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EFFECT OF TEMPERATURE ON BATTERY PERFORMANCE

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Abstract

One of the challenges limiting the introduction of the battery powered vehicles is the reduced power and energy for batteries operating at low temperatures and the safety of batteries operating at high temperatures. Previous research delineated the behaviors of the batteries especially the Li-ion cell batteries that are commonly used in the vehicles. Experimental evidence reveals the intrinsic self-heating of batteries as an important put of their behaviors. The performance of batteries is usually limited at temperatures higher than -20 ºC depending not only on the rates of discharges but also the thermal conditions. This thesis develops a battery holder and temperature control system to enable the study of temperature effect on battery performance.

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Chapter 1: Literature Review of Battery Performance at Varying Temperatures

This section will lead to an exploration of the validated models for the purpose of determining high and low temperature characteristics of the behaviors of the cells mostly in terms of voltage losses as well as the generations of the heat. The cell voltage losses can be divided into the losses which are caused by the electrical resistances as well in the electrodes, losses due to kinetics of the charge transfers on the interfaces of the electrolytes, ionic resistances as well as concentrations of the polarization in the electrolyte. The other losses can be subdivided into losses due to imperfect electrolytes as well as the losses due to the thermal variations. Mathematically, the electrical resistances are given by $R_i = \frac{V_i}{I} A_e$ [1]. The behaviors of the cells are analyzed based on their thermal effects and performance rates. The effect of the rates is examined by the comparisons of the resistances of the cells at small rates of discharges with those at higher rates of the discharges with an assumption that there are no temperature rises, that is, under the exothermal conditions which would be simulated by use of an infinite large transfer coefficients. The dependency of the resistances vanishes if the cells are simulated under ohmic conditions. The delineation of the thermal effects is done by the comparisons of the cell resistances at the isothermal conditions with those at convective heat transfers. At high temperatures, the residences are very low which leads to the over-conduction of the electrons. In addition, during such low rates, the electrolytic concentrations and polarizations become very insignificant. At such conditions, the electrolytic conduction becomes an ohmic resistor whereby the resistance is then determined by the ionic conductivities and the length of the current transport, given by the formula

$$R_e = C \frac{l}{ke^{\varepsilon}}$$

The high interfacial kinetics at the high temperatures causes an avalanche of electrons which leads to high discharge rates of the batteries within a very short time and hence the poor performance. At mild temperatures such as 25ºC, the resistances remain constant due to the infinite electrolytic concentrations and polarizations. The anodes of the conductors possess higher electrolytic resistances which lead to building up of over-potentials and hence reaching a point where the conductors assume the role of a perfect conductor [1]. The combinations of the electrolytic resistances from the anodes, the cathodes as well as the separators constitutes to the bulk resistances of the cells, which dominate at mild temperatures. On the other side, the kinetic resistances, mostly from the cathodes exhibits a high variation due to the dependence of the exchange currents. The kinetic resistances become maximum at the highest rates of discharge. At such a condition, the battery is assumed to be dormant. This is because, there is no potential that is being built up or rather current that is being generated, a condition which can be eliminated by significantly reducing the amount of the internal heat being generated [1]. When the temperatures are further reduced, the kinetic resistances become the order of higher magnitudes and dominate all of the resistances. In such a condition, if the battery is operated for more than 10 hours, the performance of the battery will never be regained. The damage occurs due to kinetic energy activation and transfers which are usually around 70 kJ/mol at the anodes and 50 kJ/mol at the cathode [1]. The two values are used in the present optimization models. The activation energies for the charge transfers become higher than the conditions of the electrochemical and electron transfer processes. Contrary to the low rates of discharge at room temperatures where the electronics kinetics at the anode is much higher than that at the cathode, the kinetics of the anode becomes rate-limiting due to the higher activation energies of the graphite [1]. These analyses are in a good agreement with the Tafel model of polarization in a wide range of simulations. They remain constant in the entire period of the discharge of the battery, except for some changes that occur due to non-uniform reactions.

Some chemical engineers have developed a model of generating a reaction front which can be used to reduce the conditions which make the discharge rates constant by use of mechanisms referred to as anode-separator-interfaces which eliminate the non-uniformities between the cathode and the anode at varying temperatures. However, the mechanism does not minimize the effects of the thermodynamics and the kinetic material properties, which have a great influence on the performance of the cell. The low rates of the discharge offer the best conditions for approximations of equilibrium states whereby high concentrations of the effects of polarization do not exist [1]. Non-linear behaviors of the battery at the high temperatures are analyzed by the linear approximations.

