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A Case Study: Infrared Thermography Technique is An Essential Tool to Determine Energy Leakage from Failing Door Seals on Prototype Cold Storage

Laxmi Raikwar Singadiya[1], J.K Shrivastava[2]

[1]Chemical Engineering Department Ujjain Engineering College Ujjain, India
raikwarlaxmi2022@gmail.com
[2]Chemical Engineering Department, Ujjain Engineering College, Ujjain, India
principal.uecu@gmail.com

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Abstract— *A study was conducted to assess the efficiency of insulation in a prototype cold storage system by using phase change materials, aiming to detect energy loss through failing door seals and insulation panel integrity issues. Infrared thermography was used for this experimental investigation, utilizing thermographic images. The cold storage, with a volume of 606 liters, maintained internal conditions at 4°C temperature and 95% relative humidity, while surrounding ambient conditions were set at 42°C temperature and 75% relative humidity. Analysis concluded that a transmitted heat gain of 202.3 Kcal from walls and doors during daylight hours, highlighting significant energy losses attributed to failing door seals.*

Keywords*— *Energy leakages, Insulation, Phase change material, Seal failing, Thermography images.

I. INTRODUCTION

After being harvested, agricultural products require preservation. A common protective technique used worldwide is cold storage. A cold storage facility is made up of structural elements and a cooling system, which produces and circulates cold air within the space. The planning and construction stages of a cold storage system are critical, as the preservation of agricultural products depends on maintaining the integrity of the cold air environment. Therefore, it is essential to ensure that the cold air within the storage facility is effectively insulated and protected. The cold storage facility experiences unnecessary energy losses due to poorly insulated walls and inadequate refrigeration system maintenance. One of the major losses is transmission load losses cause is leakage of the cold air through failing of the door seals. The identification of the cold spot of air leakages from the wall and door by naked eye is very difficult. Thermal imaging technology is one of the most promising field pertaining inspection tool is used for identification of temperature difference between cold spots and other area of the wall and door where air leakages in the cold storage facility.

The applicability of infrared (IR) technology has been used successfully more than twenty five years for Inspection and performing nondestructive testing of building elements, determination of energy leakages from the buildings' envelope, efficient visualization of fluid flow laminar/transition reason, thermal diagnosis of insulation material, healthy operation for heating ventilation air conditioning (HVAC) system's, safety inspection of electrical and mechanical systems under full load operation. In the year of 1997 E. Grinzato et al. [1] developed a numerical model for the building based on quantitative infrared thermography the results are addressed deficiency of insulation, identification of the air leakages and mapping of the moisture content. C.A Balaras et al. [2] demonstrated infrared thermographic inspection in buildings helps in preventive maintenance program. They identified energy leakages, quantified the energy saving potential, and set schedule intervention and priorities for predictive and preventive maintenance of the building envelop. N.P Avdelidis, et al. [3] was acknowledged importance of the thermal imaging technology for building materials survey to determine temperature, wavelength and surface condition effect of the building material based on emissivity measurements at laboratory. Avdelidis and A. Moropoulou et al. [4], Infrared thermography is an efficient evaluation tool for materials. Its usefulness makes it a preferred choice for many applications, and techniques of historic sites and buildings. Substantial amount of research work has been published on heat flux assessment under different conditions. Y. Le Sant et al. [5] developed one dimensional data compilation method with the help of with the help of infrared thermography for boundary layer visualization of laminar to turbulent transition area and heat flux assessment on large transonic test facility. Datcu, et al. [6] an experimental investigation was conducted using composite walls to quantify the reflected flux of the wall by infrared thermography on large surface area of the wall, the results shows good agreement between thermocouple temperatures and thermal scan of wall surface structure. Luı´s P.C. Neto et al. [7] conducted parametric study on an air curtain device by using infrared thermography. They investigated sealing effect of the different variables, door height, initial angle, temperature difference between two compartments and the jet velocity etc. Jean Charles Candoré et al. [8] performed thermal diagnosis of the insulation to detection of defects in the building with the help of passive stimulated IR thermography. The result shows that method was sensitive to the process and the thickness of insulation. The method was established the framework of heat balance and energy assessment of a building. Muhsin Kilic et al. [9] demonstrated application of IR thermography of an automobile cabin they measured thermal comfort conditions of the subject. They found this technique is more appropriate and rapid than other common temperature measurement method. Paris A. fokaides et al. [10] used infrared thermography technique to find out overall heat transfer coefficient for building envelops. The proposed technology is validated with more accurate heat flux meters and results are found in the range of 10 to 15% acceptable level. Fabio Bisegnaa, et al. [11] published a case study on thermal weak points for ancient wall structures by using passive infrared thermography. They validated effectiveness of the thermal images and its importance in preventive diagnosis. The technology is demonstrated application of IR thermography useful tool for preventing the historical building structure damages caused by the earthquake. In the recent years mock targeted thermography was used to solve the control environmental condition. L. Georgiou et al. [12] studied transient conditions of indoor air temperature with the help of mock target infrared thermography (MTIR). They developed numerical model and validated with experimental results provided by thermocouples pole.

