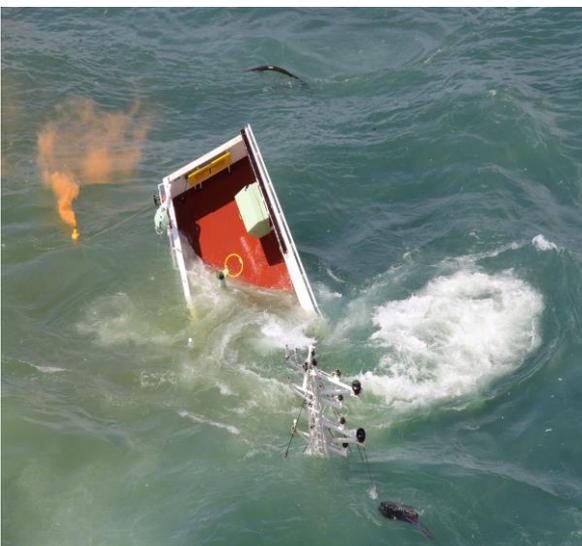# Guide for Risks of Gaseous releases resulting from Maritime Accidents

MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

REGIONAL MARINE POLLUTION EMERGENCY

RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

MEDITERRANEAN ACTION PLAN

Guide for Risks of Gaseous releases resulting from Maritime Accidents

**Regional Information System**

www.rempec.org

May 1996

Note

This document is aimed at facilitating the implementation of the "Protocol concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency" of the Barcelona Convention (Emergency Protocol, 1976) and the "Protocol concerning Co-operation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea" (Prevention and Emergency Protocol, 2002) by the Contracting Parties of the Barcelona Convention.

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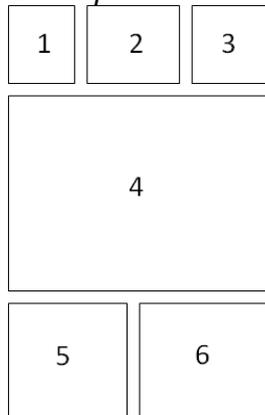
The Guidelines are downloadable from REMPEC's website (www.rempec.org) in the Section "RIS/Operational Guides and Technical Documents".

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GUIDE FOR THE RISKS OF GASEOUS RELEASES RESULTING FROM MARITIME INCIDENTS

INTRODUCTION

Gases are versatile substances, some of which provide a source of energy whilst others provide valuable feedstock for the world's chemical industries, the latter is in part due to the technological advances that have led to the many products originating from gases being exploited.

To meet the increasing demand of such products, gases, which are either produced in appreciable quantities or found naturally to be commercially exploited, are usually far removed from where they are utilized and most needed and therefore have to be transported over relatively long distances.

It is essential to provide a means of transporting such gaseous products. A common way of shifting natural gas in large quantities from one place to another is to use pipelines. In the Mediterranean, for example, natural gas is transported by the Trans-Mediterranean pipeline from Algeria to Italy. In the absence of pipelines or in instances when the use of pipelines is not feasible, other modes have to be found.

Alternative modes are the use of road tankers, rail cars and ships. To use these modes of transport, gases would have to be reduced in volume since in their original state they are far too bulky to be carried by such transport modes. One of most remarkable developments in the field of naval architecture over the last thirty years of this century has been the appearance of the gas carrier. These vessels are an eloquent testimony to the skills and far-sightedness of the pioneer cargo-containment system designers, material scientists and equipment suppliers who were able to put into practice a theory understood for decades, namely that under appropriate conditions of pressure and temperature, gases can be liquefied. This has culminated in the construction of the gas carrier.

Gas carriers are specialized ships that carry cargoes in bulk which under normal conditions are gases. By lowering the temperature or by increasing the pressure, or by a combination of these processes, a gas can be reduced to a fraction of its original volume, thereby making the transport of such a product economically viable. **Figure 1** shows the main routes for LPG and LNG carriers in the Mediterranean.

Figure 2.31 Major Routes of Maritime Traffic
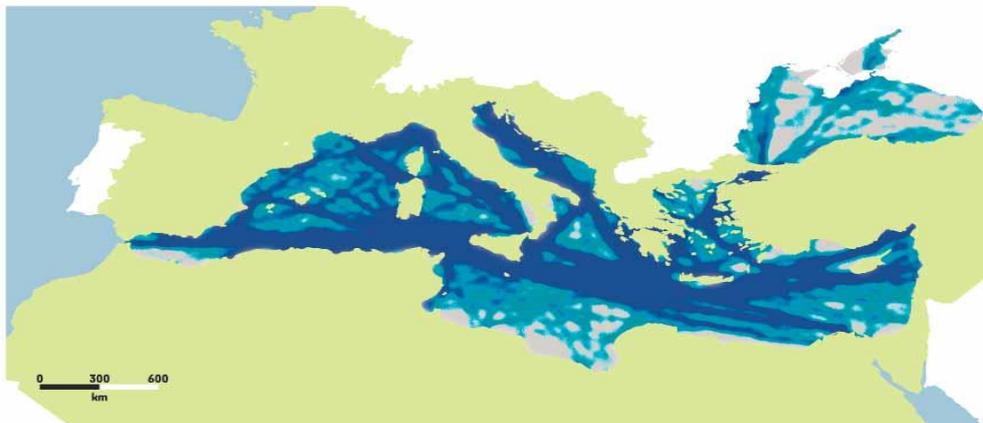
Figure 1: ***Main routes for LPG (liquefied petroleum gas) and LNG (liquefied natural gas) carriers in the Mediterranean***

In addition, gases are also carried in "package" form, which means that they are transported in receptacles of various sizes, albeit in smaller quantities, on vessels other than specialized gas carriers. The possibility of an accidental release of a gaseous product is therefore not limited to originate only from gaseous cargoes carried in bulk.

In a region intensely used by merchant shipping, irrespective of whether a particular type of ship has an exemplary safety record and therefore might not be perceived as a great risk such as is the case with gas carriers, the possibility of an accident remains. The Mediterranean is no exception and as shown in **Table 1** there have been some maritime related incidents involving gaseous or very volatile cargoes.