During the high rates of discharges, the high concentrations of the polarizations together with the sluggish kinetics lead to non-ohmic conditions due to the large increase of particle resistances. Moreover, the utilization and the distributions of the non-uniform and active materials imply high variations of the particles at various locations within the electrodes. The relationship is shown in figure 1 whereby when the average is obtained; the influences make the curve of the particles to portray diminished resistances. As shown in figure 1, the anode particles are seen to be having some monotonic variation of the resistances. The cell performances in such conditions are therefore dependent on the rates of the solid-state diffusions. At very high temperature, the rates of the diffusions are extremely high and hence this increases the rates of electronic collisions. The high rates of electrons collisions make the electron flow to be non-linear and hence lead to the low generation of battery currents which can only be improved if the temperatures are reduced [2]. At high discharge rates, the electrolyte does not act like a perfect conductor which therefore results to the imperfect conduction of the electrons. The other effect is that the electrolytic resistances in the cathodes and the anodes increase as the rate of discharge continues. The electrolytic resistance on the side of the anode has a higher rate of increase than the side of the cathode and these adds to the non-uniformities in the transfer of the electrons at higher temperatures. The high electrolytic resistances on the side of the cathode are attributed by the short ionic transport paths between the electrolytes and the anode [2]. The overall effect is the reduction in the voltages, which results due to the decreased electrolytic potential.

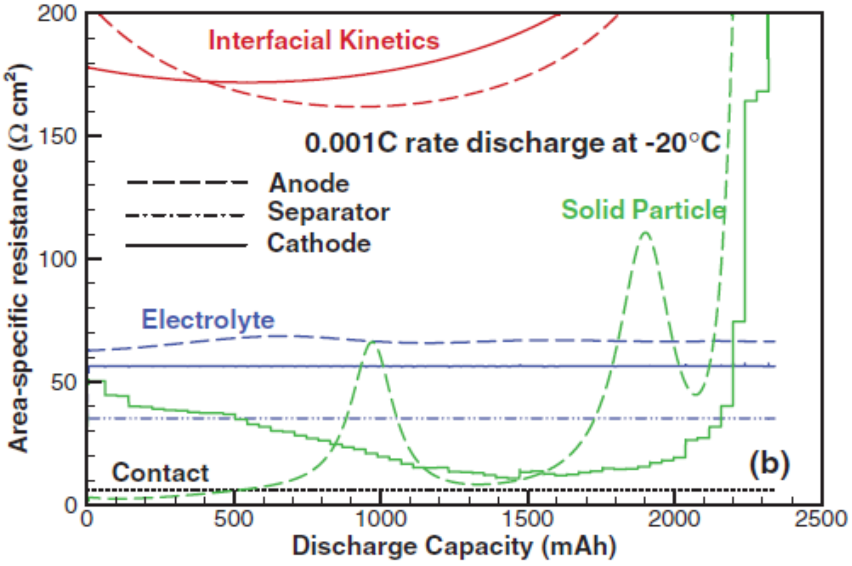

Figure 1: Anode, separator and cathode characteristics [3]

Due to decreased ionic conductivities, concentration over potentials results due to high diffusional rates of the electrolyte ions which finally results to the aggravation of the potential losses. If the temperatures increase beyond the cut-off temperatures, reversal of the ionic currents occurs, and this makes the electrons to accumulate at the anodes. In such a condition, even if the battery is charged, there will never be built up of potentials at reversed directions and the battery may never be reused again [2]. The high reversed diffusional currents occur as a result of the increase in the thermodynamic factors which results to the high ionic conductivities and the short-range solvent interactions which become extreme if the electrolytes are highly concentrated [2]. If the electrolyte is highly concentrated, the high rates of discharges lead to the accumulation of the Li-ion particles and hence the isothermal discharges. During isothermal discharges, the voltages of the cells increases quickly until it reaches cutoff voltages [2]. Beyond the cutoff voltages, the cell must be operated at mild temperatures since a slight increase in the temperatures may lead to the breakdown of the conductors as a result of the avalanche electronic conduction. For the purpose of understanding the effects, figure 2 shows the parameter distributions at cut-off voltages of the cells.

A high drop in the electronic potentials occurs from a sharp decrease in the conductivities of the ions due to the elevation of local concentrations of the ions. Careful examinations of the profiles of the electrolytic concentrations show that when the concentration of the electrolyte is above 3 mol/L, the electrolytic potential drops significantly [2].

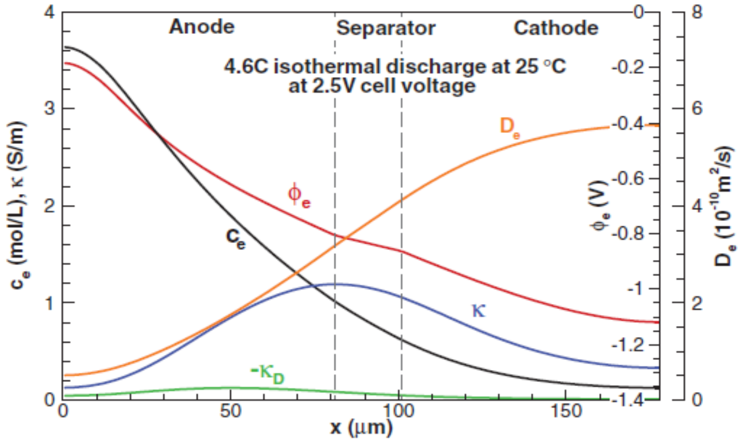

Figure 2: Electronic concentration and isothermal discharges [3]

