National Fireworks Association

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Todd A. Stevenson
Office of the Secretary
Consumer Product Safety Commission
Room 820
4330 East-West Highway
Bethesda, MD 20814

RE: Comments of the National Fireworks Association on the Notice of Proposed Rulemaking, Amendments to Fireworks Regulations, 82 Fed. Reg. 9012

Dear Mr. Stevenson,

The National Fireworks Association ("NFA") submits these comments in response to the Consumer Product Safety Commission's Notice of Proposed Rulemaking, Amendments to Fireworks Regulations, 82 Fed. Reg. 9012 ("NPR"). NFA appreciates that the Commission granted an extension to the original deadline for filing comments in this proceeding and has used that time to participate in two in-person meetings with CPSC technical staff.

NFA appreciates CPSC's efforts to refine its fireworks regulations, and acknowledges the efforts by CPSC to propose fair and meaningful regulations to improve consumer safety. NFA does not oppose most of the proposals in the NPR because, even if the link to reducing the risk of injury is tenuous for many, they are unlikely to pose significant burdens on the fireworks industry. On the other hand, NFA does strongly oppose the proposed requirement to prohibit powdered metals in the burst charge of aerial devices ("Metals Ban"). *See* NPR § IV.A.1. Because the Metals Ban would place a significant burden on American businesses without improving consumer safety, NFA focuses these comments on its opposition to that proposal.

The Metals Ban would ban *all* aerial fireworks with burst charges of more than 2 grains (130 mg) of pyrotechnic composition if they are believed to contain *any* powdered metals. Because the Metals Ban is blind to other factors that affect explosivity—such as shell construction and the amount of pyrotechnic composition in a burst charge—devices with significantly greater explosivity than those that fail the test would pass. Even more, this arbitrary standard is premised on, and would be enforced using, fundamentally flawed testing methodologies that are incapable of reliably determining the amount of powdered metals in burst charges.

Not only does the Metals Ban rely on flawed testing procedures and ignore the explosivity of burst charges, it lacks any safety justification. There is a complete dearth of data showing a correlation, let alone causation, between injuries and the powdered metals content of the burst charges of the

devices involved. To the contrary, nearly all injuries related to aerial devices do not even involve the burst charge, but are associated with the impact from the lift charge.

Likewise, there is no data to show that aerial devices in general (irrespective of whether injuries are associated with lift charges or burst charges) pose an unreasonable risk of injury. An analysis of the CPSC injury reports since 1999 shows no trend in injuries related to consumer fireworks devices, despite increased imports and significant market growth of aerial devices during this time. Further, the injury data related to fatalities involving aerial devices reveal an unsurprising fact: most incidents involve flagrant misuse. The Metals Ban would thus have no impact on safety.

Although it would have no impact on safety, the Metals Ban would likely have a devastating impact on industry. CPSC's own testing shows that the Metals Ban would result in *394% more* device failures than are produced by the standard that has been used for decades.[1] And, if the performance of devices on the market drops because of a reformulation of their burst charges, consumer demand for aerial devices would plummet.[2] American businesses would take a hit from lower sales, and they would struggle to comply with a stringent regulation that requires expensive, complex, and error-prone testing methodologies.

In sum, the Metals Ban would impose significant burdens on businesses, which risk having their inventory seized and destroyed on the basis of a flawed test, without any demonstrable benefit to consumer safety. It would also hurt the many Americans who enjoy the brilliant visual effects of the consumer aerial fireworks that are available today. For these reasons, NFA strongly opposes the Metals Ban.

I. OVERVIEW OF NFA

NFA is a trade organization dedicated to the widespread and safe use of consumer and display fireworks. At the time it was formed more than twenty years ago, NFA's primary purpose was to provide a collective voice for the many small, mom-and-pop fireworks business operators to address government regulatory issues and concerns. Since its founding, NFA's role has expanded from providing a collective voice for the industry to also promoting industry knowledge and education. NFA has grown over the years, and today has the largest membership—more than 1,200 members—of any domestic fireworks trade association. NFA represents a broad range of industry stakeholders, including importers, distributors, retailers, manufacturers, and enthusiasts of both display and consumer fireworks.

Each year, NFA hosts a convention with exhibitors, seminars, and fireworks displays and demonstrations. NFA's seminars, and its member updates, are key sources of information for many businesses about fireworks technology, safety, regulations and standards, insurance, and

[1] NPR at 9016 ("Using the CPSC Testing Manual method, staff found that 17 percent of the samples were ''intended to produce audible effects'' and exceeded the 2-grain limit. In contrast, while using the APA Standard 87–1 method [the Metals Ban], staff found that 84 percent of the samples were ''intended to produce audible effects'' and exceeded the 2-grain limit.") Subsequent testing by CPSC staff has produced similar failure rates.

[2] In evaluating the likely impact of this rule, NFA takes as true CPSC's assertions that (i) pyrotechnic materials that contain powdered metals are frequently used by fireworks manufacturers to enhance the performance of aerial devices; and (ii) the vast majority of consumer aerial devices currently sold on the market contain powdered metals.

business practices. NFA has played an important role over the past twenty years in helping its members understand and comply with the numerous regulations that govern the manufacturing, importing, distribution, sale, and use of fireworks. NFA is especially proud of the role it plays in looking out for many of its members who do not belong to the other two domestic fireworks organizations, which are dominated by the same small handful of industry titans.

NFA members not only have a business interest in ensuring that fireworks are fairly and safely regulated, but also a personal interest. NFA members enjoy fireworks with their friends and families for pleasure and to celebrate holidays, special occasions, and events. NFA recognizes that consumer fireworks have played an important role in our nation's cultural history since colonial times, when revolutionists celebrated their newfound independence with consumer fireworks.[3] Consumer fireworks continue to play an important role in celebrating our Nation's birth and other special events, and NFA seeks to preserve them for future generations.

The preservation of aerial fireworks is of particular importance to NFA's members. Aerial fireworks—like reloadable shells, single shot shells, cake shots, and stick rocket payloads—are some of the most popular and enjoyed fireworks, with their dramatic stars, colors, and other visual effects. They are also financially important. For many fireworks retailers and wholesalers, sales of aerial devices make up more than half of their total revenue from all consumer fireworks. And in many towns and municipalities where there is insufficient funding for professional fireworks displays, private citizens often host their own celebrations with less expensive consumer aerial devices. NFA is thus particularly concerned with the fair and reasonable regulation of aerial devices.

II. HISTORICAL CONTEXT OF THE REGULATION OF CONSUMER AERIAL FIREWORKS

Until the 1960s, consumer fireworks were largely unregulated at the federal level.[4] That changed in 1966 when the Federal Hazardous Substances Act ("FHSA") was amended to ban certain hazardous articles.[5] Specifically exempted from the definition of banned hazardous articles were "common fireworks."[6] The definition of "common fireworks" included devices that were "[d]esigned to produce only visual effects by combustion" or "designed to produce audible effects, if the audible effect is produced by a charge of not more than 2 grains pyrotechnic composition."[7] This standard, which determines whether a device is subject to the 2 grains limit based on whether the device is intended to produce an audible effect or a visual effect is referred to in these comments as the "Audible Effects Standard."

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[3] *Pennsylvania Packet*, 18 May 1784, 3 (advertising fireworks to the public for celebration including "rockets, serpents, wheels, table rockets, cherry trees, fountains, and sun flowers.")

[4] The Interstate Commerce Commission, predecessor to the Surface Transportation Board, had previously enacted some regulations related to the transportation of fireworks.

[5] See 15 U.S.C. § 1261 (1966).

[6] 21 C.F.R. 191.65(a) (1966).

[7] *Id.*

Limiting the pyrotechnic composition of devices that were designed to produce audible effects, but not those that were designed to produce visual effects, through the Audible Effects Standard, was an important distinction. The aim was to allow devices that produced visual effects (like stars) while banning certain powerfully explosive ground devices that gained popularity after the end of World War II. Because ground devices ignite and explode proximate to users and bystanders, they pose unique safety risks that are not shared by the burst charges of aerial devices, which ignite after the device has been carried into the sky by the lift charge.

