Effects of Varying Propane Mass Flow Rates on Temperature Fields for Flame Weeding

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Introduction

- Propane Flame Weeding is a thermal weed control process that uses heat produced by a vaporizer/torch to damage cell walls causing plant death over time.

The Positive Impacts of Flaming

  - Reduces carbon emissions
  - Eliminates the use of herbicides
  - Eliminates soil contamination

- Hoods are used in flame weeding to trap combustion exhaust gases closer to weeds at elevated temperatures.

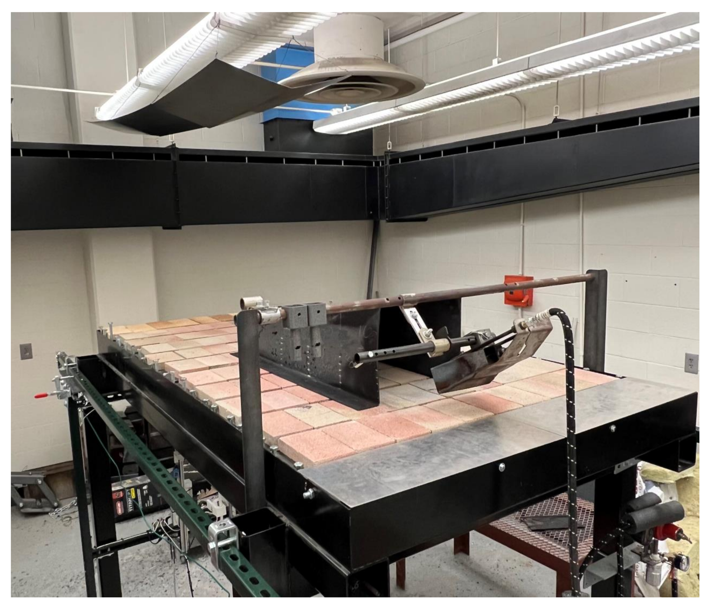

Figure 1: Flaming bench and hood-torch setup

Motivation

Flame Weeding is an organic method of weed control that provides positive environmental impacts while improving crop yields. While flaming is commonly used in organic farming, herbicide resistant weeds are making flaming a more appealing option for conventional farmers as well. Previous research has provided evidence that flaming is viable and economic. If various mass flow rates can be tested, we can determine an optimal pressure to improve weed killing efficacy while making economic use of propane.

Figure 2: Four row research flaming unit in field

Objective

Determine if varying the mass flow rate of propane increases temperatures and consequently lethality of the hood-torch setup. If we can increase the temperature through increasing the mass flow rate, we can do a better job of killing weeds. We can accomplish this in our lab setting through measuring temperatures on a test bench and looking for an average temperature of 800° C or higher under the hooded region.

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Methods

- Three tests at different mass flow rates were performed corresponding to 20, 40, and 60 psi using a 12” inlet 4” outlet flame weeding hood.
- A dedicated test bench with a mounted torch produces the flame for testing (see Figure 3).
- The bench is designed to simulate a flat surface for an optimal data collection environment.
- The torch is fed from a liquid propane tank using a pressure regulator to control mass flow rates.
- As the propane moves through the line, it is converted from a liquid to a gas before being ejected out the nozzle.
- Thermocouples are moved with a mechatronics system of a dc motor and programmed Arduino controller (see Figure 5).

