Flow Agents in Pyrotechnics

L. Weinman

9051 Sugartree Trail, Huntsville, AL 35802, USA

e-mail: ltw@hiwaay.net

ABSTRACT

Presented is a brief description of the use of flow agents in pyrotechnics. Examples of the use of several agents are described and a simple test for flowability is presented.

Keywords: pyrotechnics, flow agents, flowability, silica, aluminum oxide, carbon black

Pyrotechnic compositions most frequently comprise an intimate mixture of various particulate materials. These mixtures may, or may not, include a substance used as a binder.

One common method of utilizing these mixtures is to load them as a loose powder into some outer container and use as is. An example of this would be a concussion mortar, where a loose powdered composition sits at the bottom of an open cavity. Another common method for using these mixtures is to consolidate them in a confining outer container. An example of this would be a fountain. Both of these usages are simplified if the powdered material being used flows, relatively, freely from a storage container to the container of use. But, it is an unfortunate fact that many, if not most, pyrotechnic compositions have poor flow characteristics, or a tendency to "cake" on storage.

Over the last few hundred years, a number of methods have been developed to alleviate these problems. Of these, perhaps the oldest is slugging (as it is termed in the pharmaceutical industry). In this method the composition is formed into ill-defined pressed forms and then gently crushed to a finer condition. This method has the further advantages of increasing the "as used" density of the, now granular, material, and allowing the selection of the size of the granules to be used. This, of course, is the method used in making Black Powder. A similar method involves wetting the composition with some liquid (which may, or may not, be a solvent for one, or more, of the ingredients), and forming suitable-sized agglomerants from the wetted composition. The granules formed are then, typically, dried before use. The apparent density may also be slightly increased using this method.

However, both of the above methods require substantial processing effort to accomplish. And, for a composition such as a flash powder, may yield a material that is unsuitable for the intended purpose.

Another method to achieve suitable flow characteristics is to add a flow agent to the composition. Most flow agents act as either "ball bearings" by coating the particles of the composition, or to conduct/remove attractive static electrical charges, or both.

Probably the most common agent is silicon dioxide produced by "fuming". This process involves injecting silicon tetrachloride into an oxy-hydrogen flame. It results in sub-micron silica particles having a large surface area (>100 m^2/g). This silica product may then, if desired, be treated with an organo-silane. This treatment results in a hydrophobic material, as opposed to the untreated hydrophilic silica surface, which may lessen the effects of ambient humidity, or moisture, on the composition.

Two facts should be kept firmly in mind when contemplating using either of these two types of fumed silica:

> *The untreated silica, having a large surface area, can adsorb large amounts of water prior to using it in the mixture.*

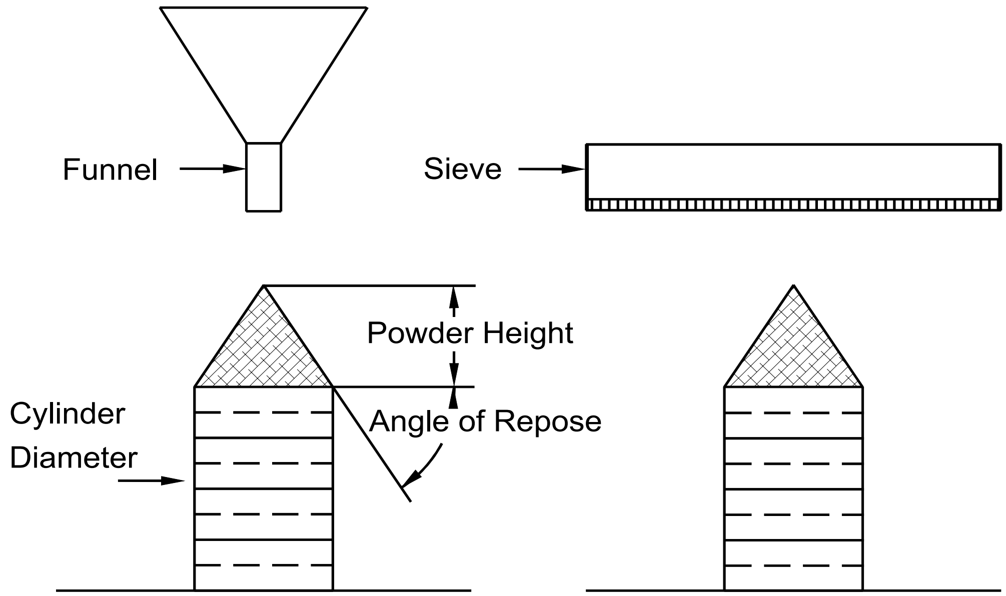

Figure 1. Determining the Angle of Repose:
tan (Angle of Repose)=[Powder Height/(0.5×Diameter)]

The treated silica, being hydrophobic, will make subsequent aqueous processing more difficult.