During World War II, the U.S. Military used M-80s to simulate artillery fire for training purposes. These M-80s were typically charged with flash composition that consisted of approximately 70% black powder and 30% aluminum powder.[8] After the war ended, there was a surplus of M-80s. Entrepreneurs relabeled these M-80s as consumer fireworks and sold them to the public. When the surplus ran out, manufacturers began producing their own versions of M-80s and other powerful devices that were intended only to make a loud bang (that is, an audible effect).

The FHSA regulations that were enacted in 1966 were intended to limit those types of devices to 2 grains (130 mg) of pyrotechnic composition. But despite the new regulations, powerfully explosive fireworks intended to only create audible effects continued to find their way to the public through a loophole for agricultural products. Powerfully explosive aerial devices that farmers used to scare birds away from crops were diverted and sold to the general public as consumer fireworks. These pest control devices, like M-80s, were designed to produce audible effects, not visual effects, and were often modified for use as ground devices.

To close the loophole for these powerful agricultural devices, regulations were proposed in 1969 to classify all such devices as banned hazardous substances.[9] Farmers strongly opposed the proposed outright ban, and the regulations were modified in 1970 to include an exception for bona-fide crop protection devices if certain procedures were followed.[10]

The modification in 1970 to the fireworks regulations preserved the Audible Effects Standard. The regulations defined as banned hazardous substances, "fireworks devices *intended to produce audible effects* . . . if the audible effect is produced by a charge of more than 2 grains of pyrotechnic composition" (emphasis added).[11] The record expressly states that "[t]he intention is not to ban so-called 'Class C' common fireworks" and that the "primary concern in this matter is to close the loophole through which dangerously explosive fireworks, such as cherry bombs, M-80 salutes,

[8] The NPR incorrectly suggests that the powdered metals in pyrotechnic compositions is a new or recent development: "Fireworks have evolved . . . and now use different types of powders. . . ." As explained in this section, the use of powdered metals was well known at the time the FDA determined that the Audible Effects Standard was the appropriate screening mechanism for powerfully explosive devices like M-80s.

[9] *See* 34 Fed. Reg. 260.

[10] *See* 35 Fed. Reg. 7415.

[11] *Id.*

and similar items, reach the general public."[12] "Similar items" to cherry bombs and M-80s are those that use a powerful charge solely to produce a bang instead of a visual effect.

Despite the known use of powdered metals in pyrotechnics at the time of this modification, no ban was imposed on the use of powdered metals. Nor was there a restriction on what a manufacturer could use to produce a visual effect. Instead, the Audible Effects Standard was implemented as a flexible and tailored approach to only ban those powerful devices that did not use an explosion to produce visual effects.

For now more than fifty years, the Audible Effects Standard has determined whether the 2 grains pyrotechnic composition limitation applies. Because aerial devices are universally manufactured with burst charges that have more than 2 grains of pyrotechnic composition, the Audible Effects Standard is the *de facto* sole determiner for whether an aerial device fails (and is subject to confiscation and destruction) or passes (and can be sold in commerce).

III. OVERVIEW OF THE EAR TEST

To test whether a device meets the Audible Effects Standard, the CPSC has, for about twenty years, relied on the "Ear Test," whereby testers light a device and then attempt to distinguish with their hearing between sounds described as booms, bangs, pops, and poofs. If a tester determines that an aerial device booms or bangs (notated as a "report" in CPSC testing forms), it is deemed as "intended to produce audible effects." Failure results in confiscation, and ultimately destruction, of inventory. On the other hand, if a tester determines that an aerial device pops or poofs, that device is not classified as "intended to produce audible effects."

Because the Ear Test is necessarily a subjective exercise that lacks a physical, quantitative measure, it has proven unreliable. NFA fully supports CPSC's attempt to find a better test for enforcing the Audible Effects Standard. Indeed, sound level meter ("SLM") testing, as discussed later in these comments, is an excellent candidate for that purpose. SLM testing would solve the shortcomings of the Ear Test by providing a physical, quantifiable, and reliable measurement to assess compliance. And it would avoid the flaws of the Metals Ban, which would drastically increase the burden on NFA's members without any demonstrable benefits to consumer safety.

IV. OVERVIEW OF THE METALS BAN

The proposed Metals Ban would ban all aerial fireworks with burst charges of more than 2 grains (130 mg) pyrotechnic composition limitation if they are believed to contain any powdered metals. Because virtually all aerial fireworks exceed the 2 grains limit, the Metals Ban would effectively ban all aerial devices with any powdered metals. The Metals Ban does not take into account the total explosivity of a burst charge; it arbitrarily passes or fails devices based on whether their burst charges are believed to contain any powdered metals. Devices with significantly less powerful burst charges could thus fail the Metals Ban while devices with significantly more powerful burst charges could pass.

[12] *Id.*

The Metals Ban would place a heavy burden on businesses because it is grossly overinclusive. According to test results published in the NPR, failure rates would increase from 17% under the Audible Effects Standard to 84% under the Metals Ban—a *394%* increase.[13] While the NPR speculates that this dramatic increase in failure rates may be attributable to the more "precise and quantifiable measurements" under the Metals Ban, there is *no* data to support this assertion. Instead, the reason for the dramatically higher failure rate is simple: the Metals Ban would be an entirely different, more stringent regulation than the Audible Effects Standard, and it would ignore the risk of hazard or explosivity of a device.

V. THE METALS BAN ARBITRARILY AND CAPRICIOUSLY BANS AERIAL DEVICES REGARDLESS OF THE ENERGETIC FORCE OF THEIR BURST CHARGES

Aerial devices come in a variety designs, with burst charges of different sizes. Below are pictures of some popular devices with typical burst charge weights per shot:

500 g cake shot

(4-9 g burst charge/shot)

200 g cake shot

(3-6 g burst charge/shot)

reloadable shell

(4-9 g burst charge/shell)

stick rockets

(1-6 g burst charge/payload)

The energetic force associated with the burst charge of each of these devices is different and depends on many design factors, including, as CPSC has recognized:

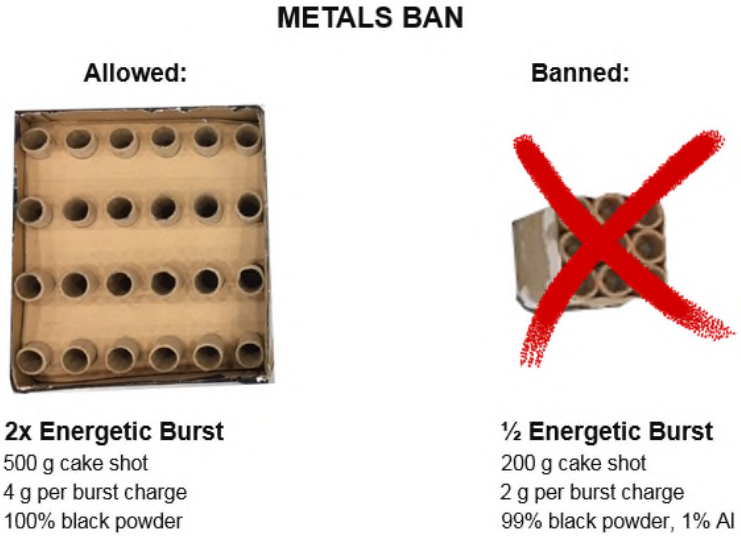
[13] NFA's testing of domestic aerial devices, *see infra* at 14-15, confirms a similar failure rate as CPSC has observed. NFA understands that AFSL has conducted testing in China (AFSL did not test a single device in the U.S.) that shows dramatically different results from CPSC's and NFA's testing. The discrepancy between foreign and domestic testing of purportedly similar products draws further into question the reliability of the testing methodologies employed.

