Office for Product
Safety & Standards

Noise Testing of Fireworks

Final report

January 2023

Executive Summary

This document replicates the content of the report ‘OPSS: Noise Testing of Fireworks’, report number HMX/21/28R produced by HSE Science and Research Centre, Buxton.

This report and the work it describes were undertaken by the Health and Safety Executive (HSE) under contract to Office for Product Safety and Standards. Its contents, including any opinions and/or conclusions expressed, or recommendations made, do not supersede current HSE policy or guidance.

The Office for Product Safety and Standards (OPSS) commissioned Health and Safety Executive Science Division (HSE-SD) to deliver a programme of fireworks testing to determine the average decibel level for common types of retail fireworks sold for public use. Accordingly, the aim of this report is to provide a factual, evidence-based record of the noise levels produced by a wide selection of fireworks, across both diferent firework types (e.g., rocket, shot tube etc.) and different firework categories (category 2 and category 3 fireworks as defined in the relevant industry standards).

A broad selection of fireworks of different types and categories were subjected to testing in order to provide a fully representative indication of the noise levels produced across the range of fireworks that are available to the public in the UK.

72 different articles were tested from 14 manufacturers/importers across 9 different firework types. On 4 occasions the 120 dB (AI Max) noise limit threshold was exceeded. These were Battery of Shot Tube articles and were evenly spread across category 2 and category 3 articles. It was found that there is a wide variation of noise levels across different firework types, particularly in the case of category 2 fireworks.

Battery of Shot Tubes and Single Shot Tube articles produced higher noise levels than all other firework types across both category 2 and category 3. The range of noise levels produced by category 2 Wheels, Roman Candles, Fountains, Batteries of Shot Tubes and Rockets was found to be wider than the corresponding category 3 articles. The single exception to this was observed for Fountains which were found to produce a wide range of noise levels across both category 2 and category 3 fireworks.

There are a number of variables that need to be considered which could influence the noise levels generated and/or recorded. These variables have been identified and grouped into either physical effects (Wind strength and direction, humidity, reflection of sound (from buildings and/or trees)) or firework effects (lifting charge, crackle stars, bursting charge). The results obtained through testing of different firework types and categories indicate that variances in noise levels can be somewhat influenced by either physical and/or firework effects that occur at the time of test.

The sample set used for this research, whilst representative of the market at the time of acquisition and testing only covers a very small portion of the firework product offering available to the public.

Contents

1 Introduction

1.1 Background

The Office for Product Safety Standards (OPSS), part of the Department for Business, Energy & Industrial Strategy (BEIS) commissioned Health and Safety Executive – Science Division (HSE SD) to complete a programme of fireworks testing to determine the average decibel level for common types of retail fireworks sold for public use.

1.2 Noise

Noise is measured in decibels (dB), with the measurement of sound consisting of two separate aspects:

- Frequency of the noise (measured in Hertz (Hz));
- Intensity of the noise

To allow it to be applied to the full range of possible noise levels, the dB scale is logarithmic, meaning that small changes in the dB value represent a significant change in noise level. The 'rule of 3' is commonly cited in this respect as an increase of 3 dB doubles the level of noise energy.

The perceived noise level decays with increased distance from the noise source (*i.e.* the further you are away from it, the lower the perceived noise would be). In terms of predicting the decay of noise levels over distance, the inverse square law is often used:

- **Inverse Square Law**: Doubling of distance, the noise level reduces by 6 dB. This principle is used within CEN Standard BS EN 15947 to determine the minimum distance that spectators should be from the firing point:
- **Category 2 firework**: Noise meter level readings taken at 8 m, spectators to be at a minimum safety distance of 15 m. Using the inverse square law, the noise level reading would be reduced by 5.46 dB.
- **Category 3 firework**: Noise meter level readings taken at 15 m, spectators to be at a minimum safety distance of 25m. Using the inverse square law, the noise level reading would be reduced by 4.44 dB.

1.3 Aim and Objectives

The aim of the test programme was to carry out noise testing on a wide selection of publicly available fireworks to ascertain the noise levels generated across both different firework types and firework categories.

Fireworks that are available to the public fall into three categories;

- **Category F1** – Fireworks which present a very low hazard and negligible noise level and which are intended for use in confined areas, including for use inside domestic buildings.
- **Category F2** – Fireworks which present a low level hazard and low noise level intended for outdoor use in confined areas.

- **Category F3** – Fireworks which present a medium hazard, for outdoor use in large open areas and whose noise level is not harmful to human health.

For the purpose of this research, OPSS selected a range of firework types from categories F2 and F3, sampled from as diverse a range of manufacturers / importers as possible available at the time of purchase. A total 72 different articles across 9 different firework types and marketed by 14 different manufacturers / importers were selected by OPSS.

Table 1. Details the firework type and categories of the selected articles

Firework Type	Category 2 (F2)	Category 3 (F3)	Total
Rocket	6	6	12
Battery/Cake (Shot Tubes)	20	7	27
Roman Candle (RC)	9	3	12
Single Shot Tube	1	1	2
Mine	1	1	2
Fountain	5	2	7
Battery of Fountains	2	-	-
Wheel	4	2	6
Fountain/Mine combination	2	-	2
Total	50	22	72

The reported test programme comprised of two testing phases;

- Phase 1: 41 articles were tested
- Phase 2: 31 articles were tested

In generating this report document, the previously issued Phase 1 report (HMX/20/33) has been updated to incorporate all the test data from Phase 2. The results obtained across both testing phases are reflected in the graphs, analysis and conclusions presented in this Report.

2 Methods

HSE-SD conducted the noise (sound) level measurements (AI Max dB) as part of the performance testing of the fireworks articles according to the CEN Standard BS EN 15947 at the distances specified within the standard.[1, 2]

Noise level meters were placed at a height of 1 m and at the required distance of:

- 15 m from the firing point for category 3 fireworks; and
- 8 m from the firing point for category 2 fireworks

The wind speed was taken prior to testing using an anemometer to confirm it was ≤ 5 m/s and within the parameters of the test (no testing was performed outside of the required test parameters).

A number of repeats were undertaken on each firework article tested, these were:

- 10 repeats for rockets; and
- 3 repeats for all other firework types.

2.1 Test Site and Noise Meter Positioning

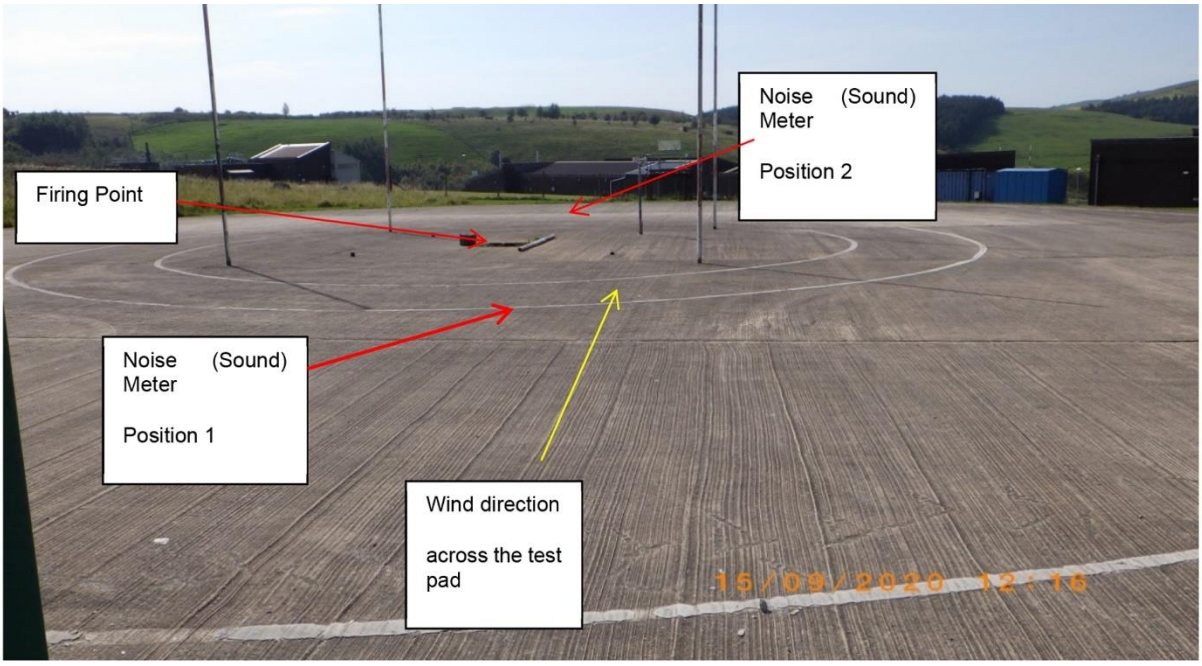
The setup of the test site for the performance testing of both category 2 and category 3 fireworks is shown in Photograph 1.

Photograph 1: Test Site for BS EN 15947 Pyrotechnic Articles Standard

Although the BS EN 15947 standard sets out that only one noise meter is required, for the purpose of this study, 2 noise meters were used to record AI Max dB. The precise positioning of the noise meters was altered depending on the wind conditions at the time of testing. The first noise meter was positioned (Noise (Sound) Meter Position 1) at the required distance from the firing point (position where the article was placed) facing in the direction of the wind. The second noise meter (Noise

(Sound) Meter Position 2) was positioned at 180 degrees to the first meter (opposite) facing directly into the wind.

An illustrative example for a category (F2) firework article set up is provided in Photograph 2.



Photograph 2: Noise (Sound) Meter Positioning (at 8 m) for a Category 2 Firework

2.2 Equipment

Prior to testing, pre-use checks were completed on both noise meters, and the wind speed was recorded using an anemometer. All equipment used during the testing was calibrated to the relevant standard and was within calibration limits.

A list of calibrated equipment used for this study:

- Pistonphone
- Noise meter
- Stopwatches
- Metre rule
- Anemometer

2.3 Noise Measurement

"A" Weighting, Impulse Weighting and AI Max dB

"A" weighting refers to a specific weighting used to best represent the response of a typical human ear to sound.[3, 4, 5]

Impulse weighting reflects the speed at which the instrument used responds to the changing noise levels.[3,4]

AI Max dB is the maximum noise level with "A" frequency weighting and impulse time weighting applied. Under these parameters, the noise meter instrument will respond very quickly to any increase in the noise level, but will take longer to fall when the noise level decreases.

The designated standard details that the noise meter readings must be to AI Max dB and the noise limit for any firework is 120 (AI Max dB) at the prescribed distance from where the firework (article) is fired (ignited) from.

3 Results and Discussion

There are a number of key variables which can have a direct effect on the noise level generated by a firework article (see section 3.1). A number of repeats were conducted on each firework article to ensure that the results produced were representative of the data set tested. **Note**: these variables may change to a lesser or greater degree between each repeat and any extrapolation or read across beyond this reference set cannot be inferred.

As an example, the noise measurements recorded during testing of Rocket 1 is shown (Figure 1).

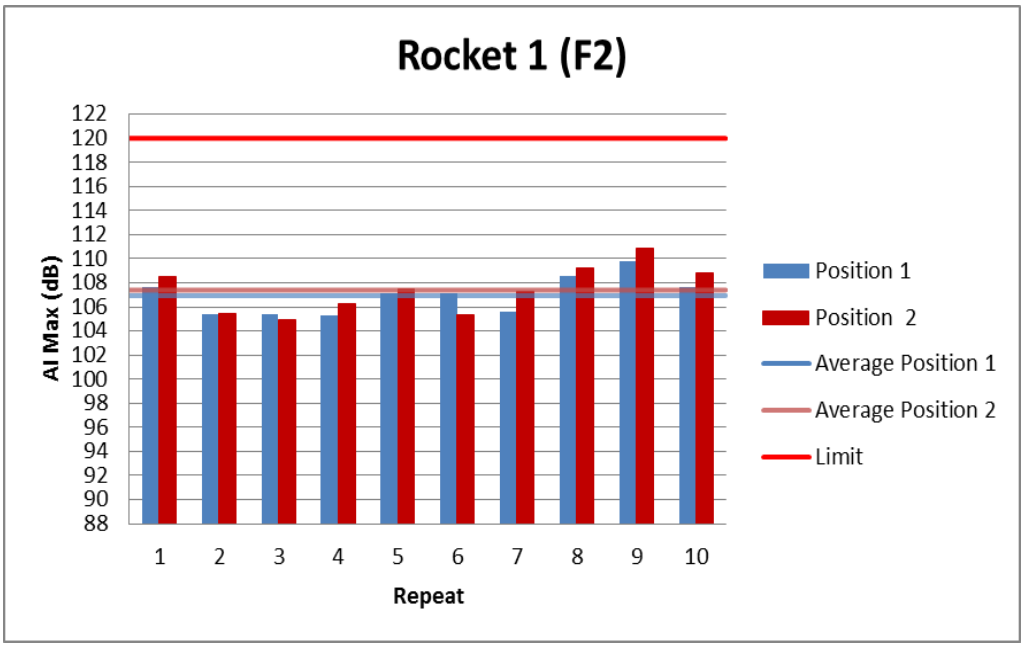


Figure 1: Individual noise levels for Rocket 1 (F2)

The variance in the noise levels recorded during the performance testing of Rocket 1 demonstrates that there are differences between each repeat rocket firing. Representations of the average noise measurement across each of the repeats at each noise meter position as well as the designated noise limit of 120 (AI Max dB) are given shown as horizontal lines.

Note: Noise level measurements recorded for all of the articles tested are included as bar graphs by both type and category in the appropriate section in Annex B (Figure 1, Figure 17 to Figure 87).

3.1 Factors Which May Affect Noise Levels

There are a number of factors which could have a local effect on the noise levels recorded for any given firework article. These factors can be split into two categories: physical effects and firework effects.

3.1.1 Physical effects

Physical factors[5] which may affect measured noise levels include but are not limited to;

- **Wind strength and direction:** a sound wave travels faster in the air when it is with the wind.
- **Reflection of sound from buildings and trees:** sound waves bounce off a barrier scattering it in different directions, affecting the sound level.
- **Cloud level (inversion):** when an inversion layer is present the air temperature increases with altitude. This temperature gradient causes sound waves to be refracted back towards the ground. Sound travels better than normal under these types of conditions, which makes the noise louder.
- **Humidity:** sound passes through hot air faster than cold air. Dry air absorbs more acoustic energy than moist air.
- **Distance:** the greater the distance from a noise source the level of noise is reduced (see section 1.2).
- **Topography:** the arrangement of natural (valleys, plains and trees) and artificial (buildings) physical features of an area will have an effect on the noise level.

3.1.2 Firework Effects

Different chemicals (metals, metal salts and oxidisers) are combined together to produce different explosive pyrotechnic compositions which are then used to create the desired effects within a firework. These explosive pyrotechnic compositions have been developed over several decades and manufacturers have become very innovative in producing both effects and colours.[5, 6]

There are a number of different effects which can be found within a firework article. These can consist of different colours; flickers; sparks; and smoke, all of which provide a visual effect. However, they may also contain aural effects. Examples of effects which produce noise within a firework article are;

- Lifting charge
- Bursting charge
- Crackle stars
- Whistles

The Net Explosive Quantity (NEQ) within any given article and each of its effects may contribute to the noise level generated. Whilst category 3 articles are allowed to contain a greater quantity of the more energetic compositions than a category 2 item, it should be remembered that some category 2 items may **only** contain effects that consist of compositions which generate noise. The designated standard (BS EN 15947-5 ‘Requirements for Construction and Performance’) details the upper limits

for explosive compositions allowed within both categories for each firework type. For Batteries and Combinations, the NEQ of the whole article is determined by adding the explosive quantities within all the constituent components of each firework type within the article (e.g., shot tubes, mines, fountains), giving the total NEQ for that Battery or Combination article. It should be noted that there are no lower limits of net explosive content for any of the different categories or firework types.[2]

Fireworks are subdivided into different types (rocket, shot tube etc.); a brief description of the article and what its principal effects are used to determine its specific firework type. Table 2 in appendix C illustrates this for all types of fireworks tested.

3.2 Data Analysis

For the purpose of the results section, noise measurement data (AI Max dB) has been averaged over the number of repeats to produce mean values. These values have been used to produce bar charts to compare category within type (F2 and F3). The upper noise limit of 120 (AI Max dB) has been included on each bar chart for reference.

The position of each noise meter (1 and 2) is identifiable on the charts by the darker bar for each article representing position 1 and the lighter bar representing position 2.

In terms of positioning of noise meters, it would generally be expected that position 2 (facing directly into the wind) would record higher noise levels than position 1 as the wind would carry the noise toward position 2. However, this is not always the case due to the influence of one or more of the physical factors listed in section 3.1.1.

Where no value has been reported this is due to the sound measurement being < 70 dB.

Where graphs illustrating the comparison of category 2 (F2) and category 3 (F3) fireworks are difficult to read due to the number of articles tested (Figures 4 , 5, 7 and 9) a larger version of each of these graphs can be found in Appendix A.

3.3 Rockets

A rocket is a firework which has a means of stability attached (all rockets tested used a wooden stick for stability) and propels into the air and displays its effects in the air. The head of the rocket is where the effects are found, with a rocket motor propelling the rocket into the air.

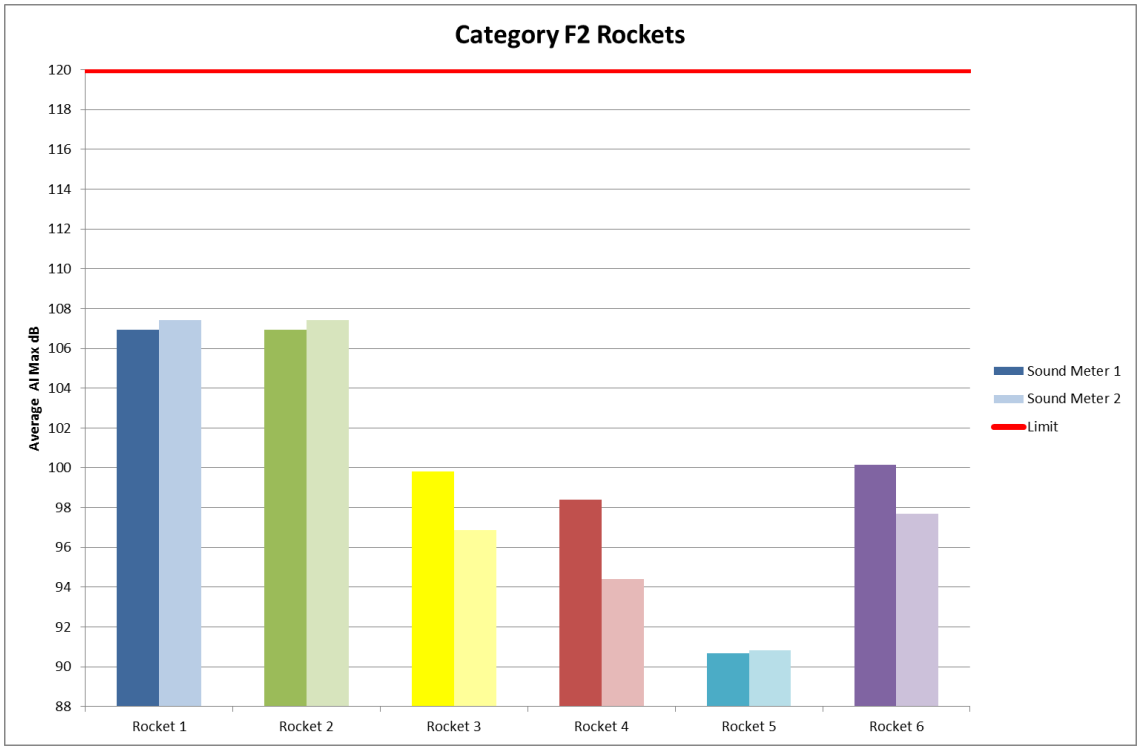


Figure 2: Category 2 Rockets

Figure 2 illustrates that within the group of category 2 rockets tested; Rocket 1 and Rocket 2 produced higher noise levels than those obtained for Rockets 3, 4, 5 and 6. As a general observation, Rockets 3, 4 and 5 were articles included within firework selection boxes (rather than standalone articles). The variability between the sound levels of the rockets tested may be influenced by one or more of the factors previously highlighted in section 3.1.

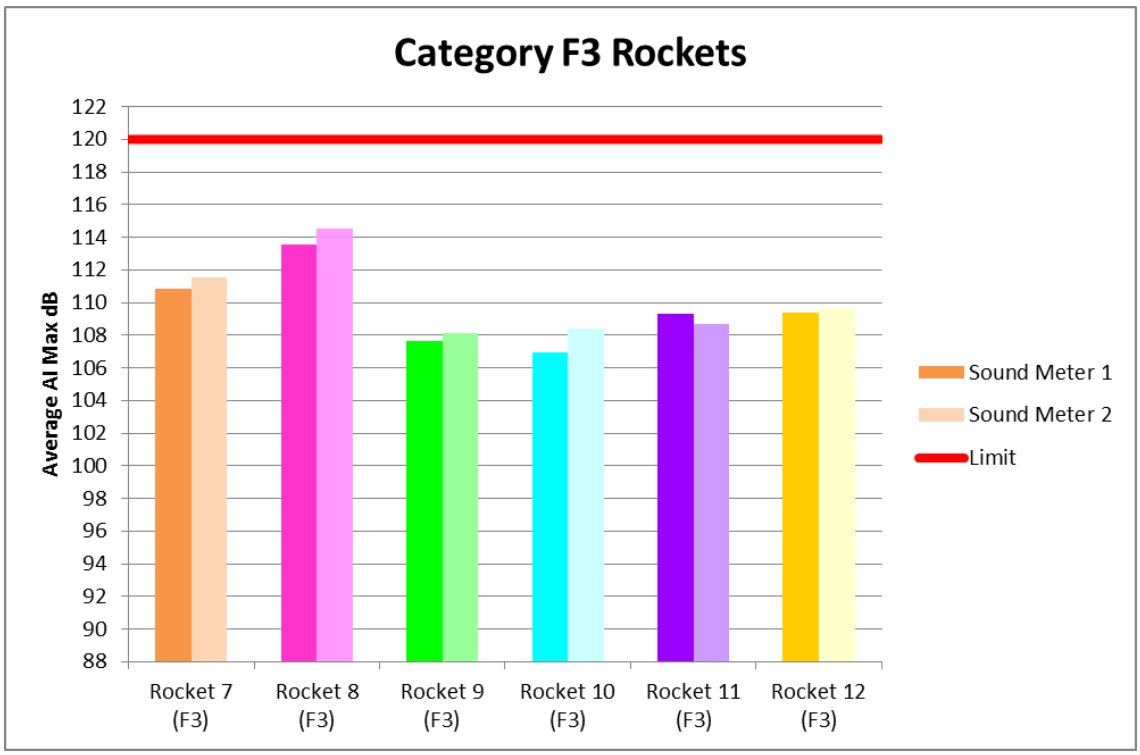


Figure 3: Category 3 Rockets

The category 3 rocket articles tested produced noise levels ranging from 107 dB to 115 dB (Figure 3). A degree of variability between articles is still visible but the noise output is more consistent than that observed for category 2 rockets. This may indicate that the pyrotechnic compositions used within the effects and the NEQ within this category are more consistent.

It should be noted that the entire selection of rocket articles tested (both category 2 and category 3) were within the limits of the designated standard.

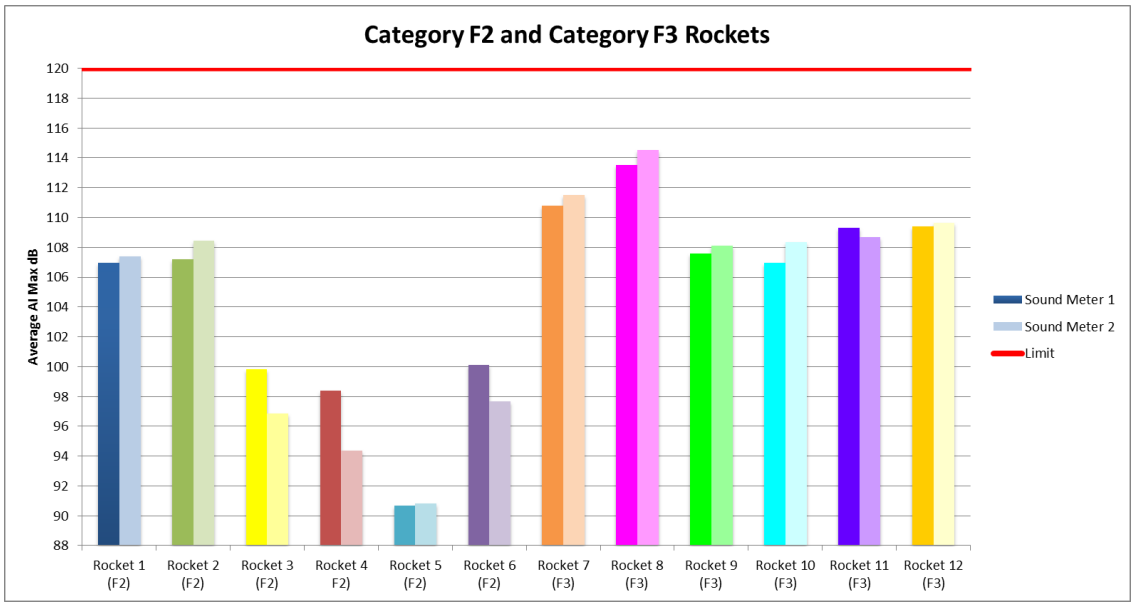


Figure 4: Comparison of Category 2 and 3 Rockets

In comparing the different rocket data sets from category 2 and category 3 there is a clear distinction between the two categories, with category 3 rockets producing consistently higher noise levels than category 2 (Figure 4).

Rockets which are included within selection boxes could be considered to be smaller and produce lower levels of noise than those articles which can be purchased separately either as individual rockets or within rocket packs.

Category 2 articles (Rocket 1, and Rocket 2) produced similar noise levels to category 3 articles (Rocket 9 and Rocket 10). The likelihood is that this is due to the fireworks' effects rather than through the influence of any physical effects.

3.4 Battery of Shot Tubes

This type of firework consists of a number or 'battery' of shot tubes and, when functioned produces a number of individual 'shots' which are ejected into the air and burst creating different noise and colour effects. Each battery can contain up to a maximum NEC of 500 g (for F2) and 1000 g (for F3).[2]

This NEC can increase to the following quantities if fountains are included in the battery, 600 g (for F2) and 3000 g (for F3).

Note: this additional explosive content is within the fountain part only.

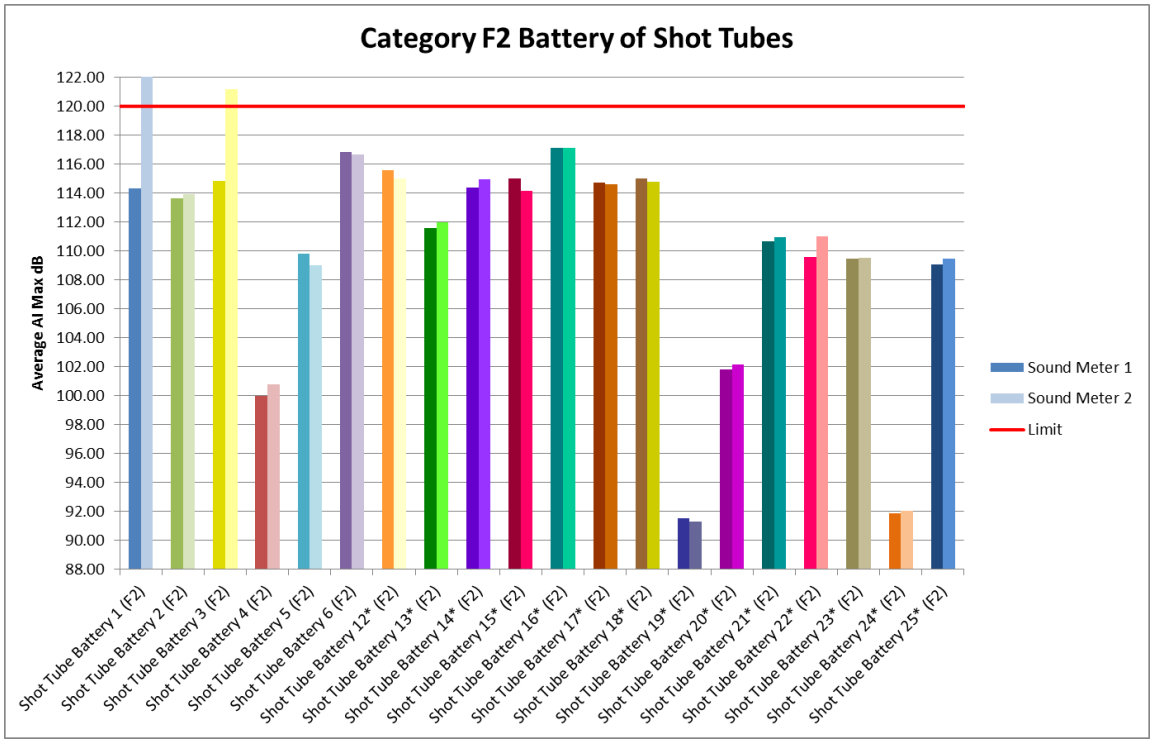


Figure 5: Category 2 Battery of Shot Tubes

Figure 5 shows that, of the category 2 shot tube batteries tested, Battery 1 and Battery 3 each had one occurrence where the noise level at position 2 was greater than the 120 dB limits.

Battery 4, Battery 5, Battery 19, Battery 20 Battery 21, Battery 22, Battery 23 and Battery 24 were articles from selection boxes. The noise levels measured from these

articles ranged from 91 dB to 111 db. It was noted that there was an appreciable difference in size of articles within selection boxes. In addition, some battery of shot tubes articles contained within selection boxes could also be purchased as standalone articles.

The variability between articles within this category is wide, with noise levels measured between 91 dB and 122 dB which is very likely to be influenced by the pyrotechnic compositions and effects found within them.

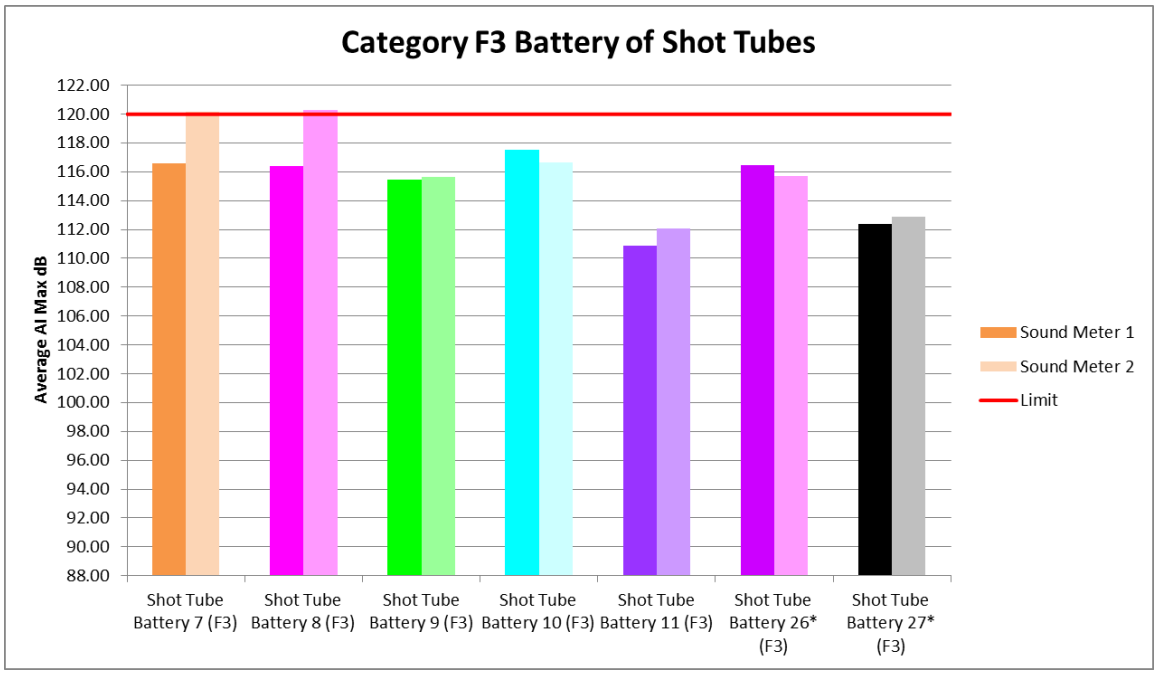


Figure 6: Category 3 Battery of Shot Tubes

Figure 6 shows that, of the category 3 batteries tested, both Battery 7 (120.6 and 120.3 dB) and Battery 8 (121.4 and 121.6 dB) had noise level readings at position 2 which were above the maximum noise limit of 120 dB.

All batteries within category 3 had measured noise levels above 110 dB and the variability across this category were less evident than those of category 2. This may suggest that the quantity and effects contained within them are more consistent.

Batteries of shot tubes were the only firework type where the noise level measurements were found to exceed the limit of 120 (AI Max dB) detailed within the designated standard.

