July 17, 2017

Mr. Todd Stevenson
Office of the Secretariat
U.S. Consumer Product Safety Commission
4330 East West Highway
Bethesda, MD 20814

Re: Comments of the American Fireworks Standards Laboratory (AFSL) and the American Pyrotechnics Association (APA) regarding Docket No. CPSC-2006-0034, Notice of Proposed Rulemaking, "Amendments to Fireworks Regulations," 016-0020 (herein "NPR")

Dear Mr. Stevenson:

The American Fireworks Standards Laboratory (AFSL) and the American Pyrotechnics Association (APA), representing the large majority of U.S. companies involved in the manufacture, importation, distribution and sale of consumer fireworks, appreciates the opportunity to submit these comments in strong support of the Commission's Proposed NPR, with the modifications and clarifications specified herein. Fireworks hold a unique place in the history, patriotism, and family gatherings of the United States and American families, and have throughout the history of our great nation. When used properly, legal consumer fireworks are safe and enjoyable, and it is safety that is at the core of our respective organizations' missions and activities.

The CPSC and its mandatory consumer fireworks safety standards have likewise been critical to ensuring that fireworks remain safe for American consumers. However, there have been no major revisions to CPSC's mandatory consumer fireworks safety standards for many years, during which time the demand for fireworks has increased and the variety and types of fireworks made and sold to consumers have changed considerably. The CPSC, the U.S. fireworks industry and, most importantly, the American consumer would all benefit greatly by the modernization of CPSC's standards that the NPR represents, again with the relatively minor changes suggested.

Not only does the NPR include a number of provisions that are already part of mandatory federal law (the Department of Transportation's APA 87-1 "Standard for the Construction and Approval for Transportation of Fireworks, Novelties and Theatrical Pyrotechnics,"[1]) but also that

[1] Available at: http://www.americanpyro.com/assets/docs/PHMSADocs/apa%20stand%20%2087-01.pdf

are contained in the widely followed and frequently updated AFSL "Standards for Consumer Fireworks."[2] Thus, while the large majority of U.S. fireworks companies and consumer fireworks currently do comply with the provisions of the NPR, its inclusion into CPSC's mandatory standards would do much to create a fair and level regulatory playing field for all makers, importers and sellers of fireworks. More importantly, final approval of the NPR, modified as suggested, will help ensure that fireworks continue to be safe and enjoyable for American consumers.

I. Overview of AFSL and APA

The American Fireworks Standards Laboratory (AFSL) was established in 1989 as an independent, non-profit and voluntary standards development and product testing and certification membership organization. Through its Consumer Fireworks Standards Committee, with representation from governmental, consumer and industry entities and individuals, AFSL establishes and maintains comprehensive performance, content and labeling standards for consumer fireworks. These regularly updated standards are able to nimbly adjust to changes in both consumer fireworks product trends and hazard issues as they arise and include all current mandatory CPSC and APA/DOT (87-1) consumer fireworks standards relevant to the consumer use of fireworks. Because AFSL standards go well beyond those established and enforced by either the CPSC or DOT, AFSL believes its standards greatly contribute to the overall safe use and enjoyment of consumer fireworks in the U.S. And AFSL has appreciated the contribution over the years CPSC staff have made to this process as non-voting members of its Standards Committee.[3]

Moreover, AFSL ensures that all fireworks imported into the U.S. by its members are thoroughly tested and certified by an independent, CPSC-recognized laboratory (currently Bureau Veritas) as meeting all applicable AFSL (including CPSC) standards prior to their shipment to or sale in the United States. Fireworks that fail to comply with AFSL standards may not be imported by the participant (AFSL member) importer, under the terms of the agreements they enter into with AFSL. AFSL estimates that 85 to 90 percent of all consumer fireworks imported into the U.S. are AFSL tested and certified.

The American Pyrotechnics Association (APA) was established in 1948 by a group of seven fireworks manufacturing companies that recognized the need to unite in order to effectively face industry-wide issues. As the nation's oldest fireworks trade group, the APA represents the entire fireworks industry – professional display, consumer and proximate pyrotechnic manufacturers, importers and distributors, domestic and foreign, companies large and small that share a dedication to the APA's principal goals of safety and compliance. Through its ongoing advocacy, compliance assistance, education and training, and public

[2] Available at: http://www.afsl.org/sites/default/files/AFSL%20Standards%2C%202017-02.pdf

[3] AFSL in particular would like to take this opportunity to suggest to the CPSC that it approve one voting member of the AFSL Standards Committee, as the Commission recently voted to allow staff to do on voluntary standards committees generally. AFSL believes that doing so would further enhance the AFSL standards development process and of course would give the agency a stronger voice in that process, which AFSL enthusiastically welcomes.

relations activities, the APA has become the face of the fireworks industry both domestically and abroad, strengthening the image of the industry and increasing confidence in its products among regulators, the media, and the general public.

In addition, APA oversees the development and maintenance of the APA Standard 87-1, "Standard for the Construction and Approval for Transportation of Fireworks, Novelties, and Theatrical Pyrotechnics." This standard is also incorporated by reference into mandatory U.S. Department of Transportation (Pipeline and Hazardous Materials Safety Administration) (DOT-PHMSA) regulations.[4] These standards, while in many instances covering many of the same consumer fireworks safety issues as AFSL standards, are intended to address the safe transport of consumer (and other) fireworks within the United States.

Combined, AFSL, APA and, of course, CSPC and DOT safety standards provide American consumers with a level of fireworks safety unmatched in the world.

II. <u>NPR Background</u>

These comments build upon those submitted in 2016 by AFSL and APA in connection with Docket No. CPSC-2016-0020, "Statement of Policy on the Commission's Interpretation of Intent to Produce Audible Effects . . . " ("SOP"). That SOP proposed to interpret the ban on fireworks that are "intended to produce audible effects" (16 C.F.R. § 1500.17(a)(3)) as effectively banning aerial fireworks (mine and shell and reloadable devices) with break or burst charges that contain fine mesh metallic powders, if the total pyrotechnic composition exceeds 2 grains (130 mg).[5] Such an interpretation would have been consistent with existing provisions of both AFSL and APA/DOT standards. More importantly, it would have signaled the end of the long-standing "sound" or "ear" test method by which the CPSC has determined compliance with the ban on fireworks intended to produce audible effects.

The present NPR builds upon this proposed SOP, and in fact strengthens it by proposing to <u>replace</u> the "no audible effects" standard (the most frequently CPSC-cited significant violation of mandatory standards)[6] with a new provision (§ 1500.17(a)(3)(i)) banning fine mesh (below 100 mesh, or 149 microns) metal powders in the break charge composition of mine and shell devices (§ 1500.17(a)(14)(i)(B)) and aerial shells with reloadable tubes (§ 1500.17(a)(14)(i)(B)), again only if the burst charge exceeds 2 grains of total pyrotechnic composition (which the large majority of such devices do). AFSL and APA are even more supportive of these proposed new provisions of CPSC mandatory fireworks regulations, since they would establish clear, overt and objective regulatory criteria for the importation and sale of consumer fireworks.

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[4] *See* 49 C.F.R. 173.56.

[5] While reference is sometimes made to this two grain threshold of the standard as indicating that it therefore an "objective" and not a "subjective" standard, notice should be made of the fact that, today, virtually <u>all</u> aerial fireworks (the category of fireworks most relevant to the NPR), do in fact contain in excess of two grains (130 mg) of total pyrotechnic composition.

[6] *See* "Fireworks Rule Review Briefing Package," December 30, 2015, p. 14, noting that "between October 2005 and October 2014 [CPSC] staff identified 495 violations . . . the highest of any CPSC fireworks regulation requirement during this timeframe."

In addition, the NPR proposes a number of important new mandatory CPSC standards for fireworks, drawn largely from either/both AFSL and/or APA/DOT safety standards. These regulatory proposals grew from the hard work of many dedicated CPSC staff in undertaking a regulatory review over the last few years of the agency's mandatory fireworks standards, culminating in the December 2015 "Fireworks Rule Review Briefing Package."

AFSL and APA have been pleased to have had an ongoing and positive dialogue with both CPSC staff and commissioners during the development and consideration of these various proposals, and we look forward to continuing that proactive dialogue as the NPR becomes finalized and implemented, including via these present comments.

III. Proposed Ban on Fine Mesh Metals in Break Charges of Aerial Devices

A. Background

1. Existing Safety Standards for Aerial Devices.

First, it should be well noted that addressing the potential consumer hazard of an overly energetic break charge is far from the only means now utilized by our members to address the safety of consumer aerial fireworks. As the CPSC is well aware, for many years AFSL and APA/DOT standards have had a number of other, key standards provisions that have helped to greatly reduce the risk of consumer injury in this regard. Indeed, a number of these standards are being proposed to at long last be adopted by the CPSC as well, and our organizations fully support that effort, as set-forth herein. Notably (with some differences between AFSL and APA standards) those include:

- 10 g limit for total break charge composition;
- Prohibition on break charge composition exceeding 25% of total composition weight for reloadable tube aerial devices/50% for mine and shell devices;
- 60 g total pyrotechnic limit for reloadable tube aerial devices;
- 200g (single tube)/500g (multi-tube) total composition limit for mine and shell devices (or 200g limit, depending on device type);
- 20 g composition limit for lift charge for reloadables/ 12 g for mine and shell devices;
- Total composition limit of 400 g for reloadable tube shell retail packages;
- Prohibited chemicals list;
- Aerial devices must function at apex of flight;
- No shrapnel or flaming debris may emit from aerial devices upon functioning;
- 60 degree tilt test for reloadable tube and multi-tube mine and shell devices;
- Base attachment requirement;
- Fuse burn time requirements (and fuse orientation standard for reloadables);
- Tube integrity test for reloadables (upside-down shell function and no blow-out);
- Various cautionary labelling requirements; and
- Miscellaneous other safety standards and requirements.

Combined, these provisions help ensure that aerial devices, an increasingly popular segment of the consumer fireworks market, are safe for consumers to use and enjoy.

2. "No Audible Effects" CPSC Standard.

In order to determine compliance with § 1500.17(a)(3), the CPSC has utilized what it terms the "calibrated sound test," or what is sometimes referred to as the "ear test," whereby aerial fireworks that exceed 2 grains in composition are functioned and a qualified CPSC technician listens to the qualitative sound produced by the break charge of the device. If the device produces what is commonly referred to as a "report" (a sound determined to produce an intentional, as opposed to an incidental sound from the break charge), it may be deemed to be in violation of the standard and therefore subject to seizure and destruction, typically at its port of entry.[7]

While this test method to determine compliance with § 1500.17(a)(3) does have an objective component to it, *i.e.* that the break charge must contain at least 2 grains of composition before the ear or sound test is applied, there can be no doubt but that the sound test is inherently subjective and prone to variation in outcomes, depending on several factors.

First, of course, is the inherently subjective and variable nature of human perception (hearing). While CPSC staff have been trained to identify only certain levels and quality of break charge sounds as being in violation of the audible effects standard, there can be no doubt but that two people trained to listen for the same threshold of sound may well come to different conclusions about whether or not a given product is violative. AFSL for one has worked for years to anticipate and duplicate the results obtained by the CPSC, working in close cooperation with agency staff, but with nevertheless limited success. Well-trained AFSL testing technicians in China have passed products using sound test, only to have those products failed by CPSC fireworks testing staff.

Indeed, it was this inherent subjectivity and lack of certainty that led AFSL to adopt to additional, more objective test procedures to try and determine which aerial devices may in fact present an overpressure hazard from the break charge: the so-called steel ball test (wherein the pressure from an aerial device is measured by the distance it causes a steel ball to move up a testing apparatus), and the "float" test, to determine the presence of fine mesh metal powders in break charge compositions, which violates AFSL standards since such powder—typically aluminum--can significantly increase the energetic effect of a break charge and therefore pose a potential consumer hazard. (These AFSL standards are of course are <u>in addition</u> to those addressing the safety of aerial fireworks in many other ways, as delineated below).

The second major source of variability is environmental conditions that may affect the way a given firework device is perceived with regard to sound, even assuming consistent

[7] As the NPR "preamble" (summary) explains, "This involves staff listening for a sound and assessing whether that sound has the qualities characteristic of an intentional effect. It is not the noise level that is determinative; rather staff listens for a crisp sharpness that is related to the pressure pulse associated with the ignition of flash powder. If staff hears this 'loud report,' then they weigh the pyrotechnic material in the break charge (which causes the audible effect) to determine whether it exceeds the 2-grain limit." 82 Fed. Reg. 9012, 9015 (February 2, 2017)

perception by the tester. Higher humidity levels (like those often found in the fireworks production areas of China) typically muffles sound. Even the particular geography, altitude, time of day or heat level of the test site can affect both the perception of the sound generated by a device, as well as the actual sound itself.

Finally, inherent variability in individual products within a given lot, or between different lots of ostensibly the same product can lead to varying results in testing outcomes. Most consumer fireworks sold in the U.S. are largely hand-made in China, and thus can vary significantly from individual item to item. Moreover, raw material components of fireworks can and do vary as well, including powders, packaging materials and other components. And the moisture level of fireworks typically will change as the products are made, stored and shipped to the U.S., causing further variation in the characteristics of the devices over time.

All of these factors combine, then, to make it difficult to say the least for AFSL or any other testing entity to consistently obtain the same results as the CPSC with regard to the audible effects standard. Thus, our organizations have for years sought to replace the sound test with a more objective and reproducible test method, which the NPR clearly represents.

AFSL and APA would like to additionally emphasize that, no matter what test method is used to determine whether or not an aerial firework device is "overloaded," and thus presumably presents an unacceptable, potential hazard to consumers, it is the energetic or explosive effect of the device that is at issue, not whether it produces a certain sound, contains metallic powder, or any other surrogate characteristic. The problem of course is that, without exhaustive, correlative testing, likely including the use of human models, it is impossible to determine the appropriate limit of the energetic effect of a break charge, and no such testing and evaluation has to date been undertaken.[8]

Thus, this standard, like virtually all consumer fireworks standards (and, for that matter, product safety performance standards generally) are essentially informed estimates of product characteristics that are more likely than not to pose an unacceptable risk to consumers through normal use and foreseeable misuse. AFSL and APA understand this reality, and so we have sought and will continue to seek reasonable standards—both voluntary and mandatory--that address legitimate safety objectives, <u>and</u> that establish objective, repeatable and practical test methods that our respective members can employ to determine the compliance of the consumer fireworks they import and sell. Replacing the ear test with our (AFSL/APA) existing prohibition on fine mesh metals in break charge compositions represents in our view a dramatic step forward in this regard, for a CPSC standard that has resulted in numerous product seizures over the years, at the cost of millions of dollars in lost product and revenue for our members.

[8] We would note in this regard that some commenters to the 2016 SOP had advocated for the CPSC to retain the "no audible effects" standard, but utilize an "objective" sound level meter test method to determine compliance. While we anticipate that the CPSC will more fully address this issue in the final NPR staff package, we note that both the CPSC and AFSL have examined the feasibility of such a test method in the past and have come to the same conclusion: that the many variables involved in such a test procedure would essentially trade one set of problems for another and would not likely result in the main objective at issue, to be able to reliably obtain in the field the field the same test results as those obtained by the CPSC when it tests consumer fireworks.

B. APA/DOT 87-1/87-1A

As noted, APA 87-1 is a set of safety standards for both consumer ("1.4G") and display ("1.3G") fireworks that are the same or similar in many respects to both CPSC mandatory and AFSL voluntary standards. Although a voluntary standard on its face, the Department of Transportation (DOT, via the Pipeline and Hazardous Materials Safety Administration, PHMSA) incorporates 87-1 into its mandatory regulations governing the transportation of fireworks, and compliance with these standards is required in order to obtain an "explosives approval" or "EX" number to legally transport such products in the U.S. While both the AFSL and APA Standards Committees monitor the activities of the other, and tries when possible to adopt compatible standards, they do differ in some respects, in part owing to their different orientation, i.e., the former focuses on consumer safety and the latter primarily on transportation safety.

Thus, with respect to the composition of break (burst) charges in aerial consumer fireworks, while there are slight differences between the relevant provisions of both standards, both effectively ban the presence of fine (below 100) mesh metallic powders break charges.[9] It should also be noted that both standards (as well as CPSC mandatory standards) have lists of chemicals that are prohibited from all consumer fireworks, notably including aluminum and titanium, which may be used in fine mesh form to increase the energetic effect of a break charge.

However, APA 87-1 is currently undergoing revision, to culminate in a new 87-1A Standard expected be finalized in the near term, and that in turn is expected to be incorporated into mandatory DOT regulations and standards. Although the process is ongoing, 87-1A is likely to include a provision to limit fine mesh metals in break charge composition in a way that would be identical or at least wholly consistent with what AFSL and APA are herein advocating (a two percent limit of such powders). Thus, any concern about having potentially conflicting DOT and CPSC standards does not, at this point, appear to be founded. .

