UK Fireworks Surveillance for Compliance with ADR and the UN Default Classification of Fireworks

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Abstract: *Fireworks compositions have been examined for a range of different fireworks. These compositions have been tested and measured to ascertain compliance (or otherwise) with the United Nations (UN) Default Fireworks Classification Table criteria for UN Hazard Division (HD) 1.4G classification.*

Non-compliance with the requirements of UN HD 1.4G criteria have been found. These have constituted exceeding the total net explosive content (NEC), time–pressure rise times of less than 8 ms for non-black powder formulation burst charge compositions, metal based flash compositions being used as burst charge, and greater than 5% flash content in shot tubes.

Fireworks that comply with the requirements of the UN default classification scheme have also been found.

Keywords: *Compliance, default classification, UN, ADR*

Introduction

The majority of fireworks imported into Great Britain (GB) are classified for transport purposes using the criteria set down in the United Nations (UN) Default Fireworks Classification Table at paragraph 2.2.1.1.7.5 in the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR).[1] Importers classify fireworks by this method and those classifications must be approved by the GB Competent Authority responsible for classification, i.e. the Health and Safety Executive (HSE)'s Explosives Inspectorate, in order to comply with legal duties under the Classification and Labelling of Explosives Regulations 1983[2] as amended (CLER), and the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (latest version)[3] (The Carriage Regulations).

The latest versions of ADR are brought into GB law via updates to The Carriage Regulations. Chapter 1.8 in ADR allows Competent Authorities to carry out compliance checks to ensure safety requirements concerning the transport of dangerous goods are met. In accordance with paragraph 1.8.1.3 of ADR, HSE ensures that duty holders comply with the UN Default Fireworks Classification Table as a means of addressing these safety concerns. This is achieved through HSE taking transport packs of fireworks as samples and having their contents examined by the Health and Safety Laboratory (HSL).

Summary of the UN default classification criteria for UN HD 1.4G fireworks

Most of the fireworks imported to the UK for consumer use require a UN hazard division (HD) of 1.4G for transport and by extension storage at retail premises. The UN default scheme gives a

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Table 1. *UN default criteria for UN HD 1.4G fireworks.*

Firework type	UN DH 1.4G criteria
Roman candle and shot tube	An inner diameter of the Roman candle tube of ≤30 mm, a pyrotechnic unit of less than 25 g and any flash burst charge ≤5% of the total NEC
Rocket	A total NEC ≤20 g, a black powder bursting charge and if report units are present these must be ≤0.13 g flash and their total amount must be ≤1 g
Mine	A total NEC of ≤150 g pyrotechnic containing ≤5% as flash composition as loose powder and/or report units. Any report units present must be ≤2 g and any whistle units present must be ≤3 g
Fountain	A total NEC of <1 kg
Wheel	A total NEC of <1 kg, with no report effects and if present any whistle units ≤5 g with a total NEC per wheel of 10 g of whistle
Batteries, combinations and selection packs	The default classification is determined by the firework having the most hazardous classification

series of criteria for such fireworks of most types, certainly all the fireworks currently available for retail sale to the general public.

The UN default classification scheme allows for fireworks that comply with a set of limits to be classified without carrying out UN Series 6 tests, as prescribed in the UN publication entitled "Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria". The criteria for achieving a UN HD 1.4G using the default system are given in Table 1 and these are a mixture of dimensions, masses and net explosive content (NEC).

Scope of the study

Previous experience of compliance checks indicated that rockets had the largest number of non-complying items following examination against the UN default table for a 1.4G classification. These were:

- Over-Net Explosive Content (NEC) i.e. >20 g total pyrotechnic mass,
- Flash powder burst charge i.e. metal and oxidiser substance,
- Non-black powder formulations i.e. potassium perchlorate based compositions.

No rockets with the allowed ≤0.13 g individual report units were found during the surveillance programme.

Shot tube batteries also produced some non-compliance issues with the UN default table for a 1.4G classification. These centred on:

- Oversized cardboard tubes i.e. >30 mm tube inside diameter,
- Total NEC of the pyrotechnic unit i.e.>25 g,
- Percentage of flash powder burst charge in the total pyrotechnic i.e. >5% of NEC.

Rockets

Basic considerations

For UN HD 1.4G rockets these limits are:

1 Total pyrotechnic NEC 20 g or less,

2 A black powder bursting charge (defined as potassium nitrate and charcoal with or without sulphur),

3 Individual report units (if present) limited to no more than 0.13 g with a total NEC for the report units being 1 g or less,

4 Any burst charge that is not black powder as defined above in point 2 would require that its time–pressure rise time[4,5] is 8 ms or greater.

