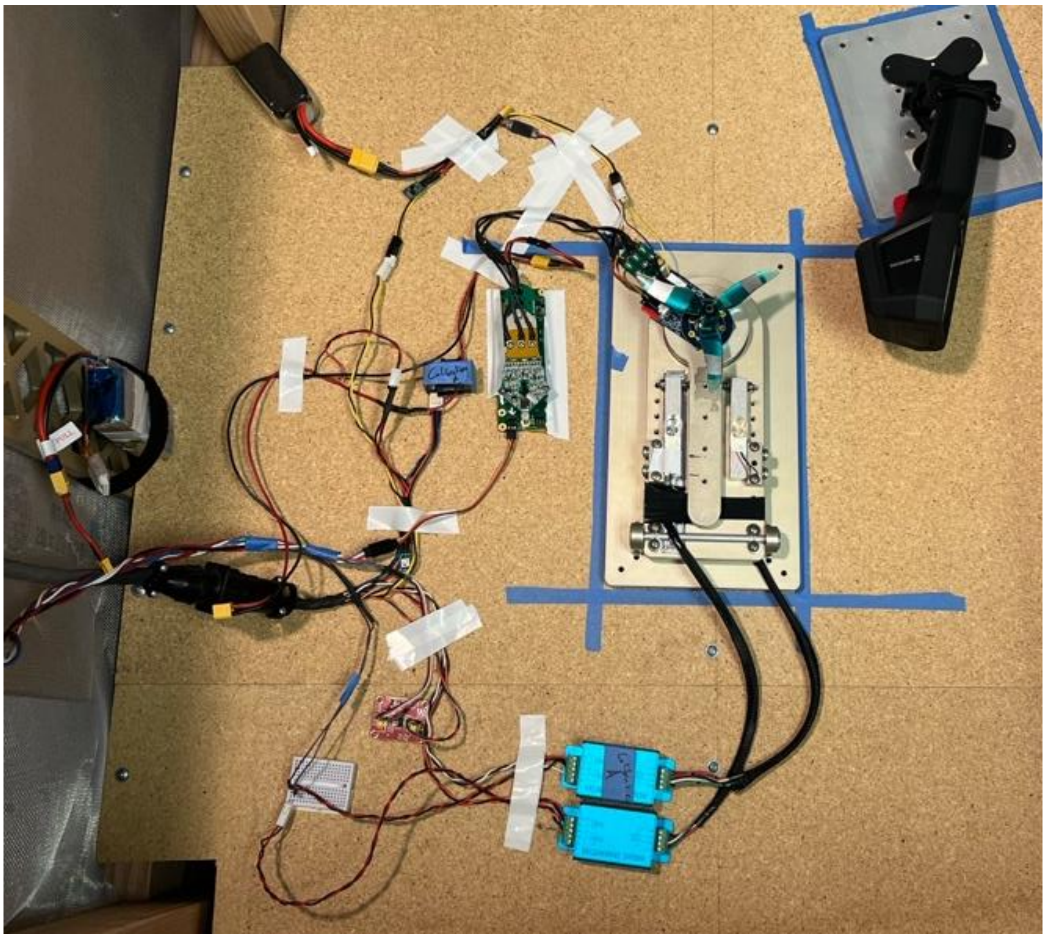
Kairos Autonomi
8700 S. Sandy Pkwy.
Sandy, Utah 84070
801-255-2950 (office)
801-907-7870 (fax)
www.kairosautonomi.com

Temperature Comparison of Motors

Introduction:

Motor temperature is a major factor in drone performance. Motors that overheat mid-flight can cause catastrophic failure and lead to loss of a drone. This study aims to investigate motor overheating by examining the Xing Flight 2207 1800KV and Arthur 1408 2800KV motors, which are known for their efficiency with two specific propellers. Further investigation included testing the T-Motor 1507 2700KV and the TOKA 1408 4100KV motors. The results from this testing show that overheating in the motors is related more to the motors capabilities than RPM.



Set-up:

Motors and propellers are mounted in the same manner as normal characterization testing. The IR heat camera is aimed at the base of the motor. Once the motor temperature stabilized at room temperature, data collection on the data acquisition system (DAQ) commenced. At this point the motor power supply would be connected, and an initial motor temperature taken. The motor was then started and run for one minute, unless temperatures rose too high, posing a risk of motor damage. In such cases, the test was stopped early. Once the minute (or sooner) had ended, ten seconds passed by before recording a final temperature. Motors would spike in temperature after stopping the motor, soon after the temperature would begin to decrease again. For this reason, delaying the temperature measurement gave a greater temperature stability and increased precision of the temperature data collected. Data collection was then stopped and transferred from the DAQ to a computer where data analysis was performed.