C. Need for two percent metals regulatory level, with variability allowance

The NPR proposes to ban the presence of fine mesh metals in the composition of break charges. However, both the CPSC staff and the fireworks industry recognize that a standard mandating essentially zero presence of metals is as illusory (since the complete absence of metals would be impractical if not impossible to demonstrate via standard instrumentation) as it is unnecessarily strict to ensure the safety of these products.[10]

Thus, in the NPR preamble, the CPSC staff have indicated the agency's intention to exercise "enforcement discretion" to "allow for minimal contamination of up to, but not exceeding, 1.00 percent of metallic powder in burst charges . . .".[11] As the preamble further explains, and AFSL and APA members well know, metallic powder contamination can result

[9] *See, e.g.,* AFSL § 2-3.2.1 and APA 87-1 § 2.5.
[10] Testing by the CPSC (the general results of which have been confirmed by separate AFSL testing, as described below) indicates that "a 1 percent addition of aluminum increases the energy of a device by 3 percent . . .". *Id*.
[11] *Id*, at 9017.

from a number of factors, notably including cross-contamination of break charge composition from other materials at component and/or finished fireworks factories, and direct contamination inside the device itself from effects (typically "stars") co-located with the break charge composition, among other possible sources of metal contamination. Moreover, CPSC staff also recognize the inherent (but controllable) variability of x-ray fluorescence (XRF) instrumentation in measuring particularly lighter metal elements like aluminum. And since staff further recognize that XRF instrumentation is the only "field expedient" means of testing fireworks (at factory locations), this variability should likewise be accommodated.[12]

AFSL and APA appreciate the agency's recognition of these realities and its stated intention to exercise its discretion to not enforce the proposed new ban on fine mesh metals in break charge composition above one percent. However, we adamantly urge the CPSC to go somewhat further and adopt a two percent contamination limit, set forth in the regulatory standard itself (rather than as an extra-regulatory expression of staff intent), and further urge the agency formally adopt an enforcement policy and test procedure that allows for XRF instrument and sample variability, (i.e., that if the standard is two percent and the instrument-sample variability is +/- 0.1 percent, an XRF measurement of 2.1 percent would expressly not be determined to be a violation by the CPSC). We firmly believe that these additional provisions are critical if the CPSC (and our organizations and members) are to fairly, reliably and uniformly ascertain compliance with the new standard, in the clear context of ensuring consumer safety.

In considering the AFSL/APA recommendation in this regard, we would like to note that a two percent regulatory allowance is significantly lower than our organizations' previous recommendation of 3.5 percent allowance, made in the context of the 2016 proposed CPSC SOP. Upon further testing and evaluation of the issue, it is our collective and considered opinion that any metal powder present in break charges of aerial devices above two percent is most likely the result of intentional introduction into the device, and not unintentional contamination. Thus, consistent with the CPSC's stated intent to adopt the current AFSL and APA/DOT bans on fine mesh metals in break charges (i.e., a limit of zero), but the agency's realization that such a complete ban is illusory and unnecessary to ensure product safety and that unintentional contamination of fine mesh metals does occur, we would now ask for consideration of a two percent regulatory limit. Such a limit, we firmly believe, is not only reasonable and achievable from both a manufacturing and regulatory enforcement standpoint, but also truly reflects our mutual intent to prevent intentionally introduced powders while preventing a regulatory trap for the unwary.

1. Two percent regulatory limit.

AFSL and APA understand the current position of the CPSC staff that a one percent compliance discretion allowance is adequate to account for unintentional contamination of metal powders in break charge composition. However, after extensive consideration, internal industry discussion, and extensive testing of aerial devices by AFSL (in concert with its testing provider, Bureau Veritas), our organizations strongly believe that a regulatory allowance level of two percent is both reasonable, will prevent potentially hazardous products from entering the market, and fairly reflects the realities of consumer fireworks manufacturing in China and elsewhere.

[12] *See Id*.

As testing conducted both by the CPSC and AFSL bear out, between zero and two percent of metal powder by weight, there is no significant increase in the energetic/explosive effects of break charges. As concluded by the CPSC according to its own, self-admittedly limited testing, "a 1 percent addition of aluminum increases the energy of a device by 3 percent."[13] Thus, according to these findings, it can be presumed that an addition of two percent aluminum powder would increase the energy of the break charge by approximately six percent, which we would suggest presents no additional hazard concern whatever with respect to aerial fireworks.

As the CPSC is well aware, and as was set forth in our comments to the SOP, in 2016 AFSL commissioned Bureau Veritas to conduct testing to measure the recoil force from reloadable tube aerial (RTA) fireworks with specially manufactured canister--shaped shells prepared with known, varying total weight percentage quantities of fine mesh (130 mesh) aluminum metal particles. The results of this testing and the full Report are included herein, at Attachment 3.

Testing by both AFSL (Bureau Veritas) and the CPSC[14] confirm that there is an approximately three percent increase in the energy contained in a break charge for every one percent increase in fine mesh metal (AL) content. AFSL has further demonstrated that there is no statistically different force generated by shells containing two, one and zero percent fine mesh aluminum metal in the break charge composition.[15] Only at five percent and then again at 10 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, which represents a reliable analog to the total explosive force of a break charge. This clearly supports an allowable level of two percent metals in break charge composition, since it expected that the energy produced by up to this level of metal powder will not produce any significantly greater hazard than those containing no metal powder.

When ignited, commercial black powder (a homogenous mixture of potassium nitrate, charcoal, and sulfur in approximately a 75/25/10 parts-by-weight ratio) has an average heat of reaction of 0.66 kilocalories per gram (kcal/g). This is to be contrasted to a reactive "flash powder" containing potassium nitrate and fine mesh aluminum, which has a heat reaction of approximately 1.7 kcal/g, or almost three times as much energy per mass as black powder only. Given this relationship, as well as our extensive, collective experience in manufacturing and testing aerial fireworks, it is our estimate that a two percent level of fine mesh metal (typically aluminum) in a black powder break charge, efficiently reacting with approximately an equal weight of a nitrate oxidizer, would produce an overall maximum energy output of slightly above that of black powder only, but certainly nothing that would be appreciably perceptible or more likely to cause injury in the event of misuse or device malfunction.

This conclusion is also borne-out by testing data issued by the CPSC via its 2015 Rule Review Staff Package, indicating that aerial fireworks containing as high as 4.16 percent

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[13] *Id*, at 9015.
[14] *Id.*
[15] *See* Bureau Veritas "Reloadable Project," Attachment 3.

aluminum in break charge composition (measured using XRF analyzers) in fact passed the CPSC sound test conducted of course by CPSC personnel. For titanium, the other metal tested by agency staff, break charge composition as high as 9.23.5 percent were found to pass the current "sound test."[16] While only 27 samples were tested by the CPSC and while we of course take issue with the sound test as being a reliable measure of the actual pressure and thus potential hazard of aerial devices, these test results represent clear evidence that even at levels of fine mesh metals well above two percent, a majority of the samples tested would not, under the current CPSC standard and test method, appear to present a significant consumer hazard. Thus, a two percent allowable level is clearly a conservative regulatory level at which to allow for metal powders.

2. Metal powder contamination.

In addition to what we believe to be a wholly appropriate (no appreciable increase in energetic effect) allowable limit of fine mesh metals in break charge composition of two percent, we also believe that this level is necessary to accommodate for truly unintentional, contaminant levels of metal powders in break charges. While no one to our knowledge has developed any data with regard to the propensity and level of contamination that may occur from stars or other effects in a break charge, or from other sources like the lift charge, clay plugs, cross contamination in factory settings by wind-born particulates and containers, general environmental contamination, etc., its generally understood (and the CPSC staff appears to recognize) that such can and does occur, especially considering the unique nature of the fireworks manufacturing process overseas.

Moreover, since fine mesh metal content at this level does not significantly increase the "bang" or other energetic effect of aerial devices, it can generally be presumed that metals at this level are, in fact, the result of contamination/unintentional introduction since intentional introduction of such small amounts of metal powders would presumably not increase the commercial appeal of these devices. This strongly suggests that unintentional contamination at below two percent is a reality in the manufacturing process and that therefore the CPSC should not penalize these companies and their products for such unintended results when there is little-to-no safety issue implicated by these levels of metals.

In addition, it is often the case that aerial fireworks purposefully contain metals (notably including magnalium, titanium and/or aluminum), to create and/or enhance the visual (as opposed to energetic) effects of aerial fireworks, including in the break charge. Typically, product specifications call for greater than 100 mesh in size of the introduced metals for this purpose. However, finer mesh metals can and often do occur as an initial byproduct of the production of these larger metal particles. In addition, metal particles rub together during the manufacture, transport and possibly storage of aerial fireworks. Combined, these and possibly other factors can and do cause some level of fine mesh metal "contamination" in break charge composition, which must be accounted for, and overtly and formally so, in the actual text of the Final Rule resulting from the NPR.

[16] CPSC *Staff Package,* p. 60.

To be clear, AFSL and APA unequivocally desire to prevent the intentional introduction of metal powders in break charges. Our current standards and our comments here fully reflect that position. Our concern is that at a one percent "allowable" level too many firms will be unnecessarily and unfairly penalized, again for no safety benefit to consumers. Thus, after considerable thought, study, internal debate and discussions with technical staff at CPSC, it is our considered opinion and recommendation that that level should be two percent, and should be established as a regulatory limit, not an expression of the current intent of agency staff to exercise enforcement discretion, discretion which of course could be subject to change over time. Only in this way will both industry and CPSC staff have full transparency and predictability, indeed, certainty going forward, no matter what changes may occur to consumer fireworks products or to the thinking of CPSC staff. And such certainty is extremely important to our industry, particularly as we communicate with our fireworks manufacturers and suppliers overseas.

3. Formal allowance for instrument-sample variability.

As CPSC staff well knows, the only "field expedient," viable test method to measure metallic elements in black powder break charge composition is XRF. And as the agency is also well aware, since virtually all fireworks testing by necessity is conducted at or near fireworks factories, XRF must be formally recognized by the agency in publishing its anticipated test method to the new metal powders limit, at whatever level it may establish.

However, especially with lighter metals like aluminum (currently the most commonly found metal powder in break charges), there typically is significant instrument variability that may provide a "false positive," i.e., may indicate a sample has failed when in fact it is compliant with a given limit. This issue is compounded by the inherent non-homogenous nature of black powder break charge composition itself with respect to metal content, which may be concentrated in some portion of the break charge and therefore skew measurements, even with measurement techniques that attempt to derive a uniform measurement from a given sample.[17]

This variability of XRF in accurately measuring for metals, typically expressed as a "+/-" value in parts-per-million (ppm) on the XRF instrument display, itself varies according to a number of factors. Factors affecting this inherent instrument variability include the specific calibration of the instrument (inclusion relating to the element[s] being measured, at what level, and included in what substrate material, among other factors); the sample type and related

[17] Note that, in conducting its fine mesh metal content testing of commercially available fireworks devices, described in Bureau Veritas test reports at Attachment 2: "testing using XRF was conducted using a 100 mesh metal sieve for the break charge composition, with the sieve being cleaned with solvent and rinsed with distilled water between samples to prevent cross-contamination. In addition, the sample break charge composition was placed in a clean sample bag and scanned three times, with the sample agitated between XRF scans to compensate for the inherent non-homogenous nature of the powder. The three readings were then averaged to obtain the reported result." While this does, we believe, significantly reduce the variability of measurements (and we would therefore recommend that the CPSC adopt the same or a substantially similar test method via its Fireworks Testing Manual), it cannot be expected to eliminate this inherent variability in measurement of break charge compositions, especially for lighter metals like aluminum which are somewhat harder for XRF to measure than heavier metals.

instrument setting (e.g., solid substrate vs. "soil"-type sample); and the time allowed for the instrument to analyze the sample, among others.

AFSL and APA understand that, for legal and other reasons, the CPSC will likely continue to "reserve the right" to conduct ICP ("wet chemistry") testing when XRF measurement of break charge samples is not determinative, owing to the variability of a given sample. However, as CSPC staff fully understand, AFSL tests 30,000 to 35,000 fireworks samples annually, representing over seven million cases of products, contrasted with the 200 to 300 samples tested each year by the CPSC. This, coupled with the fact that such testing is conducted in the field, typically at fireworks factories, makes it obvious that ICP testing is and always will be wholly impractical as a means of testing by the firework industry, whether as testing in the first instance or as validation testing. (And for those U.S. importers and other companies that may not participate in the AFSL program, it would be even more logistically and economically difficult if not untenable to order ICP testing of product samples).

Therefore, it is imperative in our view that the NPR contain a clear and binding expression that the CPSC will not consider as violative any product it tests when the amount of metal powder measured is above the allowable limit but still within the variability (margin of error) expected for that particular sample using XRF according to the prescribed CPSC test method, once that is published. Thus, if the instrument variability can be demonstrated in a given instance can be demonstrated to be +/- 0.15 percent, the CSPC should overtly and formally consider as compliant any fine mesh metal measurement in the break charge up to 2.15 percent. Doing so is only fair.

As discussed in more detail, below, on behalf of AFSL, Bureau Veritas recently conducted a second series of tests, discussed below, to help determine 1) the percentage of AFSL-certified aerial fireworks currently on the market that have various percentages of aluminum and magnesium; 2) the correlation between XRF measurement and known percentages of aluminum content in break charge composition; and 3) the correlation between XRF measurement and inductively-coupled plasma (ICP), or so-called "wet chemistry" testing.

With respect to the third element of the testing, while XRF was shown to be generally reliable when compared with ICP testing of the same samples, there was an average of about 0.15 percent (~1500 ppm) variability between the two instrumentations. (While this may seem significant, it is to be compared with a two percent requested regulatory limit, or 20,000 ppm). Thus, while we realize that individual samples will each present their own estimated variability, it would be our collective expectation that a reasonable allowance approximating this level over time would be granted as the CPSC tests products that have ostensibly passed AFSL testing, again using only XRF instruments (according to the test method to be put forward by the CPSC).

4. Market impact.

AFSL has commissioned Bureau Veritas twice over the last year to undertake testing evaluations (Attachments 2 and 3) to determine approximately the level of fine mesh metals in aerial fireworks currently on the market. In the first round, approximately 1,000 individual products were tested. In the second, approximately 600 were tested, consisting of approximately equal numbers of mine and shell and reloadable devices. Measurements were made using XRF, following test procedure guidance from the CPSC laboratory staff, to determine the presence and amounts of both aluminum and magnesium in the break charges of these samples.

AFSL has already shared with CPSC staff data derived from this testing, the first series of which was included with the AFSL/APA comments on the 2016 SOP. None of the data identifies any product or company names, which AFSL purposefully ignored and did not record during testing. The results of both series of tests were consistent, and were also consistent with much smaller sample size testing conducted and reported by the CPSC. Generally speaking, all of the results obtained by AFSL testing thus far show that approximately 85-90 percent of mine and shell devices and approximately 80-85 percent of reloadable tube devices currently on the market would be expected to pass a two percent fine mesh metals regulatory limit.[18] Slightly higher percentages of product would be expected to pass a one percent limit.

These data demonstrate that the large majority of aerial fireworks currently on the market would comply with a two percent regulatory limit for fine mesh metals, so the market disruption and/or cost to manufacturers of compliance by industry, we fully expect, would not be significant. In fact, cost savings may be actually be achieved if manufacturers ceased purchasing metal powders for incorporation into break charges. And of course a much greater percentage would be expected to come into compliance once the new standard is in effect. These data, we believe, lend further strength to the argument that a two percent regulatory allowance for fine mesh metals in break charges for aerial devices is fully reasonable, from both a feasibility and product safety assurance standpoint.

D. Minority Industry Criticism

As the CPSC is well aware, the National Fireworks Association (NFA) and some individual U.S. fireworks companies have in the past criticized the CPSC's proposal to move from the no audible effects standard and related "ear test" to a more objective and quantifiable fine mesh metal content limit for aerial fireworks. Despite continued efforts on our parts (AFSL and APA) to find common ground, NFA apparently continues to maintain its position that a fine mesh metal limit is not the appropriate replacement, if any, for the current audible effects/ear test standard. We continue to be perplexed by what can only be described as a clear minority position among the industry, and would like to briefly attempt to address NFA's criticism of the NPR in this regard, as best we can discern their position. We address their previously stated, key arguments in turn:[19]

1. Sound Level Meter (SLM) Test.

As NFA stated in its October 4, 2016 comment to the prior CPSC proposed SOP (CPSC Docket No. 2016-0020), at p. 2,*"NFA proposes that the Commission develop [sound level meter] based standard test procedures [to determine compliance with the "no audible effects" standard]."*

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[18] *See*

[19] *See* Comment of the National Fireworks Association to CPSC Docket No. CPSC-2016-0020, dated October 4, 2016.

First, AFSL and APA would like to note that our organizations and members are strongly in favor of **<u>replacing the ear test, in whatever manner makes the most sense for all involved, irrespective of how that is achieved</u>**. We are not wed to **<u>any</u>** particular standard, test method or technology, so long as we replace what we believe to be a highly subjective standard with one that is fair, objective and repeatable in the field (China), and of course one that appropriately and reasonably mitigates the risk of consumer injury. With that in mind, the CPCS and AFSL have thoroughly reviewed the possibility of measuring the "loudness" (decibel level) of aerial break charges and determined that using such a test procedure to determine whether or not a device is intended to produce an audible effect or is in fact potentially hazardous to consumers is fraught with <u>at least</u> as much variability and potential for error as the current "ear test." While an exhaustive discussion of the inherent flaws of an SLM (decibel) test method is not necessary here, as CPSC staff well know, the list of variables in undertaking any such approach is extensive, and include:

- Environmental variables (humidity, altitude, temperature, physical/geographic surroundings, etc.)
- Instrumentation variables (the type and quality of sound level instrumentation varies widely and can significantly affect test procedures and results); and
- Testing variable (distance to the fireworks device; height at which it functions; orientation to the instrument, etc).

These and other factors have led the CPSC (and AFSL) to conclude that an SLM, as stated, would likely be <u>at least</u> as fraught with inconsistent test results as the current CPSC "ear test."

2. Asserted Flaws in XRF Instrumentation to Measure Fine Metal Powder.

The second major concern cited by the NFA in its October 4, 2016 comment was that x-ray fluorescence (XRF) is an unreliable means of measuring the amount of fine mesh metals in break charge composition. Specifically, NFA cites the fact (confirmed by CPSC staff) that XRF can only measure elemental composition and cannot differentiate between elements (like titanium), from either oxides (like titanium oxide) or metallic compounds (like magnalium, or an aluminum/magnalium alloy). Finally, NFA has cited the fact that XRF is less precise than inductively-coupled plasma (ICP, or "wet chemistry") testing, wherein samples are dissolved in acid in a laboratory environment and then analyzed by these typically very large and very expensive ICP instruments.

