Wire and Wire Termination

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With the popularity of electric powered RC models it will be helpful to address some common features of wire and wire termination and connectors.

Wire: The issues that need to be considered when selecting a wire are the **wire gauge**, **stranding** and **insulation type**.

Wire gauge. Wire gauge is usually defined by the diameter of the wire for solid wire gauges and both the wire strand diameter and number of strands for stranded wire gauges. Wire gauge will often be expressed as AWG, for American Wire Gauge. Most of the wire used in the RC hobby is stranded wire, because it offers the least resistance to breakage and handles vibration fatigue better than solid wire.

Stranding In order to determine the AWG of a wire, simply measure the wire strand diameter, count the number of strands and then look up the wire AWG. (See wire gauge chart link below)

You will also need to pay attention to the current carrying capacity (Ampacity) of a given wire to determine whether or not it can handle the current that you intend for your load. Please see the attached wire AWG and ampacity tables in the addendum to this article.

Insulation type There are a large number of types of wire insulation from Teflon for high temperature to silicone rubber for flexibility. Many speed controller cables use silicone while servo leads are mostly insulated with PVC. To cover other types of insulation is outside the scope of this discussion, as you are not likely to encounter them in the RC Hobby.

Before I discuss wire termination it will be helpful to consider a few simple electrical formulas that are essential to understanding the relationship among electrical Voltage, Current, Resistance and Power.

In most electrical circuits knowing two of three formula variables allows us to calculate the unknown value. The following four simple formulas will serve you well and if you intend to participate in the electrically powered aspect of the RC hobby, will prove to be invaluable.

They are commonly known as Ohm's Law(s) (so named after German physicist, George Ohm circa 1825)

"**Ohm's law** states that the current through a conductor between two points is directly proportional to the potential difference across the two points. Introducing the constant of proportionality, the resistance,[1] one arrives at the usual mathematical equation that describes this relationship:[2]

E= IR E (Electro motive force or Voltage) = I (electrical Intensity or current) x Resistance (in Ohms).

Solving the formula for current (I) and resistance (R) yields the following:

I = E/R
R=E/I

where I is the current through the conductor in units of amperes, V is the potential difference measured *across* the conductor in units of volts, and R is the resistance of the conductor in units of ohms. More specifically, Ohm's law states that the R in this relation is constant, independent of the current."[3]

Another formula to which you need pay attention is that of **Power** and is expressed as follows:

P= IV Where **P** stands for **P**ower (in Watts), **I** stands for **C**urrent (in Amps) and **V** stands for Voltage (in Volts).

Substituting the formula for voltage: **P= I(IR)**

Therefore

$P = I^2R$

Please note that in the formula above the power increases with the square of the current!

I^2R losses in a circuit are a huge factor to consider!

Wire Termination

All common wire and wire terminations feature resistance. Because of this and the fact that resistance consumes power, it is a good practice to try and lower resistance wherever possible. One negative feature of wire terminations is oxidation, which leads to high resistance. Where possible, gold plated contacts are preferable, as they do not oxidize. Two other methods of preventing oxidation is to either use "gas-tight" connections, where the oxygen in the atmosphere is sealed out or to use an anti-oxidant chemical such as DeOxit®. (see link below)

Another enemy of wire terminations is vibration. A vibrating wire, especially if it hits mechanical resonance, which will cause the wire strands to fatigue and break, usually at the termination point. It is a good idea to use wire terminations with a strain relief, or if not possible, to tie the wire or bundle as close as possible to a fixed point on the airframe, thus preventing the wire from moving or vibrating.

Some wire terminals feature built-in strain relief, such as the contacts on most servo wire connectors. All crimp on terminals feature a “barrel”… the part of the terminal that “grabs” the wire itself. Strain relieved terminals feature an additional “closure” that holds onto the wire insulation to prevent the copper from flexing at the crimped barrel. Please note that a proper strain relief should touch and hold, but not crush the wire insulation.

The test of a proper crimped terminal is a wire pull test, where the wire is weighted and a strain gauge is used to determine how many pounds a crimped termination can withstand without breaking. (See attached table). That is the industry standard. If you make a wire termination that won’t withstand the rated pull test value, the termination is not well done!

Some examples of both and non-strain relieved and strain relieved terminations are shown below.

Examples of wire termination without strain relief.

Examples of wire terminals with strain relief.

Pin type connector with strain relief

Note the barrel and the strain relief "crimp"

RC Servo connectors with strain relief.

A word about power supplies and a caution!!!

As the electric powered (E-Flight) section of our hobby grows more and more popular, may RC fliers are using electrical generators and batteries to power their field battery chargers. The formulas above apply to these. If you have a 110 volt generator capable of ten amps **(P= IV),** The generator is capable of outputting 10amps x 110 volts or 1,100 watts. If you step that voltage down via a battery charger to say 14 volts at the battery under charge, the resultant current that can be supplied goes up to around (Power = 1,100 watts divided by 14 amps) or 78.14 amps at 14 volts Dropping the voltage from 110V to 14VDC allows for more current available. That is the current, minus some loses that the generator and battery charger can supply, as long as their respective circuits can handle the power load.

