
Igniter Continuity Tests

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Introduction

In 2000, Robert Briody performed an in-depth evaluation of the dynamic firing characteristics of several different types of electrical igniters used in model rocketry (<http://www.gwiz-partners.com/igniters.pdf>). The study showed that so long as an adequate source capacity was available, the leading types of commercial igniters could absorb significant energy and generate significant heat, thereby ensuring reliable model rocket motor ignition. Robert's paper gives us a concise view of the firing capability of these igniters, and the considerations stemming from his evaluation have no doubt influenced a variety of successful launch control designs.

In this present study, we wish to examine the continuity aspect of the igniter, attempting to determine the current levels that can be safely conducted before the risk of ignition becomes significant. Knowing this "safe" current characteristic provides the hobbyist with useful information that can aid in the design of safe continuity check circuits for modern launch control systems.

This paper examines several of the most popular hobby rocket igniters, including the newer Quest Q2G2, an igniter that operates at a much lower firing current than the others, as will be seen. The study concludes with a couple of simple continuity circuit suggestions that can reduce check currents to very low and safe levels.

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Understanding Igniters

In nearly all instances, modern commercially available electric model rocket igniters consist of a short bridge wire encapsulated by a small lump of an energetic pyrotechnic, or initiator, compound, often referred to as pyrogen. A pair of leads connected to the bridge wire provides the means to conduct electricity into the igniter.

When the igniter is subjected to an appropriate electric current under safely controlled conditions, its purpose is to generate sufficient heat so that the ignition temperature of the rocket motor propellant is reached quickly, thereby igniting the motor leading to a successful launch event. To be reliable, an igniter must stay hot enough long enough to ensure that the motor propellant ignites.

In the early days of model rocketry, an electric model rocket igniter mainly consisted of a short length of nichrome wire, a material that could reach rocket propellant ignition temperatures before failing (melting). In modern times the performance of electric model rocket igniters has been improved with the addition of an initiator compound, or pyrogen; when ignited, pyrogen produces a flux of hot burning particles that greatly enhances the ignition of the rocket motor propellant, thereby enhancing the reliability of the launch event.

In principle, an electric model rocket igniter is no different than any other piece of wire. It possesses a property known as electrical resistance, which is a measure of the wire's ability to impede the flow of electric charge, or current. The magnitude of its resistance is related to the geometric characteristics of the wire – its diameter and length – as well as the wire's *resistivity*, an intrinsic property of the material comprising the wire.

In most general wire applications, it is the intent of the design to *minimize* the resistance the wire presents to an electric circuit, as the energy absorbed by the wire due to its resistance is dissipated as heat, thereby reducing the available energy that can be delivered to the application's load. In these cases, the wire is sized according to its *ampacity*, which is a rating of the wire's maximum continuous current carrying capacity at which limit the heat loss becomes excessive. In careful

circuit engineering, the wire's electrical properties, insulation temperature limit, thickness, thermal conductivity, environment, and ambient temperature are all taken into account. These parameters are considered so as to ensure that when carrying the intended current the heat dissipated by the wire will not cause a temperature rise greater than the temperature limits of the wire's insulation. Should the wire become too hot, then the insulation begins to melt (or perhaps begins to burn), and the circuit and its surrounding environment is exposed to a significant risk of fire. Much of the National Electrical Code is devoted to this specific concern to ensure the Public's safety.

But in launch control systems our intended purpose is to deliver as much energy to the igniter as possible so that the ignition event is certain. In this application we specifically want the ignition wire to get hot, hot enough to successfully ignite the rocket motor propellant. For safety reasons we want the igniter to be a single use device; were it not, then there is the risk that the re-usable igniter would still be too hot when falling to the ground, or when inserted into a subsequent rocket motor, either of which could lead to a potential unsafe event.

In some launch control circuit designs, the igniter is placed so as to present a short circuit to the source battery once the circuit is closed. In other designs the igniter is placed in series with active control devices which control the delivery of current to the ignition path. In either case, the igniter represents the weak electrical link in the current path, its ampacity being considerably less than the other wire and appliances in the control circuit, and so in this configuration functions as a fuse. That is to say, its function is to fail ("blow") long before any other element in the ignition path should fail.

Thus when considered from this point of view we realize that a model rocket motor igniter is nothing more in function than a fuse, but rather than being used to protect an electrical system from unsafe current it is being specifically used to deliver ignition temperature heat to the rocket motor propellant.

Continuity Aspects

In a properly designed, safe, launch control system the igniter must support two functions:

- Safely support (i.e.: without ignition) the testing and validation of the launch control circuit prior to launch.
- Deliver the requisite ignition heat to the rocket motor upon command.

Our interest in this paper is with the continuity aspect of the igniter.

Validating the continuity of the ignition circuit invariably involves the transmission of a test current through the igniter itself. For this function to be performed safely, the test current must be lower than the ignition current. But how low is "safe"? Or perhaps more accurately – how high is safe?

We begin our examination with a common commercially available single pad launch controller. Two types are tested, an older Estes Single Pad Controller, as found in the Challenger 1 Starter set, kit #1416, and the ubiquitous Estes Electron Beam, as found in numerous currently available starter sets. Photo 1 shows the older Single Pad controller, and Photo 2 shows the currently available Electron Beam. The only electrical difference between the two units is the power rating of the incandescent continuity check bulb.

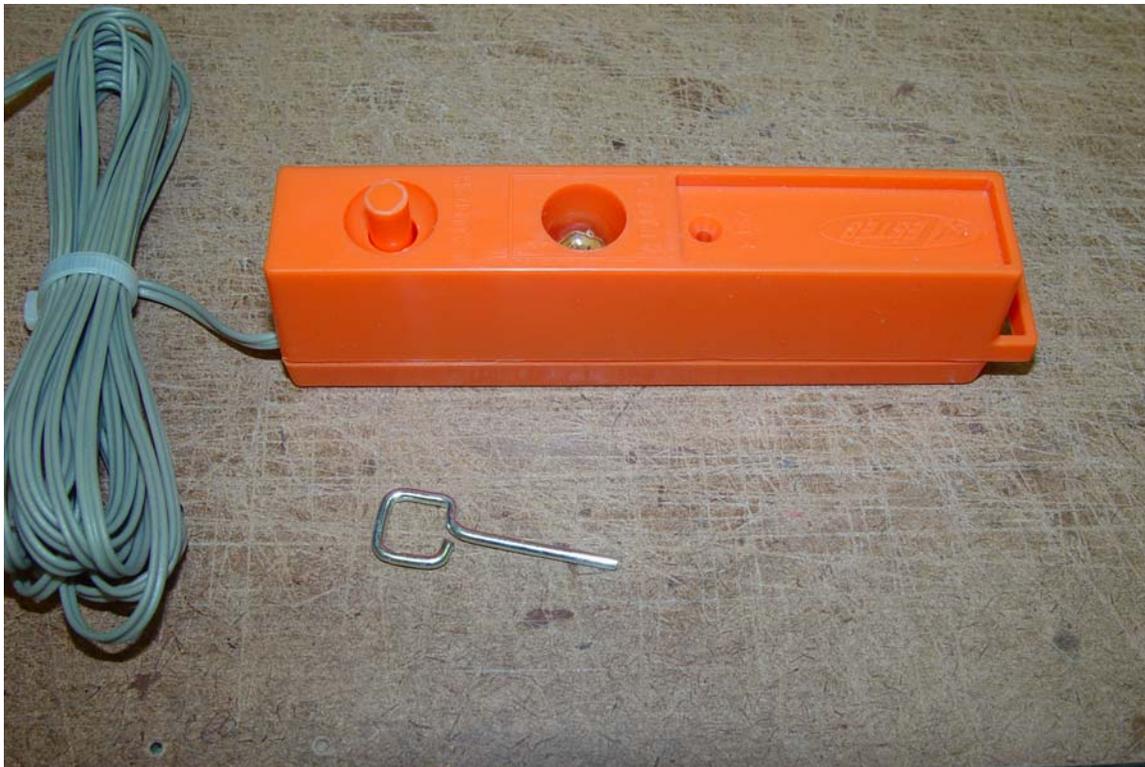


Photo 1: Estes Single Pad Launch Controller



Photo 2: Estes Electron Beam Launch Controller

The Estes Single Pad Controller

The continuity check indicator found in the Single Pad controller is a miniature incandescent bulb, and as per the kit instructions the system “is designed to use either 6 or 12 volt heavy duty lantern batteries” as the ignition source. This is a simple launch control system in that the continuity check indicator is placed in series with the battery and igniter, and provides the means to limit the current to the igniter when the Safety Key is inserted in the circuit. When the launch button is pressed, its contacts bypass the continuity indicator, thus presenting the full source voltage to the igniter; fundamentally the igniter shorts the battery until the heat generated by the igniter’s internal resistance causes the pyrogen on the igniter to flash, thereby igniting the rocket motor propellant.