While neither AFSL nor APA are experts on XRF instrumentation, we have extensively consulted with those who are, including leading testing labs, instrument manufacturers and, most importantly, relevant CPSC laboratory staff, and we are confident, as they are, that these inherent limitations are <u>not</u> significant impediments to the field-expedient use of XRF to measure metal powders <u>in the present regulatory context</u>. That is, considering the contaminant (or regulatory) level of one or two percent (10,000 or 20,000 parts-per-million, ppm); given the fact that the known oxides at issue are <u>not</u> and would not be used to increase a break charge's explosive effect; and finally that XRF <u>is</u> effective at reliably measuring the presence of an element as part of a compound (not to mention that the proposed new NPR standard would not differentiate between metals), XRF appears to provide the best and most reliable, field expedient means of measuring for the presence of fine mesh metals in break charges, which again appears to be the overwhelming source of highly energetic (or, if you will "overloaded") aerial break charges.

Neither AFSL nor APA are asserting (as the CPSC lab apparently does not) that XRF is the perfect means of measuring either fine mesh metals in break charges nor certainly of the precise propensity of a given device to cause human injury. What we are emphatically asserting, however, is that there is no known, better means of determining metals content that is feasible for testing in China or elsewhere in the field and that therefore might effectively replace the inherently flawed "ear test" to prevent overly energetic aerial consumer fireworks from entering the marketplace and posing unreasonable risk to consumers. And, it should be noted that neither NFA nor anyone to our knowledge has demonstrated any correlation to an SLM testing approach (or any other test method or standard) to precise propensity to cause injury, as discussed, no such data exist.

IV. Other NPR Proposals

Less complex is AFSL's and APA's full support for final adoption by the CPSC of the remaining proposals in the NPR, virtually all of which are identical or closely follow existing AFSL and APA/DOT standards, most of which have been in place and enforced by our organizations for a number of years.[20] We believe strongly that each of these fireworks safety provisions are necessary to protect consumers and therefore to ensure the continued, long-term safe use and enjoyment of fireworks, and therefore to our industry. These provisions are:

- Adoption of 87-1 (similar to AFSL) total composition limits and ratio limits for mine and shell, reloadable shell and some other devices and limits lift charges in aerial devices to black powder ("or similar") composition. When combined with a regulatory limit of two percent of fine mesh metal powders in break charges, we believe these provisions, among other mandatory CPSC and voluntary AFSL standards, will continue to ensure that increasingly popular mine and shell, reloadable and other aerial fireworks will be safe for consumer use.

- Adoption of 87-1 (same as or similar to AFSL) composition limits on various fountain devices, torches, wheels, and chasers. These composition limits are necessary to prevent overloaded devices from posing potential safety issues to consumers, and see widespread compliance among the industry today for that reason.

- Clarification that firecrackers are subject to 50 mg limit, regardless of "whether intended to produce audible effect" or not. This long-sought provision would clarify a current

[20] While we of course do not speak for them, we would also note that it is our understanding that the National Fireworks Association, for one, also endorses or at least does not oppose most of these additional provisions, other than the limitation on fine mesh metals in break charge composition and, we understand, certain of the proposed new definitions in the NPR. Thus, for at least these additional, very important provisions of the NPR there does appear to be near unanimity of support among the U.S. fireworks industry.

gray area of CPSC interpretation of its standards, and would help prevent firecracker-related injuries from excessively loaded devices.

- Revision and expansion of CPSC's "prohibited chemicals" list to clarify that some are allowed under 0.25% and adds HCB (0.01%) and lead (tetroxide and other lead compounds greater than 0.25%) to the list. While AFSL and APA welcome the addition of these two substances to the agency's prohibited chemicals list and a quantified limit for each, we are concerned about the inability of either AFSL or individual companies to effectively test all fireworks to each of these new chemical limits, which could pose an enormous cost and supply chain burden. Therefore, we request that the final rule and/or its preamble explain that fireworks that have been subject to a "reasonable testing program" under 16 C.F.R. Part 1107, Subpart A, and we would suggest that the parameters of the AFSL chemical screening program do, in fact, meet this regulatory requirement and would request recognition by the agency of that fact.

- Incorporation of the CPSC side ignition test (similar to APA/AFSL) as a mandatory standard. This provision would provide welcome clarity and certainty to the industry.

- Adds to CPSC base dimension requirements by requiring that bases remain attached during handling, storage and operation (similar to APA/AFSL). This provision helps prevent tip-overs and other unintended discharge of mine and shell and fountain devices and so is a needed addition to CPSC's mandatory standards.

- Adoption of APA/AFSL general prohibition on "burnout" and "blowout" of fireworks. This is likewise an important provision of our current standards that can prevent serious injury to consumers, and is therefore urged to be finally adopted by the agency as a mandatory standard.

- Adoption of APA/AFSL prohibition of projection of "metal, glass or brittle plastic fragments." We fully support adoption of this provision, which can prevent eye and other injuries from consumers standing near or under discharged fireworks.

- Clarification that "aerial bombs" are banned. We support this needed clarification of CPSC's standards.

- Adoption of the same or very similar APA/AFSL definitions of:

    - "explosive" and "pyrotechnic" composition;
    - "firecracker;" (and excludes from references to "intended to produce audible effect,"
    - "burnout" and "blowout/" and
    - "base;"

- Also creates new CPSC definition of "aerial bomb" as "a tube device that fires and explosive charge into the air without added visual effect."

AFSL and APA both fully support adoption of these definitions into CPSC's standards, as doing so will provide additional clarity to the regulated U.S. community, as well as foreign fireworks manufacturers and shippers.

V. FHSA Findings

The Federal Hazardous Substances Act (FHSA) of course requires the CPSC to make certain findings in order to adopt mandatory safety standards or bans under this federal statute, which has historically been used to adopt safety standards and bans for consumer fireworks, including via the present NPR. While it is unnecessary to provide herein either an exposition of the findings required under FHSA, nor a comprehensive analysis of those findings *vis a vis* every provision in the NPR, AFSL and APA offer the following:

A. Absence of cautionary labeling as an adequate means to address the hazard

As noted by CPSC staff in the preamble to the NPR, sufficient findings have already been made in the past by the Commission to support the banning or substantive performance regulation of fireworks in a variety of contexts, including with respect to overly energetic fireworks and those that have otherwise have the propensity to injure consumers, notwithstanding the prospect of cautionary labeling mitigating those hazards. And for consumer fireworks, this a wholly appropriate approach by the agency, and one both of our organizations endorse.

To be sure, our respective standards committees devote a great amount of time and effort to develop and require consumer warning labels that we believe are likely to mitigate hazards to the extent they do, and fireworks today come with a variety of warning labels. But, given the nature of consumer fireworks, regulations addressing hazards should reasonably anticipate both proper use <u>and</u> foreseeable misuse by consumers, and therefore it is our considered opinion that the CPSC, just as our standards committees and organizational leadership do, must err on the side of caution when it comes to the anticipated efficacy of cautionary labeling on products or otherwise.

B. Absence of substantial compliance with voluntary standards

Promulgation of regulations under the FHSA of course requires that the Commission first find the absence of "substantial compliance" with existing, voluntary standards, such that it "is likely to result in the ***elimination or adequate reduction of the risk of injury*** [addressed by the proposed regulation]."[21] With respect to the provisions of the NPR generally, and the proposal to ban/limit fine mesh metals in the break charges of aerial fireworks in particular, AFSL and APA submit that, whether existing voluntary compliance rates are 90 percent or 20 percent, given the inherent nature of consumer fireworks, almost any significant non-compliance represents the absence of an "adequate reduction of the risk of injury." Fireworks are a unique category of

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[21] 15 U.S.C. § 1262(g)(2).

consumer products under CPSC jurisdiction. Virtually no other products regulated by the agency are, by their nature, intended to explode, produce flame, or reach extremely high temperatures. When improperly loaded, made and yes, even used, fireworks can cause severe injury and even death. It is only through **total** compliance with appropriate standards that address actual hazards can we as an industry and the CPSC as a regulatory and enforcement agency be certain that there is, in fact, adequate reduction of the risk of injury, given that the risk of injury in some cases can be so significant.

While this may, at first blush be a statement against our interests as an industry, it is this fact that cause us and our members to devote the great resources and time we do to develop and implement standards and to in many other promote safety among our industry and among consumers. We want the federal government to be tough on outliers, those who would flaunt standards for short-term financial gain, but to the peril of American families, just as we are with those among our memberships who do so. Therefore, we would assert that anything less than near universal compliance with each of the provisions in the NPR constitutes a *per se* absence of "adequate reduction of the risk" of injury, and that therefore this finding is satisfied on its face by the facts available to the commission of the presence of violations of these standards and the fact that there are available on the market consumer fireworks that pay no heed to the AFSL and APA standards that we believe to be so critical to safety and to the long-term viability of a consumer fireworks market in this country.

C. Reasonable Relationship of Costs to Benefits

Again, while neither of our organizations is in a position to provide detailed cost estimates of each of the proposals in the NPR, and certainly not when compared with the anticipated alleviation of injuries we do anticipate generally from those, we do believe that, on their face, each of the provisions does meet this criteria. And we believe this because we developed them ourselves after careful consideration and believe, as stated, that any significant risk of severe injury by the use of consumer fireworks that may be addressed through any reasonable means should in fact be so addressed. And each of the provisions in the NPR, we believe, in fact is a reasonable means to address the hazard at issue. While others may disagree, as noted, our organizations represent in excess of 90 percent of the consumer fireworks imported and sold in the U.S., and so while others may disagree with our conclusion with one or more of the NPR provisions, we maintain our assertion in this regard.

D. Least Burdensome Alternative

As with the other findings discussed, above, the fact that we developed and implemented and currently do "enforce" (require compliance as a condition of membership) with all of the substantive provisions of the NPR in our view is *prima facie* evidence that we believe these to be the least burdensome alternatives available for the Commission to adopt. Indeed, our respective Standards Committees have spent and spend countless hours considering many alternatives to address various possible hazards associated with consumer fireworks, including several recently adopted by the AFSL Standards Committee to address risks associated with reloadable tube and other aerial devices. In doing so, we consult extensively available injury data and fact scenarios and patterns, substantive experts at the CSPC, state and local fire marshals, chemists, epidemiologists, factories, news accounts, etc. to understand especially new and emerging hazards as best we can and then to adequately address those in a reasonable and workable (i.e., the "least burdensome") manner.

While it is not our place nor inclination to speculate and delineate here all possible alternatives to each of the provisions in the NPR, the CPSC may rely on our word that such was done by our respective organizations at the time each of these provisions were adopted by our Standards Committees.

VI. Effective Date

Many CPSC mandatory standards have effective dates where enforcement can begin of a year or more from the date of finalization of the regulation. The present NPR proposes an effective date of the proposed new mandatory standards 30 days from publication in the Federal Register of a Final Rule, based primarily on the fact that all of the substantive new provisions are ostensibly current law, i.e., are part of the 87-1 APA/DOT mandatory standard for the transportation of fireworks.

While AFSL/APA generally agree with this approach and logic, it is our considered opinion and request that there be a more reasonable effective date, and we are suggesting at least six months from final adoption of the new standards. While it is certainly true that the provisions of the NPR are, for the most part, contained within mandatory DOT regulations, given the fundamentally different charge of the CPSC compared with the DOT, including its different enforcement focus and different resources, namely the active authority and role of the CPSC to hold and seize putative imports at ports of entry, we believe that good governance and fundamental fairness call for a longer than 30-day implementation (effective) date. And, while a one-year delay in the effective date we do believe to be excessive, a reasonable approach would appear to be six months.

Moreover, we anticipate and hope that the staff will complete its review of the public comments to the NPR and that the Commission will adopt a Final Rule by the end of calendar year 2017 or early in 2018. If so, then a six-month hence effective date would likely put the provisions into effect around or somewhat after the next 4th of July, which is of course the peak consumer fireworks season. This should, then, give U.S. importers and their foreign suppliers time to modify, as necessary, orders in time to adequately prepare for the 2019 fireworks season.

While there has been some debate among industry about what percentage of aerial devices on the market today would or would not currently be in compliance with either a one or two percent limit in fine mesh metals in break charge composition, clearly some significant percentage exceeds these limits. Given the importance of this segment of the consumer fireworks market to the industry, it would seem reasonable to give those importers and factories time to reformulate their products, as necessary, in order to assure compliance with this new CPSC standard, and we believe that six months is that reasonable amount of time.

Finally, CPSC staff, particularly within the Directorate for Laboratory Sciences, have been extremely helpful and cooperative in demonstrating to our and other organizations how the agency currently and in future intends to test and measure for the presence of fine mesh metals in break charges, namely via use of x-ray fluorescence spectrometry (XRF). While AFSL and its testing partner, Bureau Veritas, believe they understand and can replicate this anticipated test method under the new standard, there may well need to be refinements to both the methodology and industry's understanding and implementation of that. Therefore, a six-month from publication effective date would give us (industry) and the CPSC laboratory staff that additional time to refine the method prior to the limitation on fine mesh metals in break charges going into effect.

VII. Conclusion

AFSL and APA appreciate the opportunity to comment on the present NPR, as well as the years of hard work and cooperative effort the NPR represents by CPSC professional staff, commissioners, and their staffs. We truly do appreciate the herculean effort this regulatory product represents.

As stated from the outset, there is NO greater mission or objective that our organizations have than to make consumer fireworks as reasonably safe as possible. We collectively and our members individually spend an enormous amount of time, effort and resources to continually explore ways in which to ensure that consumers can continue to enjoy fireworks safely and responsibly for years to come. And, where possible, we even seek to anticipate consumer misuse of fireworks and try to mitigate such hazards to the greatest extent possible.

It is in this spirit that AFSL and APA now come together to advocate for what is in reality a very strict and demanding set of proposed mandatory standards. Clearly, fireworks currently on the market and now legal to sell would become illegal under these new standards, causing many of our members at least short term economic compliance burdens. But so long as these standards create a level regulatory playing field for all companies, and so long as compliance can be uniformly, reliably and fairly tested, we are fully willing to undertake that responsibility in order to continue to ensure the safe and enjoyable use of the products we sell.

With appropriate accommodation, then, for the need to have a reasonable regulatory allowance level of fine mesh metals in break charge composition and for instrument variability, we stand ready to jointly seek compliance and enforcement to this new and we believe far more appropriate standard and the other important standards contained in the NPR. And we continue to look forward to working with the CPSC and its excellent staff to continue the never-ending mission of product safety.

Finally, AFSL and APA would like to formally and enthusiastically thank the many professionals at the CPSC, staff and commissioners alike, who devoted countless hours developing the NPR and its predecessor regulatory activities. While in a sense the NPR is a simple and straightforward document, that simplicity belies a tremendous amount of preparatory work, from all major directorates and offices within the agency. Most particularly, both of our organizations appreciate the cooperative nature in which the agency has interacted with our us as they have developed the NPR. The CPSC is a regulatory and an enforcement agency, the mission of which is consumer safety, not industry cooperation. But often the best way to achieve the former is through the latter, and that is certainly the case here. We share the mission of product safety with our capable colleagues at the CPSC, and we very much appreciate their implicit recognition of that fact.

Thank you for the opportunity to submit these joint AFSL/APA comments on this Notice of Proposed Rulemaking.

Respectfully submitted,

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Attachments:

1. Bureau Veritas "Reloadable Project," November 12, 2015
2. Bureau Veritas "Product Evaluation," September 27, 2016
3. Bureau Veritas "Product Evaluation," July 17, 2017

Product Evaluation

Engineering Services Group

Product Description: **Reloadable Project**

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(5115)314-0046

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November 12, 2015

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Contents:
Report: Pages 1 – 14

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Executive Summary

At the request of the client, a product evaluation was conducted on **twenty-four (24) types of consumer-grade fireworks**. The purpose of this testing was to examine the recoil force when the shells were fired, the striking force when a firing tube is suspended 6” above the measurement plate and allowed to drop when fired, the downward force when a shell was placed upside down in the firing tube, the durability of the firing tubes when they are suspended and the bases are unsupported during firing, and the weights and elements of the pyrotechnic compositions of each shell type.

Recoil force measurements ranged from less than 50 lbf to 625 lbf. Suspended striking force measurements ranged from less than 50 lbf to 7,812 lbf. The downward force measured during the detonation of upside down shells ranged from 122 lbf to 19,220 lbf.

