

# Quality Control Testing Of Pyrotechnic Articles For The Beijing 2008 Olympic Games

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**Abstract:** Firework displays are commonly used to celebrate special events. They have been used in Olympic Games opening and closing ceremonies for years. During the 29<sup>th</sup> Olympic Games – Beijing 2008 Olympic Games Opening and Closing Ceremonies, firework displays were therefore used as part of the program. Due to the Chinese traditional culture and the demands of the location, the technical director demanded special requirements of all pyrotechnic articles. A working committee of the Beijing 2008 Olympic Games Opening and Closing Ceremony had been created to develop the main four firework display shows that were part of the opening and closing ceremonies of the Olympic Games and Paralympic Games. To ensure all pyrotechnic articles performed safely and as intended, technical guidance was developed for the control of all pyrotechnics used in the event. It specified the terms, product type, product classification, safety quality requirements, testing methods and acceptance criteria for testing and inspection of pyrotechnic articles used in the 29<sup>th</sup> Olympic Games. The technical document was used for the first time and referred to many GB Standards (Guo Biao Standards – China National Standards). This paper describes the requirements and control programs for all pyrotechnic articles from design, manufacturing, transportation and usage.

## Introduction

Fireworks have been used in celebration of great events around the world for many years. Similarly there are many years of experience using fireworks to celebrate national events in China, such as the China National Day on October 1, the Chinese Lunar New Year, Fireworks Festivals, local and private ceremonial celebrations or graduation etc. Usually fireworks or pyrotechnic articles are directly sourced from manufacturers by the display organization or company. The quality of fireworks or pyrotechnic articles solely or mainly relies on the internal quality control of the manufacturer and/or with the addition of experience of display personnel. Since fireworks and pyrotechnic articles are still, in the majority, dependent on labor intensive manufacturing processes, there is always the potential excuse of fireworks not being properly made or containing natural defects.

Since the announcement of the hosting of the Olympic Games 2008 in Beijing, the organizing

committee started to investigate the best possible ways and means to perform an excellent firework display show during the Opening and Closing ceremonies of the Beijing 2008 Olympic Games. It was not as simple as having a performance oriented pyro-display but there was also a higher safety requirement because the sites were large and near to the audience. In addition, those places were important and historical scenes themselves. It was not possible to adopt normal practices to prohibit the audience from going into the venues.

With a lack of experience in shooting so many pyrotechnic articles within such large areas and time, quality in terms of performance and safety was critically important to ensure excellence of both. Therefore the Committee demanded and the working committee developed the first of its kind of quality control testing of pyrotechnic articles – *Acceptance of Inspection Criteria for Pyrotechnics used in Olympic Games*,<sup>1</sup> and started the trial in 2007. All the pyrotechnic articles were selected,

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*Article Details*

*Manuscript Received:-27/09/2010*

*Publication Date:-22/11/2010*

*Article No: - 0087*

*Final Revisions:-20/11/2010*

*Archive Reference:-*

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modified, manufactured and tested according to the planned design, then completed and passed the test inspection prior to transport to Beijing for the Olympic Games 2008 in August.

### **Standard reference**

Due to the lack of such large scale display experience and the complex pattern designed, most of the pyrotechnic articles were newly developed or modified to suit the purpose. These included smokeless formulation, red color enhancement, new shooting techniques, construction techniques and manufacturing processes, etc. All such processes and products demanded a high level of quality testing and inspection. The whole quality control adopted a cradle-to-grave approach to ensure all manufactured articles were made to design, packed to transport, set to shoot, recorded and any found to be defective were destroyed.