<u>Seven Soldering tips from Lew Marascalco</u>

Soldering is used quite often in RC modeling, especially for electric powered aircraft. Here are some useful basic tips

1. Use a good rosin core tin/lead (60/40 typical) solder
2. Use a soldering iron of sufficient wattage to do the job. 35-40 watts is usually adequate for wiring up to and including 16 AWG and even 14 AWG depending on what size contact is being soldered to. For 14, 12, 10 AWG wiring connections, an 80 to 100 watt iron works best
3. Soldering iron tip shape also needs to be considered based on the job. A pointed sharp tip

is OK for small wiring connections like servo leads but a rounded more blunt tip is better for heat transfer for larger wires like battery and speed control leads.

4. Keep the soldering iron tip tinned with solder and continuously wipe it clean with a damp cloth or sponge especially before soldering.
5. Tin (apply a small amount of solder) to both the wire and contact prior to soldering.
6. Heat the parts before adding any additional solder. Usually if the parts are adequately pre-tinned, no extra solder is needed.
7. If soldering barrel type contacts (commonly required for motor and/or speed control wiring), keep the contact vertical by gripping it in a pair of needle nose pliers clamped in a small vise. Pre-tin the contact barrel about 60% full with solder. Use a cloth glove on your hand (to protect from heat transfer in the wire) to hold the wire vertical to solder into the barrel. Heat the barrel to melt the solder rather than heating the wire. Plunge the wire into the melted solder and hold as still as possible and immediately remove the soldering iron from touching the contact.
8. Practice soldering on scrap pieces to help improve your skill.

Final note: If you go to youtube and enter any of the above subjects there are hundreds of videos explaining all of the above and more.

References

***Wire termination :** **http://www.pbase.com/mainecruising/terminating_small_wires**

***Deoxit:** **http://store.caig.com/s.nl/sc.2/category.188/.f** **(Good stuff!!)**

Stay-Brite Silver Solder 3/64" 1/2 oz: http://www3.towerhobbies.com/cgi-bin/wti0001p?&I=LXFS75&P=FR&gclid=CNmvjo-A3cQCFYI9aQodLUkAng

Lead Acid Battery Safety: **http://safety.ucanr.org/files/1417.pdf**

***Wire pull test table on page 30. Everything you ever wanted to know about wire termination!**

http://www.te.com/content/dam/te/global/english/products/application-tooling/at-documents/Milwaukee-EXPO-8May13.pdf

Wire gauge chart: **http://www.seas.gwu.edu/~ecelabs/appnotes/PDF/techdat/swc.pdf**

Wire Ampacity chart: **http://www.cerrowire.com/ampacity-charts**

AND NOW, A WARNING TO ALL BATTERY USERS

A Lead acid battery is a potential bomb! If the electrolyte (the liquid in the battery) decomposes due to electrolasis, the battery has the potential to break down into hydrogen and oxygen, the gases that propelled the Space Shutttle into orbit.

I have seen a battery explode….once. NOT PRETTY!!!

Last year an Odssey battery engineer related the following to me: "In the winter, when static electricity is highest, a fellow picked up a Sears Diehard and was walking out of the store. When he touched the door handle it must have caused a spark inside the partially discharged battery. THE ESPLOSION BLEW OFF HIS LEFT ARM AND EMBEDDED THE LEFT SIDE OF HIS BODY WITH LEAD SHRAPNEL FROM THE BATTERY PLATES.

PLEASE, BE CAREFUL !!!

Please read the following………

Lead Acid Battery Explosions

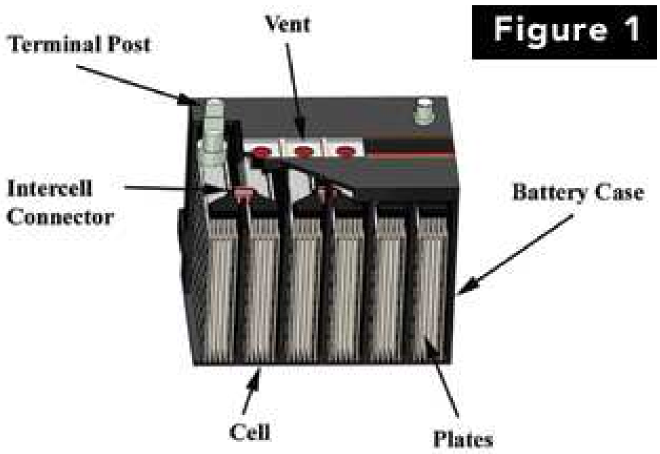
Jan 23, 2013 | By Charles C. Roberts

Share This Story

A car battery doesn't always explode just when being jump-started or charged. There are cases where they suddenly explode due to the installed position, for example, or as a result of a crash, as has been alleged in the probe leading to the Chevy Volt recall.

