<u>It Ain't Half Hot Mum.</u>

By Bob Smith

Sorry about the title but this article is going to be fairly theoretical so I thought I would start with a light-hearted beginning. The problem with writing about technological elements of this hobby is the difficulty of setting the level of the content so that it is understandable to the majority of readers but does not fall into the category which links grandparents and eggs. I will therefore apologise in advance to any readers who find this either too obvious or too complex, which may only leave the half-dozen in the middle enjoying it!

The clue in the title is heat, which in the context of electric flight is something we wish (with a few exceptions) to avoid. Let's start with an important clarification. Heat and temperature are not the same! The English language has innumerable confusions built into it, and the use of heat, hot and cold, temperature, and similar terms is one of these areas. A tale recounted to me about a sister-in-law, when very young, is a good example. One morning, when trying to avoid school, she tried to persuade her mother that she was too ill to go with the phrase "Mum, Mum, I think I've got a thermometer". Needless to say she got short shrift and was packed off to school amidst much hilarity, but it does illustrate the difficulty.

The temperature of matter is a measure of the relative level of energy within the atoms of that matter. Heat is a form of energy. The heat within a body is the total energy held by that body and is therefore dependant on the mass and other physical properties of the body. If we add heat energy to a body then its temperature will increase (and vice versa of course) but the extent of the increase is dependant on other factors. If we have two bodies of the same material but one has twice the mass of the other, then adding the same heat energy to both of them will cause the temperature of the smaller to rise twice as much as that of the larger.

Since temperature is a relative measure we need to relate it to some physical constant so if using the Celsius scale (also degrees Centigrade) we set the freezing (0ºC) and boiling (100ºC) points of water as fixed on the scale. In everyday life we relate temperatures to our normal surrounds and we call this the ambient temperature (say 20ºC for the internal environment). Since heat is energy, the laws of physics mean that energy will attempt to flow from high to low, i.e. from a hotter body to the cooler surrounds, with the rate of flow dependant upon the difference in temperature.

O.K., that's enough theory on heat, let's now look at electric flight. The theory here might be a bit more familiar to you but just to link the two areas together we can say that electricity is another form of energy. Whenever an electric current passes through a conductor it has to overcome the resistance of the conductor and that uses some of this energy by converting it from electrical to heat energy within the conductor and hence the conductor temperature rises. This is often a deliberate process e.g. in an electric fire or a soldering iron, but is always present even when the main aim is entirely different which is why TVs get hot. In this situation the heat energy is considered to be a loss. The theory here is that the voltage and current values in volts and amps are multiplied to produce power in watts. Ohm's law states that the current flow in amps is the voltage divided by the resistance in ohms.

$$(I = V/R \text{ or } V = I \times R).$$

If power in watts is $I \times V$ then this is $I \times I \times R$ which is I^2R.

Power is the rate of energy change so energy is power multiplied by time.

All of our electric flight power train is subject to this theory. As current flows from the battery to the controller and the motor then resistance in each component causes electrical energy to be converted into heat energy losses and the temperature of the component begins to increase (a double whammy as we are wasting energy and heating the components). This temperature rise is proportional to the square of the current and to the length of time the system operates, but as each component heats above ambient temperature it tries to transfer heat energy into the surrounding environment and this is a cooling effect (though often manifested as a slowing down of the rate of temperature rise).

Heat is the enemy! It eventually leads to the failure of the system. Batteries overheat (sometimes catastrophically), controllers burn out, motors cook. This also applies to ancillary equipment such as chargers and we need to include them in our considerations. How do we minimise the heat produced in our power train and other units?

The first thing is to maximise cooling. Get air flowing through the system and across the surface of the components. Just as we blow across a spoonful of hot soup to cool it, the air flowing round and past a controller will cool that. The airflow does not need to be high velocity as a steady airflow is more effective. You may think it is a good idea to wrap the controller and battery in foam to protect them in a crash but you may ruin them if they get too hot and fry. Remember also that the temperature increase resulting from operating the system is above ambient. If the increase is 40ºC and the initial ambient is only 10ºC the system will end at 50ºC. If the initial ambient is 25ºC then the final temperature will be 65ºC which will be much worse for the components. Time is also an important factor. High power systems which only operate for short periods with long cooling periods between do not give rise to large temperature rises. Low power systems operating continuously throughout the flight often will.

You also need to be aware of the effect of changes on the power train. Suppose you decide to run a larger propeller on the system. This will increase the current draw and the power and heat generated will increase in proportion to the square of the current. If the current is increased by 20% (say 10 amps to 12 amps) the power and heat will increase by 44% so the component temperature rise will also be increased by approximately the same amount. In the above example the rise will now be 58ºC and the final temperatures will be 68ºC in winter and 83ºC on a hot summer's day. This might obviously be critical in terms of the components involved.

I hesitate to add further complication to this problem but you also need to appreciate that the mechanical elements of the train will behave predictably, e.g. the motor, where there will be a simple response to overheating with problems only becoming serious when the insulation on the windings begins to break down. The unit will generally continue to operate normally up to that point with no deterioration at all until the limit is exceeded. The battery, however, is an electrochemical device and the change in behaviour when overheated is much more complex and difficult to predict. This complication often leads to a progressive breakdown which is accumulative and manifests itself in terms of an increasing loss of performance and shortening of useful life. Some of you may already have experienced this effect.