> (1) the break charge powder's explosive efficiency—the amount of "hot gas" produced; (2) the amount of break powder (below 100 mesh particle size) that the device contains; and (3) the manner in which the device has been manufactured (e.g., packing of the pyrotechnic contents, cardboard/plastic shell thickness, amount of glue-tape applied, tightness of the wrappings).[14]

Because the energetic force of the burst charge of an aerial firework depends on many factors, CPSC's efforts in replacing the Ear Test have until now focused on *performance testing*. Efforts have included exploration of a steel ball test and cage test to measure the performance of the device. NFA applauds CPSC's attempt to measure the performance of the burst charges of aerial devices because that is the only way to take into account the multiple factors that contribute to the energetics. NFA encourages the CPSC to continue its efforts to develop a test that account for the performance of a device, and suggests a genuine consideration of sound level meter testing as discussed later in these comments.

The Metals Ban takes a sharp turn from previous attempts to measure the performance of aerial devices to focusing exclusively on the presence of powdered metals in a burst charge. This myopic focus on powdered metals lacks a rational basis because devices with significantly greater energetics than devices that fail the metals test would pass.

To illustrate, take two actual devices: a 500 grams cake shot with a 4 grams burst charge per shot of pyrotechnic composition and a 200 grams cake shot with a 2 grams burst charge per shot of pyrotechnic composition. (Both devices are commonly sold and permissible under CPSC standards.) The 2 grams burst charge of the 200 grams cake shot is 99% black powder and 1% powdered aluminum, and the 4 grams burst charge of the 500 grams cake shot is 100% black powder. Even though the burst charge of the larger, 500 grams cake shot has nearly double the explosivity as burst charge of the smaller device,[15] the Metals Ban would allow the 500 grams cake shot and ban the smaller one. Here is a picture with actual devices to illustrate:



[14] Fireworks Safety Standards Development Project FY 2013 Report at 12.

[15] 1.94x, based on CPSC's assumption that 1% of powdered aluminum can theoretically increase the explosivity of a device 3%. *See* Dec. 14, 2016, Fireworks Notice of Proposed Rulemaking Briefing Package at B-5.

Banning devices with burst charges with half the explosivity of allowable devices demonstrates the absence of a rational basis for the Metals Ban.

VI. THE METALS BAN FAILS TO IMPROVE SAFETY

The Metals Ban is not supported by any data that shows that it would increase consumer safety. CPSC has not shown any correlation between powdered metals, or burst charges for that matter, and the injuries to consumers from aerial devices. This remains true despite the ever-growing trend in the number of consumer fireworks aerial devices purchased every year. In fact, the Metals Ban could *increase* the number of injuries, as consumers could turn to homemade and professional alternatives.

A. There are No Data to Show that Banning Powdered Metals in the Burst Charges of Aerial Devices Would Improve Safety.

There are no data correlating the metallic content of the burst charges of the devices involved with safety incidents. No data are cited in the record, and CPSC has confirmed in response to a FOIA request that it has none. Likewise, there are no data comparing the severity or frequency of incidents involving devices that have metallic content in their burst charges and those that do not. CPSC has even recently acknowledged that despite its investigations with "whole shell testing," it "could not find a correlation between a specific pressure released and injury potential."[16] Nothing exists in the NPR or briefing materials to cure this glaring absence of data.

Not only are there no data correlating the metallic content or specific pressure release or burst charges and injury potential, but also no data even correlating injuries to burst charges generally. Burst charges in aerial devices ignite several seconds after the lift charges ignite—the burst charges are designed to only ignite once the device is propelled into the air away from people. Indeed, the injury data involving aerial devices shows that nearly all of the injuries were related to impact of a device propelled by the *lift* charge, not the burst charge. Given the lack of any evidence correlating the metallic content of burst charges with safety incidents, there is no reasonable basis to conclude that the Metals Ban would have any effect on the risk of injury.[17]

In support of the Metals Ban, the NPR generally cites to the 2015 Fireworks Annual Report (the "2015 Report"), which identifies nine deaths and 1,200 injuries involving aerial devices that are commonly subjected to the Audible Effects Standard.[18] While these incidents are tragic, there is

[16] Howe, J., Memo re: APA 87-1 Harmonization Investigation (April 17, 2015) at p. 51 (citing Christopher Musto & Andrew Lock, Consumer Product Safety Commission, FY 2012 Fireworks Safety Standards Development Status Report (2013)).

[17] Although the NPR proposes a discretionary 1% allowance for contaminants, there is insufficient data to support that this allowance would adequately account for actual levels of contaminants. Likewise, there is no data to show an increase in the risk of injury above the proposed contamination allowance.

[18] Conspicuously absent from the NPR and briefing materials is any detailed analysis of injuries associated with aerial devices. While the CPSC does not need to sit back and wait to see whether injuries will arise related to a product; aerial devices have been sold on the market for years and data about related injuries is already available in the CPSC's

no evidence that the Metals Ban, if it had existed in 2015, would have prevented or reduced the severity any of these injuries.

Indeed, a review of the 2015 Report shows that the Metals Ban would have done nothing to reduce the risk of injury. Setting aside the fact that most injuries involved devices that would not be subject to the Metals Ban (such as sparklers[19]), more than half of all injuries were caused by misuse. The percentage of misuse increases markedly with the severity of the incidents. For example, each of the nine deaths related to aerial devices that were reported in 2015 involved misuse.[20] Seven of the nine incidents involved placing mortars (launch tubes) on chests or heads, instead of on a firm level surface like a concrete slab. Of the two other incidents, one involved a device that reportedly tipped over after being placed on gravel, instead of a solid surface, and the other involved looking down into a mortar when a device did not launch. Not only did these fatalities all involve misuse, but they also all appear to have been associated with blunt force trauma from impacts of shells propelled by *lift* charges, not burst charges. These incidents are tragic, and NFA strives to prevent similar incidents through consumer education and other means, but the Metals Ban would do *nothing* to prevent similar outcomes.

B. There is No Trend in Injuries Despite Significant Growth in the Market for Aerial Devices.

The market for aerial devices that would be subject to the Metals Ban has grown significantly in the past twenty years. Imports of consumer fireworks have nearly doubled, and at least eight states have opened up their markets to aerial devices during this time, to form a majority of states today that allow fireworks sales. For many NFA members, the past year was their best ever for sales of aerial fireworks. Yet despite this significant growth in the market for consumer aerial devices, there is no similar trend in injuries. As recognized by CPSC Staff:

> Staff has accepted, based on discussions with AFSL over the years, that the market for large, multiple-tube devices with shells exceeding 1.5 inches in diameter has expanded significantly from 1996 to the present day, *but the annual fireworks injury report does not find a statistically significant trend in injuries in that period.* Therefore, staff may consider the appropriateness of an approach to assume that the current market norms for the level of pressure released upon explosion of shells

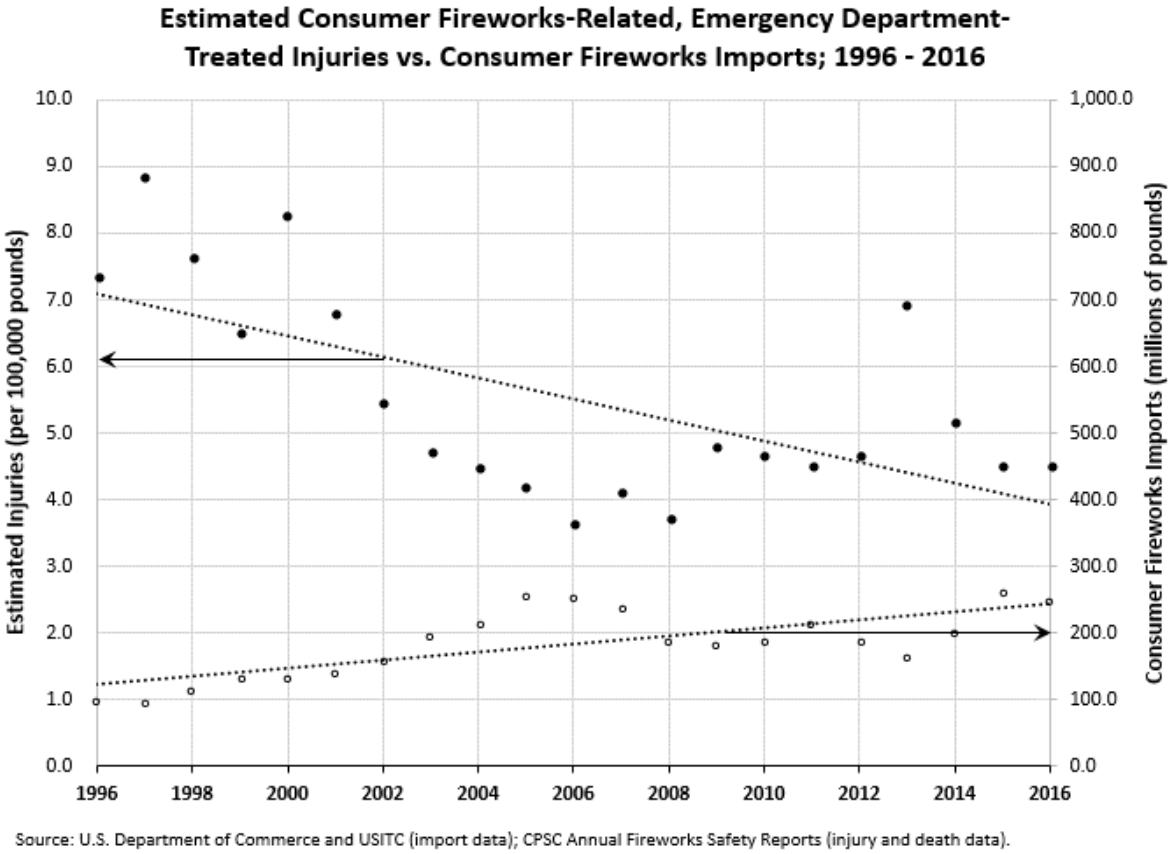
injury reports. An analysis of these reports, as explained in both this and the next section of these comments, demonstrates that there is no trend in injuries related to aerial devices, most of which injuries are caused by misuse.