The following key Chinese national standards<sup>2</sup> were adopted during the quality control processes:

*GB/T2828.1*: Sampling Procedures for Inspection by Attributes Part 1: Sampling schemes indexed by Acceptable Quality Limit (AQL) for batch-by-batch inspection

*GB10631*: Fireworks and Firecrackers – Safety and Quality

*GB/T10632*: Fireworks and Firecrackers – Rules of Sampling Inspection

*GB/T15814.1*: Fireworks and Firecrackers, Chemical Composition – Qualitative Determination of composition

*GB19593*: Fireworks and Firecrackers – Batteries and Combination

*GB19595*: Fireworks and Firecrackers – Fuses

*GB/T20613*: Fireworks and Firecrackers – Rules of Safety Performance Inspection for Storage and Transportation

*NY/T757*: Propellant Charge used in Fireworks

*QB/T1941.5*: Fireworks and Firecrackers, Chemical Composition – The determination of moisture absorption

*SN0545-1996*: Rules of Safety Inspection for pyrotechnic reagent of exporting fireworks and firecrackers

## **Discussion**

The Quality Control Testing (QCT) is the first of its kind in the Fireworks Industry using systematic testing and inspection tools controlling the manufacture of the pyrotechnic articles used in such a great event. It is a big change and a big step towards quality control management for sourcing fireworks in China.

The QCT adopts different techniques and methods in controlling the processes of sourcing raw materials, designing items, manufacturing, packaging and transportation. These were all developed into a special set of requirements for fireworks used specially for the great event of the Beijing 2008 Olympic Games, *DB11/Z 525 – 2008 Acceptance of Inspection Criteria for Pyrotechnics used in Olympic Games*. The criteria are summarized and listed as below.

### **Labeling**

The label includes external packing marking, product marking and special effect marking. All content must be in standard Chinese, clear, precise and legible. Labels for transportation packing should include the product name, product code, specification, type and classification, factory name and display company, address, telephone, production date, expiry date, content, net explosive content, volume, tracking number and wording of safety warning.

### **Packing**

The product shall be packed in an inner packing poly bag for whistling composition, black powder or smoke composition. It should be damp proof material. Combination products and fountains should be sealed by a tin-fold sheet. Outer packing should use standard shipment corrugated boxes.

### **Appearance**

Outer packing should be artistic, intact, not deformed or damaged. There should be no loose chemical composition or signs of mold/contamination.

### **Design of ignition**

The method of ignition could be an ignition fuse that complies with the requirements of GB19595

**Table 1.** *Bursting height of shells*

Item	Specification of shell							
	Size #3	Size #4	Size #5	Size #6	Size #7	Size #8	Size #10	Size #12
Shell diameter, mm	72	97	122	147	172	196	246	296
Shell tolerance, mm	+1, -2	+1, -2	+1, -2	+1, -3	+1, -3	+1, -4	+1, -4	+1, -4
Bursting height, m (min.)	80	90	110	130	170	200	240	300
Extinguished height, m (min.)	50	50	50	50	50	50	50	50
Fuse length, mm	650	750	1000	1100	1200	1400	1500	1600
Tolerance, mm	±20	±20	±20	±20	±20	±20	±20	±20

or an electric ignition head as recommended by the working committee. For both the firing ratio should be 100%.

### Construction and dimensions of main component

The construction of the main component and its effect must be manufactured in accordance with the design. The dimensions must follow the design diagram. No metal or plastic is allowed for any aerial effects. No electric igniter may be installed but a propellant charge can be filled.

### Construction and dimensions of auxiliary parts

The construction of auxiliary parts must be accordance with the design. Connection to the main component must support 100 grams weight for at least 1 minute. There should be no loosening or detaching during functioning.

### Stability

The relevant articles should be stable during a 12 degree tilt testing and functioning, while auxiliary articles shall be subject to 30 degree tilt block testing.

### Chemical composition

The chemical composition should comply with the design and should use no prohibited chemicals such as chlorate, arsenic, mercuric, gallic acid, magnesium powder, phosphorus, lead compounds and hexachlorobenzene (HCB).<sup>3</sup> Propellant charges must meet the requirements of NY/T 757. Standard methods and requirements refer to SN0545 and GB/T15814.1.

### Net explosive content

The net explosive content must be in accordance with the design and requirements of class B & C of GB10631. The content does not include fuse and filler but must be marked.

### Performance

The geometric figure, effect and shooting declination angle must be manufactured in accordance with the design. It must function at a designated height with no premature burst, and no sharp debris. Waterfalls, shells, mines, roman candles and combinations must comply with the requirements of GB10631. Smokeless items must obviously produce less smoke than regular items. An example of the specification of shells<sup>4</sup> is listed in Table 1.

