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Measurements of Glitter Flash Delay, Size and Duration

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ABSTRACT

A brief series of measurements were made on the flashes produced by a simple glitter formulation. In part this was done as a test of one theory for the chemistry of glitter. However, this was also done to produce some intrinsically interesting data that have not been previously reported. It was observed that both increasing the percentage of aluminum in the formulation and decreasing the particle size of the aluminum, decreased the delay time before the appearance of the glitter flashes. Both the size and duration of glitter flashes increased for flashes with greater delay. It was also observed that there was a rapid increase in temperature just prior to the onset of the flash event.

Introduction

Glitter effects are one of the most attractive in fireworks. Several theories have been proposed for its chemistry and are discussed in a review article by one of the authors.[1] One reason for conducting the work reported in this article was to collect some information to test one of those theories; however the thorough discussion of the theory is left to the review article. For the most part, this article simply presents the results of the study without an attempt to interpret them.

Experimental

To keep the chemistry simple and make the results unambiguous, a fairly simple glitter formulation was used. The basic formulation is given in Table 1 and is similar to one suggested by Fish.[2]

Table 1. Basic Test Glitter Star Formulation.

Ingredient	Parts
Potassium nitrate	54
Charcoal (air float)	11
Sulfur	18
Sodium bicarbonate	8
Dextrin	4
Aluminum[(a)]	[(a)]

(a) Various types and amounts of aluminum were used.

The mixture of ingredients without aluminum was prepared in sufficient quantity to make many small batches of test stars. Each batch of composition was dampened with 10% distilled water. The stars were made as cylinders ¼ inch (6 mm) in diameter and approximately ½ inch (12 mm) in length using a compacting force of approximately 50 psi. A relatively small diameter was chosen for the test stars to limit the number of glitter flashes produced per unit time, which facilitated their observation and counting. On average approximately 550 glitter flashes were observed for each test star burned.

One series of test stars was made with a spherical atomized aluminum having an average particle size of approximately 12 microns (Alcoa S-10). For these stars, the percentage of aluminum in the composition was 5, 7 or 10 percent. For another series of test stars, the aluminum was held constant at 7 percent, but the average particle size of the atomized aluminum was 3, 12 or 30 microns (using Valimet H3, Alcoa S-10 and Valimet H30, respectively).

The test stars were burned under one of two conditions. In some instances they were burned at a height of approximately 11 feet (3.3 m) and the dross droplets allowed to fall vertically under the influence of gravity. However, in most cases the test stars were burned in a horizontal air stream moving at approximately 60 ft/s (18 m/s), causing the dross droplets to be carried down wind. The air stream was allowed to diverge shortly after the point where the star was burned. Thus the wind speed gradually fell to an average of approximately 35 ft/s (11 m/s) over the range of the observed glitter flashes. The air temperature was relatively cool, approximately 45 °F (7 °C) for the gravity driven tests and 35 °F (2 °C) for the wind driven tests.

Under either test condition (gravity or wind) glitter flashes occurring at greater distances from the test star correspond to greater delay times. However, for simplicity in reporting the results of this study, for the most part, only delays in terms of distances are given. For a given delay distance, this is the distance from the burning star to the center of a one-foot (0.3-m) interval over which observations were made. For example, flash events reported for a down wind distance of 4 feet (1.3 m) are those occurring between 3.5 and 4.5 feet (1.1 and 1.4 m) from the star.

The percent of flashes versus down wind distance curves were produced using a cubic spline function. This method was chosen because the level of precision of the data is not great and because the intrinsic shape of the curves is unknown. Accordingly, it is not intended to imply that any undulations seen in the graphs are real.

Results

The effect of varying aluminum concentration (5, 7, and 10 percent) is shown in Figure 1. For this formulation, increasing aluminum concentration decreased the typical delay of the glitter flashes. This is seen in both the downwind distance at which the maximum number of flashes occurs and in the average distance traveled before the flash reaction, see Table 2. The effect of varying the particle size of the atomized aluminum (3, 12 and 30 micron) is also shown in Figure 2. For this test, increasing particle size increased the typical delay of the glitter flashes. It is possible to interpret both sets of data (effects of concentration and particle size) as glitter delay increasing as the result of decreasing the total surface area of aluminum in the composition.

Table 2. Summary of Approximate Glitter Flash Distance Information for Variations in Formulation.

