Temperature measurement of wind-driven pool fire using LabView

AE-698: INTRO TO VIRTUAL INSTRUMENTATION

Term Project Report

Submitted by:

Poomurugan C (231010053)

Betala Ankitha (231010014)

April 15, 2024

Contents

1 Objective

The objective of this project is to create a LabVIEW program for a newly established experimental setup focused on pool fires. The process involves conducting a wind driven pool fire experiment and utilizing data acquisition to capture temperature readings. Given the significance of temperature measurement in pool fire research, our program facilitates accurate temperature measurement and data recording. The results demonstrate the effectiveness of the developed LabVIEW interface in accurately determining temperature at specific locations of interest.

2 Introduction

Since the discovery of hydrocarbons for energy production, there has been a global surge in oil extraction to meet increasing demands across various industries. Due to their widespread industrial applications, hydrocarbons are stored and transported in large quantities. However, one of the significant challenges associated with their storage is the risk of accidental combustion. When ignited, these stored fuels can burn for hours, causing extensive damage to nearby properties and emitting harmful radiation. Consequently, studying these fires is crucial for researchers.

The behavior of burning hydrocarbon fuels is influenced by external factors such as wind, which can alter the direction of flames and cause them to tilt towards nearby oil tank storage, resulting in catastrophic consequences. With the growing concern over global warming, there is a shift towards cleaner combustion fuels, such as alcohol and biofuels. In this study, we focus on Ethanol, a commonly used alcohol. Ethanol is combusted in a tray, and its temperature is monitored using an R-type thermocouple. Data acquisition is carried out using a LabView program developed for this purpose.

Figure 1: Magellan oil tank fire [5].

3 Wind driven pool fire

Pool fire research is a specialized field dedicated to investigating the unique behavior and properties of flames generated by burning pools of flammable liquids within controlled laboratory environments. This research serves a crucial role in enhancing our understanding of various heat transfer mechanisms, including conduction, convection, and radiation, which play significant roles in the dynamics of fire propagation and spread. To simulate real-world conditions and assess the impact of wind on pool fires, researchers often utilize wind tunnels. These wind tunnels allow for the controlled manipulation of airflow around the flames, mimicking the effects of natural wind patterns. This aspect is depicted in Figure 2.

In the absence of external airflow (i.e., in still air), the behavior of the flame is primarily governed by buoyancy effects. However, when subjected to forced convection, such as that induced by wind or airflow, the flame's dynamics undergo significant alterations. The presence of wind can influence flame shape, size, and temperature distribution, thereby impacting the overall heat release characteristics of the fire.

Accurate measurement of temperature within the flame zone is essential for determining critical parameters such as the mass burning rate and heat release rate. These parameters provide valuable insights into the intensity and severity of the fire, aiding in the development of effective fire safety strategies and mitigation measures.

