Risk analysis of fireworks transport in cargo container ships

Ruddy Branka, Guy Marlair, Brigitte Nedelec

RISK ANALYSIS OF FIREWORKS TRANSPORT IN CARGO CONTAINER SHIPS

Ruddy Branka, Guy Marlair, Brigitte Nedelec

Institut National de l'Environnement Industriel et des Risques (INERIS)
Accidental Risk Division / Units PYRO, SUPG and DIAG
Parc Technologique ALATA – BP 2
F-60550 VERNEUIL-EN-HALATTE, FRANCE

ABSTRACT

The study deals with the analysis of the most suitable configuration for positioning the fireworks containers in the cargo ship in order to minimize the risks for the ship in case of an accident (transmission of fire or deflagration originating from containers filled with fireworks devices to other containers or arising from other containers to the those containing fireworks).

The analysis has been done in a three steps process
1) What are the hazards coming from a fireworks container in case of fire?
2) How to fill the containers it in order to minimize the outer effects?
3) Where to place them on the ship from a safety management viewpoint?

In this paper, we present;
- The most dangerous fireworks,
- Some incidents that occurred in the past and lessons learnt
- The problems linked to inappropriate classification of the fireworks,
- The hazards linked to confinement and the propagation issues,
- Some proposals for safe filling of the containers in terms of types of fireworks under consideration, quantities, segregation rules and training of operators
- Some proposals for safe filling and packing of fireworks articles in inner packaging according to their types,
- A proposal for optimizing the position selection of the containers in the cargo ship.

INTRODUCTION

Most fireworks used in the European market are produced and imported from CHINA. As a consequence, maritime transport of those articles (as dangerous goods) is quite common and important. Approximately 8000 (equivalent twenty feet) containers are imported each year in Europe, representing 30% of the world fireworks market for maritime transportation of such products by cargo ships.

As some serious accidents have been observed in the past years (see accidentology section of this paper), we have developed a risk based approach to define the best packing configurations inside the boxes, the best lay-out for boxes of fireworks inside the containers and ultimately the best positioning of maritime containers containing fireworks articles inside the cargo ship in order to reduce the risk of propagation of a fire coming from the fireworks containers or from another container.

In the following sections, we present:

- The most dangerous fireworks and the main risks affecting them
- Some issues arising from past accidentology and handling instructions
- The default fireworks classification table for transport and associated problems with inappropriate risk division classification
- The hazards and risks presented by a container full of fireworks in boxes, probabilities, propagation and possible protection
- Safe instructions during the container's filing, operator's training
- General recommendations for transportation of fireworks on a cargo ship

MAIN RISKS AND HAZARDS AFFECTING THE FIREWORKS

Within the new 2007/23/EC European Directive, fireworks are classified into 4 categories (designated as F1 to F4) according to their powder weight and operational effects when functioning. But the main risks cannot be ranked simply accordingly to this individual classification scheme. Indeed, main risks are caused by

- *The type of pyrotechnic compositions inside the fireworks and their degree of confinement*: all fireworks are made with an assembly of different inert elements, each containing one or more different pyrotechnic compositions, in charge of one effect during the functioning of the firework (igniting, ejection, delay, exploding, colours, other visual or sound effects,...). Each composition is a mixture of powders which enables the composition to ensure its function (oxidizing carrier, fuel carrier, colorant, binder,..). These compositions can be classified according to their sensitivity to external aggressions and according to their effect on the environment. The following charts present the percentages of accidents induced by pyrotechnic compositions in function of the type of aggression, and the main causes of accident are clearly the mechanic aggressions (shocks, friction, indentation, drops, crushing, ...)