The previous analysis has provided sufficient information on why batteries do not perform effectively at high temperatures due to the resistances within the cells while operating at high rates. It, therefore, shows that the generation of the heat during the battery operation as a result of the internal resistances is significant as far as battery performance is concerned [2]. The high dependencies on thermodynamics, kinetics and transport properties offer feedback to cell performances as a result of the temperature rises. In such a way, the electrochemical performances, as well as the thermal behaviors, are coupled. Comparing with the normal conditions of operations, an increase in the electrolytic resistances, as well as the partial resistances, reduces beyond 210mAh with every 10˚ C temperature rise. The electrolytic resistances of the anode still continue to increase during the discharges but at a lower rate due to warm-up of the cells [2]. On the other hand, the kinetics of the charge transfers continues to decrease, and the profiles portray two ups and downs that reflect the thermodynamics' characteristics, which therefore suggest more utilization of the active materials as well as low solid-state concentrations and polarizations. Generally, the electrolytic resistances dominate at room temperatures while the high rates of thermo-chemical coupling have been fully considered. The trends of the resistances are almost similar as shown in figure 3 whereby the contact and electrolytic resistances dominate and stay at constant levels. From this perspective, if the thermal conditions are considered at room temperatures, the cells behave like imperfect conductors since the resistances do not depend on the rates of the discharges [4].

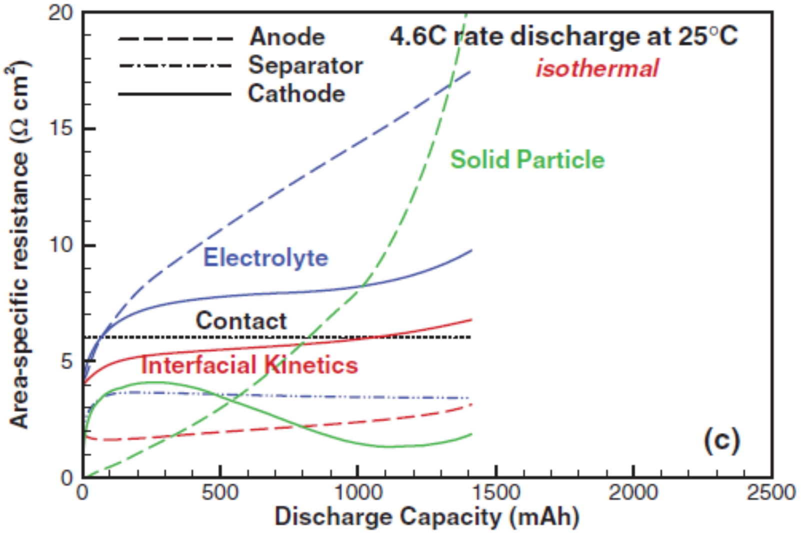

Figure 3: Effects of contact and electrolytic resistances [3]

According to the characteristics of the resistances the contact resistances as well as the Joule heating effects are the common sources of the heat generations. The entropic heat is usually negligible in the first 1400 mAh discharge capacities but rises significantly as it approaches the ends of the discharge. Much of the generated heat is used to heat up the internal components of the battery because the heat dissipated is negligible. At the exothermic conditions, the discharge capacity benefits from the self-heating properties of the cells which make the cell discharge capacities to increase from 150 mAh to 1500 mAh [4]. However, when the temperature goes beyond the cut-off operational temperatures, the mAh rating starts to decrease, and the condition damages the battery if operated for a long period of time without the necessary corrections. The decrease is usually associated with the suppressed electrolytic anode resistances which arise as a result of larger ionic conductivities as well as the salt diffusivities resulting from the rise of heat. In spite of the high activation energies of the change current densities, the kinetic resistances do not show significant decreases with rises in the temperatures, perhaps due to the transition from the Tafel modeled regions to non-linear kinetics [4]. Instead of ohmic heating dominance throughout the process of the discharges, at room temperatures, irreversible reactions contribute to too much of the internal heat generations although the Joules heating effect occurs. The contact heating, as well as the irreversible heating, becomes negligible because they are very small when compared with resistances that rise considerably with the lowered temperatures.

Chapter 2: Battery Holder Design

Electric vehicles use rechargeable batteries to run. One of the main factors of drops in performances for rechargeable batteries is temperature of the surroundings. In our real life there are different variations of temperate depending on the location as shown in the figure 4 below.