Very few research studies published on energy leakages from the cold storage facility. S. Akdemir et al. [13] studied the insulation of experimental cold storage by analysis of the thermal images. The outcome of their work provides, strong evidence that infrared thermography is an effective technique for the evaluation heat loss around sliding door of cold storage. A. Kylili et al. [14] published a review paper on passive and active infrared thermography technique the author is summarized mentioned technology useful tool for definition of defects in building sector. In recent years, P. Pathmanaban, et al. [15] analyzed cold air transmission locations by applying MAT lab software for processed and analyzed thermal images of cold storage, and concluded histogram method produced more accurate result other than diffusion error, thresholding and morphologic function methods. The aim of this investigation was to determine if thermography images could be used as a tool to evaluate performance and minimize energy loss caused by deteriorating door seals.

II. MATERIALS AND METHODS

Prototype Phase change material (PCM) incorporated cold storage facility and thermal imaging camera is used as a material in this experimental work.

2.1 Model Cold Storage

For the development of prototype model, it was essential to maintain a temperature of 5°C and a relative humidity of 96%. The wall's composition comprised a 100 mm thickness, consisting of a 5mm layer of stainless steel, 90 mm of PUF insulation, and a 5 mm mild steel plate. The door, with a 70 mm thickness, featured a 5 mm stainless steel sheet, 60 mm of poly urethane foam (PUF) insulation, and a 5 mm mild steel plate. Between the door and the storage space, a 15 mm rubber seal was placed to prevent leaks. The model having storage dimension 1.170 m x 0.785 m x 0.660 m and storage volume of the cold chamber is 0.606 m3. The weight of 48.64 kg of PCM hydrated salt (HS) is used. One ton capacity of air conditioning system is used to maintain the temperature and relative humidity inside the cold room. National horticulture board (NHB) standard 01: 2010 and ASHRAE Refrigeration hand book 2014 were followed for a design consideration of prototype PCM incorporate [16].

2.2 Instrument and Measurement

The examination of the cold storage involved the thermal imager, Testo 868 for capturing thermal images (refer to

Figure.1). The Testo 868 is equipped with several technical features, including a high-quality wide-angle lens with a 31° x 23° field of view, a detector with a resolution of 320 x 240 pixels, thermal sensitivity Noise Equivalent Temperature Difference (NETD less than 100 mK, a minimum focusing distance of less than 0.5m, The camera is equipped with a surface moisture distribution display, dynamic motor focus, isotherm functionality, audio commentary, min/max measurement on a designated area, power LEDs for illumination, and an optional high-temperature filter.

Fig.1 Thermal Imager (Testo 868)

2.3 Methodology

The quality of thermal images depends on surrounding condition like ambient temperature, airflow, and lighting conditions. The boundary conditions for the experiment were set at an outside ambient temperature of 40°C and 75% relative humidity. The inside space temperature and relative humidity were maintained at 4°C and 95%, respectively. Upon activating the camera mode, the thermal imager recorded a comprehensive exterior video of the cold storage unit. Notably, the thermal camera predominantly displayed the area in yellow, with some sections appearing in blue. The blue zones that were detected were noted, and photographs of these particular areas were captured for additional scrutiny. Lower temperatures were observed in the thermal photos that were taken. The subsequent analysis involved thorough review of each image, and selected subset thermal images were captured and determined by heat leakages area of the cold storage unit.

