EMSA

European Maritime Safety Agency

Technical Report

Safe Platform Study

Development of vessel design requirements to enter and operate in dangerous atmospheres

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1. Summary

The objective of this project was to propose and describe vessel design requirements to enter hazardous environments and having the capability of performing various operational aspects during Hazardous and Noxious Substances (HNS) incidents at sea, whilst protecting their crew and preventing an escalation of the incident. This also covers the adaptation/modification of existing vessels for HNS incident response.

The report has considered four broad areas namely:

- Identification and Analysis of the Risks associated with HNS Incidents
- Identification and Analysis of Sources of Information
- Response operations to be considered
- Development of Vessel Design Requirements.

The study has found that vessels need to be equipped to operate in a range of scenarios in order to provide a safe platform for the responders and any crew from the vessel involved in an incident.

In order to define the risks, a zone system has been utilised which indicate high, medium or low levels of risk to the responding vessel. Operation in the high risk zone which is in direct contact with any released HNS requires not only a clear understanding of the risks by the responding vessel crew, but also more robust protection measures to ensure a safe platform. Within each zone the amount of protection and design changes required for vessels to provide the safe platform function varies with the most stringent required in the high risk zone.

The hazards identified have been grouped into 5 main types to which the vessel design requirements have been devised to enhance the safety of the responding vessels. These hazard groups are:

- Flammable / Explosive Leak
- Fire
- Health Hazard / Toxic
- Cryogenic / Gases under pressure
- Corrosive.

Four types of vessel response have been identified as being appropriate to manage HNS incidents which have been mapped onto the hazard groups depending on their intended function within the response scenarios.

The worst case scenarios have been used to derive the design requirements to ensure that whenever the official response vessel arrive on scene to begin operations they have the maximum amount of protection both for their own crews and to prevent an escalation of the incident by introducing for example an ignition source in to a potential explosive atmosphere.

The identified design requirements have been based on the International Maritime Organisation's (IMO) concept of Goal Based Standards (GBS), which allows flexibility in complying, which is considered important given the range of vessels and their existing configurations.

2. Introduction

2.1. REPORT STRUCTURE

This Chapter of the report gives the overview of the project. Chapter 2 discusses the definition and assessment of Hazardous and Noxious Substances (HNS) incidents and response operations to set the scene and put the subsequent ship design requirements in context. Chapters 3 through 10 provide design requirements for the identified HNS scenarios. Chapter 11 discusses the range of vessel types which could potentially be constructed or modified to include identified design requirements and Chapters 12 and 13 provide a glossary and references respectively.

2.2. BACKGROUND

The European Maritime Safety Agency (EMSA) has been tasked in the field of marine pollution preparedness and response in European waters. With regards to HNS the Agency was further tasked by the adoption of the Action Plan for HNS to develop specific actions in the field of chemical pollution by ships, which are gradually being phased in and are further defined in EMSA's Annual Work Plans.

HNS are commonly transported by sea. Due to their hazardous nature the risks associated with HNS transport need to be carefully considered in the preparation of pollution preparedness and response plans. This task is particularly complex considering the large number of HNS currently transported in European waters. The broad definition of HNS (See Chapter 2) is applicable to a wide range of substances with very different properties and behaviours in the event of accidental release in water, making the preparation of substance specific response plans for all HNS impractical.

When a HNS incident occurs detailed information on the exact HNS involved may not be readily available, therefore pollution preparedness and response operations should cover the majority of substances. This broad range of substances results in complex pollution preparedness and response operations plans. Member States may need to invest in specific means at significant costs for responding to HNS incidents in order to be prepared for infrequent events and thus less visible to public opinion.

Considering the above, EMSA commissioned this project to develop vessel design requirements to enter into hazardous environments and perform various operational tasks during HNS incidents at sea. The vessel design requirements have been structured into categories based on the identified risks and the corresponding levels of response operations.

2.3. OBJECTIVE

The objective of this project was to develop and describe vessel design requirements to enter hazardous environments and have the capability of performing various operational aspects during HNS incidents at sea, whilst protecting their crew and preventing an escalation of the incident. This also covers the adaptation/modification of existing vessels for HNS incident response.

2.4. SCOPE OF WORK

Considering the objective of the project, the development of the vessel design requirements have been based on the identification of HNS incident risk scenarios and the analysis of existing relevant sources of information regarding vessel design requirements. The scope of this report concentrates on existing vessels which can be adapted or refitted for HNS incidents response.

The types of existing vessels considered within this project covers Emergency Towing Vessels (ETV), tugs, supply vessels, fire fighting ships, oil recovery ships and other suitable multipurpose vessels as appropriate.

2.5. METHODOLOGY

The project has broadly been carried out in four areas as follows:

- Identification and analysis of the risks associated with HNS incidents
- Identification and analysis of sources of information
- Response operations to be considered
- Development of vessel design requirements.

Each of these areas is discussed where appropriate within the report.

2.6. SCOPE LIMITS

The project addresses response operations during HNS incidents at sea. Certain response operations mentioned in this report (e.g. fire fighting, emergency towing etc.) although not included in EMSA's core mandate concerning marine pollution preparedness and response, are included for the purpose of comprehensiveness.

A range of options allow individual operators, ports or Member States to identify the most appropriate solution for their available resources to provide a response to a request for assistance. Even if the "ideal" solution is not possible for whatever reason there are other options available in order to provide a response.

Whilst the intention was to provide a number of options, the costing of those solutions was not part of the project.

The scope of work has considered the worst case scenarios by assuming that any responding vessel will arrive at a casualty vessel whilst the risk is at its most severe. It is understood that over time as an incident develops the risk may change and in many cases with the dispersal of the HNS the risk may reduce significantly. However the responding vessels are required to provide a safe platform in all incidents and assuming the worst case ensures they can fulfil that role.

This study is based on human health and safety and hence does not consider environmental issues directly although some of the response actions will have environmental implications but these were not regarded as the key drivers for the study.

Statistics have shown that 51% of accidents involved bulk liquid and solid substances, while 47% involving packaged goods transported in containers, drums etc., with 2% unknown (Reference 1). While this study focuses on bulk transportation, packaged goods make up a substantial number of HNS incidents and elements of this report will be applicable to HNS incidents involving both bulk and packaged substances.

2.7. DEFINITIONS

A glossary of definitions and terminology is provided in Chapter 13, however the following are considered key to understanding the discussion within the report.

Casualty Vessel Definition

> "A vessel which has suffered a HNS incident and requires external assistance."
>
> Note: This term is used rather than the term "Stricken Vessel" as this implies the vessel is incapacitated which may not always be the case.

Safe Platform Definition

> "A vessel which is able to provided rescue assistance and operational support during a HNS incident whilst still maintaining a place of safety for its crew, any additional response persons, and the crew of the casualty vessel once rescued"

3. Definition and assessment of HNS incidents

3.1. DEFINITION OF HNS INCIDENT SCENARIOS

In order to determine the level of design requirements needed for the vessels responding to HNS incidents in a safe manner, the potential hazards of the chemical substances present first needed to be understood.

3.2. HAZARDOUS AND NOXIOUS SUBSTANCES

To fully understand the scope and scale of the potential risks to both casualty and responding vessels a clear understanding of what is meant by a Hazardous and Noxious Substance is required. The OPRC-HNS Protocol definition (Reference 2) which is also used in the EMSA HNS Action Plan (Reference 3) is used in this reports which is:

> "Any substance other than oil which if introduced into the marine environment is likely to create hazards to human health to harm living resources and marine life to damage amenities or to interfere with other legitimate uses of the sea"

To further expand on the definition HNS covers a wide range of items in a variety of forms which may be carried as cargo in both bulk and packaged HNS, therefore it includes dangerous goods (also called Hazardous Materials or HazMat) such as solids, liquids, or gases that can harm people, other living organisms, property, the environment, or the carrier; materials that are flammable, explosive, corrosive, oxidizing, asphyxiating, bio hazardous, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances.

It should be noted that for the purposes of this study radioactive materials are not considered.

3.2.1. Identification and Analysis of Sources of Information

To provide a sound background for the identification and analysis of potential incidents related to HNS a wide range of documentation and sources of information have been reviewed for their applicability and value to the overall aims of the project. The documentation used has been limited to those available in the public domain.

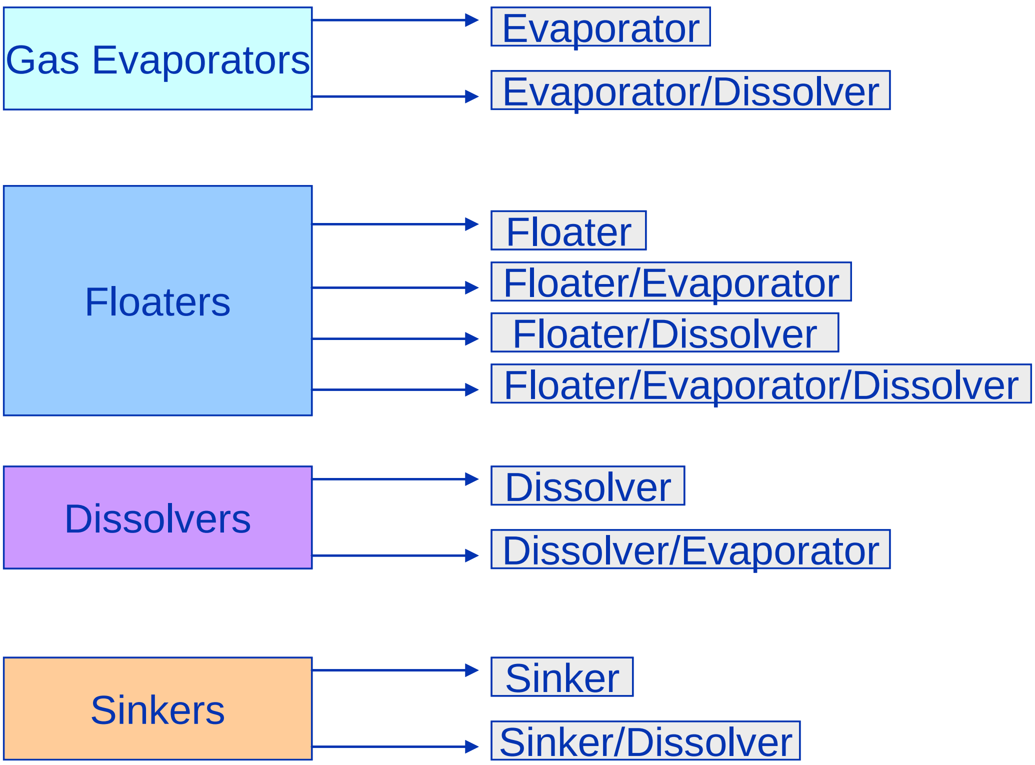
Considerable duplication, and in some cases conflicting information was identified during the research. This report is compiled from the sources of information considered most appropriate by the authors, in agreement with EMSA. Details of typical documentation reviewed are included in the bibliography in Appendix 1 and those used to develop this report are referenced as appropriate in Chapter 14.

The review of information was used to determine a common starting point for the assessment of design requirements which may be appropriate for responding vessels to incidents on a vessel carrying HNS cargo.

3.3. RISKS & IMPACTS

In order to assess the risk and impact of any given incident scenario, the behaviour characteristics of the chemical substances are also being reviewed. Chemical substances can be divided into four major behaviour categories, gas evaporators, floaters, dissolvers and sinkers and their sub categories, according to the European behaviour classification system which was initiated within the framework of the Bonn Agreement in order to classify chemical substances according to their physical behaviours when spilled into the marine environment (see Figure 1).

Figure 1: Chemical behaviour categories (Reference 3).



The chemical fate of any potential substance spilled into the sea greatly contributes to the level of risk and the impact that it may have to the crew members of both the casualty and the responding vessel. The degree of response and rescue measures will highly rely on the spill or release impact to human health and safety and may change over time. For example incident scenarios involving highly volatile substances that quickly evaporate will have reducing risk levels over time compared to other potential scenarios involving HNS that resist dispersion for a prolonged period of time, therefore maintaining risk levels for longer. Figure 2 shows examples of how some substances fit into this scenario.

Figure 2: Examples of chemicals in the different behaviour groups.
G = Gases; E = Evaporators; F = Floaters; D = Dissolvers and S = Sinkers,
Source: Helsinki Commission (HELCOM), manual on Co-operation in Response to Marine Pollution (Reference 4).

	Group	**Properties**	**Examples**
Evaporate Immediately (Gases)	G GD	Evaporate immediately Evaporate immediately, dissolve	Propane, butane, vinyl chloride, ammonia
Evaporate Rapidly	E	Float, evaporate rapidly	Benzene, hexane Cyclohexane
	ED	Evaporate rapidly, dissolve	Methyl-t-butyl ether Vinyl acetate
Float	FE FED	Float, evaporate Float, evaporate, dissolve	Heptane, turpentine Toluene, xylene Butyl acetate Isobutanol Ethyl acrylate
	F FD	Float Float, dissolve	Phthalates, vegetable oils, animal oils, dipentene, isodecanol Butanol, Butyl acrylate
Dissolve	DE	Dissolve rapidly, evaporate	Acetone, monoethylamine Propylene
	D	Dissolve rapidly	Some acids and bases, some alcohols, glycols, some amines, methyl ethyl ketone
Sink	SD	Sink, dissolve	Dichloromethane 1.2-Dichloroethane
	S	sink	Butyl benzyl phthalate, chlorobenzene Creosote, coal tar Tetreethyl lead, tetramethyl lead

The project was also aware of the need to and take levels of risk to health into account as far as possible, for example the health risk from spillage of chemicals as shown in Table 1.

Table 1: Estimated extent of the health risk in the downwind direction for different quantities of gases spilled (Reference 5).

Quantity Released in tonnes	Health Risk	
	Ammonia, chlorine, ethyl chloride, vinyl chloride	Butane, butadiene, ethylene, LPG, methane (LNG), propane, propylene
	metres	metres
0.1	1000	200
1	2000	400
10	5000	1000
100	10000	2000
1000	20000	4000

3.4. HAZARD IDENTIFICATION AND RISK ASSESSMENT

3.4.1. Method

A review of documents available in the public domain was used to identify:

- HNS incidents which have occurred
- Safety requirements for vessels carrying HNS
- Discussion with people experienced in HNS transportation.
- Details on hazards posed by various types of cargo
- Initial rescue scenarios to provide assistance to a casualty vessel.

Using the outcome of the above, as a preliminary Hazard List, a Hazard Identification and Risk Assessment workshop was held with people experienced in shipping, class rules, emergency response methods and equipment. This was subsequently reviewed by salvage experts.

The workshop used Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures, which is based on the United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS). This followed discussions with EMSA at an interim meeting and the identification of the complexity of variations in available documentation.

The output of the workshop was a hazard record sheet which was subsequently risk assessed to determine the current mitigation in place and the residual risk to any vessel attempting to provide assistance to the casualty vessel. Once the current risks were understood the team moved on to identify potential additional mitigation which would reduce the risks to responding vessels.

The identified potential mitigation measures were then taken forward to drive the development of design requirements for responding vessels. The design requirements have been developed in line with the IMO concept of Goal Based Standards (GBS) which are discussed further in context with the design requirements in Chapter 3.

When the design requirements had been determined, to a suitable level, the risks were re-assessed to determine the effect of the new mitigation provided by the designs would have. This allowed a clear understanding of the benefits, or otherwise, of each design suggestion to mitigate the risks. As a result combinations of mitigation measures could be considered in the context of the risk posed by the hazards.

Appendix 2 provides the completed Hazard Identification and Risk Assessment Sheet and Appendix 3 the criteria used to make the Risk Assessments.

3.4.2. Broad description of Hazards

Classification of hazards for the purposes of defining the hazards of HNS incidents and the development of scenarios and design requirements for responding to an incident was based upon the CLP regulations. Hazards under this regulation are divided into three parts: physical hazards, health hazards and environmental hazards as outlined in Table 2.

Table 2 CLP regulations classification of hazards

Physical Hazards	**Health Hazards**
Explosive	Acute toxicity
Flammable Gases	Skin corrosion / irritation
Flammable aerosols	Serious eye damage / eye irritation
Oxidizing gases	Respiratory or skin sensitization
Gas under pressure	Germ cell mutagenicity
Flammable liquids	Carcinogenicity
Flammable solids	Reproductive toxicity
Self-reactive substances and mixtures	Specific organ toxicity – Single exposure
Pyrophoric liquids	Specific target organ toxicity – Repeated exposure
Pyrophoric solids	Aspiration hazard
Self-heating substances and mixtures	
Substances and mixtures which, in contact with water emit flammable gases	
Oxidizing liquids	
Oxidizing solids	
Organic peroxides	Environmental Hazards (Out of Scope)
Corrosive to metals	Acute toxicity / Chronic toxicity

Based on the CLP hazard categories, the level of risk to responders to HNS incidents was assessed as detailed in the risk assessment (Appendix 2). This formed the basis of developing generic hazard categories based on type of hazards statements listed (explosive, flammable gas, heating may cause fire etc.) across the CLP categories and level of associated risk (orange and red). This produced broad hazard categories reflecting those currently used in the industry and identified through the document review, which were considered at an appropriate level to developed HNS scenarios and design requirements for responding to HNS incidents.

With the exception of environmental hazards, which are out of scope for this project as the risk to marine environment is not included and flammable aerosols which are not carried in bulk and not assessed as part of the risk assessment, the defined hazards are shown in Table 3 in comparison with the applicable CLP hazard classes.

Table 3: Defined hazard classes for development of HNS incident scenarios and corresponding CLP hazard classes.

Defined Hazards	CLP Hazard Class	
Explosive	- Explosives - Gases under pressure - Self-reactive substances and mixtures	- Oxidising liquids - Oxidising solids - Organic peroxides
Flammable	- Explosives - Flammable gases - Oxidizing gases - Flammable liquids - Flammable solids - Self-reactive substances and mixtures - Pyrophoric liquids	- Pyrophoric solids - Self-heating substances and mixtures - Substances and mixtures which, in contact with water emit flammable gases - Oxidizing liquids - Oxidizing solids - Organic peroxides
Cryogenic	- Gases under pressure	
Corrosive	- Corrosive to metals	- Skin corrosion/irritation
Toxic / Health Hazard	- Acute toxicity, - Skin corrosion/irritation - Serious eye damage/eye irritation - Respiratory/skin sensitization - Germ cell mutagenicity - Carcinogenicity	- Reproductive toxicity - Specific target organ toxicity – single exposure - Specific target organ toxicity – repeated exposure - Aspiration hazard

MEPC/OPRC (Reference 6) outlines three commonly used classifications of HNS spill response including: physical hazard (e.g. IMDG-code); reactivity; and physical behaviour. The broad hazard categories developed from the CLP regulations align with the first two classification methodologies, however the physical behaviour of HNS is only accounted for in the final hazard categories and is therefore no longer visible in the categories defined in this report.

The third reported methodology is by physical behaviour, namely their chemical behaviour in the event of a spillage into the aquatic environment as outlined in Figure 1 and Figure 2. This approach is widely used to aid emergency response by various regional agreements (Reference 6) including:

- The Helsinki Commission (HELCOM) – Governing body for the "*Convention on the Protection of the Marine Environment of the Baltic Sea Area*";
- BONN Agreement – A mechanism by which North Sea States combat pollution in the North Sea Area; and

- The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) - Cooperation in preventing pollution from ships and combating pollution of the Mediterranean Sea in emergency situations.

The GESAMP hazard profile approach (Table 4) has been considered as providing a straight forward and relevant mechanism for the prioritisation of emergency response to HNS (Reference 7). The GESAMP Human Health (Toxic Effects to Mammals) in Columns C & D aligns to defined scenarios in this project. The physical behaviour of substances (e.g. evaporates, floats, sinks) are included in Column E in the GESAMP hazard evaluation. While important in HNS response the physical behaviour of HNS leads to the same hazard identification as defined in this Chapter and has therefore not been factored into hazard classification or scenarios and ultimately the hazard classification would remain unchanged and it is important that response options are simplified as far as possible (Reference 8).

Classification of HNS incidents by physical behaviour provides useful information on their chemical behaviour in the event of spillages in the aquatic environment. However, without an associated hazard classification, taking the physical behaviour of HNS into account would ultimately not modify the hazards to responders of HNS incidents as defined in this chapter. For this reason physical behaviour of HNS has not been factored into the hazard classification or scenarios as it would remain unchanged and it is important that response options are simplified as far as possible (Reference 8).

