Using Electric Heating Devices and Temperature-Regulating Sensors to Maintain Stable Temperatures in Flight Pods During High Altitude Balloon Flights

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Abstract

In previous high altitude balloon experiments, two different types of chemical hand warming devices were tested to determine if life-supporting temperatures could be maintained within the flight pods. Although data shows that this method increased the temperatures within the experimental pods compared to external temperatures, there were still significant temperature variations during the flight. In order to stabilize the interior pod temperatures to support live organisms and temperature-sensitive equipment, a system comprised of heating pads, batteries, and thermostats was developed. Two types of temporary construction thermostats, the TEMP-STAT™ TS70 70° and the TEMP-STAT™ iO-TS70 70° were connected to battery-operated Adafruit® electric heating pads and along with a sensor suite, encased in bubble wrap, and placed within the flight pod labeled S2. A second pod was prepared in the same way except it contained only the sensor suite, and was the experimental control (S3). The flight pods were launched attached to a high altitude balloon. Altitude, ambient temperature, and temperatures within the experimental and control pods were monitored throughout the flight. Data collected indicates that within pod S2 the temperature ranged between approximately 16C and 36C, while within pod S3 the temperatures ranged between -21C and 20C. Data from an earlier preliminary launch with each pod containing just one battery-operated Adafruit® electric heating pad with no thermostat-controlled system, indicates the internal pod temperature ranged between approximately 2C and 39C. This would indicate that the thermostat-controlled system provides a more stable temperature within the flight pods during high altitude launches.

Introduction

In previous high altitude balloon experiments two types of chemical hand warming devices were compared as to their efficacy in maintaining life-supporting temperatures within the flight pods. Although these warming devices produced heat, results showed that at different points during the flight the temperatures within the flight pods varied dramatically, in some cases reaching temperatures too high to support life. In order to address this issue a method which would not only produce heat, but also incorporate a temperature regulating system needed to be developed.

Instead of chemical hand warming devices, battery-operated Adafruit® electric heating pads were employed. A first trial balloon launch was done with just the heating pads in the flight pods, but the internal flight pod temperature still fell to near 0C (Fig.3). Subsequent trials were performed in the -20°F freezer at Omaha North High School using thermostatic regulators (TEMP-STAT™ TS70 70° and TEMP-STAT™ iO-TS70 70°) connected to different numbers of heating pads and various batteries (Fig.1) to optimize the configuration that would maintain a temperature range that could support life in the flight pod during a high altitude balloon flight.

Both the TEMP-STAT™ TS70 70° and the TEMP-STAT™ iO-TS70 70° are designed to activate the heating devices when the temperature within the flight pod drops below 70°F (~21C). Once the components that maintained the desired temperature for the required time were determined, this configuration was used in the flight pods during the second balloon launch (Fig.2).

These experiments tested whether or not three battery-powered heating devices, each coupled to temperature regulating sensors would maintain life-supporting temperatures in the flight pod, and also which configuration worked best at accomplishing this.

References

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Procedures

1) Connect the black wire of the electric heating pad using a butt connector to the black wire of the 9-volt battery snap connector.
2) Connect the red wire of the electric heating pad using a butt connector to one black wire of the TS-70 sensor.
3) Connect the red wire of the 9-volt battery snap connector to the other black wire of the TS-70 sensor using a butt connector.
4) Use black electrical tape to stabilize all the connections between the 9-volt battery snap connector, the TS-70 sensor, and the electrical heating pad.
5) Repeat this process with another TS-70 sensor and one iO-TS70 sensor.
6) Obtain 2 flight pods and two sensor suites 2 and 3.
7) Using a Sharpie®, label one flight pod (2 TS-70, 1 iO-TS70, S2) to represent 2 electric heating pads each connected to a TS-70 sensor, 1 electric heating pad connected to a iO-TS70 sensor, and S2 for sensor suite 2-experimental.
8) Using a Sharpie®, label one flight pod S3 for sensor suite 3-control.
9) Line all sides of the inside of the 2 flight pods with aluminum foil (shiny side facing the interior).
10) To stabilize the heating pads inside the pod labeled (2 TS-70, 1 iO-TS70, S2), tape them to three of the interior walls of the flight pod using electrical tape.
11) Plug in all sensor suite 2 connections, and plug in 9-volt lithium batteries to the snap connectors for the three heating pads in the pod.
12) Position sensor suite 2 as far away from the heating pads and batteries as possible, inside the flight pod.
13) At the same time plug in all sensor suite connections for sensor suite 3 and place in flight pod labeled S3.
14) Fill empty space in the flight pods with bubble wrap.
15) Close the two flight pods and seal the opening seam with duct tape.
16) Secure the experimental and control flight pods inside the harnesses attached to the high altitude balloon apparatus equipped with temperature and altitude sensors.
17) Launch experimental and control flight pods to near space.
18) After the balloon's descent, collect the experimental and control flight pods.
19) Analyze temperature and altitude data from the launches. Graphs will be created showing changes in external air temperature, internal temperatures and altitude during the flight. Comparisons will be made between the experimental and control groups.