This experiment was designed to find relationships between motor performance and temperature. To find these relationships, each motors character was plotted against temperature. The following section details results. Two trends between motor RPM and motor temperature are seen and discussed. Trends between electrical efficiency and RC values with average motor temperature are also investigated. This work also leads to the conclusion that the Kairos Autonomi ESC is not limited in the RPM output of a motor.

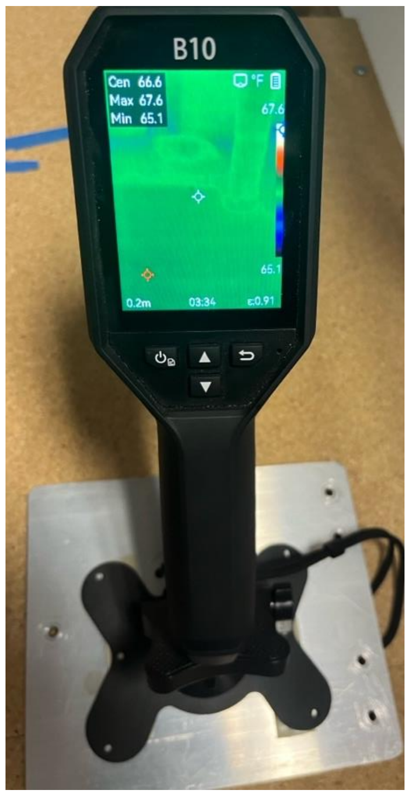


Figure 1: The Hikmicro B10 IR camera used in the experiment.

The motors used in comparison as well as the propellers used are shown in Tables 1 and 2.

Table 1: Motors used in this testing with their given ratings.

Brand	Size	KV rating
Xing Flight Motor	2207	1800
TOKA Mamba Systems	1408	2700
Arthur Motors	1408	2800
T-Motors	1507	4100

Table 2: Propellers used in testing. It is noted that the 5-inch propellers are used on the Xing flight, Arthur and T-motors motors. The other two propellers were used solely on the TOKA motor, which could not use the 5” propellers.

Brand	Diameter (in)	Pitch (in)	Mass (g)
HQ Prop 2 Blade	4	2.5	1.6
Gemfan 3 Blade	3	1.6	1.3
Gemfan 3 Blade	5.1	4.99	2.7
Ethix 2 Blade	5.1	3	5.3

The TOKA motor was included in testing for two primary reasons. First, it proved reasonable to look for trends in motor temperature as a function of motor KV ratings. Second, this higher rated KV motor had a much larger RPM possible and investigating temperature at these high RPM values would have been most beneficial. No trend in relation of motor temperature to motor KV was found in this experiment.

Motor Technical Data:

The technical data provided by the manufacturers for each motor includes metrics that predict potential drone performance. In this technical data motor manufactures usually suggest a propeller and ESC to go with the motor that maximizes efficiency. Below in Table 3 is the general recommendations for each of the motors tested.

Table 3: The general manufacturer recommendations for each motor’s operations.

Motor Brand	Battery Voltage (V)	Propeller Recommendation
Xing Flight 2207 1800KV	24	5.1*3.1 Tri-Blade
TOKA 1408 4100KV	16	3*2.8
Arthur 1408 2800KV	16	4*4.5
T-Motors F1507 2700KV	24	3*5.2 Tri-Blade

Note in this table we see that only the Xing flight motor meets the diameter requirements for both propellers. The TOKA meets the diameter requirements for its tri-blade propeller. A motor rated for a certain propeller at high voltage will decrease in performance when voltage is less than what the motor normally accepts. Smaller propellers generally are recommended at lower voltage because of this.

Results:

To not burn any motors, temperatures above 250 required early termination. This issue was observed with the Arthur, T-motor, and TOKA motors, where temperatures rose to inoperable levels, necessitating early termination of testing. These points in data analysis were only included in Figure 4 of this document where average temperature is shown at each RC Value. All other figures omit these early termination points.

