An earlier version appeared in *Fireworks Business*, No. 207, 2001.

Electric Matches: Ramp Firing Current

K. L. and B. J. Kosanke

Introduction

A major study of electric match sensitiveness was recently completed.[1] This article presents the results of a test to reveal aspects of the firing characteristics for the same collection of 10 electric match types as in the previous articles.

Ramp Firing Current Test

The ramp firing current test was selected because it was thought to be able to reveal much about an electric match's performance in a relatively small number of trials (typically about 25 match firings). In these tests, electric matches are subjected to a rapidly increasing electric current while being monitored to detect the moment the match ignites (as evidenced by the production of light). The setup for these tests is shown in Figure 1. The ramp current power supply provides the firing current; however, that current starts at zero and increases progressively. Further, the rate of increase is adjustable (i.e., the current can be set to rise relatively slowly, rise rapidly, or anywhere between). The current is monitored as a voltage drop across an NBS calibrated resistor, using one channel (A) of a digital oscilloscope. The electric match under test is located inside a light-tight enclosure along with a photo detector. When the match fires, the light produced is sensed by the photo detector and, after conditioning, the signal is directed to the second oscilloscope channel (B).

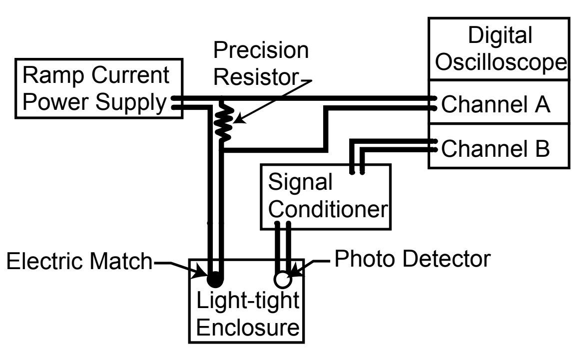

Figure 1. The configuration of equipment used to make the ramp current measurements.

Figure 2 presents data typical of that produced during the ramp firing current test of a single electric match. The electric match firing current starts to increase from zero at time t_0. At time t_1 (18.9 ms) the photo detector firsts senses light from the firing electric match. (The photo detector is adjusted to be extremely sensitive to light, such that it rapidly saturates and holds a constant value as the electric match burns. Also, to make the two traces in Figure 2 easier to see, the trace of the photo detector was shifted downward slightly.) At the time of first light output, the firing current I_f has risen to 418 mA. The firing current continues to rise reaching approximately 650 mA at time t_2 (29.9 ms), when the bridgewire fuses (melts) to open the circuit, thus dropping the electric current back to zero. (In Figure 2, the minor fluctuations seen in the oscilloscope traces are background noise mostly pick-up from a nearby commercial radio transmission tower.)

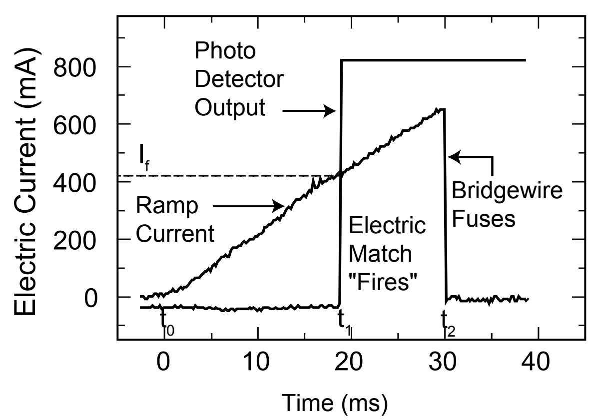

Figure 2. Typical ramp firing current test data from a firing electric match (Daveyfire A/N 28 B), showing both firing current and photo detector output.

In Figure 2, the time of electric match firing is equated with the first light produced by the match. Actually, the ignition of the electric match composition adjacent to the bridgewire must occur slightly earlier. For gas producing compositions, the time between the ignition and external light production is relatively small. Previous testing by the authors suggests that the interval for one type of gas producing composition is no more than a small fraction of a millisecond. One electric match manufacturer suggests that the time between ignition and light production may be as much as 2 ms for some gas producing compositions.[2] However, for mostly gasless compositions, the time interval could be considerably greater still.