Given that this product is considered safe for public use, and noting that it had been designed to work in conjunction with either 6 Volt or 12 Volt sources, it is reasonable to assume that the continuity check current drawn in either source configuration would be considered safe, and would not cause the unexpected firing of an Estes igniter. Operation of the device in conjunction with an Estes igniter in fact shows that this is the case. But what are the check currents in these cases?

To determine the check currents for an Estes igniter, the system was connected to a ProTek model 3205L variable power supply; a Fluke model 115 DMM was connected as an ammeter between the supply and the launch controller to measure the current. Figure 1 illustrates the test set up schematic.

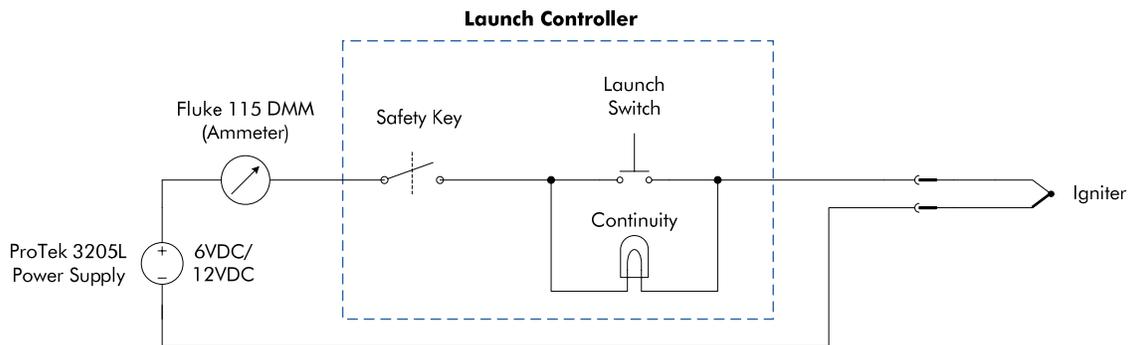


Figure 1: Estes Hand Controller Test Set Up

Photo 3 shows the check current measured in an Estes igniter when connected to this launch controller and a 6 Volt source, and Photo 4 shows the measured results for 12 Volt operation:

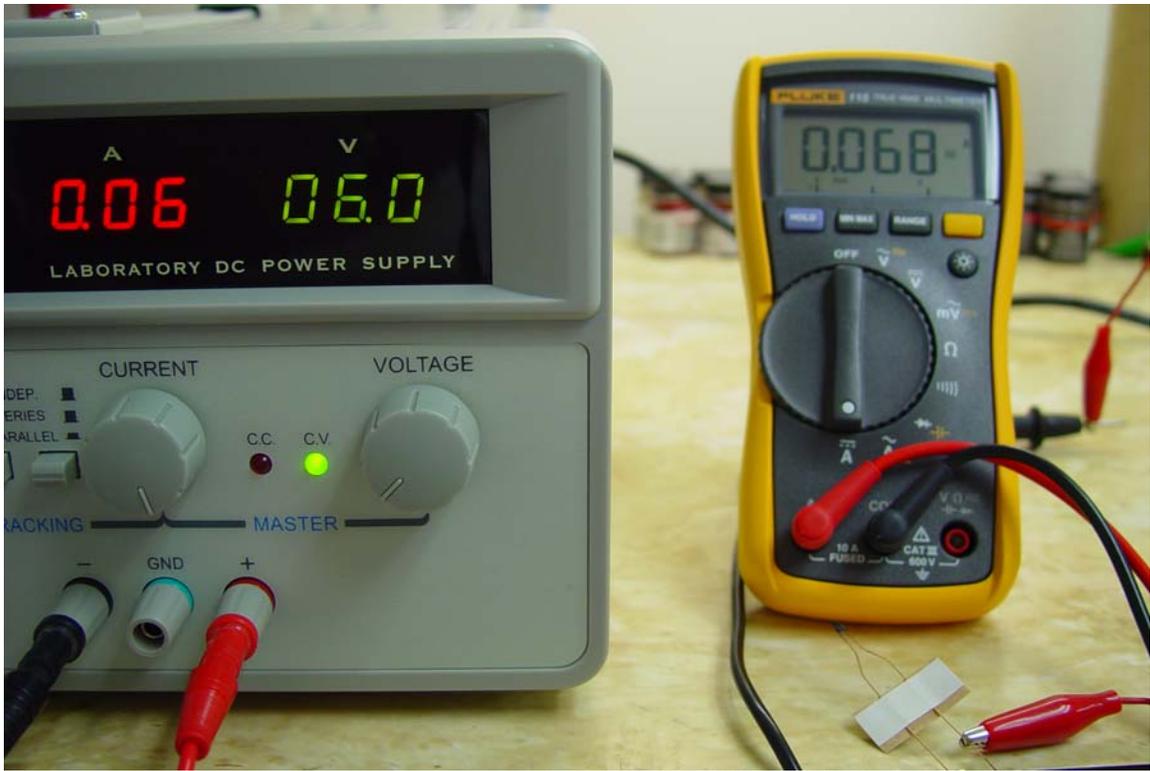


Photo 3: 6 Volt Operation – Estes Igniter

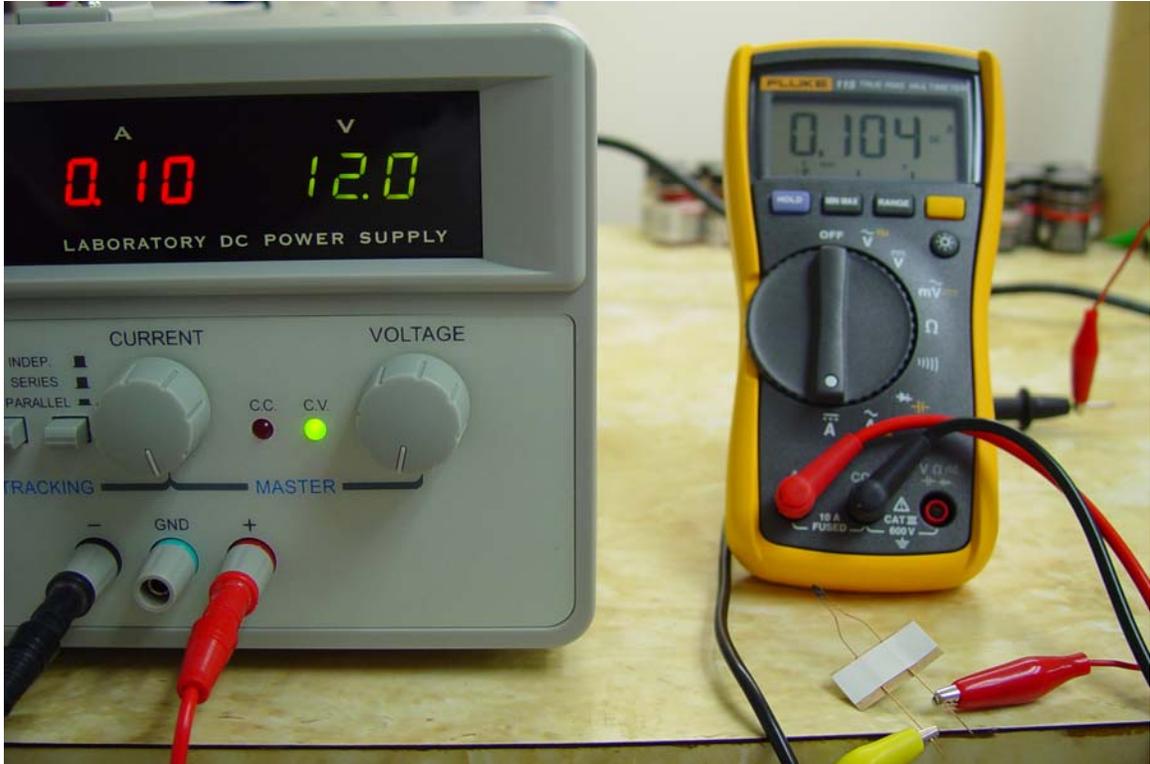


Photo 4: 12 Volt Operation – Estes Igniter

As can be seen in the 12 Volt operation case, it is possible to safely check an Estes igniter with as much as 104 mA of current.

A similar test with this Estes launch controller was performed with a Quest Q2 igniter, an AeroTech Copperhead igniter, and with an AeroTech FirstFire Jr (the Quest Q2G2 is tested later). The results are provided in the following table:

Igniter	6 Volts	12 Volts
Estes	68 mA	104 mA
Quest Q2	69 mA	105 mA
Copperhead	70 mA	105 mA
FirstFire Jr.	70 mA	108 mA

Table 1: Check Current, Single Pad Controller Bulb

The Estes Electron Beam

The incandescent check bulb in the Electron Beam is rated for 6V/3W, and so only the 6 Volt tests were performed with this unit, again respecting the Manufacturer's recommended operating conditions. The setup with an Estes igniter is shown in Photo 5:

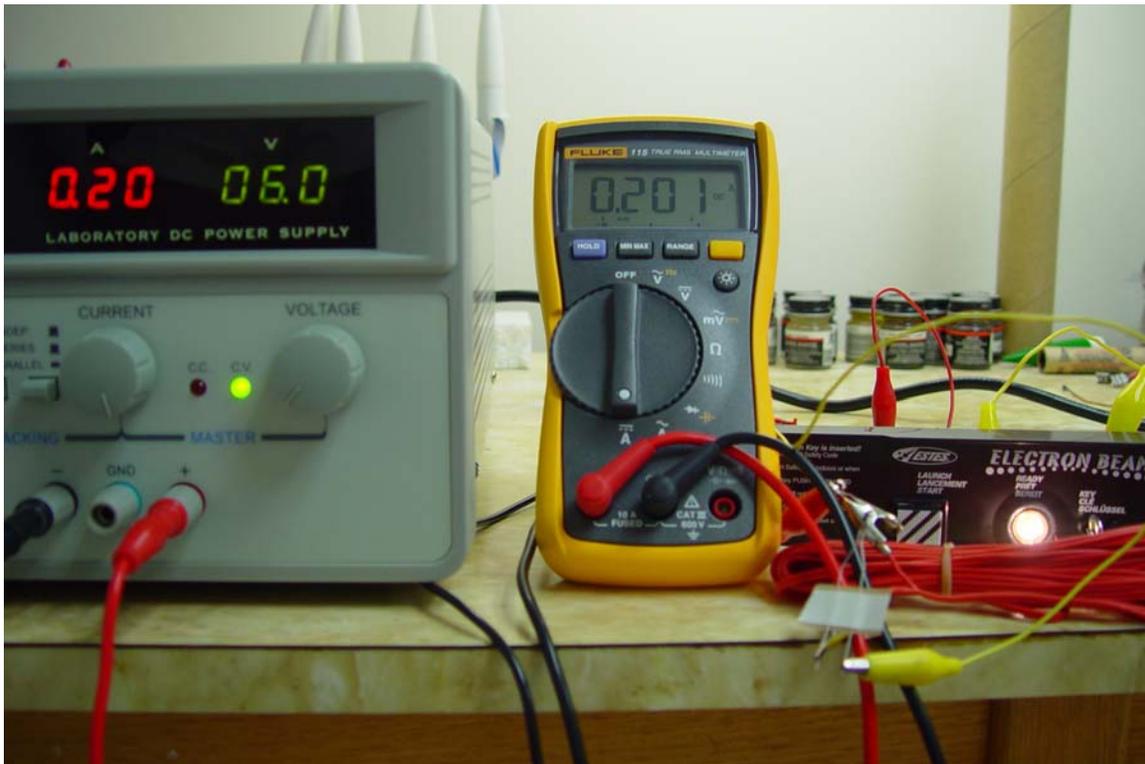


Photo 5: 6 Volt Operation – Estes Igniter

The results from this series of tests are presented in Table 2:

Igniter	6 Volts
Estes	201 mA
Quest Q2	197 mA
Copperhead	203 mA
FirstFire Jr.	204 mA

Table 2: Check Current, Electron Beam Bulb

As can be seen, the Electron Beam uses a check bulb that draws an even higher level of current than the older Single Pad controller, and again, it can be seen that a much higher level of current is still needed to enervate the igniters.

Findings

It is important to note that these values **do not** indicate the current drawn by the igniter but rather the current limited in the circuit by the impedance of the incandescent bulb once the circuit is closed by the igniter. It means that a greater current level is needed to sufficiently heat each of these igniters for any of them to reach propellant ignition temperatures.

The significance of these findings has nothing to do with the apparent compatibility that these igniters seem to have with these Estes launch controllers; each of the Estes controllers used in these tests is nothing more than a housing to hold some shorting contacts together, and either controller would fire any of these igniters so long as the source had adequate energy capacity. Rather the important point is simply that each of these igniters can be safely checked with a current of at least 200 mA; it means that many of the LED check bulb conversions that hobbyists contemplate making to their hand-held controllers can be safely made, as typically LEDs draw in the neighborhood of 20 - 25 mA when properly biased by an appropriately sized current limiting resistor. In fact such a conversion would prolong battery life, as the power dissipated by these semiconductor devices is considerably less than that of the incandescent bulb.

Determining the Maximum Safe Check Current

The continuity tests with the incandescent bulb check indicator found in common handheld controllers showed that most model rocket igniters can be safely checked at comparatively high current levels. But what is the maximum limit? At what current level does ignition become a viable risk?

We can begin to set the boundaries for this question by defining the continuity hazard event as the firing of the igniter; this would occur at the minimum current level needed to cause the pyrogen on the igniter to ignite, or flash. Note that the flashing of the pyrogen is not necessarily the same as the failure of the igniter; as Photo 7 shows, with certain igniters the pyrogen typically flashes at a temperature lower than the melting temperature of the bridge wire.