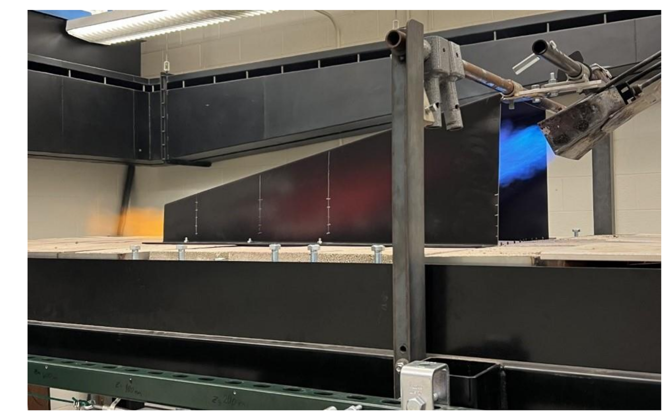


Figure 3: Hood-torch setup during a 60 psi test

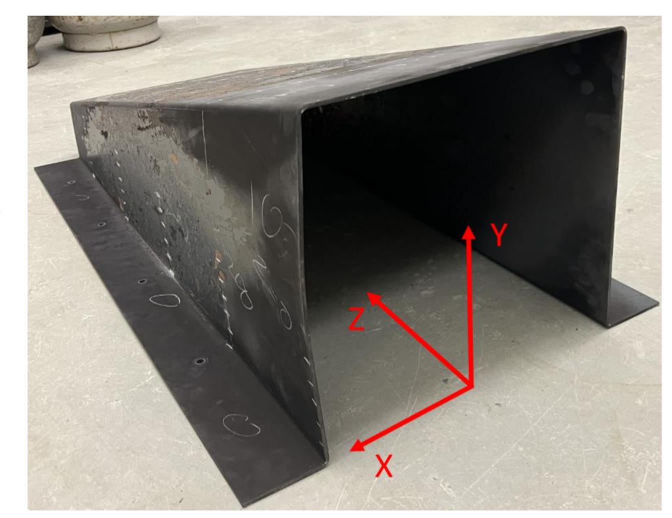


Figure 4: Diagram of the XYZ coordinate system in relation to the hood

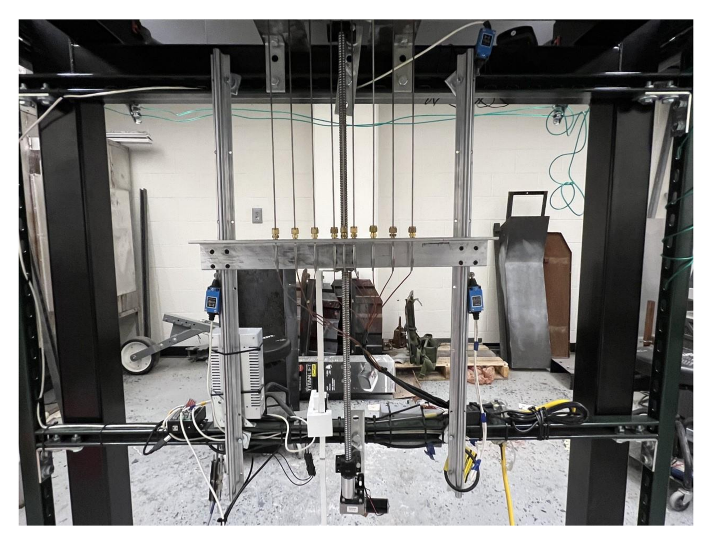


Figure 5: Thermocouple trolley system

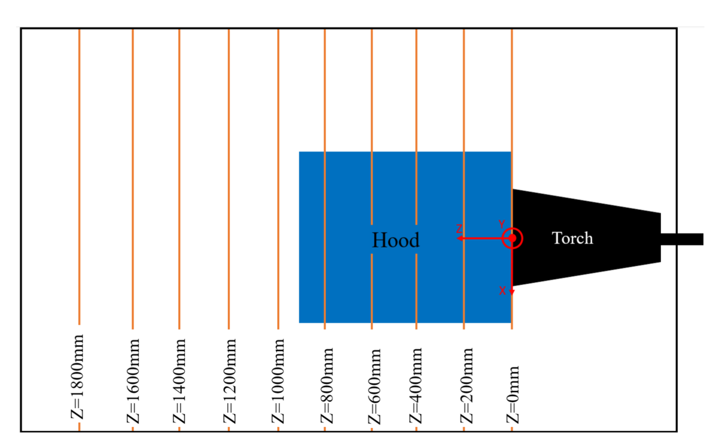


Figure 6: Diagram of constant Z planes where data is taken

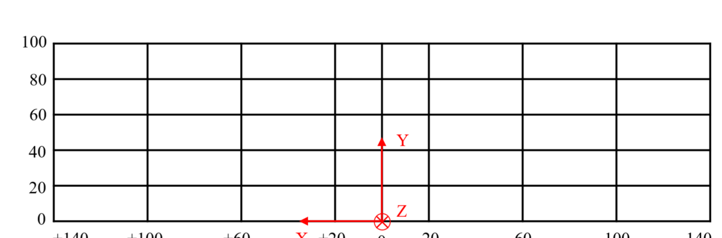


Figure 7: Diagram of XY measurement positions

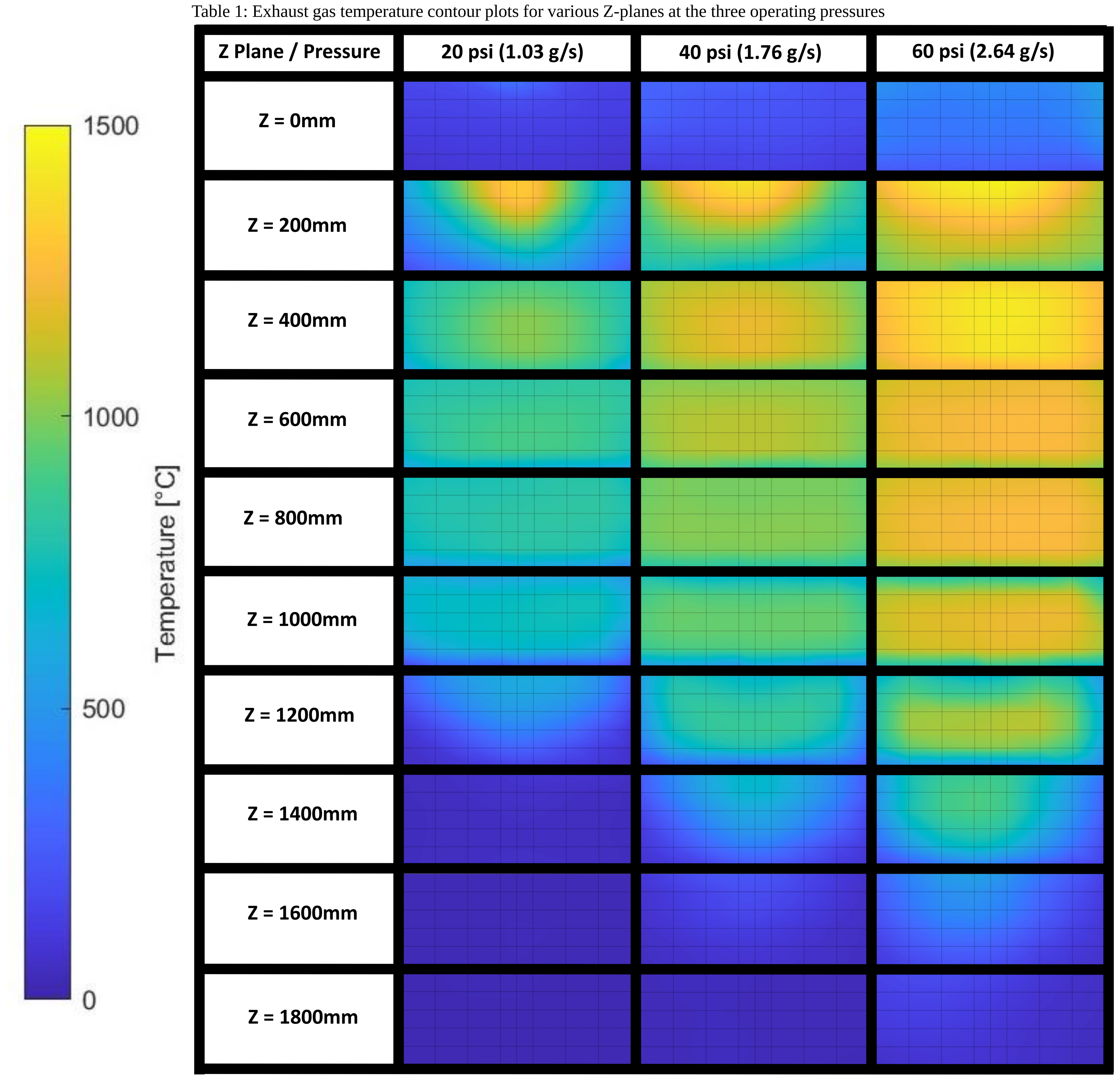
- Thermocouples are used to collect temperature measurements at XYZ positions (see Figure 4).
  - X ranges from -140 to 140 mm in 40mm increments with an additional measurement position at 0mm.
  - Y ranges from 0 to 100mm in increments of 20mm.
  - Z ranges from 0 to 1800mm in increments of 200mm (see Figure 6).
  - Each intersection indicates where a temperature measurement is taken (see Figure 7).
- Data is collected when the derivative of the previous 60 samples is under an absolute value of 1° C, or steady state, has been achieved.
- Steady state is when the temperature at the measured position becomes constant and accurate data can be collected.
- LabVIEW and MATLAB are used to collect data and process it to create temperature contour plots (see Table 1).
- Weighted averages and standard deviations of temperature data are used to analyze the temperature uniformity of the exhaust stream.

Conclusions

- Out of all three tests performed, 60 psi performed the best because it had the highest temperatures at all Z positions (see Table 1 and Figure 8).
- Due to the high temperatures and the temperature uniformity of the exhaust, 60 psi will provide the most effective weed control.
- The results of this study will be used in field research during summer 2023.

