Breaking Glass Comet Analysis

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A Brief Introduction

This analysis and this document were created to help dispel some myths and shed some light on a unique pyrotechnic effect seen in breaking glass comets, aka dripping comets. These comets normally made in the 3” and 4” size and fired from a standard mortar. When fired the comets burn with a golden charcoal effect, as the comet slows down a secondary effect lights and a falling silver white effect is seen that cascades down in a curtain like fashion.

We know a lot about the effect by watching it. First, there is no sulfide melt or delay agents employed. We know this because the aluminum does not throw off spritzels like a normal glitter. We know it is not made with flake aluminum like a typical firefly formula. The burning aluminum doesn’t float away, or hang like a firefly, it falls rather rapidly. We also know that it is a very fast burning formula because 3” and 4” comets made with the formula finish burning shortly after the trajectory has been reached.

The Analysis Process

The analysis processes chosen were based on what we know already about the effect. The real unknowns here are the ratios between oxidizer and fuel, the particle size and ratio of the charcoal, and most important the size and shapes of the aluminum involved. More emphasis was placed on answering these questions than figuring out what the exact percentages of chemicals were in the samples that were analyzed. In a formula like this, the exact percentages are almost irrelevant. The effect appears delicate enough that even small changes in the source of materials, or blending method could produce different results. Even air temperature that the comet may be shot in could make a profound change in the fullness of the effect. It is entirely possible that with such coarse aluminum, and a fast burning mix without a sulfide melt, that as much as 10% of the coarse aluminum would fall from the sky unburned.

A person wishing to recreate this effect can use the percentages shown here as a starting point for further testing. Once similar materials for the components are acquired, one could probably dial in the effect within two or three renditions. Chemical quality is also not an issue in this effect. There is clear indications of capillary recrystalization of impurities from the nitrate and sulfur and indicate a lower grade was used to make the samples that were analyzed.

The processes used and how they help answer the questions:

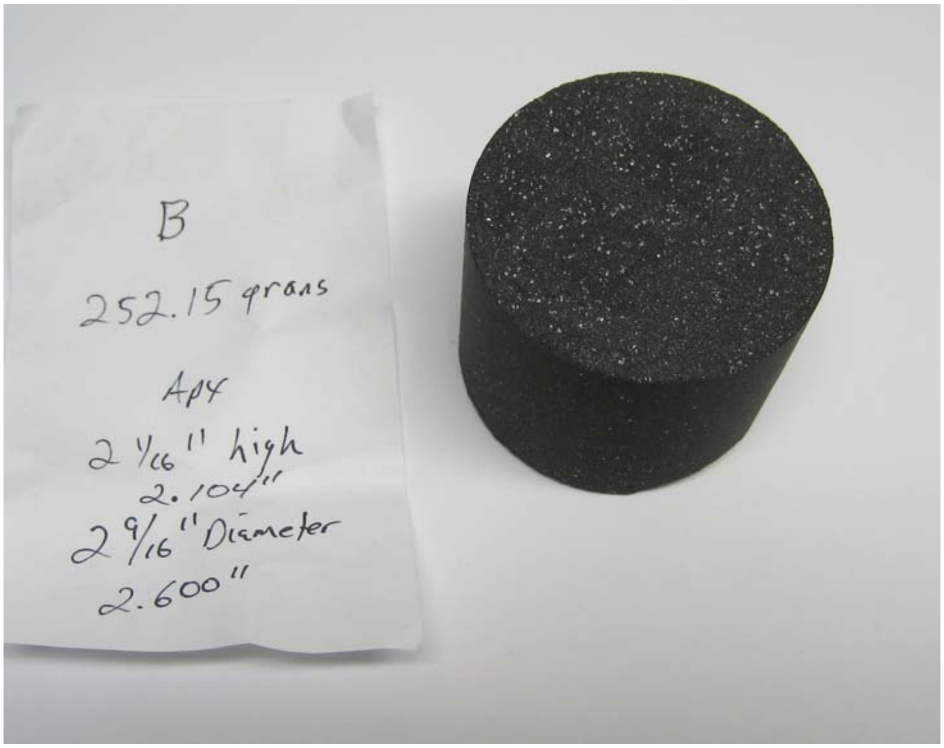
1. Soluble and insolubles were separated.
200 grams of the crushed comet were soaked for an hour in 3L of distilled water with constant stirring. The soluble part was separated from insoluble under vacuum filtration. Both parts were dried and weighed. This tells us roughly what the ratio of oxidizer to fuel is. The only soluble chemicals expected are Potassium Nitrate and a binder.