The fact that there have been incidents involving this type of cargo indicates that there is a need to address the potential accidental release of such products within the whole context of preparedness for and response to maritime incidents. In order to understand better the way these products might be dispersed once released to the environment, as well as the consequences of such releases and the mitigating measures that might be used, it is necessary to focus not only on the relevant factors that have a direct bearing on such aspects but also to have an appreciation of the basic chemistry of gases as well as a knowledge of the way gases are transported at sea.

TABLE 1 - Incident Log					
Date	*Location*	*Vessel*	*Substance*	*Incident Details*	*Source*
30.10.95	Alexandria	Capo Argento		LPG carrier went aground near the port entrance when sailing for port on charge; vessel was re-floated and entered port for inspection.	LLoyd's
26.03.94	off Ancona	Capo Cervo	Butylene	Collision with a general cargo vessel; bow damage occurred; after inspection, vessel proceeded to Ravenna to discharge cargo.	HCB
5.07.93	off Marsa el-Brega	Lulligas	Ammonia	Grounding of vessel on soft bottom; ship to ship transfer of part of cargo followed by re-floating.	LLoyd's
18.05.90	off Brindisi	Golden Star	empty	LPG carrier in collision with MV Brega: both were empty at the time.	LLoyd's
28.04.90	Brindisi	Val Rosandra	Propylene	Fire in compressor room and cargo tank during propylene discharge; no casualties but towed offshore and left to burn; later sunk.	HCB
22.10.89	off Taranto	Agip Siracusa	LPG	Vessel in collision with vehicle carrier; serious bow damage to both vessels; gas carrier discharged cargo at Ravenna.	HCB
26.02.89	Haifa	Zim Iberia	Ethylene oxide	20 cannisters fell into Haifa harbour whilst unloading; most were retrieved.	HCB
15.02.89	Skikda	Tellier	LNG	Vessel broke free during loading in heavy weather; damaging 4 loading arms; small leakage of product and hull damage; repairs to vessel undertaken at Marseille-Fos.	CEDRE
12.10.78	Hyères	Gaz East	Butane	Vessel on route from Pylos to Port St. Louis suffered severe list due to error in ballasting; crew abandoned vessel; vessel was towed to sea and sunk by French authorities.	France Focal Point

AN OVERVIEW OF THE BASIC CHEMISTRY AND THE DIFFERENT CLASSIFICATIONS OF GASES

An appreciation of the complex engineering technology that is involved in the transport of gases in general and more specifically in the sea-borne transport of gases requires a certain understanding of the physical chemistry of gases. Although this is a rather extensive and specialized subject, an examination of certain fundamental chemical principles pertaining to the different physical states of matter with a focus on the gaseous phase, coupled to a brief description of the classification of gases would facilitate such an appreciation.

1.   States of matter

Most substances can exist in more than one homogeneous physical state: solid, liquid or gas. These states are usually called "phases" i.e. the **solid phase**, the **liquid phase** and the **gaseous or vapour phase**. A substance may have two or even all three phases present simultaneously. The phase in which a particular substance exists can be considered as an expression of the orderly arrangement and distance between the component particles of the substance i.e., when they are orderly arranged and close together, the substance is a solid and as the particles move apart and begin to loose their orderliness, the substance expands becoming a liquid and then a gas. A gas is thus characterized by the disorderly distribution and random arrangement of its particles (see **Figure 1**).
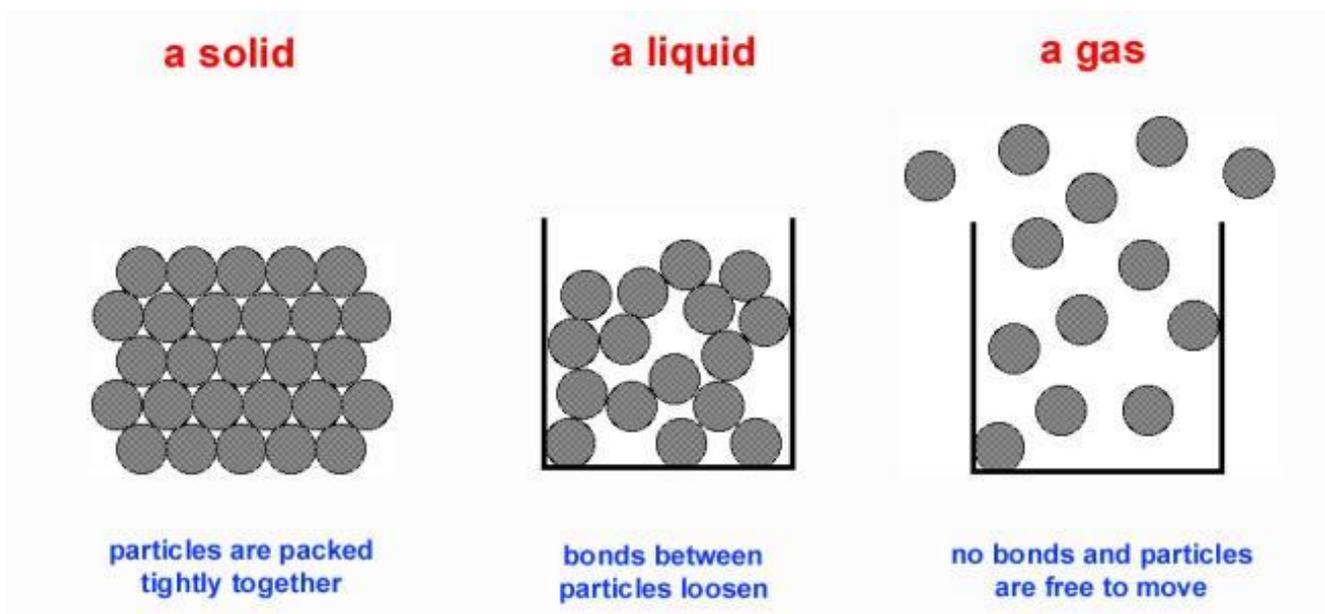
Figure 1.   ***Two-dimensional illustration of the different phases of matter***

2.   Terminology associated with states of matter – a short overview

Some common terms used in conjunction with the description of the states of matter may seem rather conventional; however it is imperative to consider their meaning and interpretation.

   i).   **Heat**: the total amount of "molecular movement" or kinetic energy present in a substance and is measured as a quantity of energy (thermal energy).