### Safety requirement

Some parameters were selected to be tested during production and these were mainly concerned with safety of handling and transportation, such as the thermal stability test which is set at 75 °C, the moisture absorption test<sup>5</sup> and 12 metre drop test.<sup>6</sup>

### Acceptance criteria

After manufacturing and before loading into containers for transportation to Beijing, all products were subject to batch testing and inspection based on the sampling criteria according to the type and size of the articles. The sampling plan basically followed GB/T2828.1<sup>7</sup> and was modified to suit the specific needs of the event. The basic sampling plan is listed in Table 2. It required a sample size twice the basic sample size plus 3 cases more. All types of defect are clearly indicated with their acceptable levels.

The defect type (see Table 4) is also clearly defined

**Table 2.** Basic sample size of pyrotechnic articles.

Batch size, $N$	$\leq 100$	1 01–500	501–1000	$\geq 1001$
Sample size, $n$	10	$10 + N \times 2\%$	$20 + N \times 1\%$	$30 + N \times 0.2\%$

Note: The basic unit for waterfalls is a single item.

**Table 3.** Rejection quantity according to batch size.

Sample size, $N$	Defect classification									
	a		b1		b2		c1		c2	
	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re
$\leq 100$			0	1	0	1	1	2	1	2
101–500			0	1	1	2	2	3	3	4
501–1000	0	1	1	2	2	3	3	4	5	6
$\geq 1001$			2	3	3	4	5	6	7	8

in terms of its nature and acceptable levels, see Table 3.

### Technical information

Suppliers or manufacturers must provide technical information to ensure the product and information match and are correct. This information includes (1) Construction diagram of the product and the effect components; (2) Pyrotechnic content and (3) Performance effect. The construction diagram shall include all product information such as product name, product code, specification model number, type, classification, total pyrotechnic content, supplier's name and address, structure

of the fixture and its assembly, etc. If the product is a shell, a mortar<sup>9</sup> shall be provided together with material, dimensions of mortar, production date, and test report. The pyrotechnic content of the article shall be clearly and precisely stated in the information with its formulation. The performance effect shall include a video file of the article, performance time, method and time of ignition, bursting height, angle of trajectory if any, geometric pattern, color, effect of smoke and other instructions.

### Conclusion

After years of experience, pyrotechnic articles used on different occasions of celebration are usually subject to loading inspection or simple shooting tests. It mainly relies on the internal quality control system that is implemented by the manufacturer, and sometimes on the quality demands from suppliers or buyers. The QCT is the first of its kind to have a complete and comprehensive quality control system enforced in the production of pyrotechnic articles in China, and probably in the world. Thus it is confirmed that through QCT, the challenging task of providing a perfectly safe and impressive display of pyrotechnic articles during the show at the Beijing 2008 Olympic Games can be successful.