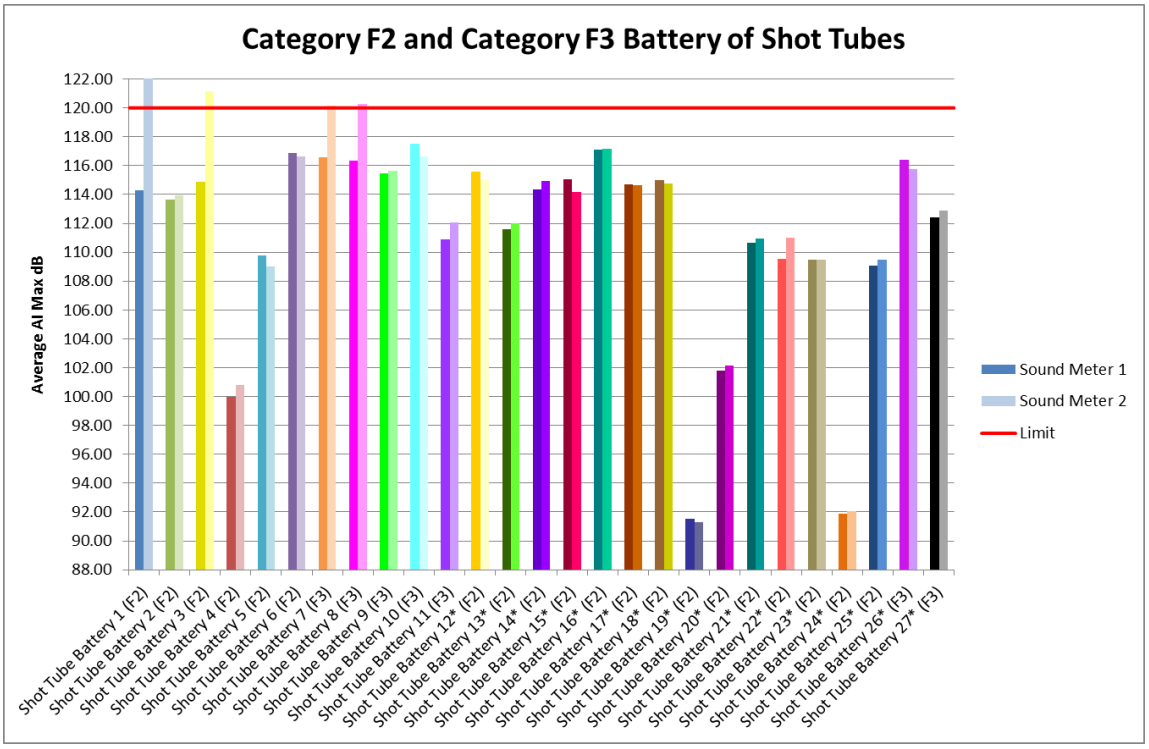


Figure 7: Comparison of Category 2 and 3 Battery of Shot Tubes

Figure 7 (a larger version of which can be found in Annexe A) shows that apart from Battery 4, Battery 19, Battery 20 and Battery 24 all other articles within this type produced sound levels greater than 108 dB.

In addition, within this firework type there is a wider range of noise levels measured across both categories, with category 2 articles producing as high if not higher levels of noise as some category 3 items. This would suggest that although category 2 articles contain overall less pyrotechnic composition within them, the effects contained in shot tubes are more likely to contain a greater proportion of noise generating effects.

All readings which were above 120 dB across both F2 and F3 categories were recorded at position 2 which likely highlights how the physical effects (such as wind direction) can impact measured noise levels.

3.5 Fountain

A fountain is a static firework that creates a vertical column of coloured flames and sparks. Some fountains also contain crackle effect which can make them quite loud.

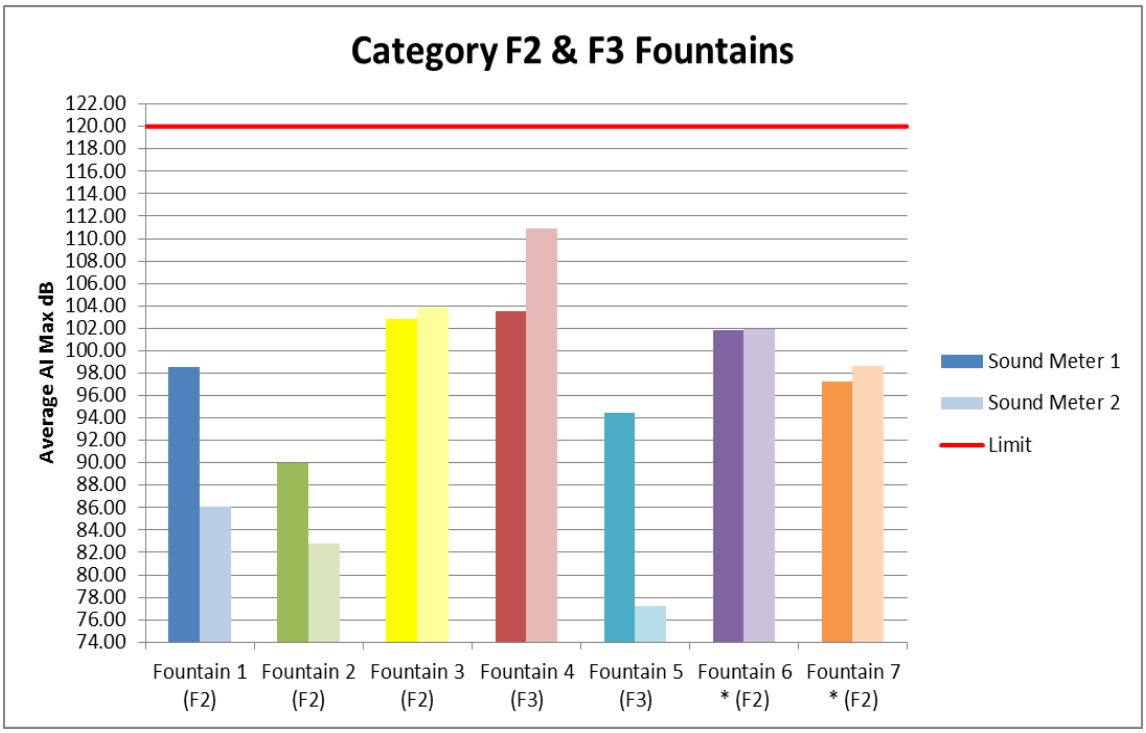


Figure 8: Comparison of Category 2 and 3 Fountains

Figure 8 shows that within the fountain firework type it is clear that there is a wide variation between category F2 and F3 (Figure 8). Fountains vary considerably in the level of noise they produce due to the type of effect found within them. As such, it is possible for instance, that a category 2 fountain may produce a higher sound level than a category 3 fountain. Some fountains consist entirely of visual colour effects whilst others contain a combination of colour effects and aural effects (such as crackles).

Fountain 4 gave rise to a noise measurement of 110 dB at position 2, which is believed to be due to the reflection of sound from a building. With the exception of fountain 4, the remaining fountains generated noise levels between 77 dB and 104 dB which may suggest that as a firework type generally they are not as loud as other firework types. All fountains tested were below the 120 dB noise limit detailed within the designated standard.

3.6 Roman Candles

A Roman candle firework propels an effect from a tube into the air. These can be single shot or multiple shots which are stacked on top of each other. Roman candles can consist of a single tube or multiple tubes bound together.

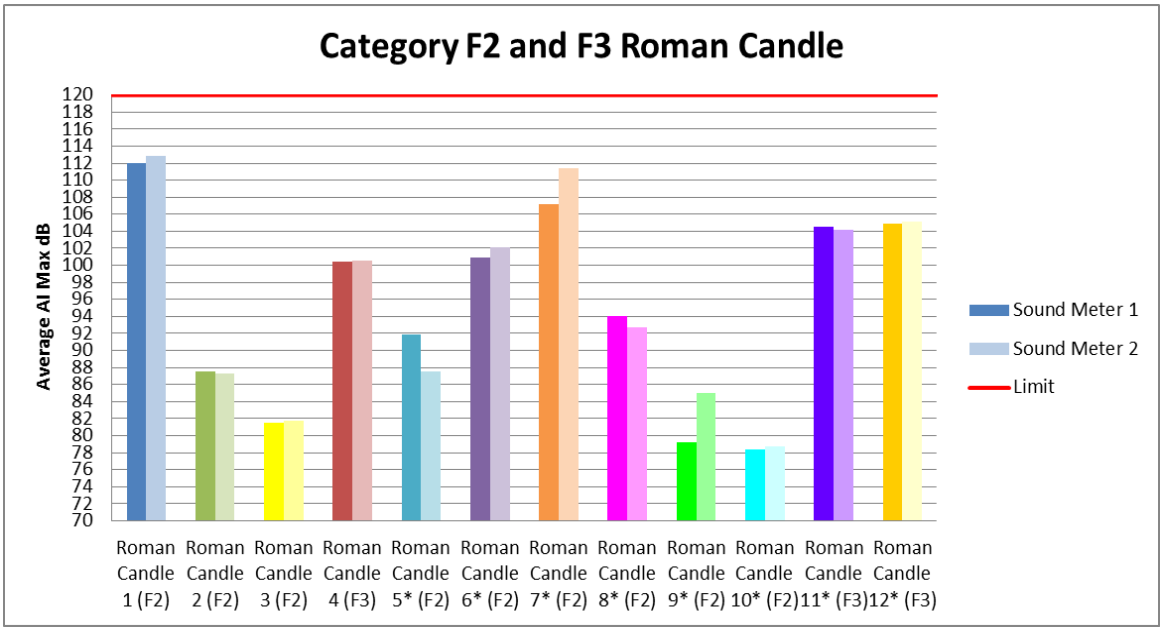


Figure 9: Comparison of Category 2 and 3 Roman Candles

Roman candles are similar to fountains in that there is variability between the categories. Once again, the level of noise produced is very dependent on what the firework effects are within the article (Figure 9).

Roman candle RC 2, RC 3, RC 8, RC 9 and RC 10 were all taken from selection boxes and generated noise levels between 78 dB and 87.8 dB.

RC 1 a category 2 item measured the highest noise level 112 dB. Average noise levels across Category 2 roman candles were between 78 dB to 112 dB. RC 4, RC 11 and RC 12 (all category 3 articles) generated noise levels between 100 dB and 105 dB.

The noise level range across category 3 articles was found to be much more consistent than for category 2 items.

3.7 Wheels

A wheel is a firework which rotates. They are attached to a post by a nail through the centre and have tubes mounted around the edge which burn like a rocket motor, which creates sufficient thrust to spin the device emitting sparks and flames. Some also contain crackle effects.

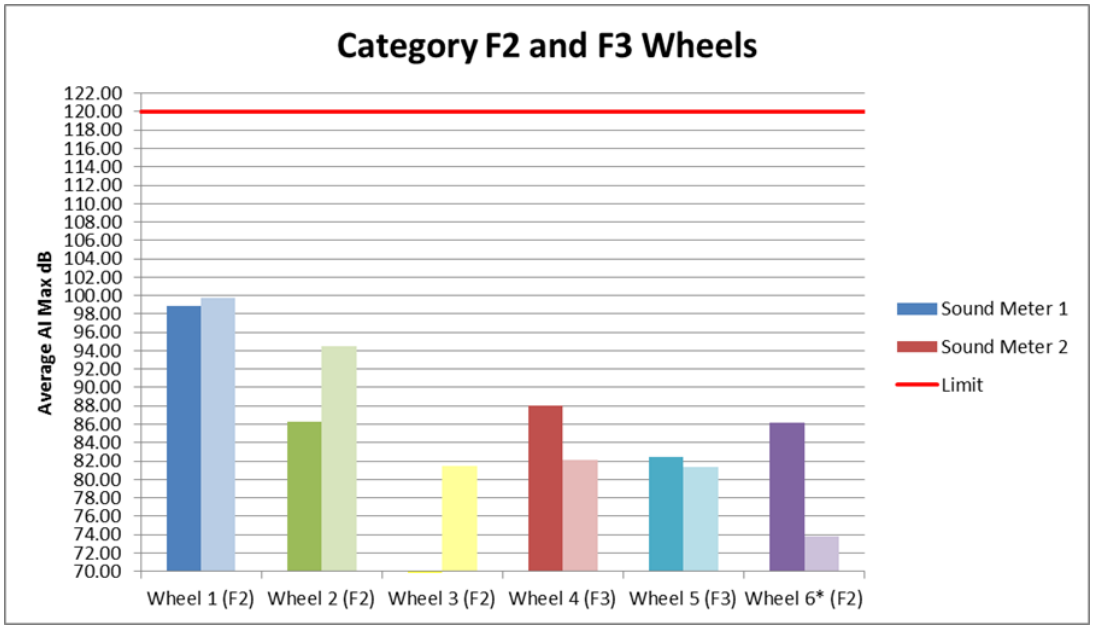


Figure 10: Comparison of Category 2 and 3 Wheels

In a similar manner to roman candles and fountains, wheels also show a high degree of variability between categories, and this is likely dependent on what particular pyrotechnic compositions are placed within the firework. This makes it possible in some cases for F2 wheels to produce more noise than F3 articles. This scenario is illustrated in Figure 10 where Wheel 1 (an F2 article) produced the highest noise levels. The noise output from wheels can also be impacted if the article does not rotate. It was noted during performance testing, that a number of wheels were observed not to rotate which may have influenced the noise generated and recorded

3.8 Single Shot Tubes

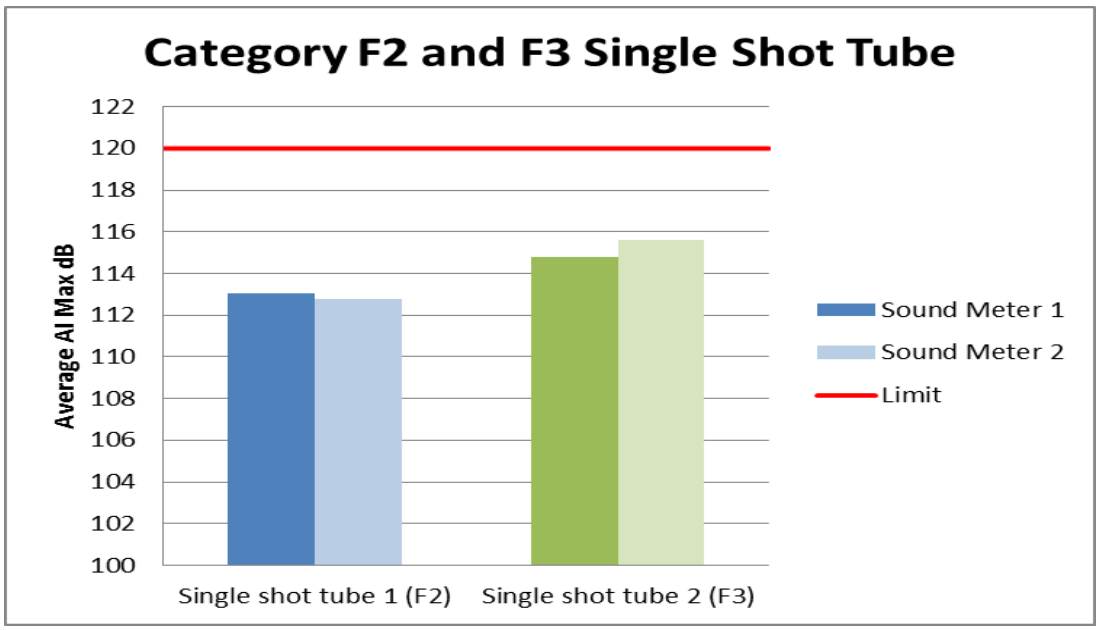


Figure 11: Comparison of Category 2 and 3 Single Shot Tubes

Single shot tubes are regarded as individual sub-units that are found in shot tube batteries (section 3.4) The noise generated is highly dependent on the firework compositions used. As a result, noise levels for both F2 and F3 articles may be quite similar (Figure 11).

3.9 Mines

A mine is a firework in which its entire contents are ignited at the same time and eject its effects upwards and outwards from a cardboard tube.

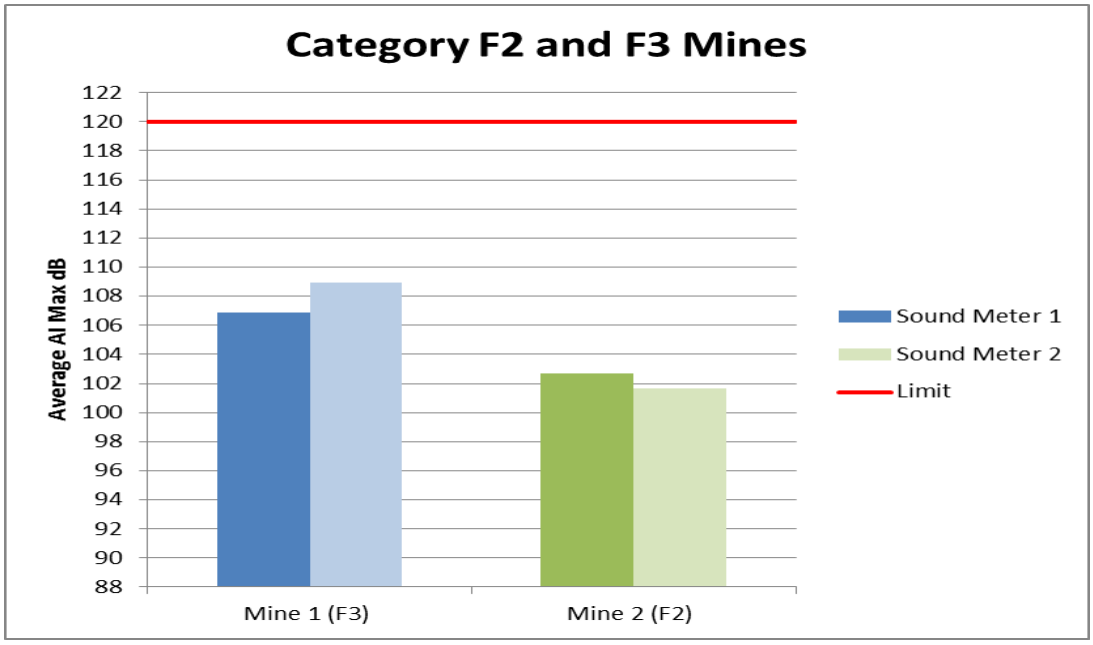


Figure 12: Comparison of Category 2 and 3 Mines

In Mines, it is once again the case that the level of noise produced is highly dependent on the pyrotechnic composition used, particularly if articles contain noise generating composition mixtures within its effects (Figure 12).

3.10 Fountain/Mine Combination

A Fountain/Mine combination is a combination of the two different firework types. The fountain is the first to be ignited followed by the mine as the finale.

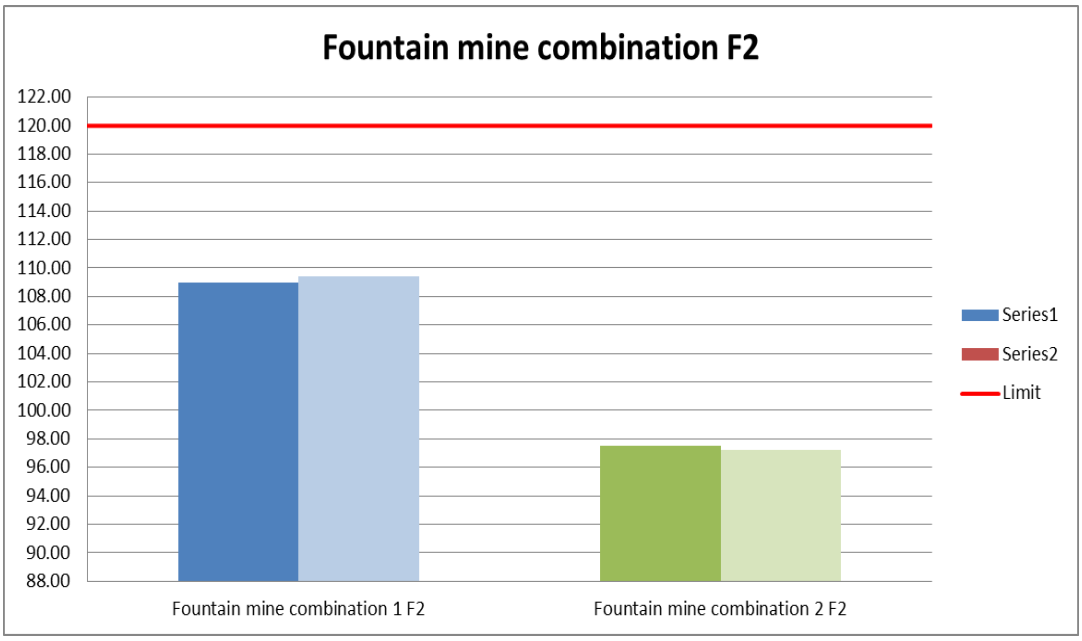


Figure 13: Comparison of Category 2 Fountain / Mine Combination

Figure 13 shows that there can be significant variation between articles within the same category *i.e.,* although only two items were tested of this article type, the results highlight that there is a high degree of variation across category 2 items.

Note: Fountain/Mine Combination 2 article was from a selection box whilst Fountain/Mine Combination 1 was a standalone article.

3.11 Battery of Fountains

A Battery of fountains is an article which contains a number of fountains.

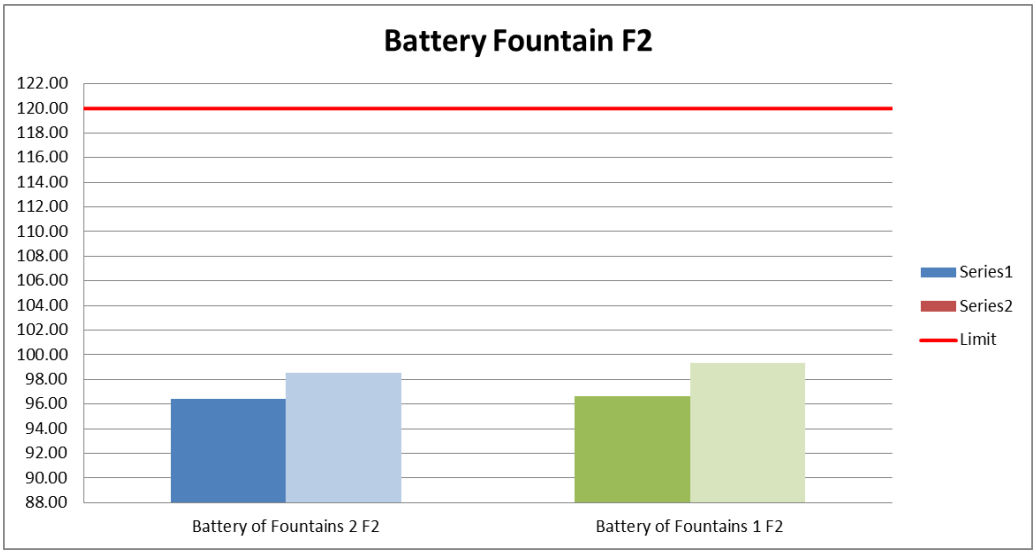


Figure 14: Comparison of Category 2 Battery of Fountains

The sample size tested of the Battery of Fountains firework type is low (2). Both articles were from selection boxes. Figure 14 illustrates that with sound level measurements of between 96 dB and 99 dB and taking into account the similar sound levels measured during testing of single fountains, that batteries of fountains may be considered as lower noise fireworks when compared to the other firework types.

4 Conclusions

The variability found across each firework type and category is generally wide. As a result, attempting to characterise and group articles into those which are more noisy or less noisy is not entirely practicable.

However, it is possible to indicate a range of noise levels for each firework type in each category. For the data sets collected from the firework articles tested within the test programmes conducted, ranges of noise level ranges recorded are shown (Figure 15 for category 2 fireworks and Figure 16 for category 3 fireworks).

It should be noted that the following firework types: battery of shot tubes; rockets; and roman candles had a greater number of articles tested than the other firework types.

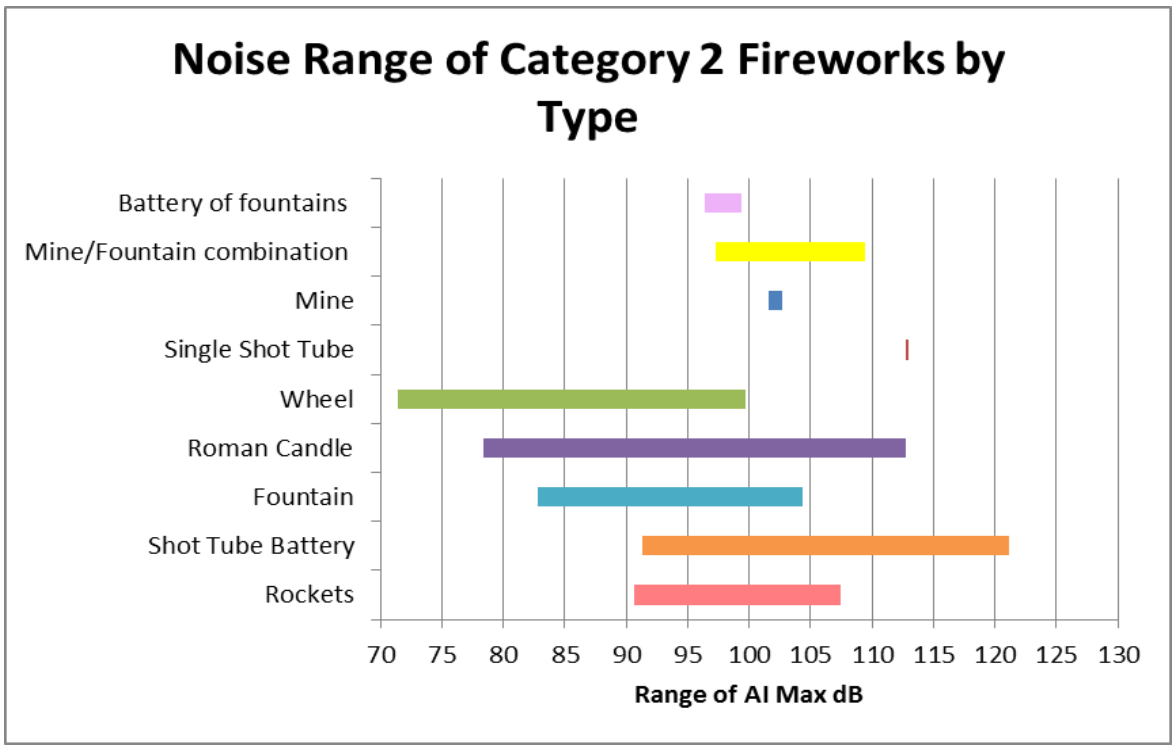


Figure 15: Range of Noise Levels for Category 2 Fireworks

Figure 15 illustrates that with category 2 fireworks the range of noise generated is generally wide across all firework types. This is considered likely to be more dependent on whether a specific firework contains a lower or higher proportion of sound generating effects and the quantity involved rather than any physical/environmental factors.

The noise measured from the total of four Wheel articles tested was in the range of 71 dB to 99 dB. For comparison, the total of twenty Battery of Shot Tubes articles tested generated noise levels in the range of 92 dB to 121 dB.

Figure 16 shows that across the different types of category 3 fireworks (with the exception of fountains), the noise range was not as widespread as observed with category 2 articles.

Overall, the range of noise across all firework types was wider across category 2 fireworks compared with that of category 3.

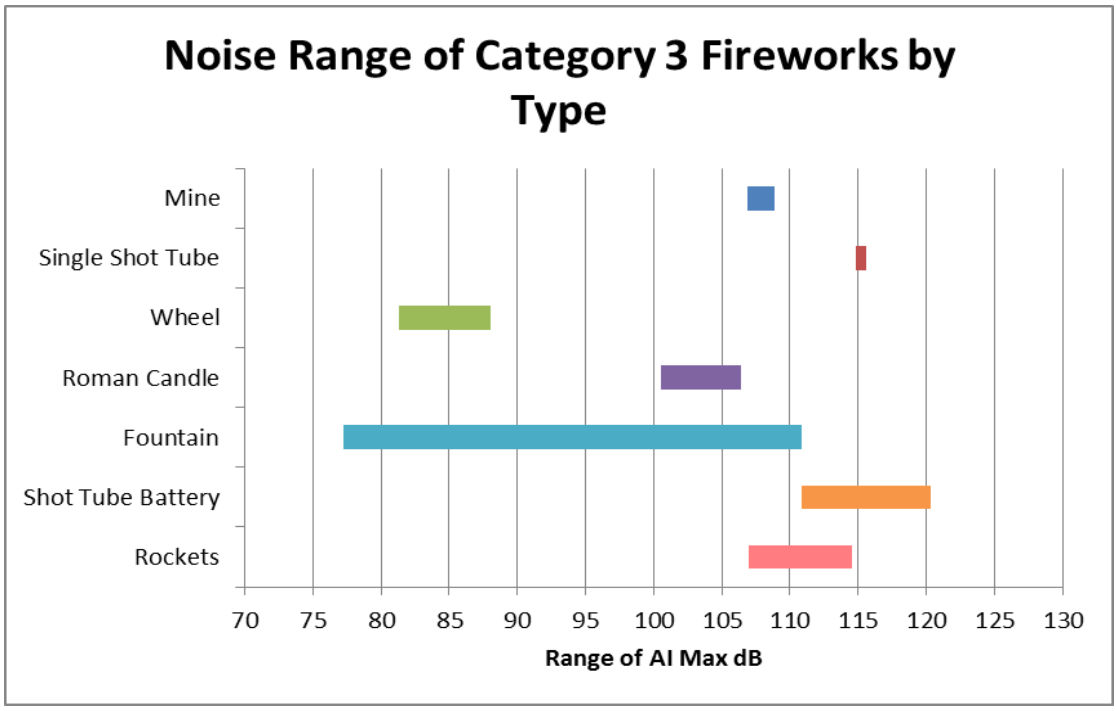


Figure 16: Range of Noise Levels for Category 3 Fireworks

Figure 16 indicates that wheels and (in general) fountains are less noisy than the other firework types tested. The results obtained illustrate a high level of variation in noise levels produced across each firework type. Category 3 Battery of Shot Tubes, Rockets and Single Shot Tubes produced higher noise levels than all other firework types. Both Figure 15 and Figure 16 identify that of all the firework types, Battery of Shot Tubes, and Single Shot Tubes produce higher noise levels across both category 2 and category 3 fireworks.

Of the 72 articles tested, 4 articles generated noise measurements above the 120 dB threshold. Of all the different firework types tested, Battery of Shot Tubes was the only firework type which exceeded this limit within both category 2 and category 3. When fireworks are used by the general public, the physical effect / environmental variables can be predicted as having some influence as each location / firework use scenario can be regarded as being unique. With so many variables (both physical and firework effects) present, it is therefore not possible to predict with any degree of confidence which fireworks types would produce higher levels of noise in any given scenario.

The range of firework articles across each of the different types and categories of articles is wide. The sample set used for this research, whilst representative has only touched a very small part of the product range currently available to the public.