Figure 1. Heating pad, battery, and thermostat configuration used in freezer tests.

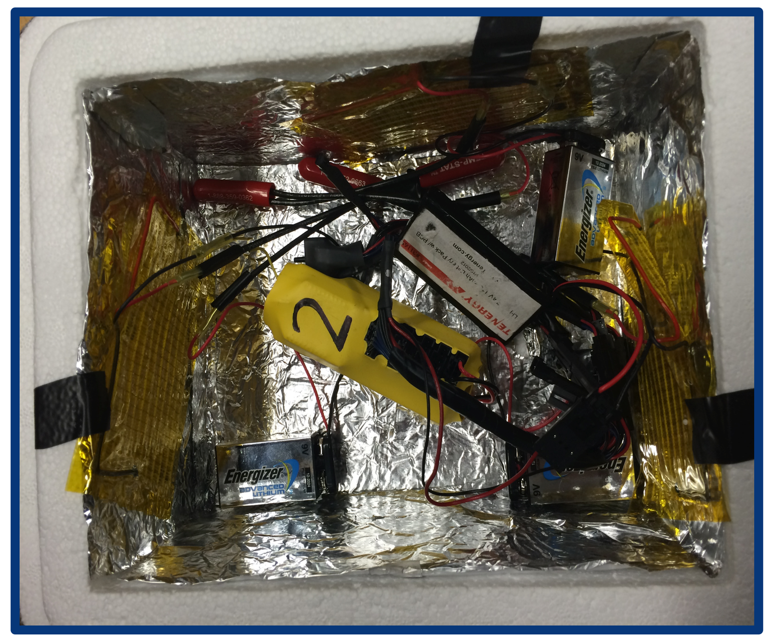

Figure 2. Heating pad, battery, and thermostat configuration used in second balloon flight.

Results

The initial high altitude balloon flight reached an altitude of 93,588.10 feet. During the two hour flight external temperature ranged from 15.71 to -37.57C. The temperature within the flight pod ranged from a low of 3.49C and a high of 36.72C, with a profile that shows a steady decline over time (Fig.3).

The second balloon launch reached an altitude of 92,692.44 feet. During the two hour flight external temperature ranged from 13.75 to -34.64C. The temperature within the flight pod ranged from a low of 18.64C and a high of 36.23C, and displays a cyclical profile, indicating that when the internal temperature dropped below 21C, the thermostats activated the heating pads and the temperature within the flight pod subsequently rose (Fig.3).

Preliminary Experiments

Experiment 1 - Single heating pad and 9 volt battery

Experiment 2 - Compared performance of two different thermostats each connected to two heating pads and two 9 volt batteries

Experiment 3 - Compared rechargeable to non-rechargeable batteries; two heating pads and batteries per flight pod

Experiment 4 - Repeat of Experiment 2; two heating pads and batteries per flight pod

Experiment 5 - Repeat of Experiment 3; different thermostats coupled to rechargeable or non-rechargeable batteries

Experiment 6 - Compared the effect of lining flight pod with aluminum foil (one pod with, one without). Non-rechargeable batteries and two heating pads in each pod

Experiment 7 - Used three heating pads and three rechargeable 9 volt batteries connected to three thermostats