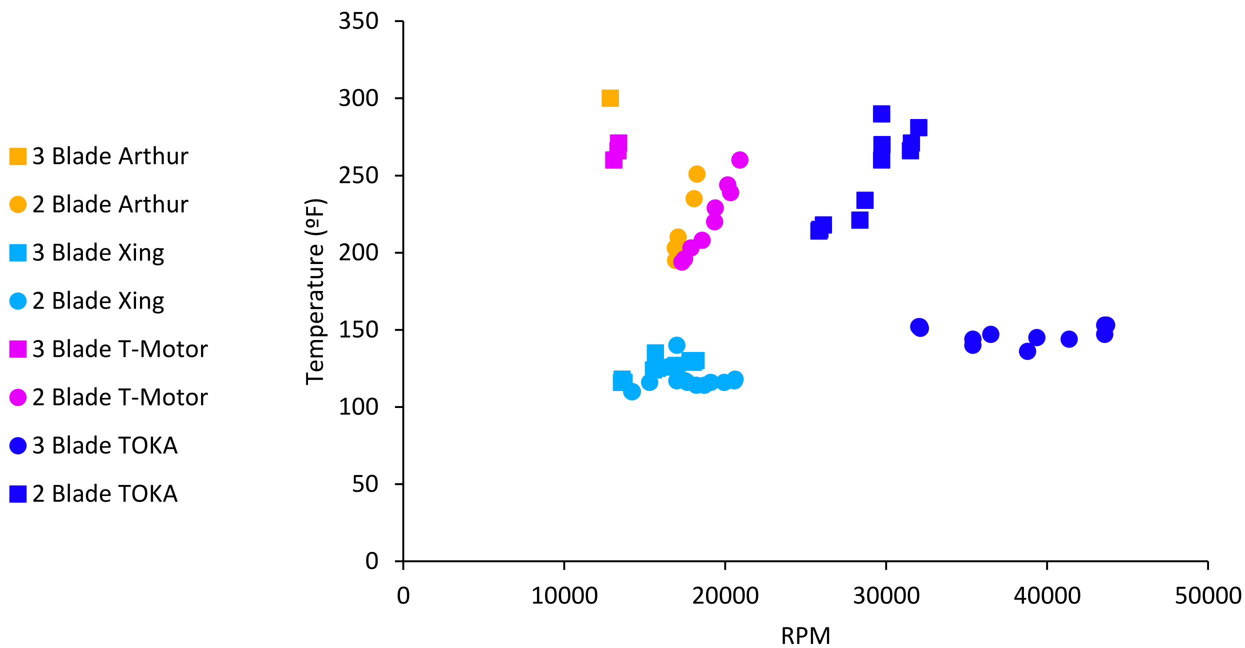


Figure 2: The figure above shows the RPM vs. motor temperature ten seconds after a 1-minute stress test. Heavier propellers have a square marker.

