OPINIONS

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Issues with UN explosives classification – a personal perspective

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Abstract: *The United Nations classification regime for explosives is well established and has undoubtedly led to improvements in transport safety. However there are challenges that the hazard-based approach faces and this paper attempts to highlight some of the more pressing issues.*

Introduction

The United Nations (UN) classification regime[1] for determination of the hazard **as presented in transport** of explosives (Class 1 dangerous goods) is well established and well recognised throughout most of the world. Even those countries that do not conform entirely to the UN requirements recognise the merit in such a system and are exposed to it through, for example, imports and exports.

However it is apparent to many that the system is being used for purposes that it was never designed for, and that it copes poorly with modern risk reduction approaches to explosive safety.

This paper is not intended to propose a sudden change from the hazard-based approach that exists now, but instead to highlight areas where developments may be needed to maintain the credibility and practicability of the system in the future.

Table 1. *UN Hazard Divisions.*

Hazard Division	Definition
HD 1.1	Substances and articles which have a mass explosion hazard (a mass explosion is one which affects almost the entire load virtually instantaneously)
HD 1.2	Substances and articles which have a projection hazard but not a mass explosion hazard
HD 1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard:
	(i) combustion of which gives rise to considerable radiant heat; or
	(ii) which burn one after another, producing minor blast or projection effects or both
HD 1.4	Substances and articles which present no significant hazard: substances and articles which present only a small hazard in the event of ignition or initiation. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire shall not cause virtually instantaneous explosion of almost the entire contents of the package
HD 1.5	Very insensitive substances which have a mass explosion hazard
HD 1.6	Extremely insensitive articles which do not have a mass explosion hazard: articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation

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What is classification for and why do we do it?

In essence the UN classification regime determines the hazard of an explosive (as a substance or an article) **as packaged for transport** and assigns three parameters – a Hazard Division and a Compatibility Group as well as a four-digit "UN Number" – to that explosive in the specified packaging as shown (in abbreviated form) in Table 1.

Fundamentally, the Hazard Division determines the quantities that may be transported in vehicles of different types, the Compatibility Group determines which explosives may be transported together, and the UN Number allows the correct Shipping Name to be presented, the correct types of packaging to be used and leads to any special provisions which should be observed.

In addition to providing information to the consignor of the explosives, and information to the transporters, critically the correct assignment of the three parameters provides emergency information to the transporter and to the emergency services in the case of accident during transport.

What are the issues?

The main issues that have been identified by the author and in discussions with other industry parties are:

- The difference between risk and hazard
- The consequential anomalies with the HD 1.5 and HD 1.6 classifications
- Initiation issues
- The importance of getting classification right
- The absence of time factors in providing information to emergency services
- The relationship between classification and packaging
- The improper extension of the UN scheme to non-transport situations
- UN Hazard Division and security
- Effects of bulk
- The default classification system for fireworks
- Time/pressure testing for determination of flash powder
- Mutual recognition of classifications
- GHS

Each will be examined in turn.

Hazard and risk

The UN system essentially only assesses the hazard of an explosive event – it considers the worst case effect of an explosion of the packaged explosives, having made the assumption that the explosion occurs (by whatever initiation means).

As such any special provisions which attempt to reduce the likelihood of an initiation taking place should be effectively redundant. For example, in the case of Rocket Motors (e.g. UN 0181) the special packaging provisions (L1) require that "their ignition systems shall be protected against stimuli encountered during normal conditions of carriage" – but this is plainly a provision to reduce the likelihood of accidental ignition and not one to contain or reduce the effect once ignition has taken place. In other words, this provision affects risk and not hazard.

Another example is the insistence by some that items are transported without electric igniters attached, or that items with or without electrical ignition require different formal classifications. While the presence or absence of a few milligrams of an igniter composition will not affect the hazard resulting from an ignition of the item, it is fair to say that it may affect the likelihood of an ignition taking place (although this is overemphasised by many) but this is an issue of risk not of hazard.