---

ii) **Temperature**: a measure of the availability of heat and describes the intensity or degree of hotness or coldness measured on a scale (e.g. Celsius, Fahrenheit or Kelvin Scale); temperature indicates the amount by which the molecules of a substance are vibrating and also indicates the direction of heat flow, since heat always flows from a warm to a cooler body.

The distinction between heat and temperature can be made clearer by considering the example of a burning match and a small fire in a grain silo which can both be of the same temperature but in the latter case, there will certainly be more heat.

iii) **Vapour pressure**: the pressure at a particular temperature in the space above a liquid which is exerted by the vapour molecules, as molecules leave the liquid to enter the vapour phase and vice-versa; it is a measure of a liquid's tendency to vaporize; as the temperature changes, so also does the vapour pressure (the higher the temperature, the higher the vapour pressure) and for any particular temperature there is always a fixed value of vapour pressure; solids also exert a vapour pressure, although for most solids, it usually becomes apparent at elevated temperatures.

iv) **Saturated vapour pressure**: the pressure at a particular temperature when a continuous exchange of molecules between the vapour and the liquid takes place in a confined space but under these conditions the space above the liquid cannot accept any further vapour.

v) **Boiling point**: a guide to the strength of the cohesive forces of a liquid and is the temperature at which the saturated vapour pressure of a liquid is equal to the pressure above it; the boiling point is a function of the pressure; under spill conditions, the boiling point would be the temperature at which the vapour pressure equals the ambient air pressure.

3. Changes of states

When a solid is heated, it melts to form a liquid and on further heating, the liquid evaporates to form a gas. In the solid state, the particles are ordered, less so in a liquid and completely disordered in a gas. The changes of state i.e. melting and evaporation can therefore be considered as disordering processes.

In changing from a solid to a liquid (fusion/melting) or vice-versa (solidification), heat must be given to or given up by the substance respectively. For example, when a solid melts, it requires additional heat to be added so that it will turn into a liquid. The heat involved when a substance changes state is called the latent heat and for a given mass of substance, the latent heat of fusion and solidification are the same. Similarly, when changing from a liquid to a vapour (vaporisation) or vice-versa (condensation/liquefaction), the latent heats are the same, although they are different from the latent heats of fusion or solidification. Using water as an example, the states of aggregation of the different physical phases of matter as a function of the uniform addition of heat are illustrated in the heating curve - **Figure 2**.

Latent heat of fusion
or of solidification

Latent heat of fusion
or of solidification

Super heat

Sensible heat

Sensible heat

100°C

0°C

Heat (joule/kilogram J/kg)

1 2 3 4 5
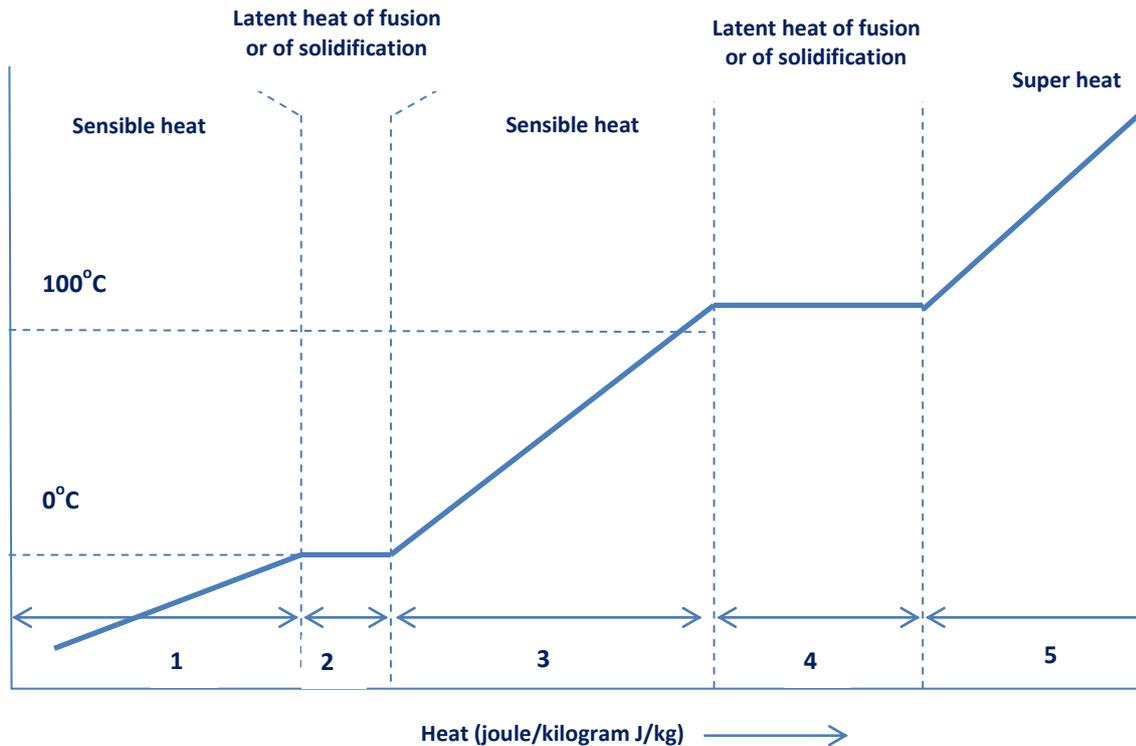
__Figure 2.__ Illustration of the behaviour of water when heated or cooled

In terms of particle order-disorder processes, the variations that accompany the changes of states shown in the diagram can be explained as follows:

Along the portion (1) of the curve, heat is supplied and the particles in the solid substance i.e. the ice crystal begin to vibrate. As more heat is added, the vibrations become greater but although no change is visible, the particles within the solid become slightly less ordered. The heat added increases the kinetic motion of the particles. Since temperature is a measure of the kinetic energy, the temperature rises along portion (1) of the curve which continues until the melting point is reached at portion (2) of the curve. At the melting point, the vibrations of the particles are so great that any added heat serves to loosen binding forces between neighbouring particles. Consequently along portion (2) of the curve, added heat does not increase the kinetic energy of the particles but goes to increase the potential energy of the particles acting against the attractive forces of the particles. Along portion (2), there is no change in kinetic energy, hence the substance stays at the same temperature, but the amount of liquid increases at the expense of the solid. Thus at 0^0C, water and ice co-exist.