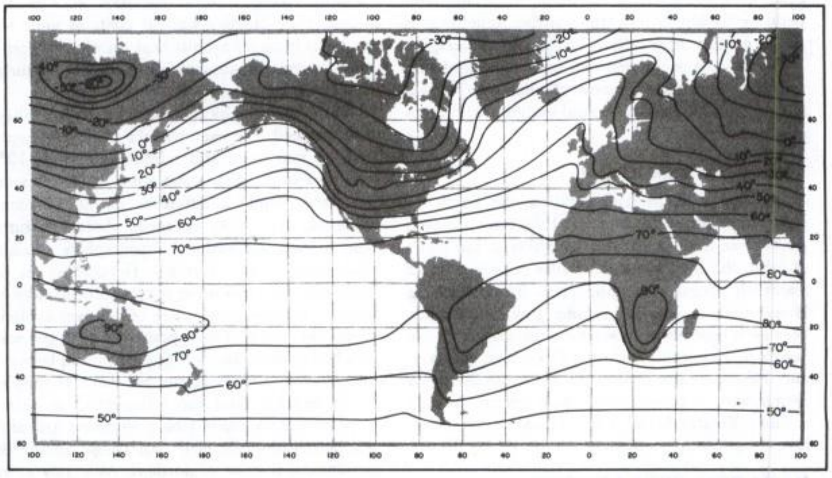

Figure 4: World-wide average temperature in January [5]

By changing the temperature and monitoring the voltage, current and battery life, a pattern on how temperature affects battery performance will be clearer. Different researchers walked through this path, but the originality of this research is in the way the temperature is controlled. To simulate the hot temperatures of the desert climate, a testing platform was designed that can sit the batteries next to each other with a heater in between as shown in figure 5. The current platform has a problem that it is not freely sitting on air, because convection heat transfer depends mostly on the surface area that has direct contact with air. To test the batteries efficiently the four sides should be of the same material, which in this case air touches the batteries from three side and the table from the fourth side. Another problem is that adhesive tape is not reliable, since testing will take days and the temperature will reach more than 40ºC that can damage the setup and the setup could fall if the tape gets loose with time.

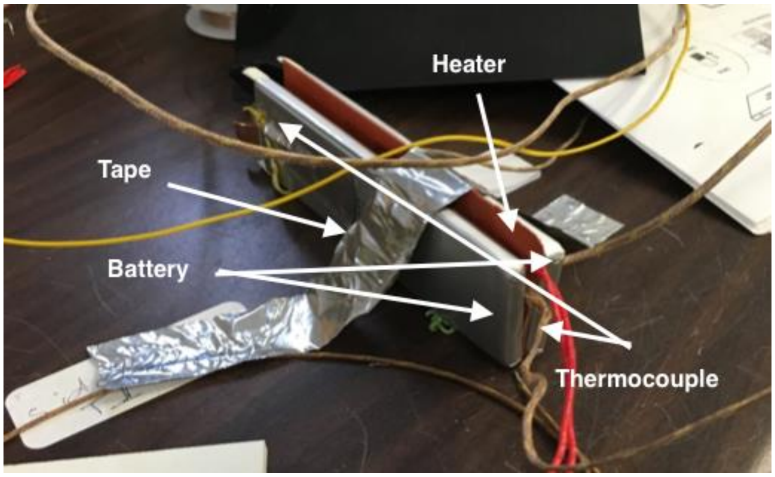

Figure 5: Current setup

Different designs for the new setup were made in order to reach the final design. When brainstorming, two designs met the criteria needed. The first design, shown in figure 6, is a slot where the battery sits, since most Li-ion batteries that need testing have the same thickness. The slot also has supports so that the battery can be placed without falling. The contact area, compared to the current setup, is minimized. The design is safer and the batteries will not fall as the testing starts compared to the current setup.

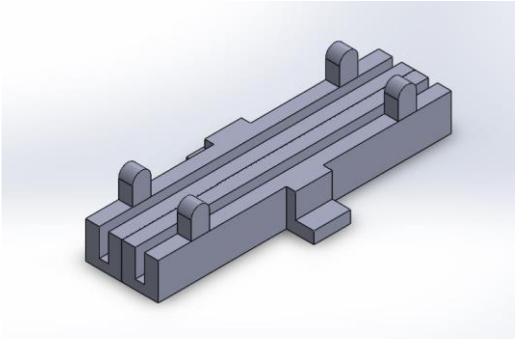

Figure 6: Design 1

The second design, shown in figure 7, has a screw mechanism that will keep the batteries in place using the normal force due to contact and the screws act as a support, so there is no fear that the battery will fall with time. Different batteries can be tested with different thicknesses since the width of the design depend on the screw not on the design itself. Also the batteries are free of any surface, as if it is hanging on the air. The contact area is less than 5% maximizing both conductive and convective heat transfers. The design can sit different sizes of batteries at the same time. Lastly, the time to assemble the design and sit the batteries is less than that in the first design.

The material used to make the design is polycarbonate that has a melting point of 147 ºC and is less likely to catch fire compared to the table that is made out of wood. Overall the new design is more reliable and efficient in gathering data than the current setup. Solidwoks model was developed and an isometric view of it is show in figure 7 below.