Rockets tend to be transported as rocket packs within a transport carton; they can also be found within some of the larger selection packs. The rocket pack may contain rockets of the same size with different effects or a set of different sized rockets each size with different effects. The

different effects within a given sized rocket may result in different total NEC. If the different NECs by effect type are known from the information provided to the UK Competent Authority then it may be possible to focus on the effect with supposed highest NEC. However, past experience has suggested that this may not always be that useful in identifying which effect has the greatest variation in NEC and hence those most likely to be over the NEC limit.

Methodology

Sampling under ISO2859-1:1999 (BS6001-1:1999)[6] relates to production inspection. The level of samples taken is determined by the lot size from the production run and ideally should be used by the manufacturer in their quality assurance programme. This level of sampling is not appropriate for surveillance sampling. A more practical sampling number was needed. The numbers chosen were in line with revised fireworks standard BS EN14035[7] in which sets of 10 fireworks articles are used for type testing.

Rockets, for example, can be considered as two basic pyrotechnic units, the rocket motor and the payload consisting of stars and burst charge or report. The payload is more easily measured as it can be removed from the rocket much more readily. Where there is clear evidence of the burst composition being a metal/oxidiser flash composition, analysis is performed by ion chromatography (perchlorate and nitrate) and inductively coupled plasma emission spectroscopy (metals, metal ions and sulphur). Similar analysis (ion chromatography) is performed for non-black powder burst charges where potassium perchlorate is the sole oxidiser or has been used in conjunction with potassium nitrate in an oxidiser/sulphur/charcoal formulation.

Where a non-black powder burst or a report charge is found the composition is tested using the HSL Flash Composition Test[8,9] (a modified UN Series 1/2 time–pressure test). The results from this test, carried out on a 0.5 g sample, regard a composition that has a rise time of less than 8 ms for a pressure rise from 690–2070 kPa as being pyrotechnic flash for classification purposes.

The rocket motor composition requires careful removal to avoid contamination with clay from the choke. There are two methods that have been used to determine rocket motor NEC, break-out and burn-out. In the break-out method this is preferably achieved by removal of all the clay with a trace amount of black powder before the black powder to be weighed is removed. Where this is not practicable due to the design of the rocket motor black powder is carefully removed until no more can be retrieved without clay contamination. To achieve removal of the pressed rocket motor composition the motor is removed from the rocket, any cardboard separated from the (usually) plastic rocket motor body and the body carefully crushed in a modified vice. Both methods (removal of clay then black powder or just removal of black powder) will slightly underestimate the amount of black powder present in the rocket motor. The alternative method, burn-out, has been shown to give almost identical results in a study at HSL. This method is considerably easier and takes the weighed rocket motor, burns the composition by igniting the fuse and reweighing after the motor cools down.

Shot tubes are generally easier to assess NEC than rockets. Comets, for example, are only lift and star. Disassembly of the article readily allows access to the lift charge and effects. If there is a bombette found rather than a comet then further disassembly will be required to access the internal compositions, and there may be a readily accessible tracer composition present. With a bombette there will be a burst charge; this is separated from any stars and weighed to ascertain if it exceeds the 5% of NEC limit. Batteries of shot tubes have the same considerations as the individual tubes and once the tubes are separated can be treated in the same way. This is also the case for Roman candles and mines.

Results

Rocket A

Rocket A was sampled as part of a surveillance programme in conjunction with Suffolk Trading Standards which ran from 2006–2008. The classification information supplied to HSE indicated that the rockets were close to the 20 g NEC limit for a UN HD 1.4G rocket under the UN default classification scheme and that the burst charge was black powder. Sampled examples had a recovered pyrotechnic content in the range 16.22–

Table 2. *Summary of rockets.*

Rocket	NEC range (g)	No. >20.0 g	t–p rise time (ms)	UN Default classification 1.4G failure mode
A	16.22–20.92	5	—	NEC over 20 g
B (2 sets of 10)	16.30–20.23	1	—	None
C	≈12	0	0.82–0.92	t–p rise time and/or composition classes the burst charge as flash – i.e. not a black powder burst plus for rocket H an NEC over 20–g
D	≈12	0	0.61–1.00	
E	15.48–16.96	0	3.18–3.46	
F	15.36–16.36	0	2.44–2.83	
G	13.85–18.71	0	2.70–3.26	
H	16.28–20.80	1	<3	
J	11.28–12.14	0	<3	
K	11.57–13.72	0	<3	
L, M, N, O, P, Q, R and S	<20	0	—	None

20.92 g and there were 5 rockets with greater than 20.0 g. Of these 3 were over 20.5 g. Analysis indicated that the burst charge was potassium nitrate, sulphur and carbon, i.e. black powder.