When sufficient heat has been added to tear all the particles from the ice crystal, added heat increases the kinetic energy of the particles and the temperature of the liquid rises - portion (3) of the curve. This continues until the boiling point is reached. At the boiling point, added heat is used to overcome the attraction between the particles in the liquid. Along portion (4) of the curve, there is an increase in the potential energy of the particles but no change in their average kinetic energy. Along portion (4) of the curve, liquid converts to gas. Finally, after all the liquid has been converted to gas, added heat raises the kinetic energy of the particles as shown by the rising temperature along portion (5) of the curve.

The curve can also be viewed in the reverse whereby, heat is removed from the substance and in this case the curve is called a "cooling curve". Since the concern is the gaseous state, it is convenient here, against the background of the preceding paragraphs to consider what

happens when a gas, in this case water vapour, is cooled. As heat is removed from the water vapour, the temperature begins to drop - portion (5) of the curve. Along this portion of the curve, the kinetic energy of the water vapour particles decreases in order to compensate for the removal of energy. This slowing down proceeds until the attractive forces become dominant and the particles coalesce to form a liquid. In the liquefaction process, particles leave the gas and enter the liquid state - portion (4) of the curve. The importance of temperature on the phase of a gas is best seen by the example of ethylene oxide which is a gas at 20^0C and a liquid at 10^0C.

In addition to the temperature, the physical state of a particular substance depends on the external pressure so that the changes between solid, liquid and gaseous states are dependent on both temperature and pressure. This relation between solid, liquid and gaseous state as a function of the temperature and pressure can be summarized on a single graph known as a phase diagram. Each substance has its own particular phase diagram which has been worked out from experimental observation and a typical phase diagram for a particular substance would look like that shown in **Figure 3** below. In the diagram, pressure is shown vertically with higher pressures at the top whilst temperature is shown horizontally with higher temperatures to the right. Very briefly, each of the regions correspond to a single (one) phase system. For all values of pressure and temperature falling inside a single phase region, the substance is in the state specified.
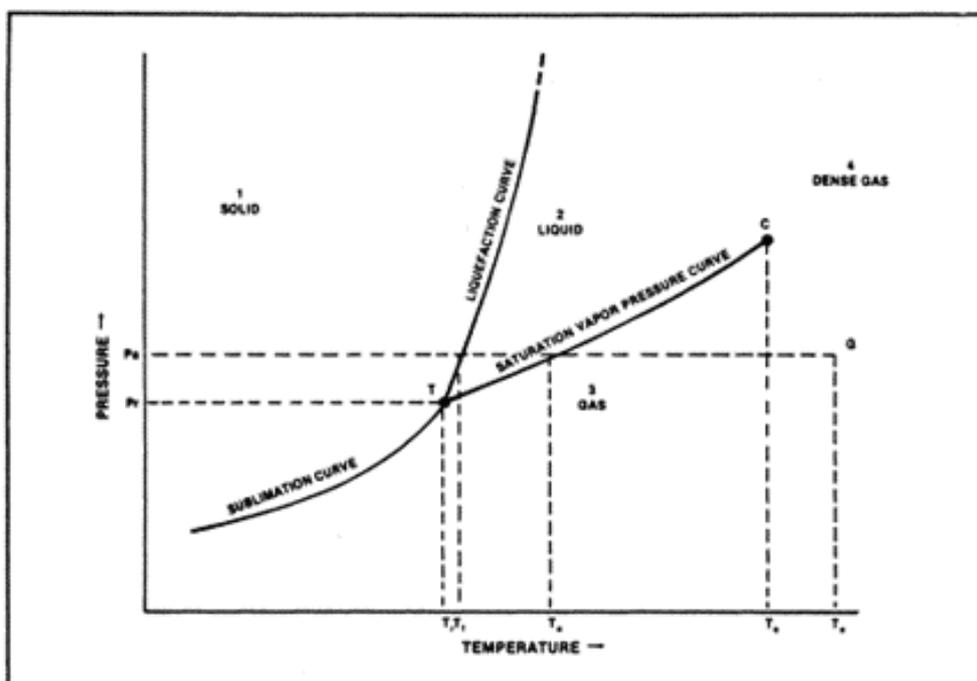
Figure 3.

The line which separates one region from another is an equilibrium line and this represents equilibrium between two phases. If one takes the solid-liquid line, this shows the temperatures and pressures at which the solid and liquid phases exist in equilibrium - the amount changing from solid to liquid being exactly balanced by the amount changing from liquid to solid. The same applies to the line which separates the solid from the vapour phase and the liquid from the vapour phase. Thus, by finding the point on the diagram which represents a particular temperature/pressure combination, the final phase of a substance can be determined. The single point where all three lines on the diagram meet is the "triple point". The triple point represents the only temperature and pressure at which all three phases can be in equilibrium together. Although at any other combination of the temperature and pressure all three phases may exist, they will not be in equilibrium. An additional usefulness of a phase diagram is that it