5 References

1. BS EN CEN 15947 -2: 2015 Pyrotechnic articles- Fireworks, Categories F1, F2 and F3. Part 5: Requirements for construction and performance
2. BS EN CEN 15947 -2: 2015 Pyrotechnic articles- Fireworks, Categories F1, F2 and F3. Part 4:Test Methods
3. https://www.eea.europa.eu/help/glossary/eea-glossary/a-weighted-decibel
4. www.cirrusresearch.co.uk A Guide to Noise Measurement Terminology
5. 2011, Dr. T. Smith, Firework Displays: Explosive Entertainment
6. 2006, Rev. R. Lancaster, Fireworks Principles and Practice
7. BS EN CEN 15947 -2: 2015 Pyrotechnic articles- Fireworks, Categories F1, F2 and F3. Part 2 Categories and types of firework

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Appendix A – Graphs

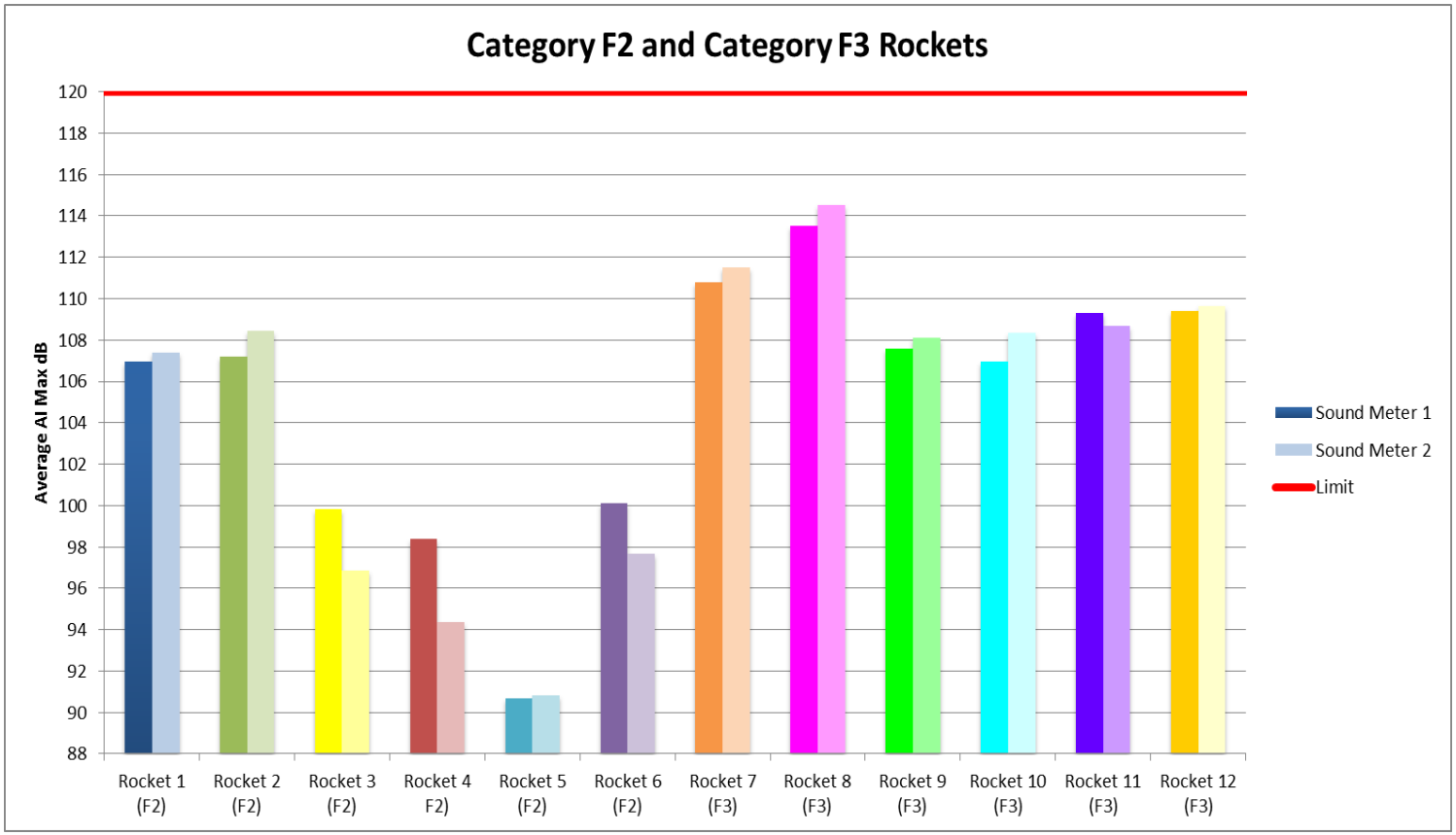

Figure 4: Comparison of Category 2 and 3 Rockets

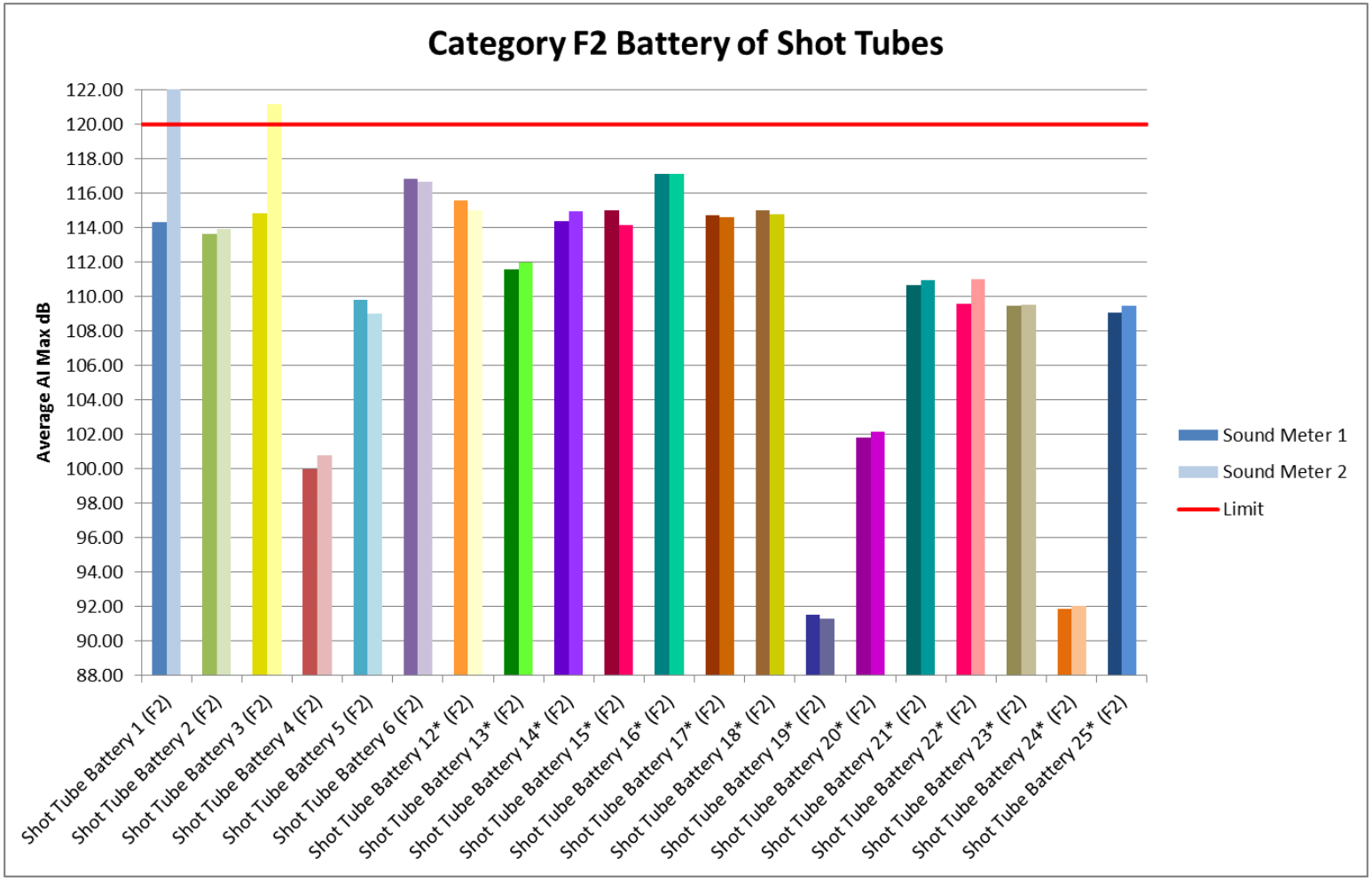

Figure 5: Category 2 Battery of Shot Tubes

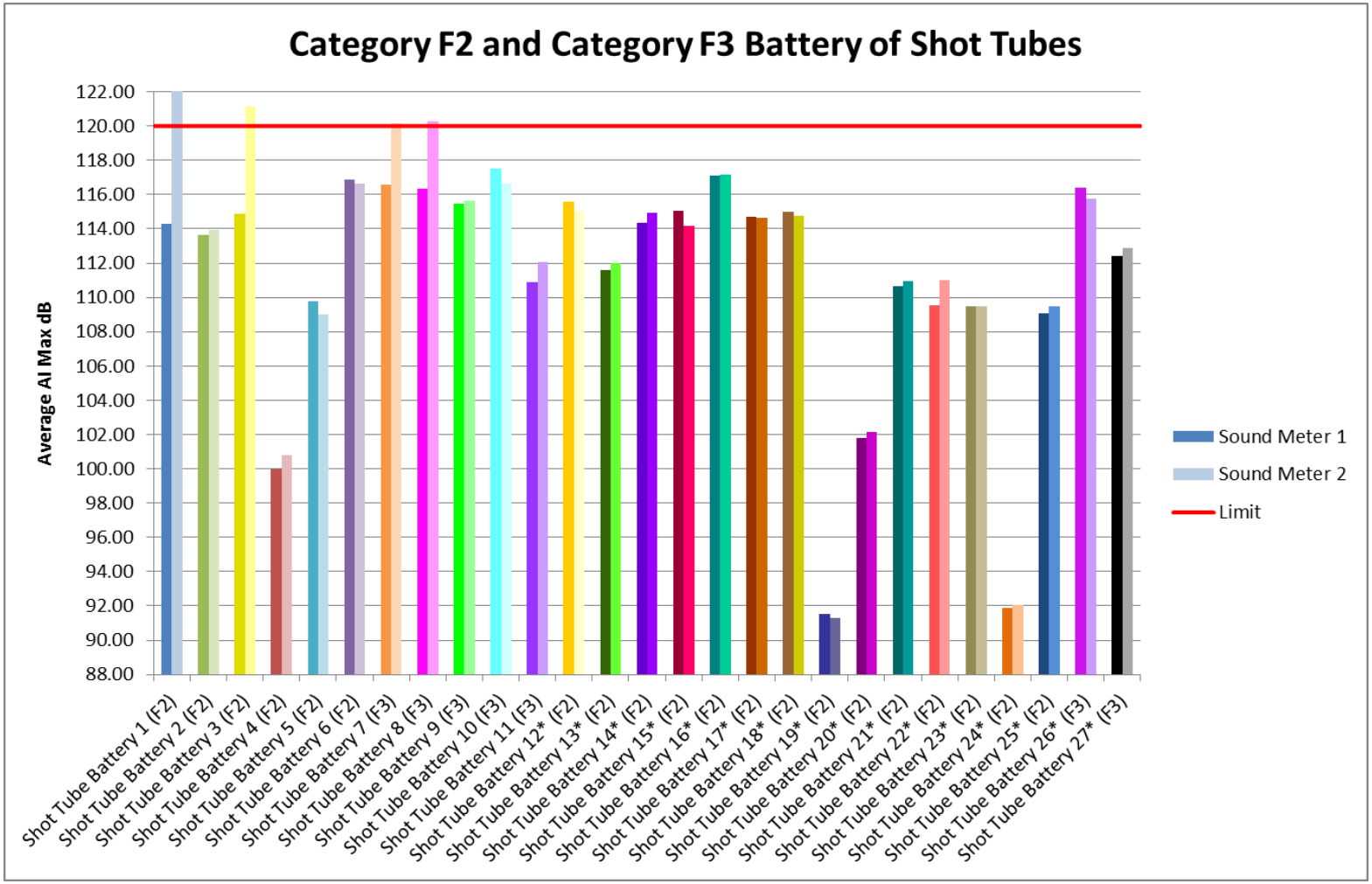

Figure 7: Comparison of Category 2 and 3 Battery of Shot Tubes

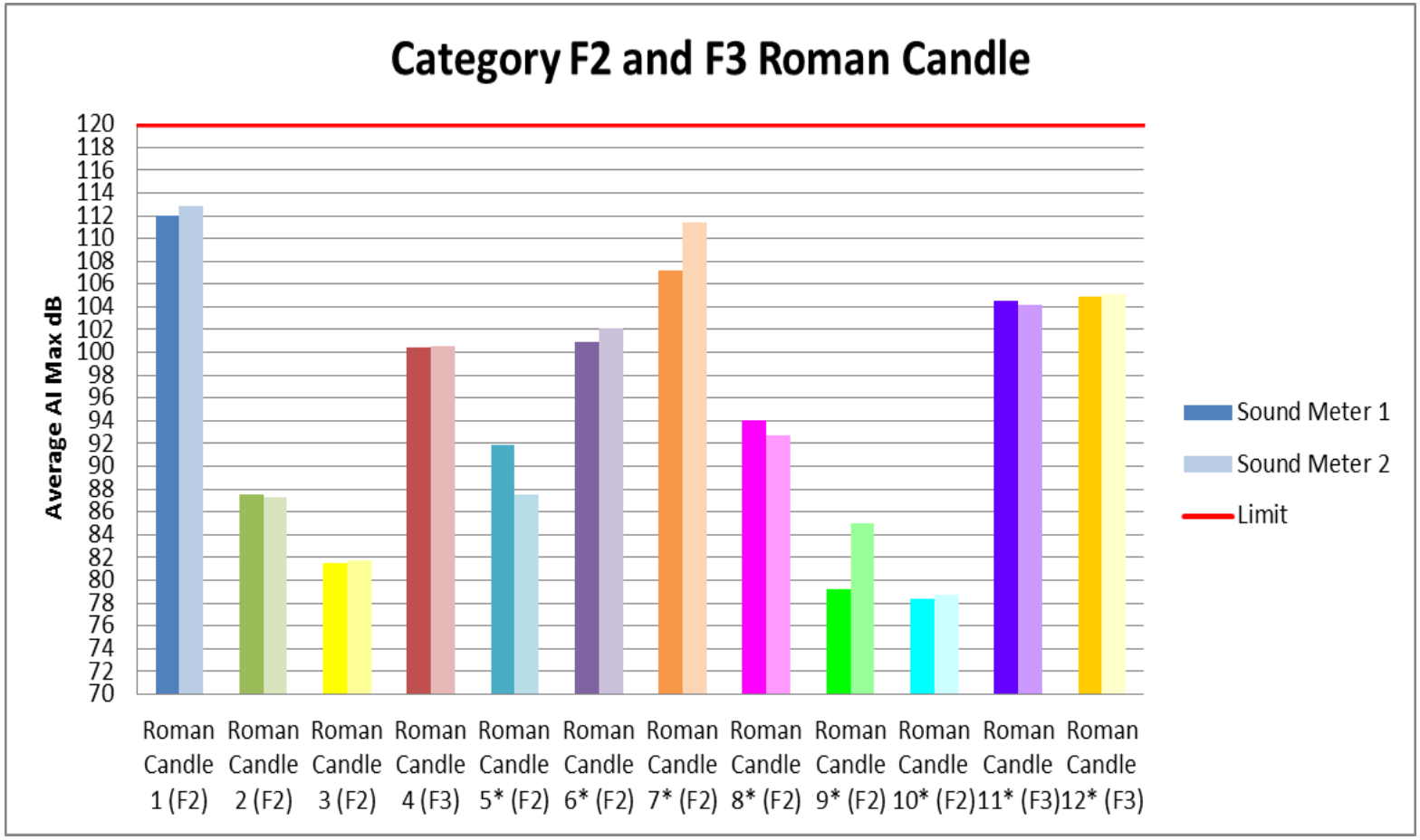

Figure 9: Comparison of Category 2 and 3 Roman Candles

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Appendix B - Individual Firework article noise measurement graph by type

B.1 Rockets

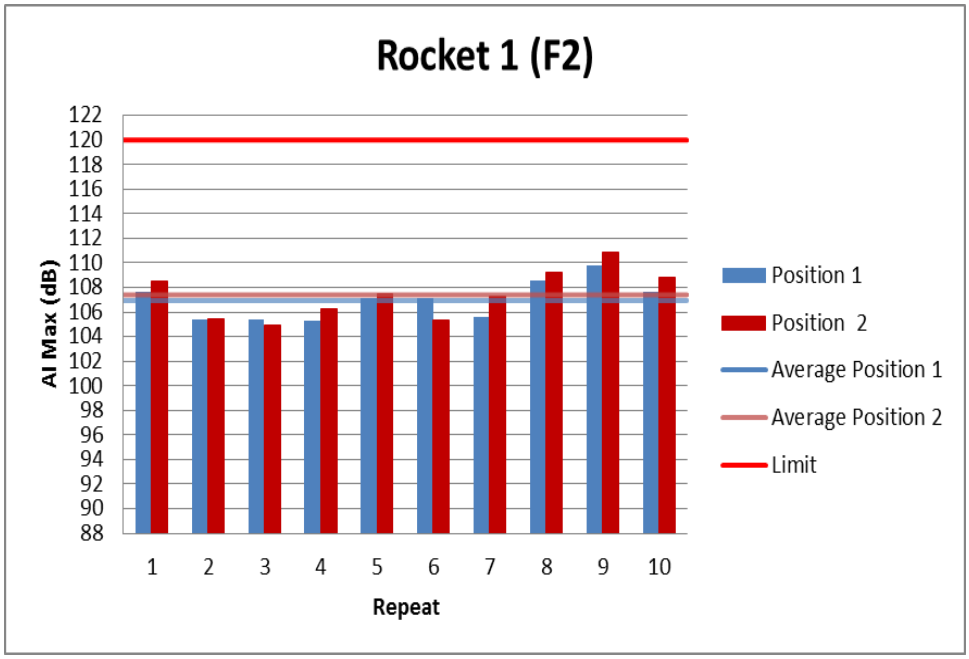

Figure 16: Individual Noise Levels for Rocket 1 (F2)

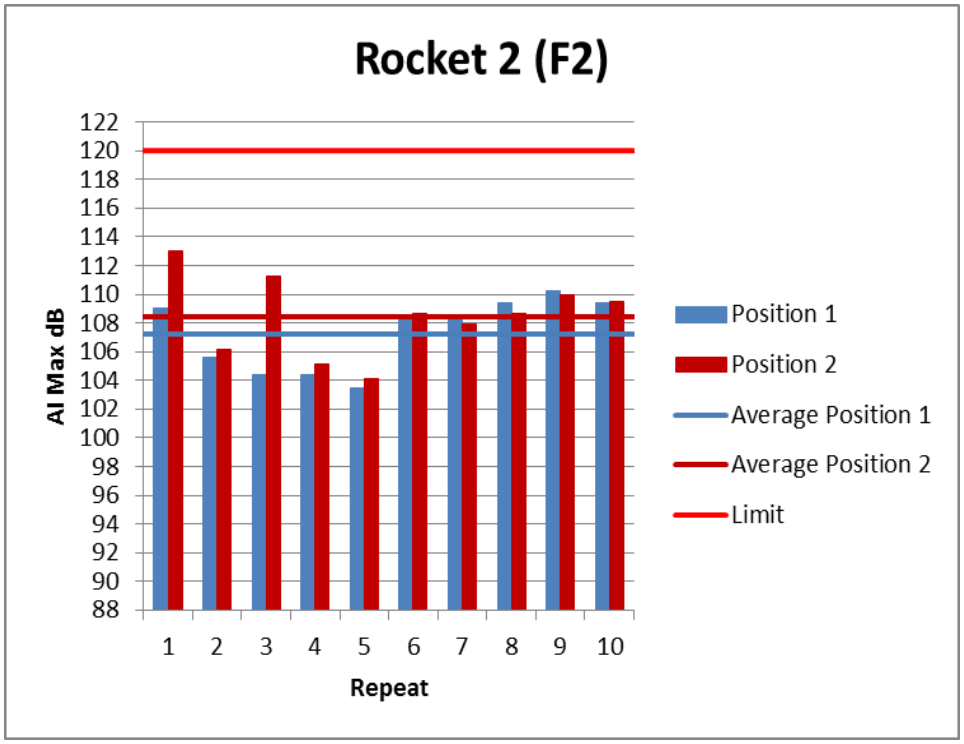

Figure 17: Individual Noise Levels for Rocket 2 (F2)

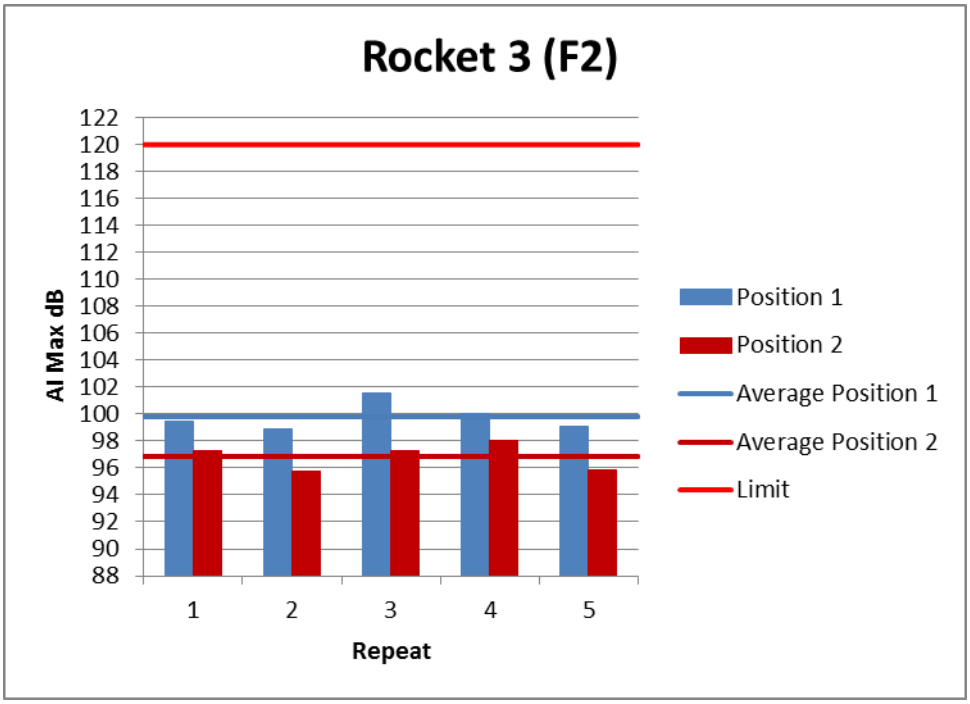

Figure 18: Individual Noise Levels for Rocket 3 (F2)

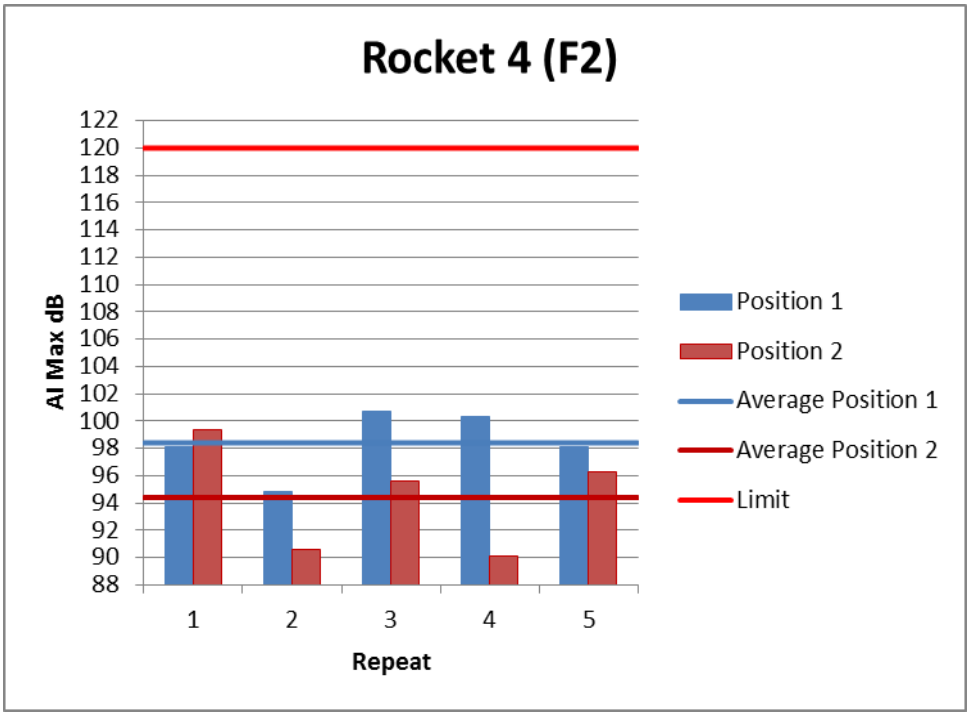

Figure 19: Individual Noise Levels for Rocket 4 (F2)

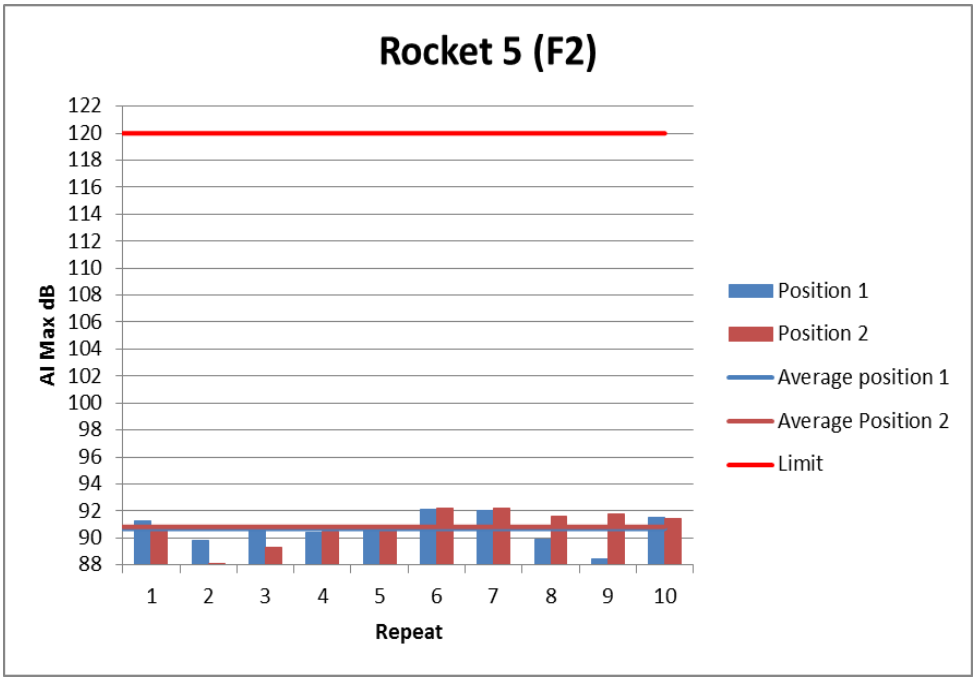

Figure 20: Individual Noise Levels for Rocket 5 (F2)

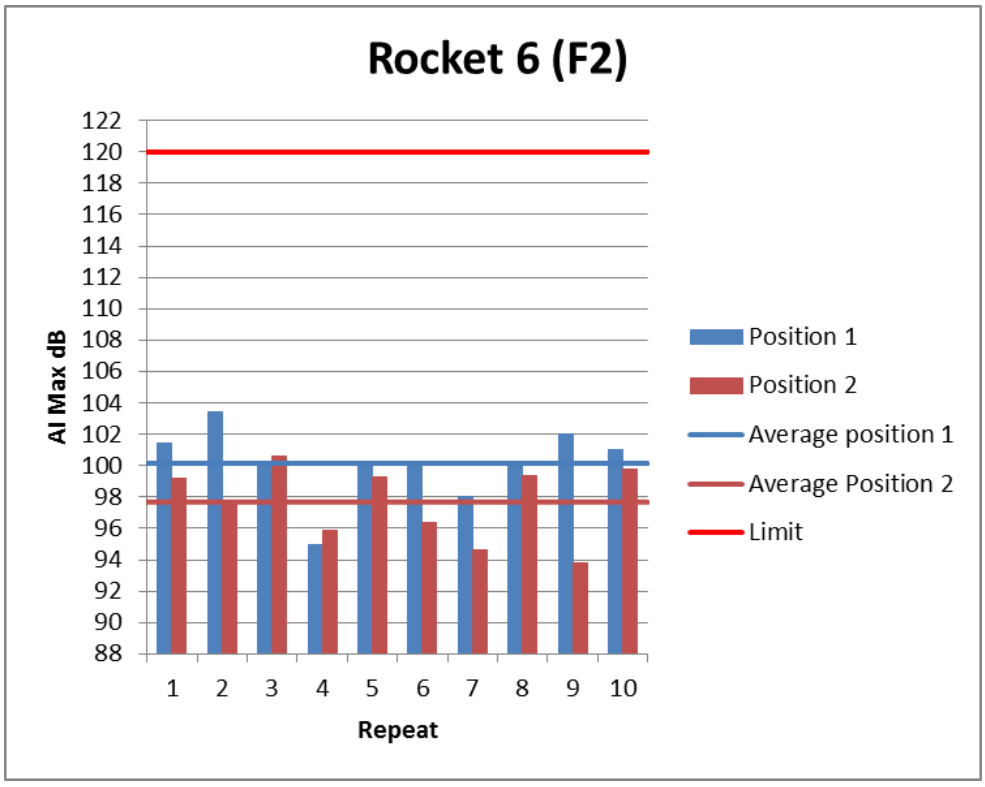

Figure 21: Individual Noise Levels for Rocket 6 (F2)

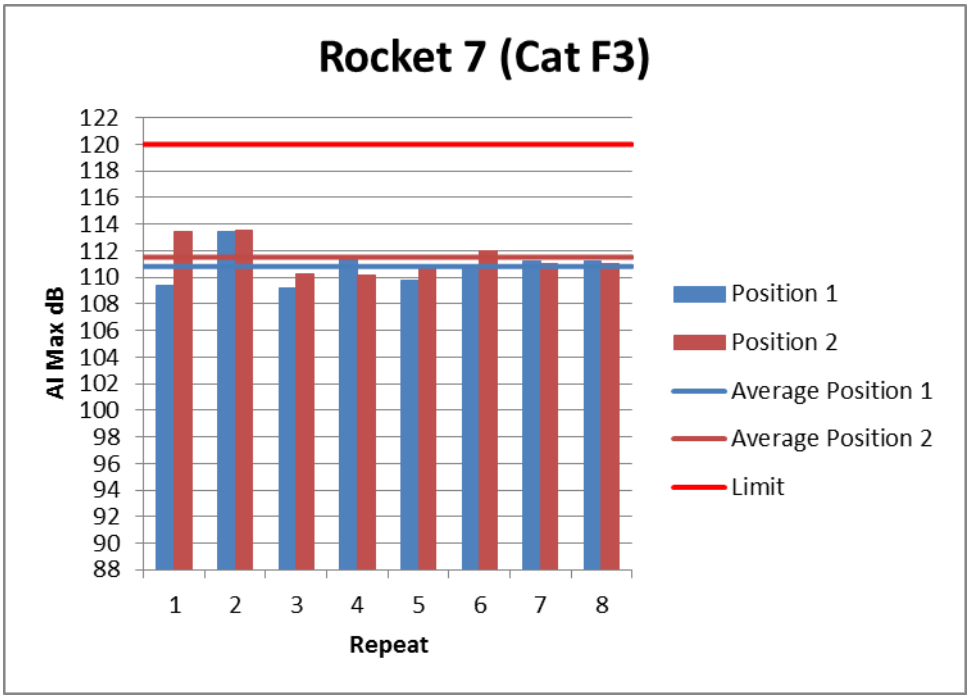

Figure 22: Individual Noise Levels for Rocket 7 (F3)

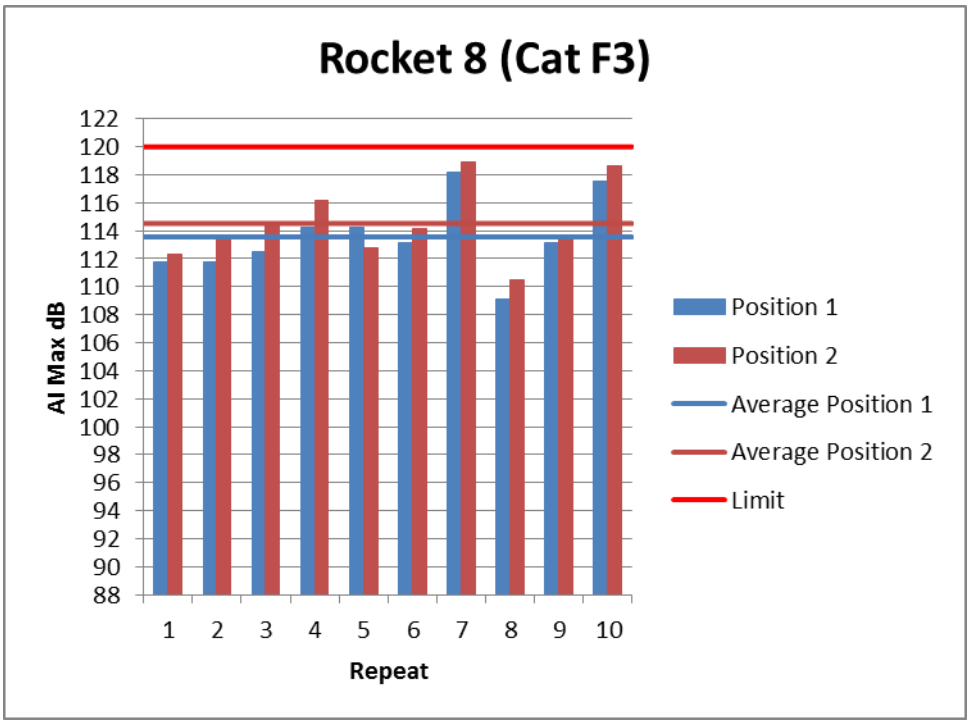

Figure 23: Individual Noise Levels for Rocket 8 (F3)

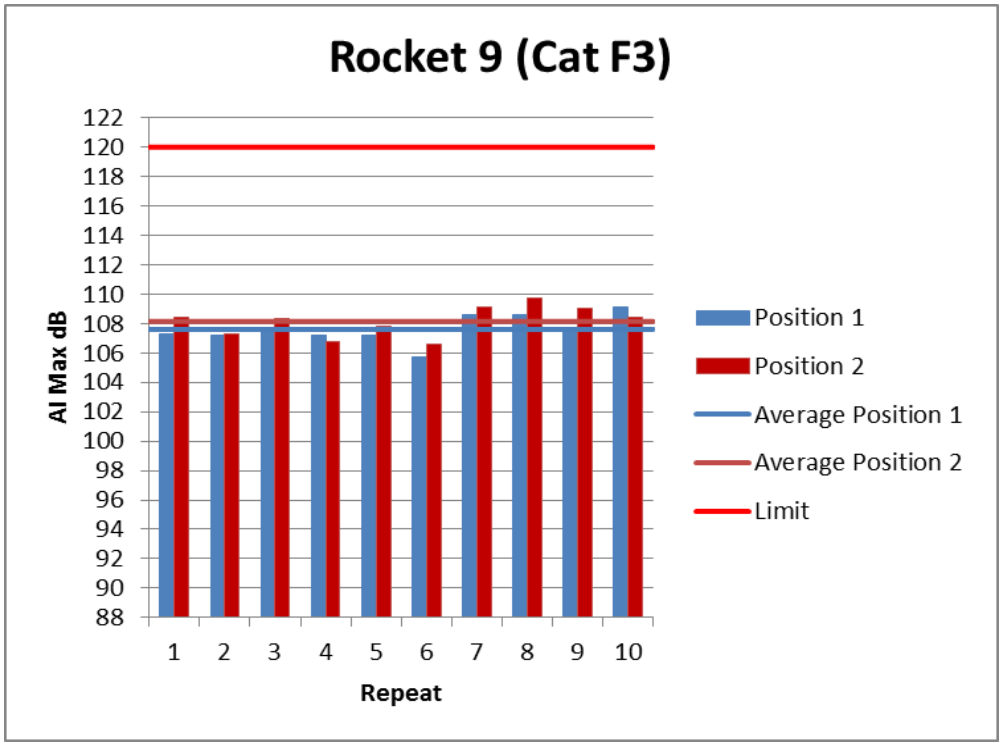

Figure 24: Individual Noise Levels for Rocket 9 (F3)