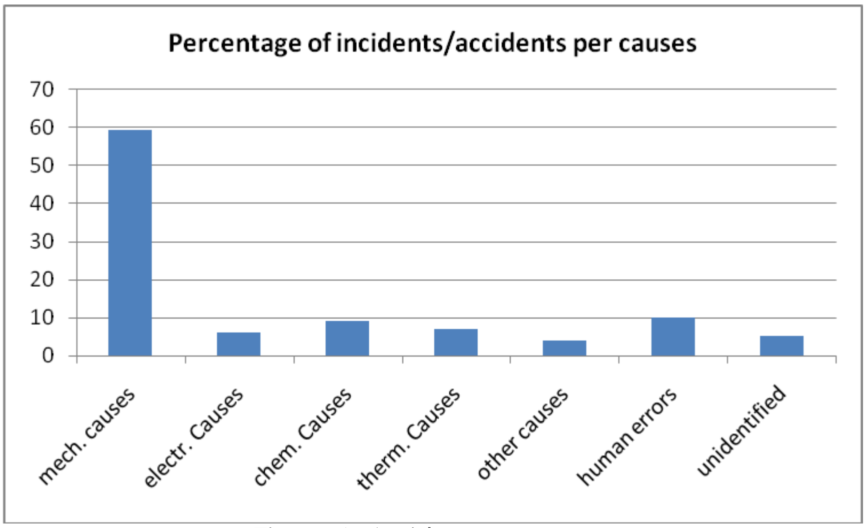

Figure 1 :Accidents per causes

If we classify the composition according to their actual hazards (as quantified by a severity index), the most dangerous reveal to be those containing chlorate or perchlorate /metal based compositions (metal elements are generally magnesium, aluminium, or titanium, in fine powders)

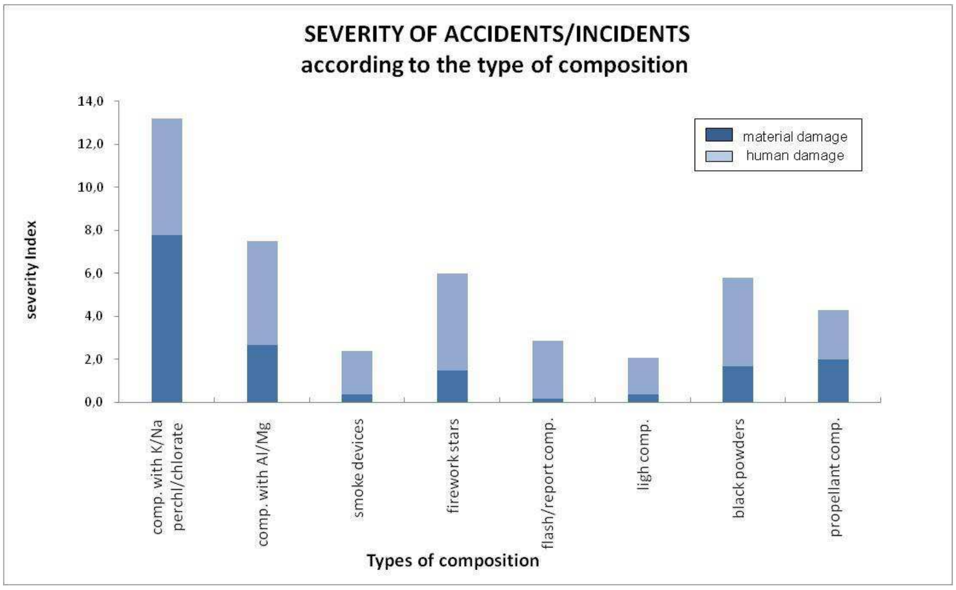

Figure 2: Severity of accidents per type of composition

- *The density of composition inside the packaging, and consequently the confinement inside the packaging*: fireworks, according to their type, confinement or quantities, can have different behaviours; mass explosion (maroons, big shells or roman candles), heavy thermal effect (fountains, Bengal, rockets) with a possibility of transition to a mass explosion in case of high storage density (see CHAF project results [1]), or light thermal effect only located in the immediate vicinity.