The ramp firing current tests for each electric match type were repeated a number of times, using a collection of different rates of current increase. For each test, the firing time t_1 (first light production) and the current flowing at that time I_f were recorded. Figure 3 (for Daveyfire A/N 28 B matches) is typical of the data produced. Note that under the condition of a rapid ramp current increase, the minimum firing time of approximately 15 ms is produced with a ramp firing current of approximately 500 mA. At the other extreme, using more slowly increasing currents, when the ramp firing currents were as low as approximately 250 mA, a wide range of firing times was produced. Further, under these conditions, some match tips failed to ignite (shown in Figure 3 as open data points and are arbitrarily plotted at 500 ms). The scatter of data points about the curve plotted in Figure 3 is thought to reflect a combination of the normally expected uncertainties in the ignition process, plus minor manufacturing variations between the electric matches. This amount of scatter is fairly typical of that seen for most other electric match types tested.

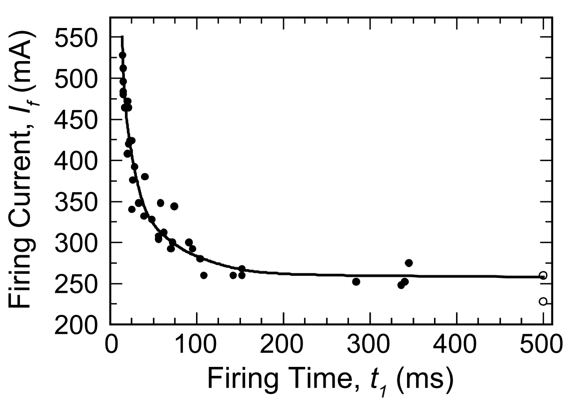

Figure 3. Ramp firing current data for Daveyfire A/N 28 B electric matches.

For some electric match types and under some conditions, the bridgewire fuses before the match fires (i.e., before light is emitted). The types of electric matches experiencing fusing before firing and the conditions under which this occurred are discussed briefly below; see Table 1 and its notes. When fuse-before-firing occurred, the firing current I_f was taken to be what was flowing at the moment of fusing, whereas the firing time continues to be the time to the first light output, t_1.

Results

The results of the ramp firing current tests are summarized in Table 1. The approximate minimum firing time gives some indication of the rapidity with which the electric match types fire. In actual application, with approximately constant applied currents, the firings will occur more rapidly than in these tests. However, even if typical firing times were as long as those listed in Table 1, they would all be rapid enough to be of no concern in designing a fireworks display. Of somewhat more interest is the corresponding ramp current for these firing times. These give an indication of the minimum reliable firing current for the electric matches. Note that for the normal sensitiveness electric matches, these currents all range from 500 to 600 mA. In contrast, the low sensitiveness electric matches require greater firing current. For example, the Martinez Specialty Titan matches require about 50% more current, and the Luna Tech Flash matches require at least 300% more current, than the normal sensitiveness matches. The ramp firing data for a collection of Daveyfire A/N 28 F matches is presented in Figure 4. The scatter in the data is such that no reliable estimate could be made for the minimum firing time and its corresponding ramp firing current; however, it is apparent that it too requires significantly more firing current than electric matches of normal sensitiveness.

An estimate of the average minimum ramp current resulting in firing of each type electric match is also presented in Table 1. While this estimate is related to no-fire current, it is somewhat greater as a result of the statistical spread (uncertainty) found in the data. The data for normal sensitiveness electric matches ranged from about 200 to 375 mA, suggesting that no-fire currents for these electric matches probably are in the range of 150 to 300 mA.

Table 1. Ramp Current Firing Results.