Other materials that may be used in similar applications are fine aluminum oxide (produced in a similar process as the silicas) and some carbon blacks. Carbon black and fine aluminum oxide have effects beyond those of silica. Conductive carbon blacks can serve to internally neutralize static charges by conduction. Aluminum oxide always develops a positive surface charge which may serve to neutralize a developed negative charge on some materials.

In using any of the above products, it will generally be found that, if the product is suitable for the use, only a small amount will be needed. Manufacturers' recommendations range from about 0.05–0.2% for potato starch up to 4–6% for zinc oxide. The author has found that, for many pyrotechnic compositions, the range is from about 0.25 to 2%.

Since these products are used as a coating for some other powder, they are usually mixed using a low shear method, such as tumbling. A user may often find that there is some particular process and sequence that works better than another for a specific application. Such differences may be adding the silica to the mixer first or second, using only screening, tumbling then screening, etc.

Achieving the best results using the least flow agent is a field fraught with possibilities.

Another use for fumed silica is to form thixotropic gels with various liquids. This property is used to make greases, rocket propellants, cosmetics, paints, and a whole host of other end products. Using the silicas in this way typically requires a high-shear mixer to form the silica/liquid gel.

One quantitative measure of goodness for flow is the angle of repose of the material in question. This angle is one of the most commonly accepted measures of flowability for solids and is used by both chemical process and civil engineers. A simple test may be easily performed by the pyrotechnician using a cylinder and funnel, or screen, and a height measuring instrument (Figure 1). The material to be tested is carefully poured, or sieved, onto the cylinder where it will collect and form a conical heap. Since the diameter at the base of the cone is a constant, the easily measured height of the cone yields the angle of repose for the tested material. Under some circumstances, it may be de-

Table 1. Results of Using Flow Agents.

Material	Angle of Repose
Flowers of Sulfur	
no additive (material was very difficult to get through the funnel, and formed varying peaks on the heap)	> 80
0.5% Cabot XC72R	38.1
1.0% Cabot TS720 (material showed a great amount of "static cling")	31.6
0.25% Cabot XC72R + 0.5% Cabot TS720 (no cling)	31.8
Potassium Nitrate	
no additive	57.6
1% Degussa Aerosil 200	44.0
1% Degussa Aerosil R972	39.1
1% Cabot XC72R	42.4
0.5% Cabot XC72R + 0.5% Degussa Aerosil R972	31.7

sirable to subject the cone of material to some small reproducible vibration or shock to obtain a more meaningful result.

Some representative data is given here to help the potential user of flow agents.

The technique used to obtain the data was as follows:

1. The base materials used were
   Potassium Nitrate, technical grade ground to pass 70% through a US Standard –325 mesh sieve
   Flowers of Sulfur — no other specification.
2. Flow agents used were
   Cabot XC72R conductive carbon black
   Cabot TS720 organo-silane treated silica
   Degussa Aerosil 200 silica
   Degussa Aerosil R972 organo-silane treated silica
3. The base material and the flow agents were dried at 70 °C for 16 hours.
4. A measurement of the angle of repose was made on the base material. See Figure 1.
5. Several hundred grams of base material was weighed and the selected weight of flow agent was added to it in a plastic cup. A lid was secured on the cup, and the cup was shaken by hand for 30 seconds. The mixture was then passed through a US Standard –100 mesh sieve, and again shaken in the cup for 30 seconds.
6. A measurement was then made on the mixture.

The results are shown in Table 1.

While there has been no attempt, here, to exhaustively detail how these agents may be used, it should be obvious, from this brief description, that flow agents are a useful item to incorporate in the pyrotechnicians armentarium.

The author wishes to thank Cabot Corporation, Degussa Corporation, and Luna Tech, Inc. for their help.