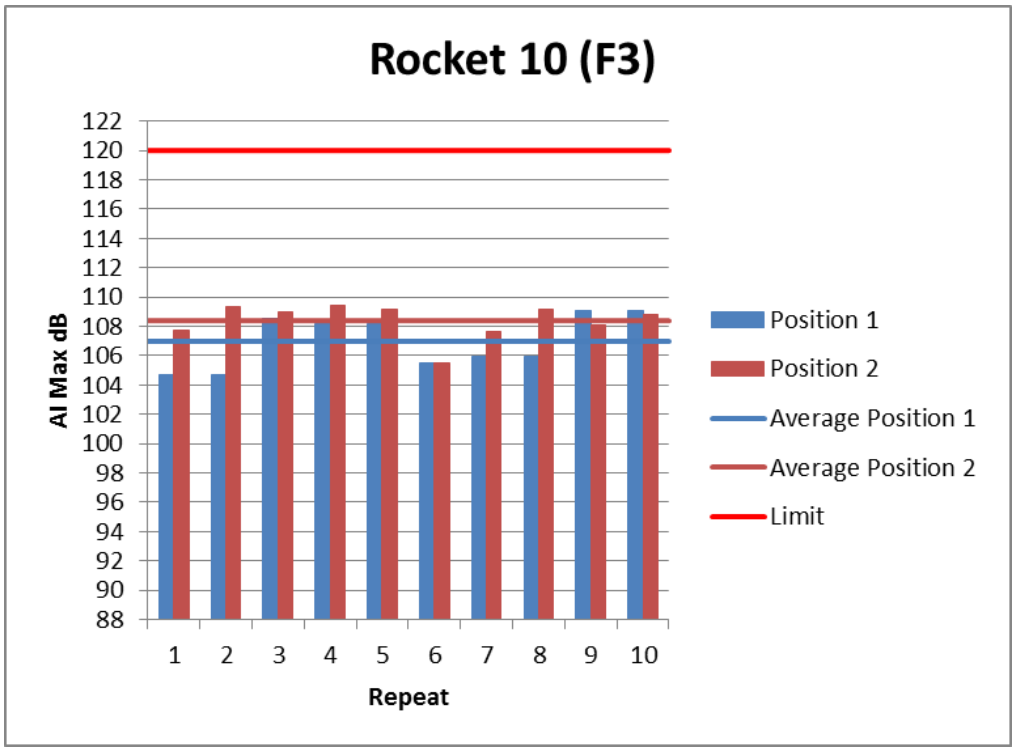

Figure 25: Individual Noise Levels for Rocket 10 (F3)

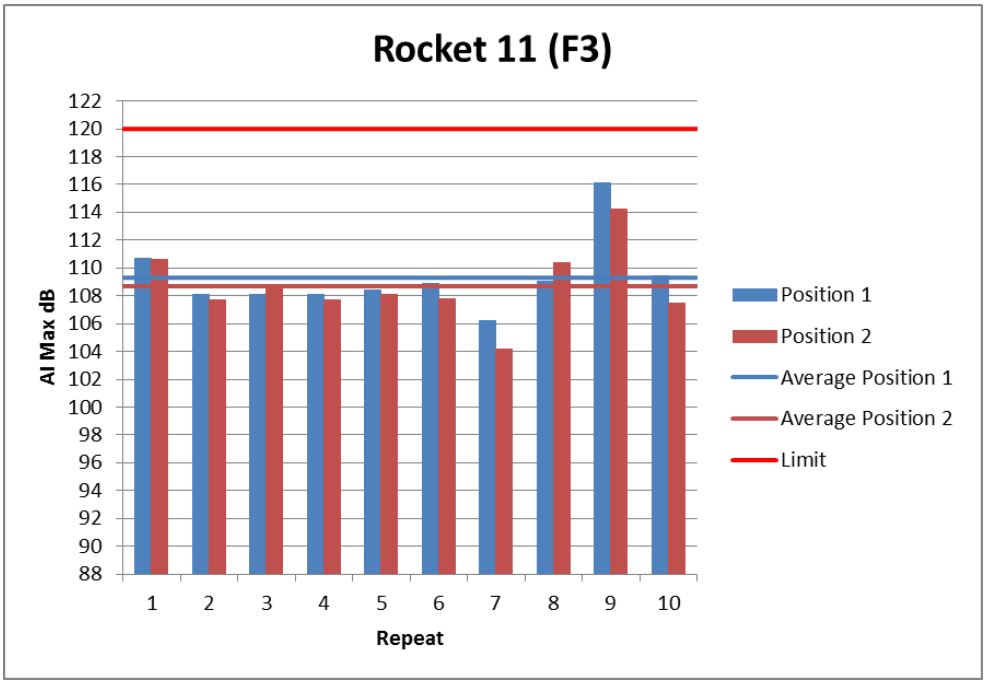

Figure 26: Individual Noise Levels for Rocket 11 (F3)

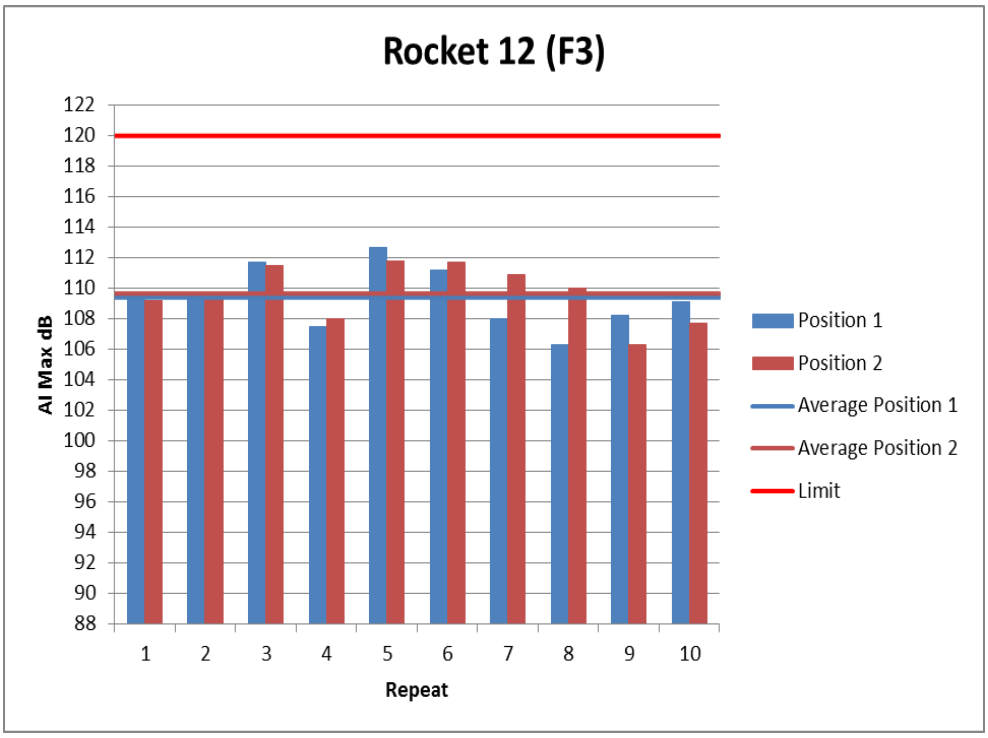

Figure 27: Individual Noise Levels for Rocket 12 (F3)

B.2 Battery of Shot Tubes

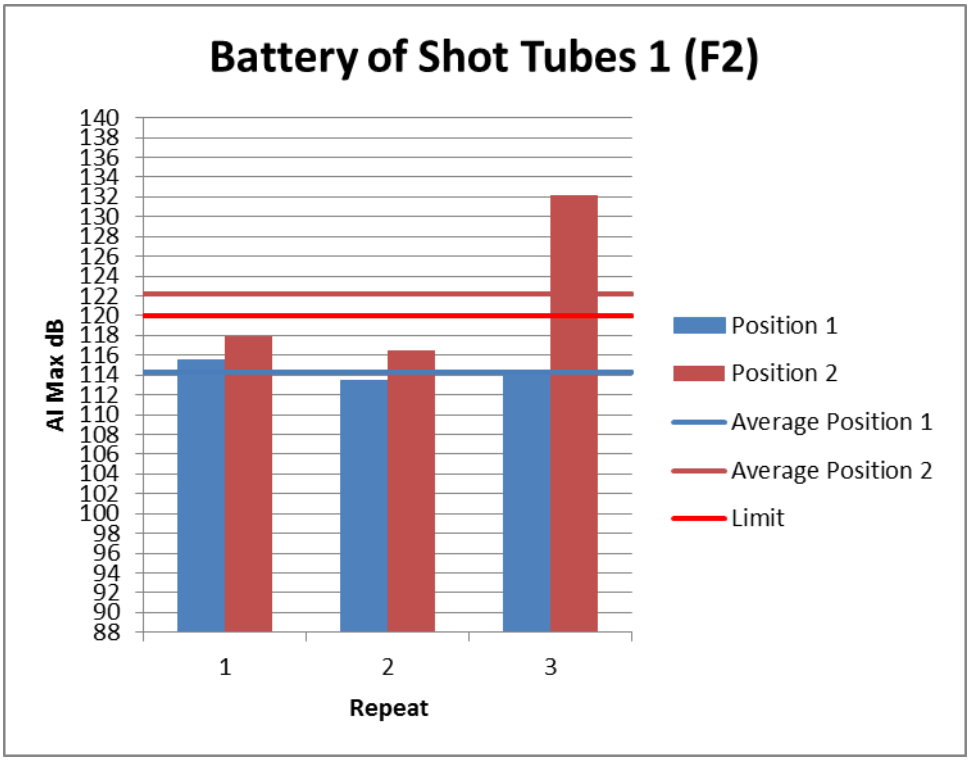

Figure 28: Individual Noise Levels for Battery of Shot Tubes 1 (F2)

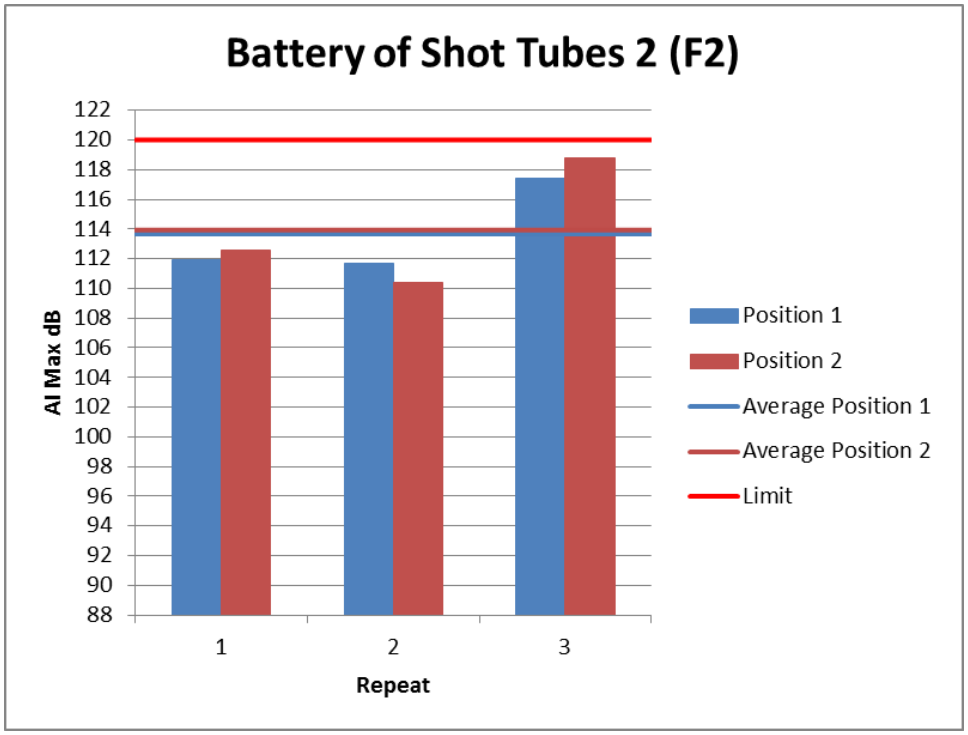

Figure 29: Individual Noise Levels for Battery of Shot Tubes 2 (F2)

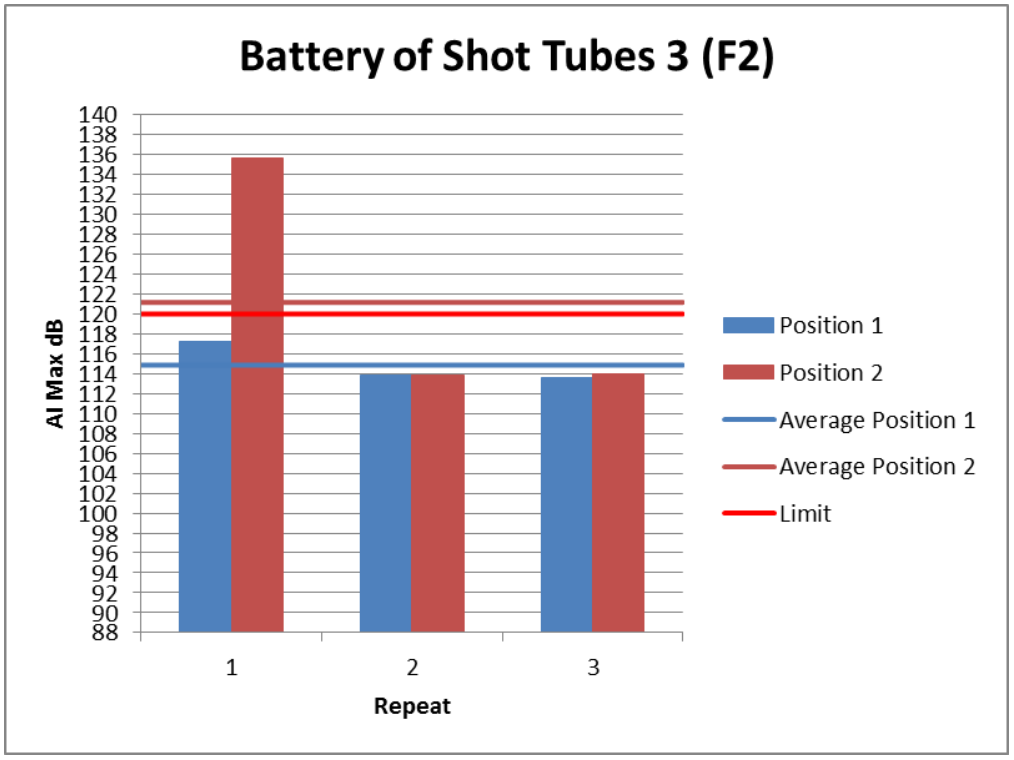

Figure 30: Individual Noise Levels for Battery of Shot Tubes 3 (F2)

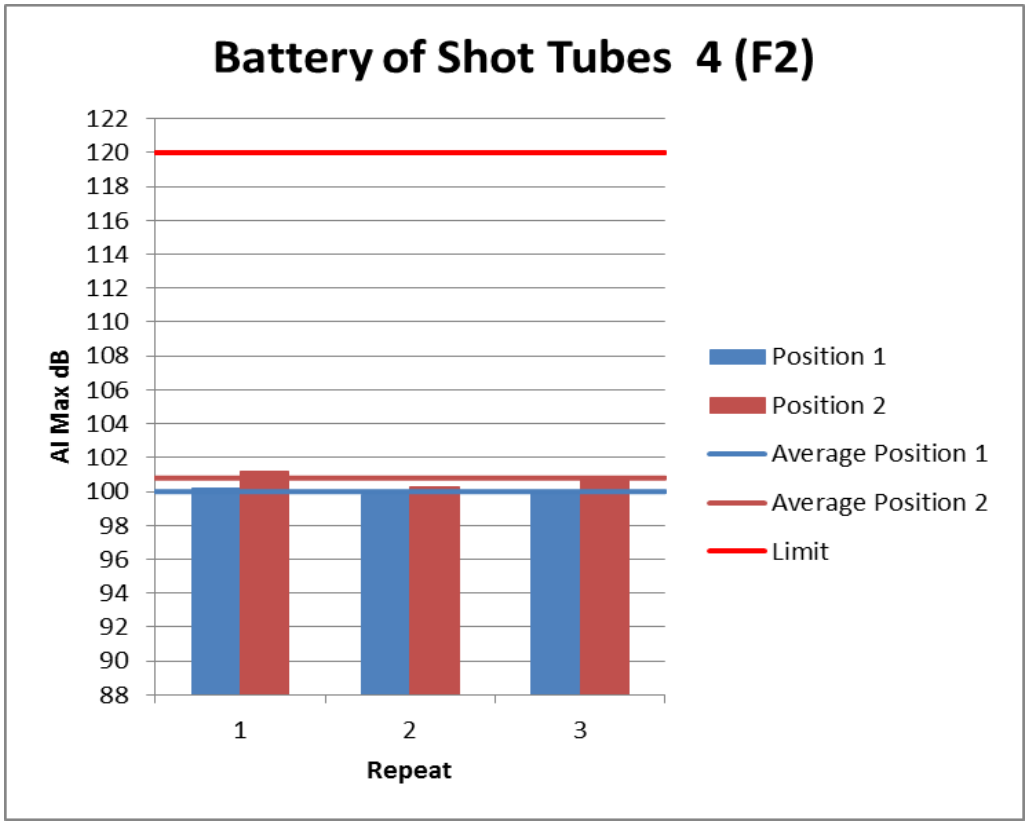

Figure 31: Individual Noise Levels for Battery of Shot Tubes 4 (F2)

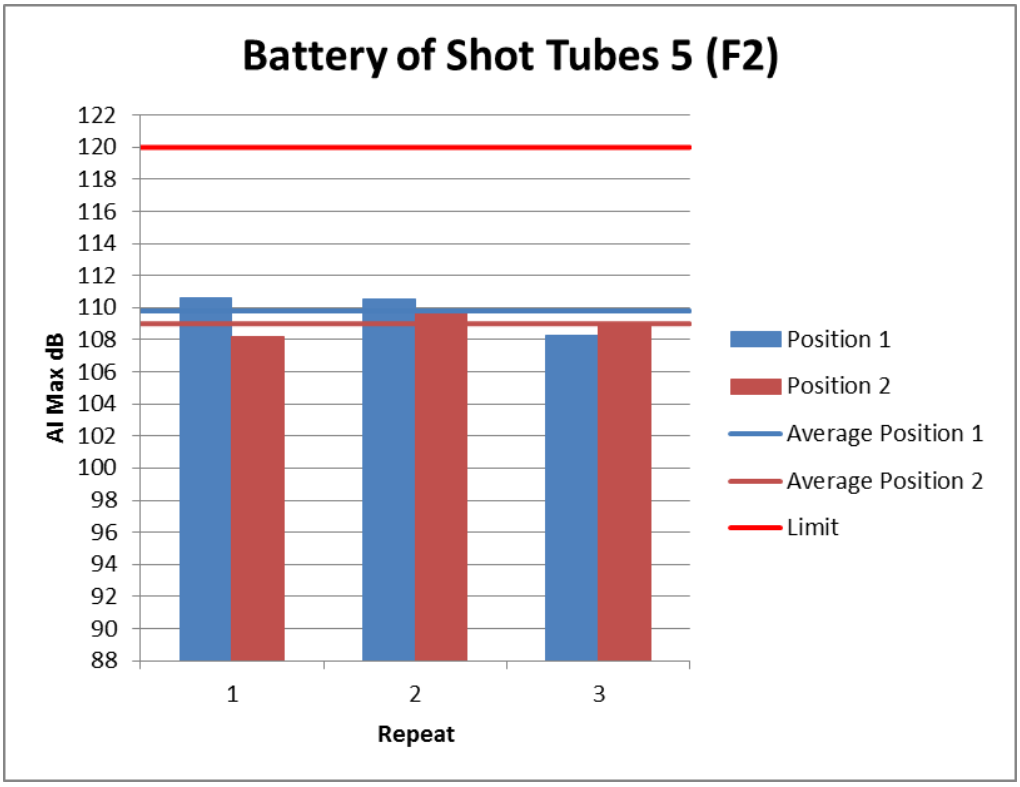

Figure 32: Individual Noise Levels for Battery of Shot Tubes 5 (F2)

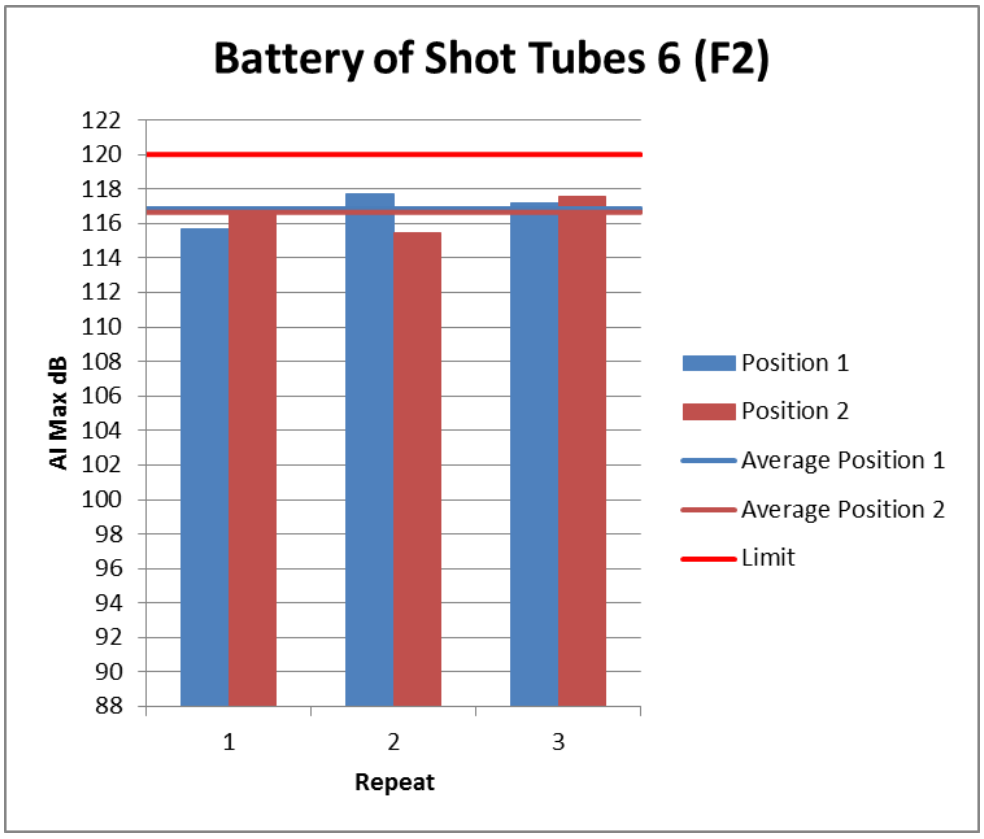

Figure 33: Individual Noise Levels for Battery of Shot Tubes 6 (F2)

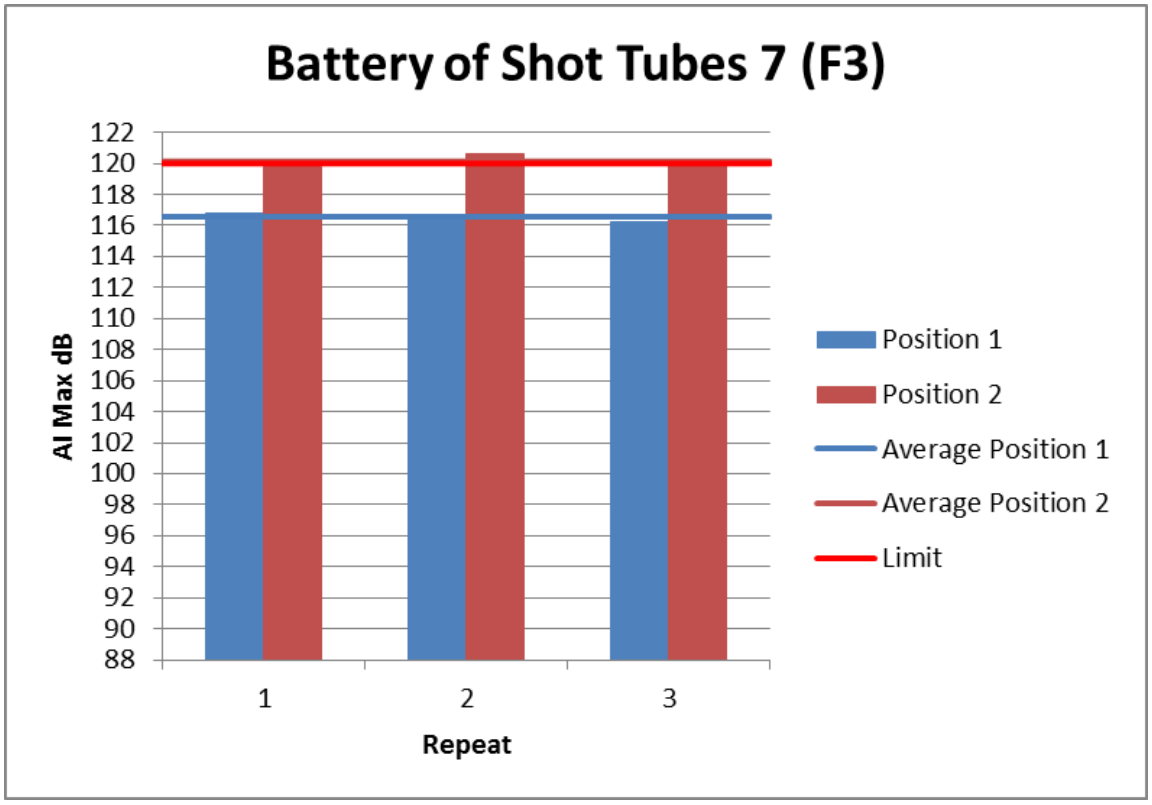

Figure 34: Individual Noise Levels for Battery of Shot Tubes 7(F3)

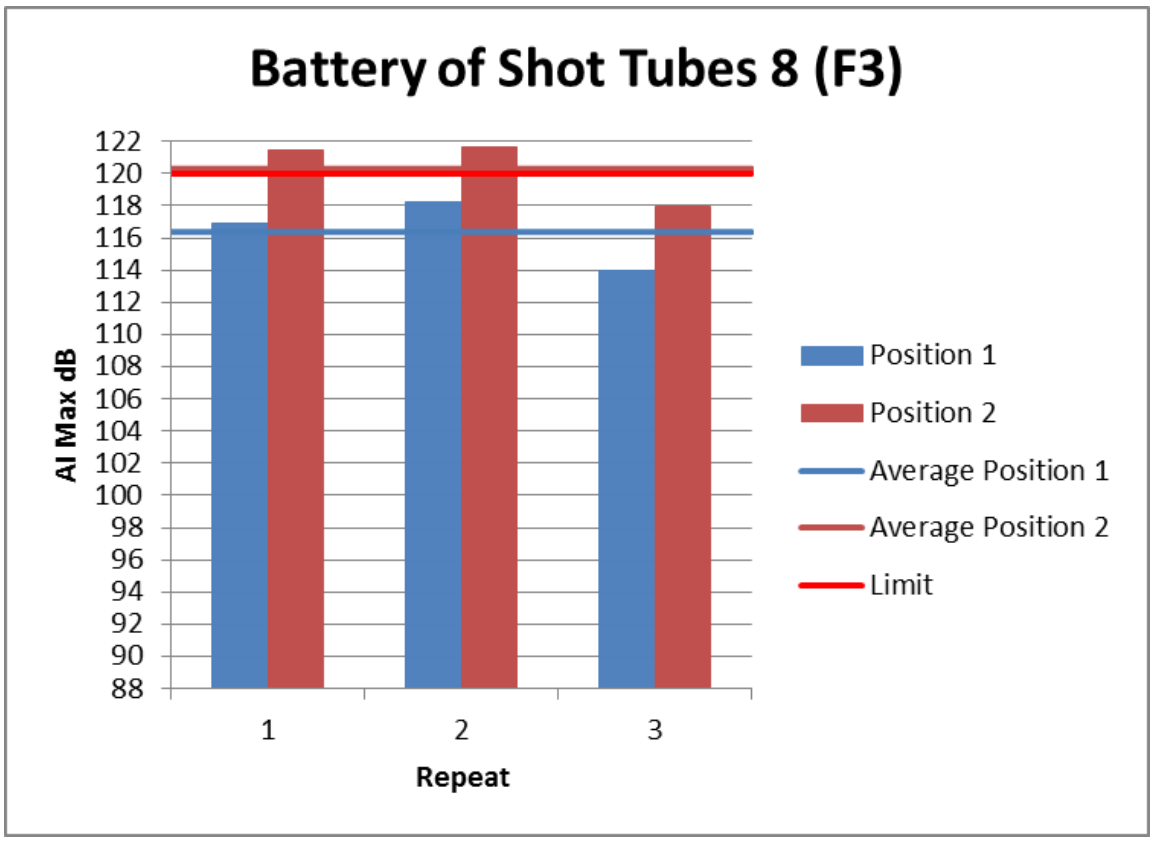

Figure 35: Individual Noise Levels for Battery of Shot Tubes 8 (F3)

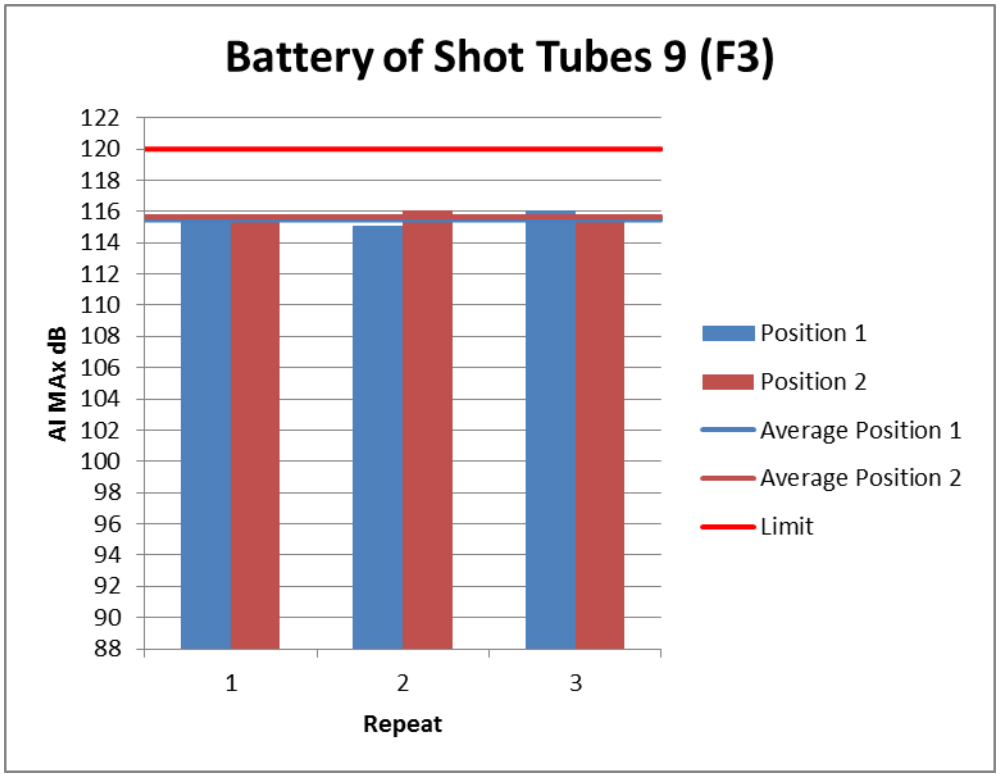

Figure 36: Individual Noise Levels for Battery of Shot Tubes 9 (F3)

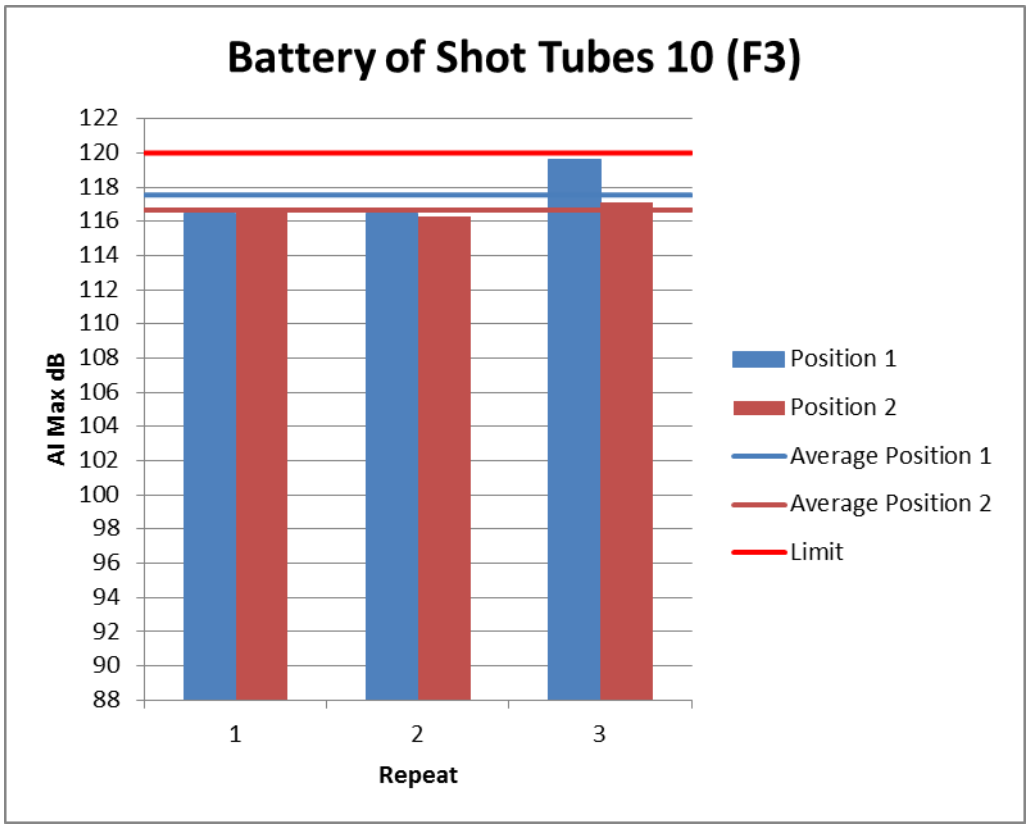

Figure 37: Individual Noise Levels for Battery of Shot Tubes 10 (F3)