Table 4 GESAMP hazard evaluation vs. hazard classification (Reference 9).

GESAMP		Hazard (Scenario)
Columns A & B	Aquatic environment	Out of Scope
Columns C & D	Human Health (Toxic Effects to Mammals)	Toxic / Health hazard
Column E	Interference with other users of sea	Limited Scope

3.5. REDUCING RISKS TO RESPONDERS ON “SAFE PLATFORMS”

The Hazard Identification and Risk Assessment teams identified during the workshop a number of potential mitigating actions. These mitigations relate to response actions or to the incorporation of design feature into new vessels or modification of existing vessels. Appendix 2 gives specific details, but the key mitigations are:

1. Avoidance of the hazardous areas with the preference being to remain in a safe area as much as possible with limited time as necessary to recover casualties in higher risk areas with entry into extreme risk only in exceptional circumstances. (See Chapter 2.7.3 for discussion on safety zones termed Zones L, M and H).
2. Addition of fire fighting equipment for self-protection and for assisting the casualty vessel.
3. Provision of pressurised accommodation/areas in the responding vessel to protect from harmful gas and vapour releases from the casualty vessel.
4. Provision of medical facilities on the safe platform and medical evacuation infrastructure.
5. Provision of decontamination facilities to casualties including decontamination of any response teams embarked onto the casualty vessel or deployed in potentially harmful areas.

Discussion with various experts in the field of providing responses to incidents identified the need for clear command and control of the response to incidents to minimise the need to enter hazardous areas which was acknowledged as being the option of last resort.

This report provides information on design requirements for vessels which allow them to respond to an incident and to give an indication of the level of protection the designs afford them in terms of approaching and potentially entering hazardous areas resulting from an HNS incident.

3.6. HNS INCIDENT SCENARIOS

Based on the potential hazards identified for HNS incidents outlined in Chapter 3.4.2, incident scenarios involving HNS can in effect be summarised into 5 key response scenarios as follows:

- Flammable / Explosive Leak
- Fire
- Health Hazard / Toxic
- Cryogenic / Gases under pressure (including LNG/LPG)
- Corrosive.

Each of the above scenarios may involve

- Rescue Operations
- Clean Up / Recovery of HNS Cargo.

The selection of these scenarios is supported by Table 5 which shows the top 100 substances transported classified by UN / IMDG Code Class and Divisions which are fully covered by the scenarios developed in this project ensuring they reflect potential HNS incidents, based on the actual substances being transported.

Table 5: UN / IMDG classes for the top 100 substances transported (Reference 6) compared to HNS Incident Scenarios

IMDG Class		No. of substances	Total quantity transported (tonnes)	HNS Incident Scenarios
2.1	Flammable gases	6	1,509,813	Flammable / Explosive Leak Fire
2.3	Toxic gases	1	1,180,241	Health Hazard / Toxic
3	Flammable liquids	35	25,691,792	Flammable / Explosive Leak Fire
4.1	Flammable solids, self-reactive substances and desensitized explosives	1	196,741	Flammable / Explosive Leak Fire
5.1	Oxidizing substances	1	209,523	Flammable / Explosive Leak Fire
6.1	Toxic substances	10	1,878,016	Health Hazard / Toxic
8	Corrosive substances	8	5,388,446	Corrosive
9	Miscellaneous dangerous substances and articles	1	56,050	

		37	15,577,587	N/A
	Totals	100	51,688,209	

Due to the nature of the potential range of cargos carried and their potential interactions with other cargo and the environment, there will be combinations of the above and few scenarios can be considered mutually exclusive. As a consequence it is not feasible to develop scenarios for every conceivable eventuality.

All potential incidents can however be grouped into the broad hazard categories above when considering safe platform design criteria. Responsible authorities will need to take potential combinations into account when selecting appropriate response vessels and their capabilities.

The high level scenarios are provided in Appendix 4 and where cargos have the potential to fall into more than one scenario then the appropriate scenarios should be read in conjunction with each other.

Chapter 11 provides a summary of the scenarios and the designs appropriate for each.

3.7. RESPONSE OPERATIONS

3.7.1. Discussion

Response operations are by their very nature reactive and no two incidents will be the same. The response of the Member State authorities to any HNS incident will have to be flexible to meet a wide range of potential situations. A number of documents reviewed support this position as discussed in the following paragraphs.

It is clear from Cefas (Reference 7) that they consider HNS a high risk for emergency response due to the wide range of variation in the way HNS may interact with the marine environment and with other HNS substances in comparison with oil, which leads to uncertainty as to the most appropriate response. They indicate that exclusion zones (effectively the Zone H used in this report) and operational responses to manage the incident need to fully understand the potential challenges which include factors such as type of hazard, time, location, substance characteristics and quantity. Therefore the design factors discussed in this report have to be somewhat generic in order to cover a broad and variable range of potential incidents.

Sound knowledge of the HNS characteristics are required to ascertain the long term effects of a spill and assist in decision making relating to the recovery and management of the impact of an HNS incident.

Early in the project it was acknowledged that given the large assortment of HNS substances and their associated harmful effects, plus the potential combinations of substances, if more than one substance type were transported at a time a similarly large range of responses may be necessary.

It was therefore identified that a “perfect” response solution for all incidents was unlikely to be possible using a single vessel. Taking this into account the project has considered the following:

- Concept to be used for defining the vessel design requirements – This considers realistic designs and identification of where differing levels of design may be appropriate for various types of vessel.
- Consideration of vessel types to be refitted – This considers what potential additions could be made to existing vessel types to allow them to provide some degree of

response. This accepted that some vessels may not be able to carry significant amounts of equipment or personnel but could still provide an acceptable level of response.

The project team has identified that there is always a level of response which can be provided although it may not be considered the optimum solution and the masters of any vessels responding to a request for assistance from a casualty vessel will remain responsible for the safety of their vessel and its crew.

3.7.2. Initial Response

The scenarios developed within this report all have a number of common themes as discussed below:

1. The first vessel to arrive at the location of the incident will in all probability be Vessels of Opportunity which we have defined as being:

> "Any vessel in the vicinity of the casualty vessel which may be able to provide assistance but is not formally part of the responsible authorities official response plan"

2. Vessels of opportunity are unlikely to have any of the dedicated design functionality described in the following Chapters, but are still worthy of recognition as they may be the only assistance available at short notice.
3. No Master of a vessel will knowingly place their vessel or crew in harm's way except in exceptional circumstances.
4. If there is a known release from the casualty vessel be it smoke, vapour or gas no Master of a vessel, including specialised response vessels and the Safe Platforms considered in this report, will knowingly enter such an area except in exceptional circumstances when there is no other avenue of approach to the casualty vessel.

Masters of responding vessels will always attempt to approach the casualty from a safe direction which minimises risk to their own vessel and minimises the possibility of making the incident worse.

3.7.3. Safety Zones

To enable determination of the response vessel requirements a three zone system has been used. This allows a range of options in providing response to a HNS incident taking into account the potential risks and the vessels which may be available to an authority.

The three zones have been designated High (H) Medium (M) and Low (L) and relate to the level of risk respectively, with H being the highest and is considered to be closest to the source of the HNS incident and hence risk as shown in Figure 3 and Figure 4 and defined in Table 6. H, M and L have been used as 1, 2, 3 etc., are used in other documents relating to regulations and the use of similar terms may prove confusing.

Figure 3 Simple diagram of the zone principle with the casualty vessel and the main location of potential HNS in the centre.

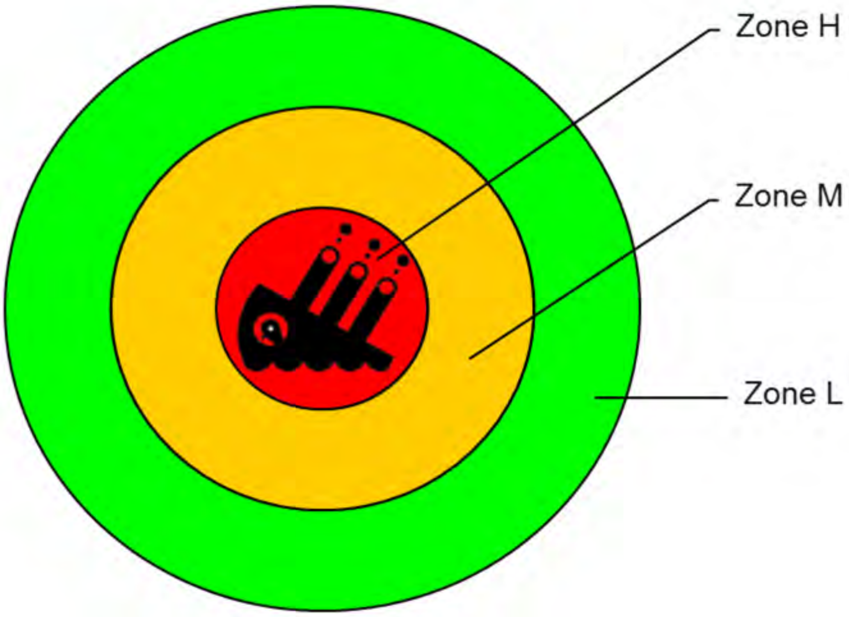


Figure 4 This shows a more realistic view of the zones taking into account wind dispersal of the released HNS substance from the casualty vessel. This could equally represent the effects of tide on substances floating on the surface. Combinations of wind and tide and other factors may give a similar scenario.

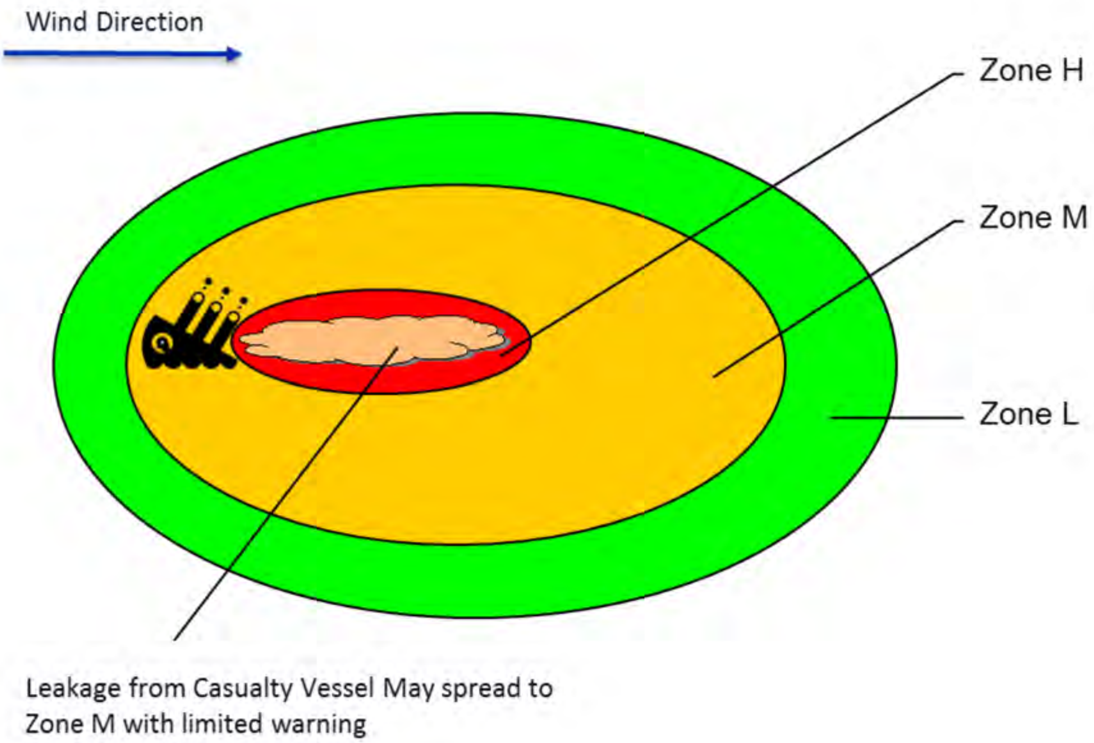


Table 6 Definitions of the Zones

Zone	Definition
H	High Risk - Zone of highest risk requiring significant protection to be provided to prevent escalation of an incident and to provide maximum protection to both the crew of the responding vessel and the casualty vessel. This Zone will cover the immediate area of any smoke, vapour or gas cloud from the casualty vessel out to the maximum radius the cloud is expected to spread. Its width will depend on the lateral spread of the cloud.
M	Medium Risk - Zone where the risk to the responding vessel is possible if environmental conditions (wind, tide etc.) change and the vessel is unable to manoeuvre to reduce the risk due to on-going response activities. This Zone will potentially surround the casualty vessel to a diameter equal to Zone H to take account the worst case 180º change in wind direction.
L	Low Risk - Zone of lowest risk where the likelihood of injury to the responding vessel crew is extremely low and only considered possible if a significant change in environmental conditions (Wind, tide etc.) occurs which cannot be countered by the vessel manoeuvring out of harm's way.

3.7.4. Zone Dimensions

The size of the zones will depend on specific incidents to which vessels are responding and will therefore need to be reactive to the level of risk presented by each incident. The HELCOM Response Manual Volume 2 (Reference 4) gives some indications as to distances which may be used and could form the basis for the proposed zone H. Table 7 gives examples from HELCOM to provide an indication of the potential scale of incidents. It is not intended to be used as a reference for managing incidents, which should as previously discussed be based on the actual incident and the hazard presented by the cargo.

Table 7[1] Examples of safety distances taken from HELCOM.

Incident Type (Hazard)	Example Substance	Safe Distance
Fire Risk	Hexane Methyl alcohol	100m
Explosion Risk	LPG (propane, butane) Ethylene	1000m
Fire Producing smoke	Hexane	100m from visible smoke
Fire Producing toxic smoke	Chlorinated hydrocarbons	100m from visible smoke
Hazardous vapours	Benzene	Point at which it is barely possible to detect gas by trace gas analysing devices
Liquefied gases that	LPG	4km for fire/explosion

[1] Warning: This table is an example only and should not be used as a definitive basis for a HNS response

gives off hazardous vapours	Ethylene	4 to 20km for health depending on substance. (based on 1000 tonnes release)

The dimensions of the zones will need to be decided by the responsible authority on a case by case basis to take into account the incident specific cargo and level of risk. Zone H could for example be aligned to established safe distance guidelines reported by HELCOM, or similar examples, with zone M covering the same radius from the casualty vessel but in all directions not directly under the influence of the escaping HNS, with Zone L being beyond that.

Responsible authorities will need to have access to experts on the specific type of cargo involved in the incident. Such experts will include but not be limited to gas, chemical and fire specialists. Therefore some form of HNS response structure will be required with clear lines of authority and responsibility for management of an incident.

It is not practicable in this report to give specific zone boundaries for the reasons already discussed.

Given differing types of incident it may, depending on the incident, be appropriate to combine zones M and L where there is a clear boundary to the hazard for example in the case of floating contamination where the extent of the risk can be clearly defined.

Any issues related to safe zones or the type of response to be provided will need to be made by the authority controlling the response and this overall procedural response is outside the scope of this study.

3.7.5. Types of Response Vessel

Four types of vessel response have been identified as being appropriate to manage HNS incidents which are:

- Vessel to approach (not to enter) and to monitor the incident area.
- Vessel to approach (not to enter) and deliver and recover response teams.
- Vessel to enter in hazardous environments, deliver response teams and rescue crew members.
- Vessel to enter in hazardous environments, deliver response teams and rescue crew members and recover hazardous substances.

These vessel responses can be mapped onto the zones described previously as follows:

Table 8 Vessel Response to Zone Mapping

Vessel Response		**Zone Applicability**
Type	**Description**	
1	Vessel to approach (not to enter zone M or H) and to monitor the incident area.	L (low risk)
2	Vessel to approach (not to enter zone M or H) and deliver and recover response teams and rescue crew members by deployment of boats into zone M.	L & M (low/Medium risk)
3	Vessel to enter in hazardous environments, deliver response teams and rescue crew members.	M & Limited H (Medium /high risk)

4	Vessel to enter in hazardous environments, deliver response teams and rescue crew members and recover hazardous substances.	H (high risk)

Type 1 vessels will only be required to operate in zone L where there is no hazard therefore they will not require protective or specialist equipment. Their function will normally involve monitoring the situation and potentially to act as on-site control providing area management in the locality of the incident, but remaining at a safe distance from the hazards.

Type 2 response vessels will as with type 1, remain outside the hazardous areas in zone L, but may deploy rescue boats into zone M to deliver response personnel or to recover crew members for the casualty vessel. In either case they may receive personnel contaminated with HNS or suffering from the effects. Hence these vessels will need to have some level of decontamination and medical facilities.

Type 3 vessels would have limited additional protection to allow them to operate in zone M and in emergencies or exceptional circumstances to enter zone H for brief period for example to pick up survivors from the casualty vessel then to immediately move out to the less hazardous zones.

Where vessel response Types 2 and 3 indicate the potential to operate in two zones, entry into the higher risk zone would assume that they remain out of the direct area of risk and out of the most likely direction of dispersal of the HNS. This should take into account their level of protection.

Type 4 vessels would have the highest levels of protection and would if required be able to operate for long periods in the high risk zone H. These vessels would in the majority of cases be either specifically designed for this role or have been modified to provide the necessary levels of protection appropriate to the incident scenario to which they are responding. Discussions indicate that this type of vessel whilst capable of prolonged exposure would in reality only enter the high risk zone when all other options have been explored.

The exact zone into which a vessel would be expected to enter would depend on the level of protection available and the level of risk posed by the incident as communicated by the responsible authority in the Member State. Issues relating to the level of protection are demonstrated by the example in Section 2.8.2.

3.8. RESPONSE TIME

3.8.1. Temporal and Spatial Considerations

When considering the types of response possible and hence the design requirements for vessel to provide those responses the temporal and spatial realities of an incident cannot be ignored completely.

If a vessel carrying HNS has an incident then as previously indicated the type and nature of the incident is likely to be specific to that vessel at the time it occurs and its location.

If an incident occurs on the high seas clear of land and the casualty vessel is in no immediate danger of running aground or being overwhelmed by weather conditions then as long as the crew can remain safe they are better served by remaining on-board as any transfer operation will increase the risk to such personnel. If a responding vessel has clear room to manoeuvre around the casualty vessel it should have no requirement to approach through zone H. In benign conditions it may also be possible to closely approach the vessel in what are effectively zone L conditions.

In contrast if the casualty vessel is close to shore in poor weather conditions and there is no room for the responding vessels to manoeuvre to a safer zone then they may be forced to approach in zone H to provide rescue or assistance which would require more self-protective measures or the ability provide assistance remotely using Fast Response Craft (FLC) or other craft or respond from a longer distance away.

3.8.2. Types of Response Operation

There are a number of response operations which may be required and the selection of the most appropriate vessel type and design capability will be critical in providing a comprehensive response.

Figure 5 gives a simple decision tree which is intended to assist the reader to follow the linking between the appropriate Chapters of this report in conjunction with the selection of the most relevant and capable vessels to provide a robust response to an incident with an example given in Table 9.

The vessels or vessels selected to respond to an incident will need to reflect the operations expected of them, which in turn requires an estimate of the zone (H, M or L) they will be expected to operate in, and hence the level of protection required to mitigate the risks in that zone for the type of incident.

Clearly any vessel could provide the function of a Type 1 vessel operating only in the low risk zone L so long as it had the necessary sea keeping capability for the location of the incident and sufficient communications equipment and situational awareness functionality to provide the monitoring role. This vessel may be one of the first to arrive on the scene and the role may be provided by a vessel of opportunity which responds to the casualty vessel's distress call. In this eventuality the first vessels(s) on the scene may not be "official" response vessels and may inadvertently place themselves in harm's way, hence the responsible authorities will need to ensure that a warning is given either by the authorities or the casualty vessel to any vessels of opportunity which respond.

Once a formal response is underway the responsible authorities will need to manage the incident in accordance with local response requirements.

Figure 5 Overview of Response Vessel Selection.