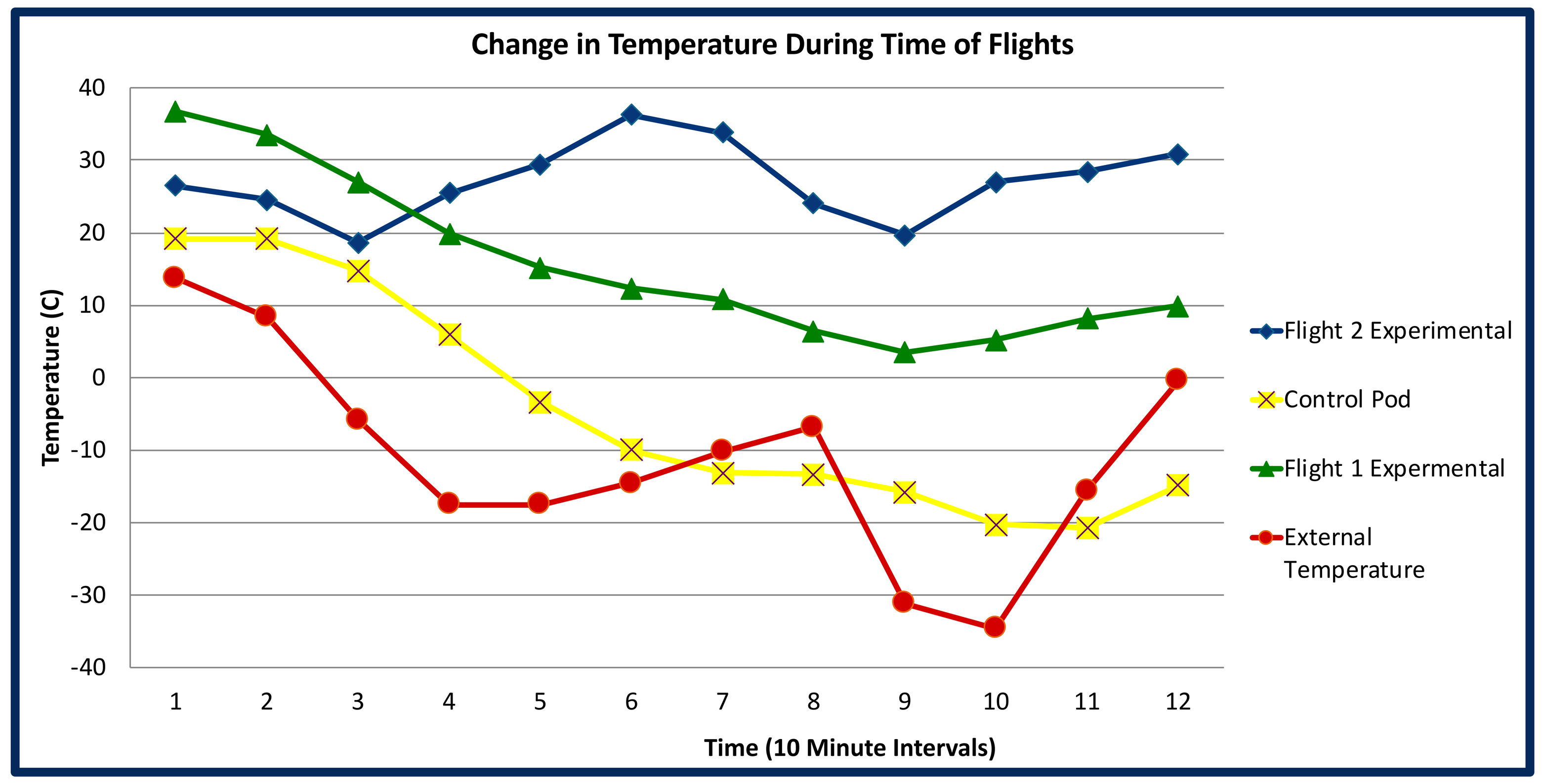

Figure 3. Change in temperature within flight pods over time during high altitude balloon launches. Data points represent readings at 10 minute intervals for the two hours of the flight.

Conclusions

In all previous experiments that employed chemical hand warming devices or battery-powered warming devices, the temperature within the flight pods always declined during the course of the flight, reflecting the decline in external temperature. By adding thermostat control, temperatures could be maintained with fluctuations that were well within the range adequate to support living organisms. By using this method of temperature control, not only will it be possible to carry out experiments that involve high altitude impacts on living systems, but temperature sensitive equipment that could previously not be utilized can be included in the studies.

Further Research

For future research, tests could be done using higher voltage batteries (the highest voltage allowable with these heating pads) which could reduce the number of heating pads required to maintain life-supporting temperatures in a flight pod during a high altitude launch.

The current system could also be utilized in experiments incorporating small organisms as life-supporting temperatures are maintained during the flight time.

Although our initial tests employing rechargeable batteries were unsuccessful, rechargeable battery tests should be continued to ensure efficient use of resources.

An alternative heat reflecting material used to line the inside of the flight pods could be tested.