[19] Curiously, although sparklers (which contain about 40% powdered metals by weight) consistently top the CPSC's injury lists, the NPR states that "[t]he Commission is omitting [sparklers] because, based on incident and injury data, the Commission does not believe these devices pose significant safety hazard to consumers to necessitate limits on their compositions." While one can speculate as to why the NPR carves out sparklers, regardless of motive, it demonstrates the capricious focus on powdered metals in the burst charges of aerial devices.

[20] The 2016 Injury Report, which was not available at the time the NPR was published, reports three fatalities related to aerial devices. This number of fatalities related to aerial devices during a year of historical sales of consumer aerial devices rebuts the notion that they have become unreasonably dangerous over time.

> typical to the marketplace is reasonable, and could be used to set guidelines on future pressure maximums.[21]

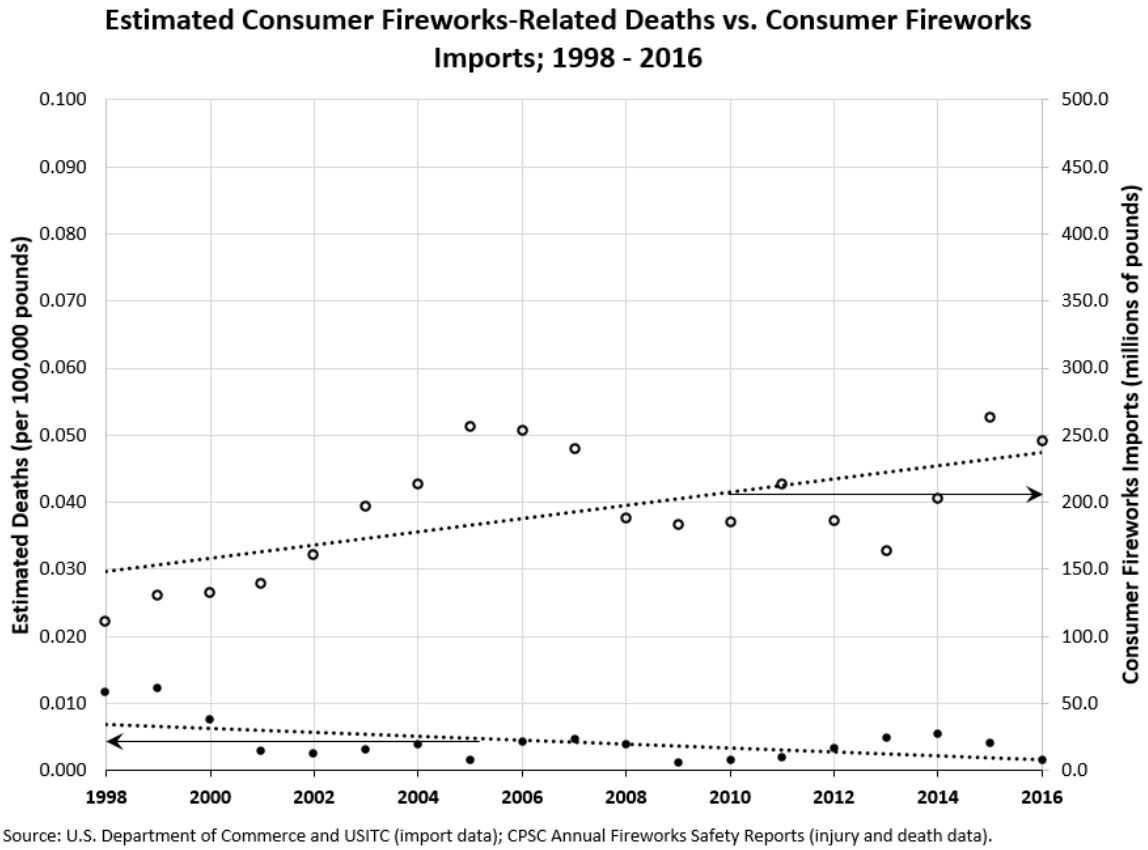
This observation by CPSC staff is supported by the CPSC's injury data from the 1999 to 2016 Fireworks Safety reports, which show no increasing trend in emergency department-treated injuries, relative to consumer fireworks imports, despite increased popularity of aerial devices, as demonstrated in graphs below:



Source: U.S. Department of Commerce and USITC (import data); CPSC Annual Fireworks Safety Reports (injury and death data).

As can be seen above, CPSC's compiled injury data actually indicate a *decrease* in the rate of injury relative to consumer fireworks imports during this time. Not only is there no apparent increased trend in emergency-department treated injuries, despite significantly increased consumer fireworks imports over the 1999 to 2016 period, there is also no apparent increased trend in fatalities, as the graph below shows:

[21] October 2013, Fireworks Safety Standards Development Project FY 2013 Status Report at 20-21 (emphasis added).



Similar to the decrease in the rate of emergency-department treated injuries, relative to consumer fireworks imports, CPSC's data indicate a *decrease* in the rate of fatalities relative to consumer fireworks imports during this time.

A review of the incident narratives from CPSC's 1999 to 2016 CPSC Fireworks Safety reports also shows that fatalities related to aerial burst charges are extremely rare. During those years, there were 128 fatalities reported related to consumer fireworks. Of those 128 fatalities, 39 (30.5%) involved consumer, aerial devices,[22] with only 3 fatalities (representing just 7.7% of all fatalities related to aerial devices, and 2.34% of total fireworks-related fatalities) apparently associated with the burst charges of those devices. The vast majority of fatalities related to aerial devices were likely associated with the lift charge, with the most common scenario being blunt force trauma from the impact of a shell. These fatal injuries attributed to blunt force trauma are nearly always the result of product misuse.

Of the 39 fatalities related to aerial devices, the vast majority (76.9%) involved misuse, most commonly with an individual holding a launch tube or device (often against a head or chest instead of setting it on a firm, flat surface), or not maintaining a safe distance at the time of ignition.[23]

[22] Excluded from this figure are any instances where the incident narratives indicate that the associated fatalities involved professional display fireworks, homemade devices, or fire.

[23] For example, incident reports included incidents where individuals looked down into launch tubes or attempted to drop already-ignited shells into launch tubes while positioning themselves above the opening of the tube.

In short, the injury data do not support the contention that the burst charges of consumer aerial devices are a significant factor in aerial consumer fireworks injuries, nor is there an apparent increased trend in injuries related to consumer fireworks. However, the injury data *do* show that the relatively low risk of injury related to aerial devices drops even lower with proper use. No safety justification exists for the Metals Ban in light of these data.

