An Introduction to the European CHAF Project

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Abstract: *The CHAF* project was instigated following a series of accidents in large-scale storage of fireworks, by far the most serious being that at Enschede in the Netherlands. The project aims to quantify and suggest means to control the hazards associated with large-scale fireworks storage by small-, medium- and large-scale investigations on a series of well-defined fireworks. Additionally, it is hoped that correlations will be found between the small- and/or medium-scale tests results and those obtained in large-scale trials, and that these will lead to better test methods to predict mass storage hazards. Reports from the individual activities undertaken in the workpackages are posted on a dedicated web site www.chaf.info as they are delivered.*

Keywords: *CHAF, fireworks, accidents, storage*

Introduction

A large number of fireworks accidents occur each year and some of these have recently been reviewed.[1] Press reports of accidents cover those occurring during fireworks use (either professional display or private use) and also accidents in manufacture, storage and transport. The CHAF project[2] was instigated as a European initiative following a number of incidents associated with the large-scale storage of fireworks culminating in that at Enschede[3] in the Netherlands. The majority of fireworks accidents occur in Asia and South and Central America while a lesser number are reported in Europe, North America and Australasia. Many of the accidents not associated with fireworks use occur at manufacturing sites and it is quite possible that the initial fire or explosion occurring during the manufacturing process will propagate to the stored fireworks and that these will produce the major contribution to the overall damage.

Accidents at storage sites have included: Stourbridge (1996), Uffculme[4,5] (1998), Enschede[3] (2000), Carmel[6] (2002), and Kolding[7] (2005). In all these incidents relatively minor initial fires propagated to bulk storage and resulted in major damage and in the case of Enschede, multiple deaths. The CHAF project is part of the European response to such incidents.

Background

In the mid 1990s the UK Health and Safety Executive commissioned large-scale trials[8] which consisted of ISO containers of fireworks initiated by an external fire. External fire had been the mode of ignition in several fireworks incidents in the UK. A mixed load of "shop goods" fireworks‡ as available at that time was found to be unlikely to result in any major hazard. The fireworks burned slowly or smouldered and when the door of the container was opened some 18 hours later the fireworks re-ignited and continued to burn slowly. On the other hand, 125 mm star shells gave a massive fireball but did not give a mass explosion. A mixed load of display and consumer fireworks give effects between the two, forcing the door to open and throwing fireworks out of the front of the container. While these trials were being conducted, but before the work was published, the Uffculme incident occurred. Investigation[9] of this incident revealed that fireworks returned from a display were fused together and were being separated in the storage area by cutting the fuse with scissors. Both actions were contrary to the company's safety

** CHAF is derived from the project title: Quantification and Control of the Hazards Associated with the Transport and Storage of Fireworks*

‡ Shop goods fireworks are those available for sale to the general public and are also termed consumer fireworks. In the UK this is very often in the form of fireworks selection boxes containing a mix of Roman candles, fountains, mines, wheels and possibly rockets, all of limited size.

procedures. This led to the ignition of one or more shells which spread through the stored fireworks, causing a large explosion that devastated the site. While a fireball resulted from the star shell trials, this did not fully account for the extent of the damage and additional United Nations (UN) Test series 6(a) and 6(b) trials[10] were therefore undertaken on a series of flash-containing fireworks to find limits where mass explosion (UN 1.1G events) occur. This work is ongoing and results are provided to the UN technical committee responsible for fireworks classification.

While this testing was in progress, the major incident at Enschede occurred. This was initially a fire at a fireworks storage site that developed into three explosions resulting in the death of 22 persons and injuries to 947.[11] Again, fireworks in mass storage had produced a mass explosion. One of the responses to this incident was a European initiative to investigate large-scale initiation of fireworks and better means of predicting the effects of such fireworks in storage and transport situations.

The CHAF programme

European collaborative programmes are part funded by the European Commission (EC) and matched funding is provided by the participating nations via their internal funding mechanisms. This particular consortium consists of Bundesanstalt für Materialforschung und -prüfung (BAM) in Germany, Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek (TNO) in Holland and the Health and Safety Laboratory (HSL) in the UK. Typically, these programmes are divided into "workpackages" dealing with different aspects of the work. In the CHAF project there are 10 such workpackages. These each have a series of deliverables; public deliverables are available on the CHAF web site (www.chaf.info) as they are presented to the EC.