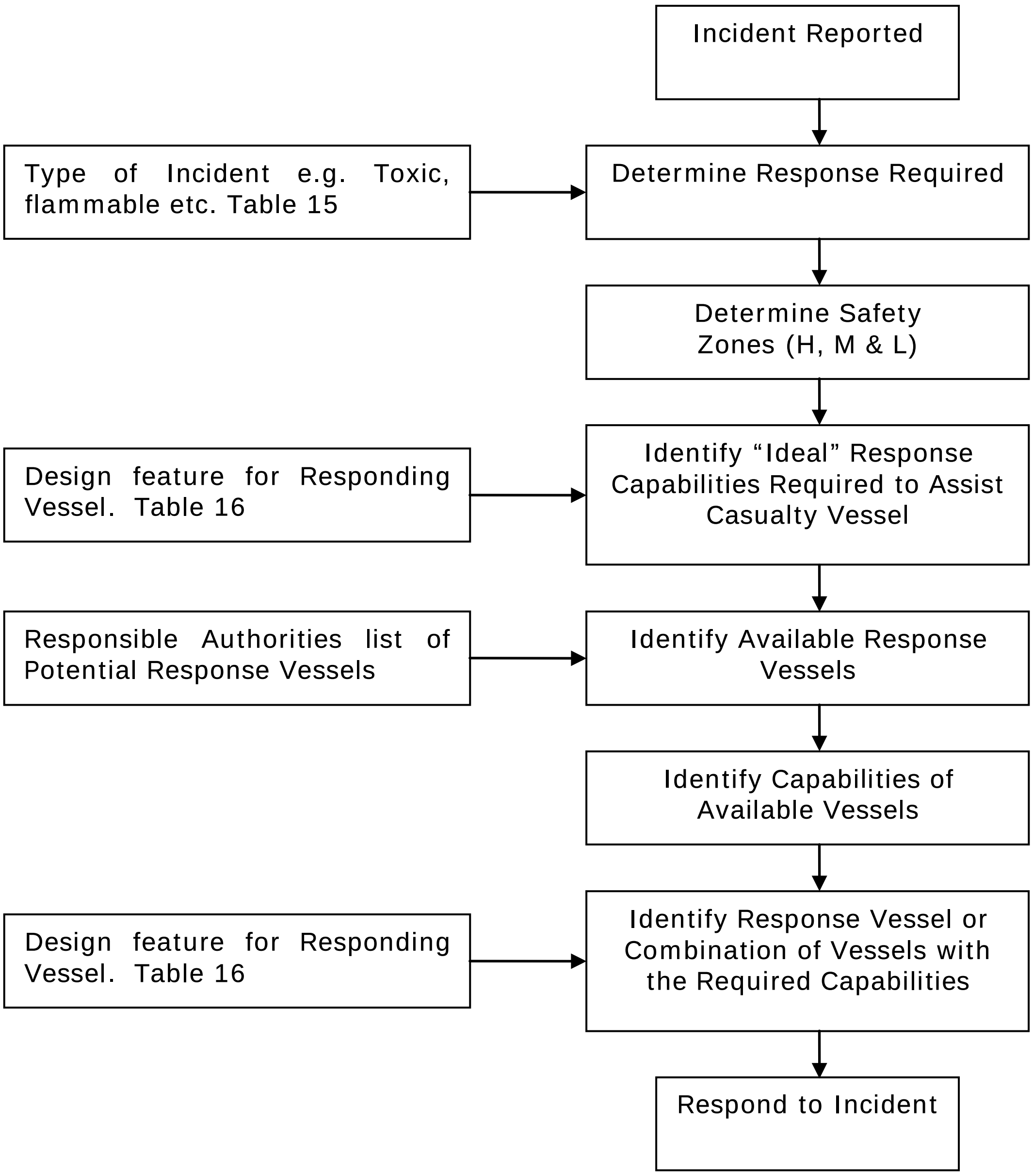


Table 9 provides an example of the process using the zones and vessel types described previously.

Table 9 Scenario Response Example.

Incident Reported:

A casualty vessel is releasing a toxic gas which has a similar density to air which in turn means it will expand and disperse in a uniform manner in the direction of the wind. The vessel has suffered a local failure and no other vessels are involved or at immediate risk. The vessel is 50 km from a Member State port in benign weather conditions. The vessel has requested stand by assistance as soon as possible. Currently the crew are attempting to manage the incident but the situation is not yet fully under control. At the time of the request the crew are not making preparations to evacuate the vessel but this may change if the incident cannot be brought under control.

Determine Response Vessel Required:

Due to the toxic nature of the escaping gas, a vessel is required which provides protection to the crew from the ingress of the gas into the vessel.

Determine Safety Zones:

Zone H will encompass the expected dispersal of the casualty’s cargo over time taking into account the properties of the substance based on expert advice and modelling where possible.

Zone M would be set up to surround zone H and cover an area sufficiently large to take into account potential weather condition changes based on the latest weather information.

Zone L would be set up outside of zone M and would expand outwards to a point where the responsible authorities consider “normal vessel traffic” can be allowed. If the risk is considered extremely low then normal vessel traffic potentially may be allowed to operate in the L zone.

Identify “Ideal” response vessel requirement:

The ideal vessel would be a Type 4 and have full gas tight protection for the responding vessel and decontamination and safe access into and out of the vessel for the recovery of casualties. This would allow the vessel to approach the casualty from any direction to take into account any manoeuvrability issues due to local obstructions or navigational hazards.

If this type of vessel was not available Type 3, 2 or 1 could be provided with reducing levels of protection but would require more local management to ensure they remained clear of the potential toxic substance.

Identify Available Response Vessels:

Member State records would be reviewed to identify the location of response vessels of any type which could provide assistance within a reasonable timeframe, determined by the responsible authorities, to assist the saving of lives.

Identify Capabilities of the Available Response Vessels:

The responsible authorities within the Member State with responsibility in the area in which the casualty vessel is located have three potential response vessels available from their database (or other records).

Vessel A is a small tug capable of reaching the casualty vessel taking into account the prevalent weather conditions but it has no protection against toxic environments;

Vessel B is a ETV which has a positive pressure system in the accommodation and other spaces but not a full gas tight citadel; and

Vessel C is a specially adapted vessel with full gas protection for the crew and response teams possibly a naval vessel or new build.

Vessel A cannot enter zones H or M as it affords no protection to the crew or responders and hence could only fulfil Vessel Response Type 1 or 2 and enter only zone L. It could therefore provide on scene coordination but is unlikely to be able to assist in the response further unless the casualty vessel crew use their own boats to transfer. Vessel A is closest to the scene of the incident and can be on station in 3 hours.

Vessel B could safely enter zone L and potentially enter zone M but would not be recommended for entry into zone H due to the level of protection available not being considered resilient enough. It could therefore fulfil vessel response Type 1 and 2 and possibly in exceptional circumstances Type 3 for limited periods. Vessel B is the furthest from the incident and would require longer time to activate than vessels A or C

Vessel C having a full citadel and protection for crew and responders could enter zones L, M and H and could therefore provide Vessel Response Type 1 to 4 inclusive, acknowledging that the risk will increase with being in the higher risk zones and increasing time within them. Vessel C is at sea and approximately 5-6 hours from the scene at best speed.

Identify Response Vessel or Combination of Vessels:

Taking response time into account the responsible authorities decide that Vessel A can be dispatched at minimum notice and can assist in providing further information whilst also warning other shipping to stay clear of the area and additionally providing a safe platform should the casualty vessel crew leave their vessel by their own means. Vessel C would also be dispatched but will take longer to arrive and will therefore provide a more robust response but at a later time and would be better suited should the incident escalate. This provides a level of support using the available response vessel type to best effect.

Respond to Incident:

Vessels A & C are ordered to sail, vessel A for immediate assistance within the safety parameters of the vessel with vessel C providing more direct support on arrival if still required.

From this example it is clear that whilst Vessel C would be the ideal solution for the incident as described, there are other options which can be used to provide some level of measured response. It is considered that there will always be a level of response which can be provided to save lives so long as the responding vessels are aware of the risks and the local conditions are taken into account.

Any recovery of HNS substances whilst desirable can be left until more favourable conditions or better equipped vessels can be brought into the overall response operation.

4. Vessel Design Requirements

4.1. DISCUSSION

The following Chapters detail the design requirements for a variety of systems and equipment to provide protection to the responding vessel, to provide rescue facilities for the casualty vessel crew, assistance to the casualty vessel and clean up response. This level of design[2] was determined by the potential hazards of the chemical substances present. The level of detail is based on the IMO GBS principle as previously discussed to allow flexibility of application to a variety of vessel types.

As discussed previously no single vessel may be available to manage an incident so the responsible authorities may need to consider identifying a number of vessels, in a coordinated multi-vessel response, relying on the combined capabilities of the responding vessels to provide the optimum available solution to the incident.

Therefore the design requirements in the following Chapters give indications of the optimum response for each design and a matrix in Table 15 shows where each design would be of benefit.

The following paragraphs give a high level overview of the key thinking behind designs in general which are considered to be relevant to any HNS incident.

4.1.1. General considerations

As previously discussed responding vessel masters will not put their vessel or crew in harm's way except in exceptional circumstances.

Given the time taken to reach any casualty vessel in severe incidents it is likely that if all avenues to control the incident have been exhausted then the vessel's crew may already have abandoned the vessel and have moved away.

If the casualty vessel crew have evacuated then in terms of safety the responding vessel may not need to approach the casualty vessel at all and will recover the crew from life rafts, life boat, rescue craft or even from the water.

If the casualty vessel is unmanned then the responding vessels will more likely be involved in a salvage operation which can potentially be done in a slower time allowing the full incident to be better understood before committing vessels into hazardous areas.

[2] **Note:** Whilst this report is provided by DNV the design requirements do not relate to DNV classification rules specifically and any reference to class or classification societies should be taken to mean any classification society recognised by the responsible authorities.

4.1.2. Actions in any Incident

When responding to any incident including HNS then the prime function of the responding vessels is the preservation of life, therefore there are common goals for the designs which can be considered.

All HNS incidents have basic requirements and the key goals for this in terms of this report and the requirements of the Safe Platform are:

- Goal 1: To assist in the saving of lives
- Goal 2: To provide medical assistance to casualties.

Other Goals outside the scope of this report will include:

- Mitigate environmental and ecological impacts
- Reduce Loss

5. Fire Scenario

5.1. PROTECTION IN A FIRE INCIDENT

The responding vessel has to have self-protection to ensure the safety of the responding crew and any additional responders carried. It should also provide protection for casualties received from the casualty vessel.

On initial arrival on scene the primary concern will be the saving of life hence the first responding vessel may not need dedicated fire fighting facilities but should be capable of assisting in the saving of life.

Subsequent vessels and incident development may require fire fighting support to be provided either from the vessel or the embarkation onto the casualty vessel of additional personnel to fight the fire.

Whilst the key element is personnel safety in some incidents the safest place for the crew of the casualty vessel may be to remain on board and not transfer to the responding vessel. In this case the responding vessel may only be required to provide fire fighting assistance to help contain the fire. In this situation the design elements relate to fire fighting capability.

Fire Fighting Design Goals

There are two goals associated with the fire fighting designs as follows:

- Goal 1: to provide self-protection for the responding vessel to prevent a fire on the casualty vessel causing an adverse effect on the responding vessel when it approaches.
- Goal 2: to provide equipment to allow the responding vessel to actively support fire fighting on the casualty vessel.

5.2. DESIGNS FOR FIRE FIGHTING AND SELF PROTECTION

5.2.1. Overview

When an incident occurs and flammable liquids or gases are released, the potential for a fire to occur or one being present when the rescue vessel arrives on scene is high. The responding vessel therefore needs to be protected from the heat, and smoke. It also needs to be able to provide appropriate assistance to the casualty to fight or mitigate the effects of the fire, so as to achieve safe evacuation of the personnel.

Therefore the design requirements for a vessel entering zone H will be more stringent than a vessel which does not approach the casualty vessel.

Fire Fighting vessels are typically identified in three classes as follows:

- **Firefighter / FiFi Class I**
  Active protection, giving it the capability to withstand higher heat radiation loads from external fires: minimum capacity of 2.400 m^3/h divided on two monitors with minimum throw length of 120 meters in still air. The minimum throw height is 45 meters measured from sea level and 70 meters away from the nearest part of the vessel. In addition the vessel has to be equipped with a spray system for self-protection.

- **Firefighter / FiFi Class II**
  Continuous fighting of large fires and cooling of structures: minimum capacity of 7.200 m^3/h normally divided on three monitors. Minimum throw length is 150 meters in still air. The throw height has to be a minimum of 80 meters from sea level measured 70 meters and away from the nearest part of the vessel.

- **Firefighter / FiFi Class III**
  Continuous fighting of large fires and cooling of structures with larger water pumping capacity and more comprehensive fire fighting equipment than for class II: minimum capacity of 9.600 m^3/h divided on 4 monitors. Minimum throw length is 150 meters in still air. The throw height has to be a minimum of 80 meters from sea level measured 70 meters and away from the nearest part of the vessel. In addition the vessel is to be fitted with two foam monitors, each with capacity of 300m^3/h and throw height of 50 meters above sea level.

These classifications of fire fighting vessel are widely accepted and well understood and all leading classification societies have rules which detail the specification for the vessel both in terms of the fire fighting equipment and the support services required. Therefore in this Chapter it is considered reference to the type of vessel is sufficient to avoid duplication existing specifications.

The use foam will normally be for the prevention of ignition or re-ignition of a fire by forming a fire suppressing blanket over the spilt substance where the threat of a fire is present. The use of foam as a fire fighting agent will be limited, but if it is used then arrangements for re-supply will need to be made by the responsible authorities. FiFi 2 & 3 requirements to provide for 30 minutes supply of foam should be achieved as a minimum on appropriate vessels.

5.2.2. Comparison of Classification Society Requirements

All classification societies have rules for fire fighting capable ships. Table 10 gives a comparison between a selection of classification societies and their respective requirements for a Fire Fighting Class 3 vessel.

Table 10: Comparison of Fire Fighting Requirements for FiFi Class III

Class Society		**DNV (Reference 10)**	**LR (Reference 11)**	**GL (Reference 12)**	**BV (Reference 13)**	**ABS (Reference 14)**
Criteria ↓	**Term for Notation →**	**Fire Fighter 3**	**Fire-Fighting Ship 3**	**FF3**	**Fire-Fighting Ship 3**	**Fire Fighting Vessel 3**
Number of Monitors		3/4	4	4	4	4
Capacity of each monitor		3200/2400	1800	2400	2400	2400
Number of pumps		2-4	2 (Minimum)	2-4	2	2-4
Total Pump Capacity m^3/h		9600	10,000	9600	9600	9600
Length of Throw (m)		180/150	150	150	150	150
Height of Throw (m)		110/90	70	70	70	70
Fuel oil Capacity in Hours		96	96	96	96	96
Number of Foam Monitors		2	Not Specified	2	2	2
Foam capacity of each monitor		5000 l/min	Not Specified	5000 l/min	At least 300 m^3/h	5000 l/min
Duration of supply (Min)		30	Not Specified	30	30	30
Height of throw (m)		At least 50	Not Specified	*	At least 50	50
Length of throw		*	Not Specified	At least 70	*	*

All fire fighting arrangements must comply with classification society and Flag state requirements appropriate to the class of fire fighting arrangement installed.

5.2.3. Self-Protection

The vessel should have a self-protection system which allows it to remain in close proximity to the casualty vessel for prolonged periods.

The vessel should have water spraying (drench/deluge) system installed with the aim to provide cooling of the ships side and superstructure to resist the effects of heat.

The system should comply with current accepted practice for this type of system and have the following minimum specifications:

- The system should provide a continuous supply to cover all vertical superstructure and deckhouses without obscuring wheel house or monitor control station visibility.
- A water spray of at least 10 $l/min/m^2$ of the areas being protected should be provided.
- Pumps and pipe work are to be capable of supplying the complete system during operation.

- If pumps are also supplying monitors they must have sufficient capacity to supply both systems.

Enhanced hull specifications may also be used to provide passive protection giving the responding vessel the ability to remain in the vicinity of the casualty vessel longer by having A60 rated hull or other protective systems which give an equivalent level of protection.

These arrangements are also addressed by classification societies and their rules should be followed.

5.2.4. Fire Fighting Support for Casualty Vessel

Response vessels are to be equipped with a formally rated fire fighting system approved by a recognised classification society. For maximum self-protection and support to the casualty vessel Fire Fighting 3 is recommended as this gives extended length of throw allowing the response vessel to remain further from the casualty. It also gives enhanced capacity to a larger number of fire fighting monitors over a more prolonged period.

Fire fighting 1 or 2 vessel may also be used where these are available but their use must take into account their limitations particularly with regard to the amount of time they can provide effective support.

If the requirement for fire fighting support is prolonged then arrangements will be required to either resupply the existing vessels with foam, fuel or alternatively to provide a replacement vessel with similar characteristics.

5.2.5. Additional Protective Equipment

Fireman's outfits are to be supplied which conform to International Convention for the Safety of Life at Sea (SOLAS) 7.4 as amended Chapter II-2, Regulation 10.1 which requires them to be in compliance with the Fire Safety Systems Code Chapter 3 Section 2.1. (Note: this is a mandatory code).

It is recommended that sufficient outfits are carried to provide for two at each fire monitor station on the vessel to allow the monitors to be permanently manned if necessary. Fire fighter class 3 vessels are required to carry 8 outfits for example.

Four sets of fire fighting outfits and safety equipment should be provided to assist fire fighters or other personnel boarding the casualty vessel. Each should consist of the following minimum requirements:

1. One self-contained air-breathing apparatus, not using stored oxygen, having a capacity of at least 1,200 l of free air.
2. Protective clothing, boots, gloves and tight-fitting goggles.
3. Steel-cored rescue line with belt.
4. Explosion-proof lamp.

An adequate supply of compressed air shall be provided and shall consist either of:

1. One set of fully charged spare air bottles for each breathing apparatus carried; a special air compressor suitable for the supply of high-pressure air of the required purity; and a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the required breathing apparatus or
2. Fully charged spare air bottles with a total free air capacity of at least 6,000 l for each breathing apparatus carried.
   Note: for prolonged operations (> 1 hour assuming 30 minutes supply in each bottle and all sets in use concurrently) carriage of spare bottles will not be sufficient and a compressor should be carried as item 1 above.

6. Flammable or Explosive Scenario

6.1. PROTECTION IN AN FLAMMABLE OR EXPLOSIVE INCIDENT

As with the fire incident primary concerns will be the saving of life and where appropriate the removal of persons from the area of risk. To achieve this any responding vessel will need to be able to recover evacuees from the casualty vessel without providing an ignition source for the explosive substance. If the substance is still contained within the casualty vessel then ignition sources are less of an issue than if the substance has started to leak and is therefore in a position where the approaching response vessel could itself provide an ignition source.

Flammable / Explosive Atmosphere Goal

Goal 1: The goal for responding vessels when attending a casualty vessel which is, or may potentially, release a flammable and/or explosive substance, is to prevent the responding vessel from providing an ignition source.

6.2. DESIGNS FOR FLAMMABLE / EXPLOSIVE ATMOSPHERES

6.2.1. Overview

When an incident occurs where flammable liquids or gases are released, the potential for a fire to occur or one being present when the rescue vessel arrives on scene is high. The responding vessel therefore needs to be protected to ensure it does not exacerbate the incident by causing the escaping cargo to ignite or explode.

Design requirements for a vessel entering zone H will be more stringent than a vessel which does not approach the casualty vessel.

Protection on board casualty and responding vessels are irrelevant if an explosion occurs. Operational considerations are therefore extremely important to avoid igniting any flammable or explosive atmosphere which may be present. Hot surfaces, sparks, arcs and electrostatic discharges are all potentially ignition sources. The responding vessels can have design features to limit or reduce the potential for them to cause ignition of the gas or vapour cloud and these include

- Installation of Spark Arresters which prevent the emission of spark which may ignite the hazardous atmosphere. EN 1834-1 *Reciprocating internal combustion engines. Safety requirements for design and construction of engines for use in potentially explosive atmospheres. Group II engines for use in flammable gas and vapour atmospheres* has guidance.
- Installation of Flame Arrester which permit the transmission of a gas/air mixture but to prevent the passage of a flame. EN 1834-1 has guidance.
- Designs for engines and auxiliary engines to operate in hazardous environments EN 1834-1 provides guidance.
- Explosion/Spark proof equipment – this is equipment particularly electrical designed to operate in an explosive environment with IEC 60079 *hazardous locations certification documents* giving guidance on the various methods available to achieve this.
- Explosion proof manual equipment e.g. Chain hoists, non-sparking hand tools etc..
- Designs for EX/ATEX approved equipment.