C. The Metals Ban Fails to Take into Account the Potential for Greater Injuries from Devices that Would Be Sold if the Metals Ban is Implemented.

While the Metals Ban would purportedly improve safety, it could actually increase fireworks injuries. A powerful, clean break for an aerial device is essential to ensuring safe performance. By reducing the energetic force of a burst charge, there would be less force to break apart the device's components. There would also be less heat to reliably ignite stars and other visual effects. Underperforming burst charges can be hazardous. Larger shell or shot casing fragments produced in less energetic bursts pose a fallout risk, and burning stars are more likely to reach the ground. Nowhere in the NPR or briefing materials is there an assessment of these risks.

There is also no assessment of the risk that decreased performance of consumer fireworks could lead to more injuries from homemade and professional fireworks. The CPSC injury data from 1999 to 2016 show that approximately a third of all fatalities related to consumer fireworks involved homemade or professional display fireworks. High-performing consumer aerial fireworks fill consumer demand for those items. If the performance of legal, properly designed consumer devices significantly decreases, more consumers may turn to homemade and professional fireworks, and more injuries and fatalities will likely result.

Finally, there has been no assessment of the risk that manufactures may turn to whistle compositions, which contain no powdered metals, for their burst charges. Whistle compositions are reasonably safe for the end-user when hydraulically compressed in paper or plastic tubes to produce pyrotechnic whistles and whistling rocket motors. As a loose powder, however, whistle compositions burn very rapidly and can function as a flash composition, producing a report even under modest confinement. An inquest on powdered metals may thus increase the risk of injury as manufacturers move to more dangerous pyrotechnic compositions.

VII. THE METALS BAN WOULD IMPOSE A HEAVY BURDEN ON BUSINESSES BECAUSE THE PROPOSED TESTING METHODOLOGY IS IMPRACTICAL

The Metals Ban would result in difficult and unreliable implementation. The $40,000 XRF Spectrometer used by CPSC not only results in unreliable errors, but is also unable to determine the composition of the burst charges of aerial devices.

A. The Metals Ban is Impractical Because the Proposed Testing Methodology is Expensive, Unreliable, and Error-Prone.

During the ninety-day extension in this comment period, NFA conducted an investigation of the efficacy of X-ray Fluorescence ("XRF") spectrometry for the accurate and precise detection and

quantification of aluminum (Al), titanium (Ti) and magnesium (Mg) in burst charges. The burst charges came from 100 consumer fireworks aerial devices, which included ball and canister shells, and shots from multi-shot cakes. The fireworks were obtained in May 2017 from diverse retail stores, as off-the-shelf items, and represent many brands and manufacturers. The fireworks were both AFSL approved (majority) and non-AFSL approved products.

Testing was performed using the same XRF device as employed by CPSC staff and in accordance with their most recent procedures. The XRF device was bought new on the market at the retail price of approximately $40,000. The testing revealed significant problems with the XRF analysis of powdered pyrotechnic compositions. The XRF spectrometer is very well suited for the determination (qualitative and quantitative analyses) of elements in solid samples. But analysis of *powdered* samples, especially those which contain finely divided metals, such as pyrotechnic compositions, are prone to quantitative errors because of particle size, inhomogeneity and segregation, and electrostatic charging effects. Not only is the testing prone to error, but even more expensive and complicated testing—Inductively Coupled Plasma-Optical Emission Spectroscopy ("ICP-OES") testing, which involves wet chemistry—would be required to provide confidence to any results obtained using XRF, especially for Mg and Ti.

A full copy of NFA's report is attached, but the salient point is that XRF fails to provide a reliable testing methodology for the Metals Ban. Importers and manufactures would not have confidence in the results they receive from XRF screening, and the cost and difficulty of the testing needed to verify results would be out of the reach of all but the largest companies.

B. The Metals Ban is Impractical Because the Proposed Testing Methodology Cannot Determine the Amount of Powdered Metals in a Burst Charge and Would Fail Devices Because of Contamination.

Another reason why the Metals Ban is impractical is that neither XRF nor ICP-OES can determine the powdered metals content of burst charges. Both are incapable of distinguishing between metals and compounds of those metals. For example, neither of these tests can distinguish between powdered aluminum (which can be used to increase the energy of a burst charge) and aluminum silicate (which is found in clay and used in the construction of most aerial fireworks).

The inability of XRF and ICP-OES to distinguish between powdered metals and compounds of those metals is a critical shortcoming because of the ubiquitous presence of metallic compounds that are used in constructing aerial devices. Aerial devices are constructed with numerous tightly packed materials like clay (which contains large amounts of aluminum silicates) and adhesives that contain metallic compounds. Metallic compounds are also found on anti-caking and flow agents that can be applied directly to burst charges. Metallic aluminum and magnalium are also often present in star compositions as fine particles with an average particle size of less than 149 microns (100 mesh) and might be present as high as 30% by weight (w/w) combined in total composition.

Because the testing methodologies that would be used for the Metals Ban cannot distinguish between metals and their compounds, or distinguish contamination in a break charge, there is no confidence in their results. The Metals Ban thus would fail to provide an enforceable standard as

there would be no way for companies to ensure their devices are in compliance, or for CPSC to test for compliance.

C. Even if the Metals Ban Were Adopted, a Higher Allowable Threshold for Metals Would Be Necessary.

The NPR asks for comments on an appropriate metals allowance under the Metals Ban. This is an important question because the language of the proposed regulation prohibits *any* powdered metals from being present in the burst charge of an aerial device. The NPR asserts that there will be a 1% *discretionary* allowance, but there would be no certainty for businesses that CPSC would exercise this discretion. It is thus critical for a reliable and fair standard that any allowance be included in the text of the regulation, and not cloaked in an unofficial, discretionary statement.

As for the allowable limit, 1% is an arbitrary threshold that lacks justification. As noted by other commentators who have performed testing of the actual performance of aerial devices, "[o]nly at five percent . . . did the force generated by the presence of metal in the break charge cause statistically significant increases in the recoil force generated by these fireworks."[24] Based on this testing, there is no basis for the proposed zero-metals prohibition or the 1% discretionary allowance.

Further, limiting the powdered metals in the burst charges of aerial devices will not reduce injuries as shown by the injury data discussed above. If CPSC were to adopt a permissible level of powdered metals, it should thus adopt a limit that reflects the current state of the market. NFA proposes a level of 15%, which level would reflect the current state of the marketplace, not harm consumers, and soften the burden on industry.

VIII. THE NPR LACKS AN ADEQUATE COST-BENEFIT ANALYSIS AND OVERLOOKS THE HARMFUL IMPACT THAT THE METALS BAN WOULD HAVE ON BUSINESSES

NFA urges CPSC to consider the disproportionately adverse impact that the Metals Ban would have on the smaller players in the firework industry. A decrease in the number or performance of aerial devices would decrease the demand for consumer fireworks, which would injure small businesses. These same businesses would have significant challenges to afford the expensive testing devices used by CPSC.

A. The NPR Fails to Consider How the Metals Ban Would Harm Businesses by Decreasing the Demand for Aerial Devices.

The NPR fails to consider whether a reformulation of aerial devices that have been sold for decades would have a severe impact on sales of those products. For many of NFA's members, aerial devices account for 50% of their total sales. Assuming, as CPSC has asserted, that those aerial devices have powdered metals in their burst charges to increase their performance, compliance with the Metals Ban would require eliminating all powdered metals. If performance is

[24] Comments of the American Fireworks Standards Laboratory (AFSL) and the American Pyrotechnics Association (APA) regarding Docket No. CPSC-2006-0034, dated July 17, 2017, at 9.

significantly decreased, stars may not travel far enough apart to create visual effects demanded by consumers, and ignition problems may result in more failed stars or require the use of stars with diminished visual qualities. This is especially true for smaller devices with relatively low amounts of pyrotechnic composition (such as the 200 grams cake shot shown above on page 7). There is no discussion in the NPR of the adverse impact this decrease in demand could have on American businesses.