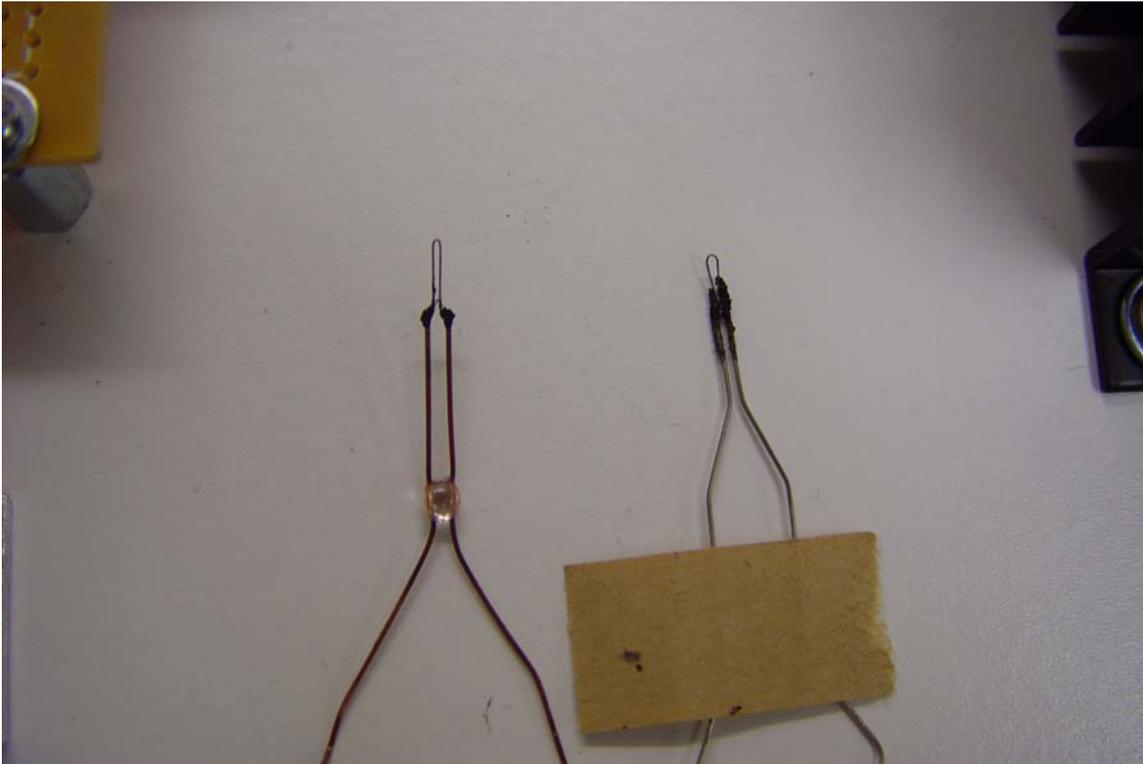


Photo 7: Flashed Igniters - Quest Q2 on the left; Estes on the right

To establish this upper current limit an electronic Igniter Test Bed was constructed, as shown in Photos 8 and 9; the Igniter Test Bed provides the means to carefully control the current passing through the test igniter. The Test Bed was powered by a ProTek 3205L Dual Power Supply, with the supply voltages set to 12 VDC. Measurements were taken with a pair of Fluke model 115 DMMs, and a Sinclair model 350 DMM. To test an igniter, current was increased in small increments and data readings were taken, until the current reached the level where the test igniter failed (i.e.: its pyrogen flashed).

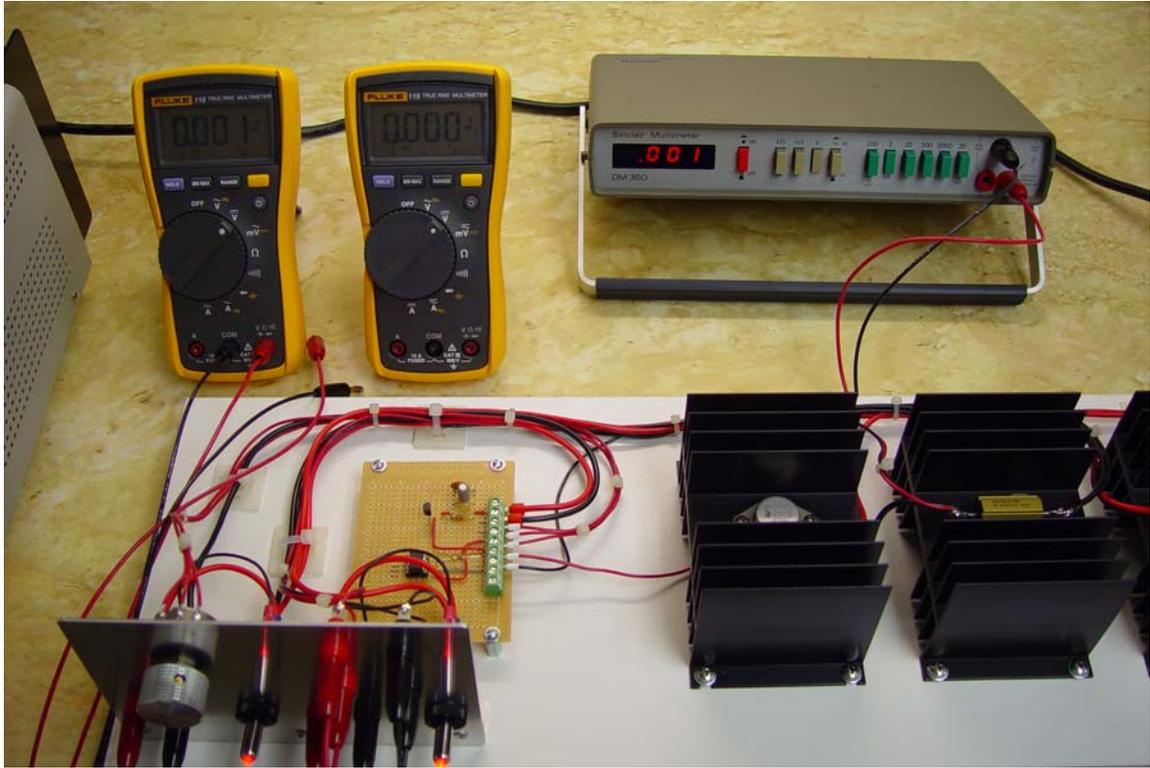


Photo 8: Igniter Test Bed

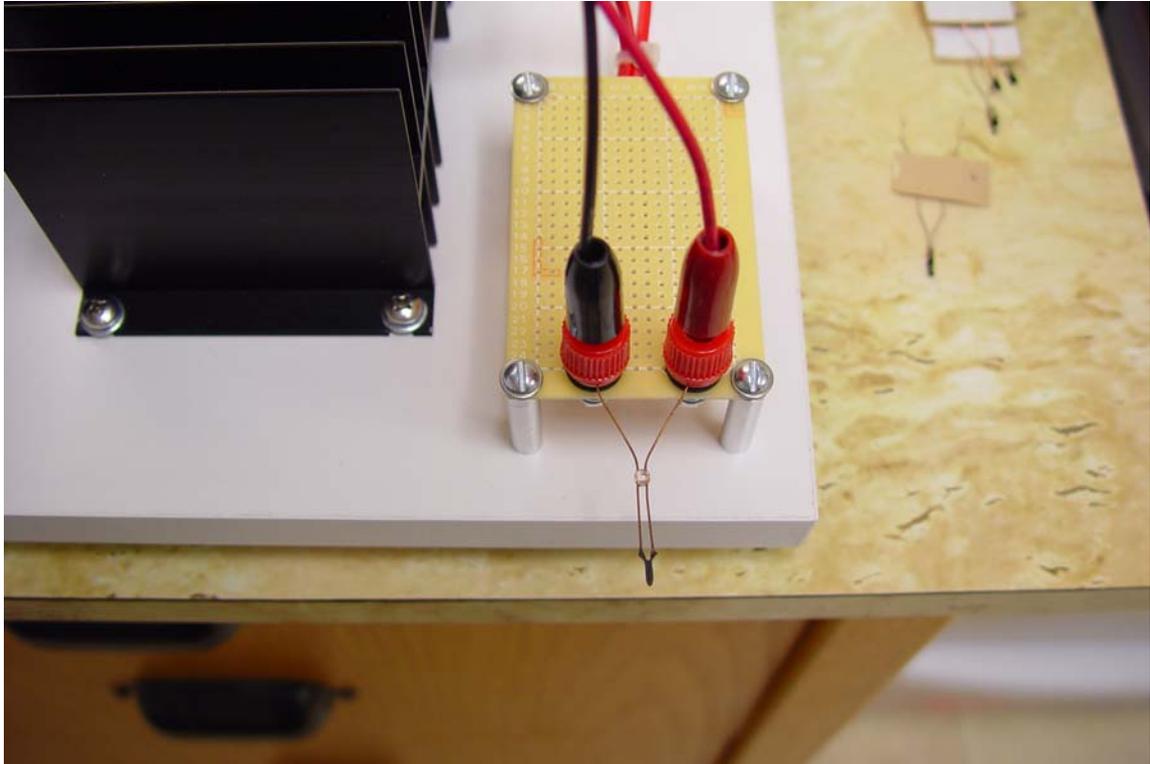


Photo 9: Igniter Connection (Quest Q2 igniter shown)

The tests were conducted in the Author's shop, where the ambient temperature is a controlled 72° Fahrenheit and the humidity is a comfortable 43%.