Results

Table 1: Exhaust gas temperature contour plots for various Z-planes at the three operating pressures



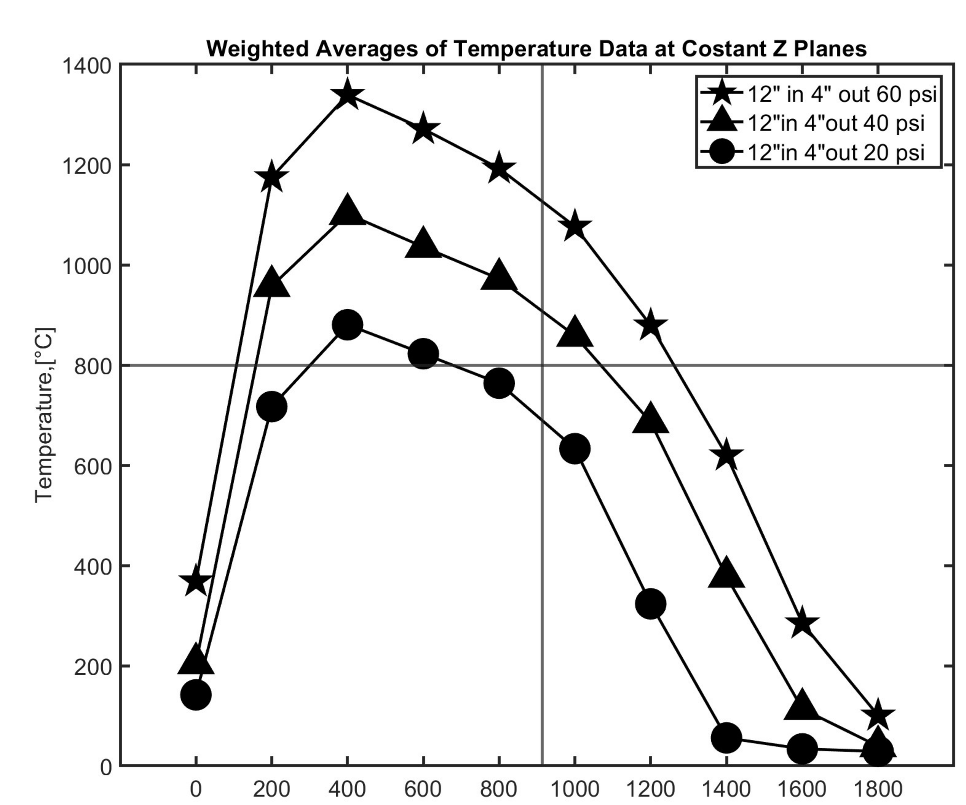


Figure 8: Plot of weighted average temperatures at constant Z planes

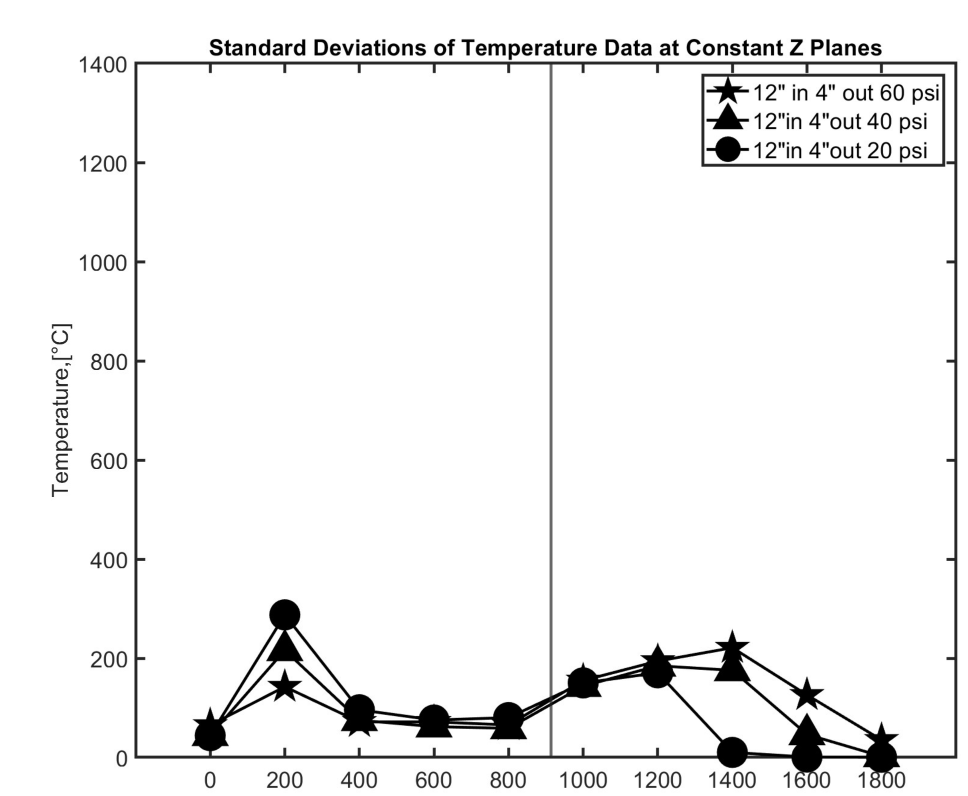


Figure 9: Plot of weighted standard deviations at constant Z planes