**Figure 1.** Shooting 5 rings in the air.

**Table 4.** *Type of defects.*

No.	Inspection item	Defect descriptions	Defect Type
1	Label	No outside packing mark, no product label and no inner tube element label	a2
		The label is not tidy; the content of the label is not clear, covered or damaged.	c1
2	Packing	No inner packing. Whistling, black powder and smoke firework products should be confined in a poly bag; the combination and fountain products should be sealed with a tinfoil sheet; roman candles should be packed with a plastic cover; other pyrotechnic products should be packed with waterproofed plastic sheet or cardboard.	a2
		The inner product is not placed properly, becomes loose and moves around.	
		The outside packing should be made of proper cardboard and sealed very firmly; the net weight not more than 30 kg. The strength or the waterproof resistance is not enough.	c1
3	Appearance	The product is not complete, is deformed or damaged.	b1
		The tube and attachment are not stuck very firmly, or split and loose.	
		The tube paper is not stuck very neatly, is covered or exposed. The product is not tidy, the pyrotechnics is loose, moldy or damaged.	c2
4	Fuse and electric igniter	The ignition method and the connection method of each element of the effect does not comply with the design. The ignition head is not complete. No waterproof materials. It is damaged and does not function.	a2
		There is no backup fuse for the combinations.	
		There is no electric ignition and fuse ignition method in the leading fuse location.	a2
		The fuse is moldy, damaged and blank.	b1
		The ignition fuse is not visible or has no protective cover. It is not firmly assembled.	c1 c1
5	Construction and dimension of main component	The product body and the effect element structure: size does not comply with the design. Metal materials and attachments should not be used in the lift product. It is not filled with propellant charge as per the design.	a1
		The manufacturer installs the ignition head in the pyrotechnic product in advance. The fuse is not firmly installed and well connected; There is only 1 fuse cord for the shells of size over 5.	
		The variation of the propellant tube, inner diameter and the tube thickness for the lift product does not comply with the design.	b1
		The variation of the length, exterior diameter of the non-lift product does not comply with the design.	c2
6	Construction and dimension of auxiliary component	The attachment structure and size do not comply with the design. The attachment is not installed very firmly. The attachment becomes loose or detached during the display process.	a1
7	Fixture	The strength of the fixture is not sufficient. Under the circumstances of blowout and low breaking, the fixture may cause secondary damage.	a1
		The installation and dismantling is not convenient.	c2
8	Stability	The stability of the product is insufficient.	a2
9	Chemicals	Prohibited chemicals used in the product.	a1
		The pyrotechnic composition is not in accordance with the design.	a1
10	Net explosive content	The chemical content does not comply with the design and product label.	a1
		The chemical content of the propellant charge and the shells is different from the design.	b1
		The chemical content of the effect charge is different from the design.	c2

**Table 4. Contd.**

		<p>The product performance is different from the design.</p> <p>The ignition method and ignition time are different from the design.</p> <p>The geometric figure formed during the functioning process does not comply with the design.</p> <p>The effect color is different from the design.</p> <p>The firing sequence of each effect element is different from the design. For the elements which have several effects, the effect sequence does not comply with the design.</p> <p>The product is blasting out and becomes loose during functioning.</p> <p>Low break, burning or sharp debris of big mass is not allowed. Meanwhile, the attachment should not become detached at the designed time.</p> <p>A smoke product should have smoke effects.</p>	
11	Performance	<p>The 29th Olympic Games product with special requirements should meet the special requirements during the functioning.</p> <p>The shell does not function or is dud. The explosion radius should not exceed the explosion height; the extinguished height should be lower than the standard figure.</p> <p>The combinations become flameout.</p> <p>The firing ratio, burning ratio and projection height for the shells, combinations and fountains is different from the acceptance criterion. The burning ratio of other pyrotechnics should comply with the requirements in GB 10631.</p>	a1
		<p>The projectile declination angle of the shells, combinations and fountains is different from the video documentations provided by the manufacturer.</p>	b1
		<p>The geometric figure formed during the functioning process is not clear and visible. It is defective and incomplete.</p>	c2
		<p>The purity of the effect color is not good.</p>	
12	Safety function	<p>The thermal conditioning, drop test and the moisture absorption ratio are not in accordance with the requirements.</p>	a1



**Figure 2.** *“FUTURE” shoots into the air.*

## Acknowledgement

On behalf of Tian Cheng Pyrotechnic Laboratory, this is to thank the introduction of Hunan Fireworks Safety Quality Supervision & Inspection Center and its cooperation in handling the project.

## References

- 1 DB11/Z 525 – 2008 Acceptance of Inspection Criteria for Pyrotechnics used in Olympic Games 2008 Beijing.
- 2 China National Standards are mandatory for firework sales in China. The quality of fireworks for export is controlled by SN Standards.
- 3 Reference to GBT 21242 – 2007 *Methods of qualitative determination of prohibitive and limitative reagent of fireworks and firecrackers.*
- 4 Reference to GB 19594 *Fireworks and Firecrackers – Aerial Shells.*
- 5 Reference to QB/T 1941.5 *Moisture Absorption.*
- 6 Reference to GB/T 20613 – 2006 *Fireworks and Firecrackers – Specification for storage and transportation safety inspection.*
- 7 GB/T2828.1 is similar to ISO2859 Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection.
- 8 Defective type can be referred to appendix G of DB11/Z 525-2008 *Acceptance of Inspection criteria for Pyrotechnics used in Olympic Games.*
- 9 GB20208 – 2006 *Fireworks and Firecracker – Barrel for shells.*