Modern regulations tend to consider risk not hazard and a sensible approach to risk reduction in the carriage of explosives would be to:

- Reduce the likelihood of initiation
- Reduce the likelihood of communication within the load
- Increase the time an event takes
- Reduce the consequences of the event presuming all of the above have failed

It is only the last of these which is truly related to hazard – the first three reduce the likelihood of, for instance, the whole of a transport load exploding simultaneously (or even in quick succession) and hence not only reduce the risk but allow a sensible and effective response by the emergency services.

Hazard divisions 1.5 and 1.6

The distinction could not be clearer than for explosives classified as 1.5 and 1.6. In both cases the definition refers to "insensitive" – but insensitivity is a measure of the likelihood of initiation not the consequences of it.

A large amount of expense and time has been devoted in developing, for example, insensitive munitions – the reasons are obvious and desirable – but this insensitivity should have no bearing on the determination of hazard during transport. Indeed the definition of HD 1.5 recognises this – it acknowledges that such explosives have a mass explosion hazard and thus, we conclude, should be classified as HD 1.1.

HD 1.6 states that such explosives have "a negligible probability of accidental initiation or propagation" – but probability is a determinant of risk and not hazard.

These inconsistencies in approach devalue the UN process and provide little valuable information to the emergency services in the case of incident.

Initiation issues

The issue of initiation is wider than just 1.5/1.6 issues. Many explosive substances will not behave as explosives unless they are properly initiated – for instance by a detonator. In the absence of such initiation, most modern plastic explosives will simply burn – yet the UN 6(a) and 6(b) tests require a detonator to be deliberately inserted into such explosives solely for the purposes of the test, with inevitable consequences which are completely unrelated to any realistic transport situation.

There seems little point in striving to develop and manufacture such explosives if the tests required for classification will rate them equal in hazard to the most sensitive explosives.

The importance of getting classification right

It is obvious that it is important to get the hazard classification "right". Although there have long been arguments that in the absence of test data all classifications should default to the "worst case", HD 1.1, this is neither practical nor sensible. There is a danger that emergency services would over-react in case of incident with the potential for future incidents to be treated complacently because the last one was seen to have been over-rated.

Of course it is also vital that the incident is not under-rated – and hence it is obvious that the only proper solution is to rate hazards properly!

A better understanding (by operators, enforcers, the emergency services and the public) of the difference between risk and hazard would be beneficial but, sadly, unlikely.

It is important, however, that the classification process is done in a timely and practical way (mutual recognition would help this – see later) in which means are taken to ensure that single items and mixed packages have an accurate classification assigned to them. It does appear anomalous that explosives require classification by Competent Authorities when all other classes of dangerous goods allow determination of hazard by the producer and/or consignee.

The undesirable effect of Competent Authority involvement is often that the process becomes bureaucratic and costly – and hence there is a temptation by some to "cheat". In principle a "simple process/strong enforcement" approach, where the enforcement activity is centred around ensuring compliance by all, would satisfy these requirements. Indeed, it does appear that in many countries the complications and costs of the process of classification have meant that items have been produced (often imported), transported, stored, used and have ceased to exist before the bureaucratic process of assigning classification has been completed. This is not an acceptable position and although no one should condone it, it is understandable.

Time factors

One of the failures of the UN system is the lack of time-critical information about the possible explosive event.

For instance HD 1.3C propellants and HD 1.3G fireworks seemingly present similar hazards to the emergency services. The former might produce a very high thermal flux on ignition for a period of a few seconds whereas the latter might eject an occasional star from a package over a period of minutes or even hours.

In dealing with an incident both the transporters and the attending emergency services would like to have an appreciation of whether the incident is likely to take

- Milliseconds
- Seconds
- Minutes
- Hours
- Days

Examples are shown in Table 2.

It would be of great benefit if there was some method of providing such information to the emergency services.