Samples Received

Figure 1
1” Single Shell 1

Figure 2
1” Single Shell 2

Figure 3
1” Single Shell 3

Figure 4
1” Canister Shell 1

Figure 5
1” Canister Shell 2

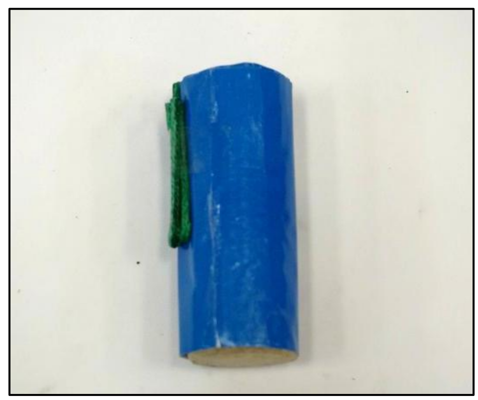

Figure 6
1” Canister Shell 3

Figure 7
Single Shell 1

Figure 8
Single Shell 2

Figure 9
Single Shell 3

Figure 10
Double Shell 1

Figure 11
Double Shell 2

Figure 12
Double Shell 3

Figure 13
Triple Shell 1

Figure 14
Triple Shell 2

Figure 15
Triple Shell 3

Figure 16
Small Canister Shell 1

Figure 17
Small Canister Shell 2

Figure 18
Canister Shell 1

Figure 19
Canister Shell 2

Figure 20
Canister Shell 3

Figure 21
Canister Shell 4

Figure 22
Canister Shell 5

Figure 23
Canister Shell 6

Figure 24
Canister Shell 7

Results

Physical Characteristics

Type	Sample	Shell Max OD (in)			
		Sup. Recoil	Sus. Strike	Sus. Dur.	Upside Down
1" Single Shell 1	1	1	1	1	1
	2	1	1	1	1
	3	1	1	1	1
1" Single Shell 2	1	1	1	1	1
	2	1	1	1	1
	3	1	1	1	1
1" Single Shell 3	1	1	1	1	15/16
	2	1	1	1	15/16
	3	1	1	1	1
1" Canister Shell 1	1	1	1	1 1/16	1
	2	1	1	1	1
	3	1	1 1/16	1	1 1/16
1" Canister Shell 2	1	1 1/16	1 1/16	1 1/16	1 1/16
	2	1 1/16	1 1/16	1 1/8	1 1/16
	3	1 1/16	1 1/16	1 1/16	1 1/16
1" Canister Shell 3	1	1 1/4	1 1/4	1 5/16	1 1/4
	2	1 1/4	1 1/4	1 5/16	1 1/4
	3	1 1/4	1 1/4	1 5/16	1 1/4
Single Shell 1	1	1 5/8	1 5/8	1 11/16	1 9/16
	2	1 5/8	1 5/8	1 11/16	1 9/16
	3	1 9/16	1 5/8	1 11/16	1 9/16
Single Shell 2	1	1 5/8	1 9/16	1 9/16	1 9/16
	2	1 9/16	1 1/2	1 9/16	1 9/16
	3	1 9/16	1 5/8	1 9/16	1 9/16
Single Shell 3	1	1 5/8	1 5/8	1 11/16	1 11/16
	2	1 5/8	1 5/8	1 11/16	1 11/16
	3	1 5/8	1 5/8	1 11/16	1 11/16
Double Shell 1	1	1 11/16	1 11/16	1 3/4	1 3/4
	2	1 3/4	1 11/16	1 11/16	1 3/4
	3	1 11/16	1 11/16	1 3/4	1 3/4
Double Shell 2	1	1 9/16	1 5/8	1 9/16	1 5/8
	2	1 5/8	1 5/8	1 9/16	1 5/8
	3	1 5/8	1 5/8	1 9/16	1 11/16
Double Shell 3	1	1 5/8	1 11/16	1 11/16	1 5/8
	2	1 5/8	1 11/16	1 5/8	1 5/8
	3	1 11/16	1 5/8	1 11/16	1 5/8

Type	Sample	Shell Max OD (in)			
		Sup. Recoil	Sus. Strike	Sus. Dur.	Upside Down
Triple Shell 1	1	1 5/8	1 5/8	1 5/8	1 5/8
	2	1 9/16	1 5/8	1 5/8	1 5/8
	3	1 5/8	1 5/8	1 5/8	1 9/16
Triple Shell 2	1	1 3/4	1 11/16	1 11/16	1 5/8
	2	1 3/4	1 11/16	1 11/16	1 5/8
	3	1 3/4	1 5/8	1 11/16	1 5/8
Triple Shell 3	1	1 3/4	1 3/4	1 11/16	1 3/4
	2	1 11/16	1 3/4	1 3/4	1 11/16
	3	1 3/4	1 3/4	1 3/4	1 3/4
Small Canister Shell 1	1	1 1/2	1 1/2	1 1/2	1 1/2
	2	1 1/2	1 1/2	1 1/2	1 1/2
	3	1 1/2	1 1/2	1 1/2	1 1/2
Small Canister Shell 2	1	1 11/16	1 11/16	1 3/4	1 5/8
	2	1 11/16	1 11/16	1 3/4	1 5/8
	3	1 3/4	1 5/8	1 13/16	1 5/8
Canister Shell 1	1	1 3/4	1 3/4	1 3/4	1 3/4
	2	1 3/4	1 3/4	1 3/4	1 3/4
	3	1 3/4	1 3/4	1 13/16	1 3/4
Canister Shell 2	1	1 3/4	1 3/4	1 13/16	1 13/16
	2	1 3/4	1 3/4	1 13/16	1 13/16
	3	1 3/4	1 3/4	1 13/16	1 3/4
Canister Shell 3	1	1 3/4	1 3/4	1 11/16	1 11/16
	2	1 3/4	1 3/4	1 11/16	1 3/4
	3	1 3/4	1 3/4	1 11/16	1 11/16
Canister Shell 4	1	1 3/4	1 3/4	1 3/4	1 3/4
	2	1 3/4	1 3/4	1 3/4	1 3/4
	3	1 3/4	1 3/4	1 3/4	1 3/4
Canister Shell 5	1	1 3/4	1 3/4	1 3/4	1 3/4
	2	1 3/4	1 3/4	1 3/4	1 3/4
	3	1 3/4	1 3/4	1 3/4	1 3/4
Canister Shell 6	1	1 13/16	1 13/16	1 13/16	1 3/4
	2	1 13/16	1 13/16	1 13/16	1 13/16
	3	1 13/16	1 13/16	1 13/16	1 13/16
Canister Shell 7	1	1 3/4	1 3/4	1 13/16	1 3/4
	2	1 3/4	1 3/4	1 13/16	1 3/4
	3	1 3/4	1 3/4	1 13/16	1 3/4

Type	Sample	Tube Max ID (in)			
		Sup. Recoil	Sus. Strike	Sus. Dur.	Upside Down
1" Single Shell 1	1	1 1/16	1 1/16	1 1/8	1 1/8
	2		1 1/16	1 1/16	1 1/8
	3		1 1/16	1 1/8	1 1/8
1" Single Shell 2	1	1 1/16	1 1/16	1 1/8	1 1/8
	2		1 1/16	1 1/8	1 1/8
	3		1 1/16	1 1/16	1 1/8
1" Single Shell 3	1	1 1/16	1 1/16	1 1/16	1 1/16
	2		1 1/16	1 1/16	1 1/16
	3		1 1/16	1 1/16	1 1/16
1" Canister Shell 1	1	1 3/16	1 3/16	1 3/16	1 3/16
	2		1 3/16	1 3/16	1 3/16
	3		1 3/16	1 3/16	1 3/16
1" Canister Shell 2	1	1 1/4	1 5/16	1 5/16	1 1/4
	2		1 1/4	1 1/4	1 5/16
	3		1 1/4	1 1/4	1 1/4
1" Canister Shell 3	1	1 7/16	1 3/8	1 3/8	1 3/8
	2		1 3/8	1 3/8	1 3/8
	3		1 3/8	1 3/8	1 7/16
Single Shell 1	1	1 13/16	1 13/16	1 13/16	1 3/4
	2		1 13/16	1 13/16	1 3/4
	3		1 13/16	1 13/16	1 3/4
Single Shell 2	1	1 3/4	1 3/4	1 3/4	1 3/4
	2		1 3/4	1 3/4	1 3/4
	3		1 3/4	1 3/4	1 3/4
Single Shell 3	1	1 13/16	1 13/16	1 13/16	1 13/16
	2		1 13/16	1 13/16	1 7/8
	3		1 13/16	1 13/16	1 3/4
Double Shell 1	1	1 13/16	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Double Shell 2	1	1 7/8	1 7/8	1 7/8	1 13/16
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Double Shell 3	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 15/16

Type	Sample	Tube Max ID (in)			
		Sup. Recoil	Sus. Strike	Sus. Dur.	Upside Down
Triple Shell 1	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 15/16	1 7/8
Triple Shell 2	1	1 13/16	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Triple Shell 3	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Small Canister Shell 1	1	1 9/16	1 9/16	1 9/16	1 9/16
	2		1 9/16	1 9/16	1 9/16
	3		1 9/16	1 9/16	1 9/16
Small Canister Shell 2	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Canister Shell 1	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Canister Shell 2	1	1 15/16	1 15/16	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 15/16	1 7/8	1 7/8
Canister Shell 3	1	1 13/16	1 13/16	1 13/16	1 7/8
	2		1 13/16	1 7/8	1 13/16
	3		1 13/16	1 7/8	1 7/8
Canister Shell 4	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Canister Shell 5	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8
Canister Shell 6	1	2	2	2	1 15/16
	2		2	2	2
	3		2	2	1 15/16
Canister Shell 7	1	1 7/8	1 7/8	1 7/8	1 7/8
	2		1 7/8	1 7/8	1 7/8
	3		1 7/8	1 7/8	1 7/8

Type	Sample	Shell Weight (g) Sup. Recoil	Shell Weight (g) Sus. Strike
1" Single Shell 1	1	14.8	11.6
	2	15.2	13.9
	3	15.0	17.3
1" Single Shell 2	1	15.3	11.9
	2	13.9	13.4
	3	12.9	13.3
1" Single Shell 3	1	13.6	10.6
	2	13.9	12.7
	3	13.8	12.9
1" Canister Shell 1	1	36.8	45.9
	2	36.9	41.2
	3	33.1	42.1
1" Canister Shell 2	1	76.6	79.8
	2	77.5	69.4
	3	64.0	73.0
1" Canister Shell 3	1	49.0	53.3
	2	52.2	56.7
	3	47.6	54.8
Single Shell 1	1	31.5	30.0
	2	29.9	28.5
	3	33.7	26.4
Single Shell 2	1	21.7	27.2
	2	27.5	27.1
	3	26.8	27.1
Single Shell 3	1	46.5	46.0
	2	52.4	37.5
	3	46.4	44.6
Double Shell 1	1	76.8	74.6
	2	77.7	82.4
	3	79.8	69.2
Double Shell 2	1	76.1	67.6
	2	73.2	62.0
	3	70.0	68.6
Double Shell 3	1	83.4	74.3
	2	82.6	64.7
	3	85.1	72.4

Type	Sample	Shell Weight (g) Sup. Recoil	Shell Weight (g) Sus. Strike
Triple Shell 1	1	83.7	88.3
	2	87.2	93.9
	3	90.8	91.2
Triple Shell 2	1	105.6	90.0
	2	101.4	87.8
	3	103.6	84.1
Triple Shell 3	1	96.0	89.1
	2	85.2	90.7
	3	87.8	90.3
Small Canister Shell 1	1	65.4	59.5
	2	70.7	73.6
	3	67.1	75.0
Small Canister Shell 2	1	64.8	58.1
	2	55.9	55.6
	3	67.7	55.0
Canister Shell 1	1	130.8	136.0
	2	143.8	140.4
	3	133.5	122.8
Canister Shell 2	1	128.9	107.8
	2	120.6	97.0
	3	128.3	106.2
Canister Shell 3	1	54.3	49.1
	2	55.0	48.4
	3	49.7	55.2
Canister Shell 4	1	121.7	115.1
	2	116.4	112.8
	3	121.2	120.2
Canister Shell 5	1	131.8	90.0
	2	131.9	85.4
	3	142.0	97.2
Canister Shell 6	1	105.7	116.3
	2	105.0	115.6
	3	114.8	123.6
Canister Shell 7	1	112.3	135.4
	2	132.2	139.6
	3	137.5	132.0

Supported Recoil Force

An unused tube included with the item shall be attached to the plate above the load cell. Three samples of each product type shall be launched in the correct orientation and the maximum recoil force observed shall be measured.

Type	Sample	Recoil Force (lbf)	Notes	Avg Recoil Force (lbf)
1" Single Shell 1	1	NR	< 50 lbf	**< 50**
	2	NR	< 50 lbf	
	3	NR	< 50 lbf	
1" Single Shell 2	1	NR	< 50 lbf	**< 50**
	2	NR	< 50 lbf	
	3	NR	< 50 lbf	
1" Single Shell 3	1	NR	< 50 lbf	**< 50**
	2	NR	< 50 lbf	
	3	NR	< 50 lbf	
1" Canister Shell 1	1	131.3	-	**130.2**
	2	118.8	-	
	3	140.6	-	
1" Canister Shell 2	1	265.6	-	**424.8**
	2	383.8	-	
	3	625.0	-	
1" Canister Shell 3	1	125.0	-	**171.9**
	2	178.1	-	
	3	212.5	-	
Single Shell 1	1	90.6	-	**90.6**
	2	NR	< 50 lbf	
	3	NR	< 50 lbf	
Single Shell 2	1	100.0	-	**93.8**
	2	NR	< 50 lbf	
	3	87.5	-	
Single Shell 3	1	131.3	-	**121.9**
	2	84.3	-	
	3	150.0	-	
Double Shell 1	1	203.1	-	**205.2**
	2	200.0	-	
	3	212.5	-	
Double Shell 2	1	137.5	-	**143.8**
	2	175.0	-	
	3	118.8	-	
Double Shell 3	1	112.5	-	**175.0**
	2	156.2	-	
	3	256.2	-	

Type	Sample	Recoil Force (lbf)	Notes	Avg Recoil Force (lbf)
Triple Shell 1	1	162.5	-	**175.0**
	2	175.0	-	
	3	187.5	-	
Triple Shell 2	1	193.3	-	**194.6**
	2	187.5	-	
	3	203.1	-	
Triple Shell 3	1	203.1	-	**177.1**
	2	134.4	-	
	3	193.8	-	
Small Canister Shell 1	1	130.3	-	**111.0**
	2	75.0	-	
	3	127.7	-	
Small Canister Shell 2	1	250.0	-	**227.1**
	2	184.4	-	
	3	246.9	-	
Canister Shell 1	1	281.2	-	**308.3**
	2	350.0	-	
	3	293.8	-	
Canister Shell 2	1	262.5	-	**242.7**
	2	87.5	-	
	3	378.1	-	
Canister Shell 3	1	93.8	-	**131.3**
	2	165.6	-	
	3	134.4	-	
Canister Shell 4	1	200.0	-	**256.2**
	2	262.5	-	
	3	306.2	-	
Canister Shell 5	1	262.5	-	**364.6**
	2	437.5	-	
	3	393.8	-	
Canister Shell 6	1	256.2	-	**245.8**
	2	237.5	-	
	3	243.8	-	
Canister Shell 7	1	234.4	-	**250.0**
	2	218.8	-	
	3	296.9	-	

Suspended Striking Force

An unused tube included with the item shall be suspended 6" above the force plate. One sample of each product type shall be launched in the correct orientation and the maximum force observed from the tube traveling down and striking the force plate shall be recorded. Note any damage to the tube.

Type	Sample	Striking Force (lbf)	Notes	Avg Striking Force (lbf)
1" Single Shell 1	1	NR	< 50 lbf	**81**
	2	NR	< 50 lbf	
	3	81.25	-	
1" Single Shell 2	1	296	-	**348**
	2	378.1	-	
	3	368.8	-	
1" Single Shell 3	1	NR	< 50 lbf	**< 50 lbf**
	2	NR	< 50 lbf	
	3	NR	< 50 lbf	
1" Canister Shell 1	1	437.5	-	**854**
	2	1469	-	
	3	656.2	-	
1" Canister Shell 2	1	1156	-	**1396**
	2	1656	-	
	3	1375	-	
1" Canister Shell 3	1	1000	-	**1000**
	2	812.5	-	
	3	1188	-	
Single Shell 1	1	215.7	-	**183**
	2	156.2	-	
	3	176.8	-	
Single Shell 2	1	406.2	-	**292**
	2	234.4	-	
	3	234.4	-	
Single Shell 3	1	312.5	-	**349**
	2	328.1	-	
	3	406.1	-	
Double Shell 1	1	NR	low break	**1563**
	2	1500	-	
	3	1625	-	
Double Shell 2	1	1466	-	**1279**
	2	1215	-	
	3	1156	-	
Double Shell 3	1	2562	-	**1966**
	2	1625	-	
	3	1710	-	

Type	Sample	Striking Force (lbf)	Notes	Avg Striking Force (lbf)
Triple Shell 1	1	2500	-	**3750**
	2	6094	-	
	3	2656	-	
Triple Shell 2	1	2656	-	**2104**
	2	1406	-	
	3	2250	-	
Triple Shell 3	1	3281	-	**1891**
	2	NR	low break	
	3	500	-	
Small Canister Shell 1	1	561	-	**552**
	2	542	-	
	3	NR	-	
Small Canister Shell 2	1	446.2	-	**440**
	2	536.7	-	
	3	337.5	-	
Canister Shell 1	1	5625	-	**5052**
	2	6094	-	
	3	3438	-	
Canister Shell 2	1	4844	-	**5104**
	2	6875	-	
	3	3594	-	
Canister Shell 3	1	1435	-	**1374**
	2	1374	-	
	3	1313	-	
Canister Shell 4	1	6562	-	**4990**
	2	3281	-	
	3	5128	-	
Canister Shell 5	1	7031	-	**6879**
	2	6562	-	
	3	7045	-	
Canister Shell 6	1	5469	-	**4688**
	2	5625	-	
	3	2969	-	
Canister Shell 7	1	7656	-	**7552**
	2	7188	-	
	3	7812	-	

Suspended Durability
An unused tube included with the item shall be rigidly mounted without any support on the underside of the base. One shell will be launched from each tube. Any failure of the tube will be recorded. Three tubes will be tested for each product type.

Type	Sample	Tube Failure	Notes
1" Single Shell 1	1	No	-
	2	No	-
	3	No	-
1" Single Shell 2	1	No	-
	2	No	-
	3	No	-
1" Single Shell 3	1	No	-
	2	No	-
	3	No	-
1" Canister Shell 1	1	No	-
	2	No	-
	3	No	-
1" Canister Shell 2	1	No	plastic base cracked
	2	No	-
	3	No	-
1" Canister Shell 3	1	No	-
	2	No	-
	3	No	-
Single Shell 1	1	No	-
	2	No	-
	3	No	-
Single Shell 2	1	No	-
	2	No	-
	3	No	-
Single Shell 3	1	No	-
	2	No	-
	3	No	-
Double Shell 1	1	No	-
	2	No	-
	3	No	-
Double Shell 2	1	No	-
	2	No	-
	3	No	-
Double Shell 3	1	No	-
	2	No	-
	3	No	-

Type	Sample	Tube Failure	Notes
Triple Shell 1	1	Yes	base and plug detached
	2	No	-
	3	Yes	base and plug detached
Triple Shell 2	1	No	-
	2	No	-
	3	No	-
Triple Shell 3	1	No	-
	2	No	-
	3	No	-
Small Canister Shell 1	1	No	-
	2	No	-
	3	No	-
Small Canister Shell 2	1	No	-
	2	No	-
	3	No	-
Canister Shell 1	1	No	base loosened
	2	No	-
	3	No	-
Canister Shell 2	1	No	-
	2	No	-
	3	No	-
Canister Shell 3	1	No	-
	2	No	-
	3	No	-
Canister Shell 4	1	No	-
	2	No	-
	3	No	-
Canister Shell 5	1	No	-
	2	No	-
	3	No	-
Canister Shell 6	1	No	-
	2	No	-
	3	No	-
Canister Shell 7	1	No	-
	2	No	-
	3	No	-

Figure 25
Triple Shell 1 Failure Example

Upside Down Shell

An unused tube included with the item shall be attached to the plate above the load cell. A shell will be inserted upside down into the tube and lit. The maximum force generated shall be recorded.