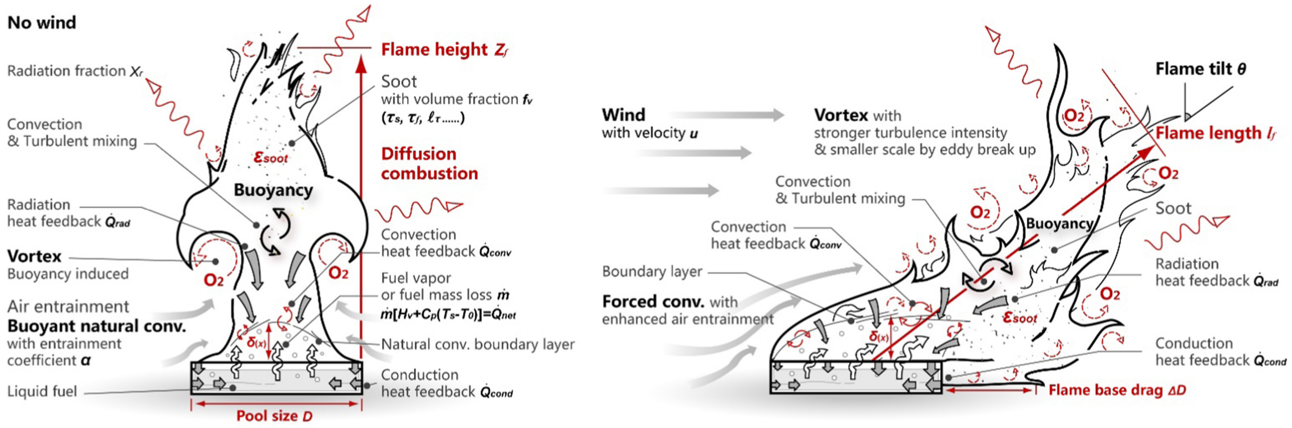

Figure 2: Scemnatic of pool fire [1]

3.1 Lip effect

4 Experimental setup

The experiments have been performed in the fire lab facility available in the IIT Kanpur aerospace department. 180 ml of Ethanol C_2H_2OH was filled in a 25cm$\times$8cm steel tray. R-type finewire thermocouples of wire diameter of 50 μm were used for temperature measurements at high spatial resolution. Velmex X-Z Xslide™ traverse mechanism having a maximum spatial resolution of 1.5 μm was employed to precisely traverse the micro-thermocouple along the centerline of the tray for acquiring the distribution of temperature profiles over the flame. This setup was placed in front of the wind tunnel for the wind effect. The wind tunnel was running at 1 m/s speed.

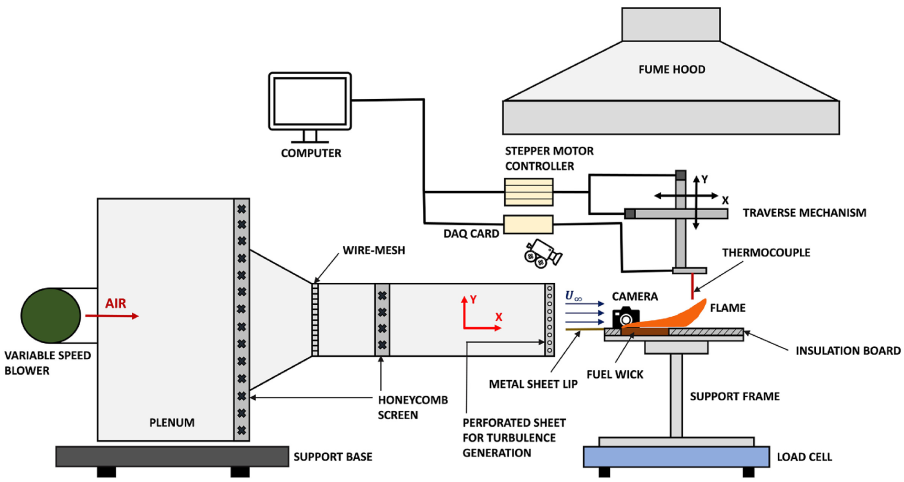

Figure 3: No wind(L) With wind (R) [4]

5 Hardware and Instrumentation

5.1 NI 9214

The NI-9214 is a high-density thermocouple input module that is designed for higher channel count systems. The NI-9214 includes features to increase overall accuracy, such as CJC sensors in the terminal block, component layout to minimize thermal gradients, and an autzero channel for offset error compensation. The device specification has been listed in table 1.

specification	value
Number of channels	16 analog input channels
ADC resolution	24 bits
Input Range	± 10V

Table 1: NI 9214 device specifications [2].