Aluminum Variation	Glitter Flash Distance Peak (ft.)	Average (ft.)
5%	5.1	7.1
7%	4.3	6.7
10%	3.8	5.8
3 µ	2.9	5.0
12 µ	4.3	6.7
30 µ	6.0	7.3

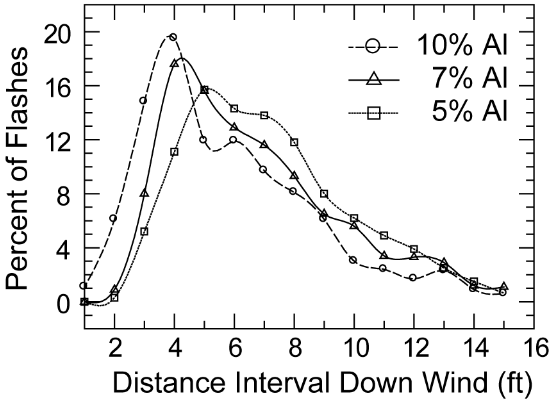

Figure 1. Graph of the percent of glitter flashes occurring as a function of downwind distance, for various aluminum concentrations.

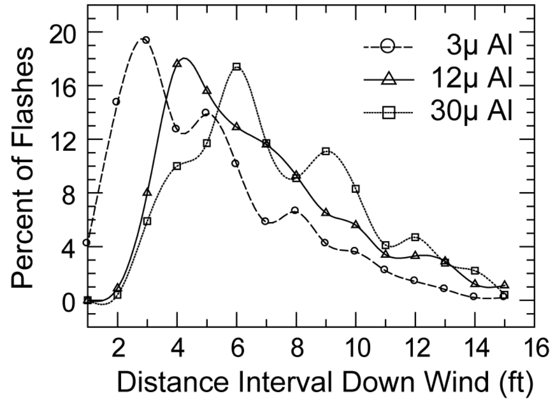

Figure 2. Graph of the percent of glitter flashes occurring as a function of downwind distance, for various aluminum particle sizes.

Although not the primary purpose of these measurements, some other interesting observations were made. Considering the likely dross droplet velocities in the air stream, it is possible to estimate the time elapsed before the glitter flashes occur, based on the distance they traveled. In this case it was simply assumed that droplet speed during the first foot traveled was half that of the air stream. Thereafter, droplet speed was assumed to equal that of the air stream at each point. Accordingly, for the formulations tested, it is estimated that the peak number of glitter flashes are typically occurring roughly 0.1 second after leaving the burning star. Similarly the average time to the occurrence of the glitter flashes is roughly 0.2 second.

There appears to be a relationship between the time interval before flash occurrence and the physical size and duration of the flash. The size relationship is demonstrated in Figure 3, which presents 1/60 second negative black and white images of typical glitter flashes. Here the flashes are organized by distance from the burning star (using 7 percent of the 12 micron aluminum) in a gravity driven test. (As in the air stream driven case, there is a functional relationship between increasing distance and increasing time.) In Figure 3, the actual size of each image area is approximately 10 inches (0.25 m); thus the size of the flashes ranges from about 1 inch (25 mm) for those flashes occurring soon, to about 3 inches (75 mm) for those flashes occurring later.

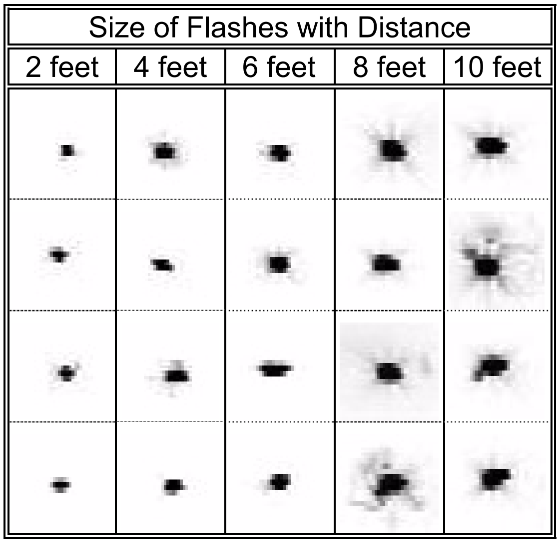

Figure 3. Examples of typical glitter flashes as a function of distance from the star (negative black and white images).

