Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods **5 June 2014**

Forty-fifth session
Geneva, 23 June – 2 July 2014
Item 2 (e) of the provisional agenda
Explosives and related matters: miscellaneous

The effectiveness of the current UN series 6(a) and 6(b) tests when used to classify fireworks for transport

Transmitted by the expert from the United Kingdom

Introduction

1. The EU funded project "Quantification and control of the hazards associated with the transport and bulk storage of fireworks" (CHAF) investigated the behaviour of different types of firework when ignited in small, medium and large-scale (ISO container) tests. The findings from the research were presented at the 9th International Symposium on Fireworks (ISF) in Berlin in 2006 and concluded that the current classification scheme for the transport of such articles was fit for purpose. However, one particular type of article (waterfalls) was identified as anomalous because it produced an unexpectedly violent explosion when tested at large-scale. The behaviour observed was consistent with a transport classification of Hazard Division 1.1 (HD 1.1) whereas all UN series 6 tests had indicated behaviour consistent with a transport classification of HD 1.3. In contrast, experiments under the same project but using a single transport pack of waterfalls in a sealed steel vessel (volume = 0.89 m^3), produced a rapid escalation to a violent explosion, which supported the behaviour observed in the CHAF large-scale test.

2. This issue is also the subject of the paper transmitted by the expert from the Netherlands (ST/AG/AC.10/C.3/2014/59).

3. Attempts to explain the mechanisms leading to the violent explosions observed in the CHAF large-scale trials using existing blast models were unsuccessful and it was suggested that propagation via hot gases was more likely. The Health and Safety Executive (HSE) commissioned research with HSL to investigate this aspect and as a result, experiments based on the UN series 6(a) and 6(b) tests were developed.

4. The procedures and the results of the project are presented in the Annex 1 to this paper. While the main aim of the project was to investigate the movement of hot gases as a vector for the transmission of ignition of fireworks within large stores, this paper only discusses the results in the context of assigning classifications for transport.

Discussion

5. The waterfalls used in these tests were the same as those used in the CHAF trials. The work has reinforced the findings from the CHAF project that, in some circumstances, the current UN series 6(a) and 6(b) test methodologies underestimate the potential of waterfalls to produce mass explosion effects. Whilst the work undertaken to date is limited,

the results from the modified 6(a) and (b) tests suggests the potential exists for a small scale test for waterfalls that replicates the effects seen in large scale testing. The effects of additional confinement through increasing the depth of sand and the wrapping in plastic demonstrated clear differences in results compared with the standard methodology.

6. The question that naturally arises is whether the modified test is applicable to other types of fireworks, or indeed propellants, which are currently classified as HD 1.3 and could unknowingly present a higher hazard when transported in bulk. It is proposed that further research needs to be performed to establish if this is the case.

7. It is recognised that although the data presented in this paper appears compelling, it does not provide enough information to conclude with any confidence that a thin layer of plastic around transport packs of fireworks is sufficient to escalate their behaviour to a mass explosion. Only 2 tests have produced mass explosion events and it could be they merely reflect a statistical likelihood of mass explosion occurring, whether the plastic is present or not.

Proposal

8. Further work is proposed as part of the 'gas-flow' project to gain confidence that the modified test is an effective small scale test that replicates the effects seen in larger scale trials. It is also proposed to expand the test material to include other waterfalls, other fireworks and propellants.

9. Views are invited from experts on the Explosive Working Group on:

- The desirability of working up the method developed in this work as a potential addition to the Manual of Tests and Criteria for articles having the potential to mass explode under confinement; and
- Whether the above should be included in future programmes of work for the Group.

Annex

Report on the use of modified 6(a) and 6(b) tests as small scale tests for the classification of fireworks

Experimental

1. In order to investigate the movement of gases around transport packs of fireworks a range of instrumented tests were performed that were based on the UN series 6(a) and 6(b) test methods given in the Recommendation on the Transport of Dangerous Goods – Manual of tests and Criteria[(1)]. Since the CHAF project had indicated that waterfalls deviated from the transport classification predicted in standard UN tests, these were used for all testing reported in this paper. Each transport pack contained two inner fibreboard boxes each containing 10 waterfall bundles that consisted of 10 individual waterfall elements connected by rope and instantaneous fuse. The Net Explosive Content (NEC) of each transport pack was 19.5 kg. Ignition of each test was achieved by remote electrical ignition of a single waterfall bundle near the centre of one of the inner boxes.