Rocket B

Rocket B was similarly sampled as part of the 2006–2008 surveillance programme. Again the classification information supplied to HSE indicated that the rockets were close to the 20 g NEC limit for a UN HD 1.4G rocket under the UN default classification scheme and that the burst charge was black powder. One rocket was found with an NEC of greater than 20.0 g and a second batch was sampled. This identified no further rockets with an NEC of greater than 20.0 g and again the burst charge was black powder.

Rockets C and D

Rockets C and D were sampled in 2009 as part of HSE's classification surveillance programme due to the information supplied indicating a flash powder burst charge. The recovered pyrotechnic composition indicated that the rocket NEC was well below the 20.0 g NEC limit for a UN HD 1.4G rocket under the default scheme. The burst charge was analysed and shown to be a potassium perchlorate, magnesium/aluminium composition (no check was made to ascertain if the metals were separate or as the alloy magnalium). The HSL Flash Composition Test gave a rise time in the range of 0.82–0.92 ms for Rocket C and 0.61–1.00 ms for Rocket D. For these small rockets the burst charge was less than 0.5 g and composition had to be aggregated for testing.

Rockets E, F and G

Rockets E, F and G were similarly sampled as part of HSE's classification surveillance programme due to the information supplied indicating non-black powder burst charge. The recovered pyrotechnic composition indicated that the rocket NEC was well below the 20.0 g NEC limit for a UN HD 1.4G rocket under the default scheme. The burst charges were analysed and shown to be a potassium perchlorate, potassium nitrate, sulphur and carbon composition. The HSL Flash Composition Test gave a rise time in the range of 3.18–3.46 ms for rocket E, 2.44–2.83 ms for rocket F and 2.70–3.26 ms for rocket G, all well below the 8 ms limit for a UN HD 1.4G rocket under the default scheme.

Rockets H, J and K

Rockets H, J and K were similarly sampled as part of HSE's classification surveillance programme due to the information supplied indicating a non-black powder burst charge. The recovered pyrotechnic composition indicated that the rocket NEC was well below the 20.0 g NEC limit for a UN HD 1.4G rocket under the default scheme for most examples. However, an example of a 20.80 g NEC rocket was identified. The burst charges were analysed and shown to be a potassium perchlorate, potassium nitrate, sulphur and carbon composition. The HSL Flash Composition Test

gave a rise time of less than 3 ms (note insufficient material for a full set of 3 firings), all well below the 8 ms limit for a UN HD 1.4G rocket under the default scheme.

Rockets L, M, N, P, Q, R and S

Rockets L to S were sampled as part of HSE's classification surveillance programme due to having been declared as containing a flash burst. The importer had the specification changed to a black powder burst charge and HSE wanted this checked prior to allocating a UN HD 1.4G classification. Total NEC was not an issue for these rockets. Analysis indicated that the burst charge was indeed black powder.

Shot tubes and shot tube batteries

Results

Shot tube A

A set of individual shot tubes that were a comet (various colours) with an added mine effect (again various colours) were examined against the requirements for shot tubes. Of these, 3 examples exceeded the 25.0 g unit NEC limit for shot tubes. There was no burst charge within the device and hence no need for analysis of any of the compositions.

Shot tube battery B

This was a large multi-shot battery with both star and whistle units. The tube internal diameters were below 30 mm and NEC ranged from 3.32–4.94 g, well within the NEC limits for a UN HD 1.4G. However, the bombette units contained a flash burst charge and this ranged from 5.8% to 10.0% of total NEC.

Shot tube batteries C, D, E and F

These shot tube batteries were well within the limits for total NEC and diameter for all tubes examined. They did, however, contain a flash burst charge that exceeded the 5% limit of NEC. This ranged from 5.8–10.0% for shot tube battery C, 7.7–14.4% for shot tube battery D, 3.9–4.9% for shot tube battery E and 3.8–6.8% for shot tube battery F.

Mines

Results

Mine A was sampled as it had declared burst charges of silver fulminate, which seemed very unlikely. Analysis of the burst charge showed it to be a potassium perchlorate/aluminium flash. Additionally the flash constituted less than 2% of the total NEC and the total NEC was 120 g. This allowed the mine to be classified under the UN default classification scheme as a UN HD 1.4G firework.