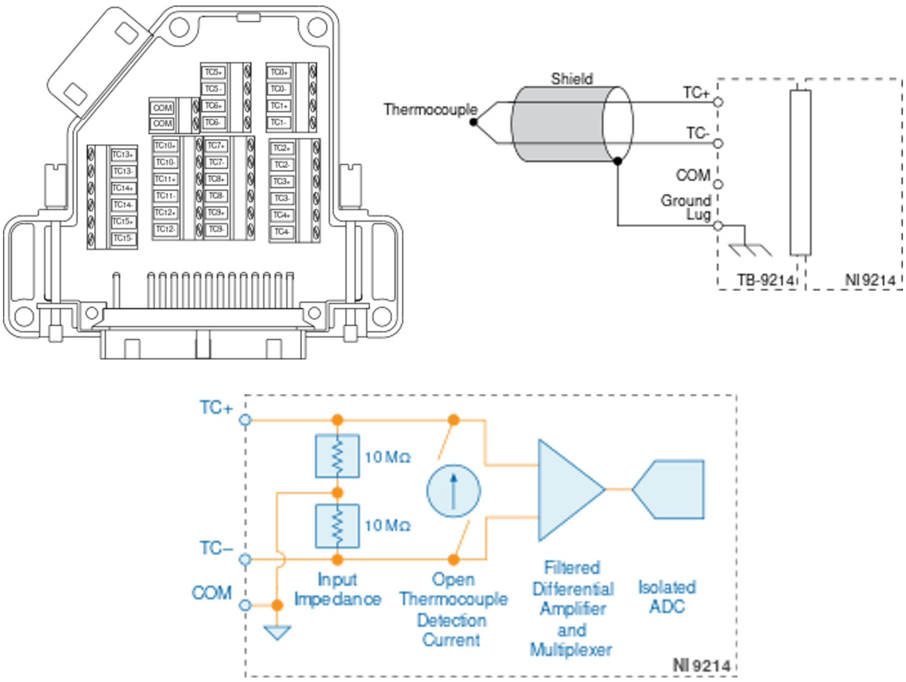

Figure 4: Left:TB-9214 Pinout,Right:Thermocouple Connections, Bottom: NI-9214 Block Diagram. [2]

5.2 cDAQ-9171

The cDAQ-9171 is a bus-powred, compact DAQ USB chassis designed for small, portable sensor measurement systems. The chassis also synchronizes the timing and data transfer between the sensor and the I/O module.

Figure 5: NI cDAQ 9171 chassis. [3]

6 Temperature measurement

The R-type thermocouple has been affixed to the horizontal bar of the Velmex X-Z Xslide™. The positioning of the traverse mechanism is controlled using the COSMOS software. Initially, the thermocouple's tip is placed at x=0.5 cm, just above the tray, where 100 sample temperature readings are recorded using the LabView program. Subsequently, the Xslider is incrementally moved upwards(y-axis) by 0.1 mm, with each movement being recorded in LabView. This vertical upward movement continues in increments of 0.1 mm until reaching a maximum height of y=0.5 mm. Once this maximum height is attained, the Xslider is returned to y=0 mm.

Next, the X location is shifted to x=8 cm, and the vertical position is adjusted using the Xslider. Again, 100 temperature readings are recorded at each shift.

Figure 6: Thermocouple and Traverse mechanism

7 LabView Programming

A dedicated LabView program was made for acquiring the temperature data. Write Delimitted spreadsheet has been used to generate a spreadsheet with three column heading. The first column will record the X location the second column will record the Y location the third column will record the mean temperature. Within the LabView program, there are two boolean indicators represented by bulbs. One illuminates when the maximum limit along the Y-axis is reached, while the other signals when the buffer is full.