Type	Sample	Downward Force (lbf)	Notes	Avg Downward Force (lbf)
1" Single Shell 1	1	222	base cracked	**412**
	2	452	base cracked	
	3	563	base cracked	
1" Single Shell 2	1	763	base cracked	**582**
	2	453		
	3	531		
1" Single Shell 3	1	NR	< 50 lbf	**122**
	2	122		
	3	NR	< 50 lbf	
1" Canister Shell 1	1	1575	tube failed	**1366**
	2	1213	tube failed	
	3	1311	tube failed	
1" Canister Shell 2	1	781	base cracked	**879**
	2	969		
	3	888		
1" Canister Shell 3	1	1000		**1302**
	2	1250		
	3	1656		
Single Shell 1	1	1188		**1521**
	2	1875		
	3	1500		
Single Shell 2	1	609		**438**
	2	328		
	3	375		
Single Shell 3	1	498	tube failed	**511**
	2	NR		
	3	524	tube failed	
Double Shell 1	1	938	tube failed	**2009**
	2	2651		
	3	2438	base detached	
Double Shell 2	1	1094	base detached	**997**
	2	897	base detached	
	3	1000	base and plug detached	
Double Shell 3	1	NR	tube failed	**994**
	2	1000	tube failed	
	3	987	tube failed	

Type	Sample	Downward Force (lbf)	Notes	Avg Downward Force (lbf)
Triple Shell 1	1	1094		**2427**
	2	3938	tube failed	
	3	2250	tube failed	
Triple Shell 2	1	438	base cracked	**1000**
	2	1125	tube failed	
	3	1438	tube failed	
Triple Shell 3	1	437	tube failed	**1000**
	2	1125	tube failed	
	3	1438	tube failed	
Small Canister Shell 1	1	1055	tube failed	**1185**
	2	1281		
	3	1219	tube failed	
Small Canister Shell 2	1	2000		**1671**
	2	1825		
	3	1188		
Canister Shell 1	1	10620	base cracked	**12030**
	2	19220		
	3	6250	tube failed	
Canister Shell 2	1	9375		**10884**
	2	13590	tube bulged	
	3	9688	tube split	
Canister Shell 3	1	510		**531**
	2	406		
	3	675		
Canister Shell 4	1	6719		**11526**
	2	13590	base cracked	
	3	14270		
Canister Shell 5	1	5312		**4958**
	2	5563	base cracked	
	3	4000	base cracked	
Canister Shell 6	1	9062		**10810**
	2	9457		
	3	13910		
Canister Shell 7	1	18120		**15727**
	2	15310		
	3	13750		

Sample Dissection

Each product type shall be dissected. The lift charge shall be weighed, the break charge and "stars" shall be separated using an appropriate sieve and weighed separately. The appearance of the break charge shall be noted.

Type	Sample	Weight (g)		
		Lift	Stars	Break
1" Single Shell 1	1	3.1660	1.7834	1.6831
	2	2.6973	2.6911	1.0258
	3	2.6566	2.7676	0.7751
	Avg	**2.8400**	**2.4140**	**1.1613**
1" Single Shell 2	1	2.5044	2.5815	1.2255
	2	2.4835	3.0613	1.0220
	3	2.5500	3.6250	1.0678
	Avg	**2.5126**	**3.0893**	**1.1051**
1" Single Shell 3	1	2.0748	3.5648	0.7638
	2	2.9922	2.9825	1.3919
	3	2.7419	3.2517	1.1924
	Avg	**2.6030**	**3.2663**	**1.1160**
1" Canister Shell 1	1	3.2816	6.1111	2.8482
	2	3.3535	6.7050	3.1013
	3	3.2073	5.6541	2.8946
	Avg	**3.2808**	**6.1567**	**2.9480**
1" Canister Shell 2	1	4.0073	28.0963	11.8321
	2	4.0027	28.2514	11.9160
	3	3.9372	28.9558	12.2363
	Avg	**3.9824**	**28.4345**	**11.9948**
1" Canister Shell 3	1	4.7584	10.6700	2.8066
	2	4.9782	8.7954	2.5788
	3	4.1216	9.9140	2.9739
	Avg	**4.6194**	**9.7931**	**2.7864**
Single Shell 1	1	3.5526	8.6731	3.0116
	2	2.8154	10.9696	1.9498
	3	3.1003	6.8730	3.2310
	Avg	**3.1561**	**8.8386**	**2.7308**
Single Shell 2	1	3.3174	6.1778	1.9389
	2	3.7192	8.1713	2.5083
	3	3.1571	7.8891	2.0082
	Avg	**3.3979**	**7.4127**	**2.1518**
Single Shell 3	1	4.0438	6.2869	1.9286
	2	3.7920	5.8583	2.0923
	3	3.8777	5.9262	1.9690
	Avg	**3.9045**	**6.0238**	**1.9966**
Double Shell 1	1	5.5608	38.5300	15.0033
	2	6.1404	32.1585	15.6871
	3	5.7785	28.5322	18.1127
	Avg	**5.8266**	**33.0736**	**16.2677**
Double Shell 2	1	6.0604	24.7598	9.2650
	2	6.7363	23.9729	9.5592
	3	6.7832	25.1278	8.1302
	Avg	**6.5266**	**24.6202**	**8.9848**
Double Shell 3	1	5.5604	21.4929	15.8284
	2	5.3102	20.3798	13.9012
	3	5.4189	19.9337	16.2938
	Avg	**5.4298**	**20.6021**	**15.3411**

Type	Sample	Weight (g)		
		Lift	Stars	Break
Triple Shell 1	1	8.6178	35.4258	19.2636
	2	7.7539	33.1535	17.4792
	3	9.0283	33.7470	20.3801
	Avg	**8.4667**	**34.1088**	**19.0410**
Triple Shell 2	1	7.7589	26.9544	14.7881
	2	7.5782	29.7478	20.1795
	3	7.9272	29.6957	17.1619
	Avg	**7.7548**	**28.7993**	**17.3765**
Triple Shell 3	1	5.3069	39.5040	11.0156
	2	5.9375	31.2847	15.1960
	3	5.3922	34.4230	12.9489
	Avg	**5.5455**	**35.0706**	**13.0535**
Small Canister Shell 1	1	3.7936	5.5240	2.6717
	2	3.8015	6.9457	2.5448
	3	3.9269	5.7958	2.6230
	Avg	**3.8407**	**6.0885**	**2.6132**
Small Canister Shell 2	1	5.5180	13.6938	14.8688
	2	5.0112	28.4796	6.5363
	3	8.3509	23.5057	9.8751
	Avg	**6.2934**	**21.8930**	**10.4267**
Canister Shell 1	1	7.7286	23.6572	14.0026
	2	8.1592	29.1651	13.9653
	3	8.0160	33.0761	14.0761
	Avg	**7.9679**	**28.6328**	**14.0147**
Canister Shell 2	1	8.2950	31.0213	10.8222
	2	10.1306	31.7863	9.9964
	3	8.7615	38.5187	9.4373
	Avg	**9.0624**	**33.7754**	**10.0853**
Canister Shell 3	1	4.3848	13.9758	5.2993
	2	4.3572	12.4990	4.7792
	3	4.2887	10.5431	5.3452
	Avg	**4.3436**	**12.3393**	**5.1412**
Canister Shell 4	1	8.1656	27.6906	7.1005
	2	9.0878	36.9774	9.2605
	3	8.7751	26.8507	6.4507
	Avg	**8.6762**	**30.5062**	**7.6039**
Canister Shell 5	1	6.3512	26.9828	10.1328
	2	6.6526	27.6322	8.6630
	3	6.9828	28.4081	9.6932
	Avg	**6.6622**	**27.6744**	**9.4963**
Canister Shell 6	1	4.4036	26.0189	8.9584
	2	4.3812	25.3756	9.0099
	3	4.4939	23.2315	10.7630
	Avg	**4.4262**	**24.8753**	**9.5771**
Canister Shell 7	1	10.8241	32.1926	7.7578
	2	11.7121	26.6210	8.4434
	3	10.0908	29.3343	9.2107
	Avg	**10.8757**	**29.3826**	**8.4706**

Type	Component	Elements Present (%)		
		Aluminum	Magnesium	Chlorine
1" Single Shell 1	Lift	ND	ND	0.14
	Stars	1.15	4.07	3.71
	Break	1.54	7.98	24.09
1" Single Shell 2	Lift	ND	ND	0.13
	Stars	13.86	1.76	1.63
	Break	36.90	5.11	12.68
1" Single Shell 3	Lift	ND	ND	0.14
	Stars	3.91	2.48	3.18
	Break	21.14	6.18	21.89
1" Canister Shell 1	Lift	ND	ND	0.11
	Stars	9.54	4.68	2.80
	Break	25.67	11.84	17.61
1" Canister Shell 2	Lift	ND	ND	0.06
	Stars	1.82	6.50	4.27
	Break	1.17	4.54	16.05
1" Canister Shell 3	Lift	ND	1.70	0.09
	Stars	11.68	11.95	4.72
	Break	17.79	6.60	20.82
Single Shell 1	Lift	ND	1.36	0.12
	Stars	0.93	4.62	14.47
	Break	1.79	8.35	22.83
Single Shell 2	Lift	ND	1.68	0.09
	Stars	1.28	6.46	15.11
	Break	1.98	9.09	22.27
Single Shell 3	Lift	ND	ND	0.10
	Stars	0.57	2.76	4.41
	Break	3.51	10.53	26.43
Double Shell 1	Lift	ND	ND	0.08
	Stars	0.71	ND	2.52
	Break	1.34	5.52	14.98
Double Shell 2	Lift	ND	1.12	0.09
	Stars	1.64	4.61	3.38
	Break	0.96	4.54	17.66
Double Shell 3	Lift	ND	1.10	0.11
	Stars	19.87	3.59	3.65
	Break	33.02	4.74	13.61

Type	Component	Elements Present (%)		
		Aluminum	Magnesium	Chlorine
Triple Shell 1	Lift	ND	1.13	0.11
	Stars	14.19	3.58	4.43
	Break	34.29	4.57	15.99
Triple Shell 2	Lift	ND	ND	0.09
	Stars	7.47	ND	2.63
	Break	29.88	3.46	10.44
Triple Shell 3	Lift	ND	1.67	0.09
	Stars	3.61	8.06	4.87
	Break	1.91	7.57	24.24
Small Canister Shell 1	Lift	ND	ND	0.21
	Stars	2.55	7.09	9.43
	Break	5.04	8.10	22.69
Small Canister Shell 2	Lift	ND	1.10	0.11
	Stars	2.46	5.00	4.94
	Break	1.58	4.78	10.58
Canister Shell 1	Lift	ND	1.55	0.13
	Stars	4.06	9.93	7.41
	Break	1.39	7.37	20.39
Canister Shell 2	Lift	ND	1.47	0.05
	Stars	13.46	2.67	2.18
	Break	36.86	4.85	16.21
Canister Shell 3	Lift	ND	1.31	0.14
	Stars	1.26	3.35	6.48
	Break	1.49	6.35	21.25
Canister Shell 4	Lift	0.39	ND	0.18
	Stars	2.12	6.12	12.59
	Break	3.14	11.01	29.32
Canister Shell 5	Lift	ND	1.51	0.09
	Stars	12.07	7.66	8.57
	Break	20.24	7.38	24.86
Canister Shell 6	Lift	0.30	1.32	0.09
	Stars	3.05	8.59	9.09
	Break	3.03	9.97	26.73
Canister Shell 7	Lift	0.36	1.22	0.13
	Stars	6.28	8.52	11.79
	Break	8.79	7.76	27.55

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Consumer Products Services, Inc.

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Project Engineer
Engineering Services Group

/jn

Product Evaluation

IAC Group

Product Description: Reloadable Shell Testing Phase IV

IBMS Number: 60162710006

Test Dates: September 22 – 23, 2016

Report Date: September 27, 2016

Prepared for:
John Rogers
American Fireworks Standards Laboratory
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Contents:
Report: Pages 1 – 5

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Background

The client directed that a market survey be conducted to using an X-ray Florescence Spectrophotometer (XRF) to identify the presence of fine mesh metal in break charges in reloadable tube as well as mine and shell devices.

Break charge samples collected blindly over a two week period from both mine and shell devices (MSDV) and reloadable tube aerial shell devices (RTAS) by BV technicians. The collection of samples was done by opening the shell, separating the break charge from any effects, and placing the sample in an unmarked plastic sample bag. These bags were aggregated with bags collected by other technicians during the same period rendering them untraceable back to the source.

A BV technician sieved samples using a 100 mesh sieve to separate any larger particles. The sieves were cleaned with solvent and rinsed with distilled water between samples to prevent cross-contamination. The resulting sample was then placed in a sample bag and scanned three times with a Fisher Scientific Niton XL3t 950S Handheld XRF Scanner. with the sample agitated between scans to compensate for the non-homogenous nature of the powder. The numbers reported for each sample were an average of the three readings. The tables below summarize these findings by the number and percentage of the number of samples that had an average of the three readings within the range specified.

MSDV				
% of Specified Metal	Number of Samples (Al)	% of Samples	Number of Samples (Mg)	% of Samples
<LOD	203	34.00%	560	93.80%
0-1%	186	31.16%	0	0.00%
1-2%	58	9.72%	13	2.18%
2-3%	74	12.40%	21	3.52%
3-4%	47	7.87%	3	0.50%
4-5%	17	2.85%	0	0.00%
5-10%	12	2.01%	0	0.00%
Total	597	100.00%	597	100.00%

RTAS				
% of Specified Metal	Number of Samples (Al)	% of Samples	Number of Samples (Mg)	% of Samples
<LOD	250	49.02%	470	92.16%
0-1%	166	32.55%	0	0.00%
1-2%	26	5.10%	7	1.37%
2-3%	28	5.49%	26	5.10%
3-4%	15	2.94%	6	1.18%
4-5%	10	1.96%	1	0.20%
5-10%	15	2.94%	0	0.00%
Total	510	100.00%	510	100.00%

After reviewing this data the client requested a series of experiments to determine whether or not small amounts of metal powder significantly increases the forces produced when the break charge detonates.

Correlation of Forces Using Standardized Shells

The client provided five different types standardized shells to be utilized in the testing. It was reported that these shells were constructed with 9 gram fine black powder lift charges, 35 grams of effect stars and 10 gram break charges with varying mixtures of fine black powder and 130 mesh aluminum powder. The composition and construction of the shells was not verified by Bureau Veritas.

Type I – 100% fine black powder
Type II – 99% fine black powder and 1% aluminum
Type III – 98% fine black powder and 2% aluminum
Type IV – 95% fine black powder and 5% aluminum
Type V – 90% fine black powder and 10% aluminum

Note that the Type V shells generated forces above the 50,000 pound capacity of the load cell and were not properly contained in the launch tube therefore no data was recorded and the testing stopped after 15 shots were attempted.

Upside Down Force

Multiple samples of each shell type were individually inserted upside down and ignited in a fiberglass launch tube resting on a test fixture consisting of a steel plate resting on a load cell (Figure 1). A storage oscilloscope was used to capture the data and the maximum force recorded (Appendix 1). A new launch tube was used with each shell. The results were entered into an Excel spreadsheet and the built-in functions (AVERAGE and STDDEV.S) along with the one-way ANOVA tool in the Excel Data Analysis Toolpak were used to analyze the data. The results are summarized in the following table.

Type	Average (lbs)	2 STD Deviations (lbs)	ANOVA "p" value
I	13601	4055	N/A
II	15719	7874	0.078
III	14863	4628	0.144
IV	18558	10082	0.002

Note: "p" value is based on ANOVA vs Type I.

Summary

The data collected was analyzed using a one-way analysis of variance (one-way ANOVA). One-way ANOVA is a widely recognized method to evaluate whether or not two sets of data have a significant statistical difference from each other. Two datasets are considered to have a significant statistical difference if the value determined for "p" is less than 0.05. This corresponds to a greater than 95% probability that the datasets represent different populations. Based on the one-way ANOVA analysis, Types II and III powder are not shown to have a statistically significant difference in force measured when compared to the Type I shells. The Type IV shells were shown to have a statistically significant difference in force measured as compared to Type I shells.

Photos

Figure 1

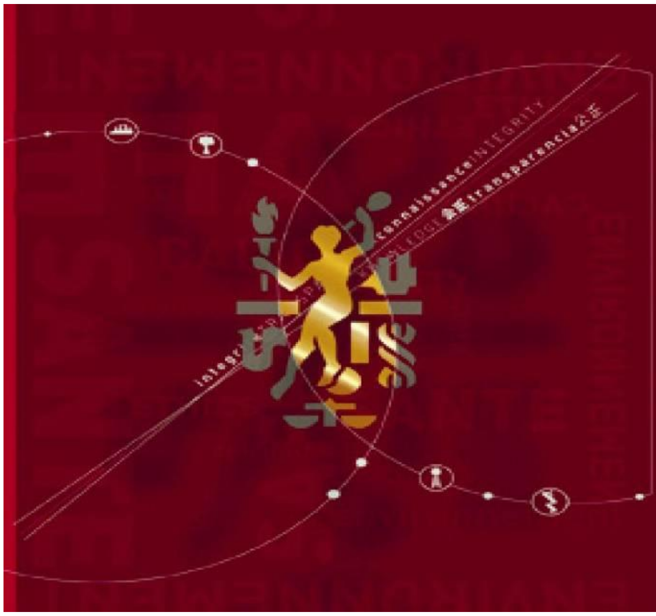
Figure 2

Appendix 1 – Recorded Forces for Shell Samples (pounds)

0%	1%	2%	5%
9375	16090	15160	18120
10470	12190	15830	11250
12500	16890	12810	16250
15780	15940	15940	16880
14220	14360	16250	17500
15160	13750	13750	17500
14840	16250	16250	16880
12870	17500	10620	17500
14380	15000	14380	19380
11410	9062	13620	17500
15310	27500	20000	33750
14530	17500	13750	20620
14890	12500		18120
16090	14380		
12190	16880		
	15000		
	10620		

Note: Number of samples recorded for each composition varies due to equipment (cable breakage), fixture (loosened fasteners), and tube (clay plug movement, tip over, etc.) issues.