2. The insolubles were screened to separate the different particle sizes and weighed.
This helps us determine if particle size is a predominant determiner in the effect.

3. The insolubles were viewed under a microscope to help determine their percentages and to reveal the particle shapes and sizes.
This further helps to determine how particle size and shape are involved in the effect.

4. A burn rate test was done.
The burn rate test will be used as a standard for subsequent formulas to determine the correct oxidizer\fuel ration with new sources of materials.

Physical Characteristics



The comet sample measured to 2.104” high and 2.600” in diameter and had a weight of 252.15 grams. This gives the comets volume equal to 11.17075 cubic inches which is a density of 22.5723 gr\in3 or 1.3775 gr\cm3. The course aluminum can easily be seen on the exterior surface.

The comets were pressed at approximately 3000 psi.

The burn rate standard was determined by ramming the crushed comet material into a cardboard tube measuring 3/8” ID by 2.25” long. Approximately 2” of the mix was rammed into the tubes. The cardboard was carefully unwrapped from the mix leaving a core of compacted mix. A hardness tester and calculations ensured that the density was roughly the same as the original sample.

The columns were lit with a piece of match and filmed at 30 frames per second to calculate the open air burn rate.

The burn rate for the comet formula was found to be: .738 inches per second.

The Soluble and Insoluble

Separation of soluble from the insoluble gave the following results.

200	**Starting value grams**	
	Qty	**percentage**
Soluble	108.35	54.175%
Insoluble	91.05	45.525%
Loss	0.6	0.300%

Making an assumption that the binder was approximately 3% of the total formula we come up with the following for total potassium nitrate

Solubles	**Consists**	**Grams**	**Percentage**
KNO3	0.94	101.849	50.925%
Dextrin\Binder	0.06	6.501	3.251%
		108.35	

The screen analysis

Once dried the insoluble matter was separated with 100 and 200 mesh screens. Three distinct particles sizes were retained and weighed.

Screening Insolubles	**qty**	**Percentage**
+100 Mesh	17.75	19.495%
+200 Mesh	9.59	10.533%
-200 Mesh	63.2	69.412%
Total	90.54	
Loss	0.51	0.560%

By looking at the retained sample and confirming under the microscope we can assume that of the particles over 100 mesh, 95% of them are aluminum.

Screen +100	**Consists**	**Grams**	**Percentage**
Aluminum	0.95	16.8625	8.431%
Charcoal	0.05	0.8875	0.444%
		17.75	

In the 100 mesh to 200 mesh range I estimated the ration of aluminum to charcoal to be 60:40

Screen +200	**Consists**	**Grams**	**Percentage**
Aluminum	0.6	5.754	2.877%
Charcoal	0.4	3.836	1.918%
		9.59	

The particles smaller than 200 mesh are estimated to in a ration of 10:70:20 Aluminum\Potassium Nitrate\Sulfur

Screen -200	**Consists**	**Grams**	**Percentage**
Aluminum	0.1	6.32	3.160%
Charcoal	0.7	44.24	22.120%
Sulfer	0.2	12.64	6.320%
		63.2	

If you put all the pieces back together and look at it from the total percentage angle you get the following estimates.