The relationship between classification and packaging

It is generally not appropriate to attempt to give an explosive an inherent classification – the classification is ultimately dependent on the packaging in which the explosive is transported. In some cases (e.g. the default classification of fireworks – see later) where the packaging is closely defined

Table 2. *Effects of time on explosion effects and possible emergency reponses.*

Timescales	Example and comments
Milliseconds to seconds	HD 1.1 event – little possibility of subsequent explosions – in all likelihood the event will be over by the time the emergency services have been notified, let alone arrived at the scene
Seconds to minutes	Possibly an HD 1.2 event when pieces of the explosive article itself or of its packaging are ejected or an HD 1.3C propellant fire. Again in all likelihood the event will be over by the time the emergency services have been notified let alone arrived at the scene
Hours	A firework fire of predominantly HD 1.3G fireworks
Days	For example an HD 1.4 event where atmospheric oxygen is required to maintain fire between the packaged items (burning fibreboard boxes). If the oxygen is depleted (e.g. in a closed vehicle or container) only when the oxygen is re-admitted (on opening the doors) will the fire and subsequent explosive events restart.

this may be possible but as a hypothetical example:

- Packing 72 theatrical maroons in a heavy-walled fibreboard box – HD 1.1G (UN 0428)
- Packing 12 of the same maroons in a metal "ammunition" style box – HD 1.2G (UN 0429) from fragments of the box
- Packing 12 of the same maroons in a weak-walled fibreboard box – HD 1.3G (UN 0430) (as individual maroons are thrown and then function to throw fiery projections outside the 1.3 test distance)
- Packing a single maroon in a light-walled fibreboard box – HD 1.4G (UN 0431); the effect is limited to the immediate area around the box if it ruptures
- Packing a single maroon in a very large fibreboard box – HD 1.4S (UN 0432) as the effects are confined within the box

Improper use for use, storage and major hazard legislation

The UN system properly determines the hazard of explosives **as presented for transport**. We make no apology for repeating that phrase often – it is critical to the understanding of the UN system and its proper application.

Unfortunately the use of Hazard Divisions of packaged explosives as a determinant has been extended into other areas:

- The suitability for sale – for instance it appears some countries regard only 1.4G (UN 0336) fireworks as suitable for sale to the public rather than striving to ensure the fireworks suitable for sale obtain a classification of HD 1.4G so that they may be transported by members of the public in their own vehicles more safely. As seen above, the classification is often dependent on packaging. Attempting to equate hazard in transport and hazard in use is unrealistic and makes no logical sense.
- The suitability for transport by air – in some countries articles have been awarded an HD 1.4S classification so they may be flown, rather than being allowed to be flown because they have been awarded an HD 1.4S classification! Recent attempts have been made to address this anomaly but they have been only partly successful.
- The thresholds for explosives in the Seveso Directives[2] are based on UN classifications – irrespective of the fact that the explosives may be stored in bulk, may not be in their transport packagings or may be in manufacture. The Seveso directive attempts to address this but fails because of the convenience of using UN Hazard Divisions. (It is notable that the Seveso Directives ignore HD 1.5 and HD 1.6.)
- The NATO use of mixed transport/storage classifications such as 1.2.1 and 1.2.2 to indicate hazard in storage of items packaged for transport and classified by the UN properly as simply HD 1.2. These terms, intended to discriminate between the different behaviour of HD 1.2 explosives in bulk storage, lead to confusion and are not used within the civil sector. Again it is attempting to use the UN system for transport to reflect hazards in storage – a purpose for which it was not designed.

In the UK a separate (but related) regime has been introduced to attempt to separate the determination of hazard as packaged for transport (the UN regime) from the hazard presented in manufacture, storage and even use.

The UK system is called "Hazard Type" and there are four divisions HT1, HT2, HT3 and HT4 which are related to HD 1.1 etc provided that the explosives are stored in their transport packages. Again it is notable that there is no HT5 or HT6.