Some findings from past incidents/accidents

The following table below contains an inventory of major accidents listed worldwide from 1996 to 2004 (various sources; French inspection of explosives, incident log, ARIA database, ...). This list is not exhaustive, the number of accidents in China appears as the highest as compared to incident numbers in other quoted countries, but this looks consistent with the very large number of manufacturers existing in this country and settled in 26 provinces (estimated to range from 4000 to 7000). The following table gives the number of fatalities listed by country and year worldwide (known accidents for which information is available).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Totals
India	25	10			30	22	50		21	5	163
Kazakhstan					8						8
Pakistan	13			8		19	6	38	8		92
China	48	27	211	201	57	111	73	222	276	63	1289
Japan					5	12					17
Philippines						2	7				9
Ceylon					1						1
Thailand							15				15
Dubai/EUA						8				2	10
Taiwan				6	6	5	4				21
Indonesia					12						12
Brazil	54	5	3								62
Mexico	36	56	1		12	41	4	9			159
Argentina										1	1
USA	7			1	1	125					134
Peru				400		12					412
Venezuela								28			28
Guatemala				8							8
Netherlands		22									22
Spain			7							1	8
Denmark	2						1				3
Portugal				8				3			11
Italy	3		3	4	3		5	3		3	24
Turkey								6			6
Hungary							2				2
Slovakia				1							1
France	3	1		1	2	1	2				10
Total	163	105	225	638	135	358	166	309	315	75	2528

Table 1

Among these accidents, very few deal with transport or storage of fireworks. The only known accident in a container ship is the HYUNDAI FORTUNE in 2006, 64 000 tonnes, bearing 5100 containers (in equivalent 20 feet), when an explosion near the YEMEN coast caused a fire that lasted several days. The ship had a cargo of 7 fireworks containers located in the area of the fire, but the actual cause of the incident remains poorly identified.

Figure 3: Fire in the Hyundai Fortune cargo ship

Among recent accidents involving containers, the best-known is the one in the port of Changsha in 2006 where 200 containers have caused a significant fire after an explosion as initial event.

Figure 4: Fire in the Changsha harbour

From the analysis of the accidental database, it comes out that:

- accidents occurring during a sleeping fireworks storage are limited
- key factors of accidents are products handling in unsuitable packaging (cardboard boxes containing fireworks in bulk for example),
- the main causes of accidents are due to mechanical stresses on products, i.e. shock during transfers (shocks, drops, violent friction), or when manipulations violate security policies. The effect of temperature on shock sensitivity is also a factor to be taken into account.

The default fireworks classification table and associated problems with inappropriate risk division classification

Among explosive products, fireworks form a specific category, characterized:

- by the diversity of products existing on the market (hundreds of them), from the simple banger to shells deploying their effects during functioning at altitudes up to 800 metres,
- by their partial use on the consumer market (therefore inducing possible sale by retail stores),
- by specific legislations (European Directive 2007/23/EC, TDGs legislation).

The Fireworks do not derogate from the pyrotechnic products classification rule. However, given the diversity of products and their packaging, an individual ranking of these products is not always possible in practice. To address this point a default classification has been set by the legislator (primarily as a recommendation in the UN model regulation for the transport of dangerous goods – the so-called orange book [4]), this classification is supposed to correspond to a worse case situation in terms of hazard ranking of the given fireworks. Fireworks assignment under N ° UN 0333, 0334, 0335, 0336 and 0337 can be done accordingly by analogy without having to run the test series 6 of the UN Manual of test and criteria [5]. The applicant, in the event of disagreement with the classification given to the products by default, may request other classification through testing (according to test series 6 procedure).

This “by default” classification system scheme has been adopted in the IMDG as can be seen in its last edition 2009: see IMDG sections. 2.2.3.5.5, Amdt. 34-08). The classification in this table only applies to objects packed in cardboard boxes. The classification in risks division is intimately linked to the product packaging. Thus, for example, separation of fireworks in a box by the mean of bulkhead may change classification from division 1. 1 G to division 1. 3 G or even to divisions from 1. 3 G to 1. 4 G.