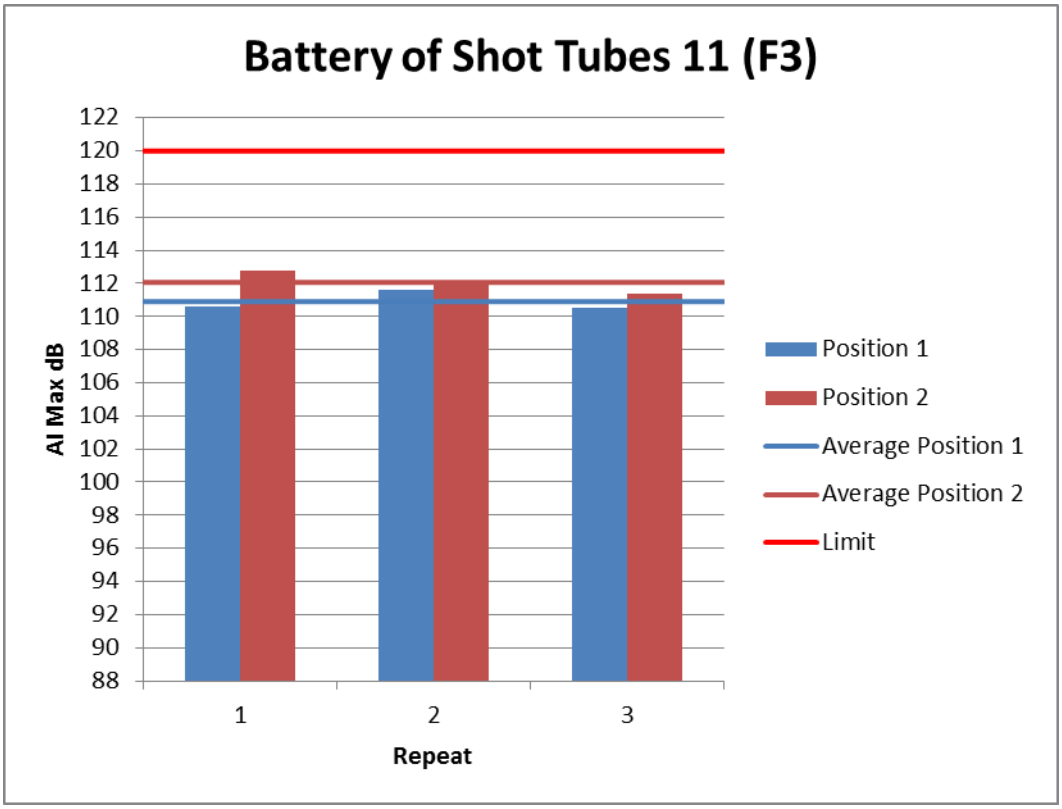

Figure 38: Individual Noise Levels for Battery of Shot Tubes 11 (F3)

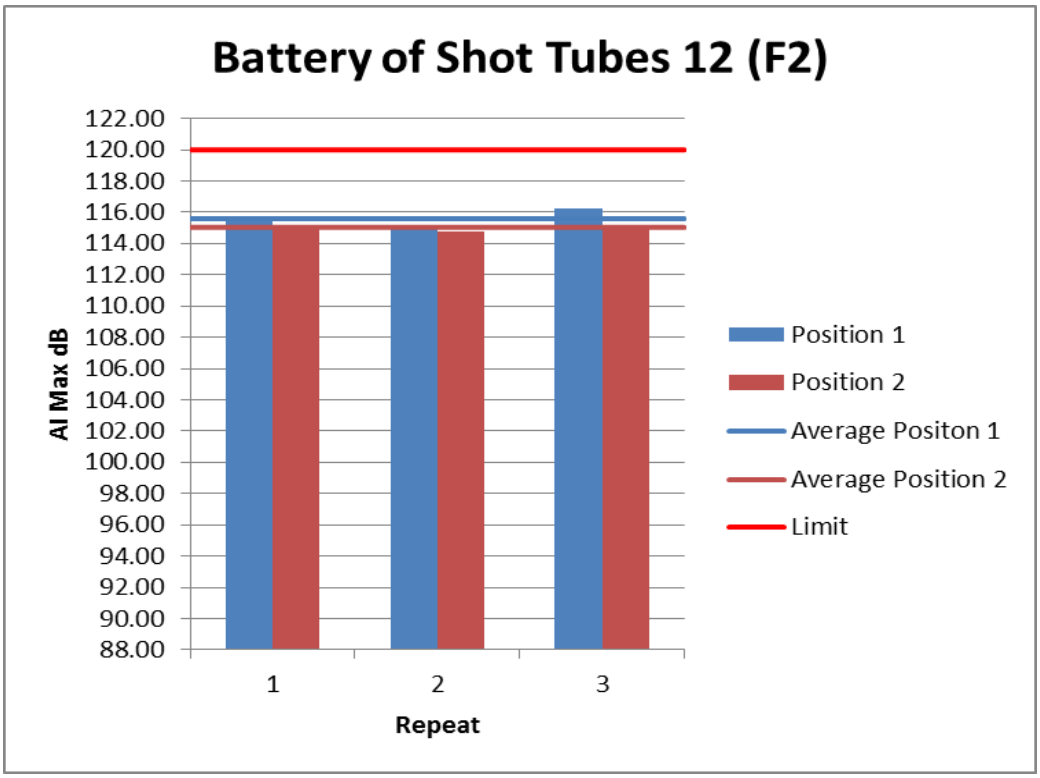

Figure 39: Individual Noise Levels for Battery of Shot Tubes 12 (F2)

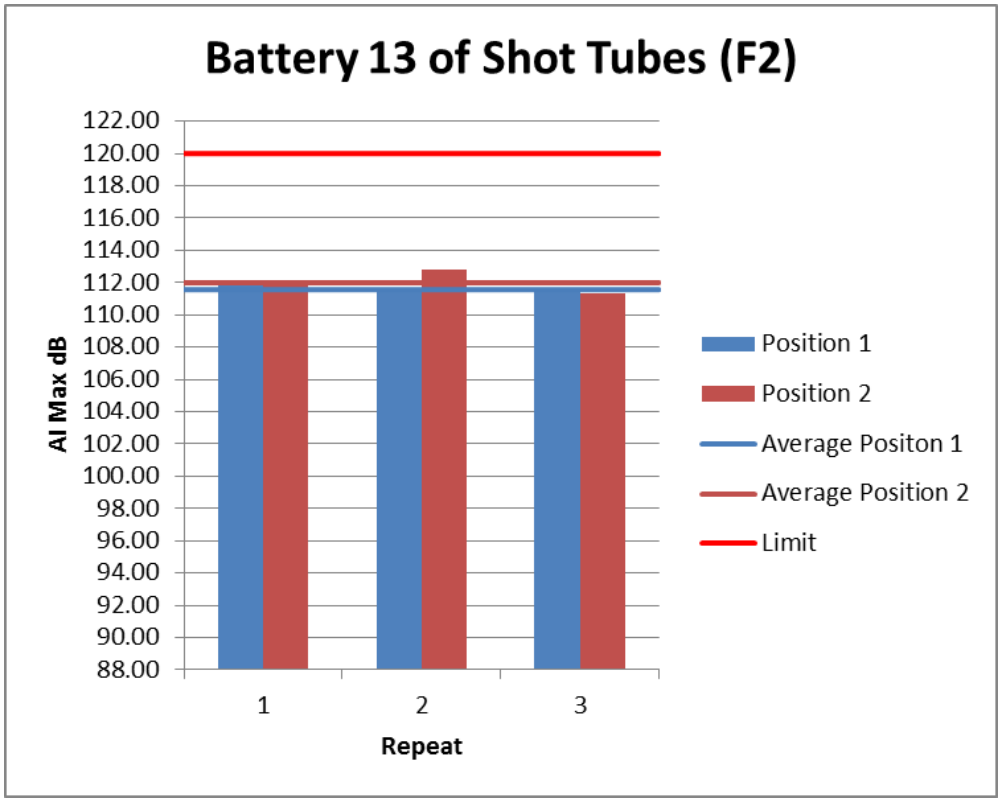

Figure 40: Individual Noise Levels for Battery of Shot Tubes 13 (F2)

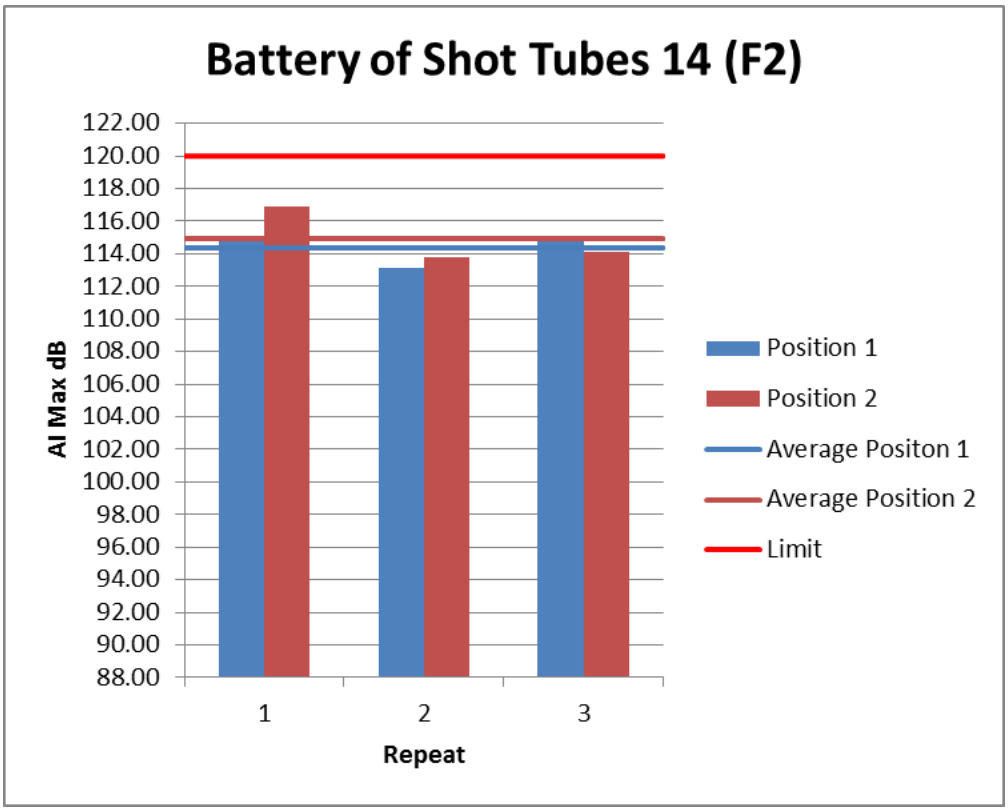

Figure 41: Individual Noise Levels for Battery of Shot Tubes 14 (F2)

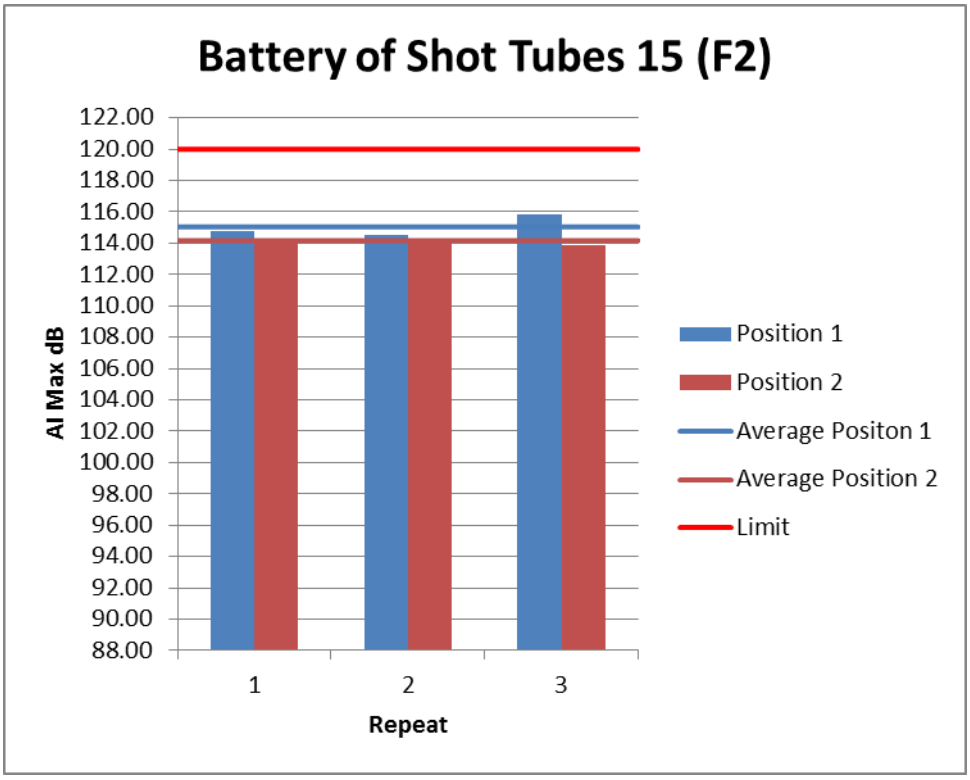

Figure 42: Individual Noise Levels for Battery of Shot Tubes 15 (F2)

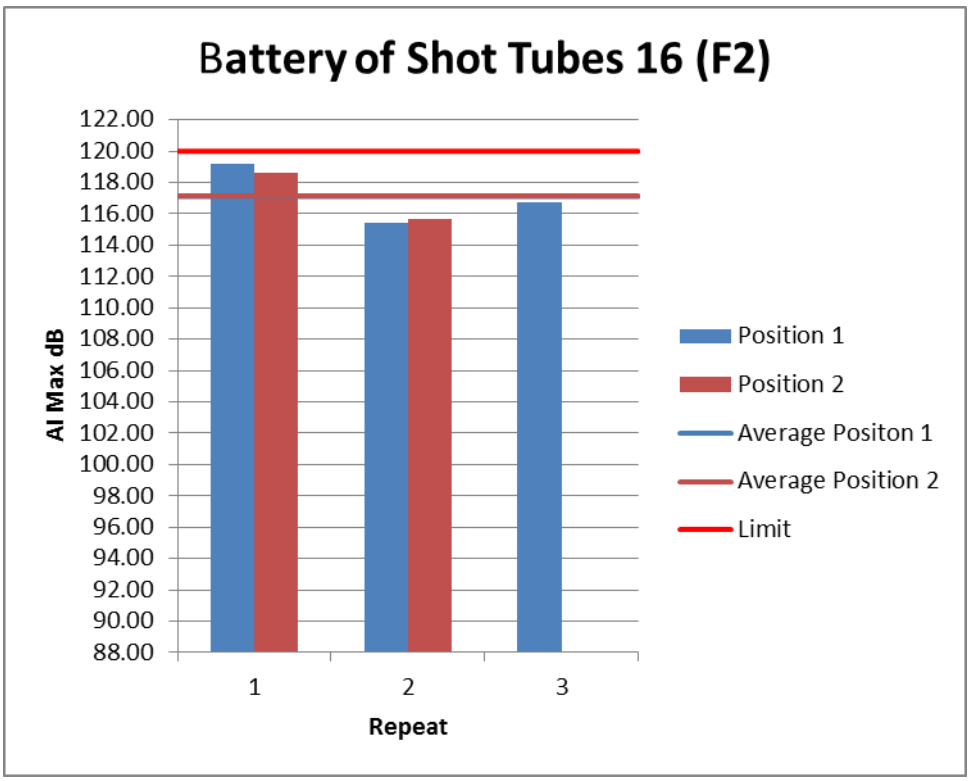

Figure 43: Individual Noise Levels for Battery of Shot Tubes 16 (F2)

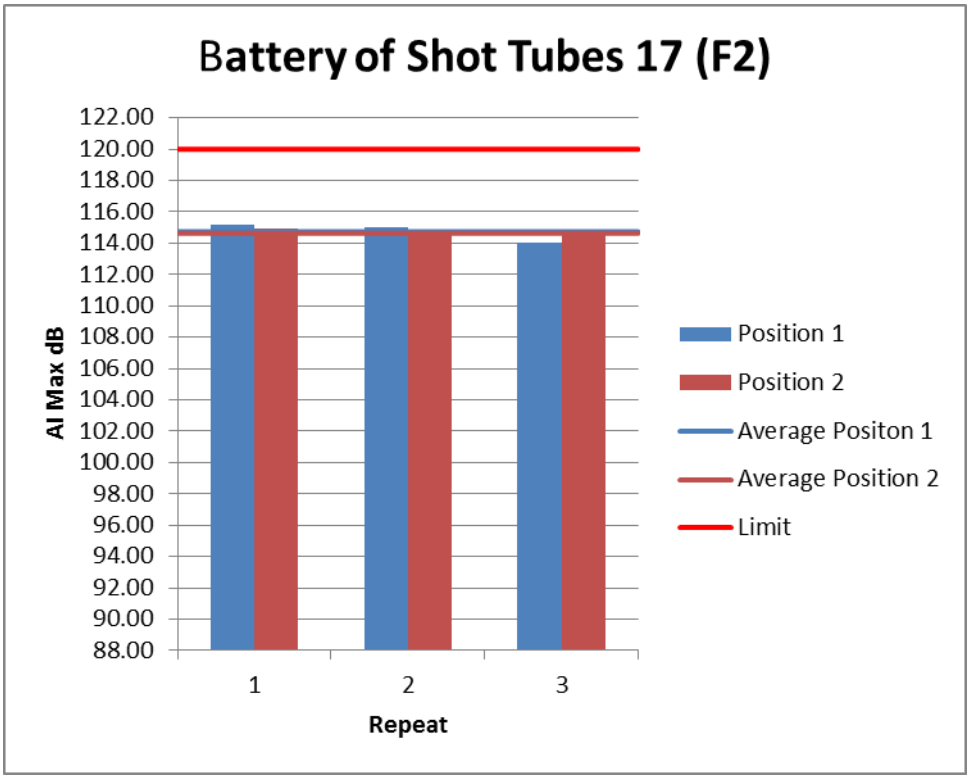

Figure 44: Individual Noise Levels for Battery of Shot Tubes 17 (F2)

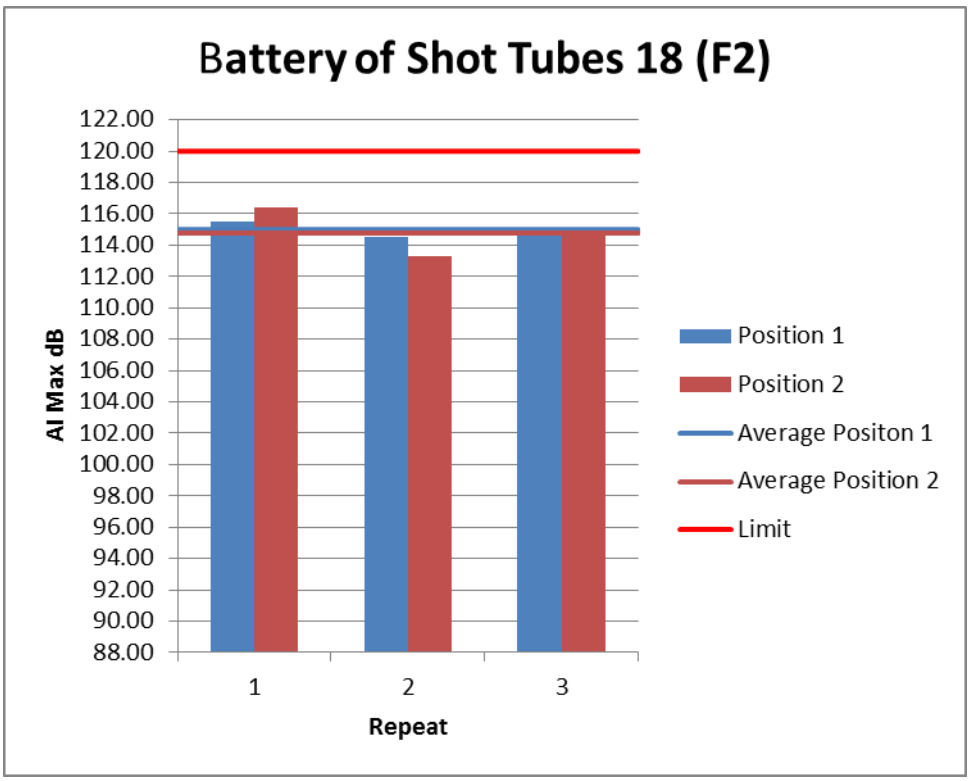

Figure 45: Individual Noise Levels for Battery of Shot Tubes 18 (F2)

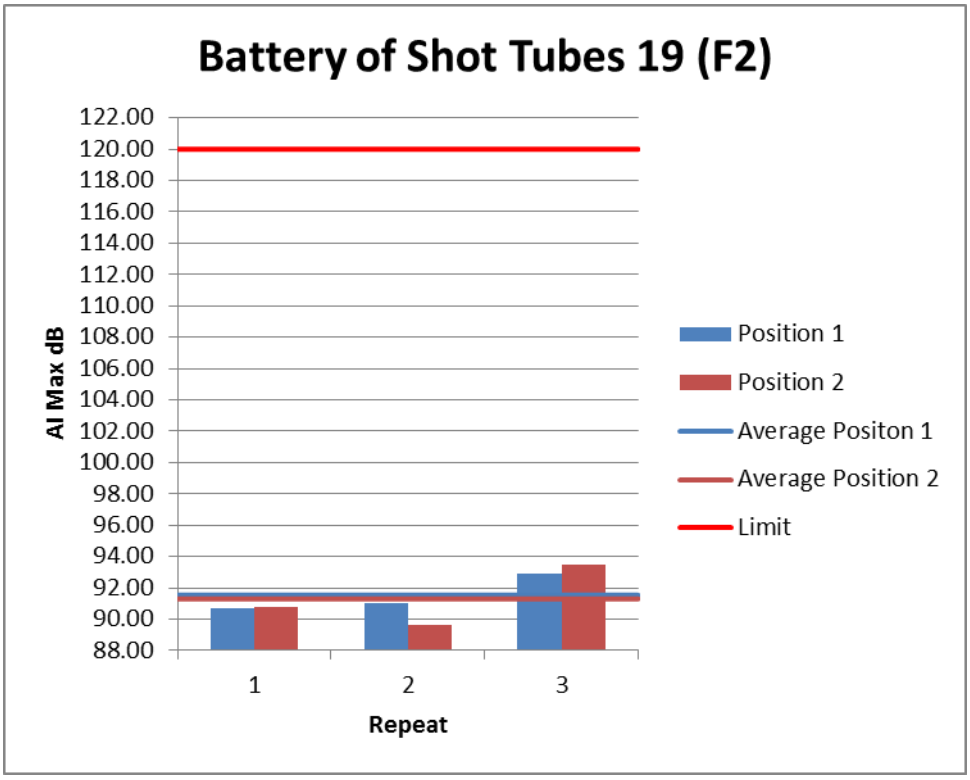

Figure 46: Individual Noise Levels for Battery of Shot Tubes 19 (F2)

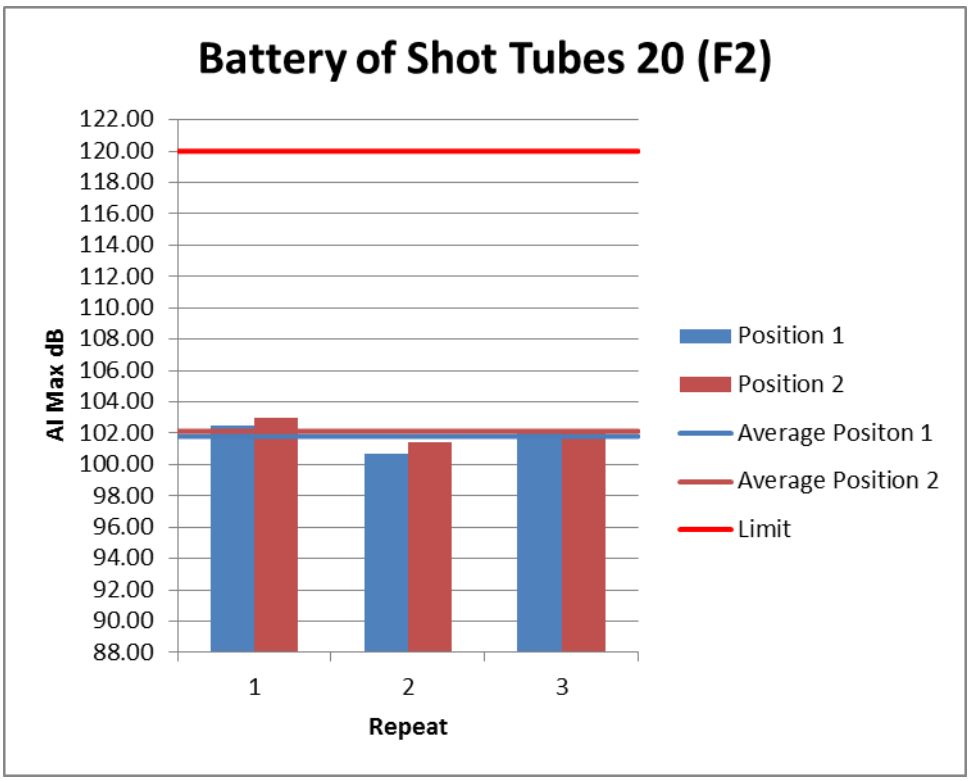

Figure 47: Individual Noise Levels for Battery of Shot Tubes 20 (F2)

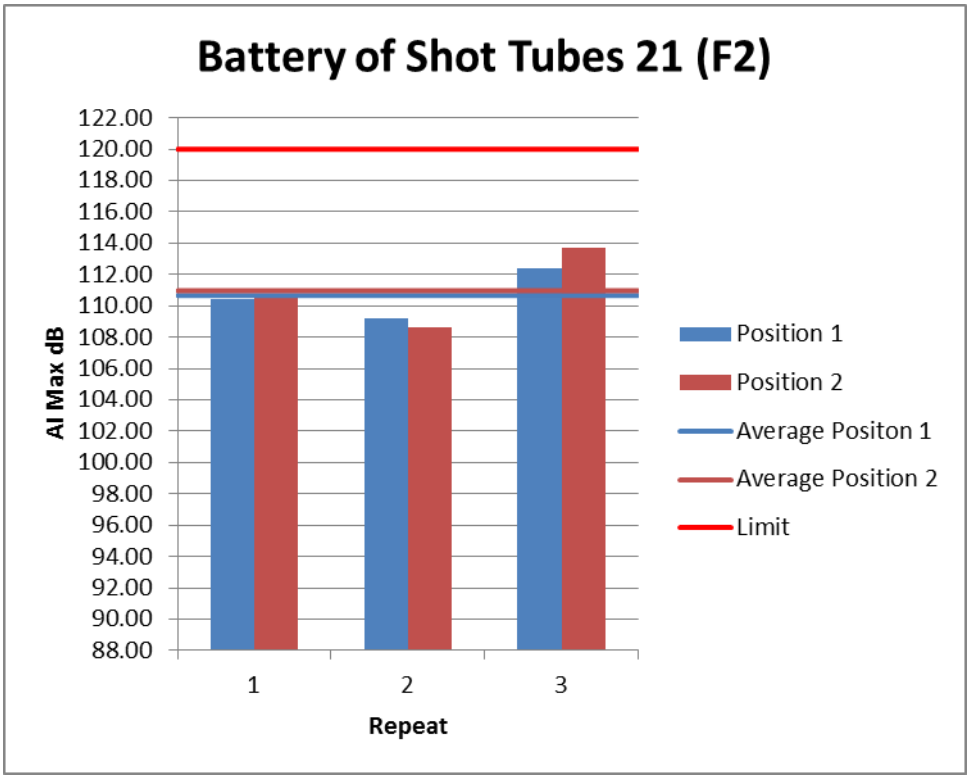

Figure 48: Individual Noise Levels for Battery of Shot Tubes 21 (F2)

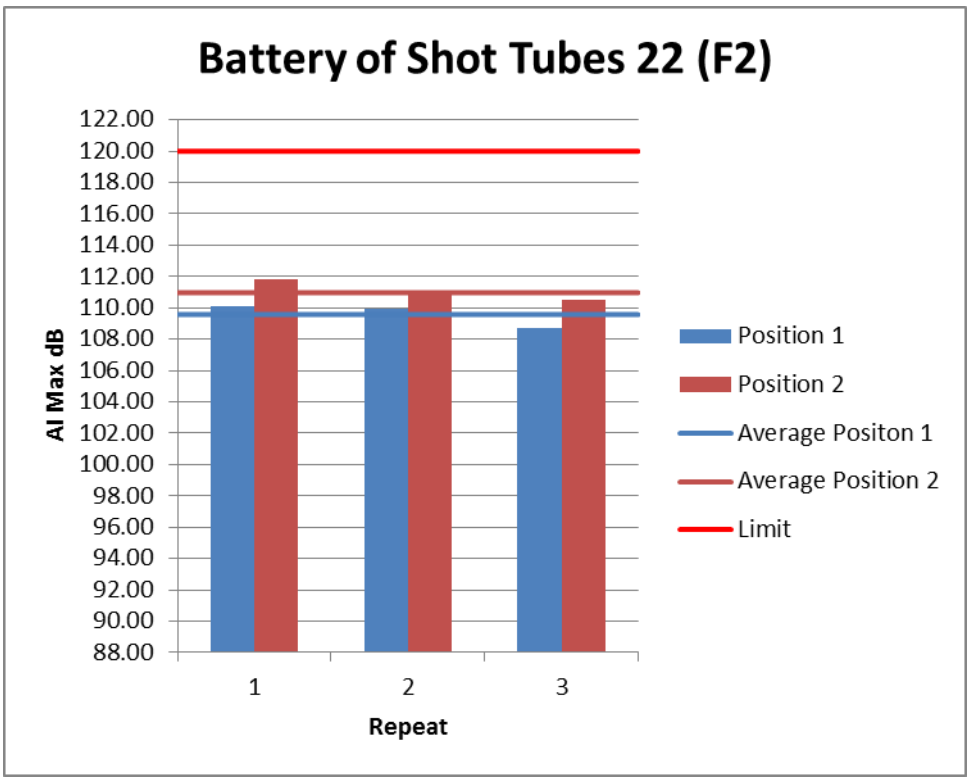

Figure 49: Individual Noise Levels for Battery of Shot Tubes 22 (F2)

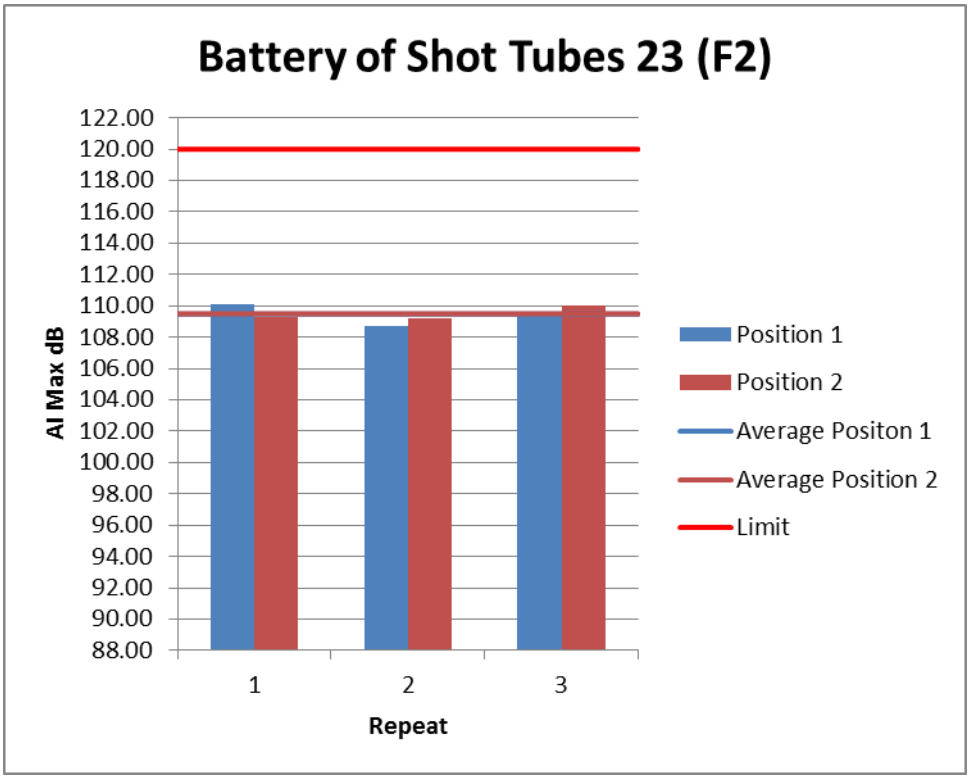

Figure 50: Individual Noise Levels for Battery of Shot Tubes 23 (F2)