Estimated	**Grams**	**Percentage**
KNO3	101.849	50.925%
Dextrin	6.501	3.251%
Charcoal	48.9635	24.482%
Aluminum Course Atomized	16.8625	8.431%
Aluminum Medium Atomized	5.754	2.877%
Aluminum Fine Atomized	6.32	3.160%
Sulfur	12.64	6.320%
	198.89	99.445%
Total Aluminum percentage		
14.468%		

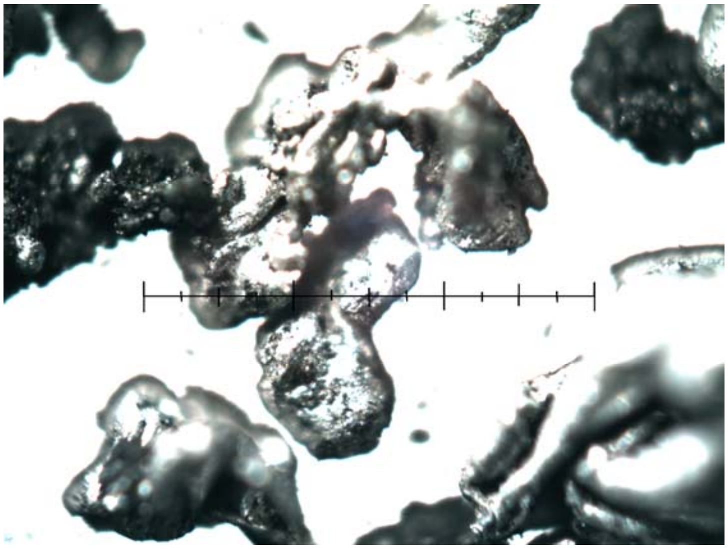
A special note about the charcoal used. Looking at the samples from the screening analysis, and reviewing the microscope images, it is clear that a majority of the charcoal is larger and rougher than airfloat, and almost all is under 100 mesh. To reproduce this particle range one would need to probably start with 80 mesh or larger charcoal and ball mill it briefly to bring it down to that range. Another way to achieve the right charcoal mix of particle sizes would be to start with a normal 75:15:10 green mix and mill it the normal amount of time. Shortly before the end of the milling an amount of 80 mesh or coarser charcoal is added, and the milling continued for a short time more.