Problems coming from the "by default" classification

Because of the relatively low possibilities of maritime transport of class 1 products, and because of the lack of clear regulations concerning the classification of fireworks products (international rules said that such products should be classified using the same principles as for conventional explosive materials which had revealed to be largely enforceable in practice, because of the infinite variety of existing Fireworks), many exporters had tendency in the past to underestimate actual hazard ranking of such articles by using categories 1.3 or 1.4 instead of 1.1 and 1.3 or 1.2 categories.

This has led in Europe to large capacity storages where lower risk category group than actually pertinent was in current use. This ended up with the occurrence of a few but extremely serious accidents that killed or endangered many people (Enschede in Netherlands, Kölding in Denmark...).

These accidents have caused a violent reaction of authorities;

- Establishment of a fireworks classification by default table for international transport,
- Directive 2007/23/EC giving essential safety requirements for the placing on the European market of such articles,
- Reconsider and upgrade security requirements of fireworks by re-labelling to appropriate risk level on arrival at the first European harbour (to be implemented by the importer, considering that the first hazard ranking performed in China is valid until the first storage place in Europe).
- Currently in Amendment No 34-08 the IMDG, a commitment exists in the framework for multimodal transport of dangerous goods (5.4.5.1) formula in which the sender declares that cargo content is described as complete and accurate by the official designation of transport and that it is properly classified, packed, marked, labelled, affixed and in all respects well conditioned to be transported in accordance with international and national regulations apply.

Despite of this commitment, the findings provided by audits carried out in harbours of Hamburg and Felixstowe by the competent authorities before unloading the ships showed that these fireworks either had not been classified at all or had been labelled as presenting the lowest risk level (1. 4 G) while in reality they belonged to a class of higher risk [3]. Law enforcement authorities in these ports have had to take the necessary measures to ensure that these products were properly classified to be delivered to their final destination. The classification was entrusted to European authorities and a large number of fireworks which had been declared belonging to class 1. 4 G or 1-3 G were then reclassified (1. 3 G, 1. 2 G / 1. 1 G).

Furthermore, another common distortion to actual regulations constraints consists simply in not considering classification of fireworks as hazard material of class 1, but to declare them as toys articles.

Most of fireworks containers contain less than 8 tons Fireworks (5 tons net weight) splitting in between 5 and 20 different products. The additional information required for classification, as they are proposed above, should not impose an additional burden to the sender.

The hazards and related risks presented by a container full of fireworks packed in boxes

The probability of occurrence of an accident can be determined by three different methods: semi-quantitative, qualitative or quantitative type. The qualitative or intuitive method is based on a meaningful and representative feedback. The following data values were determined according to this method from the analysis of the available information on past accidents. The semi-quantitative or empirical method is based on statistical data driven from accident databases. Quantitative or analytical method seeks to identify exhaustively possible causes (basic events) that lead to the feared hazardous event. The probability of the feared hazardous event is determined based on the probabilities of occurrence of the various causes that lead to this phenomenon (see table 1 below).

Probability	Example of accidental event with fireworks
P_0	Accidental functioning in package accepted for transportation, during operations of loading/unloading, from time to time outside period of high activity
P_1	Accidental functioning in package accepted for transportation, during operations of loading/unloading and handling (package leakage, friction, shocks, drops, …)
	Accidental functioning of fireworks during operations of handling, sampling or dividing
P_2	Accidental functioning during linking of fireworks without any modification of product
P_3	Accidental functioning of igniters during electric testing or checking

Table 2

The above values are determined starting from the available accidentology.

Table 2 below gives for each operation the probability of an accidental event during logistics operations regardless of the relevant division.