Attachment 3



Product Evaluation

IAC Group

Product Description:

Fine Mesh Metals in Reloadable Tube Aerial Shell and Mine and Shell Devices using X-Ray Florescence and Inductively Coupled Plasma

IBMS Number:

10171980778

Test Dates:

May 14 – June 8, 2017

Report Date:

July 17, 2017

Prepared for:

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Background

The client directed that a market survey be conducted to using an X-ray Florescence Spectrophotometer (XRF) to identify the presence of fine mesh metal in break charges in reloadable tube as well as mine and shell devices.

Break charge samples collected blindly over a four week period from both mine and shell devices (MSDV) and reloadable tube aerial shell devices (RTAS) by BV technicians. The collection of samples was done by opening the shell, separating the break charge from any effects, and placing the sample in an unmarked plastic sample bag. These bags were aggregated with bags collected by other technicians during the same period rendering them untraceable back to the source. The technicians did record whether the device passed or failed using current methods. Note that none of the devices were found non-compliant using the current methods.

A BV technician sieved samples using a 100 mesh sieve to separate any larger particles. The sieves were cleaned with solvent and rinsed with distilled water between samples to prevent cross-contamination. Five grams of the resulting sample were then placed into a SC-4331-N sample cup, covered with SC-4331-N polypropylene x-ray film circles, and sealed. The samples were analyzed with a Fisher Scientific Niton XL3t 950S Handheld XRF Scanner with the settings shown in Appendix I and the results recorded.

Complete results are found in Appendix 2 and are summarized as follows.

MSDV				
% of Specified Metal	Number of Samples (Al)	% of Samples	Number of Samples (Mg)	% of Samples
<LOD	227	72.07%	313	99.37%
0-0.5%	55	17.46%	0	0.00%
0.5-1%	9	2.86%	0	0.00%
1-1.5%	3	0.95%	2	0.63%
1.5-2%	2	0.63%	0	0.00%
2-3%	0	0.00%	0	0.00%
3-10%	10	3.17%	0	0.00%
>10%	9	2.86%		
Total	315	100.00%	315	100.00%

RTAS				
% of Specified Metal	Number of Samples (Al)	% of Samples	Number of Samples (Mg)	% of Samples
<LOD	138	45.85%	299	99.34%
0-0.5%	82	27.24%	0	0.00%
0.5-1%	16	5.32%	0	0.00%
1-1.5%	1	0.33%	0	0.00%
1.5-2%	2	0.66%	1	0.33%
2-3%	6	1.99%	0	0.00%
3-10%	51	16.94%	1	0.33%
>10%	5	1.67%	0	0.00%
Total	301	100.00%	301	100.00%

In addition, standard samples were prepared with .5%, 1%, 1.5%, 2.0%, 2.5%, 5.0%, and 10.0% 100 mesh aluminum powder mixed with standard black powder. These samples were processed as outlined above with results as follows.

Standard samples	Al%
0.50%	0.489
1.0%	1.098
1.5%	1.649
2.0%	2.448
2.5%	2.799
5.0%	5.036
10.0%	8.062

Fifty-six samples where the XRF readings for Al ranging between 0.34% and 2.88% were then sent to the BV Shanghai analytical laboratory for analysis by Inductively Coupled Plasma (ICP) analysis. Standard powder samples at 1%, 1.5%, 2.0%, and 2.5% were included as well. The samples were prepared and analyzed using the test method described in Appendix I. A comparison of these results with XRF for the same sample yielded the following results. Complete results are found in Appendix 3.

ICP < XRF	44
ICP > XRF	12
Avg Difference (ICP-XRF)	-0.150%

Appendix 1 – Methods

XRF Settings

- Soil and Minerals
- Mining – Cu/Zn
- Main – 10 sec
- Low – 30 sec (note this option is not selected in this method)
- High – 30 sec (note this option is not selected in this method)
- Light – 60 Sec
- Analyze each sample using only Main and Light filters for up to three cycles (210 seconds total)
- If first reading is ND, < 5000 ppm, or >25000 ppm analysis may be stopped at one cycle.

ICP Sample Preparation and Method

1. Weigh 30 mg of sample.
2. Add 5 ml of nitric acid (Trace Metal Grade).
3. Digest on hot block for four hours.
4. Dilute to 50 ml with deionized water.
5. Dilute 1 ml of solution from previous step with 20 ml deionized water (dilution factor 1:1000).
6. Dilute a sample of Certified Reference Material (NIST SRM 629) following the above procedure for reference.
7. Analyze with ICP standard settings for light metals.

Appendix 2 – XRF Results

Mine and Shell Devices

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	27A	Pass	3.943	0.285	1.351	0.895
MSDV	33A	Pass	10.369	0.631	1.461	0.846
MSDV	40B	Pass	0.238	0.143	< LOD	1.231
MSDV	28C	Pass	0.239	0.154	< LOD	1.364
MSDV	7B	Pass	0.251	0.147	< LOD	1.224
MSDV	44B	Pass	0.252	0.142	< LOD	1.197
MSDV	85A	Pass	0.254	0.148	< LOD	1.298
MSDV	24C	Pass	0.255	0.162	< LOD	2.072
MSDV	85C	Pass	0.255	0.147	< LOD	1.232
MSDV	41A	Pass	0.256	0.144	< LOD	1.225
MSDV	103C	Pass	0.259	0.163	< LOD	1.737
MSDV	39A	Pass	0.259	0.161	< LOD	1.373
MSDV	36C	Pass	0.267	0.152	< LOD	1.269
MSDV	3A	Pass	0.267	0.166	< LOD	1.443
MSDV	29C	Pass	0.274	0.154	< LOD	1.506
MSDV	16A	Pass	0.283	0.164	< LOD	1.426
MSDV	59C	Pass	0.283	0.164	< LOD	1.485
MSDV	84A	Pass	0.286	0.149	< LOD	1.99
MSDV	1C	Pass	0.287	0.163	< LOD	1.402
MSDV	30B	Pass	0.288	0.15	< LOD	1.251
MSDV	65A	Pass	0.289	0.173	< LOD	1.792
MSDV	67A	Pass	0.29	0.168	< LOD	1.63
MSDV	67B	Pass	0.294	0.168	< LOD	1.455
MSDV	29B	Pass	0.31	0.149	< LOD	1.266
MSDV	1A	Pass	0.312	0.161	< LOD	1.769
MSDV	106C	Pass	0.313	0.15	< LOD	1.704
MSDV	13C	Pass	0.314	0.15	< LOD	1.363
MSDV	101B	Pass	0.321	0.164	< LOD	2.437
MSDV	8C	Pass	0.323	0.153	< LOD	1.283
MSDV	64C	Pass	0.335	0.17	< LOD	1.979
MSDV	2A	Pass	0.339	0.162	< LOD	1.393
MSDV	63C	Pass	0.349	0.176	< LOD	2.505
MSDV	42B	Pass	0.353	0.158	< LOD	1.994
MSDV	13A	Pass	0.361	0.151	< LOD	1.833
MSDV	39C	Pass	0.361	0.163	< LOD	1.4
MSDV	1B	Pass	0.362	0.164	< LOD	1.396
MSDV	40C	Pass	0.362	0.146	< LOD	1.217
MSDV	20A	Pass	0.365	0.163	< LOD	1.759
MSDV	30C	Pass	0.368	0.152	< LOD	2.174
MSDV	107A	Pass	0.369	0.153	< LOD	1.289

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	37A	Pass	0.377	0.157	< LOD	1.262
MSDV	17C	Pass	0.378	0.159	< LOD	1.338
MSDV	13B	Pass	0.38	0.147	< LOD	1.531
MSDV	38C	Pass	0.381	0.167	< LOD	1.832
MSDV	40A	Pass	0.383	0.15	< LOD	1.25
MSDV	44A	Pass	0.384	0.158	< LOD	1.33
MSDV	71A	Pass	0.397	0.165	< LOD	2.009
MSDV	42C	Pass	0.402	0.164	< LOD	1.921
MSDV	43A	Pass	0.407	0.163	< LOD	1.341
MSDV	30A	Pass	0.412	0.157	< LOD	1.398
MSDV	11A	Pass	0.413	0.168	< LOD	1.704
MSDV	42A	Pass	0.415	0.16	< LOD	1.332
MSDV	107C	Pass	0.419	0.154	< LOD	1.371
MSDV	2C	Pass	0.428	0.168	< LOD	1.403
MSDV	22B	Pass	0.443	0.165	< LOD	1.385
MSDV	43B	Pass	0.45	0.156	< LOD	1.241
MSDV	101A	Pass	0.466	0.169	< LOD	1.415
MSDV	22A	Pass	0.517	0.166	< LOD	1.304
MSDV	21A	Pass	0.523	0.169	< LOD	1.302
MSDV	41C	Pass	0.543	0.154	< LOD	1.245
MSDV	38A	Pass	0.547	0.164	< LOD	1.324
MSDV	38B	Pass	0.587	0.166	< LOD	1.637
MSDV	41B	Pass	0.592	0.152	< LOD	1.207
MSDV	107B	Pass	0.606	0.163	< LOD	2.321
MSDV	43C	Pass	0.653	0.159	< LOD	1.274
MSDV	22C	Pass	0.966	0.191	< LOD	1.306
MSDV	21C	Pass	1.001	0.192	< LOD	1.288
MSDV	25C	Pass	1.089	0.175	< LOD	1.278
MSDV	39B	Pass	1.26	0.189	< LOD	1.415
MSDV	27B	Pass	1.527	0.188	< LOD	1.258
MSDV	20B	Pass	1.865	0.245	< LOD	1.283
MSDV	26B	Pass	3.345	0.254	< LOD	1.237
MSDV	27C	Pass	3.579	0.271	< LOD	1.524
MSDV	25B	Pass	3.877	0.298	< LOD	1.731
MSDV	26C	Pass	3.877	0.281	< LOD	1.455
MSDV	26A	Pass	4.772	0.307	< LOD	1.242
MSDV	25A	Pass	5.145	0.376	< LOD	1.954
MSDV	19A	Pass	5.68	0.355	< LOD	1.321
MSDV	19B	Pass	6.426	0.427	< LOD	1.213
MSDV	19C	Pass	6.677	0.408	< LOD	1.419
MSDV	33C	Pass	10.507	0.653	< LOD	1.373
MSDV	33B	Pass	10.805	0.702	< LOD	1.8
MSDV	35B	Pass	12.253	0.767	< LOD	1.839
MSDV	35A	Pass	12.733	0.736	< LOD	1.145

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	34C	Pass	12.78	0.742	< LOD	1.136
MSDV	34B	Pass	13.182	0.748	< LOD	1.189
MSDV	35C	Pass	13.582	0.741	< LOD	1.182
MSDV	34A	Pass	14.957	0.92	< LOD	1.595
MSDV	100A	Pass	< LOD	0.211	< LOD	1.292
MSDV	100B	Pass	< LOD	0.208	< LOD	1.218
MSDV	100C	Pass	< LOD	0.208	< LOD	1.519
MSDV	101C	Pass	< LOD	0.398	< LOD	1.427
MSDV	102A	Pass	< LOD	0.248	< LOD	1.981
MSDV	102B	Pass	< LOD	0.316	< LOD	1.623
MSDV	102C	Pass	< LOD	0.239	< LOD	1.401
MSDV	103A	Pass	< LOD	0.241	< LOD	1.435
MSDV	103B	Pass	< LOD	0.241	< LOD	1.389
MSDV	104A	Pass	< LOD	0.257	< LOD	1.185
MSDV	104B	Pass	< LOD	0.296	< LOD	1.171
MSDV	104C	Pass	< LOD	0.233	< LOD	1.163
MSDV	105A	Pass	< LOD	0.371	< LOD	1.353
MSDV	105B	Pass	< LOD	0.22	< LOD	1.323
MSDV	105C	Pass	< LOD	0.256	< LOD	1.137
MSDV	106A	Pass	< LOD	0.223	< LOD	1.732
MSDV	106B	Pass	< LOD	0.216	< LOD	1.325
MSDV	10A	Pass	< LOD	0.251	< LOD	1.579
MSDV	10B	Pass	< LOD	0.243	< LOD	1.714
MSDV	10C	Pass	< LOD	0.28	< LOD	2.082
MSDV	11B	Pass	< LOD	0.226	< LOD	1.853
MSDV	11C	Pass	< LOD	0.267	< LOD	1.309
MSDV	12A	Pass	< LOD	0.237	< LOD	1.366
MSDV	12B	Pass	< LOD	0.364	< LOD	1.314
MSDV	12C	Pass	< LOD	0.228	< LOD	2.309
MSDV	15A	Pass	< LOD	0.238	< LOD	1.322
MSDV	15B	Pass	< LOD	0.242	< LOD	1.368
MSDV	15C	Pass	< LOD	0.23	< LOD	1.391
MSDV	16B	Pass	< LOD	0.369	< LOD	1.662
MSDV	16C	Pass	< LOD	0.36	< LOD	1.4
MSDV	17A	Pass	< LOD	0.225	< LOD	1.333
MSDV	17B	Pass	< LOD	0.239	< LOD	1.991
MSDV	20C	Pass	< LOD	0.37	< LOD	1.72
MSDV	21B	Pass	< LOD	0.242	< LOD	1.334
MSDV	23A	Pass	< LOD	0.29	< LOD	1.388
MSDV	23B	Pass	< LOD	0.228	< LOD	1.344
MSDV	23C	Pass	< LOD	0.228	< LOD	1.341
MSDV	24A	Pass	< LOD	0.228	< LOD	1.648
MSDV	24B	Pass	< LOD	0.234	< LOD	1.677
MSDV	28A	Pass	< LOD	0.224	< LOD	1.366

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	28B	Pass	< LOD	0.219	< LOD	1.257
MSDV	29A	Pass	< LOD	0.214	< LOD	1.21
MSDV	2B	Pass	< LOD	0.243	< LOD	1.368
MSDV	31A	Pass	< LOD	0.213	< LOD	1.226
MSDV	31B	Pass	< LOD	0.218	< LOD	1.277
MSDV	31C	Pass	< LOD	0.25	< LOD	1.787
MSDV	32A	Pass	< LOD	0.216	< LOD	1.261
MSDV	32B	Pass	< LOD	0.216	< LOD	1.265
MSDV	32C	Pass	< LOD	0.236	< LOD	1.253
MSDV	36A	Pass	< LOD	0.226	< LOD	1.605
MSDV	36B	Pass	< LOD	0.22	< LOD	1.302
MSDV	37B	Pass	< LOD	0.23	< LOD	1.346
MSDV	37C	Pass	< LOD	0.216	< LOD	1.216
MSDV	3B	Pass	< LOD	0.241	< LOD	1.472
MSDV	3C	Pass	< LOD	0.276	< LOD	1.527
MSDV	44C	Pass	< LOD	0.217	< LOD	2.075
MSDV	45A	Pass	< LOD	0.243	< LOD	1.433
MSDV	45B	Pass	< LOD	0.23	< LOD	1.371
MSDV	45C	Pass	< LOD	0.245	< LOD	1.639
MSDV	46A	Pass	< LOD	0.27	< LOD	1.375
MSDV	46B	Pass	< LOD	0.233	< LOD	1.264
MSDV	46C	Pass	< LOD	0.211	< LOD	1.299
MSDV	47A	Pass	< LOD	0.213	< LOD	1.459
MSDV	47B	Pass	< LOD	0.234	< LOD	1.284
MSDV	47C	Pass	< LOD	0.293	< LOD	1.658
MSDV	48A	Pass	< LOD	0.219	< LOD	1.289
MSDV	48B	Pass	< LOD	0.212	< LOD	1.83
MSDV	48C	Pass	< LOD	0.246	< LOD	1.236
MSDV	49A	Pass	< LOD	0.213	< LOD	1.264
MSDV	49B	Pass	< LOD	0.216	< LOD	1.831
MSDV	49C	Pass	< LOD	0.225	< LOD	1.268
MSDV	4A	Pass	< LOD	0.238	< LOD	1.486
MSDV	4B	Pass	< LOD	0.364	< LOD	2.26
MSDV	4C	Pass	< LOD	0.283	< LOD	1.481
MSDV	50A	Pass	< LOD	0.227	< LOD	1.353
MSDV	50B	Pass	< LOD	0.257	< LOD	1.653
MSDV	50C	Pass	< LOD	0.228	< LOD	2.101
MSDV	51A	Pass	< LOD	0.209	< LOD	1.184
MSDV	51B	Pass	< LOD	0.206	< LOD	2.105
MSDV	51C	Pass	< LOD	0.213	< LOD	1.26
MSDV	52A	Pass	< LOD	0.203	< LOD	1.31
MSDV	52B	Pass	< LOD	0.208	< LOD	1.224
MSDV	52C	Pass	< LOD	0.208	< LOD	1.476
MSDV	53A	Pass	< LOD	0.218	< LOD	1.307