6.2.2. Designs for Equipment operating in Explosive Atmospheres

For equipment potentially required to operate in an explosive atmosphere during a HNS incident response it is important that equipment is "certified as safe equipment" in that it is certified by an independent national test institution or competent body to be in accordance with a recognised standard for use in hazardous areas and in this instance explosive atmospheres.

Different regional requirements in classification of hazards can be seen as outlined in Table 11, with the North American NEC500-503, the International Electrotechnical Commission (IEC) and the European Union "The Explosion Protection Regulations (ATEX)".

Table 11: Comparison between NEC based divisions, IEC based zone, ATEX equipment categories and Divisions and the hazard zones as defined by this project.

	Continuous Hazard	**Intermittent Hazard**	**Hazard under abnormal conditions**
This project Hazard Zones	Zone H	Zone M	Zone L
NEC500-503	Division 1	Division 1	Division 2
IEC	Zone 0 (Zone 20 dust)	Zone 1 (Zone 21 dust)	Zone 2 (Zone 22 dust)
ATEX	Category 1	Category 2	Category 3

In addition standards and regulations applicable for land based industry do not always mirror those used in the maritime industry, due to the international nature of shipping, national and regional regulations are not always implemented in to the industry. For example, the ATEX regulations and 'ATEX' certification as required by the EU Directive 94/9/EC is generally not applicable for ships. This regulation is implemented into national legislation of member states, but does not cover shipping and in some cases does not cover offshore installations either. It is therefore important that equipment is certified as safe to a recognised national, European, International or other acceptable equivalent standard.

In addition any equipment used must be approved for deployment at sea in order to ensure class and insurance are not invalidated for example in use of cranes while sailing that are not approved to do so.

6.2.3. Electrical Installations

Installed electrical equipment for operation in hazardous areas is defined in Classification Society rules. These have been developed due to requirements for explosion protection relating to the carriage of dangerous goods, however these standards would be applicable for electrical equipment when responding to HNS incidents. Table 12 provides a comparison between the selected class societies outlining electrical equipment requirements defined by IEC zones 0, 1 and 2 compared to this report's zone H, M and L.

Table 12: Comparison of Classification Society requirements for electrical equipment in hazardous zones

	Zone H	Zone M	Zone L
DNV (Reference 15)	a) Electrical equipment installed into zone 0 shall normally be certified safe for intrinsic safety Ex-ia. b) For zone 0 systems, the associated apparatus (e.g. power supply) and safety barriers shall be certified for Ex-ia application.	a) Electrical equipment installed for a vessel entering zone 1 should be certified safe with respect to one of the following protection methods: - Ex-i (intrinsic safe) category a or b - Ex-d (flameproof) - Ex-e (increased safety) - Ex-p (pressurised) - Ex-m (moulded) - Ex-s (special protection) b) Normally, Ex-o (oil filled) and Ex-q (sand filled) are not accepted. However, small sand filled components as i.e. capacitors for Ex-e fixtures are accepted.	Equipment for zone 2 installation shall be in accordance with one of the following four alternatives: a) Certified safe for zone 1 application. b) Certified safe for zone 2 application. c) Have a manufacturer conformity declaration stating that it is made in accordance with an Ex-n standard. d) Documented by the manufacturer to be suitable for zone 2 installation. This documentation shall state compliance with minimum enclosure protection of IP44, maximum temperature for internal or external surfaces according to the temperature class for the area and that the equipment contains no ignition sources during normal operation.

	Zone H	Zone M	Zone L
Lloyds Register (Reference 16)	a) intrinsically safe, category 'a' (Ex 'ia'); or b) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category 'ia', not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14, *Explosive atmospheres Part 14: Electrical installations design, selection and erection.*	a) apparatus permitted within zone 0; b) intrinsically safe, category 'b' (Ex 'ib'); c) simple apparatus as defined above, included in intrinsically-safe circuits of category 'ib'; d) increased safety (Ex 'e'); e) flameproof (Ex 'd'); f) pressurised enclosure (Ex 'p'); g) Powder filled (Ex 'q'); or h) encapsulated (Ex 'm').	a) apparatus permitted within zone 0 or zone 1; b) type of protection 'n' or 'N'; c) equipment such as control panels, protected by purging and pressurisation and capable of being verified by inspection as meeting the requirements of IEC 60079-2; or d) radio ariels having robust construction, meeting the relevant requirements of IEC 60079-15. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment.

	Zone H	Zone M	Zone L
BV (Reference 17)	• certified intrinsically-safe apparatus Ex(ia) • simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ia” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by appropriate authority • equipment specifically designed and certified by the appropriate authority for use in Zone 0.	• any type that may be considered for Zone 0 • certified intrinsically-safe apparatus Ex(ib) • simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ib” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and accepted by the appropriate authority • certified flameproof Ex(d) • certified pressurised Ex(p) • certified increased safety Ex(e) • certified encapsulated Ex(m) • certified sand filled Ex(q) • certified specially Ex(s) • through runs of cable.	• any type that may be considered for Zone 1 • tested specifically for Zone 2 (e.g. type “n” protection) • pressurised, and accepted by the appropriate authority • encapsulated and accepted by the appropriate authority • the type which ensures the absence of sparks and arcs and or “hot spots” during its normal operation (minimum class of protection IP 55).

	Zone H	Zone M	Zone L
GL (Reference 18)	- intrinsically safe circuits Ex ia - equipment specifically approved for use in Zone 0 by a test organisation recognised by GL	- equipment, permitted for zone 0 - intrinsically safe circuits Ex i - flameproof enclosure Ex d - pressurized Ex p - increased safety Ex e - special type of protection Ex s - oil immersion Ex o - encapsulation Ex m - sand filled Ex q - hermetically enclosed echo-sounders	- equipment permitted for zone 0, - equipment permitted for zone 1, - equipment of Ex n-type protection, - facilities which in operation do not cause any sparks and whose surfaces, accessible to the open air, do not attain any unacceptable temperatures, - equipment with a degree of protection of IP 55 at least and whose surfaces, accessible to the open air, do not attain any unacceptable temperatures

In general electrical equipment intended for operation in hazardous areas should meet the appropriate class society rules applicable to the vessel in question. The equipment to be installed should be of a type providing protection against the hazardous zone of intended operation. This should be compliant with a relevant standard such as the IEC 60079 series on explosive atmospheres, relevant national or European standards or alternative permitted by the class society. While class requirements can differ some commonalities apply between the selected class societies. Therefore we can summarise that the following requirements would be expected to be met for electrical equipment to be used in HNS responses:

Zone H - Electrical equipment should be certified intrinsically safe Ex ia to IEC 60079-11 – Explosive *atmospheres – Part 11: Equipment protection by intrinsic safety 'i'* or acceptable equivalent and approved by the appropriate authority.

Zone M - Electrical equipment intended for operation in zone M should be certified to the appropriate explosion proof protection standard such as IEC 60079 as per class requirements.

Zone L – Electrical and other equipment should conform to Ex-n standard or alternative requirements as defined by the class society.

All equipment required to operate in an explosive atmosphere while responding to a HNS incident would be required to be certified as safe equipment to operate in a hazardous environment. This should be to a recognised standard to ensure that in addition to electrical equipment, systems such as cranes required for operations in a hazardous area, or that cannot be isolated, are certified explosion proof and safe to operate should the response vessel enter a potentially explosive atmosphere.

Directive 94/9/EC on equipment and protective systems intended for use in potentially explosive atmospheres (ATEX) places requirements on equipment and protective systems intended for use in potentially explosive atmospheres. These cover systems including electrical equipment, non-electrical equipment and protective systems, so can be considered an example of an applicable standard to demonstrate equipment suitability. However as this regulation might not be widely utilised within the industry, requiring ATEX certified equipment for response vessels potentially could limit the selection of appropriate vessels with equipment certified to this scheme. The ATEX directive also contains a harmonized list of European standards concerning equipment and protective systems or International / national equivalents that can be used as another alternative source of standards to ensure equipment is suitable for operation in potentially explosive atmospheres.

7. Health Hazard & Toxic Scenario

7.1. PROTECTION IN A TOXIC INCIDENT

Health hazard and toxic incidents may involve liquids, solids, vapours or gases and when providing assistance the responding vessel needs to be able to protect its crew from the potential harmful health and toxic effects and provide a safe refuge from the toxic environment for any personnel received from the casualty vessel.

There is also the possibility of received casualties suffering from the effects of the toxic environment and/or contaminated with toxins therefore decontamination, hospital/casualty treatment and recovery facilities will also be needed.

It would be beneficial if one responding vessel could supply all of these facilities and there are vessels in existence which can but it is also acknowledged that the required facilities may also be provided by a combination of vessels.

One vessel may be able to approach the casualty vessel to recover crew and transfer them to a second vessel or alternatively airlift or transfer them to shore where better casualty treatment and decontamination facilities can be provided.

Health Hazard & Toxic Incident Design Goals

There are three key goals for responding to a toxic incident:

- Goal 1: To provide and ensure a safe, toxic free atmosphere for the responding vessel crew and any additional responders transported to the incident to assist the casualty vessel.
- Goal 2: To provide a safe refuge for casualties
- Goal 3: To provide a means to remove contamination from responders and casualties

7.2. DESIGNS FOR TOXIC / HEALTH HAZARDS

HNS incidents involving substances and mixtures that are toxic or cause other health hazards are probably the hardest to respond to, monitor and exactly understand the implications to the responders. Therefore the importance of protecting the response vessel and the crew and addition person on-board as well as responders entering areas where exposed to these substances is critical.

The difficulty in monitoring the dispersal of the resultant cloud following a release means that the responsible authorities will need to use dispersal monitoring programmes to provide the responding vessels with details of the safety zones and areas of hazard.

7.2.1. Overview

There is a need to protect the responding vessel's crew from toxic gas or vapours in the event of a toxic incident. Depending on the zone the vessel will be required to operate in either a full gas tight protective air pressurised citadel or a positively pressurised interior may be appropriate dependent on the level of risk from the spilt cargo and the zone of operation the responding vessel is required to enter.

Gas Tight Citadel

The outer boundary of any citadel should be gas tight to provide a toxic free environment within the citadel boundaries. Entrances to the citadel should ensure the citadel remains gas tight in all conditions. Airlocks for gas tight citadels need to prevent simultaneous opening and should be sized for entry and transport of stretcher with casualty and accompanying medical personnel. Note: this may not be the case for naval vessels which have a requirement for a minimum 1.0 m^2.

The citadel should achieve and maintain an over pressure of 0.5kPa with transition between the external and internal pressures, if via a decontamination station, in accordance with Classification Society Naval class rules. Citadel requirements are not typically specified for non-naval vessels.

Gas tight citadel requirements are significantly more robust than those for a relatively simple pressurised accommodation or work spaces discussed below and are drawn from military standards of protection which are specified within Classification Society Naval Ship Rules.

Table 13: Comparison of Citadel Requirements.

DNV (Reference 19)	**LR** (Reference 20)	**GL** (Reference 21)	**BV & ABS**
The following overpressure compared to atmospheric pressure should generally be achieved: - citadel - 0.5 kPa The NBC-zone (Citadel) is to be able to maintain a 0.5 kPa over-pressure for a 24 hours period	Gastight testing for the citadel – The pressure in the compartment is to be brought to 0,015 bar (0,015 kgf/cm2) (150 mm of fresh water) and the supply isolated. The fall in pressure after 10 minutes is not to be greater than 0,0013 bar (0,0013 kgf/cm2) (13 mm of fresh water).	The NBC protection plants shall be so designed that an overpressure of 5 hPa (mbar) in relation to the atmospheric pressure is achieved in all spaces of the citadel.	**Not Available on line**

Pressurised Accommodation / Engineering Spaces / Vessel

Accommodation and other areas accessed by the crew should be separated from atmosphere by gas-tight A60 bulkhead (or other bulkhead if A60 protection not required).

Air intakes into accommodation, engine compartments or other areas where crew may be exposed to toxic vapours or gas should be installed so that rapid and efficient gas and vapour tightening can be ensured to protect the occupants. (IBC Chapter 3.2.3)

The vessel should have a gas–safe zone within which all crew and emergency response personnel can be protected from toxic gas or vapours. All of the vessel systems including those provided for response and rescue are to be capable of full operation from within this zone.

The gas-free zone should be capable of maintaining a positive pressure over the external atmospheric conditions to ensure no gas or vapour can enter. Entrance and egress is to be managed by the use of airlocks.

A minimum overpressure of 5 Pa (0.25 mbar) with respect to the adjacent hazardous space or area is provided at all points inside the space and its associated ducts at which leaks are liable to occur, all doors and windows being closed. (Example DNV Rules Pt.5 Ch.11 Sec.2 – Page 10). Ideally the overpressure should be at least 50Pa as indicated by offshore Temporary Refuge requirements.

Ventilation should ensure 30-35 changes of air per hour and be temperature controlled to maintain habitability levels at a reasonable level.

Ventilation systems should be capable of providing re-circulated air to ensure no ingress from potentially contaminated external areas to the pressurised areas.

The pressurised areas should have CO_2 and CO monitoring to ensure oxygen levels remain within acceptable levels for occupation.

A separate air purifying system should be provided to maintain air quality over prolonged periods.

Airlocks

Airlocks should comply with The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC) 3.6 and have two gas tight doors, sized for entry and transport of stretcher with casualty and accompanying medical personnel through the airlock and into the pressurised areas of the response vessel.

The doors should be self-closing and should have warning alarms to indicate when one door is open to prevent simultaneous opening compromising the gas tight boundary of the gas-safe zone.

Airlocks should be monitored for contamination using a gas detection system appropriate to the type of HNS contamination.

Airlocks should be capable of being purged with clean air to prevent contamination entering the gas-safe areas.

Applicability to Safety Zones

The full gas tight citadel would be most applicable to zone H, as this would be the area where continual exposure would be experienced. The use of pressurised accommodation and workspaces would be applicable most to zone M, where there is no direct exposure but there is a risk that following a change in local conditions the responding vessel may need protection whilst repositioning back into a safer zone. The pressurised areas would also provide limited protection in the event the responding vessel needed to enter zone H for brief periods to save lives.

8. Cryogenic / Gases under Pressure Scenario

8.1. PROTECTION IN A CRYOGENIC / GASES UNDER PRESSURE INCIDENT

Gases under pressure may result in a blast if an uncontrolled eruption of the containment vessel occurs or the more likely scenario of a high pressure release of the gas. It may also involve cryogenic injuries.

Cryogenic / Gas under Pressure Incident Design Goals

- Goal 1: When an incident involves pressurised gases the goal is to protect the responding vessel and its crew from any potential blast effects or high pressure discharges.
- Goal 2: When LNG or other substances with potential cryogenic effects are present the goal is to protect the vessel and crew from the potential effects.

8.2. DESIGNS FOR CRYOGENIC / GASES UNDER PRESSURE

Gases under pressure classified in the CLP regulations by their physical state once they are packaged and include:

- Compressed gas
- Liquefied gas
- Refrigerated liquefied gas
- Dissolved gas

These four types of gases or gas mixtures pose pressure or freezing risks which may lead to serious damage to people/surroundings or death of people independently from other hazards the gases may pose (Reference 22). While this study primarily relates to bulk, gases under pressure such as in cylinders are discussed where appropriate. Substances such as LNG and LPG fall into this category as defined by the CLP regulation and generic scenarios defined earlier in this project. The main risks associated other than gases being released under pressure therefore include cryogenic injuries or damage to ship structures.

Designing a response vessel's hull to be resistant to LNG for example would be a challenge so protection of the responding vessel is likely to be achieved by operational considerations i.e. maintaining a safe distance, avoiding any areas of high risk to damaging the responding vessel structure and potentially also making it a casualty.

Design requirements for addressing hazards associated with gases under pressure can be addressed by following those identified for explosive and fire scenarios. Designs for protection from toxic/health hazard events might be applicable for cryogenic incidents, however these are unlikely to offer full protection to the responding vessel crew against cryogenic hazards, unless specific cryogenic protective equipment such as specialist gloves, aprons full face shields over safety glasses and the use of emergency self-contained breathing apparatus (SCBA) etc. can be provided.

9. Corrosive Scenario

9.1. PROTECTION IN A CORROSIVE INCIDENT

Corrosive incidents will result in contamination of people and/or the vessel. In general the majority of first response to save lives will be in reducing the concentration or removing the corrosive substance by dilution and washing.

Corrosive Incident Design Goals

- Goal 1: To provide effective decontamination of personnel or the vessel in contact with a corrosive substance.

9.2. DESIGNS FOR CORROSIVE

Corrosive substances and mixtures fall into two categories in the CLP regulations encompassing physical and health hazards. These include:

- Corrosive to metals.
- Skin corrosion / irritation (causes severe skin burns and eye damage)

Appropriate Personal Protective Equipment (PPE) dependent on the substance would be required to mitigate effects of skin burns and eye damage for responders leaving the security of protective areas on the vessel.

The corrosive effects of a substance can be significantly mitigated by dilution of the substance with water. This will reduce the severity of any effects to the vessel structure and to contact with personnel. The response vessel will require self-protection which it is expected can be provided locally using on-board hoses to wet the decks. FiFi equipped response vessels will also be able to provide dilution of the substance to the casualty vessel. The distance from which assistance can be provided will therefore depend on the response vessels equipment fit.

There is however the possibility that in the process of diluting the substance splashing may occur impacting on personnel therefore PPE appropriate to the substance present including eye and skin protection should be provided.

Personnel can initially be treated by diluting the substance by washing it off with any subsequent treatment provided either by on-board first aid trained people or by evacuation to hospital facilities either on larger response vessels with medical facilities or by helicopter evacuation to hospitals.

10. Common Design Features

The design details in previous Chapters have addressed specific incident scenarios. The study has identified a number of design and other requirements which will be common to all response scenarios and these are described in this Chapter.

10.1. DESIGNS FOR RESCUE OF PERSONNEL

The method of rescue will be dictated by the availability of equipment on board the response vessel, the type of cargo, environmental conditions, hazards and risks, monitoring equipment and ultimately the decision of the Master of the response vessel, as he or she first responsibility is for the safety of his own vessel and crew.

The important factor is to have a method of rescue of persons from the casualty vessel and potentially also responders from both the vessel and from in the water either in a life boat / raft or floating in the water.

Four possible scenarios are envisaged:

- Rescue of personnel already evacuated from the casualty vessel, either in a life raft or lifeboat or in the water itself is the most likely scenario for a first responder.
- Launching a smaller craft to perform transfer of personnel from the casualty vessel – this would be with the responding vessels lifeboats (or FRC if fitted) manned with staff from the responding vessel or unmanned using deployed life rafts that could be floated down from upwind of a casualty and recovered by use of the painter, thereby not placing the responding vessel or its crew in danger.
- Coming alongside the casualty vessel with the responding vessel and taking people off directly – this is highly unlikely unless in the calmest of condition and with no threat of further HNS incidents.
- Helicopter operations although dependent on distance from land for this option.

The nature of the incident, risk to casualties and response team and ultimately the decision of the master on-board the rescue vessel will dictate whether a rescue operation is conducted and whether the risks are acceptable irrespective of the equipment and tools available. This makes it hard to precisely define requirements for rescue, as a decision might be made to proceed with a rescue without the “ideal” tools and equipment, if the risks are considered tolerable.

It is envisaged that once the crew of the casualty vessel have exhausted all options in controlling the incident they will evacuate the vessel. Potentially the preferred method of rescue could be by helicopter as the likelihood is they would have a quicker response time and reach the casualty vessel faster than a responding vessel.

This Chapter looks at potential design criteria for rescue of personnel from the casualty vessel either on-board or having disembarked and also care once they are on-board the rescue vessel. Specific requirements of the rescue methodology should also take into account the requirements in previous Chapters dependent on the incident risks.

10.1.1. General requirements – Rescue Craft

In normal circumstances the use of smaller craft to rescue personnel from the casualty vessel in order to not put the responding vessel into a potential hazardous area would be the preferred option.