Logistics operation	Annual possibility of an accidental event
Container loading	10^{-3}
Charging/discharging in the cargo ship	10^{-4}
Transportation	10^{-5}

Table 3

Risk of fire/explosion propagation (domino effect)

First case - reaction by influence of initial detonation (division 1.1)

In the current state of knowledge, it is acceptable to say that the detonation of a given mass Q in kg

- causes within 0.5 $Q^{1/3}$ (expressed in metres) around this mass, the instantaneous detonation of any mass able to explode (by Shockwave)
- can lead to a distance (in meters) between 0.5 $Q^{1/3}$ and 2.4 $Q^{1/3}$, the almost simultaneous detonation of any load which may explode (boot that often impact projections).
- does not lead to simultaneous detonation:
  - beyond a distance in meters of 2.4 $Q^{1/3}$, in this case, the remaining risk of initiating is always due to projections but it does not create enough pressure to ensure the transition to detonation;
  - beyond a distance in meters of 0.5 $Q^{1/3}$, if the load exploding initially is separated from any other likely to explode by a screen or a sufficiently thick protection wall able to stop any projection

Second case - materials or objects generating intense thermal effects (division 1. 3 a)

1.3 Division products have propagation risks by thermal radiation and heat transfer that depend on:

- Nature, weight and moisture of these products.
- Their speed of combustion and therefore the duration of the initial accidental phenomenon.
- The nature of their packaging.
- The degree of containment.

If they are placed in buildings covered with Earth and fitted with a discharge pressure door, these products involve risks of spreading very strongly increased in a zone of conical shape with their centre of gravity coinciding with the cone summit. This interpretation can be considered as valid for a container when the door opens as a result of the pressure.

Third case - materials or objects with lower thermal radiation (division 1. 3b)

A mass Q (expressed in kg) of products within division 1.3 (b) placed in a lightweight building or a container presents a risk of spreading up to one of the following distances:

- 0.22 $Q^{1/2}$ metres if Q is more than 13 000 kg
- 25 metres if Q is less than 13 000 kg; for a small mass this distance may be reduced on justification
- 10 metres if the mass Q is surrounded by a screen resistant to the effects of pressure and projections as well as thermal radiation.

The above distances must be increased if substances or articles 1.3 Division are located in the presence of a significant quantity of flammable products (solvents, fuels...) which, by burning, emit a strong heat radiation, and are likely to encourage fire spread. Fireworks generally belong to the division 1.3b.

Fourth case - materials or objects whose effects are limited (division 1.4)

In this case, propagation of the accident beyond the original location of the initial event is always sufficiently slow so that people at risk can shelter.

Conclusions concerning the fireworks behaviour

As concerning summary regarding fireworks hazardous behaviour, let us state they may be classified into 3 categories of behaviour for which specific recommendations can be made;

- Fireworks experiencing explosive behaviour, even in limited quantities and in the absence of containment : the probability can be reduced by measures addressing adequate filling of the containers (special containers with compartments, with limited quantities and/or separation by 1.4 division fireworks (or inert or a double wall) corresponding to a minimum distance of 0.5 $Q^{1/3}$ between each 1.1 pallet,
- Fireworks with behaviour that may become explosive if certain prevention measures are not taken (e.g. by limiting confinement and quantities to 50% of containers overall capacity)
- Fireworks with intrinsic safer behavior (but that may render more severe the consequences of a fire coming from the outside)

Annual probability of an accident can be estimated at 10^{-5} during transport, 10^{-4} during loading or unloading and 10^{-3} for filing.

SAFE INSTRUCTIONS DURING THE CONTAINER'S FILING, OPERATOR'S TRAINING

Beyond the intrinsic danger from products and explosive objects previously exposed, and taking account of fireworks behaviour in confined environment, it is important:

- to limit the quantities loaded in order to limit the potential effects,
- to choose packages as appropriate,
- to wedge and store the fireworks inside the packages in order to limit all movement which could result in mechanical shock and/or thermal contact which could lead to an accidental event
- to avoid the co-storage of incompatible materials.