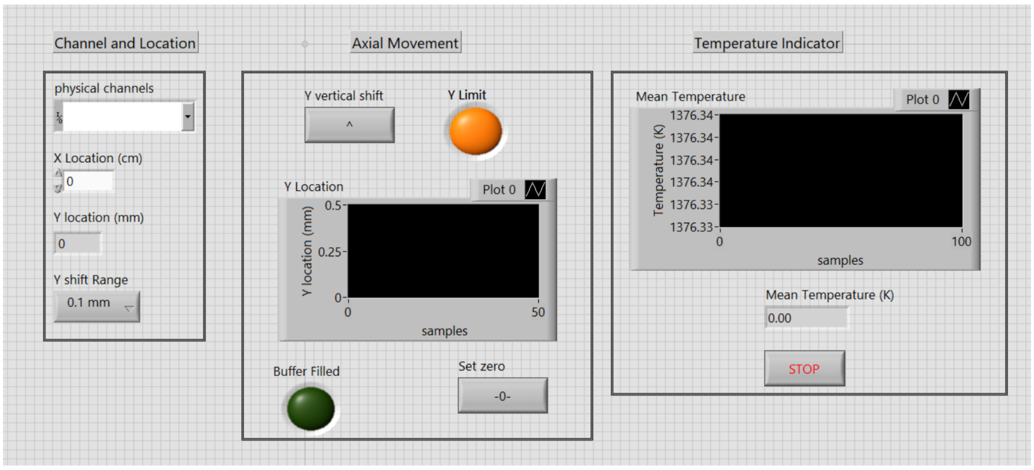

Figure 7: VI Front Panel

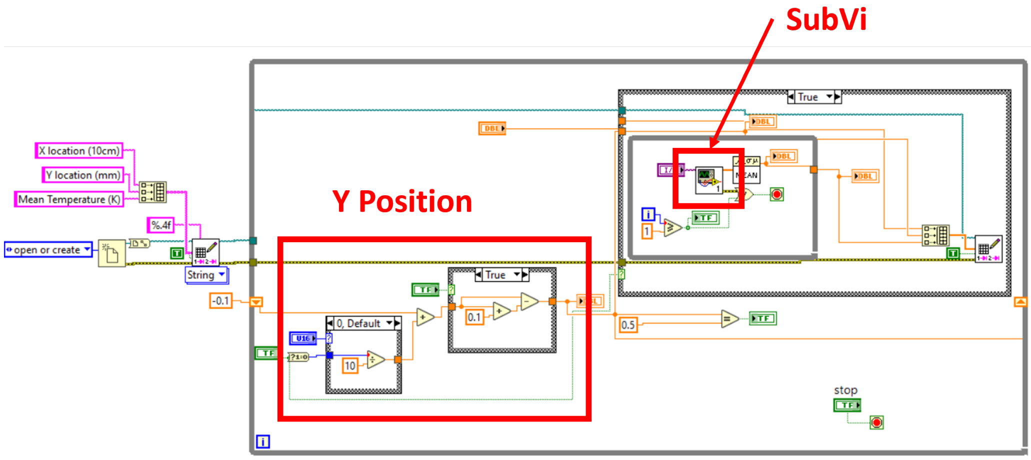

Figure 8: VI Block diagram

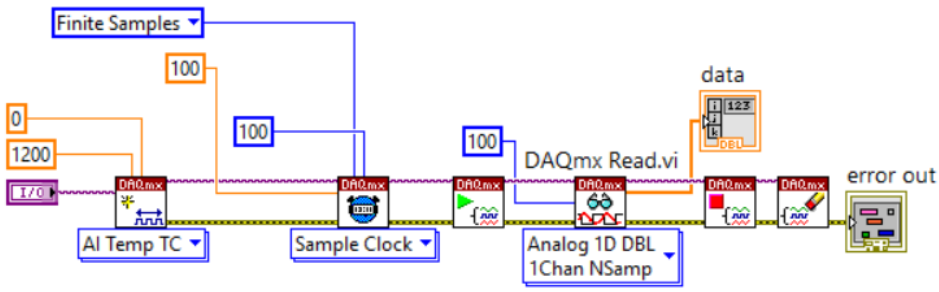

Figure 9: SubVi

8 Results and discussion

The gathered data was imported into OriginPro for visualization. The analysis reveals a distinct pattern: at x = 0.5 cm, the flame temperatures remain relatively low. However, as we progress along the y-axis, the temperatures steadily rise. This phenomenon suggests that initially, lower temperatures result from fuel evaporation, while the upward temperature trend signifies increased air supply and the attainment of a stoichiometric mixture.