Rescue Craft may only be fitted with their standard SOLAS equipment of lifeboats and life rafts. These will be constructed and approved as per the regulations and deployed accordingly. However the preferred option would be for rescue craft to have additional small rescue craft fitted, either as a permanent fixture or additional life rafts supplied before leaving port.

Design requirements for small rescue craft include for example:

- Fast Rescue Craft (FRC) meeting the requirements of 1983 Amendments of SOLAS 1974, LSA-Code, IMO/MSC/Circ.809. and MSC 81(70) /ARRC.
- Rescue boat approved according to SOLAS 1974/96, LSA code MSC 81(70) IMO, Res. MSC.218(82) and IMO Res MSC.226(82), Part 1, Section 7 and EU Directive 96/98/EC.

Other requirements include extra life boats on the recovery vessel to account for the increased carriage of personnel on-board. In addition a helicopter landing area or winch area would facilitate the removal of casualties to shore quicker as and if needed.

10.1.2. Recovery of persons in the water

Freeboard and Rescue Zone

To facilitate recovery of personnel from the water and or rescue craft a responding vessel designed with a designated rescue zone on both sides of the vessel which has an obstacle-free deck space with a length of at least 3m (Reference 23) and a width that provides free passage for persons carrying a stretcher (the so called “rescue zone”) would be the ideal situation. The rescue zone must be localised in such a way that the effect of propellers and thrusters is noticed as little as possible. The freeboard at the location of the rescue zone must be a maximum of 1.75m (Reference 23), unless it has been demonstrated that a higher freeboard does not impede taking persons on board. The deck must be equipped with an anti-slip layer at the location of the rescue zone, for the protection of the crew. Provisions must be made to prevent the crew from being knocked overboard.

Climbing nets and rescue nets

Rescue vessels should be equipped with climbing nets along the total length of the rescue zone on both sides or have another system with which people can come on board the vessel from the sea or from a rescue craft.

A rescue vessel should be equipped with either a rescue net with hoisting tackle or at least one mechanically operated system for bringing incapacitated persons on board. The hoisting tackle can also be used for launching and recovery of FRCs.

Systems designed, other than rescue nets, can be used for recovery of personnel in the water and would involve a methodology in getting personnel out of the water and on board. Design requirements such as technologies for lifting personnel out of the water would be advantageous such as:

- Provision of nets ideally incorporating a Par buckle action;
- A scoop system e.g. Dacon Scoop;
- Equipment to hoist the person out of the water by attaching a strop or harness to the person and a suitably positioned eye or davit arm to achieve lifting; and

- A boat hook which incorporates a loop which, once fitted around the person, forms a lifting harness.

10.1.3. Casualty Treatment and Care

Casualties should be handled in an efficient and professional manner having due regard to their medical condition. The medical condition of casualties should be stabilised and external medical advice sought as soon as practicable. Requirements for dealing with casualties might be crucial depending on availability to air lift casualties to land based facilities based on numbers, distances to shore and availability of helicopters.

In some cases it potentially may be necessary to have available on-board decontamination facilities and areas to administer medical treatment and recovery.

Such decontamination facilities should be positioned to allow contaminated persons to enter the facility as close to the point of arrival on-board the responding vessel as practicable. The area should be partly open and equipped with a shower system suitable for cleaning rescued persons and crewmembers before entering the reception area.

A recovery/reception area should be provided for walking injured or personnel following decontamination procedures at this time information on the casualties should be complied.

Unless qualified medical personnel are on-board a rescue vessel or can be airlifted to the rescue vessel only limited medical care can be undertaken on the rescue vessel as its crew will not be qualified beyond a basic medical care on-board level.

More detailed medical support can be provided by radio to the rescue vessel or with dedicated training for rescue craft personnel plus the provision of a chemical medical locker (contents to be reviewed by qualified medical panel) (Reference 24).

10.1.4. Location of facilities

The facilities described in this Chapter may be incorporated into the design of the vessel during new build or where there is sufficient space during a modification package. The facilities may also be provided by vessels with sufficient deck space to take a standard container, which has been equipped to provide medical and/or decontamination facilities. There are several designs of portable decontamination facilities on the market which would only require the supply of power and water. Portable facilities range from tented solutions to containerised and vary in size from 2/3 person capabilities up to larger sizes.

Tented solutions may be a viable option if the prevailing weather conditions are suitable. The tented solutions are typically semi- rigid frames with a weather proof cover which are subdivided into a number of compartments to make up a portable de-contamination facility. These incorporate cleaning areas with shower arrangements, which require a water supply that could be provided either by local connections to the response vessel systems or by embarking a separate water supply. In this case the supply would have to be sized to match the consumption rate of the facilities provided. A separate “clean” area allows of treatment and re-dressing into clean clothes free form contamination.

Containerised solutions provide similar facilities but are more robust for use in the marine environment.

Portable solutions therefore could also be supplied from portable generators and tanks where space is available with suitable hold down/securing points. The footprint required also varies but typically deck space of 10x3m will be required plus space for portable generators etc.

The advantage of portable facilities is that vessel need only embark the equipment when required and any vessel with sufficient space could be used with due consideration to the zone of operation. Unless the vessel also has suitable installed protection as previously described to protect the crew, then operation would be limited to zone L with occasional entry to zone M when there is a low risk of contamination or the hazardous substances being blown in to the vessels path.

When considering portable solutions the selection of a tented solution rather than containerised solutions, will need more stringent restrictions due to their relatively fragile nature and lack of suitability for the marine environment.

Responsible authorities could therefore identify a range of available equipment suppliers near key ports where potential response vessels are located so that they can quickly identify the most appropriate units.

These units may not be protected against the potential contamination so would be more suited for vessels operating outside of the high and medium risk zones with casualties transferred to them.

Any portable decontamination units would need to meet the following broad criteria.

- Be sufficiently robust enough for the prevalent weather conditions; and
- Be capable of being secured to the vessel deck.

Response vessels would need to have the following:

- Sufficient deck space for the units;
- Securing points;
- Capability to connect power/water as required (temporary fits may be sufficient);
- Consumable spares for the unit to ensure continued availability;
- Ability to manage waste water from the unit; and
- Facilities to manage contaminated clothing etc.

10.2. DECISION MAKING ONSITE / MONITORING OF SITUATION

The responsible authorities are expected to take overall responsibility and command and control of any response to an HNS incident. This will not remove the master's responsibility to his vessel and its crew not to put them in harm's way. As a result local decision making will be required by the masters of any vessels involved in the response activities.

In order to make informed decisions the masters will need to have information readily available as to the potential risks. To assist in this the following equipment will also be required on the responding vessels.

10.2.1. Detection Systems

As far as possible all detection and monitoring should be carried out from a position remote from the casualty vessel but it is recognised that the capabilities of the available detection equipment varies and may require the responding vessel to approach the casualty vessel. If this is the situation then the response vessel should approach from a safe direction away from the known sources of danger.

Where the HNS has a potentially flammable or explosive hazard associated with it then any detection equipment should be certified for operation in these environments.

Gas and vapour detection

Gas and vapour detectors suitable for the detection of the type of HNS involved in the incident. These will need to be both for personal us and for determining the extent of any hazardous area. This will assist in determining the true extent of the boundary of zone H.

Gas detection systems will need to be capable of detecting toxic gases and vapours and also explosive and flammable limits.

It should be noted that detecting for toxicity is not the same as detecting for flammability or explosives as the concentrations of the substance to be explosive may for example be different from its toxic concentration.

There are many systems available on the market which broadly fall into two groups either installed or hand held. These units can have ranges up to about 45 metres which means the response vessel will have to approach any area carefully to allow time for the detector to register the presence of a substance and for the vessel to respond. In all cases a single detector may be able to monitor for more than one substance but may, as in the case or the widely used Dräger tube system, need to be set up for the specific substance. Hence a range of detection kits may need to be held by the responsible authority to take into account the numerous substances carried. These need not be permanently on a particular vessel as long as they can be embarked at short notice to respond to an incident.

There are other detection systems such as mass-spectrometry, gas chromatography, High Pressure Liquid Chromatography, flame ionisation and many others, which whilst effective their application in the marine environment when emergency response is required might not be considered practical.

Heat Detection and Monitoring

Heat detection and monitoring equipment to enable the temperature of the casualty vessel hull to be determined. These can include laser thermometers and thermal imaging cameras.

Remote heat detection using thermal imaging can be achieved using vessel mounted equipment which can be relatively small and light (one example found using a simple search on the internet was about 400 x 500 mm weighing 50kg and could be integrated into the vessel using a low voltage power requirement and NTSC/PAL interface to a monitor). These can have a significant range and many are used for search and rescue operations. Many are used by the military and are therefore robust.

Alternatively hand held thermal imaging cameras are routinely used by fire departments ashore and could be utilised by the response vessels, however their ranges are limited (typically up to about 30m) and would require the responding vessel to approach the casualty vessel. They would however give indication of changes in temperature whilst in close proximity allowing the responding vessel to move to a safer distance.

10.3. DESIGNS FOR APPROPRIATE PPE

Various texts reviewed have identified that a key mitigation is the provision of Personnel Protective Equipment (PPE) suitable for the hazards which may be encountered.

Different PPE may be required for fire/explosive areas compared with the requirements for toxic environments. Therefore the responding vessel needs to be equipped with PPE appropriate to the hazards posed by the HNS incident.

The quantities of PPE carried should be sufficient for the responding vessel crew who may be exposed, plus additional for any responders carried in addition to the normal crew complement. It would also be advantageous to carry additional equipment for crew from the casualty vessel in case they are unable to access their own or require additional to be provided.

The space required for the PPE will depend on the numbers required but any vessel should be able to accommodate sufficient without modification. A typical full set of PPE would require in the order of 0.5 m^3 of space, which includes space for SCBA, suit etc. PPE should be stored in accordance with the manufacturer's instructions which may require hanging space. Disposable protective equipment is also available, which excluding SCBA, requires smaller storage space per suit, (e.g. about 20cm^3) but is less robust.

Where appropriate the PPE could be included as part of the decontamination arrangements as this is where it will be of most benefit.

The PPE will need to take into account the potential risks with flame proof, pressurised intrinsically safe being examples of things to consider. PPE can be also worn with SCBA either underneath the suit or on top and recognised companies provide equipment for known and unknown gases, liquefied gases and working in explosive zones.

In a hazardous material spill (excluding fire and explosion possibilities) some response organisations define levels of protection in 4 levels for example in the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (Reference 5) as follows.

- Level A protection which is worn in unknown situations or when the situation requires the highest level of eye, skin and respiratory protection. The SCBA and the totally encapsulated suit are the protective equipment of choice for these conditions.
- Level B protection which is worn when the situation requires the highest level of respiratory protection but a lesser degree of skin protection is needed. The SCBA and chemical resistant suits are the protective equipment of choice for these conditions.
- Level C protection which is worn in situations where the hazards are known and the atmospheric concentration of the contaminant does not present a continuous hazard. Assuming also that the atmosphere is not oxygen deficient which means that a SCBA is not needed, adequate respiratory protection can be obtained by using air-purifying respirators. Air-purifying respirators and standard clean-up clothing consisting of liquid-repellent coveralls are the protective equipment of choice for these conditions.
- Level D protection which is worn in situations where there are no airborne contaminants of concern and where the likelihood of harm by contact with the spilled material is minimal. Coveralls are the protective equipment of choice for these conditions.

10.4. TRAINING / COMPETENT PERSONS

In the event of an HNS incident it is likely that a salvage expert will have been retained, either by the Flag State, Member State or owner of the vessel, who will in turn be supported by other key personnel with the appropriate training and experience including experts in salvage, towage, hazardous cargo's, gas dispersion, decontamination and monitoring.

These teams mobilise very quickly in the event of an incident, however, the first vessel on site might well be a merchant vessel without this support, and it is assumed that ETV, ocean or harbour tug would have salvage expert assistance. The merchant vessel, until relieved, will be on the on-scene commander, who should maintain his position at a safe distance upwind of the vessel, and offer a safe haven for survival craft from the casualty, that are able to make it to his vessel under their own steam. The master of the merchant vessel should not deploy his own personnel until the risk from the HNS have been fully analysed and only then if he is confident in the competence and training of his own personnel.

10.5. DESIGNS FOR CLEAN-UP / RECOVERY OF HNS CARGO

The large variety of HNS that can be encountered by responders to HNS incidents means the equipment used is not as straightforward as in oil response, since the differing physical behaviour of each chemical once released means a variety of monitoring and response equipment and tools may be needed (Reference 25).

Released chemicals into the aquatic environment can be categorised by their physical behaviour as evaporators, floaters, dissolvers and sinkers as outlined in Figure1. MEPC/OPRC (Reference 6) reported on the chemical behaviour of the top 100 transported substances and classification of spilled substances and found the majority to be evaporators or dissolves, which rapidly dissipate into the air or water column, making recovery technically impossible. Therefore spill clean-up response would be limited to persistent substances that float or sink and recovery of substances still within packaging or within the ship itself.

"In many cases, response action is not technically possible due to the inherent properties and hazards associated with a substance" (Reference 1). Whilst this may be correct for clean-up of HNS spills, this would occur later in the HNS response timeline and therefore would not be relevant to providing a response to save lives as the main focus in this paper appears to be environmental. Therefore the Safe Platform discussed in this report still needs to be able to provide the live saving function in often hazardous circumstances.

10.5.1. Recovery of HNS spills into the water

Floaters

For substances that float, in particular persistent floaters, these could potentially be dealt with using oil spill and oil recovery equipment (Reference 6), such as containment booms and oil skimmers appropriate for the HNS, ensuring care is taken to undertake a risk assessment due to the potential hazards associated with HNS compared to oil (Reference 3).

Sinkers

For the recovery of substances that sink, a clean-up response is considered unlikely due to the small percentage of substances transported that exhibit this physical behaviour, which frequently are also not persistent (Reference 6). In such cases dredging equipment potentially could be used to recover HNS and contaminated sediments, ensuring precautions and equipment is suitable for the HNS recovery.

Packaged

Recovery and clean-up of packaged HNS is unlikely to be part of the first response which focuses on saving life and providing a safe platform for responders and casualties. In most cases clean-up is unlikely to be feasible, with planning for a controlled release, recovery or leaving in-situ following the initial response. This activity would typically be completed by experts, such as salvors considering the requirements for specialist knowledge, equipment and PPE in order to transfer cargo, secure cargo holds and/or containers in a safe manner (Reference 26).

10.5.2. Recovery of HNS from Casualty Vessel

In instances that HNS is still on-board the casualty vessel, salvage companies would be expected to play a critical role and potentially not be part of the initial response of rescuing personnel on board, potentially using different vessels to those rescuing the crew from the casualty vessel. In instances of HNS in bulk and packaged form, appropriate equipment for ship to ship transfer would be required. For removal of bulk cargo (typically liquid bulk) transfer of HNS from the casualty vessel to response vessel would require the appropriate hose systems, specialised pumps and other equipment appropriate for the HNS in question. Transfer of packaged goods will require appropriate lifting gear derricks etc. for the package or a specialist salvage platform with similar capability (Reference 3).

10.5.3. HNS Response Vessel Design Requirements

In addition to the equipment required for recovery of HNS from the water or casualty vessel, the response vessel will need to have tanks / containment units and equipment so that HNS can be transferred, loaded and stowed safely, ensuring incompatible goods are segregated in accordance with the nature of the recovered HNS, whether they are in bulk or packaged form in order to ensure recovered substances do not pose a risk to the ship, its crew and the environment. Design, construction standards and equipment required to minimize these risks in regards to the cargo carried are detailed in the following regulations:

- International Convention for the Safety of Life at Sea (SOLAS), Chapter VII - Carriage of dangerous goods;
- International Maritime Dangerous Goods (IMDG) Code;
- International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC Code);
- International Maritime Solid Bulk Cargoes (IMSBC) Code; and
- Classification Society Rules applicable for the types of vessel and cargo carried which address the above regulations.

While these regulations cover the transportation of hazardous goods they detail requirements for design and construction such as tank types, materials for construction, ventilation, environmental controls, segregation, fire protection, storage, loading and unloading, which would be applicable in selecting the appropriate vessel for recovery and transportation of spilt or recovered HNS from the casualty vessel.

As discussed the large variety of HNS encountered and the differing physical behaviour and characteristics mean the response and vessel selection will be determined by the response team and clean-up and recovery of HNS is unlikely to be completed as a first response. The response team will be informed by suitably qualified experts knowledgeable in the HNS characteristics and hazards to assist in determining the most appropriate actions for clean-up and recovery of HNS. Defining designs for clean-up and recovery for all HNS incidents would not technically be feasible. For example spray booms and storage tanks for chemicals could be required for neutralisation of spilled HNS by dosing the spill with either acid or bases, or use of a sprinkler system to “knockdown” gases, scrubbing them from the air. Specific requirements will be determined by the response team and physical characteristics and risks associated with the HNS.

10.6. DESIGNS FOR TOWING ARRANGEMENTS / MANOEUVRING CASUALTY VESSEL

Towing of a casualty should only be undertaken by a properly equipped vessel class approved for ocean towage which would cover issues regarding deck strengthening, and winch sizes in relation to bollard pull. It might be possible to assist a stricken vessel, by use of a towline, to maintain its position or its aspect to wind and wave but long term towage is considered non-viable without a properly equipped vessel. Towing capacity should be sufficient to change vessel position with regard to wind direction to move toxic area away from windward areas. In the case of an explosive or toxic risk to centres of population then the towing capability should be sufficient to move the casualty vessel to a less vulnerable area.

The Maritime Safety Committee (MSC 84) has adopted requirements to have emergency towing procedures on cargo ships. Compliance will be required for new ships constructed on or after 1 January 2010; and for existing ships constructed before 1 January 2010 by 1 January 2012, therefore it can be assumed that all casualty vessels will be fitted with emergency towing arrangements. Such arrangements will be class approved to ensure they are of sufficient strength for the operations to be undertaken.

It is likely that a towing pennant, compatible with the bollard pull of the tug, connected to a suitable towing connection would be utilised. To aid connection a floating rope, with a minimum breaking load of 40 tonnes, and sufficient length to trail at least 75 metres astern of the tow, should be attached to the after end and joined to the tow line. A conspicuous, easily handled plastic buoy should be attached to the end of the floating rope trailing astern. Any arrangement shall be agreed with the Master of the tug to ensure that reconnection is possible in an emergency. Whatever the arrangement agreed, care shall be taken that no chafe can occur to the floating line when deployed.

Classification Society rules relating to towing activities are limited to the requirements for specialist vessels such as ETVs and tugs and their ability to tow other vessels. For non-specialist vessels which covers the majority of vessels at sea, Classification Society rules only relate to the ability of vessels to be towed in case of emergency.

10.7. DESIGNS FOR ENHANCED MANOEUVRABILITY

Manoeuvring within the vicinity of a casualty will always be subject to the prevailing conditions, the aptitude of the Master and the systems available to him on his vessel. The principal should always be, if in doubt to stand off at a safe distance and use smaller rescue craft or allow the rescue craft from the casualty to approach the safe platform. The more manoeuvrable a vessel the closer the safe platform will be able to approach the casualty, thereby decreasing the distance and rescue craft will need to transit.

The most advanced systems for maintaining position and increasing manoeuvrability is Dynamic Positioning (DP) as fitted to many offshore vessels. These systems are computer controlled systems to automatically maintain a vessels position and heading by using its own propellers and thrusters. Position reference sensors (Sat Nav), combined with wind sensors, motion sensors and gyro compasses, provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position. Dynamic Positioning may either be absolute in that the position is locked to a fixed point over the bottom, or relative to a moving object like another ship. One may also position the ship at a favorable angle towards wind, waves and current, called weathervaning.

Vessels fitted with such systems would provide the ideal Safe Platform, but their availability in many areas would be limited. Consequently the second best alternative would be ETV’s, ocean-going tugs and harbour tugs that are suitably equipped and registered for limited oceangoing operations.

- Both ocean-going and harbour tugs are highly manoeuvrable, and many various propulsion systems have been developed to increase manoeuvrability and thereby increase safety. Kort nozzles, Nozzle-rudders, Z-drive or (azimuth thrusters) and the Voith Schneider propeller (VSP), also known as a cycloidal drive are some of the many such systems which create highly manoeuvrable vessels. Tugs fitted with such systems would be able to render close quarters assistance and able to maintain their position relative to a casualty.