However in bulk and in situations where the explosives are not in their transport packages the Hazard Type may differ (up or down) from the equivalent Hazard Division. In essence the Hazard Type may be related to (all related to an explosive storage situation for simplicity):

- The packaging (or not) of the explosives
- The quantity (or the explosive loading density within the store)
- The orientation within a store
- The orientation of the store itself (e.g. a store could present an HT3 hazard through the doors but an HT4 hazard in all other directions
- The construction of the store

UN Hazard Divisions and security

ADR has, in recent editions, extended its scope to embrace transport security as well as transport safety. The rationale for combining the two is sound, but the implementation is not. As noted above, the UN Hazard Division of an explosive substance or particularly an explosive article is intimately related to its packaging. The possible security threat of a particular article is not and cannot be related to its packaging – after all it is most likely that the article would be removed from its outer packaging before use!

There are many real examples of where an explosive article has had specific packaging designed to reduce the hazard in transport – for instance 1.2G pyrotechnic articles can be packaged to present a 1.3G or 1.4G hazard. The hypothetical example given above could even make items classified as 1.1G in one configuration present a 1.4S hazard in another. This is a sensible approach for the manufacturer/consignor to take – it reduces the hazard in transport and potentially reduces costs and allows more economical shipments. However, the article remains the same – take the article out of the box and it must necessarily present the same security risk.

To use the crude criteria in ADR section 1.10, based almost

solely on the Hazard Division, misses the point that the safety hazard posed by packaged explosives is intimately linked to its packaging!

The only simple way for ADR to proceed to address the security provisions for explosives would be to make decisions about the "High Consequence Dangerous Goods" status by reference to individual UN numbers, and present this information in the existing Table A – The Dangerous Goods list.

In this respect it is vital that regulators understand that the hazards posed by packaged explosives are dependent on the packaging. This will be explored further in the section dealing with the provisions of GHS.

Effects of bulk

The hazard identified by application of the UN tests may be realistic for the quantities involved but may not represent the hazard in bulk storage (for which classification is not appropriate and should not be used anyway) or bulk transport (for instance within an ISO container). Following well publicised incidents at Enschede[3] and Kolding[4] much work has been done to investigate the true "hazard classification" of bulked up fireworks.

Many authorities within Europe collaborated to address the "Quantification and control of hazards associated with the transport and bulk storage of fireworks" – the CHAF trials[5] – and although most of the trials gave results analogous to the classifications awarded from UN test data and the derived default classification table, there were anomalous results where a higher explosive event was observed (although explanations are somewhat contentious).

The failure is not with the classification of fireworks *per se*, it rests with the inappropriate extension of trials data on small samples to the bulking up in ISO containers for transport. We believe however that this is not a unique feature of fireworks – most explosives (especially those containing sensitive explosive substances or significant proportions of flash powder) would react in the same way. However to date no large scale trials have been carried out on items other than fireworks.

The CHAF project and subsequent small scale investigations take a fundamentally different approach to that of the existing UN regime – in time (but not yet) it may be appropriate to re-examine the whole basis of the UN regime to adequately reflect the results across the whole of the explosives sector.

The default classification system for fireworks

The UN developed (following the adoption of a similar scheme in the UK many years before) a "default" classification regime for assignment of Hazard Divisions to fireworks.

In part at least, the need for such a scheme was driven by the diversity of products available, their individual value, and the complexity of testing. It was also in part a recognition that it was better to have a scheme to allow users to obtain a meaningful classification easily, than for products to be wrongly classified or for producers and consignors to classify for convenience!

Any default scheme must necessarily be rather pessimistic, and the option is always available (and indeed encouraged) to applicants to demonstrate (by test or by analogy) a classification related to a lower hazard, perhaps by specifically designed packagings.

However there are problems with the UN default regime:

- There are anomalies within it – for instance between Roman candles and shot tubes (which are in essence single shot Roman candles) or between fountains and waterfalls. The CEN Standard EN 16261 recognises these differences and so should the UN
- There are default classifications missing. It would be sensible to remove these omissions even if the items are not in common circulation – they may be in the future. Again the definitions in EN 16261 could assist here
- It should be extended to *identical* items which are not fireworks. For instance, following the adoption of the EU Directive on pyrotechnic articles many items that were previously regarded as fireworks (and were classified as such) are now properly termed "Articles Pyrotechnic for technical purposes" (UN 0428-0431). The default classification scheme could usefully be extended to such articles and a formal proposal is being submitted to the UN for consideration
- It may well be appropriate to introduce a new UN series for "Articles Pyrotechnic – for special effects use" to go alongside "Articles Pyrotechnic for technical purposes" (UN 0428-0431) and relate these to European Standard (CEN) T1 and T2 or similar articles and hence restrict UN 0428-0431 to CEN P1 and P2 articles or similar
- It calls into question whether an item in a specific packaging should in theory have more than one classification at all – but this can only happen when the erroneous link between classification for transport and other use of UN Hazard Divisions in non-transport regulations is broken.

Furthermore similar approaches could be adopted for other explosives articles, for instance small arms ammunition. Parameters could include:

- Calibre
- Net explosive content
- Type of package
- Number in package (or explosive loading density of packages)

The advantages are many – simplification, better understanding of the issues of changing packaging etc and such a scheme could be developed with no reduction in

safety.

Time/pressure testing for determination of flash powder

Following some extensive arguments, the UN adopted an approach of assigning pyrotechnic composition to some fireworks classifications (essentially UN 0333 to 0336) on the basis of amount of "flash composition" contained within a particular article and the results of the "time/pressure" test carried out on such compositions.

This decision followed the seeming assumption by members of the UN committee charged with investigating this area that the existing definition (based on composition) was inadequate and had led manufacturers to change their compositions to avoid being deemed "flash".

Unfortunately there were severe problems in this approach, highlighted but ignored at the time, and which still remain unresolved.

Firstly the initial results[5] showed extreme variations in the time criterion applied. This highlighted potential practical issues with the test and which indicated the need for further work to be carried out before the tests were adopted into the UN regime.

Secondly the body which carried out such tests recommended a value of 4 ms as the cut off point for assigning a composition as flash powder – this took into account the desire to exclude blackpowder (UN0066) from the definition of flash powder – and as a consequence of the deviations highlighted above. Unfortunately the UN decided (without further tests) to adopt a figure of 8 ms which meant that many non-flash compositions potentially required testing.

Thirdly, the test required compositions to be tested "in the form" in which they were found in the article – but necessarily removing them from the article means that they may no longer behave in a similar manner to how they do in the article itself.

Although the time/pressure tests were an attempt to address a perceived problem of the potential of flash powder in fireworks to mean a packaged article produced an HD 1.1 hazard, there are several fundamental problems with this approach:

- Testing compositions in isolation is not a determinant of the behaviour of those compositions within articles. For example, the flash powder used as the bursting charge of a firework shell does not spontaneously ignite to detonation when the shell is initially functioned (i.e. is fired from a mortar) – it is protected by the casing and physical arrangement of the shell itself
- The tests takes no account of any special packaging features designed to prevent any mass explosion taking place
- The approach is limited to fireworks, but if it is a valid concern that items containing flash powder could present an HD 1.1 hazard then the principles should apply to any article containing flash powder.

The time/pressure saga was a particularly low point in industry's relationship with the UN and, some 10 years on from the adoption of the principles, industry's view that it was hurried and unscientific have been vindicated.

Mutual recognition of classifications

ADR,[7] the European agreement concerning International Carriage of Dangerous Goods by road (and the equivalents for transport by other modes), which are derived from the UN Recommendations and Model Regulations, require explosives to be classified. They do not require that explosives are reclassified by different Competent Authorities depending on transport arrangements and eventual use.

In the UK, after long discussions involving the author and others with the Competent Authority (DfT and HSE), this position was accepted and now classifications of explosives that have been carried out by a contracting party to ADR are accepted without further bureaucratic involvement of the UK Competent Authority. Consignors are still required to have evidence of proper classification, but they are not required to carry out their own tests or to formally demonstrate classification "by analogy". Explosives that have been classified by non-ADR contracting parties do not, understandably, benefit from this position, although it is hoped in time that the scheme will be extended to all contracting parties to the UN Recommendations (ADR technically is a European agreement only).