Workpackage 1 – Management and Coordination

This is the overall management task for the project, monitoring and reporting to the EC. Formal progress reports are made on a 6-monthly basis. This includes coordination and progress meetings between the partners. Additionally, the coordinator for the project is responsible for other EC related communications. This workpackage runs throughout the project.

Workpackage 2 – Critical Review Panel

A "half-way" review where a mixture of regulators and fireworks company representatives reviewed the work and made recommendations on the remainder of the programme.

Workpackage 3 – Transfer of information

The communication within the project and to the outside world is covered by this workpackage. This includes maintaining the CHAF website, communicating with outside bodies (UN, International group of scientific experts on the explosion risks of unstable substances, IGUS), writing scientific papers to disseminate the findings. This workpackage runs throughout the programme. Additionally, an International Fireworks Symposium will be held in Berlin in April 2006 at which the results from the CHAF project will form a key part.

Workpackage 4 – Literature review

This workpackage is divided into four areas:

1. an overview of fireworks types and compositions, based on the types covered in the European standards for fireworks EN14035 parts 1-37,
2. an assessment of research on reaction mechanisms taking place in fireworks and between adjacent fireworks articles,
3. a summary of legislation on storage and transport of fireworks in European Union countries, and
4. a review of environmental and health impact of major fireworks accidents.

All four reviews have delivered reports (deliverables D4-1 to D4-4) which are posted on the CHAF website.

Workpackage 5 – Instrumentation development

The quantitative information required from the practical workpackages was assessed and suitable instrumentation techniques were recommended or developed. A series of validation tests was also performed to assess the suitability of the instrumentation. This has generated three

deliverable reports:

1. a review of the data to be generated,
2. selection of the instrumentation, and
3. validated instrumentation

All three are reproduced on the CHAF website and will form the basis of a future article.

Workpackage 6 – Instrumented benchmarking.

One of the main objectives of this workpackage was to select a series of fireworks for testing using UN series 6 tests with additional instrumentation (mainly pressure transducers and thermocouples). Fireworks were selected to be in a clearly defined UN transport category (1.1 – mass explosion, 1.3 – major fireball and 1.4 – minor fireball) or likely to be on the borderline of UN 1.1/1.3 and UN 1.3/1.4 as benchmark examples. The UN series 6(b) and 6(c) tests were performed to give well defined UN transport classification of the fireworks, with the additional pressure and temperature data used for comparison to other workpackage results.

This workpackage has delivered its results in the form of reports which can be found on the CHAF website.

Deliverable D6-1 presents the rationale for the selection of fireworks types for the test series. These fireworks fall into three sets:

1. those chosen as reference materials; a 1.4G fountain, 1.3G waterfall, 1.3G Roman candle and a 1.1G report shell,
2. those chosen for shock initiation and at the 1.3/1.1G boundary; a Roman candle with report, a star shell, a report rocket and a star burst rocket,
3. those chosen for heat initiation; bag mines and waterfall.

Deliverable D6-2 presents the test plan and methodology and the final combined D6-3 and D6-4 reports give detailed results from the test series.

Workpackage 7 – Small-scale characterisation

This workpackage designed and tested small scale test apparatus to investigate the propagation of flame (or detonation) both within a firework and between fireworks in 1 and 2 dimensions. These were substantial tubes (1-D) and boxes (2-D) in which the propagation of the burning (or detonation) of fireworks could be investigated. This completed workpackage has produced two deliverables:

1. a methodology report setting out the mechanisms investigated and the test methods, and
2. a report on the application of the test methods and their findings.

Again, the results from this workpackage will be correlated with those from other practical workpackages.

Workpackage 8 – Medium scale characterisation of packaged fireworks

The medium-scale testing developed the small-scale work into a 3-dimensional test for examining time/pressure output from fireworks tested in their transport packages. The vessel used is an approximate 1 m^3 cylinder with instrumentation to measure internal pressure and temperature. This is currently in the early stages of testing. Findings will be reported via the website and in future articles for publication.

Workpackage 9 – Instrumented full-scale validation tests

This is a series of full-scale trials employing steel ISO containers (and, possible, concrete structures) to investigate hazards from specific firework types in mass storage. This workpackage was informed by previous workpackage results to select pertinent fireworks for test. These have been manufactured and testing will take place during 2005.

Workpackage 10 – Development of testing methodology

The final workpackage takes the results from the practical workpackages and will provide a series of recommendations on suitable tests to be carried out to predict the performance of bulk stored fireworks in the event of accidental initiation.

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