In any case, automotive battery explosions can cause severe injury and can even be fatal, depending on where one is standing during the explosion. These explosions present added considerations for adjusters who are tasked not only with processing the resultant claims but also in identifying subrogation opportunities.

Let's first examine the anatomy of a typical automotive battery before delving into cases of catastrophic failure. As shown in **Figure 1** below an automotive battery, typically of lead/acid construction, is an electrochemical container that produces voltage, which causes electrical current to flow to various components in an automotive vehicle. An outer polymer case (high density polypropylene) acts as a container for an electrolyte (sulfuric acid), six cells and lead plates. Each cell delivers 2.1 volts, with a total voltage of 12.6 volts, at full charge. Vents are installed at the top of the battery to vent gasses formed during the normal charging cycles.



During the charging cycle, hydrogen gas is generated and accumulates in the head space above the electrolyte level, prior to venting. Hydrogen gas has a wide range of explosive limits in air, ranging from 4 to 72-percent hydrogen in air and is easily ignited by a flame or spark. If the hydrogen is ignited inside the battery, then it typically blows off the top of the battery case, showering sulfuric acid in the immediate vicinity along with fragments of the battery case. The explosive energy generation is so rapid that the vents cannot relieve the pressure in time to prevent an explosion.

Figure 2 to the upper right is a view of a two-year-old battery that exploded, causing personal injury from acid burns. This occurred when a standby generator was starting during its normal maintenance test cycle. The top of the battery was blown away, suggesting that hydrogen was ignited inside the battery.

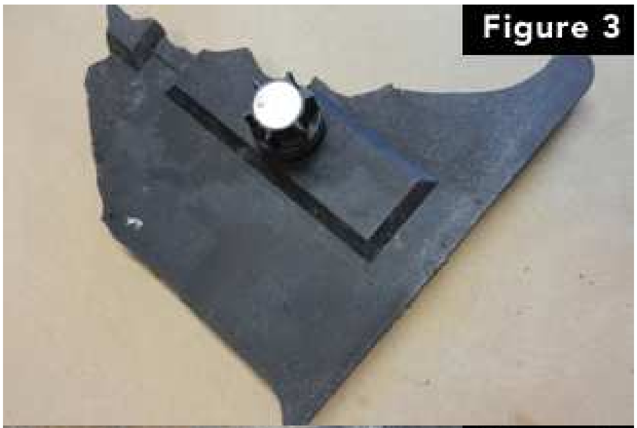


Figure 3 here shows a battery fragment that was found imbedded in the ceiling of the building that enclosed the generator. Inspection of the battery shown in **Figure 2** revealed that one of the intercell connectors (**Figure 4**) was loose and corroded.

Other internal explosive ignition conditions may exist that are not related to a manufacturing defect:

- A conductive bridge may be formed between two plates as a result of low electrolyte levels. When a high current demand is placed on the battery, it can arc, igniting hydrogen gas and initiating an explosion. This is a result of improper battery maintenance where the electrolyte level should be monitored periodically and lost electrolyte replaced. Maintenance free batteries have a hydrometer that measures the specific gravity of the electrolyte (an indicator of the concentration of the electrolyte and hence, the electrolyte level) and indicates whether or not a battery should be replaced.

- External ignition sources often manifest themselves in the form of loose battery cable connections or a poor connection with battery charger clamps that generate an electrical arc. Jump starting vehicles with dead batteries can result in electrical arcs at the dead battery terminals if the last set of clamps is attached to the dead battery. Recommended procedure is to attach the jumper clamps to the dead battery first and then to the live battery.
- Battery explosions have occurred as a result of tools being placed between the battery terminals. Some individuals test a battery by placing a screw driver across the terminals to see if an arc jumps, revealing whether the battery is supplying electrical energy or not. This can result in a battery explosion since the current through the screw driver is not regulated, can be very high and generate an electrical arc, causing an internal or external explosion.
- Corrosion, which can cause electrical resistance and a possible arc ignition source, may develop at battery terminals as shown in **Figure 5**, which also illustrates a loose or improperly secured battery clamp.

As in most investigations, retention of the evidence is desirable if subrogation is anticipated. In battery explosion losses, fragments may be found scattered throughout the scene and imbedded in the building structure. Collecting these pieces helps the technical analyst determine the cause of the explosion. It is encouraged to have the battery analyzed in a timely manner to reduce the effect of corrosion, which can obscure evidence.

A loose connection inside a battery can result in an electrical arc jumping across the gap, igniting the hydrogen. In this case, the loose connection was determined to be a result of a manufacturing defect.