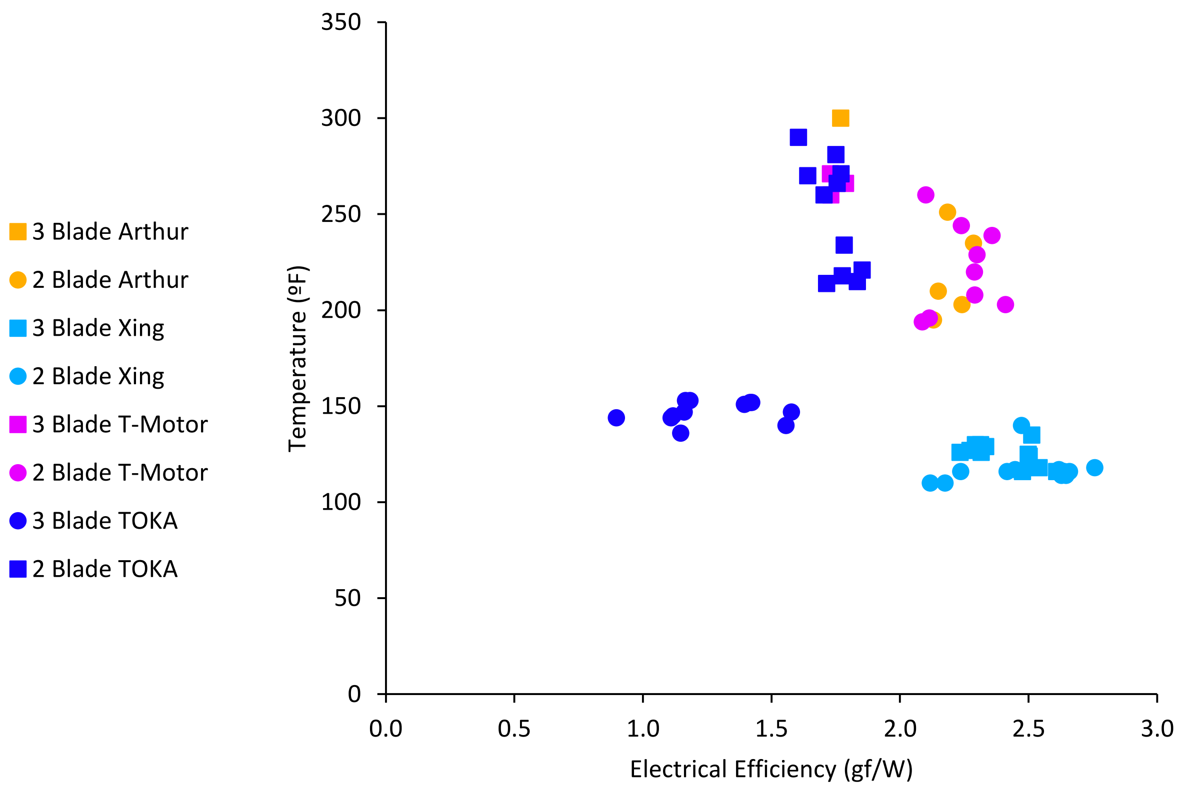


Figure 3: Electrical efficiency vs. motor temperature. Electrical efficiency is how well the motor converts electrical power into thrust. Heavier propellers have a square marker.

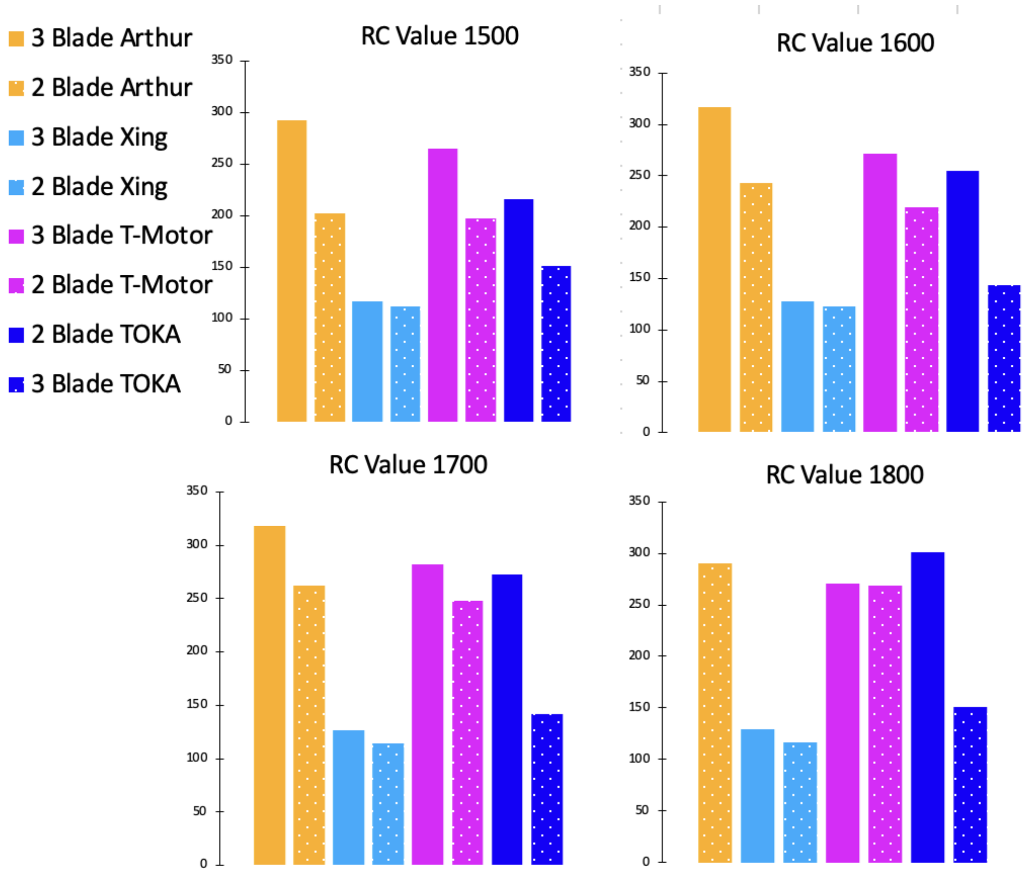


Figure 4: Average temperature of each motor and propeller at discrete RC values. The RC value is directly related to the RPM of a moto, though this relation varies between each propeller and motor.

