).

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Presently, there are several products available to consumers who would like to utilize this technology in the construction field, such as handheld thermal imaging cameras and night vision goggles. While there is an array of thermal cameras on the market, they vary in terms of price depending on whether the camera series is defined as a performance, professional, or expert level. Regardless, the use of such cameras continues to be an effective way to enhance building construction and to identify infiltration and exfiltration during and after a project.

## THERMAL IMAGING IN CONSTRUCTION APPLICATIONS

Despite efforts to create and maintain sustainable buildings, the amount of energy consumption among commercial and residential structures continue to pose a problem. This energy consumption has resulted in concerns about the exhaustion of natural resources, as well as the environmental impacts and consequences. In developed countries, it has been said that global energy consumption in buildings has steadily increased from 20 percent to 40 percent (Pérez-Lombard, Ortiz, & Pout, 2008). Due to this rise in energy consumption, the efficiency of construction processes and energy sources are of primary concern. There are many factors that contribute to the increased energy consumption in buildings, one of which is air infiltration/exfiltration.

Infiltration is defined as the movement of air that penetrates a building, while exfiltration is air that escapes from inside a structure. The process of infiltration occurs when air permeates through the weak envelopes in buildings, such as under doors, door frames, windows, and small gaps (Raman, Prakash, Ramachandran, Patel, & Chelliah, 2014). The results of such infiltration can include reduced air quality, interference with proper operation of ventilation systems, and increased energy consumption (Raman et al., 2014). To understand and attempt to quantify air infiltration and its effects on energy consumption, various models and methodology have been proposed.

To assess the impact of air infiltration, models such as the Lawrence Berkeley Laboratory and Alberta Air Infiltration attempt to understand air leakage rates for buildings under various temperatures and wind conditions (Joseph & Dutta, 2014). Utilizing the standard test methodology of the ASTM E-779, air leakage is measured by creating controlled depressurization conditions. To do this, a Blower Door device, often referred to as the Fan Pressurization technique, is used to pressurize or depressurize a building. (Raman et al., 2014). While the Blower Door method is widespread within the literature of infiltration measurement, utilizing microphone arrays and beamforming algorithms have also been proposed. Furthermore, due to the lack of the fan pressurization method having the ability to measure air infiltration under normal weather conditions, a method was introduced in China based on the mass balance of particles (Li & Li, 2015). This method is said to be an effective way to measure infiltration in large, commercial spaces.

While determining airflow rates are often calculated by fan pressurization and tracer gas tests, using carbon dioxide as a tracer has been used as well (Chen Ng & Wen, 2011). Other methods have also been proposed, such as the limiting area method, or LAM. This approach recognizes the smallest openings in the flow path limiting airflow within a building structure (Whitehead & Frisque, 2014). Accounting for wind pressure and stack pressure, or the difference in air density between the inside and outside, LAM is said to produce stronger simulation calculations than other methods. Aside from the above methodologies, recent efforts to assess air leakage has focused on the use of thermal imaging. Of primary interest in the current work is the use of thermal technology and its capabilities in regard to infiltration measurement.

While the inception of thermal imaging was driven by the needs of military systems, it is now being utilized within construction to quickly assess infiltration (Woolaway, 2008). Through the use of thermography, infrared technology uses color display of temperature fields. This provides a visual display of the heat flux within buildings, expressing the air leakage that often occurs at common thermal bridges, such as balconies, joints of walls and foundation, and corners (Pusnik, 2013). Infiltration leaks leave a "thermal signature," and can therefore be identified by infrared thermal imagers (Woolaway, 2008). Thermal imaging thus provides a means to measure what the human eye cannot detect, and does so in a non-destructive and non-intrusive manner (Bianchi, Pisello, Baldinelli, & Asdrubali, 2014).

Not only can thermal imaging assist in the assessment of infiltration levels, but it can also aid in analyzing defects in electrical panels and other mechanical equipment. For example, thermal imaging has been used as an auto-diagnosis tool for electrical distribution panels. Thus, researchers use thermal imaging to build diagnostic features in an attempt to reduce maintenance costs and accidents (Wang, Wu, & Jiang, 2015). Furthermore, identifying "hot spots" with thermal imaging cameras may assist in finding faults in induction motors (Eftekhari, Moallem, Sadri, & Hsieh, 2013). This process utilizes the thermal camera's ability to identify excessive heat, providing a means to compare temperature profiles between healthy motors and faulty ones.