- In General terms most ocean going ships are not equipped with significantly enhanced manoeuvrability systems, although bow and stern thrusters will frequently be fitted and the operation of these will allow some enhanced manoeuvrability but they would not be considered sufficient to bring a vessel safely alongside another vessel in all but the calmest of conditions. However some vessels are now fitted with pod type propulsions, which enhance manoeuvrability but again these are not designed for inter-ship operations, but would allow a vessel to hold station outside of a hazardous area to render assistance.

11. Summary of Design Requirements for Scenarios

The previous Chapters have detailed the design requirements for a variety of systems and equipment to provide protection to the responding vessel depended on the hazard scenario and vessel response type. The following tables provide a summary of the various design requirements discussed previously and their relationship to the hazard scenarios and the zone system described in earlier Chapters.

Table 14 outlines the type of vessel response activities by safety zone which links into Table 15, which provides a matrix showing the relationship between the hazard scenarios, safety zones and design requirements for responding vessels. It should be noted that where two options are shown the higher requirement is the optimum but other options provide some benefits and may allow the responding vessel to continue.

Table 14: Vessel Response activity per hazard scenario and safety zone

Scenario Description	Zone	Vessel Type
Flammable leak	H	3 or 4
	M	2 or 3
	L	1
Fire	H	3 or 4
	M	2 or 3
	L	1
Explosive	H	3 or 4
	M	2 or 3
	L	1
Cryogenic / Gases under pressure	H	3 or 4
	M	2 or 3
	L	1
Corrosive	H	3 or 4
	M	1, 2 or 3
	L	1
Health Hazard / Toxic	H	3 or 4
	M	2 or 3
	L	1
Rescue	H	3 or 4
	M	2 or 3
	L	1
Clean Up	H	3 or 4
	M	1, 2 or 3
	L	1

Note: higher specification vessels can be used in zones identified for lower specification vessels but not vice versa.

Table 15: Matrix showing relationship between the Hazard Scenarios, Zones and Design Requirements.
Key P = Preferred S = Secondary & O = Discretional Options

		Chapter 4					Chapter 5						Chapter 6					Chapter 9											
Scenario Description	Zone	FiFi 1	FiFi 2	FiFi 3	Drenching System	Passive Fire Protection (A60/J120/H120)	Spark Arrest	Flame Traps	Water cooled exhausts	EX/ATEX	Engines for operation in hazardous atmospheres (flammable and explosive-atmosphere safe)	EX/ATEX equipment	Gas Tight Citadel	Citadel, overpressure system supported by breathing air reservoir / pumped filtered air	Closed Vent	Air Circulation System	Decontamination facilities	Medical Facilities	Recovery Area	Enhanced Manoeuvrability	FRC/ARRC	Other Small Rescue Craft	Extra Lifeboats/Liferafts	Gas Detection System	Towing Arrangements	Low Freeboard	In Water Recovery Systems	Appropriate PPE	Clean up Equipment
Flammable/Explosive Atmosphere	H	S	S	P	P	P	P	P	P	P	O	P	P	S	P	P	O	S		P	O			P	O			P	
	M	S	S	P	S	S	S	S	S	S	O	S	S	P	P	P		S		S	O			P				P	
	L											O		O	O	O		O		O				S				P	
Fire	H	S	S	P	P	P								S	P	P		S		P	O			S	O			P	
	M	S	S	P	S	S								S	P	O		S		S	O			S				P	
	L													O	O	O		O		O				O				P	
Health Hazard / Toxic	H				P						O		P	S	P	P	P	S		P	O			P	O			P	
	M										O		S	P	P	S	S	S		S	O			P				P	
	L													O	O	O	O	O		O				S				P	
Cryogenic / Gases under pressure	H	S	S	P	S	S								O				S		P				P	O			P	
	M													O				S		S				P				P	
	L																	O		O								P	
Corrosive	H	S			S												P	S		S					O			P	
	M	S															S	S		S								P	
	L																O	O		O								P	
Rescue	H	S															O	P	P	P	P	S	O		S	S	S	P	
	M	S															O	P	P	S	P	S	O		S	S	S	P	
	L																O	P	P	O	P	S				S	S	P	
Clean Up	H	S												O			O	O	O	S					S			P	P
	M	S															O	O	O	S					S			P	P
	L	S															O	O	O	O								P	

12. Vessel Types

12.1. OVERVIEW

The project was required to consider a range of vessel types which could potentially be constructed or modified to include the design details provided in the previous Chapters. The types of vessel initially considered included:

- Emergency Towing Vessel (ETV) – Generally larger vessels which may be powerful, capable, towing vessels carrying salvage equipment such as pumps and fire fighting equipment and already have some of the design requirements in place and able to intervene positively in most marine emergencies. These may potentially be more capable of modification than standard tugs.
- Tugs – All ports have tugs available some of which will already be capable of responding to a fire incident. How these provide the level of protection required in response to the identified risks was also considered. Not all tugs are considered to be capable of modification either due to age, size or sea going capability. For example larger ocean going tugs are assumed to be more capable of being modified to meet response requirements than smaller vessels.
- Supply/Support ships – These were considered to have clear cargo decks which could be utilised for responders equipment for larger scale incidents. They were also assumed to also be more capable of incorporating design changes than tugs.
- Oil Recovery Ships – These were considered to have space for additional equipment or uses dependent on size and functionality. They may also have some of the design requirements already in place.

It was quickly seen that in response to some incidents other types of vessel may also be capable of responding for example:

- Naval Vessels which in general, depending on their size and class, already have facilities to pressurise a citadel which include airlocks for access providing safety in toxic incidents. They also have facilities for helicopters which provides either an aviation response or if required open deck space for carriage of other equipment. They also have a large, skilled complement of personnel who are all trained in fire fighting and emergency procedures and therefore could provide responders in the event of an emergency. Many Navies practise such responses as part of normal training,
- Heavy lift ships which have large deck areas which could accommodate equipment and accommodation facilities.
- Ferries which have facilities for large numbers of people but also have vehicle decks which could potentially carry emergency response equipment although these would be limited as it is not considered practical for ferries to be adapted to operate in more hazardous zones.
- Small Water Area Twin Hull (SWATH) vessels were considered to give a stable platform however this term relates to a hull form rather than a specific type of vessel which would still need to meet the design requirements discussed in this report.
- Chemical tanker were also considered due to their existing safety and construction standards for HNS cargos but these were discounted as potential rescue/safe platforms due to the risks associated with any cargos already on board. However they may be used for lightering operations when the initial incident is stabilised.

The above indicates that the project has considered many types of vessel and potential solutions which include the less obvious vessels. Not all of these have been included in the report as they were not considered viable when the scenarios were investigated further. No review of specific existing vessels has been carried out across Member States as part of this work and only generic vessel types have been considered.

Table 16 gives a matrix which shows which scenarios and which incidents the various types of vessel could be deployed to assist with assuming they have had the design requirements incorporated.

12.2. VESSEL CAPABILITY

It is apparent that although the number of vessel “types” is relatively small whilst there are structural, class and equipment requirements the final design can vary significantly dependent on the owners operational requirements. Therefore there is no international standard design for these vessel types and many variations across Member States in design and capability will exist. As a result the technical feasibility of undertaking modifications which take into account the structural limitations of each vessel is impractical and the decision as to whether a vessel can be modified will need to be assessed on a case by case basis. The practicality of modifying an existing vessel and the cost benefits will need to be balanced such that it does not distract from the primary function and commercial viability of the vessel.

It can safely be assumed that any vessel type can be modified if sufficient funds are available but such modifications would need to focus on existing structural limitations and the potential for increased structural strength. Any modifications will also need to consider the potential impact on the vessel stability as can any changes to existing equipment such as engine, generators, pumps and tanks (to accommodate FiFi or recovered HNS requirements). It is also possible that major design changes to the accommodation for medical facilities, decontamination, pressurised accommodation and responders & rescued personnel will lead to pipework and wiring changes throughout the vessel.

The following paragraphs give an overview of vessel types and their potential suitability for modification.

All Vessel Types

It is likely that all vessel type could have some form of pressured protection against the ingress of toxic substances ranging from the full citadel to increased internal pressure in manned compartments. This aspect would depend on the availability of services to provide the increased ventilation and the degree of difficulty in making areas gas tight.

Drenching systems around the accommodation could relatively easily be installed and they could be fitted with heat and gas detection equipment, (even if only hand held) additional life rafts, chemical suits, and respiratory equipment.

All vessels should be capable of assisting casualties even if this is only limited to providing helicopter winching areas to allow their evacuation to shore side hospitals.

ETV

An ETV is a multi-purpose boat used by state authorities to tow disabled vessels on the high seas in order to prevent dangers to individuals and the environment, therefore the focus is on the towing arrangements with the deck space dedicated to handling the large towing cables. Most ETV's have fire fighting capability installed; modifications and retro fitting of systems would be possible but unlikely to be cost effective. The spare deck space, which could be utilised to carry decontamination and medical facilities, would if utilised compromise the vessels towing ability. These vessels would be able to deploy booms and spraying equipment during HNS recovery operations and are likely to be fitted with lifting equipment. In addition work boats, semi ridged boats and life rafts could be deployed by these types of vessels.

Ocean Going Tugs

Similarly to ETV's ocean going tugs are primarily designed with salvage in mind, and are equipped to be able to undertake a variety of tasks in a salvage operation so will have work boats, lifting, and towing equipment as standard as well as salvage pumps. Those which do not already have FiFi equipment could be modified to carry fire fighting equipment, but this would be subject to the ability to carry the equipment and to install upgraded services to support the installation. However, it is highly unlikely that ocean going tugs without fire fighting capabilities are in operation. In most other aspects an ocean going tug and ETV can be considered as similar in their abilities having open deck spaces that could be used for recovery tanks, spraying and booming equipment.

Supply / Support Ships

These will have clear deck space and hence could accommodate portable decontamination, medical or HNS recovery equipment dependant on the response requirements. Some may already have FiFi equipment and others could be modified subject to the service availability constraints discussed for other vessel types. The anchor handling supply vessels will have large winching and towing arrangements. Some of the support vessels are designed as standby vessels for the offshore oil industry and are fitted to act as a *Place of Safety* in the event of evacuation from an oil rig and therefore are equipped with rescue craft and low freeboard to take casualties from the water.

Harbour Tugs

Harbour tugs are becoming larger as ship sizes develop in the major ports but in general they tend to be relatively small and therefore structural modification is unlikely. There may be space to install fire fighting equipment, but this will be subject to available pumps and tank storage or the ability to change these items to accommodate the new systems. Many harbour tugs already have fire fighting equipment but may not be suitable for operations further out to sea. Deck space on these vessels is limited therefore units for decontamination and medical facilities, spraying and recovery would create difficulties.

Oil Recovery Ships

These already have facilities for the recovery of oil hence could be adapted for HNS recovery particularly where the substance will float on the surface. However the properties of the recovered substance would need to be carefully reviewed to ensure safety of the personnel on the recovery vessel. Few are likely to have fire fighting capabilities to assist the casualty vessel but most could be modified to add this capability.

<u>Naval Vessels</u>

These are most likely to already have some resistance to contamination particularly larger vessels which will have citadels already installed and the means to provide decontamination facilities for casualties. They will also have more medical facilities readily to hand. Naval vessels also have a crew which normally have had more training in providing assistance to other vessels than the average vessel, which will be of benefit during any response. Additionally the operation of the citadel and associated decontamination facilities, along with the use of protective equipment will have been practised regularly again providing benefits to the response operation.

It is considered unlikely these vessels would be modified to install any other equipment as this may impact on their primary military functions, but they remain a very useful option as part of a coordinated response.

Table 16 shows the potential capability of existing vessel types by identifying three characteristic namely:

- Those vessels where some vessels of the type may already have some of the design features fitted;
- Those which it is believed could be modified or adapted to incorporate some of the design solutions without too many technical challenges; and
- Where it is believed design features could temporarily be installed.

If all of the design solutions were fitted on a new build they would create the “ideal” HNS Safe platform.

Table 16: Vessel Capability Matrix

		Chapter 4					Chapter 5						Chapter 6					Chapter 9											
Vessel	Capability	FiFi 1	FiFi 2	FiFi 3	Drenching System	Passive Fire Protection (A60/J120/H120)	Spark Arrest	Flame Traps	Water cooled exhausts	EX/ATEX	Engines for operation in hazardous atmospheres (flammable and explosive-atmosphere safe)	EX/ATEX equipment	Gas Tight Citadel	Citadel, overpressure system supported by breathing air reservoir / pumped filtered air	Closed Vent	Air Circulation System	Decontamination facilities	Medical Facilities	Recovery Area	Enhanced Manoeuvrability	FRC/ARRC	Other Small Rescue Craft	Extra Lifeboats/Liferafts	Gas Detection System	Towing Arrangements	Low Freeboard	In Water Recovery Systems	Appropriate PPE	Clean up Equipment
ETV	Maybe Equipped	x	x	x	x	x	x	x			x		x	x	x	x	x	x	x	x	x	x			x	x			
	Could be Equipped	x			x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x		x	x	x	x
	Temporary Fit possible											x									x	x	x				x	x	x
Ocean going Tug	Maybe Equipped	x	x	x	x	x	x	x			x			x	x	x				x					x				
	Could be Equipped	x			x		x	x	x	x	x	x		x	x														x
	Temporary Fit possible											x					x	x	x		x	x	x				x	x	x
Harbour tugs	Maybe Equipped	x	x	x	x	x	x	x							x	x				x					x				
	Could be Equipped	x			x		x	x	x	x		x		x	x														
	Temporary Fit possible											x									x	x	x				x	x	x
Supply/Support Vessels	Maybe Equipped	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x			x	x			
	Could be Equipped	x			x		x	x	x	x	x	x		x	x	x					x	x							x
	Temporary Fit possible											x					x	x	x		x	x	x				x	x	x
Oil Recovery Ships	Maybe Equipped					x	x	x						x	x	x				x	x	x			x				x
	Could be Equipped	x			x		x	x	x	x	x	x		x	x	x	x	x	x		x	x						x	x
	Temporary Fit possible																x	x	x		x	x	x				x		x
Naval Ships	Maybe Equipped				x								x	x	x	x	x	x	x	x		x		x	x			x	
	Could be Equipped	x			x		x	x	x	x														x				x	
	Temporary Fit possible																				x		x				x	x	x

Maybe Equipped = Some vessels of this type may already have this item fitted
Could be Equipped = Some vessels of this type could be modified to have the item fitted
Temporary Fit possible = Some vessels of this type have the potential for temporary addition of the item for the response period.

13. Glossary

A number of terms are used within this report and for clarity the definitions of the key terms used in the context of this report are provided in this Chapter. As far as possible these definitions are based on commonly used phraseology within the maritime industry.

Table 17 Glossary

Term	Definition
ATEX	Directive 94/9/EC concerning equipment and protective systems intended for use in potentially explosive atmospheres, commonly referred to as ATEX ("Atmosphères Explosibles")
Casualty Vessel	A vessel which has suffered a HNS incident and requires external assistance. Note this term is used rather than the term “Stricken Vessel” as this implies the vessel is incapacitated which may not always be the case.
Cefas	Centre for Environment, Fisheries and Aquaculture Science (Cefas is an executive agency of the UK Department for Environment, Food and Rural Affairs (Defra)
Citadel	In this report unless stated otherwise citadel refers to a gas tight safe area protecting the vessel crew from external toxic substances by providing an internal positive pressure it should not be confused with the increasing use of the term for protecting crew from pirate attacks
CLP	Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures
EMSA	European Maritime Safety Agency
ETV	Emergency Towing Vessel
FiFi	Fire Fighting
FLC	Fast Response Craft
GBS	Goal Based Standards
GESAMP	The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is an advisory body of the United Nations (UN)
GHS	United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS)
Hazard Class	This means the nature of the physical, health or environmental hazard; in accordance with the Regulation (EC) No 1272/2008 Of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures.
Hazardous and Noxious Substances (HNS)	Any substance other than oil which, if introduced into the marine environment is likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea
Hazardous and Noxious Substances (HNS) – Further	HNS definition includes dangerous goods (also called hazardous materials or HazMat) such as solids, liquids, or gases that can harm

Term	Definition
detail	people, other living organisms, property, the environment, or the carrier; materials that are flammable, explosive, corrosive, oxidizing, asphyxiating, bio hazardous, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances. Not included for the purpose of this study are radioactive materials.
HELCOM	Helsinki Commission
HVAC	Heating, ventilation, and air conditioning
IBC	International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk
IEC	The International Electrotechnical Commission
IGC	The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IMDG Code	International Maritime Dangerous Goods (IMDG) Code
IMO	International Maritime Organization
IMSBC	International Maritime Solid Bulk Cargoes (IMBSC) Code and Supplement, 2009 Edition
MSC	Maritime Safety Committee
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LSA Code	Life Saving Appliances Code
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) assists the Mediterranean coastal States in ratifying, transposing, implementing and enforcing international maritime conventions related to the prevention of, preparedness for and response to marine pollution from ships
Responder	Any vessel supplying assistance to the Casualty Vessel
Responding Vessel	Any vessel supplying assistance to the Casualty Vessel
Responsible Authority	The port, member state or other authority with responsibility for managing a HNS incident within their area of authority (e.g. in the UK this would be the SOSREP)
Safe Platform	A vessel which is able to provided rescue assistance and operational support during a HNS incident whilst still maintaining a place of safety for its crew, any additional response persons, and the crew of the casualty vessel once rescued
SCBA	Self-contained breathing apparatus
SOLAS	The International Convention for the Safety of Life at Sea
SWATH	Small Waterplane Area Twin Hull
Vessel of Opportunity	In this report this refers to any vessel in the vicinity of the casualty vessel which may be able to provide assistance but is not formally part of the responsible authorities' official response plan.
VSP	Voith Schneider propeller

14. References

The following references are referred to directly within this report a bibliography in Appendix 1 lists additional documentation reviewed which may have provided insight but is not referred to directly.

Reference	Title
1	IMO, 2011. Risk of chemical spills at sea. (MEPC/OPRC-HNS/TG 12/5/3)
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15. Appendix 1 Bibliography

This bibliography details the most significant sources of information reviewed in researching for this study.

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39 Centre of Documentation, Research and Experimentation on Accidental Water Pollution, Cedre

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41 EMSA Action plan for Pollution Preparedness and Response

16. Appendix 2 Hazard identification & risk assessment record

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Explosives	1.1 substances, mixtures and articles which have a mass explosion hazard (a mass explosion is one which affects almost the entire quantity present virtually instantaneously)	explosive, mass explosion	multiple deaths, multiple serious injuries loss of vessel	none	1	4		stand off zone 1 or zone 2 offer small craft rescue	1	2		Unlikely to be carried in bulk
	1.2 Substances, mixtures and articles which have a projection hazard but not a mass explosion hazard	explosive, severe projection	Multiple deaths, multiple serious injuries loss of vessel volatile projectiles	none	1	4		stand off zone 1 or zone 2 offer small craft rescue	1	2		Unlikely to be carried in bulk
	1.3 substances, mixtures 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 which gives rise to considerable radiant heat or ii) which burn one after another, producing minor blast or projection effects or both	explosive, fire, blast or projection	Multiple deaths, multiple serious injuries loss of vessel volatile projectiles fire toxic fumes	normal fire fighting equipment SCBAs upwind navigation	2	4		enhanced fire fighting capabilities drench system (FiFi) air re-circulation system passive fire protection offer small craft rescue zone 3	2	2		Unlikely to be carried in bulk
	1.4 substances, mixtures and articles which present no significant hazard: substances mixtures 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	fire or projection	Single death minor injuries localised fire toxic fumes	normal fire fighting equipment SCBAs upwind navigation	1	3		enhanced fire fighting capabilities drench system (FiFi) air re-circulation system passive fire protection offer closer craft rescue zone 3	1	2		Unlikely to be carried in bulk

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	1.5 very insensitive substances or mixtures which have a mass explosion hazard: substances and mixtures which have a mass explosion hazard but are so insensitive that there is little probability of initiation or of transition from burning to detonation under normal conditions	explosive, mass explosion	multiple deaths, multiple serious injuries loss of vessel	none	1	4		stand off zone 1 or zone 2 offer small craft rescue	1	2		Unlikely to be carried in bulk
	1.6 extremely insensitive articles which do not have a mass explosion hazard: articles which contain only extremely insensitive detonating substances or mixtures and which demonstrate a negligible probability of accidental initiation or propagation	minor explosion	death injuries	normal fire fighting equipment SCBAs upwind navigation keep off open decks structure protection	2	3		enhanced fire fighting capabilities drench system (FiFi) air re-circulation system passive fire protection offer small craft rescue zone 3	2	2		Unlikely to be carried in bulk
	Unstable explosives	un stable explosives	N/A	N/A	0	0	0	N/A				Very Unlikely to be carried in bulk
Flammable gases	Category 1 (Gases, which at 20oC and a standard pressure of 101.3 kPa: a) are ignitable when in a mixture of 13% or less by volume in air or b) have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit)	extremely flammable gas	multiple deaths major injuries loss of vessel fire explosion toxic fumes	normal fire fighting upwind navigation	3	4		drenching system passive fire protection EX equipment EX/ATEX equipment funnel height flame traps pressurised vent system citadel system zone of operation 1, 2 or 3 small FRC equipped to meet EX/ATEX SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system)	2	2		Explosive risk redued if spark/flame reduction mitigation inplace on resonding vessels entering hazard zone.