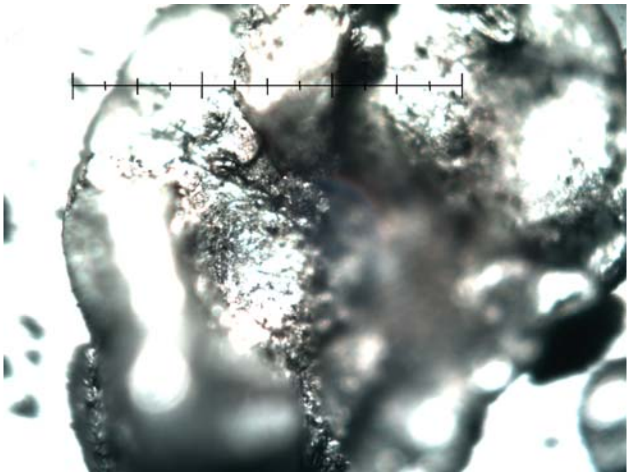
A Look Under The Microscope

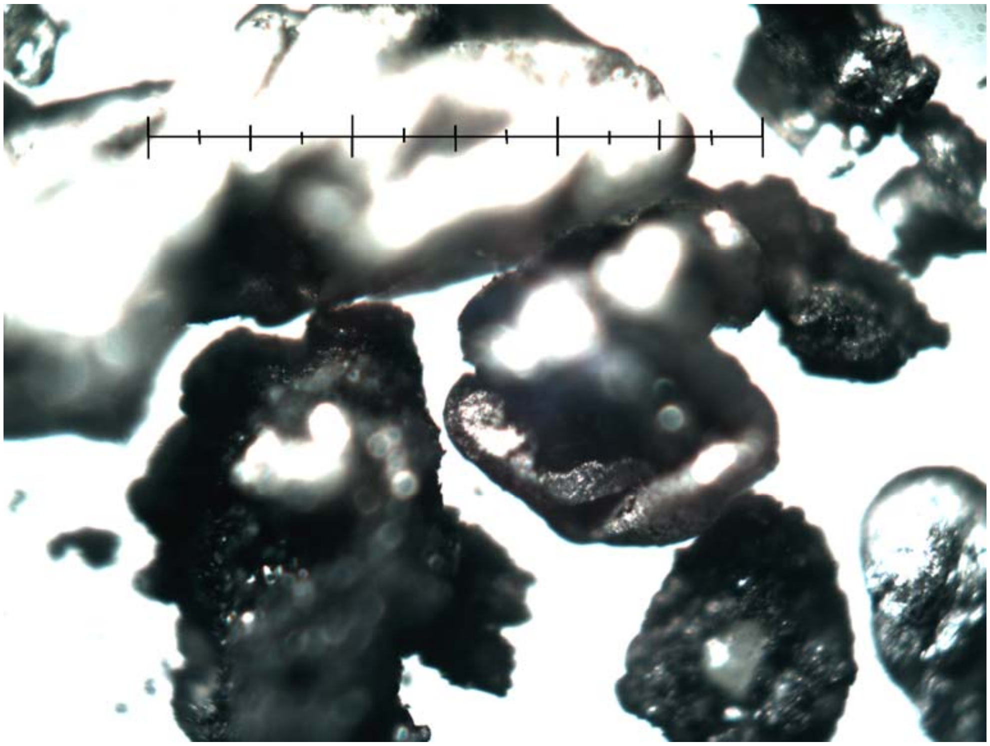
Most of the images below contain a scale that is 300 microns in width with sub increments of 25 microns.

Over 100 mesh

The screen analysis shows that almost 20% of the insoluble matter is what you see below. A coarse atomized aluminum in the 100 to 500 micron, or 30 to 100 mesh range. Very big stuff and very hard to find. The most likely source would be waste from the production of finer grades of atomized.