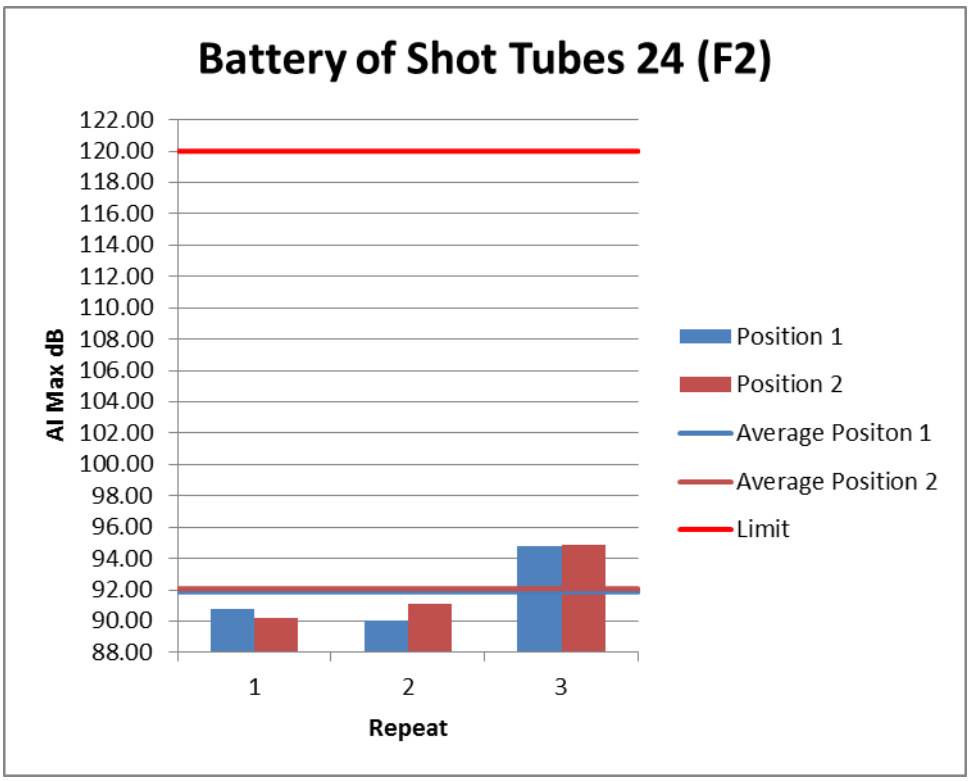

Figure 51: Individual Noise Levels for Battery of Shot Tubes 24 (F2)

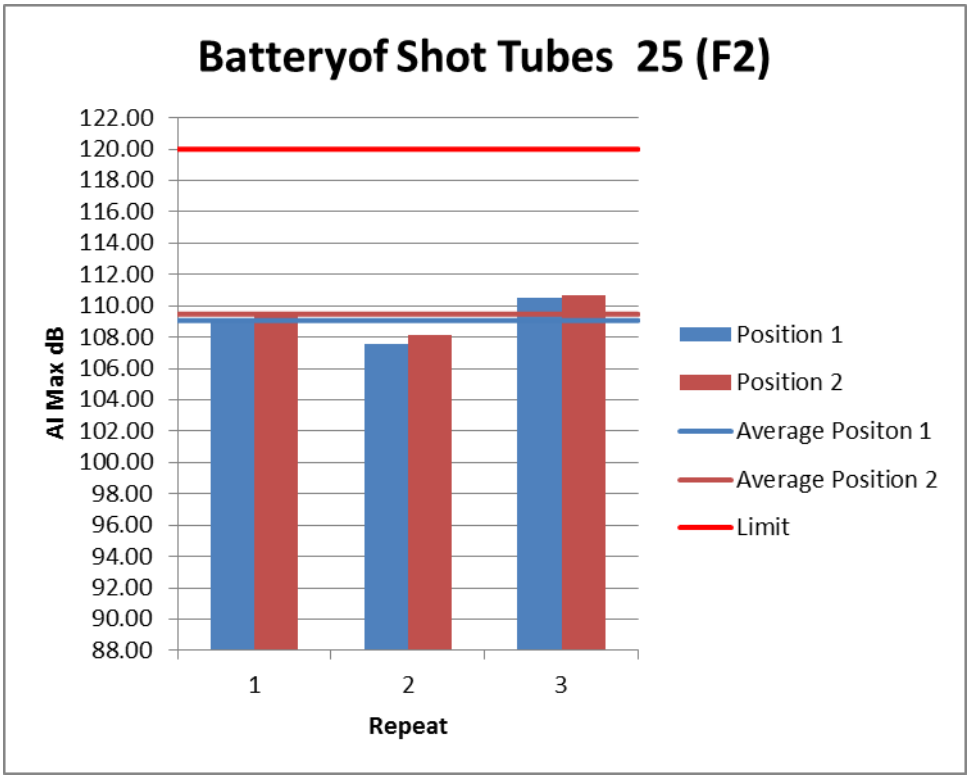

Figure 52: Individual Noise Levels for Battery of Shot Tubes 25 (F2)

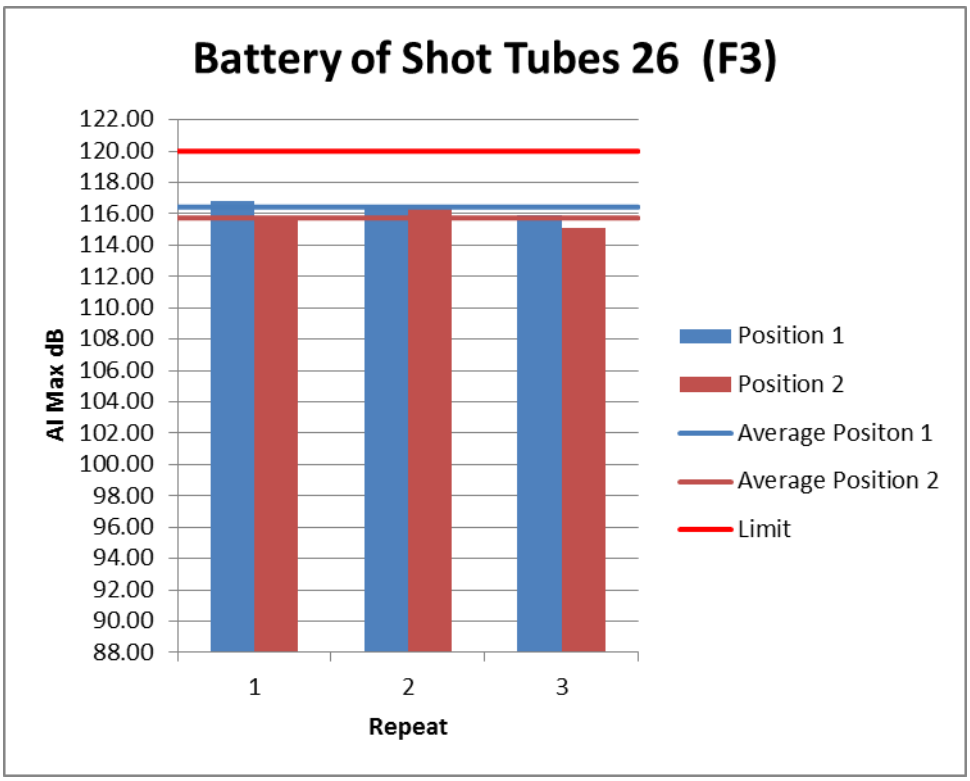

Figure 53: Individual Noise Levels Battery of Shot Tubes 26 (F3)

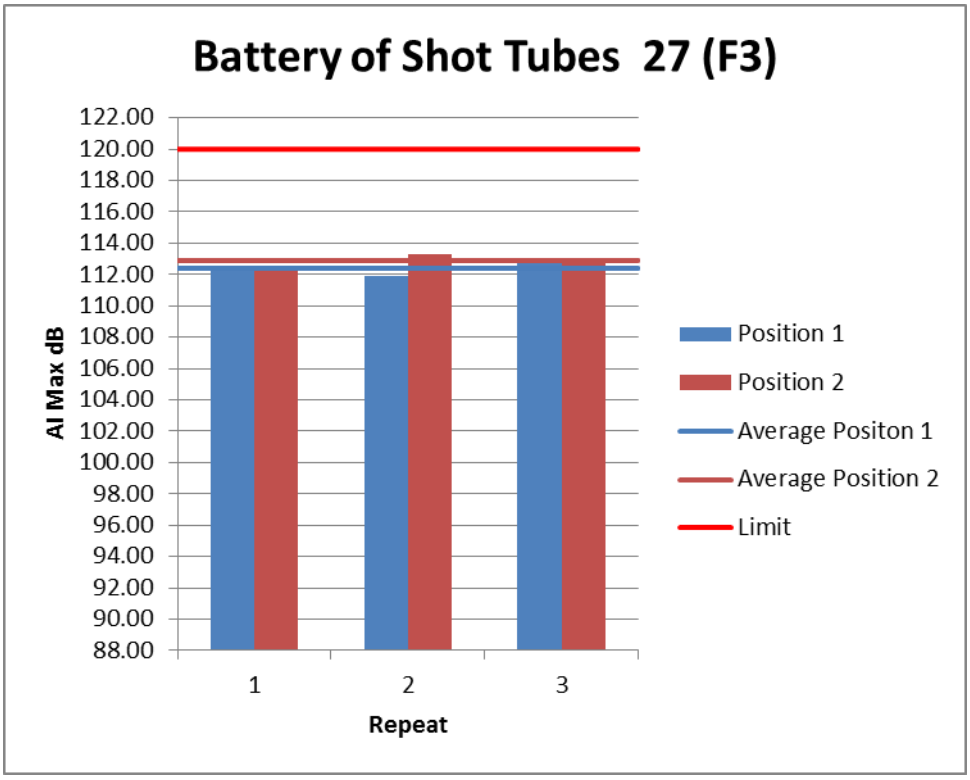

Figure 54: Individual Noise Levels for Battery of Shot Tubes 27 (F3)

B.3 Fountain

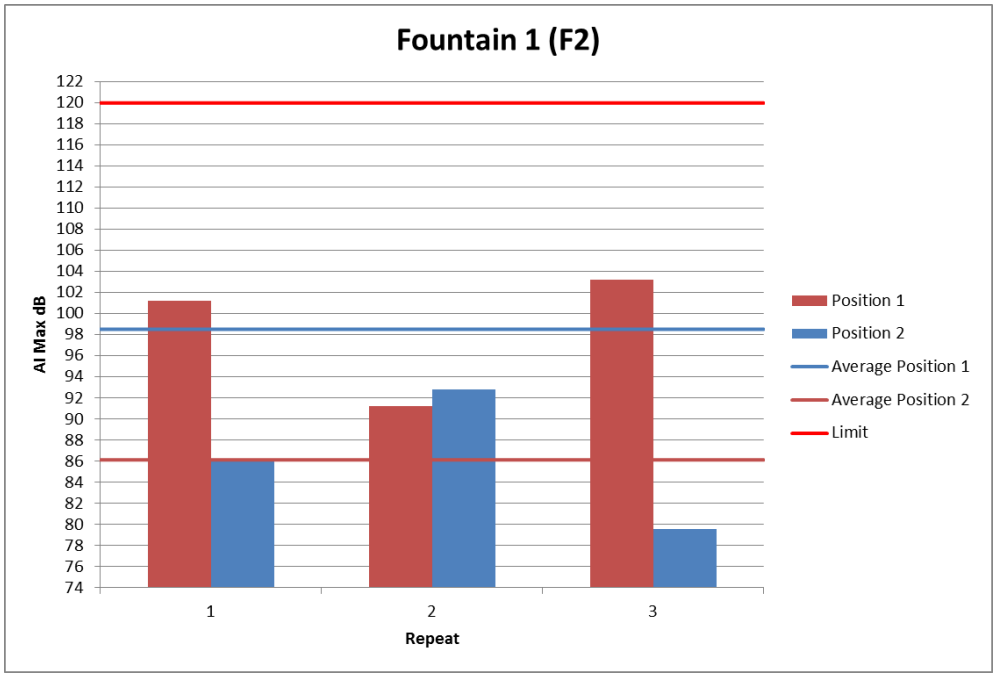

Figure 55: Individual Noise Levels for Fountain 1 (F2)

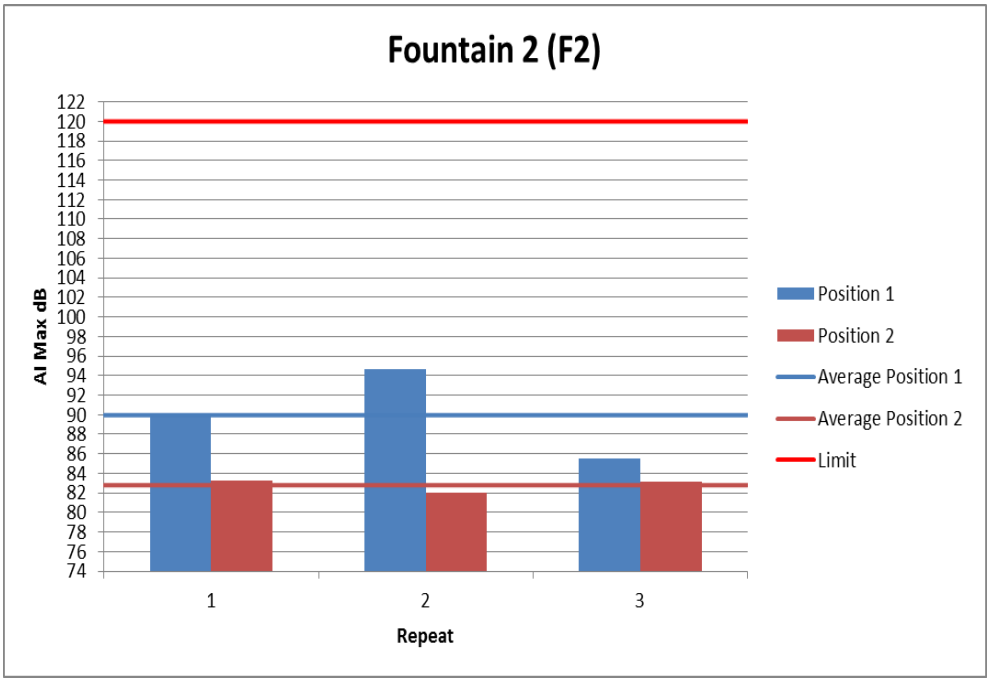

Figure 56: Individual Noise Levels for Fountain 2 (F2)

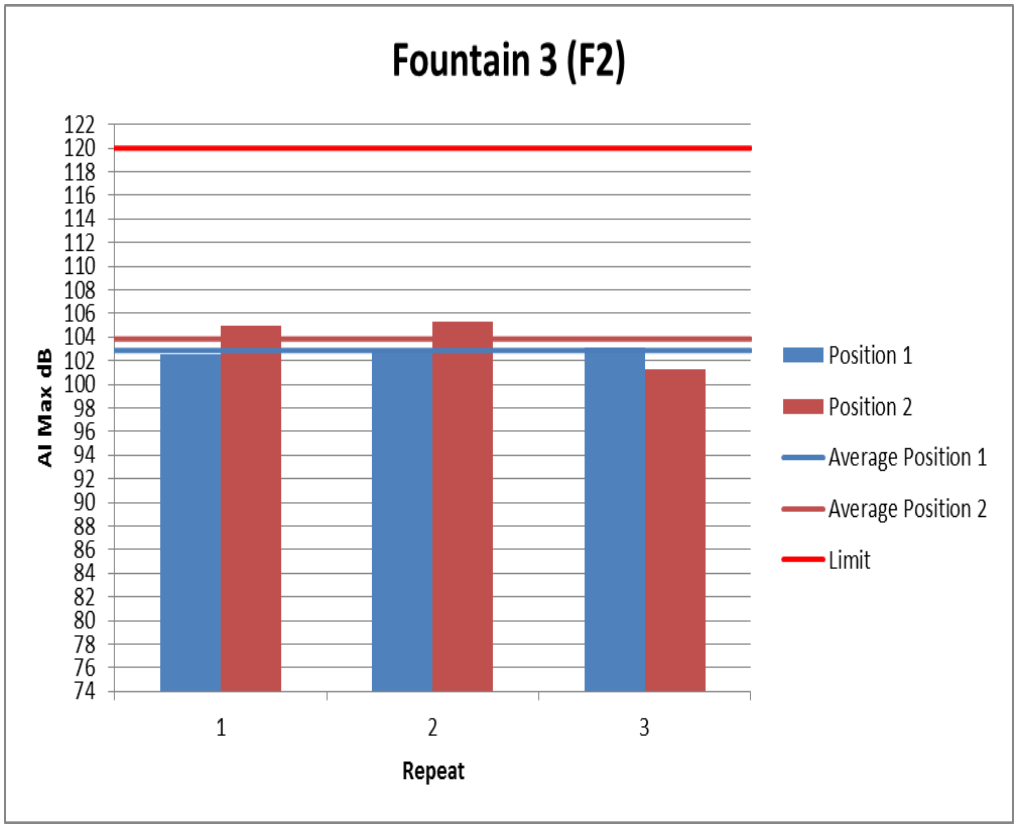

Figure 57: Individual Noise Levels for Fountain 3 (F2)

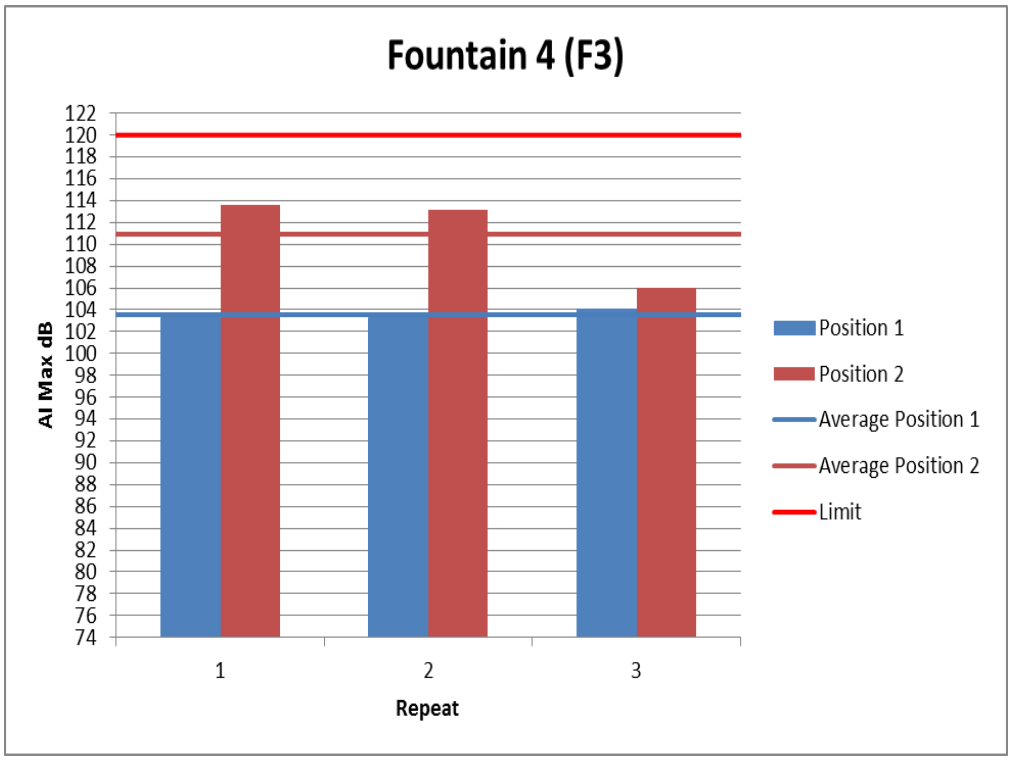

Figure 58: Individual Noise Levels for Fountain 4 (F3)

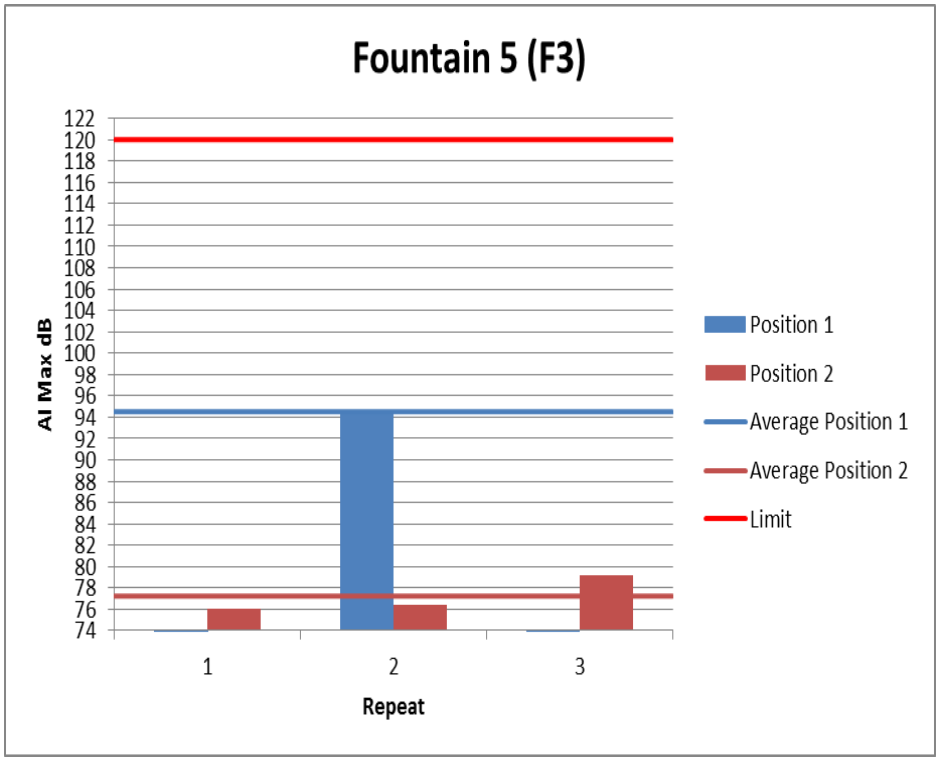

Figure 59: Individual Noise Levels for Fountain 5 (F3)

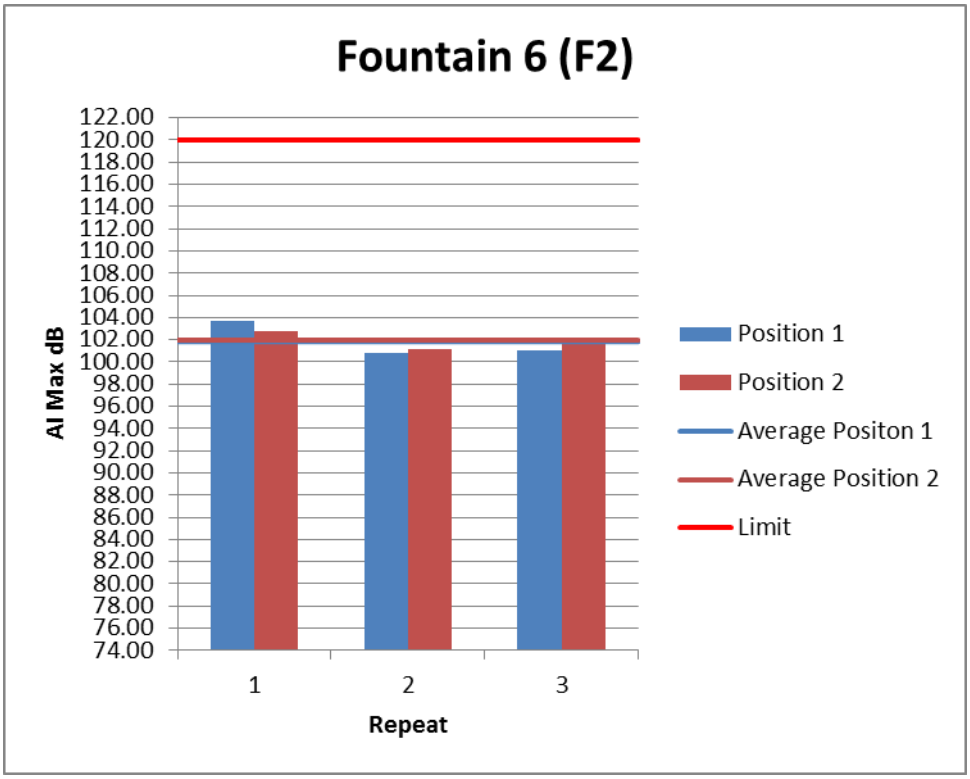

Figure 60: Individual Noise Levels for Fountain 6 (F2)

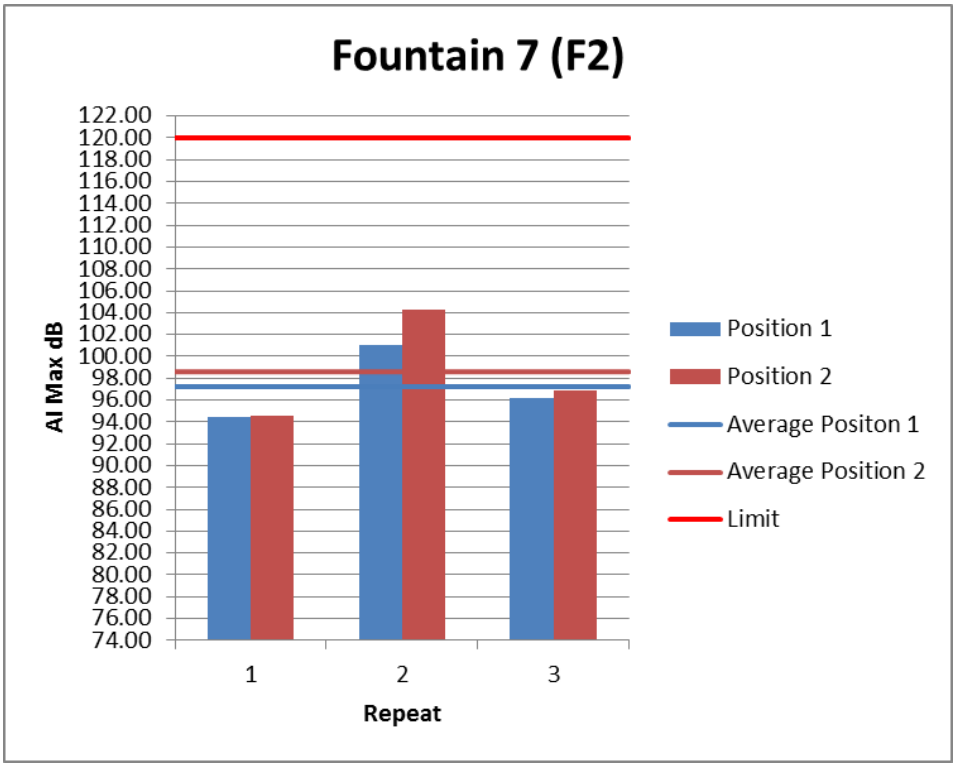

Figure 61: Individual Noise Levels for Fountain 7 (F2)

B.4 Wheels

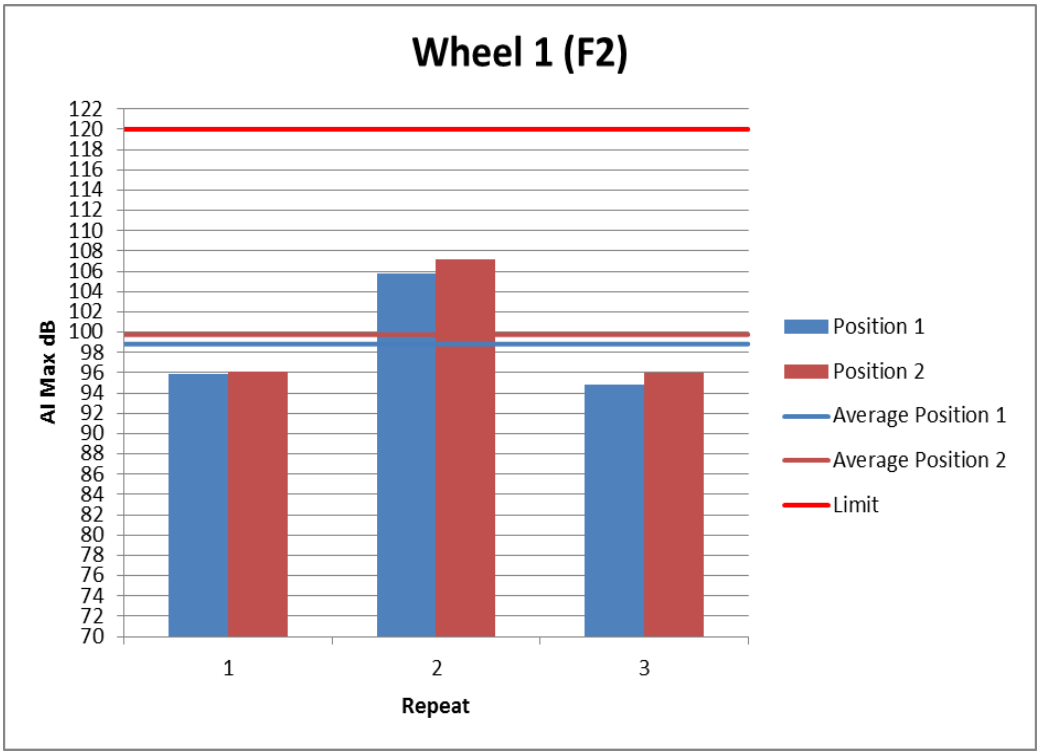

Figure 62: Individual Noise Levels for Wheel 1 (F2)

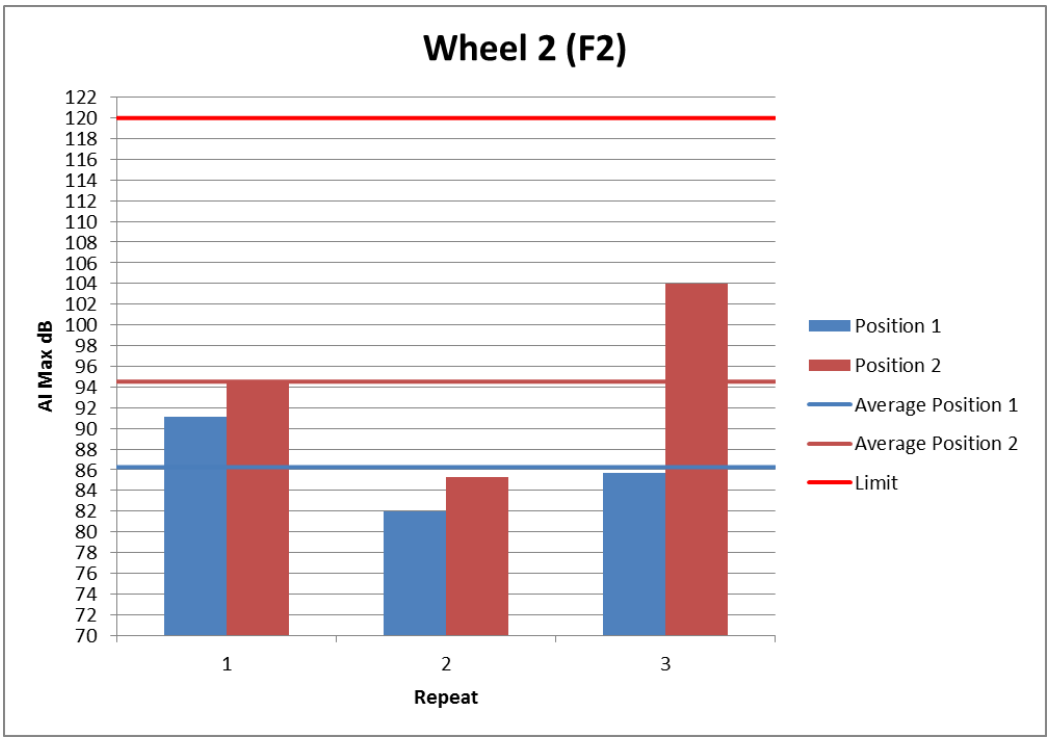

Figure 63: Individual Noise Levels for Wheel 2 (F2)

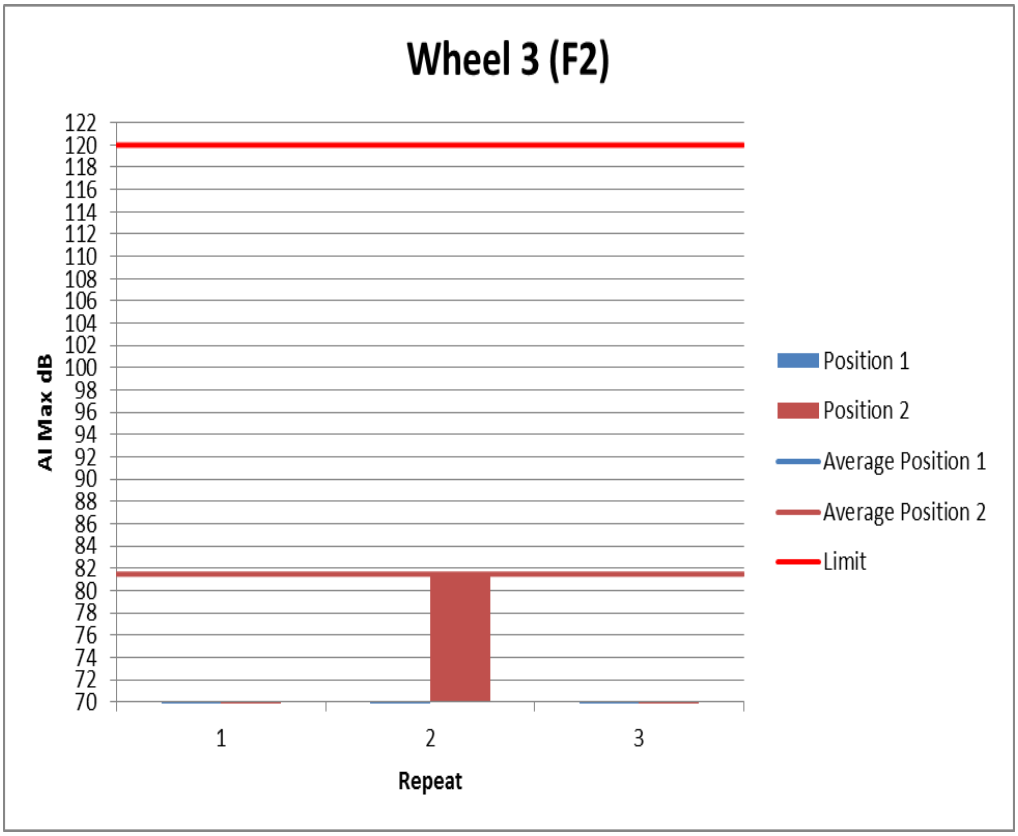

Figure 64: Individual Noise Levels for Wheel 3 (F2)