Freedom of Information requests of the UK Government asking how many classifications had been changed in the UK from those awarded by other ADR signatories was the final decider – in the period sought not a single classification had been changed from that awarded elsewhere, although UK industry was charged for generating new UK classifications and the process took, in many cases, several months to complete.

We would encourage the UN (and ADR) to formally adopt mutual classification recognition for all dangerous goods, but specifically for explosives where at present classifications are already subject to a Competent Authority approval. The logic of this approach is unchallengeable – the purpose of the UN Recommendations (and ADR) exist to ensure a commonality of approach and to make domestic and international journeys safer as a result. There is nothing to be gained by duplication of process. Again, where there are obvious or systemic failings then enforcement action should be taken to eliminate such issues.

GHS

The adoption of the Globally Harmonised System for classification of dangerous goods (GHS) and its convergence with the UN recommendations has inherit merit, but it fails to appreciate the role of packaging in explosive classification.

In contrast, for instance, the corrosive nature of a particular strength solution of sodium hypochlorite is the same regardless of whether the container is glass, plastic or even metal. As outlined above the classification of an explosive (and particularly an explosive article) is dependent on the nature and construction of the article, and the nature of the packaging. Explosive articles cannot and should not be classified outside their packaging. There are a limited number of exemptions within the UN system itself (for items over 400 kg, and nationally[8] where this is permitted, but in essence the packaging is integral to the classification.

For instance, some have suggested that any article containing blackpowder should be labelled under GHS as HD 1.1D – the classification of "raw" blackpowder itself, irrespective of the fact the article does not behave like "raw" blackpowder. There are many examples of, for instance, fireworks and flares where the correct classification of the article **as packaged for transport** is HD 1.4G and that even articles outside of their transport packaging present only a very localised effect in case of incident or in proper functioning. It would be meaningless to label such items as HD 1.1D because they happen to contain a small quantity of blackpowder.

The extension of UN classification of explosives a**s packaged for transport** to non-transport situations (and especially to GHS labelling of articles) highlights the problems that have been outlined above and demonstrates a lack of understanding of the principles of explosive classification. We can only hope that efforts to divorce GHS from UN classification of explosives is successful.

Conclusions

The United Nations Recommendations and Model Regulations regarding the classification of explosives have undoubtedly improved the safety of transport of such items through a consistent approach and education of all parties involved in obtaining proper classifications for their shipments which truly reflect the hazards as presented for transport.

However it has become apparent that there are problems associated with the process itself, and the fundamental principles which lie behind it. Most of the issues relate to the attempt to extend the principles of classification into areas that it was never designed for – and we would urge those developing future editions of the UN Recommendations and ADR to revert to the sole and proper purpose:

…to determine the hazard **as presented for transport**….

This opinion paper addresses some of these issues and is intended to stimulate future discussions.

Acknowledgements

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I hope that the paper will stimulate discussion around the explosives community and help inform debate and revisions to the UN system, and hence lead to a greater understanding of the unique properties of explosives and hence ultimately to safer transport and to safer storage.

References

1 UN Recommendations on the Transport of Dangerous Goods – Model Regulations and UN Manual of Tests and Criteria, accessed via http://www.unece.org/trans/danger/danger.html

2 There are now three Seveso directives. For more information see http://ec.europa.eu/environment/seveso/index.htm

3 See the final report on the Enschede disaster for more information – http://www.nbdc.nl/cms/servlet/nl.gx.nibra.client.http.GetFile?id=498631&file=Final_consideration_(Slotbeschouwing_Engels).pdf

4 For more information see the Kolding website – http://www.kolding.dk/brand/0032135.asp (in Danish)

5 An Introduction to the European CHAF Project, D. Chapman – see http://www.jpyro.com/wp/?p=116

6 Defining Flash Compositions: Modifications to UN Time/Pressure Test, D. Chapman and K. Howard . See http://www.jpyro.com/wp/?p=1176

7 European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). See http://www.unece.org/trans/danger/publi/adr/adr2013/13contentse.html

8 For instance see UK Authorisation 151 – https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/3283/authorisation-151.pdf