We present below existing regulatory demands as well as possible recommendations on the quantities to be loaded, type of packing preferred as well as the bulkhead which could be envisaged to limit the effects in the event of an accidental event occurrence in a container

Accordance with IMDG AMdt 34-8

Unless otherwise provided, the packs containing substances of class 1 shall comply with the provisions applicable to the Group of moderately hazardous materials (packing group II) (4.1.1.16)

The table 3 below mentions (4.14.1) packing instruction required for each firework UN number which can be assigned to fireworks articles for their maritime transport.

UN number	Designation	Division	Packing 4.1.4.1
0333	Fireworks	1.1G	P135
0334	Fireworks	1.2G	P135
0335	Fireworks	1.3G	P135
0336	Fireworks	1.4G	P135
0337	Fireworks	1.4S	P135

Table 3

Packaging must comply with the General provisions of 4.1.1 (holding of shock to the usual demands on transport, packaging must not react dangerously with dangerous goods ….) and 4.1.3 (Special packing provisions) as well as the provisions particular relating to the packaging of goods of class 1 mentioned in Chapter 4.1.5 of the IMDG code.

Packing instruction P135 shows the type of internal and external packaging that are allowed for maritime transport.

Segregation of materials in the containers

Incompatible materials must be separated from each other. Two materials or objects are considered incompatible when their stowage joint can cause excessive risks in the event of a leak or spill or other accident.

This segregation may be obtained by separating incompatible materials in accordance with certain distances between dangerous goods or by requiring the presence among them one or more steel bulkheads or one or more steel bridges, or a combination of both. The intermediate spaces between these dangerous goods may be filled by another compatible with hazardous materials concerned cargo.

The G and S compatibility groups can be loaded in the same container. Segregation rules concerning the loading of the fireworks in a container together with other dangerous goods is not permitted for divisions 1.1, 1.2, 1.3 because the words "away from" are not listed in the table of contents separation for any class, nor in the list of dangerous goods.

On the other hand, as a general rule, non-dangerous goods can be loaded together with fireworks. Beyond regulatory IMDG, type of packing preferred is proposed below.

Maximum quantity in a container

Aiming at limiting the overpressure effects of Fireworks Division 1.1 :

To limit the overpressure effects, it is necessary to limit the quantity of products counted as net mass of explosives. If the fireworks container is surrounded by empty containers on each of its six sides, this corresponds to take a distance effect of 2.40 m (width of a container) and from the formula $0.5\ Q^{1/3}$ it comes that the appropriate net weight limiting quantity for such a distance is Q = 110 kg.

Limiting the thermal effects of Fireworks Division 1.3 :

To limit the heating effects and if we limit the container loaded of fireworks by empty containers on each of its six sides, this corresponds to take a distance effect of 2.40 m (width of a container), and from the formula $0.22\ Q^{1/2\ \mathrm{to}}$ it comes that the appropriate net weight for such a distance is Q = 118 kg.

To limit the Fireworks Division 1.3 behaviour to thermal effects, it is recommended to load the container at half of its overall capacity. A full load of the container could lead to a division 1.1 with mass explosion behaviour and overpressure effects. Tests that confirm this statement were performed by CHAF (quantification and Control of the Hazards Associated with the transport and Bulk Storage of Fireworks)

- on a 20 feet container containing 4 tons of 1.3G fireworks. A loud bang was observed with overpressure effects.
- Containing 2 tons of 1.3 G fireworks with results limited to fire, and thermal effects. Test videos are online www.chaf.info site.

We recommend the following combinations based on divisions with an indication of the maximum loading. The total quantity in net mass of fireworks by container 20 feet does not exceed 2 tons if containing 1.1G or 1.2G or 1.3G products (to multiply by 2 for 40 feet containers).