graphically illustrates that a gas can be liquefied and therefore reduced in volume by removal of heat and/or by pressure by pressurizing (compressing) as shown in **Figure 4**.
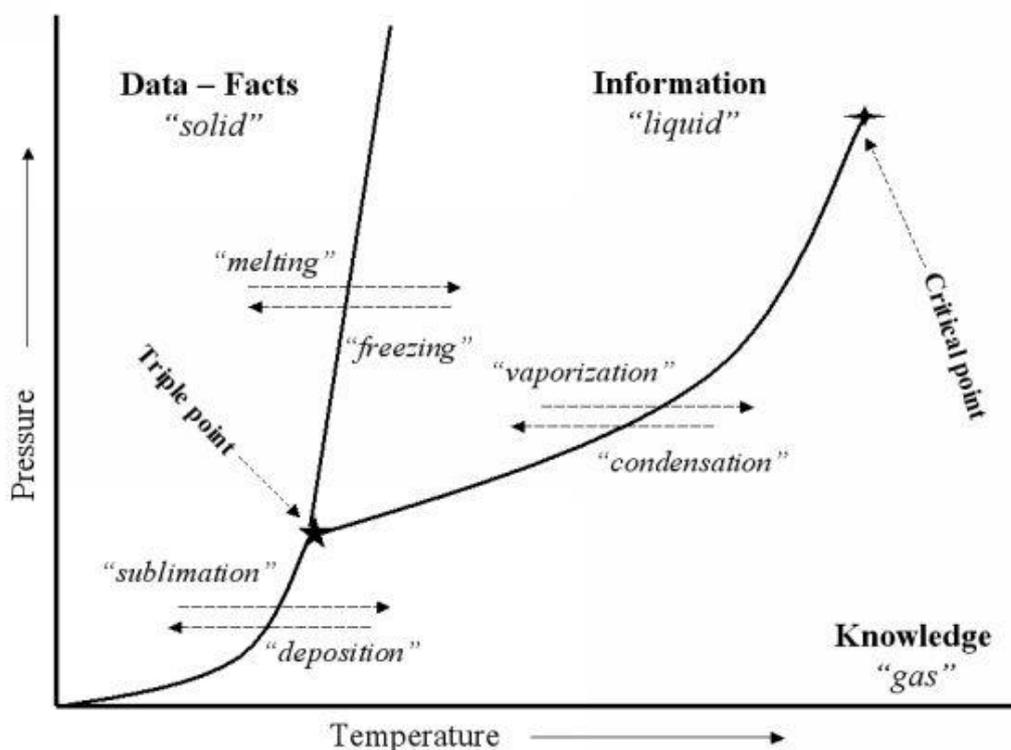
Figure 4. Phase diagram showing how a gas can be liquefied by removal of heat and/or pressurizing

4. Liquefaction of gases

As shown in Figure 4, the most favourable conditions for liquefaction of a gas are high pressure or low temperature or a combination of both. Two counterbalancing factors are involved in the process of liquefaction. These are the intermolecular attractive (intermolecular cohesive) forces which tend to bring the particles together and which increase with higher pressure and the thermal (kinetic) energy of the particles which tends to keep the particles apart and which decreases with lower temperatures.

There is, however, for each gas, a temperature above which the attraction forces are not strong enough to produce liquefaction, however high the pressure. This temperature is called the **critical temperature**. The critical temperature depends on the magnitude of the attractive forces between the particles of a substance. Above the critical temperature, no amount of pressure can produce liquefaction. Above its critical temperature, a gas may be regarded as a "permanent" gas, since it cannot be liquefied. Below the critical temperature, it is appropriately described as a vapour since it can always be liquefied if the pressure is increased sufficiently. Viewed differently, if a substance exists in its gaseous state, below its critical temperature, it is considered a vapour. If a substance exists as a gas above its critical temperature it is called a gas. Thus, for example gaseous water which has a critical temperature of 374^0C will be considered as water vapour if heated above its boiling point of $100\ ^0C$ but below 374^0C. A gas can be therefore liquefied by keeping the pressure constant and cooling the gas. The minimum pressure to compress a gas to its liquid state at its critical temperature is known as the **critical pressure**.

Annex I lists the critical temperatures and pressures of some common gas cargoes.

It is also usually found that substances with high critical temperatures are easy to liquefy and can be liquefied by pressure alone, whilst substances with low critical temperatures need to be cooled before they can be liquefied. Thus, extending this generalization to the cargo listing of Annex I, all the cargoes would be below their critical temperature at the normal ambient range of temperatures during sea passage. They can therefore be liquefied by pressure alone and be carried at ambient temperature. For the carriage of methane, or ethane or ethylene as liquids, this is not possible because the critical temperatures are too low and some refrigeration process is required for their carriage (or storage) as a liquid.

5.   Description and general characteristics of gases

Based on the foregoing, a gas can be described as a formless fluid whose component particles are in constant motion and arranged in a completely disorderly fashion. Unlike a solid which has shape and volume or a liquid which has volume but no shape, a gas has neither shape nor volume. A gas is thus, the most diffused state of matter and like other states of matter is nothing other than matter in a specific homogenous physical state. A common distinction between a liquid and a gas is that whereas a gas may be reduced in volume, a liquid is relatively incompressible.

General characteristics common to gases are:

- they can be reduced in volume, implying that matter in the gaseous phase is not as compact as in the liquid and solid state;
- they are indefinitely expansible and will always occupy all the volume of any vessel in which they are confined, implying that matter in the gaseous state is in constant motion; this energy due to the motion of the component particles of the gas is called kinetic energy;
- they exert pressure (force) on the interior wall of the vessels in which they are confined implying that gases exert a pressure on all boundaries with which they are in contact.

6.   Classification of gases

Gases can be broadly classified according to:
- their hazardous properties;
- their physical properties;
- their usage;
- their behaviour once spilled.

6.1   Classification according to hazardous properties

This category can be further sub-divided into:

- **flammable gases**: these are gases which will burn in the presence of oxygen and an ignition sources e.g. methane, propane;
- **non-flammable gases**: these are gases which will not burn in air, however within this sub - category there are those which support combustion, often called oxidizing gases whilst there are those which do not support combustion and are called inert gases e.g. helium, argon;
- **toxic gases**: gases which will endanger human life on exposure e.g. arsine, phosgene, chlorine;

- **reactive gases**: gases which will react with other materials or within themselves by a process other than burning at the same time liberating heat which sometimes also results into flaming e.g. fluorine, acetylene, vinyl chloride.