Two types of readings were taken for each igniter – the current passing through the igniter, and the corresponding voltage drop across the igniter. Data was collected for each igniter until the point of pyrogen flash was reached. From this data, load curves were plotted for each igniter type.

It must be noted that the data sets provided in this report are indicative, but not definitive; much larger sample sizes would be needed to provide precise characterizations of the continuity curves for each igniter type.

Findings

Estes Igniter

Four Estes igniters were selected at random and tested. The load curves were plotted and the associated chart can be found in Figure 2. The average flash resistance of the four tested igniters was 0.711 Ω , and the average flash current was found to be 1.059 A.

Of interest is the variance in the flash current – this ranged from a minimum of 0.956 A to a maximum of 1.172 A, a variance of about $\pm 10\%$ relative to the average. This compares to a burnout resistance variance of about $\pm 5\%$ relative to average, suggesting that the flash current is sensitive to other factors, such as the amount of pyrogen encapsulating the igniter tip, variances in the formulation of the pyrogen, as well as its age. In any case, it can be seen that the typical Estes igniter requires a current of about 1 A to fire.

Quest Q2 Igniter

Two Quest Q2 igniters were available at the time of the test. The load curves were plotted and the associated chart can be found in Figure 3. The average flash resistance of the two tested igniters was 1.507 Ω , and the average flash current was found to be 0.580 A.

The Quest Q2 igniters were found to have a much broader parametric variance as compared to the Estes igniter, although it must be noted that the Q2 test sample size was small, and a higher test sample population would be of benefit to the analysis. Of interest is the fact that the Q2 will fire at considerably less current than the Estes igniter.

Copperhead Igniter

As shown in Figure 4, the Copperhead igniter displays an interesting load curve, in that its characteristic is essentially linear until very near the flash point. As this point is approached, the voltage drop across the igniter begins to rise rapidly, failing to reach stasis. Eventually, the heat rise in the igniter reaches the point where the pyrogen flashes. Unlike the Estes or Quest igniters, the flashing of the pyrogen on the Copperhead usually leads to a complete failure of the igniter.

Of the four samples tested, the average resistance just prior to the flash point was found to be 0.592 Ω (2.019 Ω at the flash point), and the average firing current was found to be 1.664 A.

FirstFire Jr. Igniter

Similar to the Copperhead, the FirstFire Jr. also exhibited a very linear load characteristic until just near the flash point, as shown in Figure 5. Of the four samples tested, the average resistance just

prior to the flash point was found to be 0.744 Ω (2.001 Ω at the flash point), and the average firing current was found to be 1.768 A.

Quest Q2G2 Igniter

Of the five igniter types tested, the Quest Q2G2 was one of the most energetic; upon reaching the flash point, the igniter exhibited a strong “popping” reaction, and the flashing of the pyrogen was coincident with the complete failure of the igniter. Unlike the other igniter types, the Q2G2 is a high resistance igniter, offering a much lower firing current as will be seen. Six Q2G2 igniters were tested, and the associated load curves are shown in Figure 6.

The average firing current of the six samples was 0.271 A, significantly lower than any of the other igniters tested in this study. It must be noted though that two of the six igniters fired at 0.217 A and 0.219 A, very near the load current presented by the incandescent continuity check bulb used in the Estes Electron Beam launch controller. As a safety measure the Q2G2 should not be used in conjunction with the Electron Beam without modifying the controller to incorporate a lower current check function.

The average resistance of the six igniters at the flash point was 3.986 Ω , although it must be noted that four of the six igniters exhibited an average flash resistance of 3.463 Ω .

What the testing shows is that the Q2G2 cannot be reliably used in conjunction with an Estes Electron Beam controller without risking unplanned ignition events; however it will comfortably pass the current of an LED check indicator without hazard, this typically being in the range of 20-25 mA.