Discussion

Rocket NEC

A protocol for acceptance for UN HD 1.4G classification has been developed. This uses sets of 10 fireworks taken at random from a transport pack. All sampled fireworks should be below the limits set within ADR and the UN default classification scheme. If all these 10 rockets were under 20.0 g then the UN HD 1.4G classification would be allowed subject to them not contravening one of the other requirements. If one rocket was found marginally over the 20.0 g limit then a second batch of ten was examined and the combined results considered by HSE. A number of rockets

Table 3. *Summary of shot tubes.*

Firework	NEC range (g)	No. >25.0 g	% flash	UN Default classification 1.4G failure mode
Shot tube A	24.44–25.54	3*	N/A	NEC over 25 g
Shot tube battery B	3.32–4.95	0	5.8–10.0	Flash >5% of total NEC
Shot tube battery C	3.32–4.94	0	5.8–10.0	Flash >5% of total NEC
Shot tube battery D	3.29–4.42	0	7.7–14.4	Flash >5% of total NEC
Shot tube battery E	4.03–4.80	0	3.9–4.9	None
Shot tube battery F	3.96–4.89	0	3.8–6.8	Flash >5% of total NEC

* Batch of 5 samples provided, level of non-compliance was such that an additional set of 5 was not requested to make up to the normal set of 10.

that were over the 20 g limit were found (Rockets A, B and H); of these B was allowed a UN HD 1.4G as only one rocket in 20 was marginally over the limit and this was accepted as a "rogue".

Rocket burst charge

The UN default classification scheme does not allow for a flash burst charge in a UN HD 1.4G rocket. Similarly, a non-black powder burst (i.e. a composition that is not potassium nitrate, sulphur and carbon) is not allowed if the HSL Flash Composition Test gave a rise time of <8.0 ms. Rockets that had a burst charge that was not black powder and had a t–p rise time of <8 ms were found (rockets C and D, E, F, G, H, J and K failed). Clearly from these limited surveillance results there are a large proportion of rockets being supplied in the UK where the burst charge is not black powder.

Shot tube NEC

Small diameter shot tube batteries have not been found to exceed the NEC limit within the UN default classification scheme. The only large diameter (i.e. approaching 30 mm) items examined for classification purposes were shot tubes with mine effect, having both a large comet and a bag of small stars with a lift charge under the effects. However, the payload NEC was pushed over the 25 g limit by the added mine effect precluding a UN HD 1.4G classification under the default scheme.

Shot tube percentage flash

By far the greatest problem with shot tubes was from bombettes that had a flash burst charge. The UN default scheme sets a 5% limit on the proportion of pyrotechnic composition that can be a flash burst charge in any tube. The bulk of the shot tube batteries that failed to achieve the UN HD 1.4G classification were due to these flash burst charges. This is clearly a concern to importers as such items are now a major element in selection packs and display packs. The smaller items with low total NEC are the more likely to fail to meet this UN default criterion than larger items with a higher total NEC. The importers are free to undertake UN Series 6 testing on these smaller batteries with the possibility of attaining a UN HD 1.4G classification by this route. Results from suitable examples could then provide evidence for classification by analogy for other examples with similar tube size, similar effects, percentage flash composition and NEC.

Misleading information

Information provided by the importer of a mine initially indicated that the composition contained potassium perchlorate and silver. When this was questioned the importer contacted his Chinese supplier who then declared the composition as containing silver fulminate. Analysis showed the composition to be a perchlorate/aluminium flash composition, thus the originally declared silver metal was aluminium. As all the tubes tested had the flash burst at less than the limit of 5%, the properly declared flash burst charge would have generated a UN HD 1.4G under the UN default scheme. This incident does raise concerns regarding the declared compositions which may suggest that surveillance of product should be carried out by the importers.

Conclusions

The surveillance reported has found a number of items that do not comply with the requirements of the UN default classification scheme. Clearly it is of legal importance that such surveillance be carried out to maintain safety in transport of fireworks. Many of the fireworks examined have complied with the requirements of the UN default classification scheme for a UN HD 1.4G hazard code assignment. Where fireworks have failed to meet the criteria the problems of non-black powder burst charges and total NEC have predominated. This paper has dealt with the surveillance of fireworks where classification was sought through the use of the UN default table. There remains the alternative option for importers to suggest a classification based on actual performance of the products in UN Series 6 tests.

Disclaimer

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