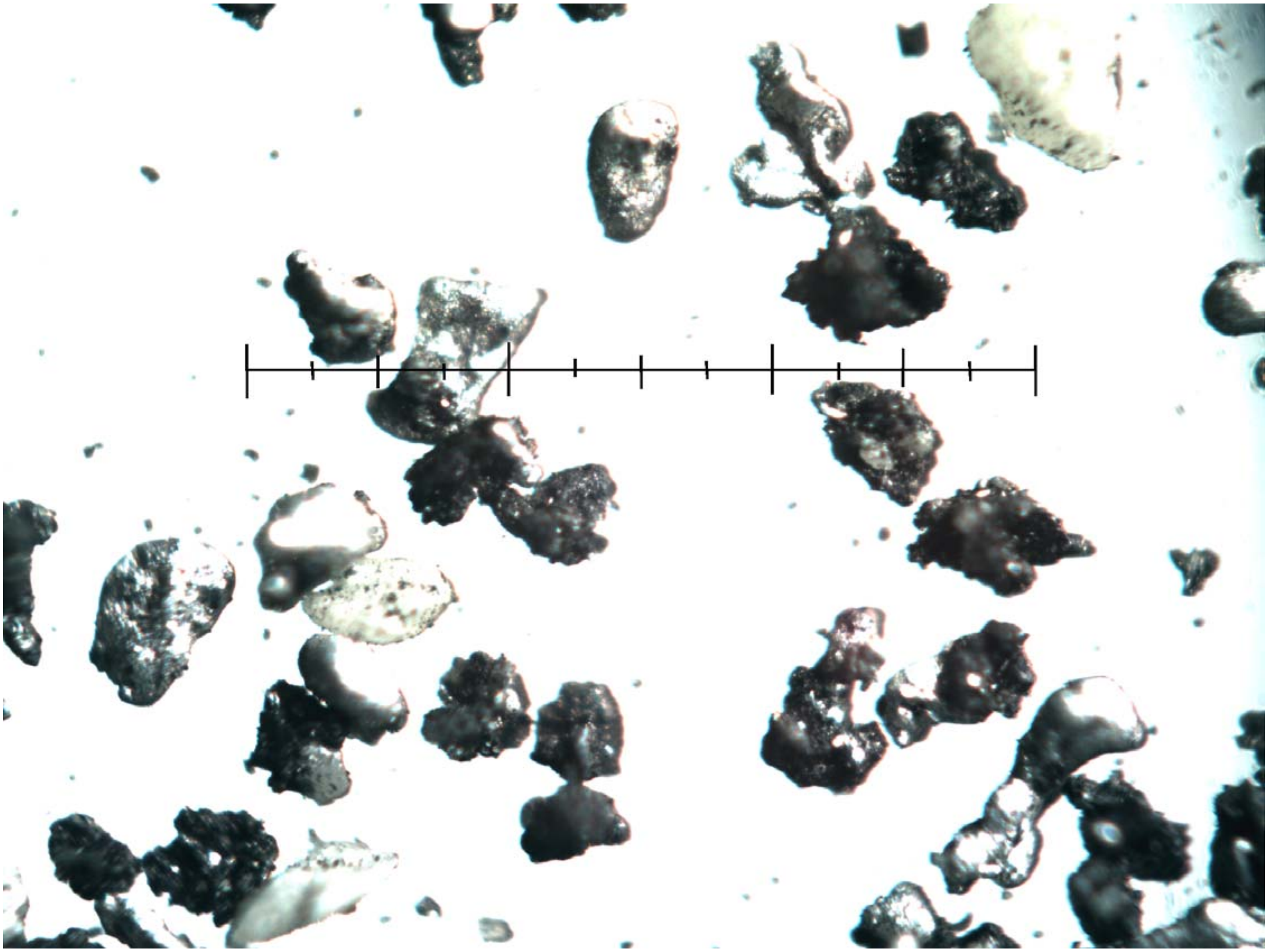






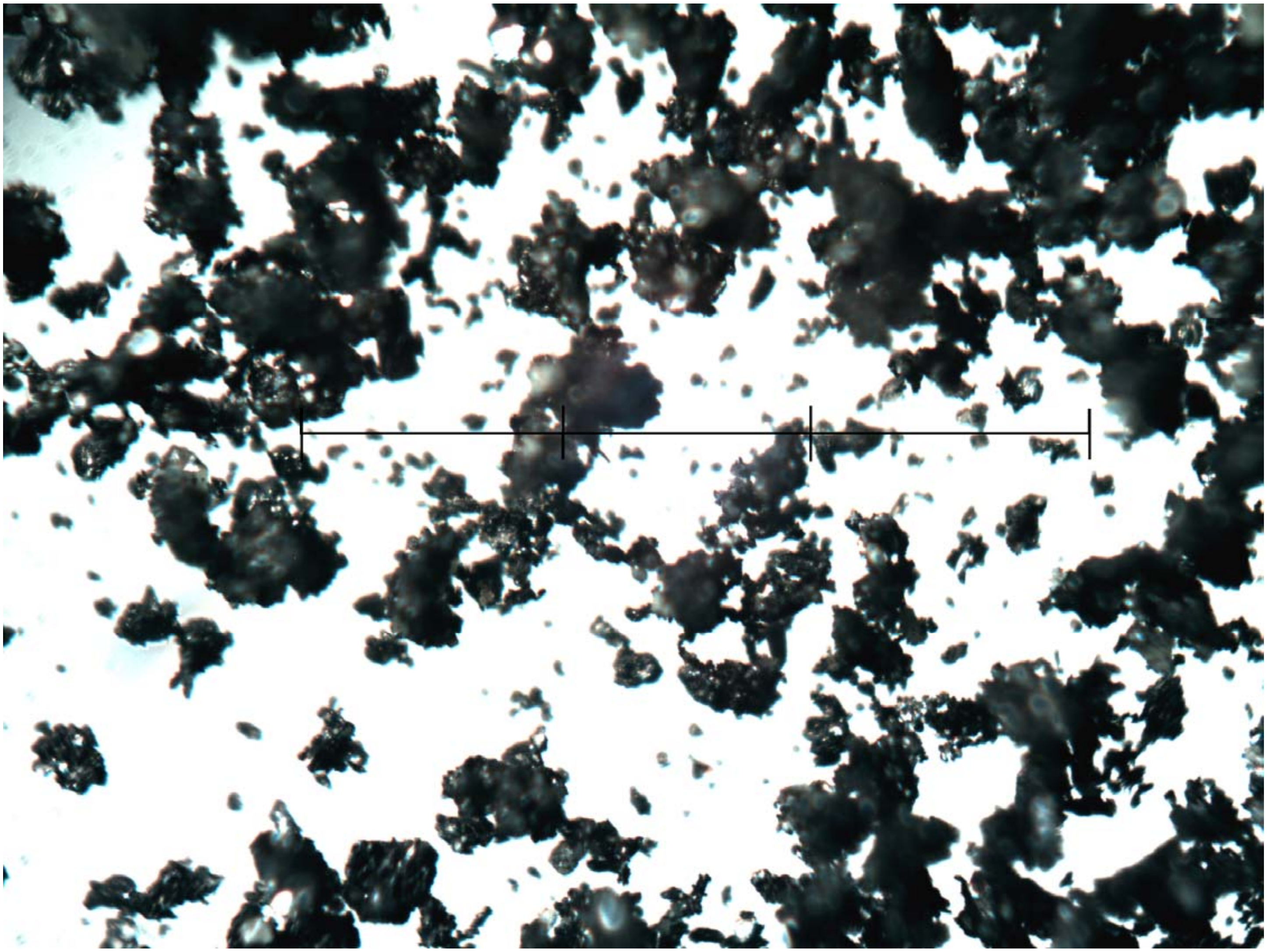
100 to 200 mesh

In the 100 to 200 mesh range you see similar atomized aluminum with almost 40% of this range being granular charcoal.

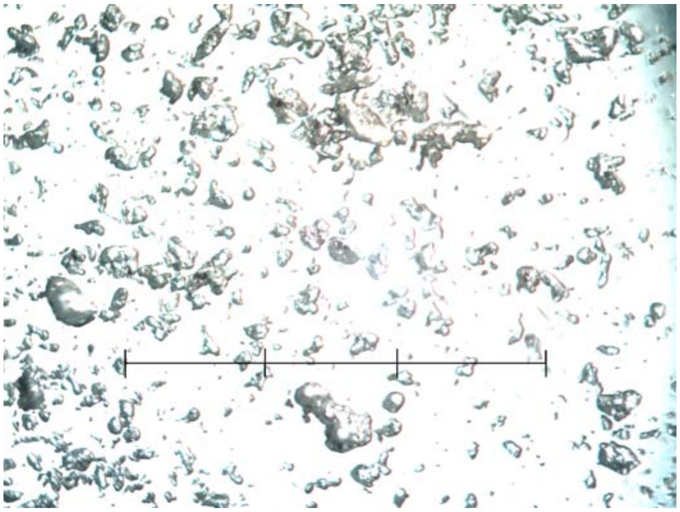


Under 200 Mesh

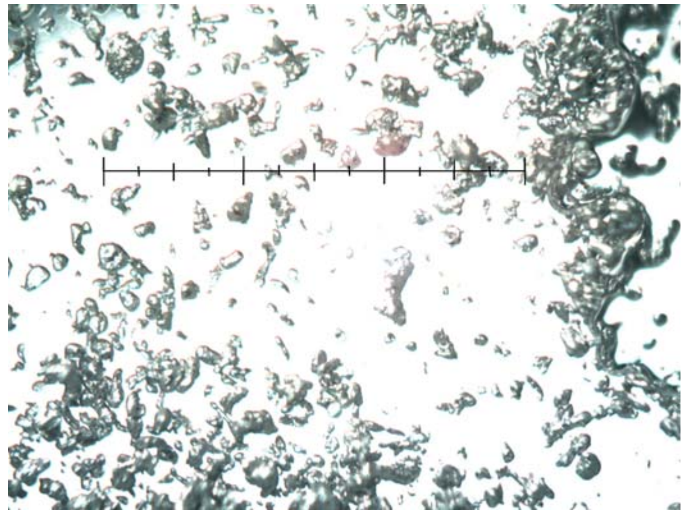
This particle range is predominantly charcoal. Quite a bit of it is larger than airfloat. Looking at charcoal in this range from samples that have been bound and pressed can also be deceiving because the charcoal particles tend to stay clumped together. It is still clear that a predominant amount is coarser than airfloat. You can also see a smattering of finer atomized aluminum.