There also appears to be a correlation between the observed duration of the glitter flashes and the distance from the burning star (delay time). This was established by observing the number of successive video fields (each 1/60 second) during which individual flashes were visible. For each down wind distance from test stars, 25 observations of the duration of flashes were made, and an average duration was calculated. These data are listed in Table 3 and graphed in Figure 4. Using a statistical model wherein a glitter flash can initiate at any time during the 1/60 second image interval, it can be estimated that

$$D = \frac{N-1}{60}$$

where D is the approximate average flash duration and N is the average number of video fields over which glitter flashes are seen. Using this relationship, average flash durations were calculated as a function of distance in the air stream from the burning star. These flash durations ranged from approximately 3 to 13 ms (Table 3).

Table 3. Average Glitter Flash Duration as a Function of Down Wind Distance.

Down Wind Distance (ft)	Ave. No. Fields	Ave. Flash Duration (ms)(a)
4	1.20	2.8
6	1.20	3.8
8	1.32	5.5
10	1.48	7.5
12	1.52	10.2
14	1.86	13.3

(a) Values were calculated using the curve fitted flash durations from Figure 4.

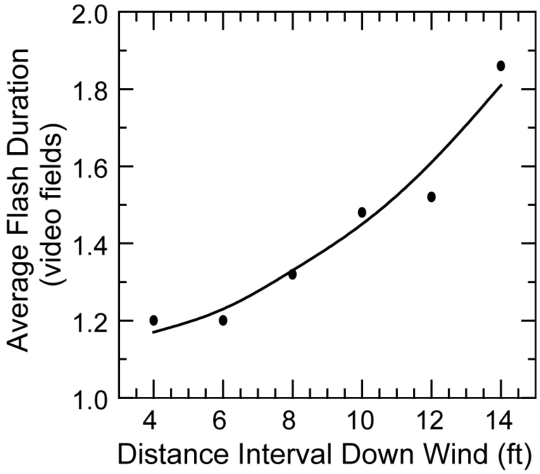

Figure 4. Graph of the average number of video fields for glitter flashes as a function of distance.

Figure 5 is a composite negative black and white image of a glitter dross droplet traveling to the left, until the time when it is just beginning to flash. The figure is composed of a series of individual 1/60 second (17 ms) video fields; however, to help identify the passage of time and the progress of the droplet, every other video image was omitted. Note that the intensity of the emitted light is roughly constant until about the last three images, where its intensity (darkness) noticeably increases. Figure 6 is a graph of this dross droplet's image intensity prior to the onset of the flash reaction. In Figure 6, all of the video images were captured and analyzed, not just the half presented in Figure 5. The light intensity at first remains fairly constant and then rapidly increases just prior to the onset of the flash reaction.

Figure 5. Composite image of a glitter dross droplet just prior to the start of the flash reaction.

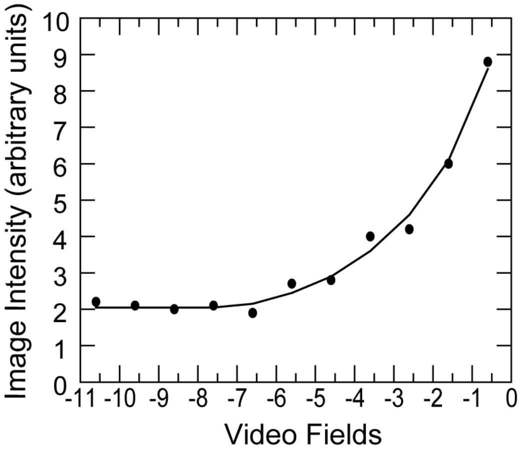

Figure 6. Graph of video image intensity of the dross droplet from Figure 5.

Light intensity is a function of temperature, thus the temperature of the glitter dross droplet is increasing just prior to the flash reaction. However, at this time, the response function (intensity versus wavelength) of the video camera is not known. Thus it is not possible to assign temperatures to the dross droplet. (There are plans to make such measurements in the future.)

Conclusion

The results reported in this article are somewhat interesting on their own and do provide potential insight into the control of the glitter flash reaction. However, they also provide a basis to draw an inference regarding the chemistry operating in the glitter phenomenon. However, the discussion of glitter chemistry is left for another article by one of the authors.[1]

The results presented are based on only a limited amount of data and for only one type of formulation. Further, in some cases, assumptions and approximations have been made. Thus a good measure of caution is warranted before drawing firm conclusions from these results.

Acknowledgments

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References

1) C. Jennings-White, "Glitter Chemistry", *Journal of Pyrotechnics*, No. 8 (1998).

2) T. Fish, "Glitter Stars Without Antimony," *Pyrotechnics Guild International Bulletin*, No. 24 (1984).