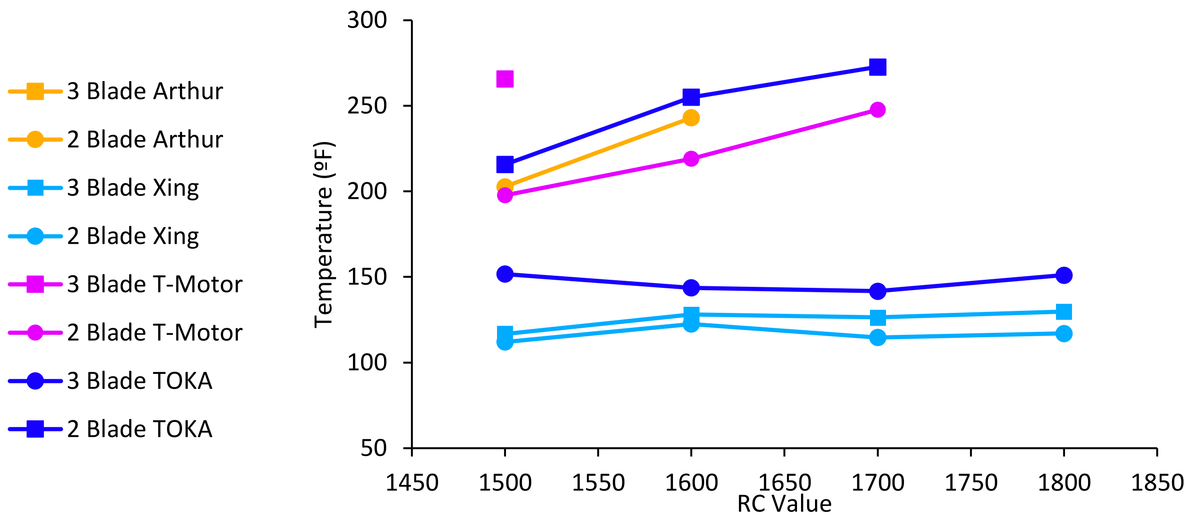


Figure 5: RC value vs. average motor temperature. Heavier propellers have a square marker.

From Figures 2, 4, and 5 we can see that heavier propellers cause a temperature to increase more in the motor, even though there may not be a correlation between motor temperature and RC values for every propeller.

Other trends require omitting data points from the tri-blade T-motor test and dual-blade Arthur test, due to them lacking sufficient data points. We can see two overall trends. Two motor and propeller combinations increase in temperature with increasing RPM and motor output. The other three combinations do not. Now the question arises, why this the case? The answer to this question lies in the manufacture recommendations for proper combinations given in Table 3. In that table we find that only the Xing flight motor meets the diameter requirements for both of its propellers and the TOKA meets the diameter requirements for its tri-blade propeller. Though the exact propeller recommended for each motor is unclear, the Xing flight is clearly seen to operate well with both 5" propellers. The TOKA motor with the tri-blade propeller also seems to operate well with minimal heating change. For these three combinations we don't see any change in motor heating with changing motor output. It is reasonable to say that when motors are paired with a preferred propeller no excess heat is generated. When a motor is improperly paired, we do see motors heating with increasing RPM and RC value.

In a previous document power loss was discussed in-depth. To summarize any electrical power not converted into mechanical power is power lost to heat. With this expectation it would have been expected to see a trend in motor temperature vs. electrical efficiency. This is not the case for any motor combination.

Max RPM:

We hypothesized that the Kairos ESC might have a maximum RPM limit. To verify this, we conducted specific tests.