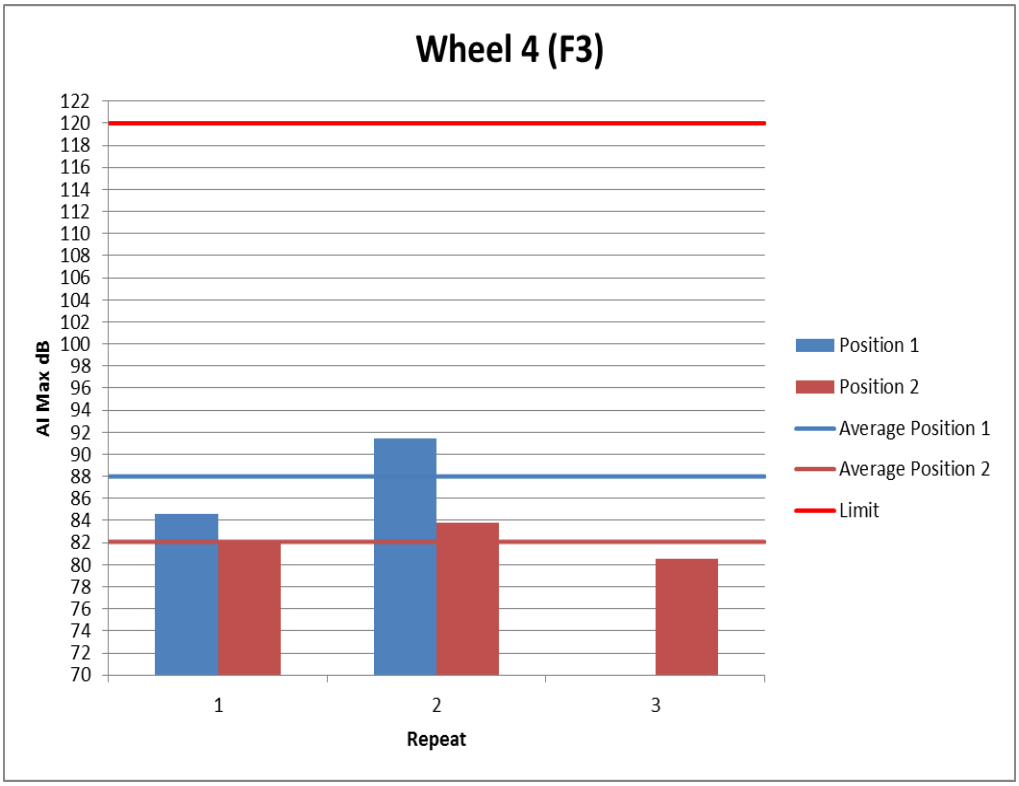

Figure 65: Individual Noise Levels for Wheel 4 (F3)

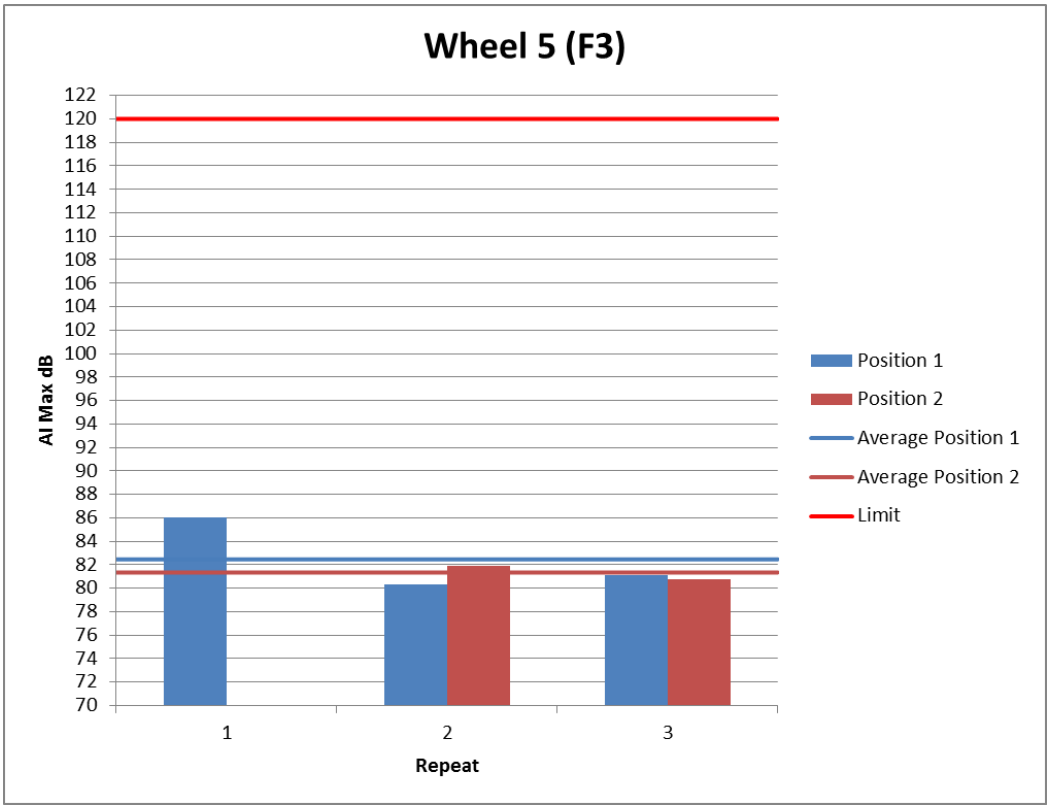

Figure 66: Individual Noise Levels for Wheel 5 (F3)

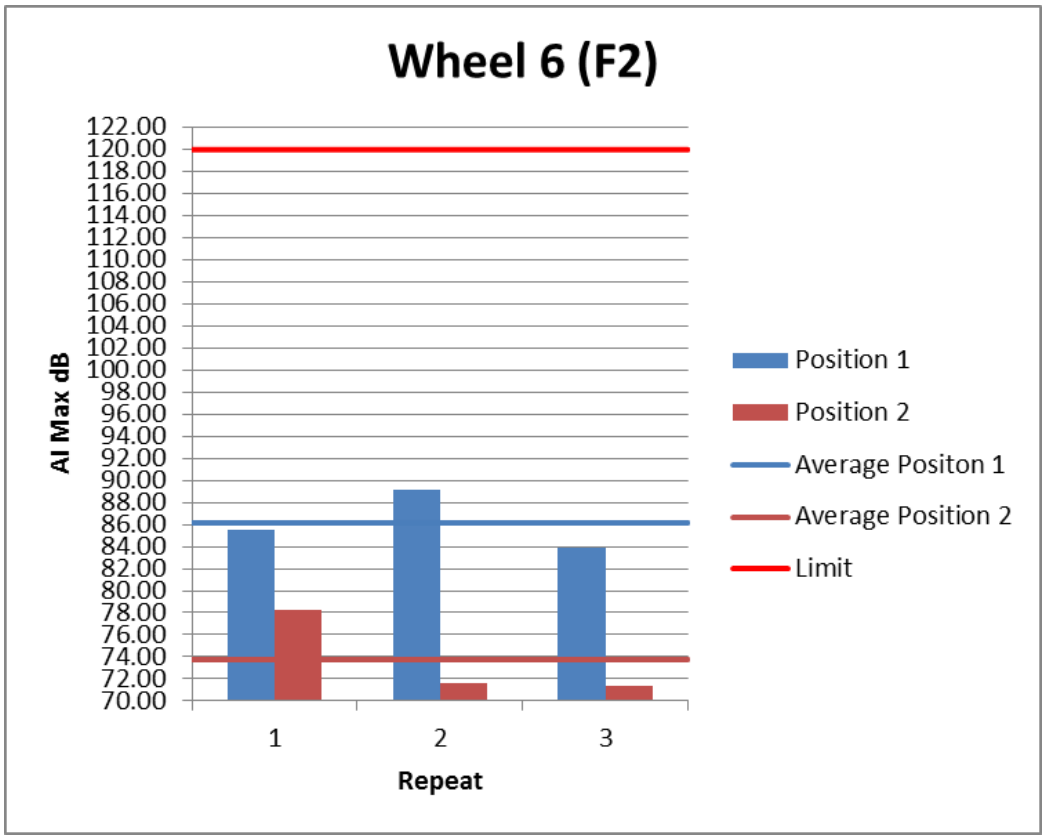

Figure 67: Individual Noise Levels for Wheel 6 (F2)

B.5 Roman Candles

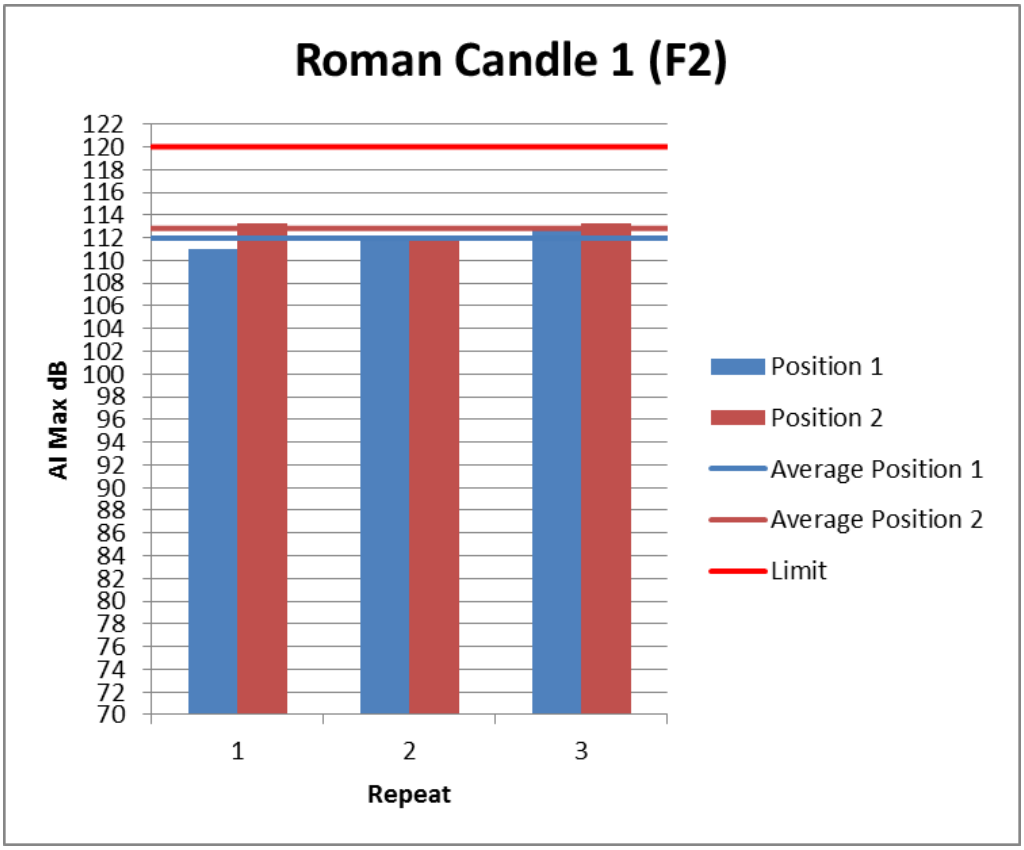

Figure 68: Individual Noise Levels for Roman Candle 1 (F2)

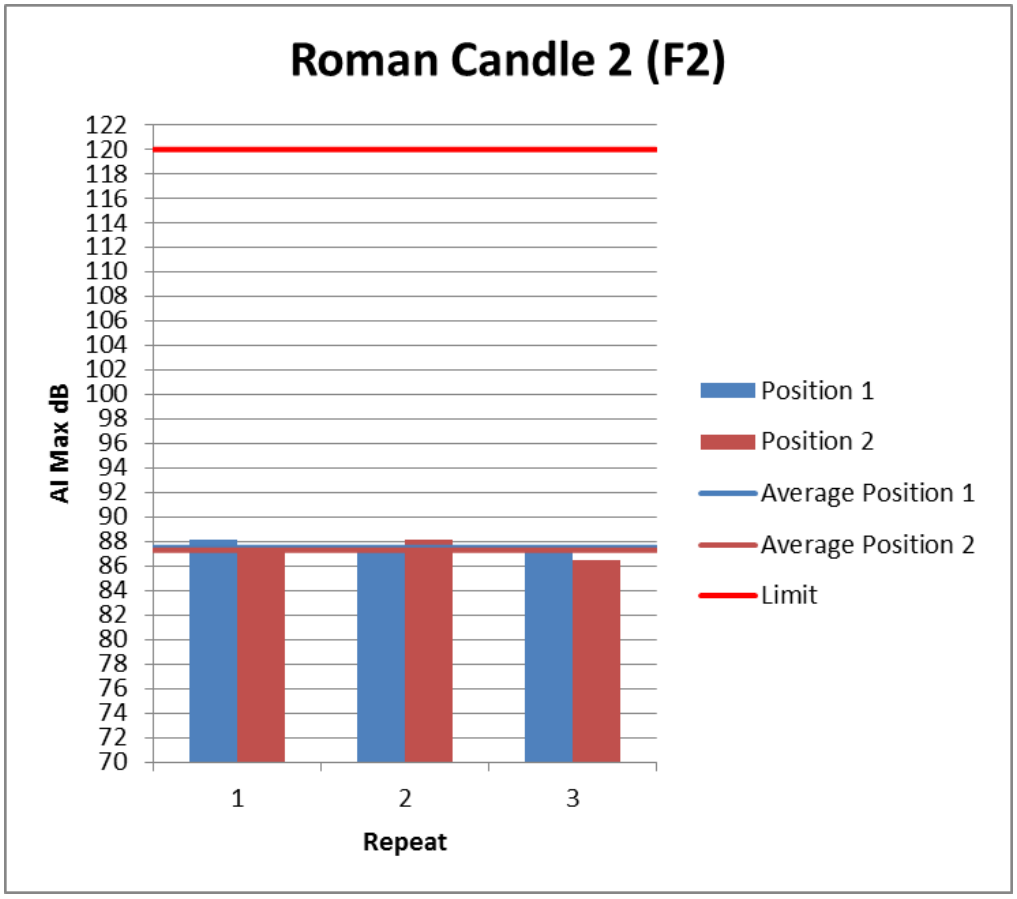

Figure 69: Individual Noise Levels for Roman Candle 2 (F2)

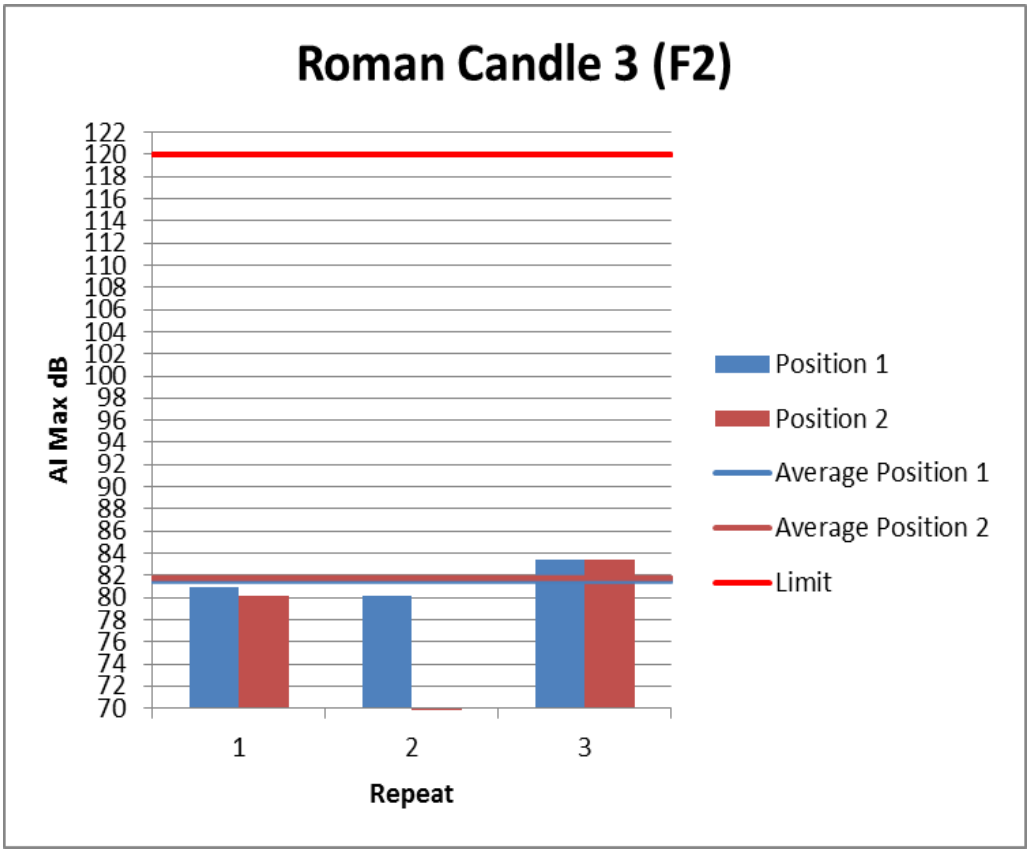

Figure 70: Individual Noise Levels for Roman Candle 3 (F2)

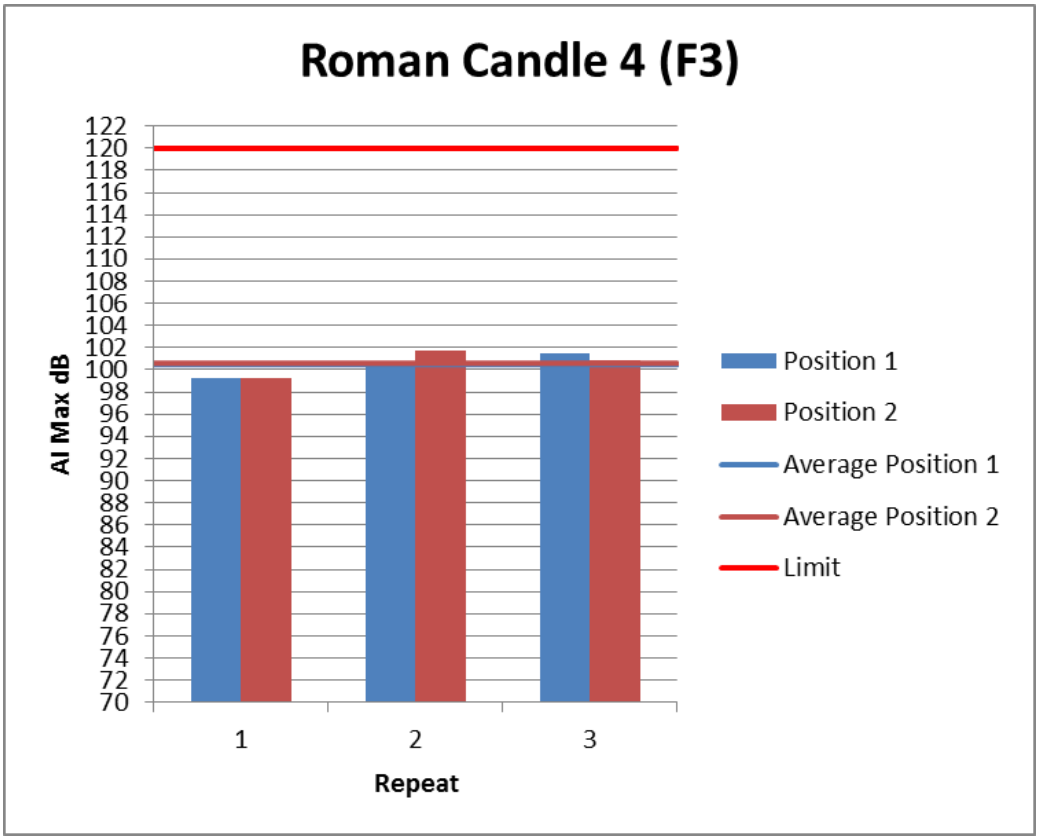

Figure 71: Individual Noise Levels for Roman Candle 4 (F3)

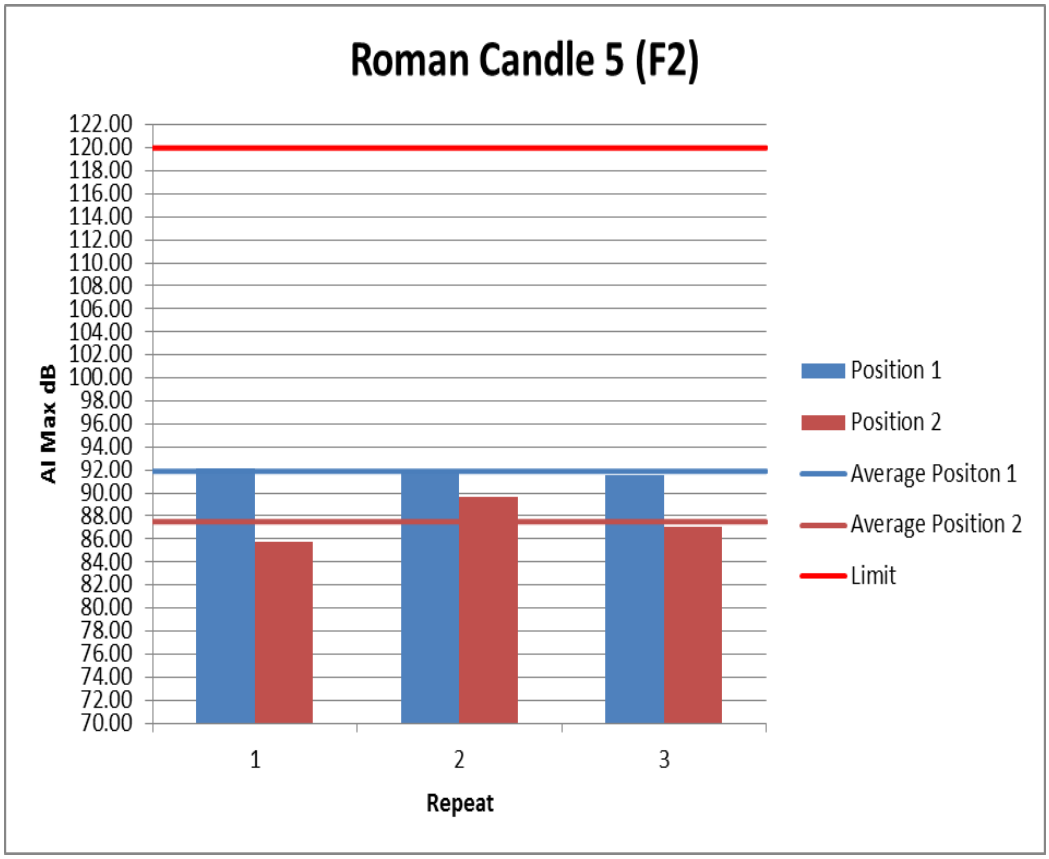

Figure 72: Individual Noise Levels for Roman Candle 5 (F2)

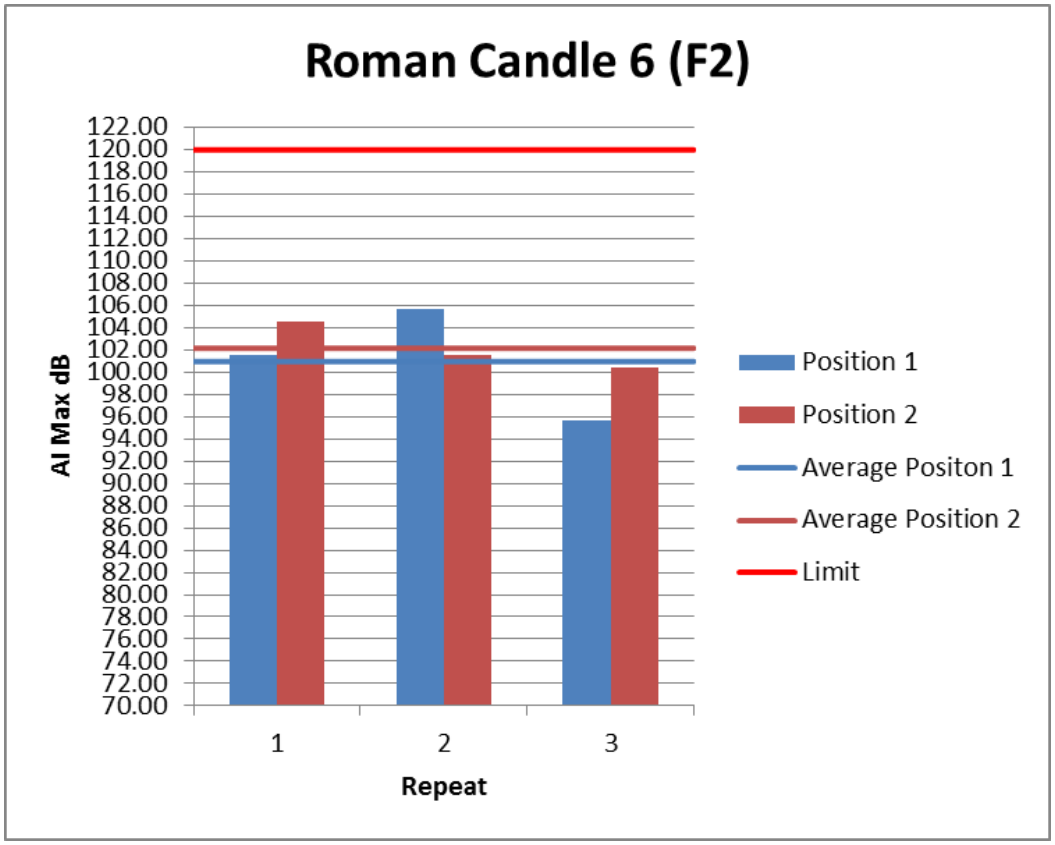

Figure 73: Individual Noise Levels for Roman Candle 6 (F2)

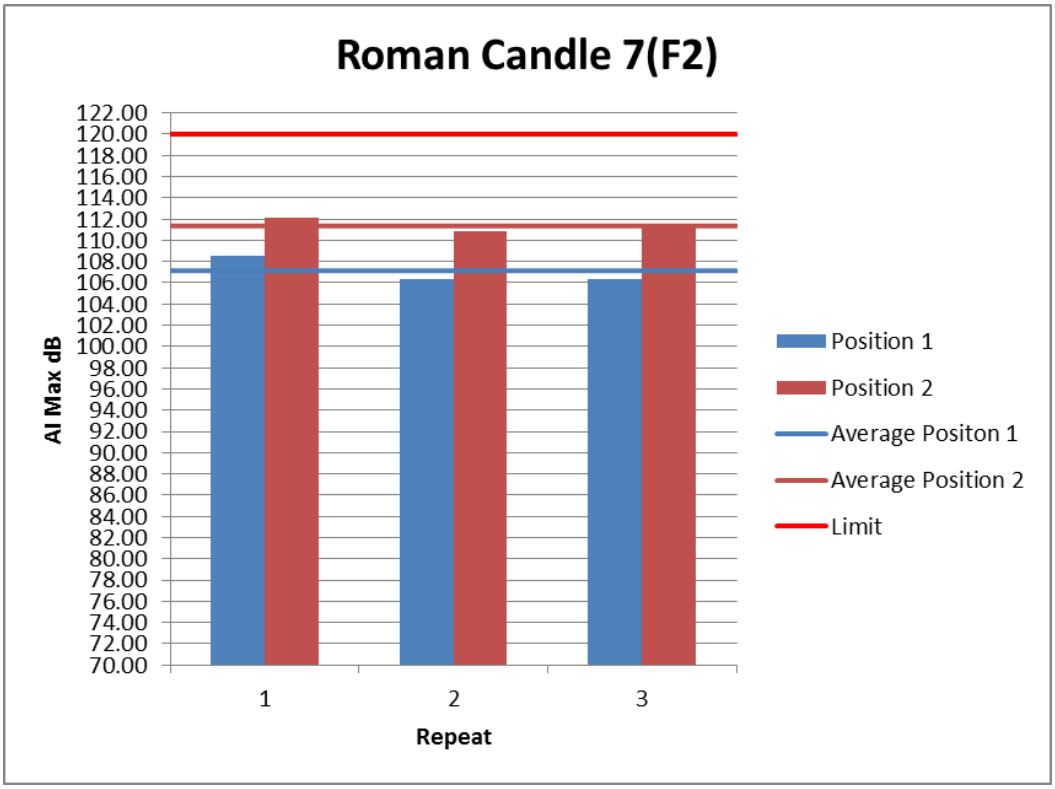

Figure 74: Individual Noise Levels for Roman Candle 7 (F2)

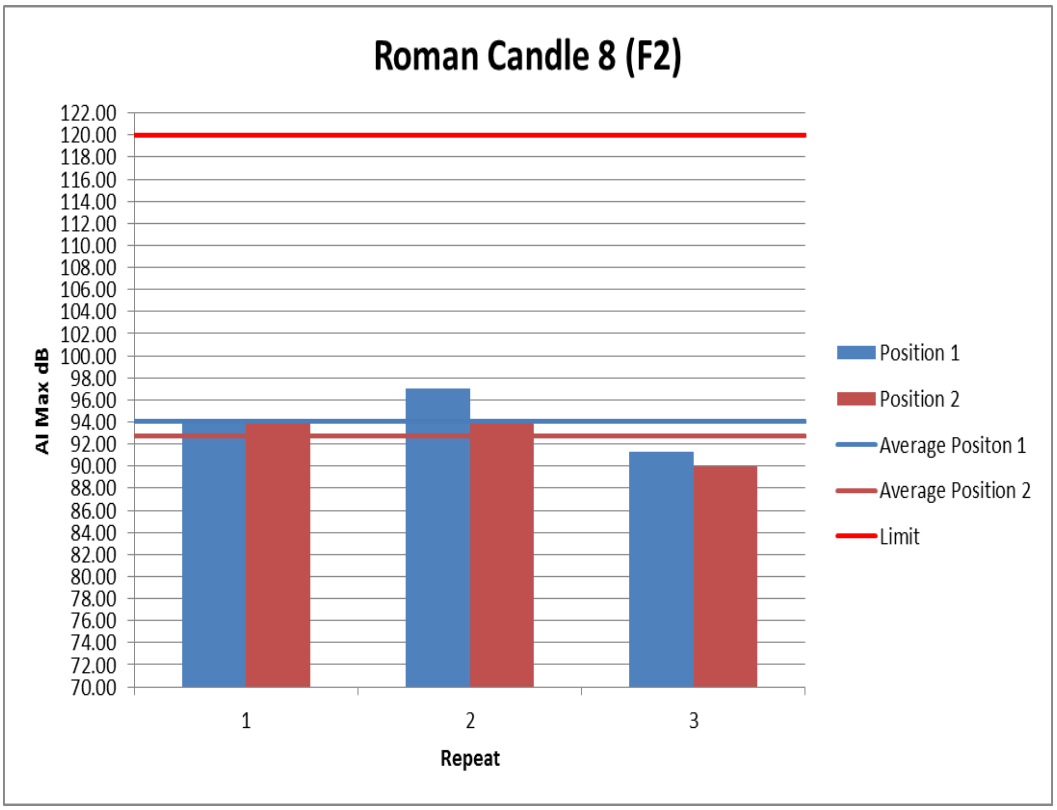

Figure 75: Individual Noise Levels for Roman Candle 8 (F2)

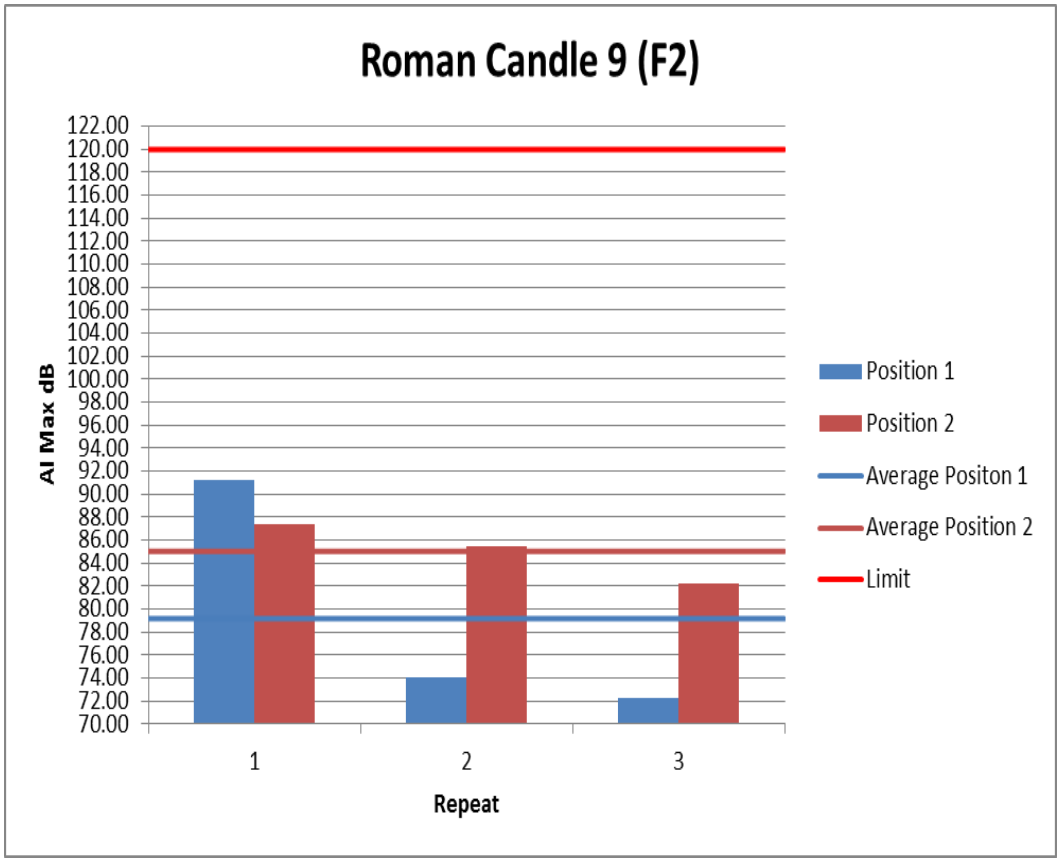

Figure 76: Individual Noise Levels for Roman Candle 9 (F2)