Figure 2: Estes Igniter Load Curves

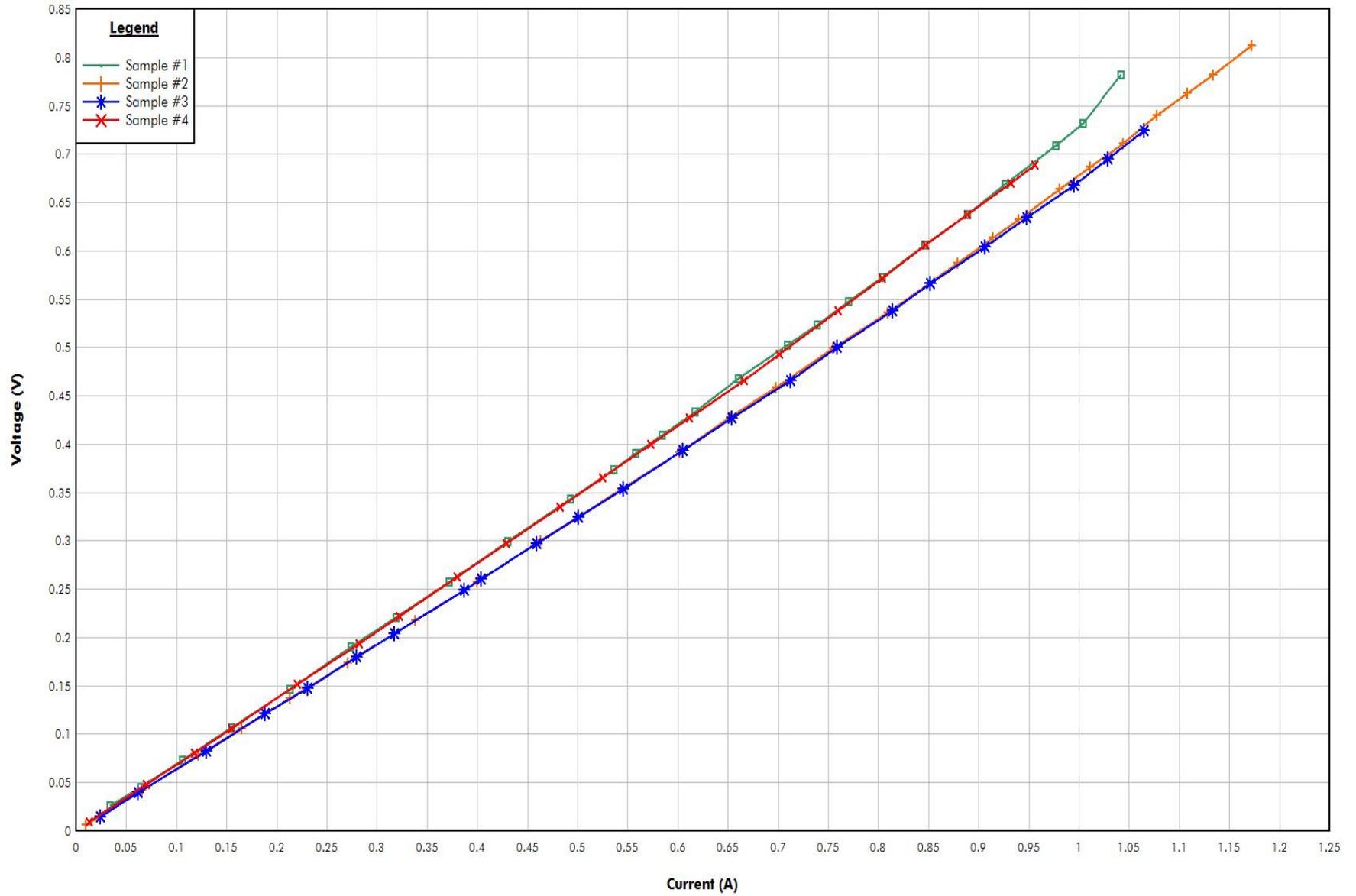


Figure 3: Quest Q2 Igniter Load Curves

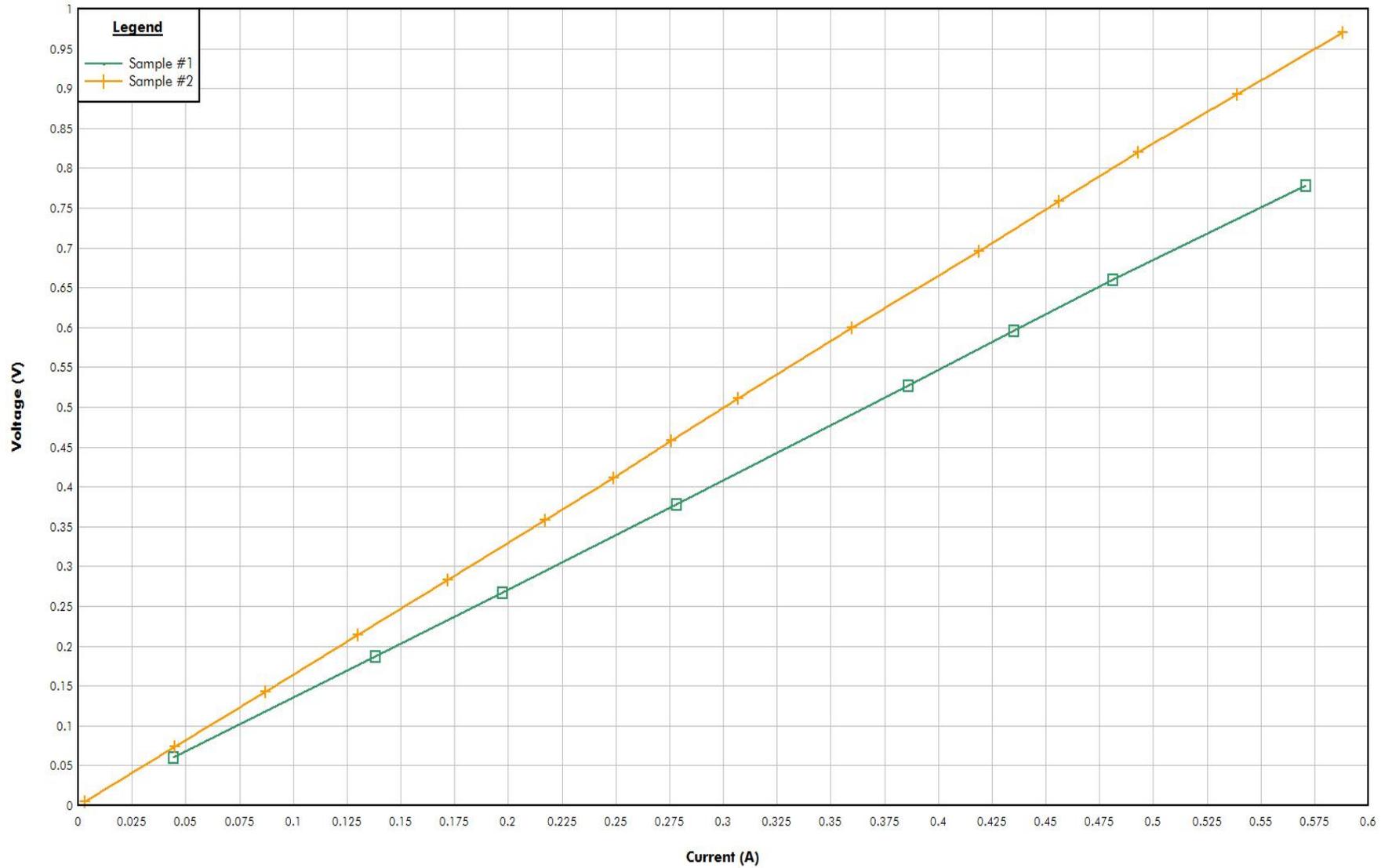


Figure 4: Copperhead Igniter Load Curves

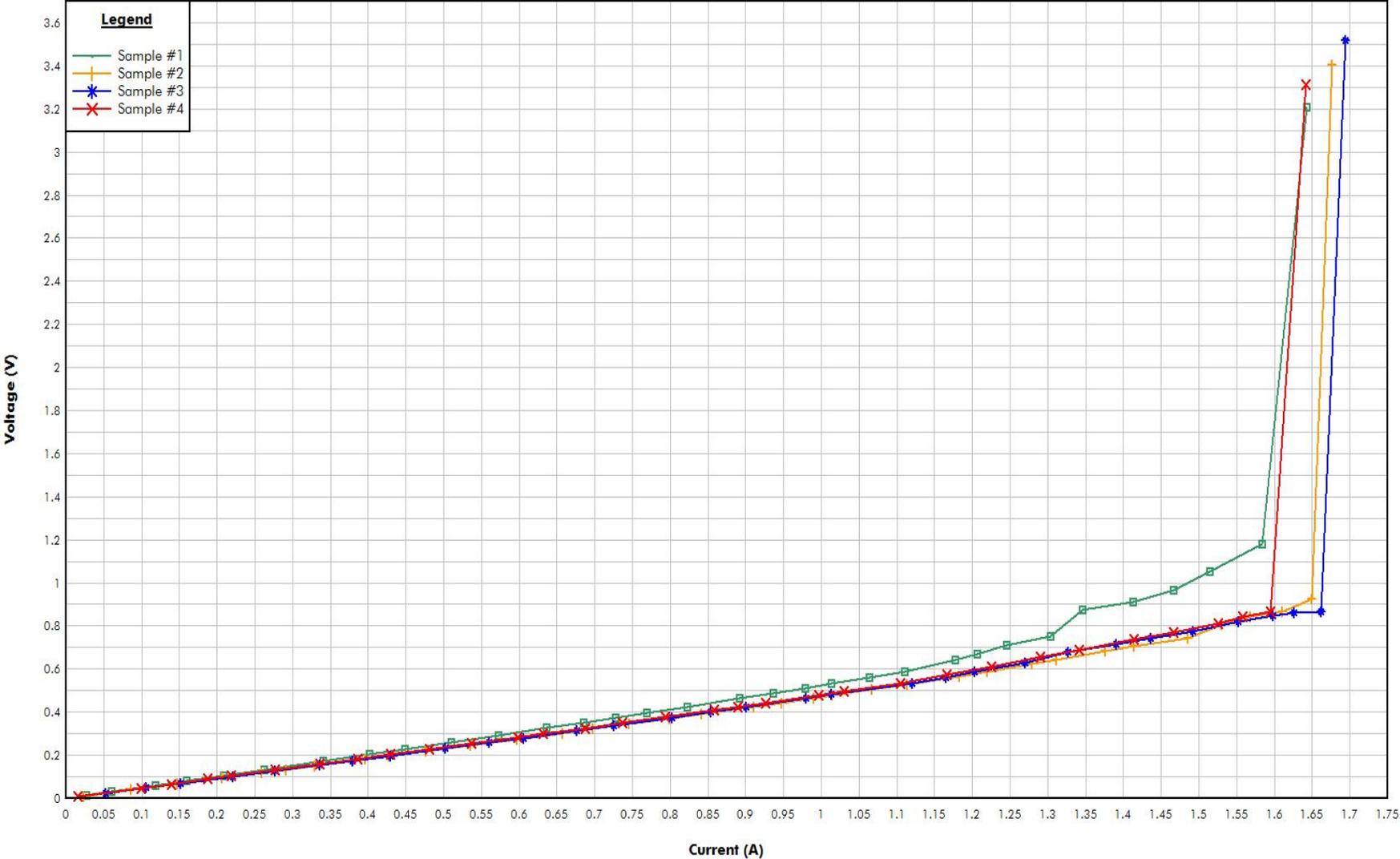


Figure 5: FirstFire Jr. Igniter Load Curves

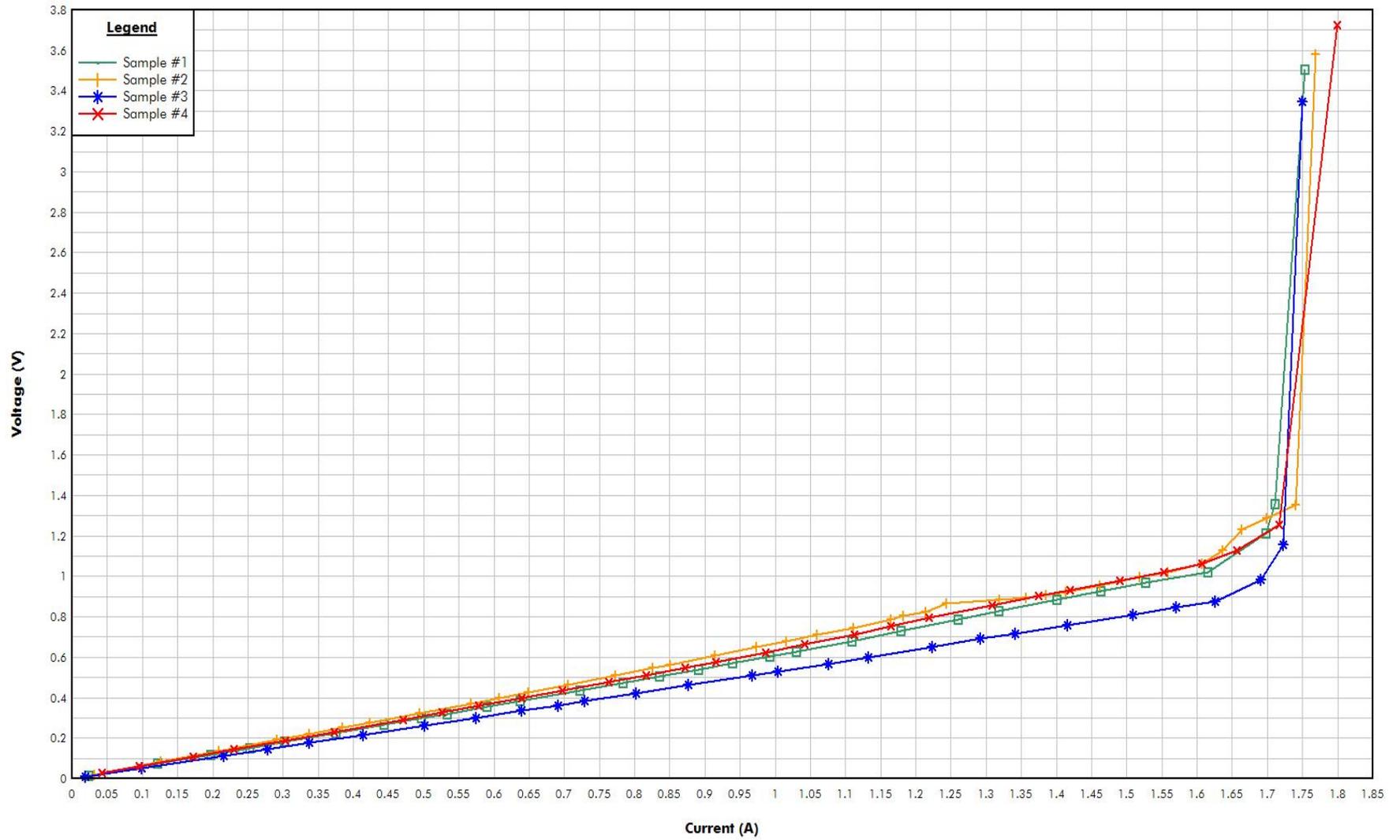
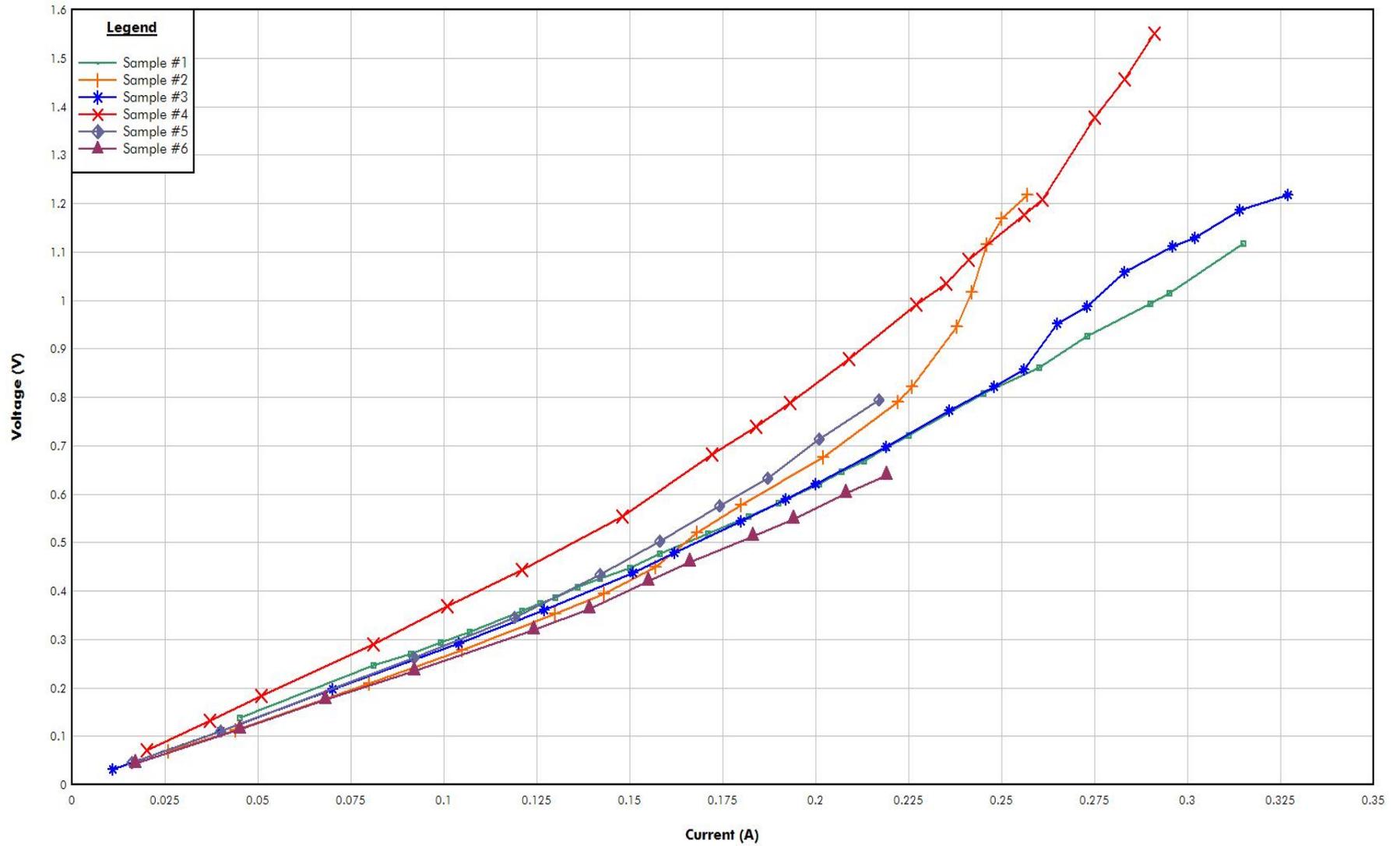


Figure 6: Quest Q2G2 Igniter Load Curves



Conclusions

Testing showed that with the *exception* of the Quest Q2G2, each of the igniter types can readily handle a continuity check current of at least 200 mA without posing a safety risk. In fact, a higher check current could be safely sustained by these igniter types so long as it kept within a safe derated limit of the firing current of the chosen igniter. Designing a continuity check circuit for a system intended to fire these igniter types would have to respect the lower firing current of the Quest Q2.