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	53B	Pass	< LOD	0.206	< LOD	1.314
MSDV	53C	Pass	< LOD	0.227	< LOD	1.337
MSDV	54A	Pass	< LOD	0.288	< LOD	1.628
MSDV	54B	Pass	< LOD	0.213	< LOD	1.857
MSDV	54C	Pass	< LOD	0.225	< LOD	2.113
MSDV	55A	Pass	< LOD	0.32	< LOD	1.362
MSDV	55B	Pass	< LOD	0.238	< LOD	1.442
MSDV	55C	Pass	< LOD	0.232	< LOD	2.295
MSDV	56A	Pass	< LOD	0.233	< LOD	1.372
MSDV	56B	Pass	< LOD	0.272	< LOD	1.386
MSDV	56C	Pass	< LOD	0.233	< LOD	1.402
MSDV	57A	Pass	< LOD	0.339	< LOD	2.21
MSDV	57B	Pass	< LOD	0.239	< LOD	1.583
MSDV	57C	Pass	< LOD	0.318	< LOD	2.013
MSDV	58A	Pass	< LOD	0.395	< LOD	1.505
MSDV	58B	Pass	< LOD	0.263	< LOD	1.566
MSDV	58C	Pass	< LOD	0.235	< LOD	2.463
MSDV	59A	Pass	< LOD	0.374	< LOD	1.43
MSDV	59B	Pass	< LOD	0.267	< LOD	1.435
MSDV	5A	Pass	< LOD	0.321	< LOD	1.719
MSDV	5B	Pass	< LOD	0.251	< LOD	1.946
MSDV	5C	Pass	< LOD	0.235	< LOD	1.629
MSDV	60A	Pass	< LOD	0.328	< LOD	1.467
MSDV	60B	Pass	< LOD	0.242	< LOD	1.483
MSDV	60C	Pass	< LOD	0.252	< LOD	2.348
MSDV	61A	Pass	< LOD	0.38	< LOD	1.49
MSDV	61B	Pass	< LOD	0.405	< LOD	1.704
MSDV	61C	Pass	< LOD	0.401	< LOD	1.467
MSDV	62A	Pass	< LOD	0.247	< LOD	1.463
MSDV	62B	Pass	< LOD	0.244	< LOD	2.104
MSDV	62C	Pass	< LOD	0.243	< LOD	1.821
MSDV	63A	Pass	< LOD	0.35	< LOD	1.46
MSDV	63B	Pass	< LOD	0.275	< LOD	1.431
MSDV	64A	Pass	< LOD	0.252	< LOD	1.475
MSDV	64B	Pass	< LOD	0.362	< LOD	1.85
MSDV	65B	Pass	< LOD	0.254	< LOD	1.501
MSDV	65C	Pass	< LOD	0.255	< LOD	1.477
MSDV	66A	Pass	< LOD	0.25	< LOD	1.433
MSDV	66B	Pass	< LOD	0.253	< LOD	1.527
MSDV	66C	Pass	< LOD	0.249	< LOD	1.487
MSDV	67C	Pass	< LOD	0.335	< LOD	1.423
MSDV	68A	Pass	< LOD	0.249	< LOD	1.454
MSDV	68B	Pass	< LOD	0.389	< LOD	1.718
MSDV	68C	Pass	< LOD	0.332	< LOD	1.723

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	69A	Pass	< LOD	0.297	< LOD	1.349
MSDV	69B	Pass	< LOD	0.347	< LOD	1.373
MSDV	69C	Pass	< LOD	0.323	< LOD	1.572
MSDV	6A	Pass	< LOD	0.306	< LOD	1.454
MSDV	6B	Pass	< LOD	0.354	< LOD	1.469
MSDV	6C	Pass	< LOD	0.252	< LOD	1.471
MSDV	70A	Pass	< LOD	0.361	< LOD	1.381
MSDV	70B	Pass	< LOD	0.228	< LOD	1.397
MSDV	70C	Pass	< LOD	0.252	< LOD	1.385
MSDV	71B	Pass	< LOD	0.232	< LOD	1.377
MSDV	71C	Pass	< LOD	0.281	< LOD	1.658
MSDV	72A	Pass	< LOD	0.347	< LOD	1.531
MSDV	72B	Pass	< LOD	0.233	< LOD	1.473
MSDV	72C	Pass	< LOD	0.378	< LOD	1.423
MSDV	73A	Pass	< LOD	0.216	< LOD	1.322
MSDV	73B	Pass	< LOD	0.241	< LOD	1.838
MSDV	73C	Pass	< LOD	0.23	< LOD	2.31
MSDV	74A	Pass	< LOD	0.208	< LOD	1.273
MSDV	74B	Pass	< LOD	0.223	< LOD	1.419
MSDV	74C	Pass	< LOD	0.213	< LOD	1.253
MSDV	75A	Pass	< LOD	0.216	< LOD	1.577
MSDV	75B	Pass	< LOD	0.21	< LOD	1.287
MSDV	75C	Pass	< LOD	0.211	< LOD	1.451
MSDV	76A	Pass	< LOD	0.216	< LOD	1.288
MSDV	76B	Pass	< LOD	0.211	< LOD	1.6
MSDV	76C	Pass	< LOD	0.211	< LOD	1.234
MSDV	77A	Pass	< LOD	0.224	< LOD	1.286
MSDV	77B	Pass	< LOD	0.218	< LOD	1.309
MSDV	77C	Pass	< LOD	0.214	< LOD	1.258
MSDV	78A	Pass	< LOD	0.216	< LOD	1.325
MSDV	78B	Pass	< LOD	0.222	< LOD	1.398
MSDV	78C	Pass	< LOD	0.222	< LOD	1.33
MSDV	79A	Pass	< LOD	0.272	< LOD	1.585
MSDV	79B	Pass	< LOD	0.218	< LOD	1.483
MSDV	79C	Pass	< LOD	0.216	< LOD	1.734
MSDV	7A	Pass	< LOD	0.21	< LOD	1.206
MSDV	7C	Pass	< LOD	0.215	< LOD	1.3
MSDV	80A	Pass	< LOD	0.214	< LOD	1.294
MSDV	80B	Pass	< LOD	0.292	< LOD	1.303
MSDV	80C	Pass	< LOD	0.213	< LOD	1.291
MSDV	81A	Pass	< LOD	0.217	< LOD	1.278
MSDV	81B	Pass	< LOD	0.286	< LOD	1.679
MSDV	81C	Pass	< LOD	0.219	< LOD	1.849
MSDV	82A	Pass	< LOD	0.22	< LOD	1.324

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	82B	Pass	< LOD	0.224	< LOD	1.73
MSDV	82C	Pass	< LOD	0.228	< LOD	1.34
MSDV	83A	Pass	< LOD	0.232	< LOD	1.368
MSDV	83B	Pass	< LOD	0.226	< LOD	1.301
MSDV	83C	Pass	< LOD	0.312	< LOD	1.415
MSDV	84B	Pass	< LOD	0.228	< LOD	1.273
MSDV	84C	Pass	< LOD	0.217	< LOD	1.245
MSDV	85B	Pass	< LOD	0.223	< LOD	1.209
MSDV	86A	Pass	< LOD	0.24	< LOD	1.508
MSDV	86B	Pass	< LOD	0.249	< LOD	2.11
MSDV	86C	Pass	< LOD	0.275	< LOD	2.311
MSDV	87A	Pass	< LOD	0.252	< LOD	1.597
MSDV	87B	Pass	< LOD	0.261	< LOD	1.994
MSDV	87C	Pass	< LOD	0.308	< LOD	1.776
MSDV	88A	Pass	< LOD	0.355	< LOD	1.653
MSDV	88B	Pass	< LOD	0.253	< LOD	2.021
MSDV	88C	Pass	< LOD	0.356	< LOD	1.925
MSDV	89A	Pass	< LOD	0.245	< LOD	1.968
MSDV	89B	Pass	< LOD	0.254	< LOD	2.532
MSDV	89C	Pass	< LOD	0.303	< LOD	1.52
MSDV	8A	Pass	< LOD	0.364	< LOD	1.26
MSDV	8B	Pass	< LOD	0.232	< LOD	1.243
MSDV	90A	Pass	< LOD	0.289	< LOD	1.564
MSDV	90B	Pass	< LOD	0.244	< LOD	1.52
MSDV	90C	Pass	< LOD	0.398	< LOD	1.645
MSDV	91A	Pass	< LOD	0.251	< LOD	1.524
MSDV	91B	Pass	< LOD	0.256	< LOD	1.551
MSDV	91C	Pass	< LOD	0.252	< LOD	1.762
MSDV	92A	Pass	< LOD	0.366	< LOD	1.512
MSDV	92B	Pass	< LOD	0.246	< LOD	1.527
MSDV	92C	Pass	< LOD	0.284	< LOD	1.679
MSDV	93A	Pass	< LOD	0.294	< LOD	1.344
MSDV	93B	Pass	< LOD	0.246	< LOD	1.788
MSDV	93C	Pass	< LOD	0.266	< LOD	1.8
MSDV	94A	Pass	< LOD	0.367	< LOD	1.58
MSDV	94B	Pass	< LOD	0.253	< LOD	1.865
MSDV	94C	Pass	< LOD	0.261	< LOD	2.292
MSDV	95A	Pass	< LOD	0.287	< LOD	1.236
MSDV	95B	Pass	< LOD	0.253	< LOD	1.416
MSDV	95C	Pass	< LOD	0.204	< LOD	1.084
MSDV	96A	Pass	< LOD	0.204	< LOD	1.383
MSDV	96B	Pass	< LOD	0.203	< LOD	1.186
MSDV	96C	Pass	< LOD	0.289	< LOD	1.259
MSDV	97A	Pass	< LOD	0.22	< LOD	1.383

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
MSDV	97B	Pass	< LOD	0.194	< LOD	1.194
MSDV	97C	Pass	< LOD	0.212	< LOD	1.224
MSDV	98A	Pass	< LOD	0.213	< LOD	1.2
MSDV	98B	Pass	< LOD	0.206	< LOD	1.206
MSDV	98C	Pass	< LOD	0.309	< LOD	1.642
MSDV	99A	Pass	< LOD	0.268	< LOD	1.663
MSDV	99B	Pass	< LOD	0.189	< LOD	1.456
MSDV	99C	Pass	< LOD	0.183	< LOD	1.082
MSDV	9A	Pass	< LOD	0.217	< LOD	1.786
MSDV	9B	Pass	< LOD	0.244	< LOD	1.441
MSDV	9C	Pass	< LOD	0.237	< LOD	1.242

Note: <LOD means result less than the level of detection

Reloadable Tube Aerial Shell Devices

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	1	Pass	< LOD	0.246	< LOD	1.259
RTAS	2	Pass	0.243	0.146	< LOD	1.448
RTAS	3	Pass	0.665	0.186	< LOD	1.719
RTAS	4	Pass	0.522	0.159	< LOD	1.52
RTAS	5	Pass	0.276	0.153	< LOD	1.426
RTAS	6	Pass	< LOD	0.275	< LOD	1.247
RTAS	7	Pass	0.451	0.166	< LOD	1.869
RTAS	8	Pass	0.35	0.16	< LOD	1.446
RTAS	9	Pass	0.398	0.159	< LOD	1.451
RTAS	10	Pass	0.33	0.159	< LOD	1.414
RTAS	11	Pass	0.284	0.149	< LOD	1.238
RTAS	12	Pass	< LOD	0.332	< LOD	1.344
RTAS	13	Pass	< LOD	0.284	< LOD	1.574
RTAS	14	Pass	< LOD	0.23	< LOD	1.346
RTAS	19	Pass	6.257	0.471	< LOD	1.147
RTAS	20	Pass	3.049	0.238	< LOD	1.237
RTAS	22	Pass	5.507	0.389	< LOD	1.039
RTAS	24	Pass	9.289	0.541	< LOD	1.255
RTAS	25	Pass	8.089	0.494	< LOD	1.343
RTAS	26	Pass	8.551	0.522	< LOD	1.348
RTAS	27	Pass	5.045	0.356	< LOD	1.477
RTAS	28	Pass	8.005	0.473	< LOD	1.32
RTAS	29	Pass	9.023	0.573	< LOD	1.383
RTAS	30	Pass	7.61	0.458	< LOD	1.338
RTAS	31	Pass	9.003	0.56	< LOD	1.294
RTAS	32	Pass	4.548	0.348	< LOD	1.878
RTAS	33	Pass	1.615	0.191	< LOD	1.422

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	34	Pass	4.394	0.33	< LOD	1.412
RTAS	35	Pass	4.777	0.344	< LOD	1.448
RTAS	36	Pass	2.884	0.242	< LOD	1.392
RTAS	37	Pass	2.902	0.256	< LOD	1.564
RTAS	38	Pass	5.327	0.369	< LOD	1.265
RTAS	39	Pass	1.901	0.198	< LOD	1.197
RTAS	40	Pass	3.001	0.258	< LOD	1.334
RTAS	41	Pass	3.033	0.26	< LOD	1.34
RTAS	42	Pass	3.866	0.311	< LOD	1.376
RTAS	43	Pass	2.32	0.234	< LOD	1.952
RTAS	44	Pass	2.537	0.256	< LOD	2.232
RTAS	45	Pass	1.386	0.177	< LOD	1.182
RTAS	46	Pass	2.703	0.246	< LOD	1.343
RTAS	47	Pass	3.997	0.308	< LOD	1.433
RTAS	48	Pass	2.228	0.227	< LOD	1.345
RTAS	49	Pass	< LOD	0.203	< LOD	1.104
RTAS	50	Pass	< LOD	0.213	< LOD	1.241
RTAS	51	Pass	< LOD	0.328	< LOD	1.179
RTAS	52	Pass	< LOD	0.202	< LOD	1.163
RTAS	53	Pass	< LOD	0.203	< LOD	1.12
RTAS	54	Pass	0.291	0.148	< LOD	1.241
RTAS	55	Pass	< LOD	0.2	< LOD	1.14
RTAS	56	Pass	< LOD	0.3	< LOD	1.314
RTAS	57	Pass	0.227	0.149	< LOD	1.225
RTAS	58	Pass	0.396	0.151	< LOD	1.923
RTAS	59	Pass	< LOD	0.241	< LOD	1.841
RTAS	60	Pass	0.39	0.151	< LOD	1.226
RTAS	61	Pass	< LOD	0.25	< LOD	1.321
RTAS	62	Pass	< LOD	0.297	< LOD	1.314
RTAS	63	Pass	0.262	0.163	< LOD	1.407
RTAS	64	Pass	7.983	0.435	< LOD	1.249
RTAS	65	Pass	8.521	0.516	< LOD	1.196
RTAS	66	Pass	8.117	0.438	< LOD	1.229
RTAS	67	Pass	10.164	0.618	< LOD	1.202
RTAS	68	Pass	10.667	0.576	< LOD	1.246
RTAS	69	Pass	19.715	0.485	< LOD	4.318
RTAS	70	Pass	< LOD	0.391	< LOD	1.411
RTAS	71	Pass	< LOD	0.244	< LOD	1.421
RTAS	72	Pass	5.182	0.338	< LOD	1.207
RTAS	73	Pass	5.628	0.371	< LOD	2.013
RTAS	74	Pass	5.326	0.406	< LOD	2.013
RTAS	75	Pass	5.115	0.318	< LOD	1.223
RTAS	76	Pass	< LOD	0.336	< LOD	1.421
RTAS	77	Pass	< LOD	0.309	< LOD	2.24

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	78	Pass	< LOD	0.343	< LOD	1.373
RTAS	79	Pass	< LOD	0.234	< LOD	1.339
RTAS	80	Pass	< LOD	0.237	< LOD	1.391
RTAS	81	Pass	< LOD	0.342	< LOD	1.368
RTAS	82	Pass	0.233	0.154	< LOD	1.347
RTAS	83	Pass	< LOD	0.37	< LOD	1.824
RTAS	84	Pass	< LOD	0.229	< LOD	1.36
RTAS	85	Pass	< LOD	0.233	< LOD	1.382
RTAS	86	Pass	< LOD	0.324	< LOD	1.428
RTAS	87	Pass	< LOD	0.21	< LOD	1.708
RTAS	88	Pass	< LOD	0.207	< LOD	1.917
RTAS	89	Pass	< LOD	0.219	< LOD	1.358
RTAS	90	Pass	< LOD	0.21	< LOD	1.25
RTAS	91	Pass	< LOD	0.218	< LOD	2.267
RTAS	92	Pass	< LOD	0.22	< LOD	1.289
RTAS	93	Pass	< LOD	0.219	< LOD	1.912
RTAS	94	Pass	< LOD	0.299	< LOD	1.514
RTAS	95	Pass	< LOD	0.228	< LOD	1.364
RTAS	96	Pass	< LOD	0.221	< LOD	1.348
RTAS	97	Pass	< LOD	0.269	< LOD	1.625
RTAS	98	Pass	< LOD	0.217	< LOD	1.339
RTAS	99	Pass	< LOD	0.256	< LOD	1.835
RTAS	100	Pass	0.369	0.162	< LOD	1.471
RTAS	101	Pass	< LOD	0.236	< LOD	1.495
RTAS	102	Pass	0.316	0.158	< LOD	1.731
RTAS	103	Pass	0.479	0.169	< LOD	1.404
RTAS	104	Pass	0.569	0.165	< LOD	1.338
RTAS	105	Pass	< LOD	0.247	< LOD	1.674
RTAS	106	Pass	0.412	0.163	< LOD	1.489
RTAS	107	Pass	0.274	0.168	< LOD	2.144
RTAS	108	Pass	0.4	0.169	< LOD	1.766
RTAS	109	Pass	0.392	0.165	< LOD	1.35
RTAS	110	Pass	0.435	0.167	< LOD	1.823
RTAS	111	Pass	0.286	0.165	< LOD	1.53
RTAS	112	Pass	0.234	0.154	< LOD	1.348
RTAS	113	Pass	0.337	0.164	< LOD	1.398
RTAS	114	Pass	< LOD	0.233	< LOD	1.347
RTAS	115	Pass	0.367	0.152	< LOD	1.235
RTAS	116	Pass	< LOD	0.208	< LOD	1.16
RTAS	117	Pass	< LOD	0.209	< LOD	1.794
RTAS	118	Pass	< LOD	0.317	< LOD	1.25
RTAS	119	Pass	< LOD	0.214	< LOD	1.194
RTAS	120	Pass	< LOD	0.227	< LOD	1.305
RTAS	121	Pass	< LOD	0.231	< LOD	1.596