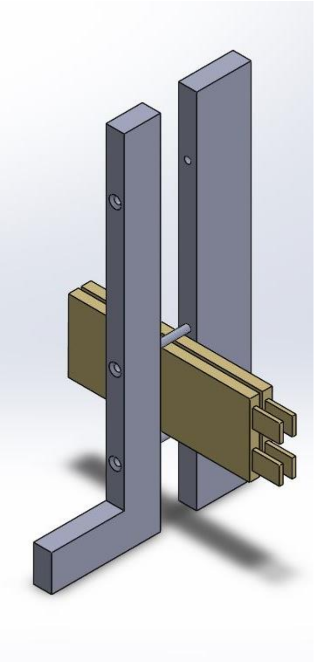

Figure 7: Testing platform

To reduce the contact stress on the faces of the batteries another set of platform was added that will further increase the stability of the design. In addition, a base was added to vary the distance between the two platforms, because different batteries have different dimensions and depending on the length of the battery the platforms will be seated differently on the base. The platforms use a screw mechanism to fit on the base. The final implemented design is shown in figure 8 below.

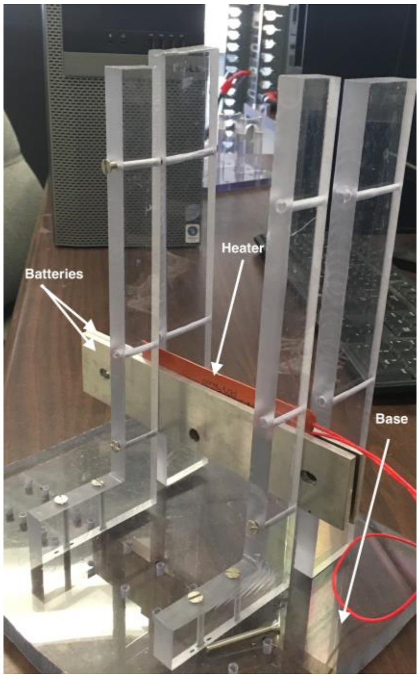

Figure 8: Final setup

The main target of changing the setup is to maximize the convective heat transfer by reducing the contact area between the setup and the batteries. Also maximize the conductive heat transfer by holding the batteries together. Controlling the temperature of the batteries is the next step that will be discussed in the next section.

Chapter 3: Control System Battery Temperature

Battery temperature depends on different factors such as surrounding temperature, and temperature variations inside the battery. To gather data, a Data Acquisition (DAQ) system connected to a microcontroller, Arduino, was used. A heater is placed in between the batteries, simulating the high temperatures as shown in figure 5 above. The microcontroller will control how the system responds to high temperatures and control the temperature at a specific point, by a simple on and off function, ensuring safe testing procedures. Also, it is connected to two thermocouples, one is placed outside of the first battery and the other is between the battery and the heater, to monitor the temperature. The closed loop diagram in figure 9 explains in detail the process done to collect the data.

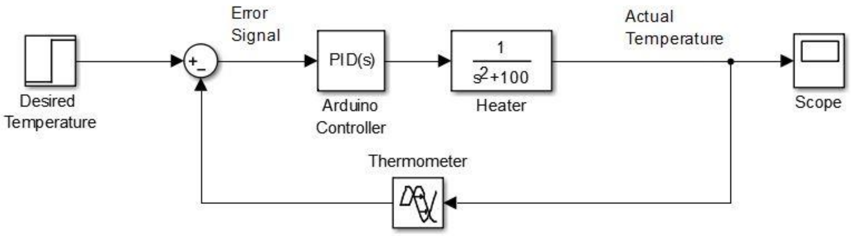

Figure 9: Closed loop diagram of the system

After monitoring the temperature of the batteries and trying to control it at 33°C the plot in figure 10 was constructed. The heater is heating up gradually, sensor 1 heats up faster than sensor 2 because it is placed next to the heater, however sensor 2 is placed on the outside as and it heats up due to conduction compared to convection for sensor 1. The mean of the sensors is taken to reduce any over or under estimation of the model. As expected, there are a lot of oscillations, because the system takes a reading every 0.25s and the heaters needs time for the maximum heat to be delivered. The program had a simple on or off function, turning the heater on when the temperature is below the control temperature and off when the temperature is beyond the control temperature. The program is included in Appendix A.