III. RESULT AND DISCUSSION

The experimental and thermographic examination was analyzed and the finding shows that the energy loss in cold room was obtained from the door seals. The analysis was done with five thermal images taken at different location of cold storage. Each image is taken separately for the result analysis.

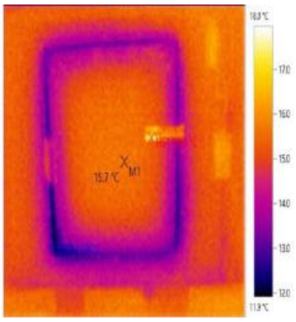

Fig 2(a) front view

Fig 2(b) Prototype cold storage

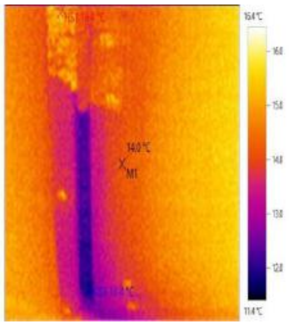

Fig 2(c) bottom left corner

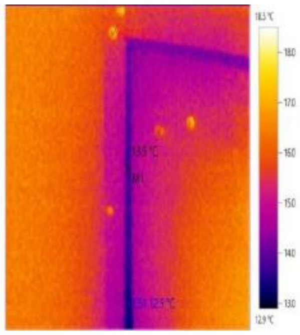

Fig 2(d) top left corner

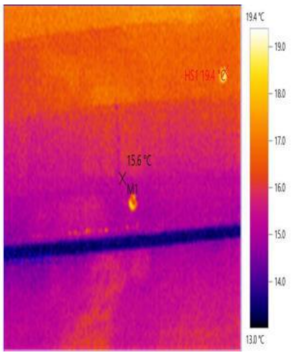

Fig 2(e) bottom right corner

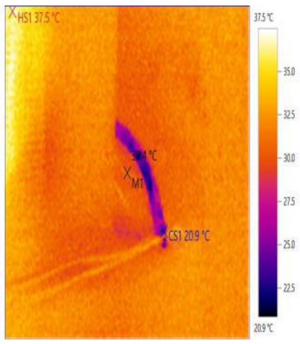

Fig 2(f) refrigerant pipe

Fig. 2: IR images with visual edges of doors taken a, b, c, d, e, f

According to Fig. 2 (a, c, d, e, and f) shows some typical cases of door issues and energy leakages from cold areas. Gaps around door are major problem in this study. Fig. 2 shows blue images of the cold storage is specific locations, which indicate significant heat loss through door and failure of seals. Fig.2 (a) and Fig.2 (b) are the front view images of the door. Fig 2(c) and Fig.2 (d) clearly illustrates

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that the air leakages at bottom left corner side and top left corner side of the door. Fig.2 (e) again demonstrated completed dark blue lines, which means cold areas, the air leakages from bottom right corner area of the door and seal failure issue in prototype cold storage. It is also observed that Fig.2 (f) demonstrated energy losses from the refrigerant pipe of the refrigerant system. The cold spot temperature was measured 11.9^{0}C with the reflected temperature is 20^{0}C and the emissivity is 0.95 in the image Fig.2 (a). The cold spots were measured 11.4^{0}C and 12.9^{0}C with the reflected temperature is 20^{0}C and the emissivity is 0.95 in the image Fig.2 (c) bottom left corner and Fig.2 (d) top left corner respectively. The cold spots were measured 13^{0}C and 20.9^{0}C with the reflected temperature is 20^{0}C and the emissivity is 0.95 in the image Fig.2 (e) bottom right corner and Fig.2 (f) refrigerant pipe respectively.

IV. CONCLUSIONS

The primary aim of this paper was to elucidate and expound upon the following statement that the application and effectiveness of infrared thermography for inspecting cold storage facilities to determine energy leakages resulting from failing door seals and integrity issues in the insulation panels. The studies were performed on the cold storage wall surfaces and door seals, It was shown that infrared thermography involves capturing thermal images, as evidenced by the findings of the door seal under investigation provides significant information for the performance assessment of cold storage and the energy conservation opportunity in the agriculture sector of India. In particular, it can be used efficiently for the performance assessment of insulation materials and operating cost of conventional cold storage. Conclusively, thermography ought to be considered as a valuable appraisal tool for the energy conservation in cold storage system.

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