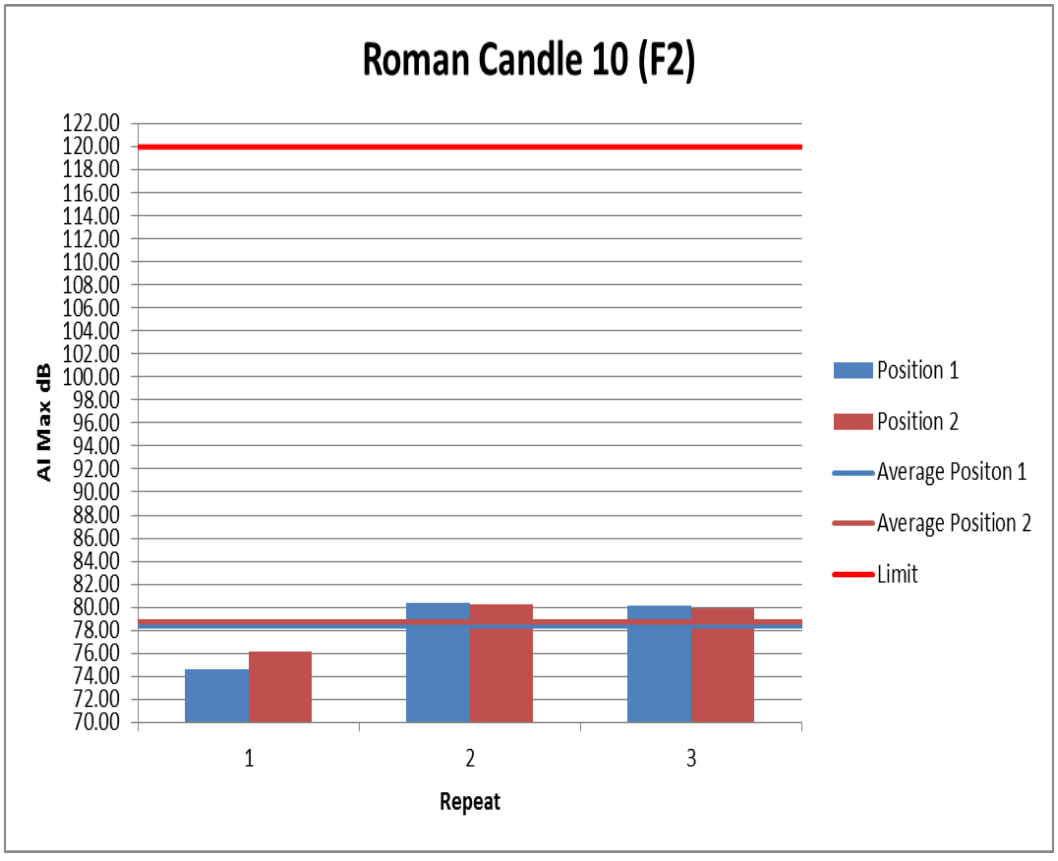

Figure 77: Individual Noise Levels for Roman Candle 10 (F2)

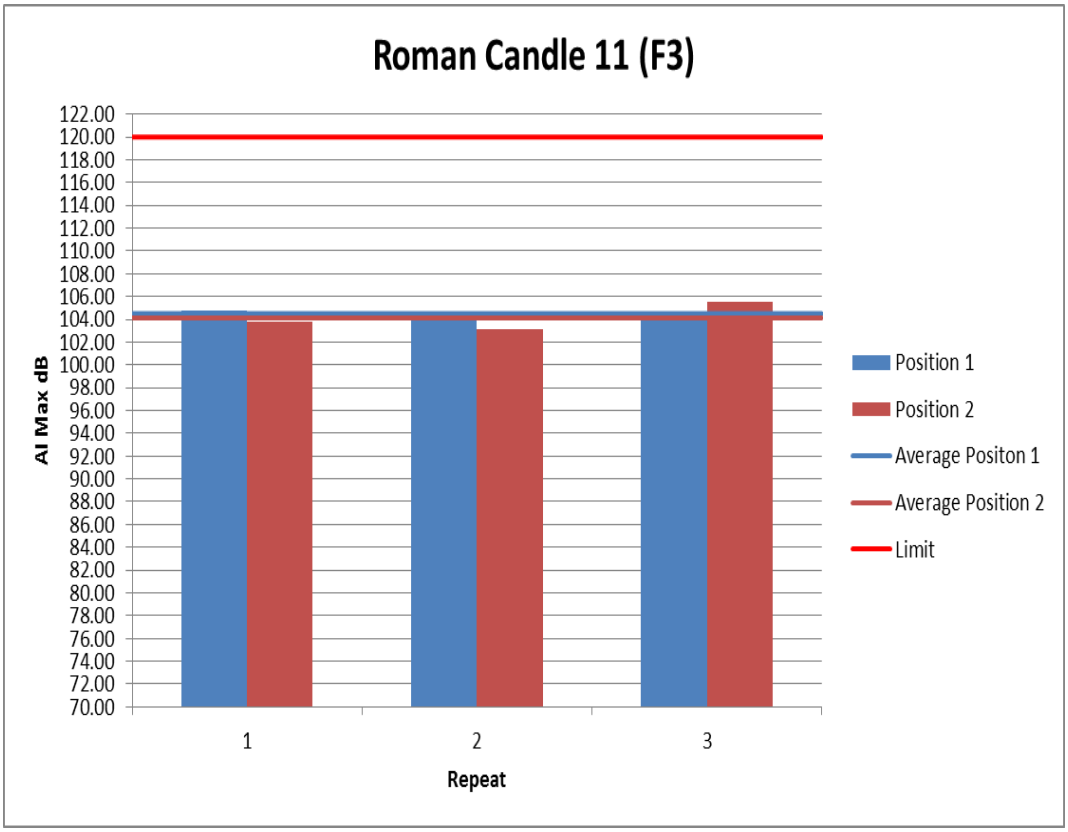

Figure 78: Individual Noise Levels for Roman Candle 11 (F3)

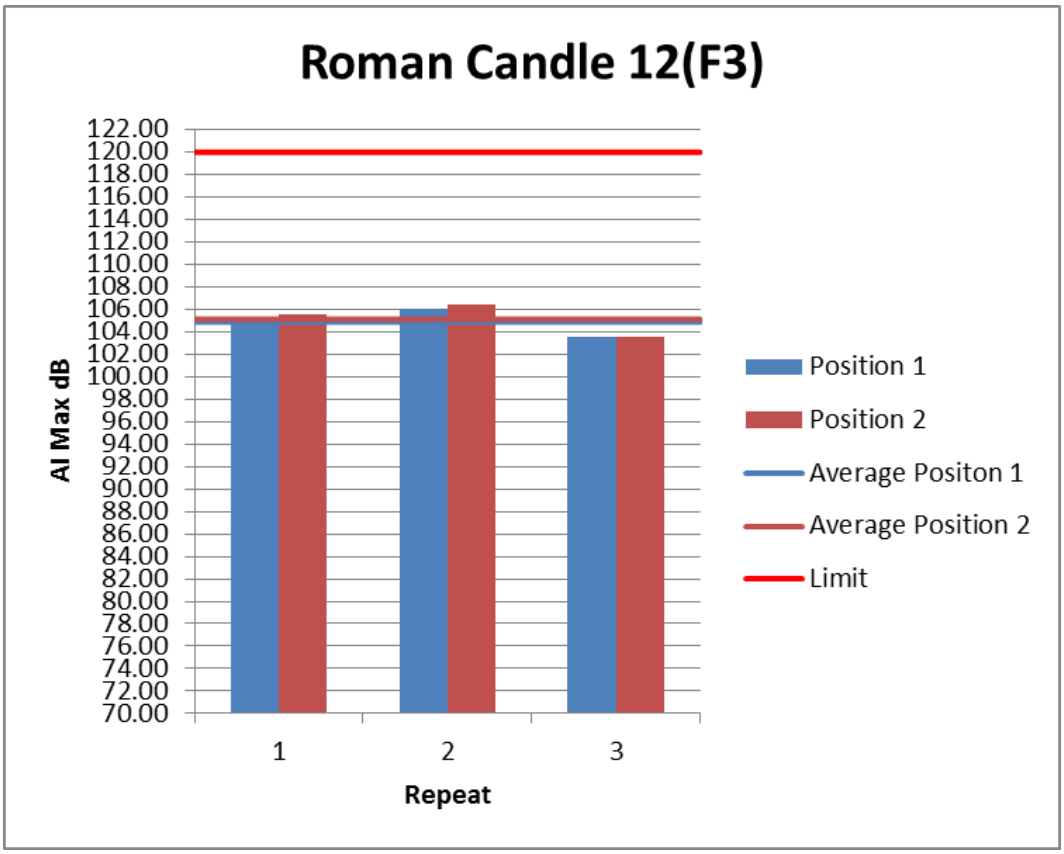

Figure 79: Individual Noise Levels for Roman Candle 12 (F3)

B.6 Single Shot Tube

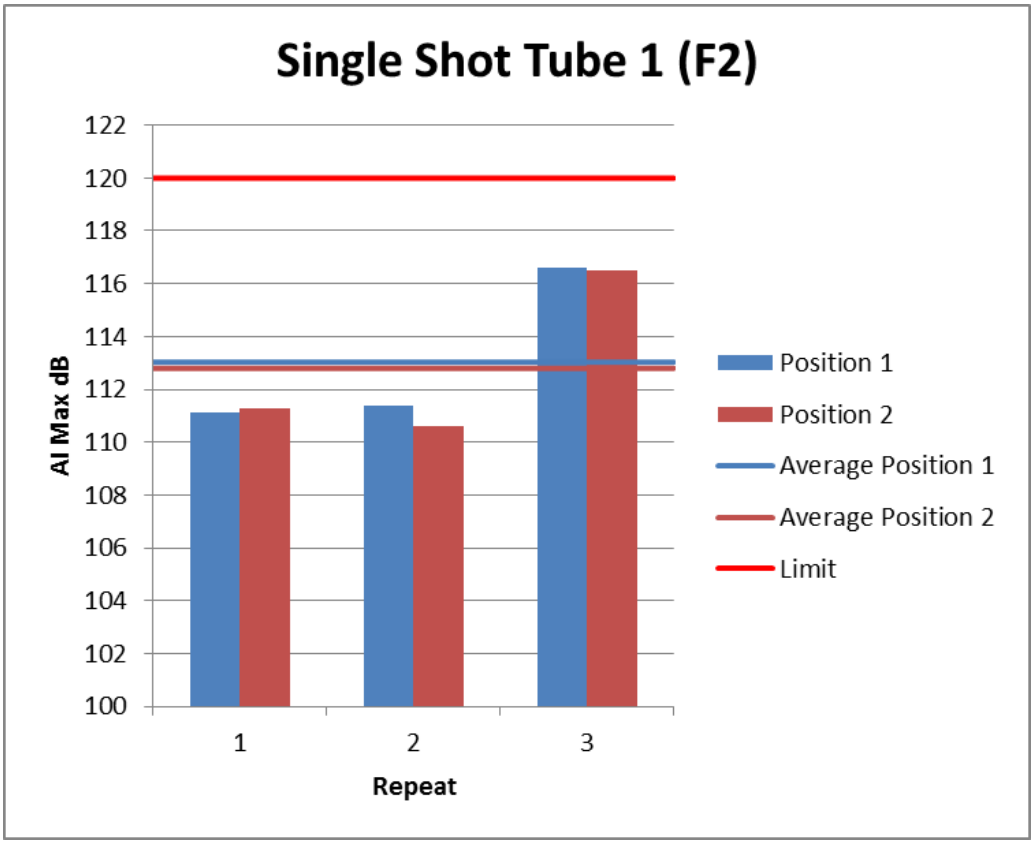

Figure 80: Individual Noise Levels for Single Shot Tube 1 (F2)

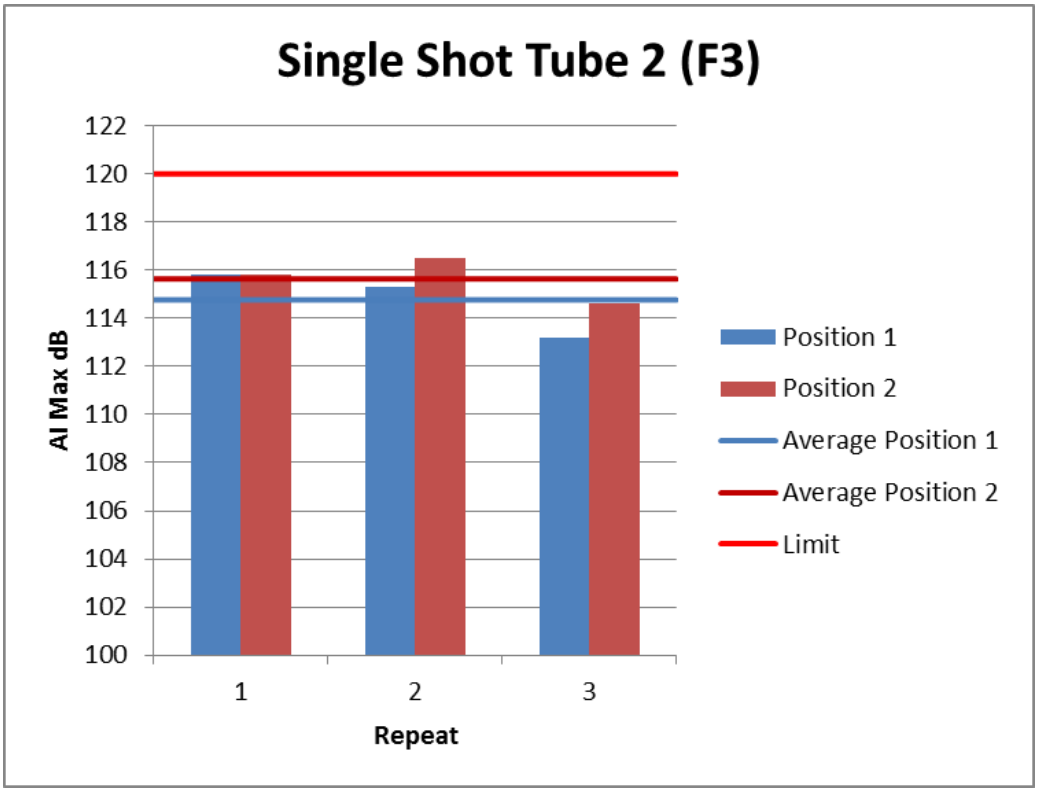

Figure 81: Individual Noise Levels for Single Shot Tube 2 (F3)

B.7 Mines

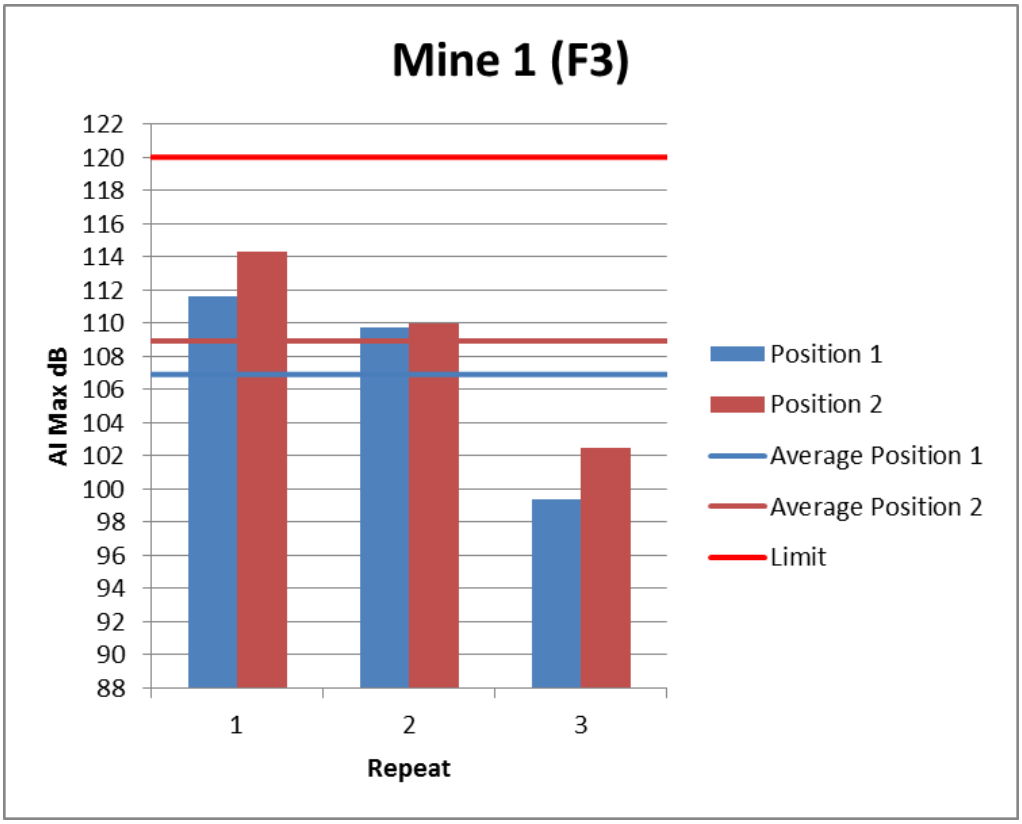

Figure 82: Individual Noise Levels for Mine 1 (F3)

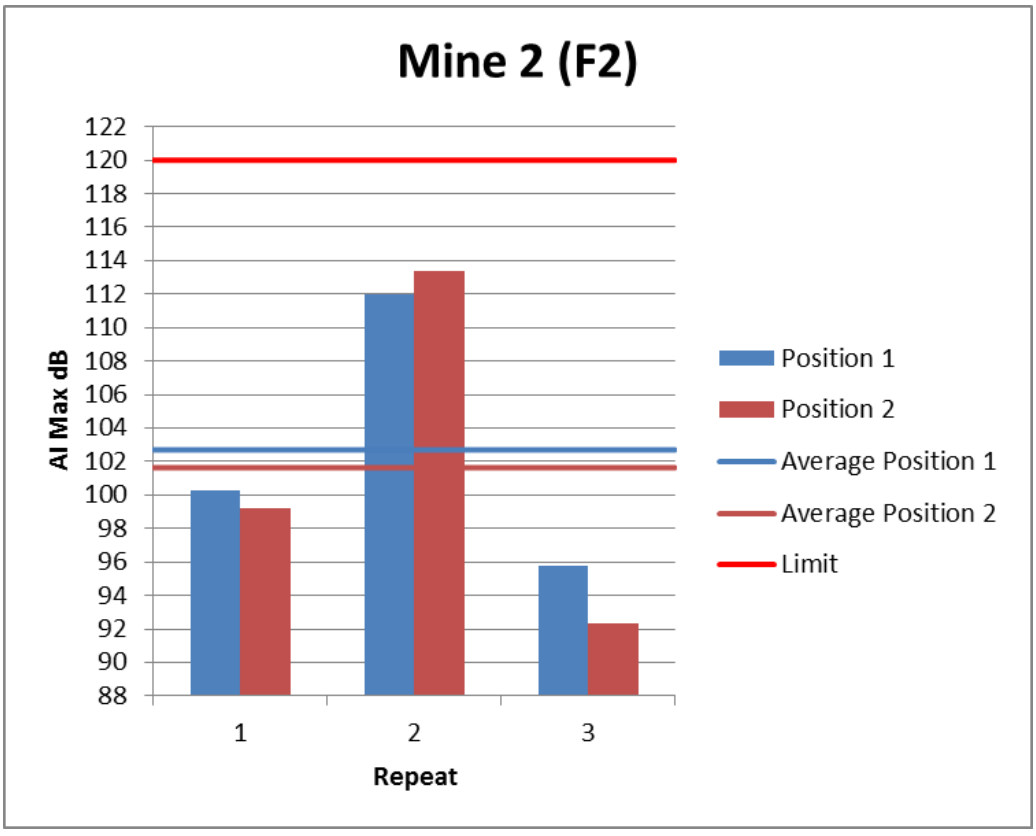

Figure 83: Individual Noise Levels for Mine 2 (F2)

B.8 Fountain/Mine Combination

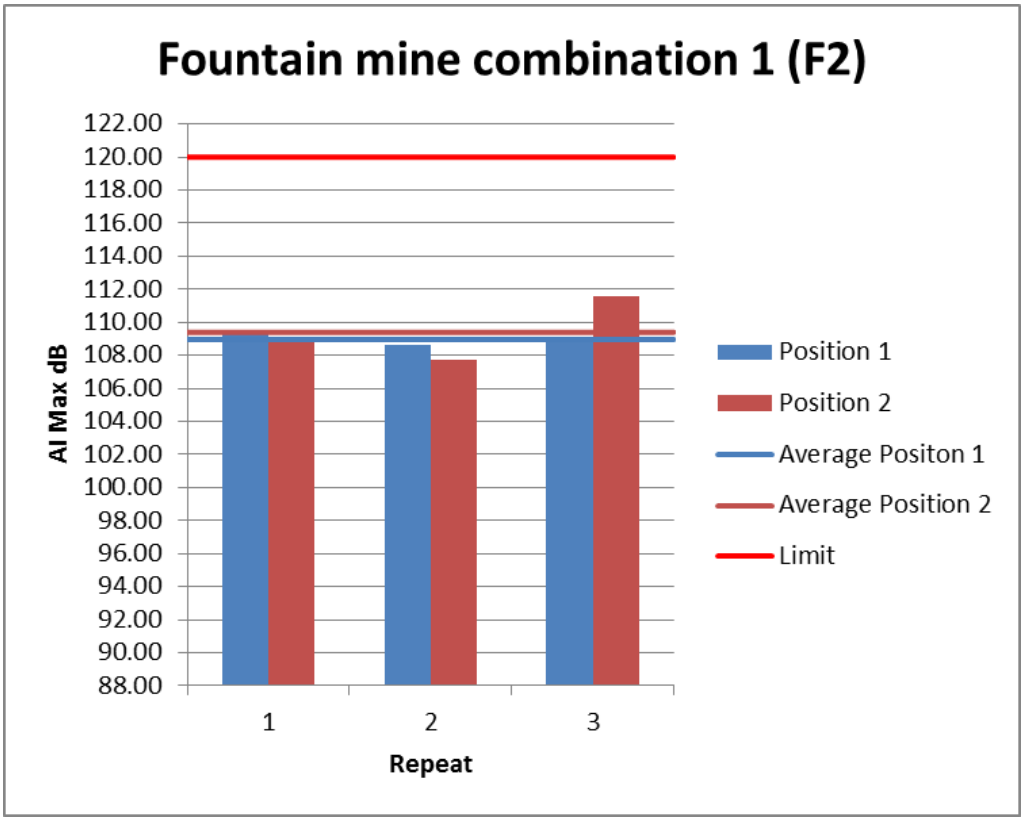

Figure 84: Individual Noise Levels for Fountain/Mine Combination 1 (F2)

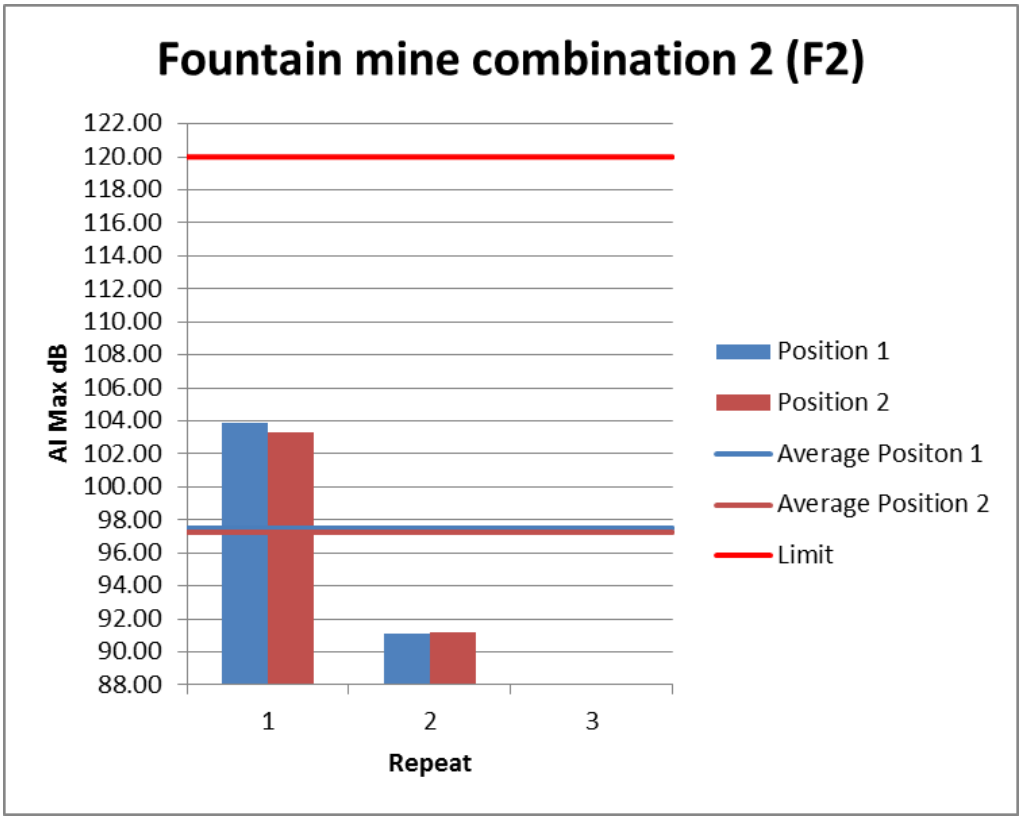

Figure 85: Individual Noise Levels for Fountain/Mine Combination 2 (F2)

B.9 Battery of Fountains

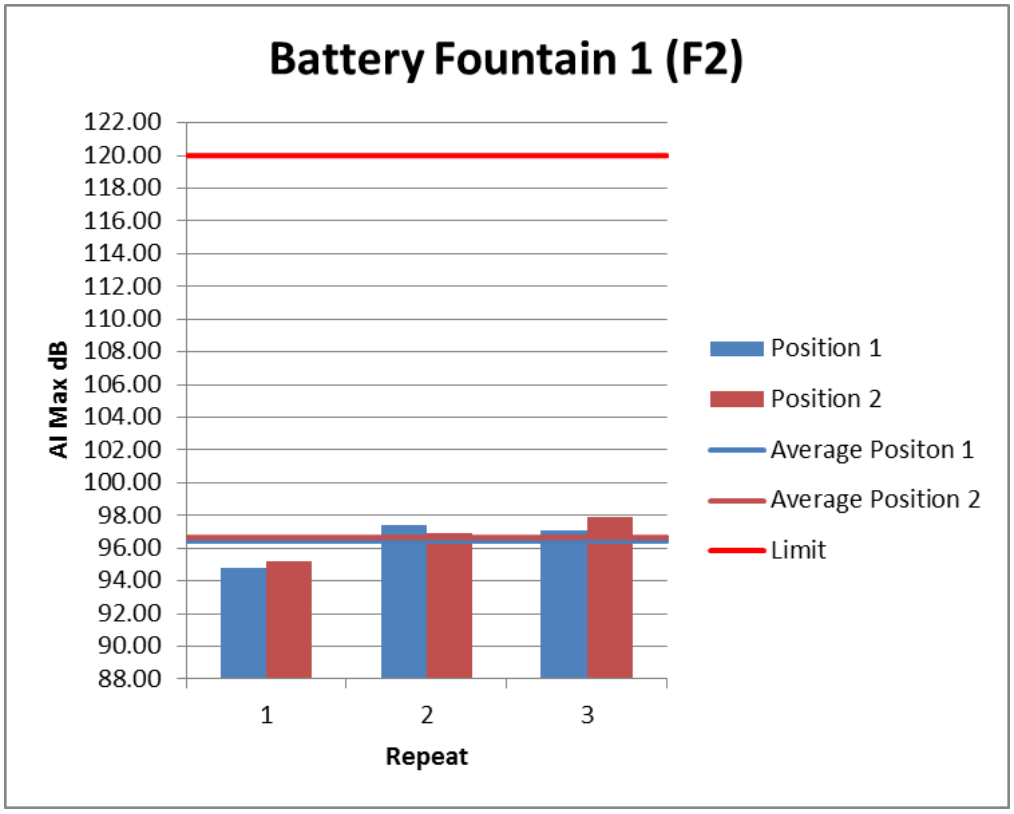

Figure 86: Individual Noise Levels for Battery of Fountains 1 (F2)

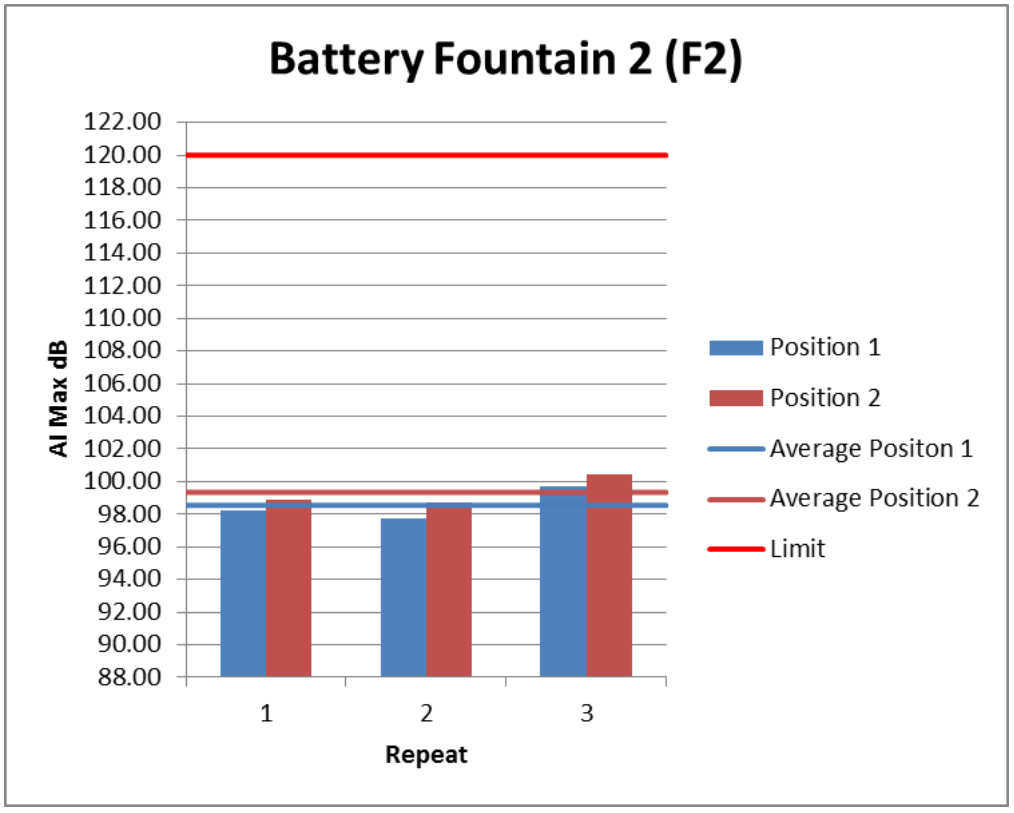

Figure 87: Individual Noise Levels for Battery of Fountains 2 (F2)

Appendix C - Categories and types of firework

Table 2. Categories and Types of firework

Type	Brief Description	Principal effects
Rockets	Tube containing pyrotechnic units and/or pyrotechnic composition with or without a bursting charge, equipped with a rocket motor and stick(s) or other means for stabilization of flight	Ascent, with or without additional visual and/or aural effects, and production of visual and/or aural effects in the air
Battery	Assembly including several elements, each of the same type and corresponding to one of the types of firework listed in this part of EN 15947:2015 and in accordance with EN 15947–5:2015, 4.3, with one or two points of ignition, which does/ does not require external support	As for the individual elements
Fountain	Non-metallic case containing sparks- and flame producing pyrotechnic composition and designed to be placed on the ground, or to be fixed in the ground, or to be fixed to a support, or to be held in the hand	Emission of sparks and flames with aural effect other than report or without any aural effect
Roman Candle	Tube containing alternate propellant charges, pyrotechnic units and transmitting fuses	Ejection of the pyrotechnic units in succession, producing a series of visual and/or aural effects in the air
Wheel	Assembly including a non-metallic tube or tubes containing pyrotechnic composition and provided with a means of attaching it to a support so that it can rotate	Rotation around a fixed point or axis and emission of sparks and flames, with or without aural effect(s) (other than report)
Shot Tube	Tube containing propellant charge and a pyrotechnic unit, with or without a bursting charge	Ejection of the pyrotechnic unit, producing a visual and/or aural effect in the air
Mine	Tube containing propellant charge and pyrotechnic units and/or non-pyrotechnic objects and designed to be placed on the ground or to be fixed in the ground	Ejection of the content in a single burst producing a widely dispersed visual and/or aural effect in the air

Source: BS EN 15947-2:2015, Pyrotechnic articles, Fireworks, Categories F1, F2 and F3[7]

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