6.2. Classification according to physical properties

This category can be further sub-divided into:

- **non-liquefied compressed gases**: gases which inside a gas container are at normal temperature and exist in the gaseous state under pressure e.g. argon, helium, air, hydrogen;
- **liquefied compressed gases**: gases which are liquefied by increasing the pressure and exist in the liquid and gaseous state at equilibrium in the gas container e.g. propane, butane, chlorine;
- **cryogenic liquids**: liquids made from gases liquefied by cooling to very low temperatures via refrigeration systems and are maintained in their containers at low temperatures at relatively low pressure e.g. LNG, oxygen, hydrogen.

6.3 Classification according to usage

This category can be further sub-divided into:

- **fuel gases**: gases used for burning to produce heat, power or light e.g. LPG, LNG;
- **industrial gases**: gases used in industrial processes such as welding and cutting, refrigeration e.g. acetylene;
- **medical gases**: gases used for health care purposes such as anaesthesia and respiratory therapy e.g. nitrous oxide.

6.4 Classification according to behaviour in the marine environment once spilled

This category can be further sub-divided into:

- **insoluble gases**: gases which do not dissolve or only slowly dissolve in water; this sub-category relates to gases both heavier and lighter than air e.g. butane, methane;
- **soluble gases**: gases which dissolve in water e.g. ammonia.

CHAPTER 2

MARITIME TRANSPORT STRUCTURES FOR GASES

Gaseous products are considered hazardous cargoes in that they possess hazards such as corrosively, toxicity and flammability. In addition to the problems of transporting a cargo which is inherently hazardous are the normal difficulties of ensuring the safe transport and handling of cargo at sea and in port areas.

These products can be transported in either of two ways; i) as packaged dangerous goods; ii) in bulk. To this end, an international regulatory framework has been developed whose aim is to put into place safeguards when such products are transported in bulk and in packaged form. The following is a brief description of the way gases can be carried at sea and the international regulations associated with their carriage.

1.   Gases carried out as dangerous goods

Packaged dangerous substances are usually known as **dangerous goods**. Gases carried as dangerous goods are placed in some kind of receptacle. The receptacle is either placed directly on board the vessel or in or on a transport unit which itself is then placed on the vessel.

1.1   Types of receptacles

Gases are carried in rigid receptacles. These are receptacles which will retain their shape when either full or empty, even when compressed at pressures. Normally an encountered in carriage at sea. They come in various sizes and the types of receptacles used for the carriage of gaseous products include:

- **cylinders** which have a tubular like shape with a circular cross section and a valve (regulator) or valve arrangement at one end of the cylinder; same might have a seal instead of a valve which is meant to be used with equipment having a valve arrangement; most cylinders come with a heat sensitive pressure relief device or plug which prevents internal over pressurization with catastrophic consequences if the cylinder is subjected to intensive heat.

  cylinders for carrying gases could be if two types:

- **uninsulated cylinders** are usually made of steel although it not uncommon to find cylinders made of aluminium or fiberglass with an aluminium outer casing; they have rounded shoulders on top and screw-on caps or cylindrical rings for valve protection; they could range approximately in size up to 0.25m diameter and 1.5m height;

- **insulated cylinders** used for cryogenic liquids which consist of a core insulated metal cylinder with an outer protection metal jacket; the area between the cylinder and the jacket is normally under vacuum; the cylinders have a small protection ring at the top to protect the valve and a footring for handling; they could range approximately in size up to 0.6m diameter and 1.5m height;

Illustrations of the various types of cylinders are shown in **Figure 1**.

Figure 1. *Various types of gas cylinders (not to scale)*

- **tube modules** which consist of several steel cylinders positioned horizontally which are permanently mounted inside an open box frame with the cylinder valves at one end enclosed in a box-like compartment; an illustration of a tube module is shown in **Figure 2**;

Figure 2. A tube module

- **ton containers** which are cylindrical pressure tanks made of steel approximately 0.9m diameter and 2m length; the name "ton container" comes from their capacity to transport one ton of chlorine; the valves are found at one and under a protective cover plate held in place with bolts; two rolling bands around the mid-waist of the cylinder facilitate handling; various aspects of a ton container are found in **Figure 3**;
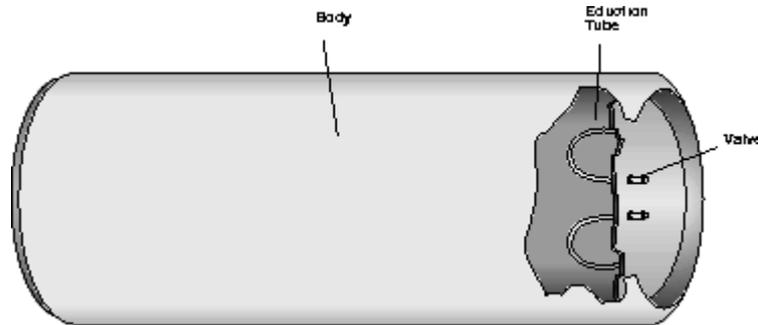
Figure 3.   *A ton container*

- **intermodal tank containers** which consist of a tank barrel mounted in a metal supporting framework; the type of framework could be either box (full frame) or beam (end frame); illustrations of the two types of frameworks are shown in **Figure 4**; both types are equipped with corner casting for handling purposes; typically the length of a tank container is 20ft although 40ft tank containers do exist but are rare due to the high gross container weight; the tank barrel is manufactured with a particular product or range of products in mind and is typically made from unlined steel or mild steel with an interior impervious lining; tank containers come equipped with numerous fittings and attachments for filling, discharging, safety and vacuum relief and air-line connection, plus any other requirements dictated by the product(s) to be carried;

BOX TYPE FRAME   **BEAM TYPE FRAME**

Figure 4.

tank containers suitable for the carriage of gaseous products can be of two types:

- **pressure portable tanks** which transport liquefied compressed gases;