B. The NPR Fails to Consider the Burden on Businesses that Would Arise From Trying to Comply with the Metals Ban Given the Shortcomings in the Testing Methodologies.

There has been no analysis of the inevitable cost to business of struggling to comply with the Metals Ban using expensive equipment that does not produce reliable results. As described above in the previous section, the testing methodologies that would be used for the Metals Ban are unreliable, error-prone, and expensive. In fact, CPSC has acknowledged in response to a FOIA request that it has no documents to show its cost-benefit analysis of the Metals Ban, or an analysis of the likely costs from false positives due to (i) inability of XRF and/or ICP-OES based testing to distinguish metals from their compounds and (ii) contamination that does not affect the explosivity of a burst charge. These costs must be considered in weighing the merits of the Metals Ban.

C. The NPR Fails to Consider the Unique Characteristics of the Fireworks Industry that Would Magnify the Harm to Small Businesses.

The NPR also does not take into account the unique nature of fireworks sales, which in many states is limited to a short sales window of only a few weeks out of the year. U.S. businesses that plan to sell fireworks must place their orders from factories abroad well in advance (often a full year ahead) of this narrow sales window to ensure on-time delivery. Virtually all aerial devices are imported, and there is little or no domestic stock to replace inventory that fails testing. U.S. businesses thus stand to suffer significant financial harm if their devices are prohibited by the Metals Ban. Not only do these businesses stand to lose their significant capital investment from the lost inventory, but there is no other inventory from which businesses can make sales. The financial harm mounts with the costs of permits, retail space, and other fixed expenses that cannot be avoided when there is not sufficient inventory. Because aerial devices account for half of all sales of many businesses, and because the Metals Ban would arbitrarily fail many of these devices simply because of flaws in the testing methodology, the financial harm from this proposed regulation would be severe.

The severity of the financial harm would be magnified for small businesses, many of which import only a few containers of fireworks each year. If those fireworks fail CPSC's testing, the importers lose their entire investment and have no means of replacing that inventory in time for the fireworks season. While large importers may be able to survive the loss of a container of fireworks (or hundreds of containers for the industry titans), a single container can put a small importer out of business. This is particularly true because these small importers often buy these fireworks on credit. So, when their containers are seized by CPSC, they not only lose their product but are then straddled with debt.

D. Optional DOT Regulations That Allow, But Do Not Require, Compliance with APA 87-1 Are Irrelevant in Weighing the Harm to Businesses.

It is irrelevant that the Department of Transportation's regulations allow for—but do *not* require—certification to the American Pyrotechnics Association's design standard (APA 87-1), which prohibits any powdered metals in the burst charges of aerial devices.[25] The DOT regulations do not excuse the CPSC of its obligations under the Federal Hazardous Substances Act and the Administrative Procedures Act to weigh the actual burden that the proposed ban would place on the American fireworks industry. CPSC's own testing shows that a majority of fireworks on the market today would fail, and thus CPSC must genuinely consider the state of the market in its cost-benefit analysis.

IX. SLM TESTING IS A LESS BURDENSOME ALTERNATIVE TO THE METALS BAN THAT LOOKS TO THE PERFORMANCE OF THE TESTED DEVICE

As a less burdensome alternative to the Metals Ban, NFA proposes that CPSC genuinely consider retaining the Audible Effects Standard that has been in place for fifty years and replacing the problematic Ear Test with sound level meter (SLM) testing. NFA appreciates the time and effort that the CPSC staff has devoted to trying to replace the Ear Test with a fair and reasonable standard, but the Metals Ban is not it.

NFA encourages CPSC staff to genuinely consider SLM testing as a viable alternative to the Ear Test. SLM testing is routinely used throughout the world for risk assessment of the hazards attendant the explosion of explosive devices. With an appropriate separation distance between the center of an explosion and an SLM, the energy output is acoustic (sound waves) and readily measured by the meter in impulse mode. In other words, SLM testing is a valid, quantifiable, and reproducible method for measuring the energy output of a fireworks explosion. For measuring the break of an aerial display device, multiple SLMs can be employed to increase the confidence in the sound level measurement.

An SLM based assessment for the Audible Effects Standard offers several promising advantages, including:

- SLM results account for all factors that contribute to the explosivity of a burst charge, not just the pyrotechnic composition;

- SLM testing instruments can record and digitally store multiple sound level measurements in dB in several alternate frequency responses (*e.g.*, A, C, linear) to account for not just the volume of sound but also the *quality* of the sound;

[25] Under 49 CFR § 173.56, approval for shipping of new explosives generally requires certain testing by an approved explosive test lab. As an alternative to these testing procedures, consumer fireworks may be approved under 49 CFR 173.65, which involves certification under APA 87-1. But this approval is *optional*; there is *no requirement* that all consumer fireworks must comply with the zero-powdered metals limit in APA 87-1.

- The threshold for passing or failing the SLM testing could be set at a level equivalent to the state of devices currently on the market that have proven safe through years of use;

- Test sites already used for conducting the Ear Test could be used for SLM testing;

- Even sophisticated SLM instruments that can account for variabilities (like ambient air temperature and relative humidity), and that can detect the *quality* of a sound, cost a fraction of the devices necessary for testing under the Metals Ban; and

- SLM testing allows the CPSC to design, in collaboration with outside expertise, standard procedures for sound level measurements of the burst charges of individual shells and even shots from normally functioning cakes. Once standard procedures are established, anyone, anywhere can follow the procedures and obtain a measurement with confidence that it will be in agreement with those recorded elsewhere.

Further, SLM testing could provide a mechanism for updating the Ear Test with less administrative burden. SLM testing could be used to identify the quality of sounds that fail under the current Ear Test through recording and statistical analysis of CPSC's trained testers. Assuming a consistent standard emerges from this testing, it could be used as the threshold pass/fail level for enforcement of the current Audible Effects Standard using SLM.

NFA welcomes the opportunity to work with CPSC and industry to develop standard procedures for SLM testing, including field protocol, testing conditions, equipment specifications, and threshold pass/fail levels with appropriate distances. The ease of accurate, reproducible testing would enable NFA's members and other manufactures, importers, and distributers, to use the standard procedures to ensure compliance.

Even if a solution to the Ear Test cannot be achieved through SLM testing, other less burdensome alternatives should be explored. For example, because the main source of grave injuries related to aerial devices is associated with recklessly holding a launch tube during use (often on top of a head or chest), adjustment of current warnings or enhanced consumer education may reduce injuries with little cost. CPSC should explore the efficacy of current warnings (including prominence, order, and language) to see if a simple change in wording and formatting may achieve the shared goal of reducing injuries.

X. NFA's COMMENTS ON OTHER PROPOSALS IN THE NPR AND RESPONSES TO SPECIFIC QUESTIONS

NFA does not oppose most of the proposals in the NPR because, even if the link to reducing the risk of injury is tenuous for many, they are unlikely to pose significant burdens on the fireworks industry. NFA's position on each one follows:

A. Limit the Chemical Composition and Pyrotechnic Weight.

Although there is no data showing these limits would improve safety, NFA does not oppose them because they are unlikely to place a significant burden on the fireworks industry.

B. Add Hexachlorobenzene (HCB) and Lead Tetroxide and Other Lead Compounds to the List of Prohibited Chemicals.

Although there is no exposure data, NFA does not oppose these prohibitions because of the nature of the chemicals and because there is unlikely to be an adverse impact on the fireworks industry.

NFA supports a limit of 0.25% for prohibited chemicals, with the exception of a 0.01% limit for HCB. These trace amounts are unlikely to pose any significant safety risk given the use of fireworks and unlikeliness of any significant exposure.

C. Adopt a Test Method to Evaluate Side Ignition of Fuses.

NFA does not oppose this proposal.

D. Require Bases to Remain Attached to Devices.

NFA does not oppose this proposal.

E. Prohibit Devices From Projecting Fragments When Functioning.

NFA does oppose prohibiting devices from projecting fragments, but encourages clear and precise criteria for what fragments are prohibited. Size, hardness, and other factors should be considered in setting this standard as the APA standard lacks clarity.

F. Provide New Definitions.

(i) **Aerial Bomb –** NFA does not support the proposed definition because it fails to track the historical definition of powerful devices that were not intended to produce only an audible effect.