Loading	Division	Maximum per load (net weight of pyrotechnic composition)
Loading type 1	1.1G	Maximum 110 kg to avoid overpressure effects if surrounded by empty containers
	1.4G and/or 1.4S	1890 kg Or more if 1.1G is less than 110 kg
Loading type 2	1.3G or 1.2G	< or equal to 2 tons max
	1.4G and/or 1.4S	The remaining according to the quantity of 1.3G or 1.2G, until 2 tons max.

Table 4

Types of packaging preferred

To avoid any movement of substances of class 1 inside the ship, storing packages in containers is an important element which will help limit unwanted event occurrences

- Big size rockets should not be arranged in parallel rows inside the packages, but tumbled and layered perpendicular (to be sure all rockets heads are not located near each other)
- Density of active material in boxes must be limited to 35 kg/m^3 for the most sensitive fireworks (low confinement and high vivacity) and 90 kg/m3 for less sensitive fireworks (high confinement and medium vivacity), which determines the fill factor mass of active material (with the boundaries of the table above)
- Spherical form fireworks (bombs, maroons) should be strictly compartmentalized with a housing for each fireworks, so that they cannot move and this also help to comply with the permitted maximum density
- The fuses must be protected by a cover and arranged to avoid friction
- The most sensitive fireworks may be transported either by bringing together and coping with non-propagation distances or by mixing with low sensitive fireworks (very high confinement and low vivacity) boxes or boxes filled with inert elements which may be considered as elements of bulkhead, or by using compartmentalized containers.

Permissible amount of fireworks on a container ship

No limit appears in the IMDG[2] about maximum quantities of dangerous goods that can be embedded on a ship that has less than 12 passengers.
Limitation of the quantities of fireworks to load the container door therefore comes from ;

- Restrictions on the limited quantities of explosives for temporary parking on land, which can be different in each harbour and ship loading docks
- The ship document of compliance
- The Dangerous Goods loading plan and safety distances corresponding to segregation rules as well as the distribution loads and stowage categories.

REGULATIONS FOR LOADING FIREWORKS IN A CARGO SHIP

The table below lists, for each UN numbers that can be assigned to fireworks, the stowage category allowed to ships having on board a maximum of 12 passengers.

UN Number	Designation	Division	Stowage category	Meaning
0333	Fireworks	1.1G	Category 7	In closed containers above or below deck
0334	Fireworks	1.2G	Category 7	In closed containers above or below deck
0335	Fireworks	1.3G	Category 7	In closed containers above or below deck
0336	Fireworks	1.4G	Category 6	In closed containers above or below deck
0337	Fireworks	1.4S	Category 5	In closed containers above or below deck

Table 5

In addition to these requirements, the IMDG lays down the following stowage provisions for class 1:

- With the exception of goods Division 1.4, the class 1 goods must not be stowed on the rank the more outdoors,
- The class 1 goods must be stowed in a fresh portion of the ship and kept cool as far as possible while they are on board,
- They must be at least 3 m from any source of heat.
- Compartments where they were strapped under deck must be dry.
- Containers should be loaded and stowed securely to prevent moving during transport.
- The class 1 goods must be stowed as far as possible of the accommodation zone and machinery rooms and must not be stowed directly above or below these premises.
- They must be separated from those premises by a metallic partition.
- Divisions 1.1, 1.2, 1.3 must not be stowed within 3 m of bulkhead. Idem on the deck, they must be stowed at 3 m from the vertical projection of the houses.
- The class 1 goods must not be stowed in a horizontal distance of less than 6 metres of any fire, machines, kitchens, ventilation ducts, exhaust pipes of any other source of ignition.
- These goods must always be stowed so as to not clutter up passages and be at least 3 m from all facilities necessary for safe operation of the ship and at least 8 m from gateway and salvation craft.
- As a general rule, cables and electrical equipment must not be installed in the compartments to hold class 1. If they are present, however they must be isolated from the power source in order that no part of the circuit located in compartment is powered.
- A lightning protection must be installed.
- Compartments must be locked.
- Instructions must be given to freight operators on the possible risks that may be presented by the class 1 goods and related necessary precautions.
- Containers loaded with fireworks from different divisions can be transported together in a same compartment and next to each other in deck because groups G and S compatibility allow it.