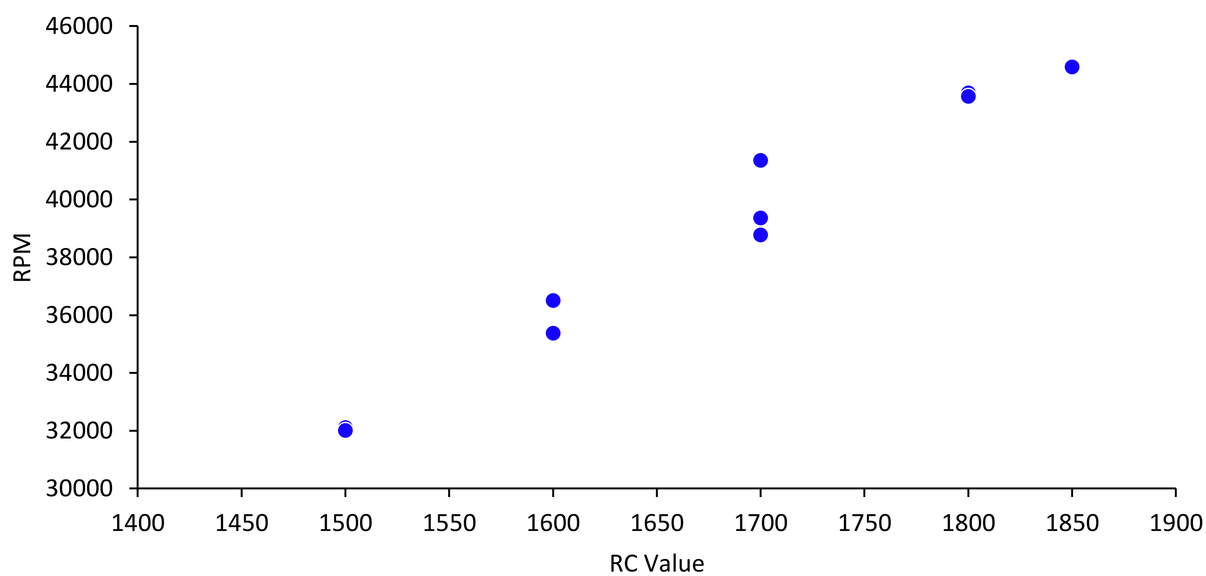


Figure 6: The figure above shows the change in RPM with changing RC values for the TOKA 1408 4100KV motor with the tri-blade propeller. This is the highest KV rated motor in stock with its preferred propeller. The highest possible RPM should be obtained from this motor.

In Figure 6 the max RPM can go well above 44,000 RPM for the described combination. The temperature at the highest RC value was also monitored. In this specific test the IR camera was moved to view the ESC and battery cable. The overall temperature of the system never exceeded 200ºF. Figure 7 shows a thermal image taken during the test.

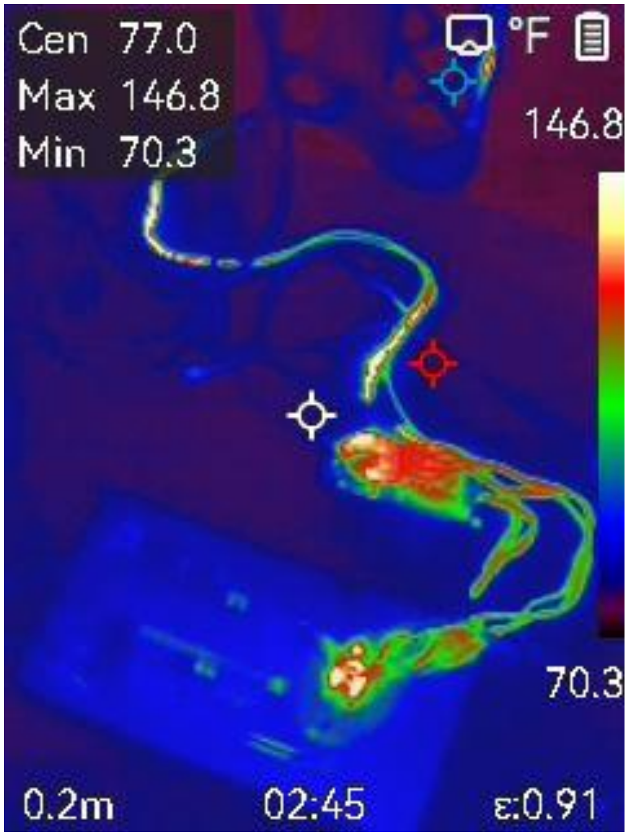


Figure 7: A thermal image taken during the test of the TOKA 1408 4100KV with the tri-blade propeller at the highest possible RC Value.

Motors and propellers that are properly paired should have no limit to the achievable RPM but should reach maximum output without burning the motor. One caveat to this is time at maximum output. The time at maximum output should not exceed manufacture limitations. In most cases the limit for max output is around 90 seconds.

Conclusions:

This study underscores the critical importance of following manufacturer recommendations for motor and propeller combinations to prevent overheating and ensure optimal performance. Two general trends emerge in this experiment. First, improperly paired motors cause an increase in motor temperature with increased motor output. Second, properly paired motors experience no significant increase in motor temperature with increased motor output. Properly paired motors and propellers are also not limited in RPM by the Kairos ESC.

****

Revisions

Name/Signature	Date	Description
Cameron H Miller	6-26-2024	Adjusting content and wording.