Testing of the Quest Q2G2 showed that its firing current is much lower, in some cases being just marginally more than 200 mA. This strongly suggests that this igniter should not be used with a standard Estes Electron Beam controller, as the firing current is in the same range as the load presented by the Electron Beam's incandescent check bulb.

A launch control system intended to safely fire all five igniter types would have to respect the lower firing current of the Quest Q2G2, and should limit the check current to less than 100 mA. Low current indication devices, such as LEDs, would make suitable choices for the checking function.

Apart from safety, an additional benefit attained by minimizing continuity check current levels is the extension of battery life, especially important in the single handheld controllers, which often operate from 4 AA cells. On the other hand, lowering the check current to microampere levels increases the probability of false check indications, as the typical launch environment offers multiple current leakage paths for such a high impedance design.

Continuity Circuit Design Considerations

In launch systems employing electronic continuity check circuitry, greater flexibility is available to the circuit designer to arrive at a strong visible continuity indication at a low, safe, check current. For a typical Estes hand controller, the incandescent check bulb can be replaced with a high brightness LED and a series connected current limiting resistor; making this modification lowers the check current to the active forward bias current of the LED. Figure 7 schematically illustrates this modification.

Typical LEDs draw between 20-25 mA at between 1.8 V - 2.0 V, so for hand controllers operating at 6 VDC a standard 180 Ω or 220 Ω , 1/2 Watt resistor would work fine as the current limiting appliance. For 12 Volt operation, the resistor would need to be a larger value, such as 470 Ω or 510 Ω , 1/2 W.

Introducing a transistor into the check circuit as the current control appliance provides the means to dramatically lower the continuity check current; typically the transistor Base current is used as the check current, and the LED is placed as the load in the Collector circuit. When the transistor is biased as a switch (saturated), the check current can be limited to just a few milliamps. Figure 8 illustrates just one example of a transistorized check circuit, and is something that could be fitted to a single handheld launch controller. This particular circuit delivers a check current of about 2.5 mA to the igniter, making it safe for essentially all igniters. For 12 Volt operation, the resistor values would need to be doubled to maintain the same check current level.

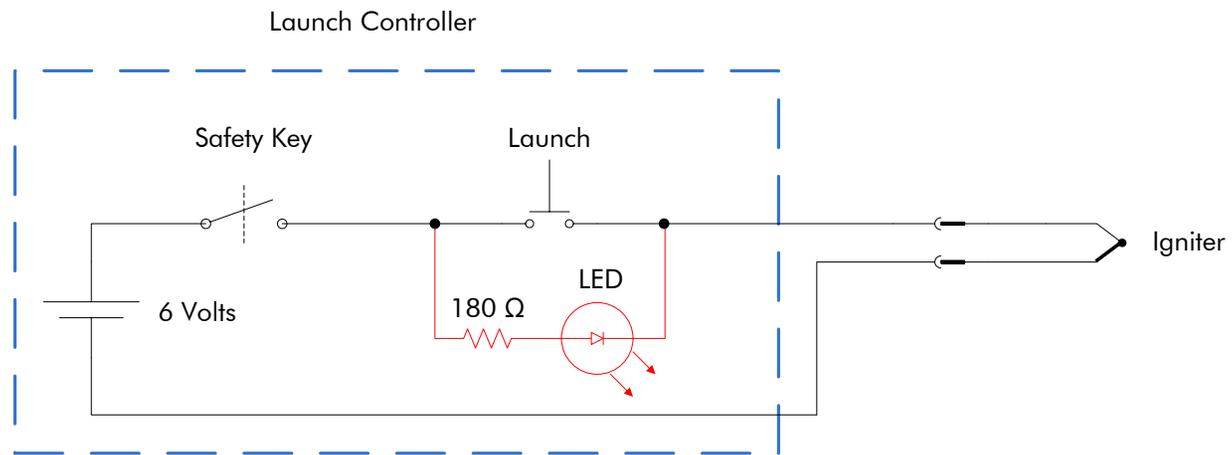


Figure 7: LED Continuity Check Indicator

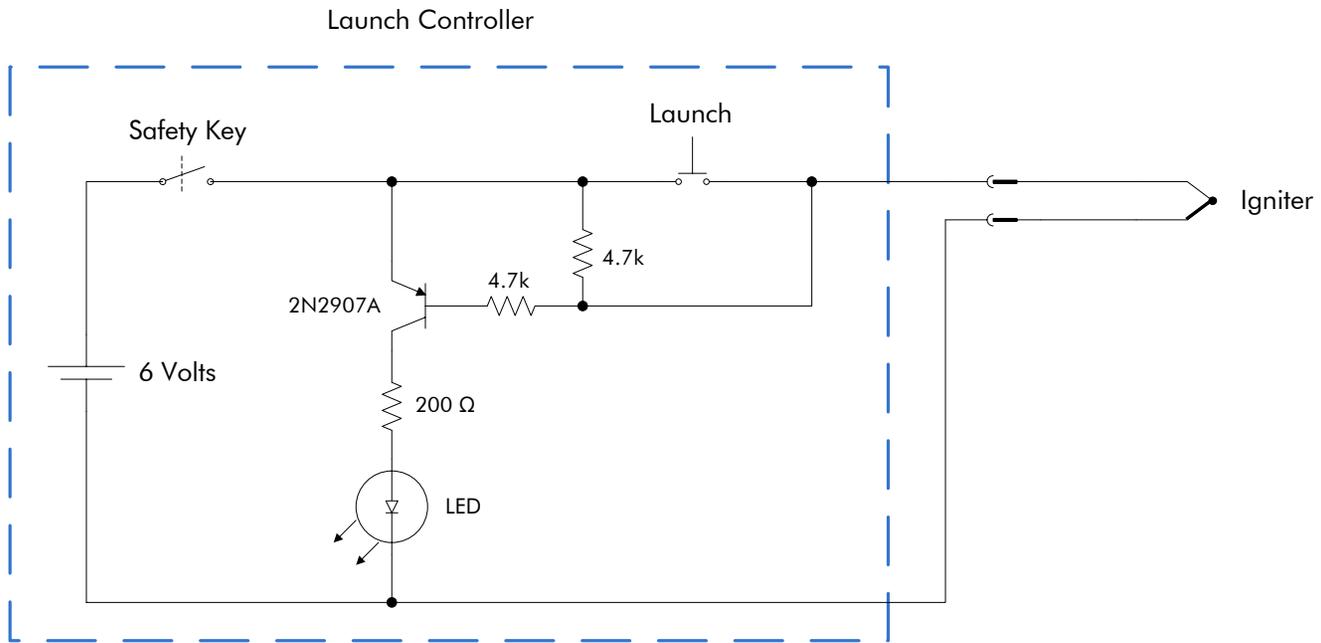


Figure 8: Transistorized Continuity Check Circuit