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Thermal imaging is clearly used for an array of duties within construction. In alignment with detecting infiltration in buildings, thermal imaging can aid in the building inspection process as well. In an article by Holden (2011), pyroelectric arrays are said to be extremely cost effective and efficient when doing queue management. Furthermore, these products are often referred to as uncooled thermal detector arrays that are becoming widely available for commercial use. Other methods, such as single image rectification, is a photogrammetric technique that provides geometric and thermal information about building facades (Gonzalez-Jorge et al., 2012). It is tested by comparing laser scans and thermal data. The method has been found to be highly accurate, and as such may be extended for the use of building inspection tasks in the future.

Other applications of thermal imaging exist within the construction field, such as mechanical damage assessment. Power line maintenance technicians can also use this technology to locate overheated joints and high-voltage lines in an effort to prevent electrical failures (Grainger). As well as these areas, the first infrared cameras were designed to detect gases. This application is still being used as a means to detect any absorption or emission of a gas (Vollmer & Mollman, 2010). Furthermore, thermal imaging is used in power plants in an effort to detect hot spots and leak detection in pipes and valves.

## REFERENCES

[1] Bianchi, F., Pisello, A., Baldinelli, G., & Asdrubali, F. (2014). Infrared thermography assessment of thermal bridges in building envelope: Experimental validation in a test room setup. *Sustainability, 6(10)*, 7107-7120.
[2] Chen, N., & Jin, W. (2011). Estimating building airflow using CO2 measurements from a distributed sensor network. *HVAC&R Research*, *17*(3), 344-365.
[3] Eftekhari, M., Moallem, M., Sadri, S., & Hsieh, M. (2013). A novel indicator of stator winding inter-turn fault in induction motor using infrared thermal imaging. *Infrared Physics & Technology*, *61*, 330-336.
[4] González-Jorge, H., Lagüela, S., Krelling, P., Armesto, J., & Martínez-Sánchez, J. (2012). Single image rectification of thermal images for geometric studies in façade inspections. *Infrared Physics & Technology*, *55*(5), 421-426.
[5] Holden, A. (2011). Applications of pyroelectric materials in array-based detectors. *IEEE Transactions On Ultrasonics Ferroelectrics & Frequency Control*, *58*(9), 1981-1987.
[6] Joseph, T., & Dutta, A. (2014). Experimental analysis of airtightness and estimation of building air infiltration using two different single zone air infiltration models. *International Journal of Energy & Environment*, *5*(4), 419-430.
[7] Li, H., & Li, X. (2015). A new method to assess the infiltration rate in large commercial complex in Beijing, China.
[8] Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and buildings*, *40*(3), 394-398.
[9] Phillips, T. J. (2002, September). High performance thermal imaging technology. *III-Vs Review*. p. 32.
[10] Pusnik, I. (2013). Applicability of thermal imaging for assessment of energy efficiency in buildings. *AIP Conference Proceedings*, *1552*(1), 1009-1013.
[11] Raman, Prakash, Ramachandran, Patel, & Chelliah (2014). Remote detection of building air infiltration using a compact microphone array and advanced beamforming methods. *Illinois Institute of Technology.*
[12] Rand, K. (No date). Retrieved from http://www.physicscentral.com/explore/action/infraredlight.cfm.
[13] *Thermal Imaging Cameras Explained* (2015, September). Retrieved from https://www.grainger.com/content/qt-thermal-imaging-applications-uses-features-345.
[14] Wang, M., Wu, P., & Jiang, W. (2015). Application of infrared thermography and extension recognize method to intelligent fault diagnosis of distribution panels. *IEEJ Transactions on Electrical & Electronic Engineering*, *10*(4), 479-486.
[15] *What is Infrared.* (2017). Retrieved from http://www.flir.com/about/display/?id=41536.
[16] Whitehead, D., & Frisque, A. (2014). Estimating tall building infiltration at main entryway. *HVAC&R Research*, *20*(4), 395-403.
[17] Woolaway, J. T. (2008). Infrared technology trends and implications to home and building energy use efficiency. *AIP Conference Proceedings*, *1044*(1), 217-231.