Similarly, when observing the region around x = 8 cm, we observe a repetition of this trend: lower temperatures at the bottom and higher temperatures at the top. An observation emerges from this analysis: as we traverse along the x-axis, flame temperatures decrease, whereas movement along the y-axis leads to temperature increase. These outcomes are plotted in Figure 10

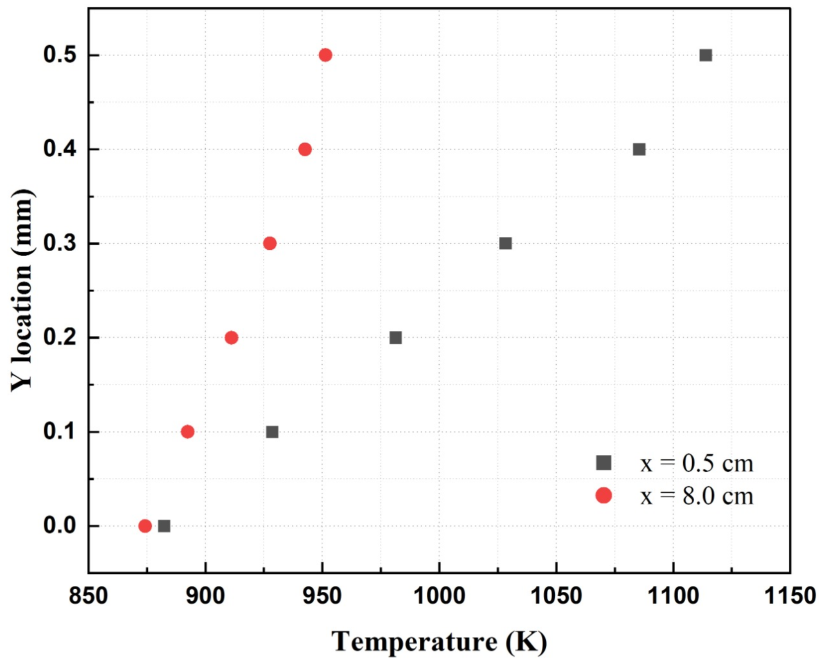

Figure 10: Temperature variation

9 Conclusion

The wind-driven pool fire experiment was conducted, and mean temperature data at various locations were acquired using the developed LabView Program. The collected data demonstrates the accuracy of the LabView capability in capturing temperature variations. It reveals a consistent pattern: temperatures decrease along the X-axis and increase along the Y-axis.

Acknowledgments

We want to extend our appreciation to everyone who contributed to the success of this project. We express our sincere gratitude to **Dr. Kamal Poddar** for his guidance in introducing virtual instrumentation concepts, such as measurement systems, data acquisition devices, and LabView software, during this course. Additionally, we would like to acknowledge **Alankrit** and **Sandeep** for their assistance during the experiment.

References

[1] Longhua Hu. A review of physics and correlations of pool fire behaviour in wind and future challenges. *Fire Safety Journal*, 91:41–55, 2017. Fire Safety Science: Proceedings of the 12th International Symposium.

[2] National Instruments. *NI-9214 Specifications*. National Instruments, 2023. Accessed: April 14, 2024.

[3] National Instruments. *NI cDAQ 9171 Chassis Specifications*. National Instruments, 2023. Accessed: April 14, 2024.

[4] Alankrit Srivastava, Saurav Kumar, and Ajay V. Singh. Heat transfer in wind-driven fires stabilized under a mixed-convective turbulent flow environment. *Fire Safety Journal*, 142:104040, 2024.

[5] Williams Trial Group. Six workers hospitalized after magellan oil tank fire. https://www.williamstrial.com/blog/2020/december/six-workers-hospitalized-after-magellan-oil-tank/, 2020. Accessed: April 14, 2024.