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	122	Pass	< LOD	0.233	< LOD	1.341
RTAS	123	Pass	< LOD	0.355	< LOD	1.239
RTAS	124	Pass	< LOD	0.366	< LOD	1.335
RTAS	125	Pass	0.294	0.155	< LOD	1.297
RTAS	126	Pass	< LOD	0.23	< LOD	1.534
RTAS	127	Pass	< LOD	0.233	< LOD	1.34
RTAS	128	Pass	0.302	0.146	< LOD	1.266
RTAS	129	Pass	0.519	0.159	< LOD	1.319
RTAS	130	Pass	0.343	0.137	< LOD	1.158
RTAS	131	Pass	0.548	0.15	< LOD	1.443
RTAS	132	Pass	0.4	0.151	< LOD	1.285
RTAS	133	Pass	0.697	0.157	< LOD	1.517
RTAS	134	Pass	< LOD	0.218	< LOD	1.335
RTAS	135	Pass	0.348	0.138	< LOD	1.83
RTAS	136	Pass	0.448	0.155	< LOD	1.326
RTAS	137	Pass	0.305	0.135	< LOD	1.152
RTAS	138	Pass	0.478	0.154	< LOD	1.645
RTAS	139	Pass	0.484	0.15	< LOD	1.328
RTAS	140	Pass	< LOD	0.228	< LOD	1.108
RTAS	141	Pass	0.585	0.159	< LOD	1.239
RTAS	142	Pass	0.455	0.153	< LOD	2.128
RTAS	143	Pass	0.462	0.155	< LOD	1.239
RTAS	144	Pass	0.322	0.147	< LOD	1.283
RTAS	145	Pass	3.344	0.366	< LOD	1.721
RTAS	146	Pass	0.455	0.167	< LOD	1.439
RTAS	147	Pass	0.243	0.141	< LOD	1.24
RTAS	148	Pass	< LOD	0.275	< LOD	1.352
RTAS	149	Pass	< LOD	0.216	< LOD	1.73
RTAS	150	Pass	0.271	0.155	< LOD	1.35
RTAS	151	Pass	0.339	0.16	< LOD	1.466
RTAS	152	Pass	0.374	0.155	< LOD	1.236
RTAS	153	Pass	< LOD	0.222	< LOD	1.227
RTAS	154	Pass	0.255	0.153	< LOD	1.296
RTAS	155	Pass	< LOD	0.321	< LOD	1.369
RTAS	156	Pass	< LOD	0.236	< LOD	1.516
RTAS	157	Pass	< LOD	0.243	< LOD	1.92
RTAS	158	Pass	< LOD	0.356	< LOD	1.835
RTAS	159	Pass	< LOD	0.192	< LOD	1.613
RTAS	160	Pass	< LOD	0.271	< LOD	1.313
RTAS	161	Pass	14.488	2.449	4.972	1.136
RTAS	162	Pass	< LOD	0.21	< LOD	1.207
RTAS	163	Pass	< LOD	0.226	< LOD	1.284
RTAS	164	Pass	0.274	0.164	< LOD	1.863
RTAS	165	Pass	17.971	1.132	< LOD	1.883

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	166	Pass	0.274	0.141	< LOD	1.552
RTAS	167	Pass	0.378	0.149	< LOD	1.363
RTAS	168	Pass	0.376	0.154	< LOD	1.233
RTAS	169	Pass	0.414	0.153	< LOD	1.763
RTAS	170	Pass	0.347	0.153	< LOD	1.771
RTAS	171	Pass	0.344	0.158	1.683	0.903
RTAS	172	Pass	0.515	0.153	< LOD	1.213
RTAS	173	Pass	0.389	0.153	< LOD	1.285
RTAS	174	Pass	0.365	0.155	< LOD	1.593
RTAS	175	Pass	0.301	0.143	< LOD	1.871
RTAS	176	Pass	0.356	0.141	< LOD	1.134
RTAS	177	Pass	0.442	0.159	< LOD	1.928
RTAS	178	Pass	0.455	0.166	< LOD	1.9
RTAS	179	Pass	0.267	0.154	< LOD	1.315
RTAS	180	Pass	0.468	0.152	< LOD	1.943
RTAS	181	Pass	0.517	0.155	< LOD	1.537
RTAS	182	Pass	0.242	0.147	< LOD	1.708
RTAS	183	Pass	0.361	0.147	< LOD	1.211
RTAS	184	Pass	0.484	0.152	< LOD	1.217
RTAS	185	Pass	0.606	0.169	< LOD	1.316
RTAS	186	Pass	0.586	0.161	< LOD	1.266
RTAS	187	Pass	0.482	0.155	< LOD	1.711
RTAS	188	Pass	0.563	0.152	< LOD	1.634
RTAS	189	Pass	0.542	0.164	< LOD	2.225
RTAS	190	Pass	0.6	0.161	< LOD	1.276
RTAS	191	Pass	0.571	0.16	< LOD	1.824
RTAS	192	Pass	0.402	0.157	< LOD	1.421
RTAS	193	Pass	< LOD	0.209	< LOD	1.567
RTAS	194	Pass	3.846	0.293	< LOD	1.079
RTAS	195	Pass	3.183	0.236	< LOD	1.097
RTAS	196	Pass	3.731	0.291	< LOD	1.389
RTAS	197	Pass	4.327	0.281	< LOD	1.142
RTAS	198	Pass	3.287	0.287	< LOD	1.689
RTAS	199	Pass	4.241	0.266	< LOD	1.139
RTAS	200	Pass	3.627	0.279	< LOD	1.192
RTAS	201	Pass	4.177	0.275	< LOD	1.128
RTAS	202	Pass	3.923	0.307	< LOD	1.588
RTAS	203	Pass	4.007	0.301	< LOD	1.257
RTAS	204	Pass	3.175	0.234	< LOD	1.109
RTAS	205	Pass	4.183	0.288	< LOD	1.418
RTAS	206	Pass	5.046	0.379	< LOD	1.749
RTAS	207	Pass	5.547	0.368	< LOD	1.119
RTAS	208	Pass	5.157	0.356	< LOD	1.427
RTAS	209	Pass	4.765	0.338	< LOD	1.162

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	210	Pass	4.553	0.344	< LOD	1.446
RTAS	211	Pass	4.215	0.284	< LOD	1.283
RTAS	212	Pass	< LOD	0.223	< LOD	2.14
RTAS	213	Pass	< LOD	0.218	< LOD	1.258
RTAS	214	Pass	< LOD	0.214	< LOD	1.3
RTAS	215	Pass	< LOD	0.264	< LOD	1.242
RTAS	216	Pass	< LOD	0.22	< LOD	1.272
RTAS	217	Pass	< LOD	0.243	< LOD	1.283
RTAS	218	Pass	< LOD	0.217	< LOD	1.266
RTAS	219	Pass	< LOD	0.277	< LOD	1.582
RTAS	220	Pass	0.355	0.149	< LOD	1.516
RTAS	221	Pass	< LOD	0.225	< LOD	1.35
RTAS	222	Pass	< LOD	0.223	< LOD	1.223
RTAS	223	Pass	< LOD	0.361	< LOD	1.333
RTAS	224	Pass	< LOD	0.243	< LOD	1.495
RTAS	225	Pass	< LOD	0.253	< LOD	1.465
RTAS	226	Pass	< LOD	0.219	< LOD	1.681
RTAS	227	Pass	< LOD	0.346	< LOD	1.286
RTAS	228	Pass	< LOD	0.223	< LOD	1.261
RTAS	229	Pass	< LOD	0.218	< LOD	1.281
RTAS	230	Pass	< LOD	0.215	< LOD	1.31
RTAS	231	Pass	< LOD	0.297	< LOD	1.316
RTAS	232	Pass	< LOD	0.225	< LOD	1.521
RTAS	233	Pass	< LOD	0.227	< LOD	1.344
RTAS	234	Pass	< LOD	0.221	< LOD	1.312
RTAS	235	Pass	< LOD	0.227	< LOD	1.365
RTAS	236	Pass	< LOD	0.327	< LOD	1.304
RTAS	237	Pass	< LOD	0.301	< LOD	1.345
RTAS	238	Pass	< LOD	0.252	< LOD	1.38
RTAS	239	Pass	< LOD	0.222	< LOD	1.576
RTAS	240	Pass	< LOD	0.225	< LOD	1.325
RTAS	241	Pass	< LOD	0.244	< LOD	1.325
RTAS	242	Pass	< LOD	0.26	< LOD	2.038
RTAS	243	Pass	< LOD	0.411	< LOD	1.552
RTAS	244	Pass	< LOD	0.262	< LOD	1.587
RTAS	245	Pass	< LOD	0.26	< LOD	1.53
RTAS	246	Pass	< LOD	0.286	< LOD	1.574
RTAS	247	Pass	< LOD	0.238	< LOD	1.396
RTAS	248	Pass	< LOD	0.285	< LOD	1.556
RTAS	249	Pass	< LOD	0.247	< LOD	1.547
RTAS	250	Pass	0.329	0.162	< LOD	1.421
RTAS	251	Pass	< LOD	0.32	< LOD	1.856
RTAS	252	Pass	< LOD	0.308	< LOD	1.955
RTAS	253	Pass	< LOD	0.259	< LOD	1.578

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	254	Pass	0.316	0.177	< LOD	1.567
RTAS	255	Pass	< LOD	0.404	< LOD	1.594
RTAS	256	Pass	0.646	0.163	< LOD	1.31
RTAS	257	Pass	< LOD	0.269	< LOD	1.554
RTAS	258	Pass	< LOD	0.259	< LOD	1.625
RTAS	259	Pass	< LOD	0.416	< LOD	1.606
RTAS	260	Pass	6.704	0.396	< LOD	1.398
RTAS	261	Pass	7.822	0.513	< LOD	2.253
RTAS	262	Pass	7.416	0.424	< LOD	1.374
RTAS	263	Pass	6.482	0.377	< LOD	1.354
RTAS	264	Pass	5.615	0.351	< LOD	1.352
RTAS	265	Pass	6.964	0.401	< LOD	1.325
RTAS	266	Pass	< LOD	0.374	< LOD	1.536
RTAS	267	Pass	< LOD	0.245	< LOD	2.38
RTAS	268	Pass	< LOD	0.258	< LOD	2.566
RTAS	269	Pass	< LOD	0.333	< LOD	1.584
RTAS	270	Pass	< LOD	0.407	< LOD	1.625
RTAS	271	Pass	0.373	0.156	< LOD	2.147
RTAS	272	Pass	0.233	0.147	< LOD	1.24
RTAS	273	Pass	< LOD	0.321	< LOD	1.227
RTAS	274	Pass	0.219	0.143	< LOD	1.194
RTAS	275	Pass	< LOD	0.288	< LOD	1.199
RTAS	276	Pass	< LOD	0.201	< LOD	1.201
RTAS	277	Pass	< LOD	0.325	< LOD	1.364
RTAS	278	Pass	< LOD	0.21	< LOD	1.829
RTAS	279	Pass	< LOD	0.252	< LOD	1.218
RTAS	280	Pass	< LOD	0.283	< LOD	1.964
RTAS	281	Pass	< LOD	0.233	< LOD	1.202
RTAS	282	Pass	0.334	0.102	< LOD	0.643
RTAS	283	Pass	0.438	0.108	< LOD	0.77
RTAS	284	Pass	0.337	0.104	< LOD	0.65
RTAS	285	Pass	0.319	0.101	< LOD	0.639
RTAS	286	Pass	0.214	0.097	< LOD	0.622
RTAS	287	Pass	0.278	0.101	< LOD	0.695
RTAS	288	Pass	0.283	0.103	< LOD	0.635
RTAS	289	Pass	0.216	0.1	< LOD	1.036
RTAS	290	Pass	0.462	0.105	< LOD	1.047
RTAS	291	Pass	0.428	0.105	< LOD	0.652
RTAS	292	Pass	0.287	0.136	< LOD	1.085
RTAS	293	Pass	0.216	0.143	< LOD	1.487
RTAS	294	Pass	< LOD	0.27	< LOD	1.187
RTAS	295	Pass	0.276	0.143	< LOD	1.17
RTAS	296	Pass	< LOD	0.206	< LOD	1.534
RTAS	297	Pass	< LOD	0.201	< LOD	1.302

Category	Sample No.	On-site result	Al (%)	Al Error (%)	Mg (%)	Mg Error (%)
RTAS	298	Pass	< LOD	0.32	< LOD	1.639
RTAS	299	Pass	< LOD	0.399	< LOD	1.601
RTAS	300	Pass	< LOD	0.266	< LOD	1.986
RTAS	301	Pass	< LOD	0.352	< LOD	1.765
RTAS	302	Pass	< LOD	0.331	< LOD	1.648
RTAS	303	Pass	< LOD	0.253	< LOD	2.187
RTAS	304	Pass	< LOD	0.256	< LOD	1.616
RTAS	305	Pass	< LOD	0.241	< LOD	1.5
RTAS	306	Pass	< LOD	0.268	< LOD	1.572
RTAS	307	Pass	< LOD	0.254	< LOD	1.589

Appendix 3 – ICP Results

Mine and Shell Devices

Category	Sample No.	XRF Al (%)	XRF Al Error (%)	XRF Mg (%)	XRF Mg Error (%)	ICP Mg (%)	ICP Al (%)
MSDV	22B	0.443	0.165	< LOD	1.385	0.176	0.296
MSDV	43B	0.45	0.156	< LOD	1.241	0.945	0.531
MSDV	101A	0.466	0.169	< LOD	1.415	0.064	0.152
MSDV	22A	0.517	0.166	< LOD	1.304	0.152	0.289
MSDV	21A	0.523	0.169	< LOD	1.302	0.218	0.418
MSDV	41C	0.543	0.154	< LOD	1.245	0.314	0.401
MSDV	38A	0.547	0.164	< LOD	1.324	0.394	0.508
MSDV	38B	0.587	0.166	< LOD	1.637	0.553	0.553
MSDV	41B	0.592	0.152	< LOD	1.207	0.276	0.377
MSDV	107B	0.606	0.163	< LOD	2.321	0.049	0.058
MSDV	43C	0.653	0.159	< LOD	1.274	0.835	0.783
MSDV	22C	0.966	0.191	< LOD	1.306	0.148	0.256
MSDV	21C	1.001	0.192	< LOD	1.288	0.259	0.458
MSDV	25C	1.089	0.175	< LOD	1.278	0.103	0.829
MSDV	39B	1.26	0.189	< LOD	1.415	0.955	1.33
MSDV	27B	1.527	0.188	< LOD	1.258	0.102	1.08
MSDV	20B	1.865	0.245	< LOD	1.283	0.142	0.407

Reloadable Tube Mine and Shell Devices

Category	Sample No.	XRF Al (%)	XRF Al Error (%)	XRF Mg (%)	XRF Mg Error (%)	ICP Mg (%)	ICP Al (%)
RTAS	171	0.344	0.158	1.683	0.903	0.057	0.277
RTAS	283	0.438	0.108	< LOD	0.77	ND	0.276
RTAS	177	0.442	0.159	< LOD	1.928	0.044	0.319
RTAS	136	0.448	0.155	< LOD	1.326	0.128	0.367
RTAS	7	0.451	0.166	< LOD	1.869	0.144	0.397
RTAS	142	0.455	0.153	< LOD	2.128	0.204	0.461
RTAS	146	0.455	0.167	< LOD	1.439	0.41	0.581
RTAS	178	0.455	0.166	< LOD	1.9	0.039	0.173
RTAS	143	0.462	0.155	< LOD	1.239	0.18	0.392
RTAS	290	0.462	0.105	< LOD	1.047	ND	0.275
RTAS	138	0.478	0.154	< LOD	1.645	0.131	0.357
RTAS	103	0.479	0.169	< LOD	1.404	0.043	0.122
RTAS	187	0.482	0.155	< LOD	1.711	0.045	0.237
RTAS	139	0.484	0.15	< LOD	1.328	0.15	0.381
RTAS	184	0.484	0.152	< LOD	1.217	0.04	0.26
RTAS	172	0.515	0.153	< LOD	1.213	0.057	0.411
RTAS	181	0.517	0.155	< LOD	1.537	0.042	0.179
RTAS	129	0.519	0.159	< LOD	1.319	0.147	0.38
RTAS	4	0.522	0.159	< LOD	1.52	0.619	0.804
RTAS	189	0.542	0.164	< LOD	2.225	0.045	0.214
RTAS	131	0.548	0.15	< LOD	1.443	0.16	0.422
RTAS	188	0.563	0.152	< LOD	1.634	0.043	0.31
RTAS	104	0.569	0.165	< LOD	1.338	0.041	0.422
RTAS	191	0.571	0.16	< LOD	1.824	0.045	0.185
RTAS	141	0.585	0.159	< LOD	1.239	0.111	0.371
RTAS	186	0.586	0.161	< LOD	1.266	0.05	0.222
RTAS	190	0.6	0.161	< LOD	1.276	0.045	0.188
RTAS	185	0.606	0.169	< LOD	1.316	0.173	0.232
RTAS	256	0.646	0.163	< LOD	1.31	0.075	0.356
RTAS	3	0.665	0.186	< LOD	1.719	0.352	0.604
RTAS	133	0.697	0.157	< LOD	1.517	0.148	0.386
RTAS	45	1.386	0.177	< LOD	1.182	ND	2.61
RTAS	33	1.615	0.191	< LOD	1.422	ND	2.28
RTAS	39	1.901	0.198	< LOD	1.197	ND	2.51
RTAS	48	2.228	0.227	< LOD	1.345	ND	2.34
RTAS	43	2.32	0.234	< LOD	1.952	ND	2.42
RTAS	44	2.537	0.256	< LOD	2.232	ND	2.58
RTAS	46	2.703	0.246	< LOD	1.343	ND	2.49
RTAS	36	2.884	0.242	< LOD	1.392	ND	2.39