- **cryogenic portable tanks,** each consisting of a tank within a tank with insulation between the inner and outer tanks; insulation could consist of expanded polyurethane, polystyrene or mineral wool or a combination of such materials whilst cladding is applied over the insulation; the space between the inner and outer tanks is normally maintained under vacuum;

- **road tank trailers and vehicles,** each consist of a cargo tank that is permanently mounted on a truck or mounted on a trailer which is then drawn by a motor vehicle; a lot of what has already been described for the safety and constructional requirements of intermodal tank containers also applies to road tank trailers and vehicles; road tank trailers and vehicles can be of two types:

  - **pressure cargo tanks** which transport liquefied and compressed gases; they have circular cross sections with rounded ends or heads; these tanks may also carry different substances in separate compartments; separate temperature gauges are found for each compartment;

  - **cryogenic cargo tanks** which transport cryogenic liquids; as in the case with all receptacles carrying cryogenic liquids, this type of cargo tank consists of a tank within a tank with a space between the inner and outer tank held under vacuum and filled with insulation material; each tank has a circular cross-section with dish-like ends;

- **tube trailers** which resemble tube modules but instead are permanently mounted on a trailer;
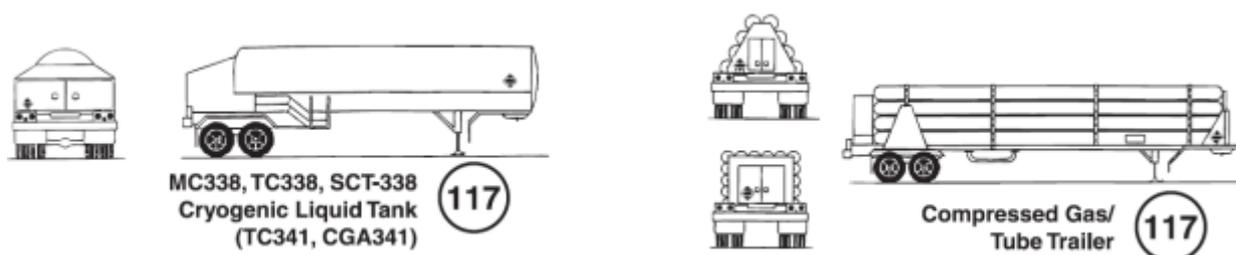
Figure 5.   *Examples of road trailers and vehicles carrying gaseous products*

- **rail cars** which consist of tank cars that are constructed to transport gases; all of what has been previously described for the safety and constructional requirements of portable tanks containers and road tank trailers also applies to rail cars; tank cars are divided into: i) pressure tank cars; ii) cryogenic tank cars; iii) tube cars; illustrations of the different types of rail cars are shown below in **Figure 6**.

Figure 6.

MC331, TC331, SCT-331
High Pressure Tank (117)
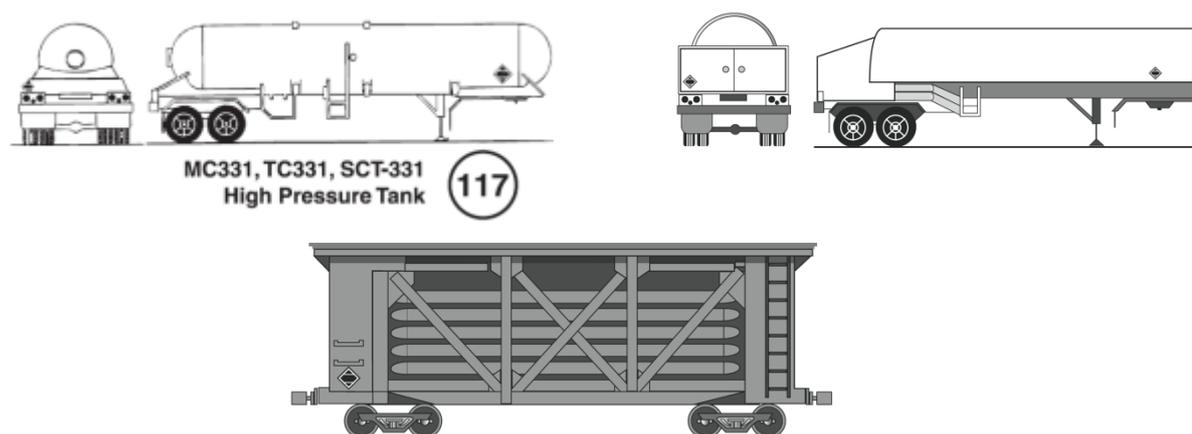
1.2 Vessels carrying dangerous goods

Before the development of integrated cargo transportation systems, the availability of modern construction methods for ships and the existence of sophisticated shore handling equipment, the general cargo ship was probably the most common type of merchant vessel which carried packaged dangerous goods. Reflecting the adaptability of the shipbuilding industry, a wide variety of mercantile ships are in existence today which are able to carry such cargo.

Different types of ships can be recognized by certain distinctive features in their general appearance because the design of a ship depends mainly on the work she is set out to do. A breakdown of the more common categories of vessel which can carry dangerous goods including gaseous products are as follows (see **Figure 7**):

- **General cargo ships** (when the vessel operates on a regular service between ports, the term liner is used although some countries employ the term freighter; when the vessel is employed on charter to take cargo from port to port at any time anywhere in the world, the term tramp is used). General cargo ships can be of two types. The first are break bulk carriers which carry dry cargo in small consignment e.g. crates, bags or barrels. These vessels contain dunnage to support and separate cargo in their cargo spaces which tend to be box-shaped. These vessels have four or five holds and one or two tween decks which run practically the full length of the ship, so that the various items carried can be methodically stowed for convenient access at the relevant ports of discharge and the weight of the cargo more easily distributed. The second type are multi-purpose carriers designed to carry a variety of cargoes at the same time. Special systems are available to transport break bulk, refrigerated (frozen) and liquid cargoes.