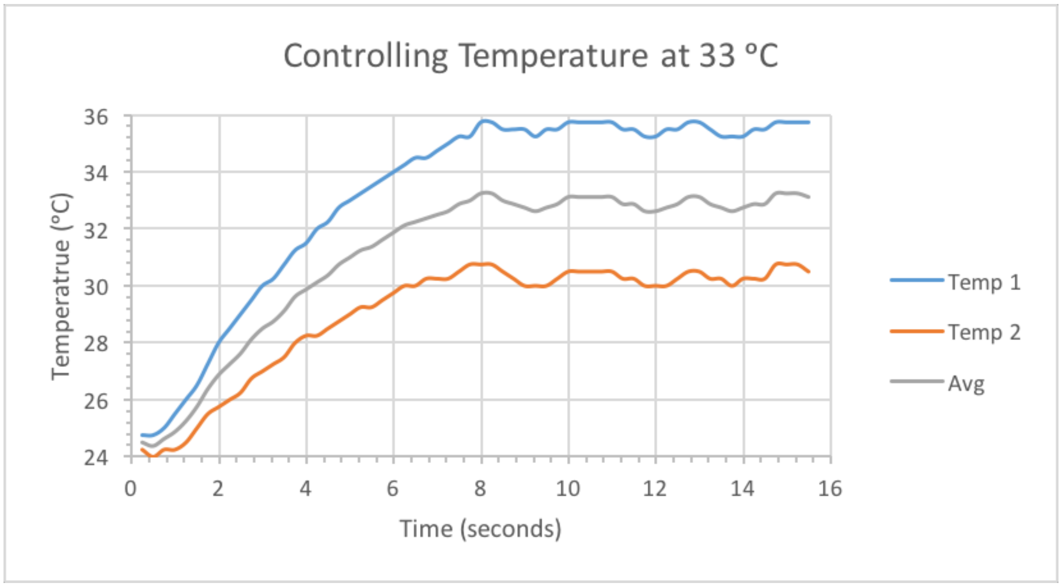

Figure 10: Controlling Temperature at 33°C using simple on/off function

In order to make the results more accurate and precise, Pulse with Modulation (PWM) function was used. PWM is a square signal that controls the amplitude and frequency of the signal. This can be used in testing the performance of the batteries. By setting a temperature to be reached, the heater will keep heating up to the given temperature, but as the heater draws near to the temperature the voltage supplied decreases, thus slowly decreasing the heat dissipated by the heater. For PWM to work properly, three inputs are needed maximum temperature and the time for the heater to be on and off. The on and off time creates the square signal and the maximum temperature determines the amplitude of the signal.

The main drawback of PWM is that it takes more time to reach the specified temperature, because as the set point is being reached, the voltage supplied decreases and the heat dissipated by the heater decreases. In addition, PWM immensely decreases the use of the heater being constantly switched on and off and rather decrease the voltage supplied gradually. Also, PWM has an advantage in reducing the unwanted noise which reduces the oscillations while controlling the temperature. The square signal that the PWM simulates is shown below in figure 8, this signal outlines the model for the Proportional, Integral, Derivative (PID) controller that further creates a more accurate simulation rather than PWM. The program is included in Appendix B.

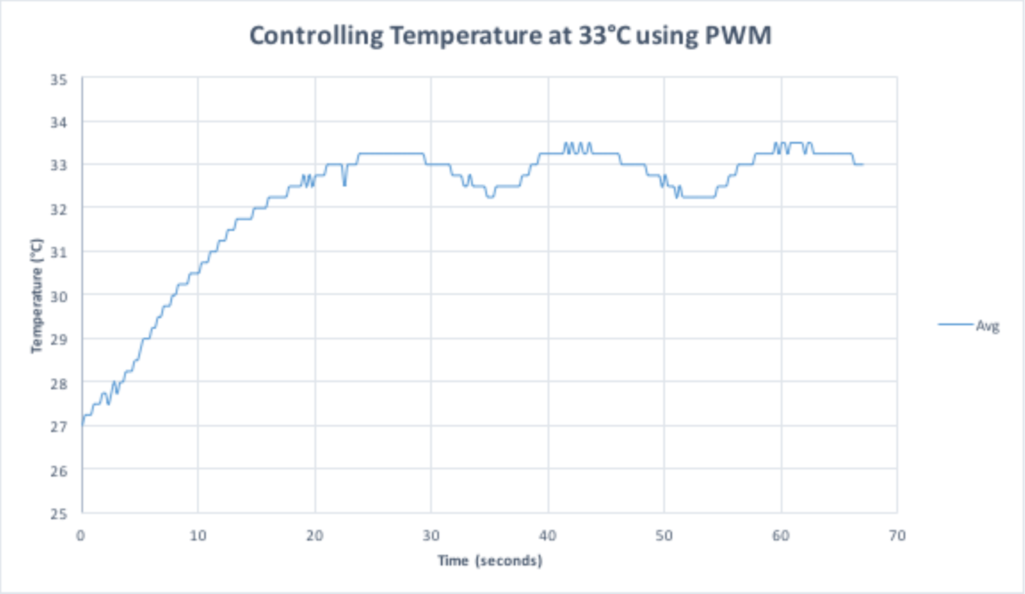

Figure 11: Controlling Temperature at 33°C using PWM

Conclusion and Future Work

The battery holder design maximized the conductive and convective heat transfer in order to monitor the battery performance. After setting up the platform, a temperature control system was developed to simulate high temperatures. Two approaches were developed using a heater connected to a microcontroller. The first program was a simple on/off function where the heater starts heating up till the controlled temperatures is reached and then the heater stops. The second program was a Pulse with Modulation (PWM) function where the voltage of the heater decreases as the controlled temperature is being approached. Overall, the PWM program is more efficient and accurate.

A Proportional, Integral, Derivative (PID) controller could be implemented to further increase the accuracy of the project. The three step process makes a representation of the system and controls it more effectively. The first step, Proportional, controls the temperature with some oscillations, because the temperature will increase or decrease depending the state of the heater. The PWM in Appendix B is a representation of the Proportional part of the PID. The second step, Integral, reduces and minimizes the oscillations by checking the pattern of the process after some time and correct the Proportional part of the system. The last step, Derivative gives a faster response by predicting what will happen next, which brings the system to a final representation of the whole system [6]. The PID controller could be used as a thermostat in homes, since it controls temperature at a specific point and reduces the use of electricity.