The term should be left in 16 CFR § 1500.17(a)(3) because it is a useful example of the types of devices that the regulation was intended to address.

(ii) **Base** – NFA does not oppose.

(iii) **Blowout** – NFA does not oppose.

(iv) **Burnout** – NFA does not oppose.

(v) **Burst Charge –** NFA does not oppose this definition, which takes only the

first two sentences from the definition found in APA 87-1. NFA would strongly oppose adoption of the rest of the definition for the same reasons that it opposes the Metals Test.

(vi) **Chemical Composition** – NFA does not oppose.

(vii) **Explosive Composition** – NFA does not oppose.

(viii) **Firecrackers** – NFA does not oppose.

(ix) **Lift Charge** – NFA does not oppose, provided it applies to all aerial devices, including shells, shots, mines and comets.

(x) **Pyrotechnic Composition** – NFA recommends adoption of the following definition: A mixture of elements or compounds that is capable of a self-contained exothermic reaction, for the production of heat, light, gas, smoke, propulsion and/or sound.

G. Effective Date of New Regulations.

NFA welcomes a transition from the Ear Test, but urges CPSC to be mindful of the timing for implementation of any new requirements. Fireworks devices are ordered 8 to 12 months in advance of the anticipated sell-date. If a final rule becomes effective immediately after publication, small companies could be driven out of business by failures of devices ordered before the rule was in effect. The NPR does not serve as adequate notice to industry members, as there is no certainty as to when or whether a final rule will be promulgated. Therefore, to ensure compliance and protect the members of the industry, the minimum effective date for any final regulation that results from this NPR must be at least one year from publication.

XI. CONCLUSION

NFA appreciates the hard work and dedication of CPSC and its staff in attempting to improve fireworks regulations in the United States. Consumer safety is a noble goal that is shared by NFA. For this reason, NFA intends to continue to engage with CPSC and other industry organizations to promote the fair and reasonable regulation of consumer fireworks.

Because the Metals Test would hurt the fireworks industry without improving safety, NFA urges CPSC to withdraw its proposal and continue its search for a reasonable replacement for the vexing Ear Test. It is critical that any test ultimately adopted preserve the popular devices that have been enjoyed by consumers for decades and that have proven safe with proper use.

Thank you in advance for your consideration.

Sincerely,

Nancy Blogin
Executive Director
National Fireworks Association

Supplement to Comments of the National Fireworks Association on the Notice of Proposed Rulemaking, Amendments to Fireworks Regulations, 82 Fed. Reg. 9012, dated 17 July 2017

An initial investigation of the use of XRF spectrometry to determine powdered aluminum, titanium and magnesium in consumer fireworks burst charges

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Executive Summary

This report provides the results of a short term investigation of the efficacy of XRF spectrometry for the accurate and precise detection and quantification of aluminum (Al), titanium (Ti) and magnesium (Mg) in burst charges. The burst charges were extracted from 100 consumer fireworks aerial devices, which included ball and canister shells, and shots from multi-shot cakes. The fireworks were obtained in May 2017 from diverse retail stores, as off-the-shelf items, and represent many brands and Chinese manufacturers. The fireworks were both AFSL approved (majority) and non-AFSL approved products.

The testing revealed significant problems with the XRF analysis of powdered pyrotechnic compositions. The XRF spectrometer is very well suited for the determination (qualitative and quantitative analyses) of elements in solid samples. However, analysis of powdered samples, especially those which contain finely divided metals, such as pyrotechnic compositions, are prone to significant quantitative errors because of particle size inhomogeneity and segregation, and electrostatic charging effects. Although the actual powdered metal content of the 100 samples tested is unknown, there is little confidence in the values from XRF testing for the aluminum, titanium and magnesium in the burst charges.

The instrument used in the investigation is the same make and model which the CPSC employs, namely, a Thermo Fisher Scientific, Niton XLt3 950 GOLDD+, augmented with the matching portable test stand, and the same Premier Lab Supply, SC-4331 XRF Sample Cells (cups) and TF-240-255 polypropylene XRF Thin films (cell windows). The XRF spectrometer was operated in the Mining Cu/Zn Mode and 240 second scans were conducted. Standards used to evaluated the performance of the instrument included high purity solid metal samples of aluminum (99.999%), titanium (99.99%) and magnesium (99.95%), and powdered metal samples of aluminum (99.95%, <75μm), titanium (99+%, <45μm) and magnesium (99.5%, -325 mesh).

In strict accordance with the CPSC's most recent test procedures, each aerial device (projectile) selected from the fireworks was carefully opened to expose the mixture of stars and burst charge. Any of the burst charge seen by eye to be contaminated with clay or other non-pyrotechnic materials was removed. The remaining comingled stars and burst charge was transferred to a 100 mesh sieve and screened. The burst charge which passed the screening was transferred to a windowed XRF cup and then irradiated by the XRF spectrometer for the elemental analysis. No other steps in the sample preparation, including drying or homogenization, were employed.

The 100 burst charges tested provided the following results.

(1) The aluminum content varied from 0.0 to 35.77% w/w (by weight). The mean (average) is 8.04% w/w, and the median is 2.37% w/w.
(2) Ninety five percent (95%) of the burst charges had aluminum measurements exceeding 0.1% w/w Al, 55% exceeded 1.0% w/w Al, and 42% exceeded 5.0% w/w Al.
(3) The titanium content varied from 0.0 to 16.37% w/w, with the mean of 0.75% w/w and the median, 0.02% w/w.
(4) The magnesium ranged from 0.0 to 6.28% w/w with the mean and median of 0.47 and 0.0 % w/w, respectively.

Because of the nature of powdered pyrotechnic compositions, having varying particle sizes subject to segregation, and components affected differently by electrostatic charging, the use of XRF spectroscopy for the determination of powdered metals in burst charges is prone to errors. These errors reduce substantially the confidence in the accuracy of the analyses.

Introduction

Provided in this report are the results of a short term investigation of the efficacy of XRF spectrometry for the accurate and precise detection and quantification of aluminum (Al), titanium (Ti) and magnesium (Mg) in burst charges. The burst charges were extracted from 100 consumer fireworks aerial devices, which included ball and canister shells, and shots from multi-shot cakes. The fireworks were obtained in May 2017 from diverse retail stores, as off-the-shelf items, and represent many brands and Chinese manufacturers. The fireworks were both AFSL approved (majority) and non-AFSL approved products.

The identical make and model of XRF spectrometer, accessories, and the current test procedures known to be used by CPSC staff for burst charge analysis were employed in this investigation.

Experimental

A Thermo Fisher Scientific, Niton XLt3 950 GOLDD+ XRF Spectrometer was used, augmented with the matching portable test stand, and Premier Lab Supply's, SC-4331 XRF Sample Cells (cups) and TF-240-255 polypropylene XRF Thin films (cell windows). The spectrometer was operated in the Mining Cu/Zn Mode and two, 120 second scans (240 seconds total) were conducted. The filter settings were; Main filter - 30 sec., Low filter - 30 sec., and Light filter - 60 sec.

Standards used to evaluated the performance of the instrument included high purity solid metal samples of aluminum (99.999%, Sigma Aldrich 266574-25 cm^2), titanium (99.99%, Sigma Aldrich 348813-1), and magnesium (99.95%, Solution Materials MG-R-1.18.13), and powdered metal samples of aluminum (99.95%, <75µm, Sigma Aldrich 202584), titanium (99+%, <45µm, United International Research) and magnesium (99.5%, -325 mesh, Sigma Aldrich 465666-50G). All the metals were used as received unless otherwise indicated.

A set of eleven, surrogate pyrotechnic compositions, comprised of the high purity powdered Al admixed with analytical reagent grade, potassium chloride (KCl, 99.0-100.5%, Sigma Aldrich P3911-1KG) was prepared as XRF standards. The KCl was ground in a glass mortar and pestle to a powder which passed a 100 mesh screen. Both the Al and the KCl were dried in a laboratory oven at 105°C for 4 hours before the

5 g mixtures of the two were prepared. The mixtures of Al/KCl contained 0.00, 5.00, 10.00, 15.00, 20.00, 25.00, 30.00, 35.00, 40.00, 45.00 and 50.00% w/w (by weight) Al. Each of these 5 g mixtures was transferred without additional sieving to a XRF sample cup and capped.