Figure 5: Containers above and below deck

Protection against fire

It is possible to intervene as soon as a fire event starts, if the fire fighting means are available and if it begins far from the explosive products. Regardless of the outcome of this original intervention that must keep of short duration, one must then evacuate. Generally, it is recommended not to intervene on a pyrotechnic facility on fire but;

- to alarm, to warn the crew and to evacuate the area concerned or neighbour of the place of the disaster
- to go away as soon as possible of the area and go to a rally point
- In any case, staff members don’t have to fight a fire of explosive products. Only provisions to avoid a possible extension of the fire can be taken. Where this extension cannot be prevented, the secure zone must be maximized

Pyrotechnic products decompose without additional oxygen carrier from outside their formulation. This is what differentiates them with ordinary combustibles like oil and other flammable products; in addition they continue to react the same way under water which can sometimes even be a factor worsening if there is presence of fine metal powders.

Water can be effective on small amounts of explosive products, in the case of a workshop for example but not in case of a storage fire. Water can also play a shield role so that the intervention teams specially equipped to intervene to save people; it also allows you to cool the surrounding installations to avoid rapid extension of the fire.

History has also shown that even if the fire appears to be mastered, extreme caution is still needed to allow for enough cooling time and be ready to cope with side reactions like cook-off (initiation and violent breakdown of neighbouring explosive products by slow heating).

Automatic (sprinklers or inert gases such as CO2) fire extinguishing systems are not effective on fireworks in boxes in a container, the fire may smouldering and pyrotechnic compositions do not need oxygen to work.

Only a complete flooding of the fireworks can be effective, which is possible in a cargo ship but very long compared to the reactivity of a fireworks fire, once detected.

CONCLUSIONS IN TERMS OF SAFE PRINCIPLES FOR TRANSPORTATION OF FIREWORKS ON A CARGO SHIP

Recommendations target both filling fireworks in maritime containers and container loading and stowing on the container ship.

1/ proceed to **pertinent fireworks classification regarding Transportation of Dangerous Goods**: the first recommendation concerns the classification of the fireworks. The only way to get a secured classification is asking to the sender the risk division of fireworks issued by the transmitting competent authority (which is for the time being only required by the ADR and not by the IMDG).

2/ **limit the quantities**: the second recommendation is then to limit the quantities loaded to limit the effects in the event of accidental scenarios,

3/ select **an adequate packaging**: the third recommendation is to ensure the quality uploads by choosing a type of packaging adapted to avoid moving material goods during stowage. These actions will help to reduce the probability of an accidental event and therefore limit related risks.

4/ make use of suitable **containers**: a possibility is to use containers with fire walls able to contain a Fireworks fire. To our knowledge, there are no such containers that are in current use for maritime transportation, this type of fire resistant container is however in use for the storage of dangerous goods.

5/ define **a safe position for stowage fireworks containers on ship**: in order to limit the thermal effects, we recommend to position the fireworks containers onside the deck and far from accommodation areas, and enclosed as far as possible with empty containers to limit the spread of the thermal effects (or to use special containers). Another possibility is the stowage below deck inside the first dock, if equipped with a rapid flooding system and fire detectors (inside containers).

REFERENCES

[1] Chapman, D., CHAF project report, 2006.

[2] IMDG, §2.1.3.5.5 fireworks default classification

[3] Sub committee of experts for dangerous goods transportation, 35th session, Geneva, 22-26 June 2009, point 2 of the Agenda: “Information to be delivered on the DG transportation document in case of fireworks”

[4] Recommendations on the Transport of Dangerous Goods, Model Regulations - Sixteenth revised edition, ST/SG/AC.10/1/Rev.16

[5] Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria - Fifth revised edition, ST/SG/AC.10/11/Rev.5