Supplier Name	Product Designation	Minimum Firing Time / Current[a] (ms)	(mA)	Ave. Min. Firing Current[b]	Statistical Spread[c]	First Light Versus Fusing Time[d]	Other Notes
Aero Pyro		14	600	325	Slightly Broader	Before	
Daveyfire	A/N 28 B	15	500	250	Average	Before	
	A/N 28 BR	15	500	250	Average	Before	
	A/N 28 F	(e)	(e)	(e)	Much Broader	Slightly After (f)	
Luna Tech	BGZD	27	600	300	Average	Variable (g)	
	Flash	35	1900	1250	Slightly Broader	After	(h)
	OXRAL	19	600	200	Slightly Narrower	Before	
Martinez Specialties	E-Max	17	500	300	Average	Before	
	E-Max Mini	15	600	375	Slightly Broader	Before	
	Titan	28	900	450	Much Narrower	Near Same	(h)

a) Minimum firing times and the corresponding currents are approximations and only apply for the conditions of these tests. These values were determined subjectively by examination of the plotted results for each electric match type in the area where the curves (like that shown as Figure 3) become near vertical. (Firing times are actual times to first light production.) It was felt appropriate to report those ramp-firing currents to only the nearest 100 mA. These currents are not the same as “All-Fire” currents for the electric matches.

b) Average minimum firing currents are approximations and only apply for the conditions of these tests. These values were determined subjectively by examination of the plotted results for each electric match type in the area where the curves (like that shown as Figure 3) become near horizontal. It was felt appropriate to report those ramp-firing currents to only the nearest 25 mA. These currents are not the same as “no-fire” currents for the electric matches.

c) The statistical spread in the data is a subjective estimate of the degree to which the collection of each type electric match produced consistent ramp firing results. This is an estimate of how close on average the data points fell to the curve fit line. See Figure 3 for example, which is defined as having an average data spread.

d) “Before” indicates that the electric match produced light before its bridgewire fused, as in Figure 2. “After” indicates that the electric match produced light after the bridgewire fused, as in Figure 5.

e) These results varied so widely (See Figure 4) that it was not felt to be appropriate to attempt to assign values.

f) At higher ramp currents, light production occurred after the bridgewire fused, whereas at somewhat lesser currents the firing and fusing were essentially simultaneous.

g) Two production lots of Luna Tech’s BGZD electric matches were used in this study and insufficient care was taken to identify exactly which matches were used in these ramp-current tests. While the firing times and currents seemed to be consistent between the two lots, the fusing times seemed to be different. Most electric matches produced light before their bridgewires fused; others fired at about the same time the bridgewire fused. The reason for the difference was not discovered.

h) Occasionally when using minimal firing current, there was an incomplete ignition of the electric match composition, with only the tip igniting (Luna Tech) or one side igniting (Martinez Specialty). See Figure 6.

Perhaps the most interesting ramp current results are the statistical spreads observed during the testing. For the purposes of this study, the spread demonstrated in Figure 3 for the Daveyfire A/N 28 B electric matches was considered to be typical (average). Note in Table 1 that most electric matches were designated as being average, or only slightly narrower or broader than average. However, one electric match type, Martinez Specialty Titan matches, had a statistical spread significantly narrower than average, and one electric match type, Daveyfire A/N 28 F matches, had a statistical spread significantly broader than average. (See Figure 4). As in Figure 3, the two data points shown as open dots in Figure 4 were instances where the electric matches did not ignite and are arbitrarily plotted with a firing time of 500 ms. It would seem that matches with lesser spreads might prove to be more reliable (predictable) in their performance, while those with wider spreads would be less predictable in their performance. This could possibly translate to their being less reliable in series firing of many matches. However, this has not been proven, and it is not known the extent to which such differences would be noticeable in actual use.

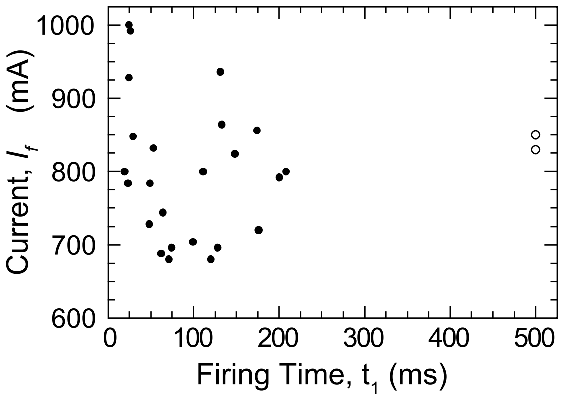

Figure 4. Ramp firing current data for Daveyfire A/N 28 F electric matches.