A burst charge, which would be allowed in 1.4G fireworks in many EU member countries, containing 1.2 g of a 70% w/w potassium perchlorate($KClO_4$) – 30% w/w aluminum (<45μm) flash composition admixed with 8.8 g of 3F black powder was prepared. This burst charge thus contained 3.6% w/w Al. The entire 10g uniform mixture was sieved on a 100 mesh screen. The powder which passed, predominantly flash composition, was transferred to an XRF cup and capped.

In strict accordance with the CPSC's most recent test procedures, each of the 100 aerial devices (projectiles) selected from the consumer fireworks was carefully opened to expose the mixture of stars and burst charge. Any of the burst charge seen by eye to be contaminated with clay or other non-pyrotechnic materials was removed, using a micro-spatula, tweezers or paintbrush. The remaining comingled stars and burst charge was transferred to a 100 mesh sieve and screened. The burst charge which passed the screening was transferred to a windowed XRF cup and capped. No other steps in the sample preparation, including drying or homogenization, were employed.

Results and Discussion

The XRF analyses of the solid metal standards of Al, Ti and Mg provided results very close to the assays reflected in the certificates of analysis. For example, frequent scans of the solid Al, Ti and Mg, typically showed 99+% purity. While scans of the powdered Al standard showed a 99+% purity, the scans of the powdered Ti and Mg resulted in low measured purities, with the Ti in the range of 70-77% and the Mg at 60-65%. The reason(s) for the low measured purities of the titanium and magnesium is unknown.

The 100 burst charges tested provided the following results.

(1) The aluminum content varied from 0.0 to 35.77% w/w. The mean (average) is 8.04% w/w, and the median is 2.37% w/w.

(2) Ninety five percent (95%) of the burst charges had aluminum measurements exceeding 0.1% w/w Al, 55% exceeded 1.0% w/w Al, and 42% exceeded 5.0% w/w Al.

(3) The titanium content varied from 0.0 to 16.37% w/w, with the mean of 0.75% w/w and the median, 0.02% w/w.

(4) The magnesium ranged from 0.0 to 6.28% w/w with the mean and median of 0.47 and 0.0 % w/w, respectively.

The Al, Ti and Mg content in the burst charges results is surprising high, considering the majority of the products are AFSL approved.

To better understand how the powdered state of the burst charges could affect the XRF analyses, the set of eleven mixtures of Al/KCl were scanned. In the figure below is a plot of the accurately known composition (x-axis) versus the XRF measurement for each 5g sample (y-axis). When the standard 5.00% w/w Al sample measured at 25.29%, it was obvious the powdered state and the sample cup were contributing to an erroneous measurement of the Al content. The remaining nine, non-zero percent Al samples also manifested this behavior. While the 5g powdered samples of the Al/KCl mixtures showed an increasing darkening in the shade of grey corresponding with the Al content, when the powders were transferred to the cups, the appearance of the powder directly in contact with the interior surface of the

polypropylene window showed little variation. In fact, the powdered Al appeared to dominate the powder layer in direct contact with the window.

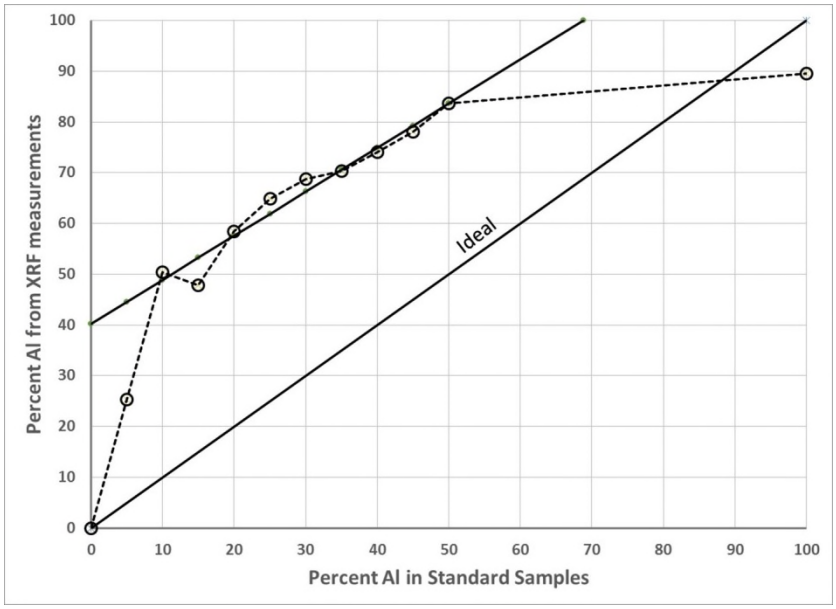

Figure – A plot of the percentage by weight of powdered aluminum in a mixture with potassium chloride (standards) versus the percentage of aluminum determined by XRF measurements.

Two phenomena are at play. First, although the KCl was pulverized by grinding in a mortar and pestle, the average particle size was larger than that of the Al. This size difference, an inhomogeneity, will normally by gravity settlement result in the Al segregating and concentrating at the bottom of the cup. The bottom of the cup is, of course, the interior surface of the polypropylene window. Second, the polypropylene film is very easily electrostatically charged. The mere separation of the 4 μ thick film from the protective paper backing sheet, charges the film's surfaces. As polarizable conductors, the powdered Al particles will be strongly attracted to a charged polypropylene film surface. This would also be the case for other film materials, e.g., Mylar.

Both the particle segregation and the electrostatic charge attraction result in a pronounced concentrating of Al powder at the film's interior surface. Because the XRF spectrometer's irradiation or penetration depth is limited to about a mm at most, it will be the powder closest to the window which will provide the basis for the analysis. For the Al/KCl standards, the high Al content in the powder layer in contact with the windows resulted in Al percentages which did not reflect the bulk concentration. To demonstrate the effect of electrostatic attraction of the Al to the interior surface of the window, approximately 2 g of the high purity Al powder was transferred to a cup. Then the powder was poured out leaving behind a very thin layer of Al clinging to the window. From the exterior, the layer appeared to be a fairly uniform dusting. A scan of this thin layer resulted in a measurement of 99.75% Al. Not only does this demonstrate the role of electrostatic attraction, but it also brings into serious question the need for 5 g burst charge samples. It is noteworthy that the 5 g, 100.00% Al standard measured 88.59% Al.

The XRF analysis of any pyrotechnic composition containing powdered metals will be adversely influenced by one or both phenomena. Grinding a burst charge in an attempt to achieve particle size homogeneity and minimize segregation is dangerous and should not be included in any test procedure.

The use of ionizers (high voltage or radioisotopic) to neutralize any electrostatic charge on the film, will certainly reduce the surface charge, but the transfer of pyrotechnic powder into the cup, will likely triboelectrically reestablish the charge on the interior window surface. The use of a high voltage ionizer proximate to a burst charge is also dangerous. Although Compton scattering may be present in the powdered burst charge samples, it, as well as any spectral line interferences are likely minimal.

The XRF analysis of the 1.2 g of $KClO_4$/Al flash powder separated by screening through a 100 mesh sieve from the admixed, 8.8 g of 3F black powder, resulted in a measurement of the Al at 55.21%. The aluminum content in the flash composition was 30.00% w/w and only 3.6% w/w in the original burst charge. The particle size segregation coupled with electrostatic attraction played a principal role in the erroneous determination.

Conclusions

Because of the nature of powdered pyrotechnic compositions, having varying particle sizes subject to segregation, and components affected differently by electrostatic charging, the use of XRF spectroscopy for the determination of powdered metals in burst charges is prone to errors. These errors reduce substantially the confidence in the accuracy of the analyses.

Based upon the results of this initial investigation into the efficacy of XRF spectrometry for the accurate and precise detection and quantification of aluminum (Al), titanium (Ti) and magnesium (Mg) in burst charges, it is not well-suited for the quantification of the powdered metals.