Operation of cells used on the electric vehicles has been studied at high temperatures, both theoretically and experimentally. The study has revealed some of the factors which lead to reduced performances of the cells during high heating conditions. During high temperatures, the cathodes generate a lot of mass electrons which are conducted throughout the electrode towards the anode in order to constitute an electric current. The conduction of this released electrons depend on factors such as properties of the material making up the electrolyte as well as the active materials [7]. It also depends on the length as well as the surface areas of the electrodes. When the temperatures are very high, the many electrons will need high surface areas for smooth conduction. If the surface areas are very small for the case of the thin electrodes, the collisions of the electrons lead to random flow of electrons which constitute poor battery performances. In addition, the high discharge rates at high temperatures leads to the poor performance of the batteries. The analysis has provided sufficient information on why batteries do not perform effectively at high temperatures due to the resistances within the cells while operating at high rates. It therefore shows that the generation of the heat during the battery operation as a result of the internal resistances is significant as far as battery performance is concerned. The high interfacial kinetics at the high temperatures causes an avalanche of electrons which leads to high discharge rates of the batteries within a very short time and hence the poor performance [7]. The kinetic resistances become maximum at the highest rates of discharge. At such a condition, the battery is assumed to be dormant. This is because, there is no potential that is being built up or rather current that is being generated, a condition which can be eliminated by significantly reducing the amount of the internal heat being generated.

Appendix A

```
#include <SPI.h>
#include "Adafruit_MAX31855.h"

// Default connection is using software SPI, but comment and uncomment one of
// the two examples below to switch between software SPI and hardware SPI:

// Example creating a thermocouple instance with software SPI on any three
// digital IO pins.

#define MAXDO   5
#define MAXCS   4
#define MAXCLK  3
#define MAXDO2   8
#define MAXCS2   7
#define MAXCLK2  6
// initialize the Thermocouple
Adafruit_MAX31855 thermocouple(MAXCLK, MAXCS, MAXDO);
Adafruit_MAX31855 thermocoup(MAXCLK2, MAXCS2, MAXDO2);
double avg;

const int powerPin = A0;
boolean powerOn = false;



void setup() {
#ifndef ESP8266
  while (!Serial);     /
#endif

  Serial.begin(9600);

  Serial.println("Control Temperature");


  pinMode(powerPin, OUTPUT);
  digitalWrite(powerPin, HIGH);

  delay(500);
}

void loop() {
  // basic readout test, just print the current temp
  Serial.print("Internal Temp1 = ");
  Serial.println(thermocouple.readInternal());
  Serial.print("Internal Temp = ");
  Serial.println(thermocoup.readInternal());
  double c = thermocouple.readCelsius();
  double c2 = thermocoup.readCelsius();
  if (isnan(c)) {
    Serial.println("Something wrong with thermocouple1!");
  }
  else
  {
    Serial.print("Temp1 = ");
    Serial.println(c);
  }
  if (isnan(c2))
```

```
  {
    Serial.println("Something wrong with thermocouple!2");
  }
  else
  {
    Serial.print("Temp2 = ");
    Serial.println(c2);
  }

  avg = (c + c2) / 2;
  Serial.print("AVG = ");
  Serial.println(avg);
  if (avg <= 33)
  {
    digitalWrite(powerPin, HIGH);
  }
  else if (avg >= 34)
  {
    digitalWrite(powerPin, LOW);
  }

  delay(1000);
}
```