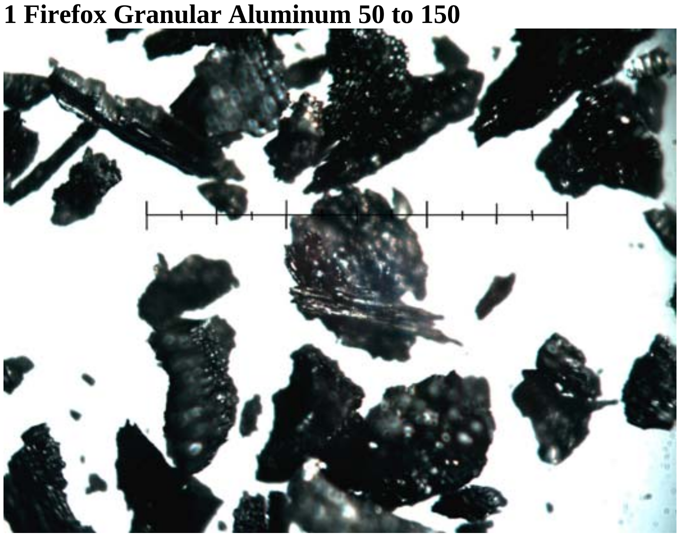
Reference images



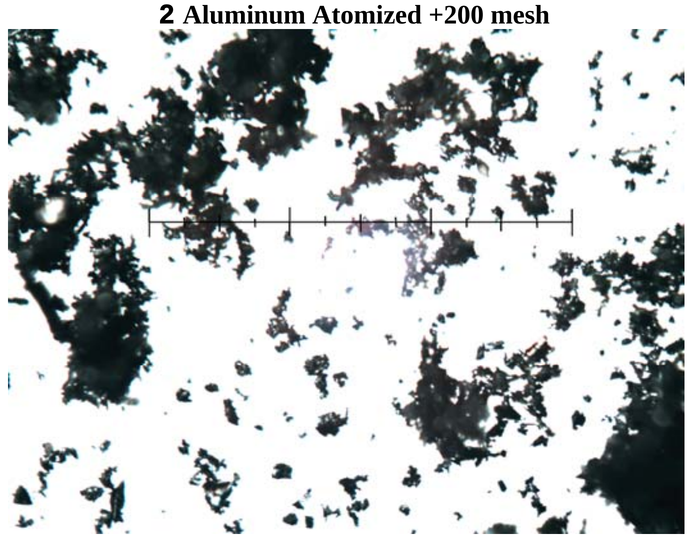
1 Firefox Granular Aluminum 50 to 150



2 Aluminum Atomized +200 mesh



3 Charcoal 80 mesh commercial



4 Charcoal Commercial Airfloat

The image of the Firefox 50-150 mesh granular aluminum was added because it was hoped that this particular aluminum would be sufficient to reproduce the effect. Unfortunately because the material is clearly mislabeled, there is no chance that it can be used as is. First it is definitely atomized and not granular, and he material is also predominantly finer than 200 mesh. An accompanying image is shown of a 200 mesh atomized standard. At the time of the writing the author does not know of a source of the aluminum required to reproduce the effect.

Starting points for further work

To move into the recreation of the effect I would take two approaches. The first would be to make a mix with the first formula below. I would just screen the ingredients together, wet with 5% water, and press and dry the comets. Fire them and adjust based on the results

Ingredient	Percentage
KNO3	50
Dextrin	3
Charcoal Airfloat	20
Charcoal Coarse	7
Aluminum Course Atomized	10
Aluminum Fine Atomized	4
Sulfur	6
	100

The second approach I would do is to start with a good meal. Either commercial, or home made meal that has been milled, wetted and dried. I would then screen in the aluminum, coarse charcoal and binder, wet, and then press.

Meal method	
Meal	68%
Charcoal Coarse	15%
Aluminum Coarse	10%
Aluminum Fine	4%
Dextrin	3%