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 2 (gases, other that those of category 1 which at 20oC and a standard pressure of 101.3 kPa, have a flammable range while mixed in air)	flammable gas	multiple deaths major injuries loss of vessel fire explosion toxic fumes	normal fire fighting upwind navigation	2	4		drenching system passive fire protection EX equipment EX/ATEX equipment funnel height flame traps pressurised vent system citadel system zone of operation 1, 2 or 3 small FRC equipped to meet EX/ATEX SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system) towing arrangements enhanced manoeuvrability	2	2		
Flammable aerosols	category 1	extremely flammable aerosol	N/A		0	0	0					will not be carried in bulk form hence not assessed
	category 2	flammable aerosol	N/A		0	0	0					will not be carried in bulk form hence not assessed
Oxidizing gases	category 1. (any gas which may generally by providing oxygen cause or contribute to the combustion of other material more than air does)	may cause or intensify fire, oxidiser	firedeath/injuries structural vessel damage	normal fire fighting equipmentu pwind navigation	2	3		drenching systempassive fire protectionEX equipmentEX/ATEX equipmentfunnel heightflame trapspressurised vent systemcitadel systemzone of operation 1, 2 or 3small FRC equipped to meet EX/ATEXSCBAgas detection equipmentremove heat sources (e.g. exhaust cooling system)remove oxygen sourcetowing arrangementsenhanced manoeuvrability	1	3		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Gases under pressure	Compressed gas (a gas which when packaged under pressure is entirely gaseous at -50 oC, including all gases with a critical temperature ≤ -50oC)	contains gas under pressure may explode if heated	explosion death/injuries structural vessel damage	normal fire fighting equipment upwind navigation	1	3		drenching system passive fire protection funnel height flame traps pressurised vent system zone of operation 1, 2 or 3 FRC/ARRC SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system) towing arrangements enhanced manoeuvrability	1	3		
	Liquefied gas (a gas which when packaged under pressure is partially liquid at temperatures above -50 oC. A distinction is made between: a) high pressure liquefied gas: a gas with a critical temperature between -50oC and +65oC and b) low pressure liquefied gas: a gas with a critical temperature above +65oC)	contains gas under pressure, may explode if heated	explosion death/injuries structural vessel damage	normal fire fighting equipment upwind navigation	2	3		drenching system passive fire protection funnel height flame traps pressurised vent system zone of operation 1, 2 or 3 FRC/ARRC SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system) towing arrangements enhanced manoeuvrability	1	3		
	Refrigerated liquefied gas (a gas which when packaged is made partially liquid because of its low temperature)	contains refrigerated gas, may cause cryogenic burns or injury	explosion death/injuries structural vessel damage burns	normal fire fighting equipment upwind navigation	1	3		drenching system passive fire protection funnel height flame traps pressurised vent system zone of operation 1, 2 or 3 FRC/ARRC SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system) towing arrangements enhanced manoeuvrability citadel system chemical suits	1	2		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Resid ual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	Dissolved gas (a gas which when packaged under pressure is dissolved in a liquid phase solvent)	contains gas under pressure may explode if heated	explosion death/injuries structural vessel damage	normal fire fighting equipment upwind navigation	2	3		drenching system passive fire protection funnel height flame traps pressurised vent system zone of operation 1, 2 or 3 FRC/ARRC SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system) towing arrangements enhanced manoeuvrability	2	2		
Flammable liquids	category 1 (lash point <23oC and initial boiling point ≤ 35oC)	extremely flammable liquid and vapour	firedeath/injuries structural vessel damage	normal fire fighting systemupwind navigation	3	3		remove heat and ignition sourcesenhanced fire fighting systemsdrenching systemoperation zones 1, 2, 3passive fire protection system (e.g. A60/J120/H120)	2	2		
Flammable liquids	category 2 (flash point < 23oC and initial boiling point > 35oC)	highly flammable liquid and vapour	fire death/injuries structural vessel damage	normal fire fighting system upwind navigation	2	3		remove heat and ignition sources enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
Flammable liquids	category 3 (flash point ≥ 23oC and ≤ 60oC)	flammable liquid and vapour	fire death/injuries structural vessel damage	normal fire fighting system upwind navigation	1	3		remove heat and ignition sources enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
Flammable liquids	category 4 (flash point >60oC and ≤ 93oC)	combustible liquid										not implemented yet through CLP

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Flammable solids	category 1 (burning rate test: substances or mixtures other than metal powders: a) wetted zone does not stop fire and b) burning time < 45s or burning rate > 2.2 mm/s. metal powders: burning time ≤ 5 min)	flammab le solid	fire death/injuries structural vessel damage	normal fire fighting system	3	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
	Category 2 (burning rate test: substances or mixtures other than metal powders: a) wetted zone stops the fire for a least 4 min and b) burning time < 45s or burning rate > 2.2 mm/s. Metal powders: burning time > 5min and ≤ 10min)	flammab le solid	fire death/injuries structural vessel damage	normal fire fighting system	2	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
Self-reactive substances and mixtures[3]	type A (any self reactive substance or mixture which can detonate or deflagrate rapidly as packaged)	heating may cause explosio n	fire death/injuries structural vessel damage	normal fire fighting system	3	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
	type B (any self reactive substance or mixture possessing explosive properties and which as packaged neither detonates nor deflagrates rapidly but is liable to undergo a thermal explosion in that package)	heating may cause explosio n or fire	fire death/injuries structural vessel damage	normal fire fighting system	2	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
	type C (any self reactive substance or mixture possessing explosive properties when the substance or mixture as packaged cannot detonate or deflagrate rapidly or undergo a thermal explosion)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		

[3] a) self-reactive substances or mixtures are thermally unstable liquid or solid substances or mixtures liable to undergo a strongly exothermic decomposition even without participation of oxygen (air). This definition excludes substances and mixtures classified under the GHS as explosives, organic peroxides or as oxidising.
b) a self-reactive substance or mixture is regarded as possessing explosive properties when in laboratory testing the formulation is liable to detonate, to deflagrate rapidly or to show a violent effect when heated under confinement

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	type D (any self reactive substance or mixture which in laboratory testing: i) detonates partially, does not deflagrate rapidly and shows no violent effect when heated under confinement, or ii) does not detonate at all, deflagrates slowly and shows no violent effect when heated under confinement, or iii) does not detonate or deflagrate at all and shows a medium effect when heated under confinement)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
	type E (any substance or mixture which in laboratory testing neither detonates nor deflagrates at all and shows low or no effect when heated under confinement)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
	type F (any substance or mixture which in laboratory testing neither detonates in the cavitated state nor deflagrates at all and shows only a low or no effect when heated under confinement as well as low or no explosive power)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
	type G (any substance or mixture which in laboratory testing neither detonates in the cavitated state nor deflagrates at all and shows no effect when heated under confinement nor any explosive power provided that it is thermally stable (self-accelerating decomposition temperature is 60oC to 75oC for a 50 kg package) and for liquid mixtures a diluent having a boiling point greater than or equal to 150oC is used for desensitisation)				0	0	0		0	0	0	no hazard listed in CLP to be considered in other categories table 2.8.1 CLP reg
Pyrophoric liquids	category 1 (the liquid ignites within 5 min when added to an inert carrier and exposed to air, or it ignites or chars a filter paper on contact with air within 5 min)	catches fire spontaneously if exposed to air	fireinjuries	normal fire fighting system	1	3		enhanced fire fighting systemsdrenching systemoperation zones 1, 2, 3passive fire protection system (e.g. A60/J120/H120)	1	2		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Pyrophoric solids	category 1 (the solid ignites within 5 min of coming into contact with air)	catches fire spontaneously if exposed to air	fire injuries	normal fire fighting system	1	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
Self-heating substances and mixtures[4]	category 1	self heating may catch fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		Confirmation of HNS status required
	category 2	self heating in large quantities may catch fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	2		
Substances and mixtures which, in contact with water emit flammable gases	category 1 (any substance or mixture which reacts vigorously with water at ambient temperatures and demonstrates generally a tendency for the gas produced to ignite spontaneously or which reacts readily with water at ambient temperatures such that the rate of evolution of flammable gas is equal to or greater than 10 litres per kg of substance over any one minute)	in contact with water releases flammable gases which may ignite spontaneously	multiple deaths major injuries loss of vessel fire explosion toxic fumes	normal fire fighting upwind navigation	2	4		drenching system passive fire protection EX equipment EX/ATEX equipment funnel height flame traps pressurised vent system citadel system zone of operation 1, 2 or 3 small FRC equipped to meet EX/ATEX SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system)	2	3		

[4] A self-heating substance or mixture is a solid or liquid substance or mixture other than a pyrophoric liquid or solid, which by reaction with air and without energy supply is liable to self-heat. This substance or mixture differs from a pyrophoric liquid or solid in that it will ignite only when in large amounts (kgs) and after long periods of time (hrs or days)

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 2 (any substance or mixture which reacts readily with water at ambient temperatures such that the maximum rate of evolution of flammable gas is equal to or greater that 20 litres per kg of substance per hour, and which does not meet the criteria for category 1)	in contact with water releases flammable gases	multiple deaths major injuries loss of vessel fire explosion toxic fumes	normal fire fighting upwind navigation	2	4		drenching system passive fire protection EX equipment EX/ATEX equipment funnel height flame traps pressurised vent system citadel system zone of operation 1, 2 or 3 small FRC equipped to meet EX/ATEX SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system)	2	3		
	category 3 (any substance or mixture which reacts slowly with water at ambient temperatures such that the maximum rate of evolution of flammable gas is equal to or greater than 1 litre per kg of substance per hour and which does not meet the criteria for categories 1 and 2)	in contact with water releases flammable gases	multiple deaths major injuries loss of vessel fire explosion toxic fumes	normal fire fighting upwind navigation	1	4		drenching system passive fire protection EX equipment EX/ATEX equipment funnel height flame traps pressurised vent system citadel system zone of operation 1, 2 or 3 small FRC equipped to meet EX/ATEX SCBA gas detection equipment remove heat sources (e.g. exhaust cooling system)	1	3		
Oxidizing liquids	category 1 (any substance or mixture which in the 1:1 mixture, by mass, of substance (or mixture) and cellulose tested spontaneously ignites or the mean pressure rise time of a 1:1 mixture by mass of substance and cellulose is less than that of a 1:1 mixture by mass of 50% perchloric acid and cellulose)	may cause fire or explosion, strong oxidiser	firedeath/injuries structural vessel damage	normal fire fighting equipment	2	3		drenching systempassive fire protectionpressurised vent systemcitadel systemzone of operation 1, 2 or 3FRC/ARRCSCBAremove oxygen sourcetowing arrangementsenhanced manoeuvrability				

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	Category 2 (any substance or mixture which in the 1:1 mixture by mass of substance (or mixture) and cellulose tested exhibits a mean pressure rise time less than or equal to the mean pressure rise time of a 1:1 mixture by mass of 40% aqueous sodium chlorate solution and cellulose and the criteria for category 1 are not met)	may intensify fire, oxidiser	fire injuries	normal fire fighting equipment	2	2		drenching system passive fire protection pressurised vent system citadel system zone of operation 1, 2 or 3 FRC/ARRC SCBA remove oxygen source towing arrangements enhanced manoeuvrability	2	1		
	category 3 (any substance or mixture which in the 1:1 mixture by mass of substance (or mixture) and cellulose tested exhibits a mean pressure rise time less than or equal to the mean pressure rise time of a 1:1 mixture by mass of 65% aqueous nitric acid and cellulose and the criteria for categories 1 and 2 are not met)	may intensify fire, oxidiser	fire injuries	normal fire fighting equipment	2	2		drenching system passive fire protection pressurised vent system citadel system zone of operation 1, 2 or 3 FRC/ARRC SCBA remove oxygen source towing arrangements enhanced manoeuvrability	2	1		
Oxidizing solids	category 1 (any substance or mixture which in the 4:1 or 1:1 sample to cellulose ratio (by mass) tested exhibits a mean burning time less than the mean burning time of a 3:2 mixture by mass of potassium bromate and cellulose)	may cause fire or explosion, strong oxidiser	fire death/injuries structural vessel damage	normal fire fighting equipment	2	3		drenching system passive fire protection pressurised vent system citadel system zone of operation 1, 2 or 3 FRC/ARRC SCBA remove oxygen source towing arrangements enhanced manoeuvrability	2	1		
	category 2 (any substance or mixture which in the 4:1 or 1:1 sample to cellulose ratio (by mass) tested exhibits a mean burning time equal to or less than the mean burning time of a 2:3 mixture (by mass) of potassium bromate and cellulose and the criteria for category 1 are not met)	may intensify fire, oxidiser	fire death/injuries	normal fire fighting equipment	2	2		drenching system passive fire protection pressurised vent system citadel system zone of operation 1, 2 or 3 FRC/ARRC SCBA remove oxygen source towing arrangements enhanced manoeuvrability	2	1		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 3 (any substance or mixture which in the 4:1 or 1:1 sample to cellulose ratio (by mass) tested exhibits a mean burning time equal to or less than the mean burning time of a 3:7 mixture (by mass) of potassium bromate and cellulose and the criteria for categories 1 and 2 are not met)	may intensify fire, oxidiser	fire death/injuries	normal fire fighting equipment	2	2		drenching system passive fire protection pressurised vent system citadel system zone of operation 1, 2 or 3 FRC/ARRC SCBA remove oxygen source towing arrangements enhanced manoeuvrability	2	1		
Organic peroxides[5]	type A (any organic peroxide which as packaged can detonate or deflagrate rapidly)	heating may cause an explosio n	firedeath/injuries structural vessel damage	normal fire fighting system	3	3		enhanced fire fighting systemsdrenching systemoperation zones 1, 2, 3passive fire protection system (e.g. A60/J120/H120)	3	2		
	type B (any organic peroxide possessing explosive properties and which as packaged neither detonates nor deflagrates rapidly but is liable to undergo a thermal explosion in that package)	heating may cause fire or explosio n	fire death/injuries structural vessel damage	normal fire fighting system	2	3		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	2	2		
	type C (any organic peroxide possessing properties when the substance or mixture as packaged cannot detonate or deflagrate rapidly or undergo a thermal explosion0	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	1		

[5] organic peroxides are liquid or solid organic substances which contain the bivalent -o-o structure and may be considered derivatives of hydrogen peroxide where one or both of the hydrogen atoms have been replaced by organic radicals. the term also includes organic peroxide formulations (mixtures). organic peroxides are thermally unstable substances or mixtures which may undergo exothermic self accelerating decomposition. in addition, they may have one or more of the following properties:
(a) be liable to explosive decomposition
(b) burn rapidly
(c) be sensitive to impact or friction
(d) react dangerously with other substances
an organic peroxide is regarded as possessing explosive properties when in laboratory testing the formulation is liable to detonate to deflagrate rapidly or to show a violent effect when heated under confinement.

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	type D (any organic peroxide which in laboratory testing: i) detonates partially does not deflagrate rapidly and shows no violent effect when heated under confinement, or ii) does not detonate at all deflagrates slowly and shows no violent effect when heated under confinement, or iii) does not detonate or deflagrate at all and shows a medium effect when heated under confinement)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	1		
	type E (any organic peroxide which in laboratory testing neither detonates nor deflagrates at all and shows low or no effect when heated under confinement)	heating may cause fire	fire injuries	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	1		
	type F (any organic peroxide which in laboratory testing neither detonates in the cavitaed state nor deflagrates at all and shows only a low or no effect when heated under confinement as well as low or no explosive power)	heating may cause fire	fire injuries structural vessel damage	normal fire fighting system	1	2		enhanced fire fighting systems drenching system operation zones 1, 2, 3 passive fire protection system (e.g. A60/J120/H120)	1	1		
	type G (any organic peroxide which in laboratory testing neither detonates in the cavitated state nor deflagrates at all and shows no effect when heated under confinement nor any explosive power, provided that it is thermally stable (self accelerating decomposition temperature is 60oC or higher for a 50 kg package) and for liquid mixtures a diluent having a boiling point of not less than 150oC is used for desensitisation)				0	0	0		0	0	0	no hazard listed in CLP to be considered in other categories table 2.15.1 CLP reg
Corrosive to metals	category 1 (corrosion rate on either steel or aluminium surfaces exceeding 6.25 mm per year at a test temperature of 55oC when tested on both materials)	may be corrosive to metals	minor structural vessel damage	wash down of affected areas	1	1		none required - post incident deck wash sufficient	1	1		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Acute toxicity	category 1	fatal (if swallowed, in contact with skin, if inhaled)	deathserious injury	upwind navigation	2	3		chemical suitsSCBAgas detection systemcitadel systempressurised vent systemdrench systemdecontamination facilitiesmedical facilitiesrecovery areaappropriate PPE	2	2		assumption based on gas/vapour/dust
	category 2	fatal (if swallowed, in contact with skin, if inhaled)	death serious injury	upwind navigation	2	3		chemical suits SCBA gas detection system citadel system pressurised vent system drench system decontamination facilities medical facilities recovery area appropriate PPE	2	2		assumption based on gas/vapour/dust
	category 3	toxic (if swallowed, in contact with skin, if inhaled)	serious injury	upwind navigation	2	3		chemical suits SCBA gas detection system citadel system pressurised vent system drench system decontamination facilities medical facilities recovery area appropriate PPE	2	2		assumption based on gas/vapour/dust
	category 4	harmful (if swallowed, in contact with skin, if inhaled)	serious injury	upwind navigation	2	2		chemical suits SCBA gas detection system citadel system pressurised vent system drench system decontamination facilities medical facilities recovery area appropriate PPE	2	1		assumption based on gas/vapour/dust

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 5	may be harmful	serious injury	upwind navigation	2	2		chemical suits SCBA gas detection system citadel system pressurised vent system drench system decontamination facilities medical facilities recovery area appropriate PPE	2	1		not part of CLP
Skin corrosion / irritation[6]	corrosive: category 1A category 1B category 1C	causes severe skin burns and eye damage (all cat)	serious injury	limited PPE washing facilities	2	2		chemical suits decontamination facilities medical facilities recovery area appropriate PPE	2	1		
	skin irritant category 2 category 3	causes skin irritation (cat 2 only)	minor injuries	limited PPE washing facilities	2	2		chemical suits decontamination facilities medical facilities recovery area appropriate PPE	2	1		
Serious eye damage / eye irritationserious[7]	irreversable effects on the eye category 1	causes serious eye damage	serious injury/loss of sight	limited PPEeye protectioneye wash bottlessafety specs/goggles	2	2		appropriate PPEmedical facilitiesdecontamination arearecovery area	2	1		

[6] Skin corrosion is the production of irreversible damage to the skin, namely visible necrosis through the epidermis and into the dermis following the application of a test substance for up to 4 hrs. Corrosive reactions are typified by ulcers, bleeding, bloody scabs and by the end of observation at 14 days by discolouration due to blanching of the skin, complete areas of alopecia and scars. histopathology should be considered to evaluate questionable lesions.