Appendix B

```
#include <SPI.h>
#include "Adafruit_MAX31855.h"
#define MAXDO1   5
#define MAXCS1   4
#define MAXCLK1  3

#define MAXDO2   8
#define MAXCS2   7
#define MAXCLK2  6

Adafruit_MAX31855 thermocouple1(MAXCLK1, MAXCS1, MAXDO1);
Adafruit_MAX31855 thermocouple2(MAXCLK2, MAXCS2, MAXDO2);
char Case;
//int sensorpin = 0;                 // analog pin used to connect the sharp sensor
int val = 0;
int On_Time;
#define Off_Time 2                 //OFF TIME OF PWM IN SECONDS I set it to 2 seconds for testing purposes
int Temperature;
int enable_ton;
int enable_tOff;
int Time_Off;
int Time_On;
int PWM;
int sec;
void Generate_Pwm();

void setup() {
   pinMode(13,OUTPUT);
   Serial.begin(9600);
  /*basically I have used arduino timer interept technique to creat pwm signal to avoid any kind of delays in the code.
    I have initialized the timer interept to tick every 1 sec on compare match means when program start the timer register
    will be incremented untill its value is equal to the that I have stored in a timer register*/
   cli();          // disable global interrupts
    TCCR1A = 0;     // set entire TCCR1A register to 0
    TCCR1B = 0;     // same for TCCR1B
    OCR1A = 15624;// set compare match register to desired timer count:
    TCCR1B |= (1 << WGM12);// turn on CTC mode:
    TCCR1B |= (1 << CS10);// Set CS10 and CS12 bits for 1024 prescaler:
    TCCR1B |= (1 << CS12);
    TIMSK1 |= (1 << OCIE1A);// enable timer compare interrupt:
    sei();             // enable all interrupts
   Serial.println("Press 1 to Enter Time and Temperature ");
   Serial.println("Press 2 to start ");
   Serial.println("Press 3 to Emergency stop");
   Serial.println("Press 4 to Reset ");
}

void loop() {

   double T1 = thermocouple1.readCelsius();
   double T2 = thermocouple2.readCelsius();


 if (Serial.available()>0) {
```

```
    Case = Serial.read();
    switch (Case) {
    case '1':
      Serial.println("Enter heater on Time: ");       //Prompt User for Time Input
      while (Serial.available()==0) {}                 //Wait for user input
      On_Time=Serial.parseInt();

      Serial.println("Enter your Temperature: ");      //Prompt User for Temperature Input
      while (Serial.available()==0) {}                //Wait for user input
      Temperature=Serial.parseInt();
      break;
    case '2':
         PWM=1;

      break;
    case '3':
         PWM=0;
         digitalWrite(13,LOW);
      break;
    case '4':
      sec=0;
      break;
    default:int num=0;
   break;
    }

    Serial.print("Time:");  //Serial.print("Time:");
    Serial.print(On_Time);
    Serial.print("\n");
    Serial.print("Temperature:");
    Serial.print(Temperature);
    //delay(1000);
  }
   if(PWM ){
    Generate_Pwm();
    Serial.print("sensor1 = ");Serial.print(T1);Serial.print("'C");Serial.print("\t");
     Serial.print("sensor2 = ");Serial.print(T2);Serial.print("'C");Serial.print("\t");
     if(enable_tOff==1)
     {
         Serial.print("    PWM = OFF");
      }
      else
       {
         Serial.print("    PWM = ON");
       }
              Serial.print("\t\t");
               Serial.print("SECONDS=");
               Serial.print(sec);
            Serial.println();


           // Serial.print("pwm enabled");
           }
          }

       ISR(TIMER1_COMPA_vect)
       {      //digitalWrite(13,HIGH);
         sec++;
```

```
if(enable_tOff==1){
  if(sec >= Off_Time){
    enable_tOff=0;
    sec=0;
  }
}
else{
  if(sec >=On_Time){
    enable_tOff=1;
    sec=0;
  }
}
}
void Generate_Pwm(){
    if(enable_tOff==1){
      digitalWrite(13,LOW);
    }
    else{
      digitalWrite(13,HIGH);
    }
  }
```

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ACADEMIC VITA

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EDUCATION

Pennsylvania State University (PSU), University Park, PA – Schreyer Honors College
(January 2013 - Dec 2016)

- **Bachelor of Science in Mechanicals Engineering**
- **Bachelor of Science in Economics**
- **Minor: Engineering Leadership Development**

WORK EXPERIENCE

Effect of Temperature on Battery Performance, Penn State Research (Sept 2015 – Dec 2016)
Research Assistant

- Examine how age and heat influence battery performance.
- Used microprocessors to perform complex mathematical calculations to control batteries at a specified temperature.
- Designed and built different mounts and models that are needed for the research.

Abu Dhabi Polymers Company (Borouge), Ruwais, UAE (May 2016 – June 2016)
Technical Intern

- Gained perspective in manufacturing of plastics (PE,PP,LDPE,XLPE)
- Learned problem-solving skills with the different problems in the factory.
- Brainstormed ideas on how university graduates should gain their technical experience.

Etisalat, Abu Dhabi, UAE (May 2010 – June 2010)
Financial Officer

- Prepare, examine, and analyze accounting records, financial statements, or other financial reports to assess accuracy, completeness, and conformance to reporting and procedural standards.
- Improved and accelerated the process of reviewing closed cases. The department was late on the timeline by six months, when I finished my internship the team was late by one month.

LEADERSHIP AND VOLUNTEERING

Wharton MENA conference (April 2016)

- Indulged in interesting panels the focus on youth employment in the MENA region
- Met with aspiring students, officials and entrepreneurs in the region.

UAE Student Forum, Washington, DC (Nov 2013, Nov 2014, Nov 2015)

- Handled inquiries from students regarding ADNOC scholarships by utilizing my communication skills.
- Organized the event and proposed ideas for future forums.
- Awarded a letter of certification from His Excellency Ambassador Yousef Al Otaiba,

Ambassador for ADNOC students in PSU (Jan 2013 – Present)

- Coordinated with ADNOC to provide aid to new students, and current students who are in need of help (More than 60 students in total).
- Reported students' comments and various suggestions to ADNOC scholarships office.

Global Lions Ambassadors, Harrisburg, PA (Jan 2013 – May 2014)

- Hosted international guests, met different people, attended conferences. Improved Communication and protocol skills. Started overseas relations with other friends.
- Presented my experience in the U.S. to PSU's Board of Administration, representing international undergraduate students.