Developing an external temperature sensor verification device for the BD MAX

Teresa Sroczynski
Mentored by Rohini Rao and Joshua Sunday

Introduction

The BD MAX, a machine developed by Becton, Dickinson and Company (BD), is a diagnostics platform used to test for the presence of different pathogens using polymerase chain reaction (PCR). PCR is a technique used to quickly replicate the DNA of a specimen. To do this, the DNA is mixed with a solution of primers and dyes and then cycled through a series of predetermined temperatures. This causes the desired DNA strands to replicate and stand out, making it is easier to locate the presence of a pathogen. In the BD MAX the sample is heated on a heater board. As heating the sample is a key step of PCR, it is important that a defective heater board can be quickly identified if the machine has failed to function properly.

To address this issue, two previous SMA students developed prototypes for on-site trouble shooting tools. They created aluminum blocks which heated to a preset temperature to check the internal temperature sensors' accuracy, allowing customers to discover a heating issue on-site. During the 2016–2017 school year, Dylan Mariano created the first block (Block A), heated by hot water pumped through an internal channel (Figure 1); it was a good proof of concept but impractical for onsite use (Mariano, 2017). During the 2017–2018 school year Emma McClure created a second block (Block B) heated with an electronic heater pad (Figure 2); it was easier to use but had uneven heat distribution (McClure, 2018). In this iteration of the block (Block C), the goal was to create an electronic heater with improved heat distribution.



Figure 1: Block A. The block is 111.125 mm by 71.273 mm. The two plugs on the block's ends were connected to tubes supplying hot water to the block, through a small pump. A plastic cover was used to allow the user to ensure water movement during use.

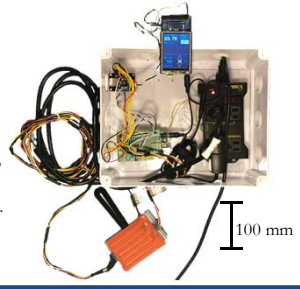


Figure 2: Block B. The heating block is below the control system in the white box. The control system was comprised of an Arduino Uno (bottom left), an OSEPP microSD Breakout (middle left), an Arduino Mega and attached control screen (upper middle), and power supply connector (right).

Materials and Methods

The newly created Block C was designed in Autodesk Fusion 360, incorporating suggestions from Block B's creator and the mentors and machinists at BD. The final design of Block C (71.14 mm × 11.03 mm × 15 mm) was made with aluminum in BD's machine shop. This height change showed promising results in preliminary testing. A thermally conductive pad (t-Global Technology H48-2-150-150-1.0-1A) was added to the bottom of the block to spread heat out more evenly as this concept showed promising results in preliminary testing. The control system was also modified to allow for easier testing of multiple block designs in rapid succession (Figure 3).

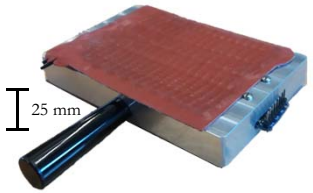


Figure 3 (left): Block C setup for testing. The orange pad is the heating pad. The blue horizontal pieces on the sides are the thermal resistors (thermistors) used to read the block's temperature. Their locations were altered to more securely dock in the BD MAX for testing. A thermally conductive pad was placed under the block.

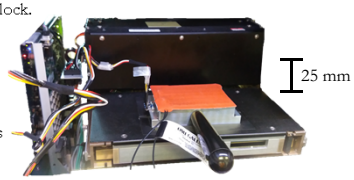


Figure 4 (right): Block B on the BD MAX for testing. The block was placed on the heater board. The thermistor was attached and the pad was turned on.

Both Block B and Block C were heated to temperatures from 40 °C to 70 °C at 10 °C intervals and placed on the MAX's heater board (Figure 4). The MAX's internal temperature sensors' readings were collected shortly after the block reached the preset temperature as range differences over time were seen in preliminary testing.

Results

When testing the block, the thermistors malfunctioned, requiring changes to the testing procedure. Instead, an infrared thermometer was aimed at the location of the thermistor and used to read temperatures. The heating element was manually controlled by turning it off when the block reached the desired temperature and turning it back on when it dropped below the temperature.

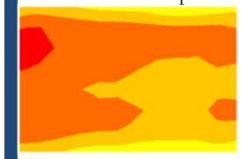
Testing showed that as the preset temperature of Block C increased, so did the range, while Block B's was more constant (Graph 1). A two-sample standard deviation test, which compares the standard deviation of two sets of data, showed that Block C did not have a statistically significant smaller standard deviation than Block B when heated to the same temperature, $p > 0.9$ for all tested temperature ranges. However testing did show that Block C's temperatures were closer to the intended temperature of the MAX's heating element.

Results (cont.)

	Block B				Block C			
	40 °C	50 °C	60 °C	70 °C	40 °C	50 °C	60 °C	70 °C
Temperature Range	21.2	27.2	19.8	16.4	26.2	35.0	35.4	42.6
Average Temperature	104.3	105.2	145.3	144.3	69.4	85.5	97.4	108.4
Actual - Intended Temperature	64.3	55.2	85.3	74.3	29.4	35.5	37.4	38.4

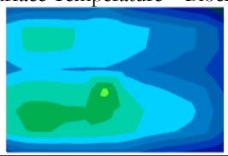
Table 1 (left): This is the summary of data gathered on the MAX at the different temperature settings.

Surface Temperature – Block B



Graph 1 (left): A contour plot of the temperature readings from Block B heated to 70 °C.

Surface Temperature – Block C



Graph 2 (left): A contour plot of the temperature readings from Block C heated to 70 °C.

Conclusion

The goal of this project was to improve upon the trouble shooting tool created by Emma McClure by lowering the temperature range across the temperature testing block read by the MAX. Given that the standard deviation in Block B's readings were consistently lower then those in Block C, this was not accomplished. This was most likely due to the thermally conductive pad. Bubbles between the pad and the block appeared during testing, reducing heat transfer, increasing the range. This could also be due to issues with the testing method as the infrared thermometer did not accurately read the temperature of the aluminum. This was most likely due to its reflectivity. Future research should include finding an alternative sensor to replace the thermistors.

Reference

Mariano, D. (2017). *Design and testing of a convenient diagnostic tool to test BD MAX™ temperature sensors.* Retrieved from http://www.scienceandmathacademy.com/academics/srt4/student_work/2017/mariano_dylan.pdf

McClure, C. E. (2018). *Designing a device to verify BD MAX™ temperature accuracy.* Retrieved from http://www.scienceandmathacademy.com/academics/srt4/student_work/2018/mcclure_emma.pdf