In those cases when electric matches fired (produced light) significantly after their bridgewires fused, there is a potential concern that under some circumstances, they could conceivably fail to fire at all, especially if fired in a series circuit with many electric matches. However, this has not been confirmed by testing, and it may merely be the result of the electric matches burning internally prior to their external light emission. However, for two of the more rapidly rising ramp currents used in the testing of Luna Tech Flash Matches, it was observed that the bridgewires fused without successfully producing an ignition of the electric match. The reason for this was not determined. (The fire after fuse question will be considered further in the next article of this series.)

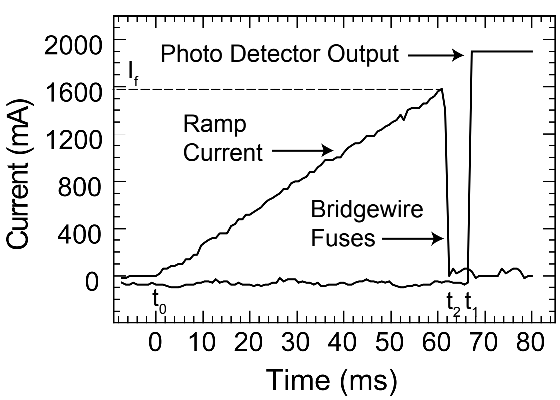

Figure 5. An example of the ramp current test data when the bridgewire fuses shortly before there is light output (Luna Tech Flash match).

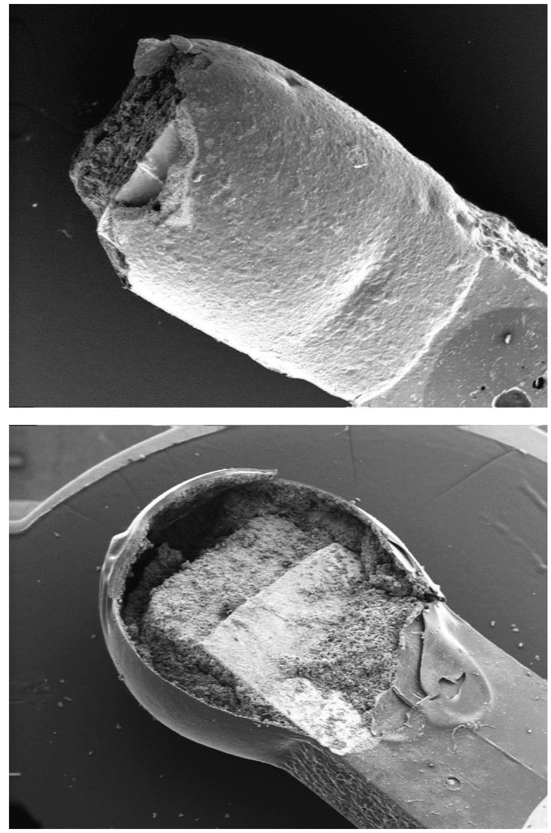

Figure 6. Electron micrographs of a Luna Tech (upper) and a Martinez Specialty (lower) electric match with incomplete ignition.

Acknowledgments

The authors gratefully acknowledge that the four electric match suppliers provided samples of their products, at no cost, for testing. Further, the American Pyrotechnic Association provided a grant to help cover some costs of this study. Finally, the authors appreciate the technical comments provided by L. Weinman, M. Williams and P. Martinez on an earlier draft of this article. Note that while many of the company and product names are apparently registered trademarks, they have not been specifically identified as such in this article.

References

1) K. L. and B. J. Kosanke, "Studies of Electric Match Sensitiveness", *Journal of Pyrotechnics*, No. 15, 2000; also appearing in this collection of articles.

2) P. Martinez, private communication, 2001.