One last factor to tie in with this area of analysis. I have said above that temperature rise is dependant upon the wattage at which the system operates. This involves both current and voltage but some of the manufacturers of the equipment we use seem to have slipped into the habit of setting unrelated values into their specifications. The prime example of this is with chargers where the literature tells us that the unit will charge at up to "X" amps and work with up to "N" cells (equivalent to "Y" volts). This may well be true but the information is meaningless if the small print then says that the power limit of the charger is "W" watts where W is a fraction of X x Y. You can only charge at X amps with a low cell count or charge N cells at a very low current. Watch out for this and be aware of the implications.

Remember the two rules :-

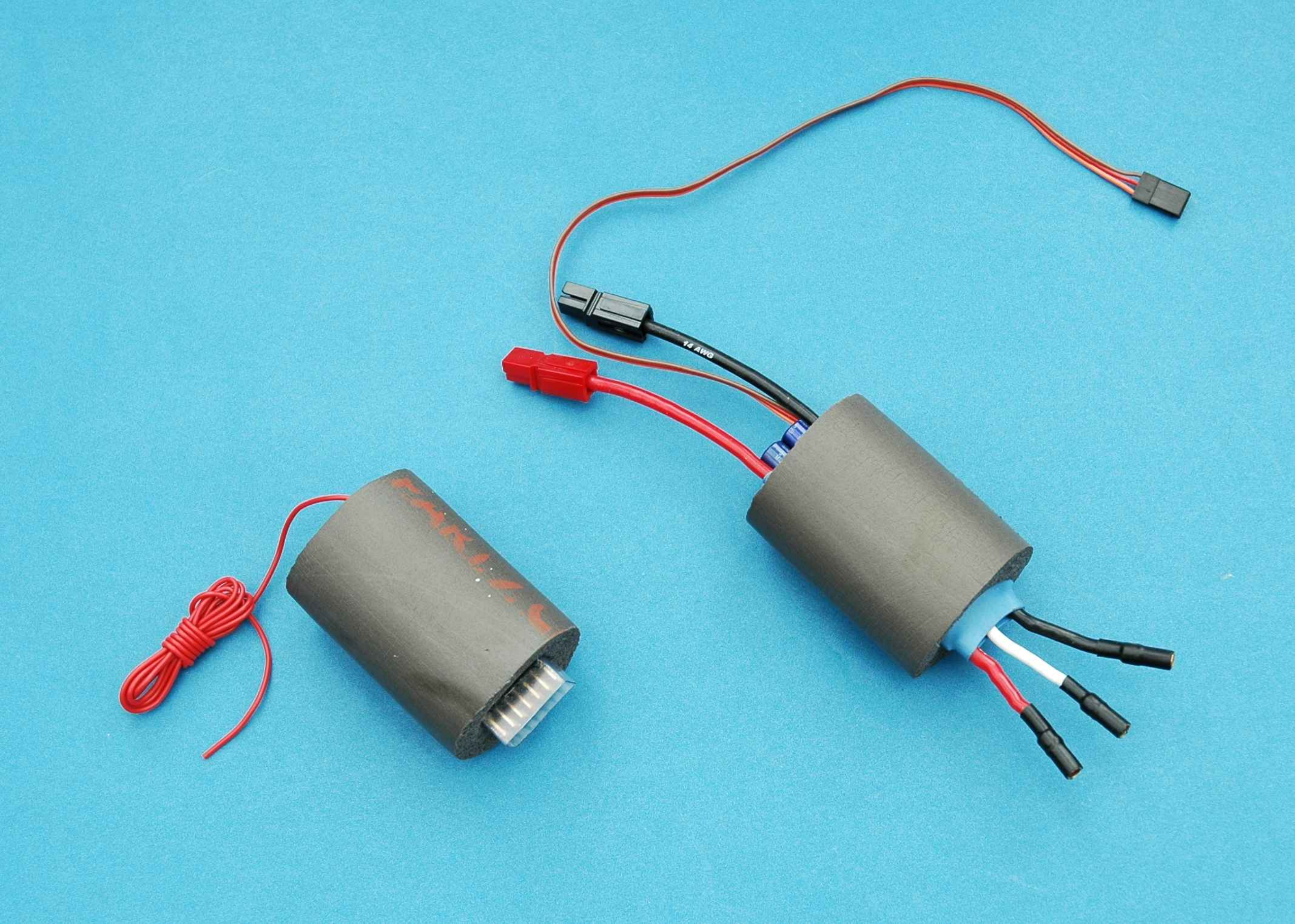
Heat is the Enemy.

And **Always work in Watts.**

Photo Captions.

1. **Deliberate heat from electricity, a filming iron.**
2. **Foam wrapping, Receiver yes, ESC no.**
3. **Typical Charger specification confusion.**


CHUNG KWANG


14 AWG

Charger Specification

Battery……LiPo, LiIo, and LiFe only.
Cell Count……………………………1 to 6S.
Charge Current……………4 Amp Max.
Discharge Current………500mA Max.
Dimensions………100 x 60 x 20 mm.
Weight………………………………………100 g.
Power………………………………………50 W.
Overcharge………………auto cut-off.
Operation…………………………3 button.
Data Indication…………LED display.