2. A list of the tests performed is given in Table 1 and shows that in some instances the depth of burial of the transport packs was 1 m for single pack tests even though the UN6 (a) method indicates that a burial depth of 0.5 m is sufficient. This deviation was implemented so that the degree of confinement was comparable for some of the single and multiple transport pack tests. Where multiple pack tests were performed, the transport packs were arranged so that the long sides of the packs were next to each other (Figure 1). In order to control confinement as much as possible, kiln-dried free flowing sand to specification HST 65 was used. Other deviations from the prescribed methodologies were:

- To seal the transport packs in plastic bags in some instances (Figure 2), this variation was believed to provide momentary additional resistance to the flow of hot gases into the surrounding sand thereby increasing the rate of reaction of the waterfalls.
- To perform the tests above ground in wooden shuttering (Figure 3). This was necessary since bedrock is very close to the surface on the HSL site which precludes burial.

3. Although the tests were instrumented this has little bearing on the results from a transport classification point of view and will not be discussed further in this paper.

Table 1: Tests performed on transport packs of CHAF waterfalls

Test parameter	Single pack tests			Multipack tests		
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Depth of burial	0.5	1.0	1.0	1.0	1.0	1.0
No. live transport packs	1	1	1	1	1	2
No. inert transport packs	0	0	0	1	1	0
Sealed in plastic (Y/N)	Y	N	Y	N	Y	Y

Figure 1: Alignment of transport packs in multi-pack tests

Figure 2: Method of sealing transport packs in plastic sheet

Figure 3: Method of burial of transport packs in wooden shuttering

Results

4. The results of the tests together with the UN classification test originally performed during the CHAF project (CHAF classification test 1) are given in Table 2. The Table also shows data from a CHAF test based on the UN series 6(b) test but using 27 transport packs of waterfalls (CHAF classification test 2). This test was performed after the mass explosion occurred in the CHAF large-scale test in order to see if the violent explosive behaviour was a scale effect.

Table 2: Results of tests performed on transport packs of CHAF waterfalls

Test parameter	**HSL single pack tests**			**HSL multipack tests**			**CHAF classification tests**	
	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**	**Test 6**	**Test 1**	**Test 2**
Depth of burial	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
No. live transport packs	1	1	1	1	1	2	3	27
No. inert transport packs	0	0	0	1	1	0	0	0
Sealed in plastic (Y/N)	Y	N	Y	N	Y	Y	N	N
Mass explosion (Y/N)	N	N	Y	N	N	Y	N	N

5. The data indicate that for single pack tests buried to a depth of 1.0 m (HSL tests 2 and 3) the inclusion of the plastic seal causes an escalation to a mass explosion, whereas a single pack sealed in plastic but buried to only 0.5 m does not (HSL test 1), suggesting that confinement is an important factor in determining whether a test escalates to a mass explosion.

6. HSL multipack tests 4 and 5 used a single transport pack of 'live' waterfalls and a second transport pack of inert articles. The addition of the plastic seal (HSL test 5) had no visible effect, both tests showed sequential ignition of the articles. These tests were primarily performed to investigate the movement of hot gases from one transport pack to another. The failure of test 5 to produce a mass explosion may be due to the increase in free volume of the two packs without any increase in pyrotechnic composition to sustain escalation to mass explosion.

7. HSL Test 6 used two 'live' transport packs of waterfalls sealed in a single plastic envelope and buried to a depth of 1.0 m. The test produced a mass explosion. While this seems to reflect the same behaviour as test 3 where a single pack was sealed in plastic, there were significant differences. Test 3 produced a single mass explosion event with no visible precursor events. This was in contrast to Test 6 which generated sufficient pressure to rupture the sand covering followed by a period of approximately 5 seconds where sequential functioning of waterfall elements occurred. This was followed by a large single explosive event, which appeared to be the mass explosion of the second transport pack of waterfalls. This behaviour seems to mirror the events that took place in the CHAF large-scale test on waterfalls, which generated sufficient pressure to force one of the doors of the ISO-container open followed by approximately 3.5seconds of sequential burning before the rest of the contents of the container exploded en masse.

References

Recommendations on the Transport of Dangerous Goods – Manual of Test and Criteria, 5th revised Ed., United Nations, New York, 2009, pp143-148.