[7] Eye damage is the production of tissue damage in the eye or serious physical decay of vision following application of a test substance to the anterior surface of the eye which is not fully reversible within 21 days of application.

Eye irritation is the production of changes in the eye following the application of test substance to the anterior surface of the eye which are fully reversible within 21 days of application

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	irritating to eyes category 2A	causes serious eye irritation	serious injury	limited PPE eye protection eye wash bottles safety specs/goggles	2	2		appropriate PPE medical facilities	2	1		
	mildly irritating to eyes category 2B	causes eye irritation	minor injuries	limited PPE eye protection eye wash bottles safety specs/goggles	2	1		appropriate PPE medical facilities	2	1		
Respiratory or skin sensitization[8]	respiratory sensitisation category 1A (substances showing a high frequency of occurrence in humans or a probability of occurrence of a high sensitisation rate in humans based on animal or other tests. Severity of reaction may also be considered) category 1B (substances showing a low to moderate frequency of occurrence in humans or a probability of occurrence of a low to moderate sensitisation rate in humans based on animal or other tests. Severity of reaction may also be considered)	may cause allergy or asthma symptoms or breathing difficulties if inhaled	serious injury/allergy and or asthma	limited SCBA	2	2		appropriate PPE medical facilities	2	1		

[8] A respiratory sensitizer is a substance that will lead to hypersensitivity of the airways following inhalation of the substance.
A skin sensitiser is a substance that will lead to an allergic response following skin contact.

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	skin sensitisation category 1A (substances showing a high frequency of occurrence in humans and or a high potency in animals can be presumed to have the potential to produce significant sensitisation in humans. Severity of reaction may also be considered) category 1B (substances showing a low to moderate frequency of occurrence in humans and or a low to moderate potency in animals can be presumed to have the potential to produce sensitisation in humans. Severity of reaction may also be considered)	may cause an allergic skin reaction	allergy	limited PPE washing facilities	2	2		appropriate PPE medical facilities	2	1		
Germ cell mutagenicity[9]	category 1A (substances known to induce heritable mutations in germ cells of humans, positive evidence from human epidemiological studies)	may cause genetic defects	serious injury	none	1	2		appropriate PPEcitadeldecontamination area	1	1		
	category 1B (a) positive results from in vivo heritable germ cell mutagenicity tests in mammals or b) positive results from in vivo somatic cell mutagenicity tests in mammals in combination with some evidence that the substance has potential to cause mutations to germ cells. this supporting evidence may for example be derived from mutagenisity/genotoxic tests in germ cells in vivo or by demonstrating the ability of the substance or its metabolites to interact with the genetic material of germ cells or c) positive results from tests showing mutagenic effects in the germ cells of humans, without demonstration of transmission to progeny for example, an increase in the frequency of aneuploidy in sperm cells of exposed people)	may cause genetic defects	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		

[9] Mutation is defined as a permanent change in the amount or structure of the genetic material in a cell.

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 2 (substances which cause concern for humans owing to the possibility that they may induce heritable mutations in the germ cell of humans. Positive evidence obtained from experiments in mammals and or in some cases from in votro experiments obtained from: a) somatic cell mutagenicity tests in vivo in mammals or b) other in vivo somatic cell genotoxicity tests which are supported by positive results from in vitro mutagenicity assays.)	suspected of causing genetic defects	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		
Carcinogenicity	category 1A (known to have carcinogenic potential for humans, the placing of a substance is largely based on human evidence)	may cause cancer	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		
	category 1B (presumed to have carcinogenic potential for humans,	may cause cancer	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		
	category 2 (suspected human carcinogens. The placing of a substance in category 2 is done on the basis of evidence obtained from human and or animal studies but which is not sufficiently convincing to place the substance on category 1.	suspected of causing cancer	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		
Reproductive toxicity	category 1A (known human reproductive toxicant)	may damage fertility or the unborn child	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		
	category 1B (presumed human reproductive toxicant)	may damage fertility or the unborn child	serious injury	none	**1**	**2**		appropriate PPE citadel decontamination area	**1**	**1**		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
	category 2 (suspected human reproductive toxicant)	suspected of damaging fertility or the unborn child	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		
Specific target organ toxicity – Single exposure	Category 1 (substances that have produced significant toxicity in humans or that on the basis of evidence from studies in experimental animals can be presumed to have the potential to produce significant toxicity in humans following single exposure)	causes damage to organs	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		
	category 2 (substances that on the basis of evidence from studies in experimental animals can be presumed to have the potential to be harmful to human health following single exposure)	may cause damage to organs	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		
	category 3 (transient target organ effects)	may cause respiratory irritation or may cause drowsiness or dizziness	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		
Specific target organ toxicity – Repeated exposure	category 1 (substances that have produced significant toxicity in humans or that on the basis of evidence from studies in experimental animals can be presumed to have the potential to produce significant toxicity in humans following repeated exposure)	causes damage to organs	serious injury	none	1	2		appropriate PPEcitadeldecontamination area	1	1		
	category 2 (substances that on the basis of evidence from studies in experimental animals can be presumed to have the potential to be harmful to human health following repeated exposure)	may cause damage to organs	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		

Cat.	Sub Category	Hazard	Consequences	Existing Safeguard	Risk Rank			Proposed Mitigating Action	Residual Risk Rank			Notes
					Prob	Cons.	Value		Prob	Cons.	Value	
Aspiration hazard	category 1 (chemicals known to cause human aspiration toxicity hazards or to be regarded as if they cause human aspiration toxicity hazard)	may be fatal if swallowed and enters airways	serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		
	category 2 (chemicals which cause concern owing to the presumption that they cause human aspiration toxicity hazard)		serious injury	none	1	2		appropriate PPE citadel decontamination area	1	1		not implemented yet by CLP
Environmental Hazards												Environmental issue are not within the scope of this study
Acute toxicity / Chronic toxicity												Environmental issue are not within the scope of this study

17. Appendix 3 Risk Assessment Criteria

Event Risk Matrix			Minor	Moderate	Major	Catastrophic
			CONSEQUENCE →			
			1	2	3	4
Likely >80% Probability	LIKELIHOOD ↑	4				
Moderate >60% Probability		3				
Unlikely >20% Probability		2				
Rare >5% Probability		1				

Risk Ranking	
Low = Acceptable	
Medium = Requires longer term corrective action	
High = unacceptable	

Probability = Likelihood of the outcome whilst carrying out an response to an HNS incident

CONSEQUENCES		
		People effects (PE)
Catastrophic	4	• Multiple Fatalities or •Significant irreversible disability or effects to more than one person
Major	3	• Single Fatality or •Significant irreversible disability or effects to one person
Moderate	2	•Extensive injuries or impairment to one person •Medium term largely reversible disability to one or more persons
Minor	1	•Significant medical treatment, disabling or lost time injury < 2 weeks

18. Appendix 4 HNS Scenarios

General Scenario Requirements

During the research and discussions undertaken whilst preparing this report it was identified that a number of factors needed to be taken into account whatever the type or nature of the HNS incident. These factors are detailed below and will be relevant to each of the scenario overviews provided in the subsequent pages.

The response to an incident will broadly follow the following timeline:

1. An incident is reported by the casualty vessel or other source witnessing the incident. (E.g. other vessels involved members of the public, etc.).

2. If the incident was sent as a general alert via common radio frequencies (e.g. Channel 16) then nearby vessels may respond immediately depending on the nature of the alert.

3. The responsible authorities once alerted would begin to coordinate a response.

4. Responsible authorities will need to determine as a range of information in order to decide on the most appropriate response. Information required will include:

    - Vessel details:
    - Location
    - Vessel specifics – size, cargo, number of persons on board
    - Nature of the incident
    - Other vessel(s) at risk
    - Persons at risk
    - Cargo involved or at risk in the incident
    - Current actions underway to contain the incident
    - Local conditions (Weather, sea state) current and forecast

5. From the available information the responsible authorities will seek to determine:

    - Seriousness and potential for escalation
    - Assistance required by the casualty vessel
    - Time frame for provision of assistance
    - Type of vessels best able to supply the optimum assistance to the incident
    - Alternative vessels to provide a level of assistance if optimum vessels are not available

6. The responsible authorities will direct and manage the provision of appropriate vessels or other units (e.g. helicopters) to respond. The responding vessels should be those best equipped to provide assistance i.e. optimum type and capability but it is acknowledged this may not be possible therefore responding authorities may need to consider alternatives.

    When deciding on the optimum vessel type and capability to respond the responsible authorities will need to consider:

    - Risks to responding vessel crew
    - Risks to the casualty crew
    - Potential for incident escalation
    - Time to arrive at the incident scene with the necessary equipment / personnel if additional to responding vessels normal complement
    - Location of the incident

- Nature of the incident
- Distance from the casualty vessel to any vessel(s) able to respond
- Type of vessel(s) able to respond to meet timeline requirements
- Equipment carried on-board vessel(s) able to respond to meet timeline requirements

General Scenario Assumptions

With any incident there are a number of assumptions which will be necessary and are in line with normal practice for any vessel responding to an incident alert whether responding directly to a radio request for assistance or when directed by the responsible authorities as part of a coordinated response. These assumptions include:

- The responding vessels primary aim will be the saving lives;
- The casualty vessel will make every effort to minimise the incident e.g. they will try to contain a leak, fire, flood etc. as far as possible without putting crew at unnecessary additional risk;
- The master of any responding vessel will assess the scene on arrival and will not place his crew in unnecessary risk unless in exceptional circumstances;
- The master of the responding vessel will approach nay incident from a safe direction (e.g. upwind from smoke or any cargo releases);
- The responding vessel will only provide assistance beyond saving lives when it is safe to do so without endangering its own crew or any crew from the casualty vessel;
- The responding vessel may use daughter boats to provide assistance if it is considered by the master unsafe to approach the casualty vessel directly;
- The responding vessel may require the casualty vessel crew to make their own way to the responding vessel;
- The casualty vessel crew will remain on-board the vessel as long as it is safe to do so;
- If evacuating the casualty vessel the crew will use life boats and/or life rafts before considering entering the water (e.g. jumping overboard);
- It may be more practicable to evacuate the casualty vessel by helicopter if one with suitable winching capability is available and it is safe to do so.

Scenario Descriptions

The following pages give an overview of the hazard scenarios derived from the workshop used to develop design requirements and take into account the general requirements and assumptions given previously. The scenarios described are:

Scenario 1 – Flammable / Explosive Leak

Scenario 2 – Fire

Scenario 3 – Health Hazard / Toxic

Scenario 4 – Cryogenic / Gases Under Pressure

Scenario 5 – Corrosive

Scenario 6 – Example of a combination hazard due to the nature of the substance released – Flammable & Toxic

The last page provides additional mitigation which is considered applicable to all scenarios depending on the escalation of the incident.

Scenario 1 Explosive / Flammable

Hazard Description

The casualty vessel has a release of a substance which may result in an explosion if the criteria for ignition of the substance are met by either equipment on the casualty vessel or the responding vessel(s).

This hazard may include military vessels and their supply ships which routinely carry explosives in the form of ordinance/munitions. Due to nature of these vessels and security issues this has been assumed to be outside the scope of this review but many of the hazards are considered to be applicable to this type of vessel.

Initial Response Vessel Hazards

When responding to a request for assistance responding vessels need to be aware that ignition of the explosive substance may be caused by:

- Ignition sources on the response vessel.
- Ignition sources on the casualty vessel.

The responsible authority will need to make responding vessel aware of the risks as should the casualty vessel if they are in a position to communicate with the responding vessel.

The casualty vessel should also warn other vessels to keep clear of the hazard area if possible.

On-going Response Vessel Hazards

The potential to ignite the explosive substance is likely to decrease as the substance is dispersed, evaporated or dissolved.

Protection to Mitigate Identified Hazards

A key mitigation is to avoid entering the hazardous area as far as possible and only when required to safe life.

Awareness of the cargo characteristics and remaining outside ignition risk area:

- Requires clear communication with the casualty vessel and/or the responsible authorities and a clear understanding of the danger area.

Responding vessel should ideally include the use of ignition reducing technology e.g. using low ignition boats / equipment to prevent ignition.

Training for operations in explosives scenarios for the responding vessel crew would be preferable but the provision of on scene advice from experts in the field would assist.

Scenario 2 – Fire

Hazard Description

A casualty vessel has a release of a substance which either directly results in a fire or has the potential to result in a fire if the criteria for ignition of the substance are met by either equipment on the casualty vessel or the responding vessel(s). Potentially some substances may self-ignite in the right conditions whilst others react on contact with water to ignite and cause a flammable atmosphere.

Initial Response Vessel Hazards

Hazards to the crews of the casualty and responding vessel(s) include burns ranging from minor to fatal.

The responding vessel may also be damaged due to the effects of the fire which may put rescue attempts at risk.

There is also the risk that the atmosphere on the responding vessel will become contaminated (e.g. smoke potentially containing toxic by product of fire) from contaminated air intakes, heating, ventilation, and air conditioning (HVAC) contamination.

On-going Response Vessel Hazards

As above but substances may dissipate, evaporate etc. reducing overall risk of fire occurring with time. Additionally as fire progresses original fuel source will be consumed but the fire may also spread to other areas of the vessel.

Potential for longer term effects to the responding vessel crew and responders due to extended periods within area of contamination with limited or no access to appropriate protective equipment.

Potential to re-ignite fire if fire suppression fails.

Protection to Mitigate Identified Hazards

Training for operations in response to fire scenarios.

Provision of Personnel Protective Equipment (PPE).

Protective measure for vessel crew not involved in direct operations (boundary cooling/movement of vessel from area of risk).

SCBA.

HVAC Filtration / Isolation.

Scenario 3 – Health Hazard / Toxic

Hazard Description

Release of toxic substance as a result of an accident or equipment failure on the casualty vessel. Personnel on both the casualty and responding vessels at risk of contamination by various routes e.g. Inhalation, skin contact, etc.

Lethal doses and exposure over time issues make this scenario uncertain as different substances can have immediate or long term effects on personnel. Also symptoms of contamination or infection may not be apparent immediately.

Initial Response Vessel Hazards

Long term or acute health affects resulting from exposure to substance.

Immediate effects may be seen on personnel before becoming aware of the hazard.

Changes in wind direction which may blow contamination over the casualty or responding vessels. This will be especially relevant if the vessels cannot manoeuvre.

Lack of awareness of personnel on how to manage the incident due to the nature of the substances leading to contamination.

Potential contamination of on-board water supplies from contaminated sea water intake.

Potential contamination of on-board air supplies from contaminated air intake e.g. HVAC contamination.

On-going Response Vessel Hazards

As above but substances may dissipate, evaporate etc. reducing overall risk with time.

Potential for longer term effects due to extended periods within area of contamination with limited or no access to appropriate protective equipment.

Protection to Mitigate Identified Hazards

Training for operations in toxic scenarios

Provision of Personnel Protective Equipment (PPE)

Protective measure for vessel crew not involved in direct operations (citadel)

Decontamination equipment e.g. washing facilities, clean clothing

Self-Contained Breathing Apparatus

Isolated water systems to prevent contaminated water being drawn into vessel water systems

HVAC Filtration / Isolation

Scenario 4 – Cryogenic & Gases Under Pressure

Hazard Description

Cryogenic: Key hazard relates to freezing of personnel coming into contact with any released substance.

Gases under pressure: Risk of projectile or high pressure release of substance due to pressurisation of the container. May relate to bulk or containerised cargo, the later may require recovery from the sea following an incident.

Personnel injuries and potentially fatalities.

Harm to vessel hull and equipment from blast effects of substance.

Initial Response Vessel Hazards

Lack of awareness of personnel on how to manage the incident due to the nature of the substances leading to responding vessel being put in harm's way.
Harm to responding vessel from cryogenic or blast effects.

On-going Response Vessel Hazards

As above but substances may dissipate, evaporate etc. reducing overall risk with time if the containment vessel is breached. If the vessel remains intact the hazard will continue until the cargo is properly stored.

Protection to Mitigate Identified Hazards

Training for operations in pressurised and cryogenic gas scenarios

Provision of Personnel Protective Equipment (PPE)

Scenario 5 – Corrosive Substances

Hazard Description

Release of corrosive substance as a result of an accident or equipment failure. Personnel at risk of contamination by various routes e.g. inhalation, skin contact, etc.

Minor to major burns.

Disfigurement.

Harm to vessel hull and equipment from corrosive effects of substance.

Initial Response Vessel Hazards

Irritant to acute health affects resulting from exposure to substance.

Immediate effects may be seen on personnel before becoming aware of the hazard.

Changes in wind direction which blow contamination over the vessel.

Lack of awareness of personnel on how to manage the incident due to the nature of the substances leading to contamination.

Potential contamination of on-board water supplies from contaminated sea water intake – unlikely due to concentration being decrease on contact with water.

Potential contamination of on-board air supplies from contaminated air intake, HVAC contamination – unlikely due to concentration being decrease on contact with air.

On-going Response Vessel Hazards

As above but substances may dissipate, evaporate etc. reducing overall risk with time.

Protection to Mitigate Identified Hazards

Training for operations in corrosive scenarios.

Provision of personnel protective equipment (PPE).

Protective measure for vessel crew not involved in direct operations (citadel).

Decontamination equipment e.g. washing facilities, clean clothing.

Self-Contained Breathing apparatus.

Isolated water systems to prevent contaminated water being drawn into vessel water systems.

HVAC Filtration.

Scenario 6 – Example of a combination Hazard due to the nature of the substance released – E.g. Flammable & Toxic

Hazard Description

Potential for fire or self-ignition of substance.

Some substances react on contact with water to ignite and cause a flammable atmosphere.

Potential for response vessel or casualty vessel to cause ignition.

Release of toxic substance as a result of an accident or equipment failure. Personnel at risk of contamination by various routes e.g. inhalation, skin contact, etc..

Lethal toxic doses and exposure over time issues make this scenario uncertain as different substances can have immediate or long term effects on personnel. Also symptoms of infection may not be apparent immediately.

Fire effects may cause toxic elements to become aerosols.

Initial Response Vessel Hazards

Burns ranging from minor to fatal. (Fire)

Damage to vessel from effects of fire. (Fire)

Long term or acute health affects resulting from exposure to substance. (Toxic)

Immediate effects may be seen on personnel before becoming aware of the hazard. (Toxic)

Changes in wind direction which blow contamination over the vessel. (Toxic)

Lack of awareness of personnel on how to manage the incident due to the nature of the substances leading to contamination. (Toxic)

Potential contamination of on-board water supplies from contaminated sea water intake. (Toxic)

Potential contamination of on-board air supplies from contaminated air intake (original toxic substance additional to smoke), HVAC contamination. (Fire & Toxic)

On-going Response Vessel Hazards

As above but substances may dissipate, evaporate etc. reducing overall risk of fire occurring with time. Additionally as fire progresses original fuel source will be consumed.

Potential for longer term effects due to extended periods within area of contamination with limited or no access to appropriate protective equipment.

Potential to re-ignite fire.

Protection to Mitigate Identified Hazards

Training for operations in response to fire and toxic scenarios.

Provision of Personnel Protective Equipment (PPE) both for fire and toxic elements.

Protective measure for vessel crew not involved in direct operations (Citadel (toxic) /boundary cooling (fire) /movement of vessel from area of risk (toxic & fire)).

Self-Contained Breathing Apparatus

HVAC Filtration / Isolation.

Protective measure for vessel crew not involved in direct operations (citadel).

Decontamination equipment e.g. washing facilities, clean clothing.

Isolated water systems to prevent contaminated water being drawn into vessel water systems.

Common Facilities which will be required for the majority of incidents include:

Medical supplies (for managing the effects to casualties)
Casualty reception/treatment facilities
Area for management of fatalities where space allows

Helicopter access, e.g. heli-deck facilities, access to deck with space for winching operations, anti-static lines for winching operations.

Sea recovery facilities for casualties in the water.

Training or the provision of responders with expert knowledge of the substances and responses being carried out.

About EMSA

The European Maritime Safety Agency is one of the European Union's decentralised agencies. Based in Lisbon, the Agency provides technical assistance and support to the European Commission and Member States in the development and implementation of EU legislation on maritime safety, pollution by ships and maritime security. It has also been given operational tasks in the field of oil pollution response, vessel monitoring and in long-range identification and tracking of vessels.

http://www.emsa.europa.eu

EUROPEAN MARITIME SAFETY AGENCY