- **Cellular container ships** which are specialized carriers that carry containers in which could be found packaged dangerous goods. The majority of containers are designed for general dry cargo (box-type) but specialized units can take liquid, powder, or refrigerated cargo. Containers when on deck need to be lashed and secured. The carrying capacity of these ships is specified in TEUs (twenty equivalent units).

- **Ro/ro unit load vessels** where the cargo is moved on and off using trailers normally carrying containers. A common characteristic of these vessels is their intermodal capacity, which means that their cargo can move directly onto the road system. Other vessels which operate on a roll-on/roll-off method are passenger and car ferries.
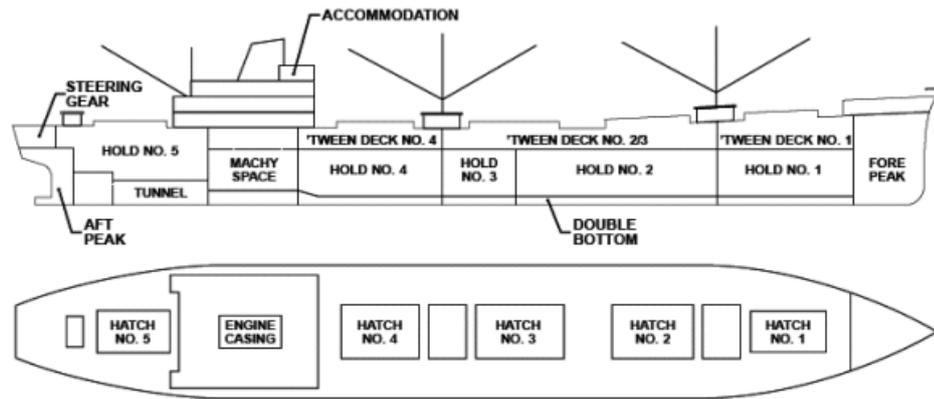
Break bulk carrier

Container Ship

Figure 7. **Illustrations of some vessels which transport packaged dangerous goods**

1.3 International regulations governing the carriage at sea of gaseous dangerous goods

Chapter VII of the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS), 1974, contains requirements covering the carriage of dangerous goods at sea.

Further measures are included in the IMO's *International Maritime Dangerous Goods Code* (IMDG Code)* which was first adopted by the IMO Assembly resolution A.81(IV) of 27 September 1965. Although the main concern of chapter VII of SOLAS and the IMDG Code is safety, many substances listed can also cause pollution and in 1987, the IMDG Code was extended to cover pollution aspects. The IMDG Code is infact used to implement the requirements of Annex III of MARPOL 73/78.

The IMDG Code sets out comprehensive recommendations for the transport of dangerous goods at sea concerning their classification, documentation, marking and labelling, packing and packaging, stowage and segregation, fire prevention and fire fighting and other related subjects. The Code is published as a consolidated version in four loose-leaf volumes. Amendments are published regularly to keep pace with the technological developments of cargoes. A fifth volume contains additional information on subjects such as medical first-aid, safe use of pesticides in ships etc.

In the Code, substances are grouped together under various class headings. Each class has an introduction giving general information on chemical properties, packing, stowage, segregation, fire fighting and where appropriate specifications for the carriage of limited quantities. Each substance usually has an individual page (schedule) to itself and the information in each schedule includes the proper chemical (shipping) name and formula, the United Nations identification number, observed human health effects, chemical properties, packing, stowage and where applicable the explosive limits and flash point.

Gases carried as packaged dangerous goods on board ships have varied chemical properties and are transported under different conditions. They may be compressed, liquefied at ambient temperature under high pressure, dissolved under pressure in a solvent which is then absorbed in a porous material, or liquefied by refrigeration. They may be non-flammable, flammable, poisonous, corrosive, support combustion or be a combination of all or some of these. Some of the gases are lighter than air whilst others are heavier. The Code groups gases under Class 2.

For the purposes of stowage and segregation on board ships, Class 2 is further divided according to the hazards presented by gases during transport:

Class 2.1	-	Flammable gases
Class 2.2	-	Non-flammable gases
Class 2.3	-	Poisonous (toxic) gases

To indicate more accurately the hazards presented by gases, the classification required by regulations 2 and 5 of chapter VII of SOLAS 1974, as amended, has to be supplemented by the additional description of the subclass.

2. Gases products carried in bulk

Gas carriers are designed to **carry gases in liquid form in bulk**. The general arrangement of a gas carrier is similar to that of the conventional oil tanker in that the machinery and accommodation are aft whilst the cargo containment is spread over the rest of the ship to forward. However, the cargo containment and its incorporation into the hull of the vessel is very different due to the need to carry gaseous cargo under pressure or refrigerated or under a combination of both. There are thus, many features which are unique to gas carriers due to the basic requirement for pressurizing and cooling gases during transport.

Fundamental to these requirements is the material of construction of the cargo tanks. It is important to realise that tanks designed to carry pressurized substances have to be able to withstand the pressure exerted by the cargo at the highest temperature encountered by the vessel during its voyage.

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*Code: Within the context of the IMO, a code contains detailed technical recommendations on a specific aspect of shipping for improving the safety of international maritime trading and the protection of environment.

2.1   Types of gas carriers

For tanks which carry bulk cargoes in refrigerated form at below ambient temperature, the design pressure of the tank depends on the degree of refrigeration of the cargo and the material used in the construction of the tanks would need sufficient ductility. If the cargo is refrigerated so that the tank can be operated at atmospheric pressure, there is no need to fulfil the requirements for a pressure tank. In this case, the cargo is said to be "fully refrigerated" and the temperature is maintained at or below the cargo's boiling point at atmospheric pressure. If the cargo is not fully refrigerated, it can still exert a significant vapour pressure and the tanks would need to be designed to take a relatively low temperature and withstand a certain degree of pressure.

Based on the different tank systems, <u>gas carriers can be categorized as follows</u>:

- **fully pressurized vessels**: these are the most basic type of gas carriers and are the simplest of all gas carriers in terms of containment systems and cargo-handling equipment; cargo is carried in pressure tanks designed to a withstand working pressure of 15-17 bars (a few ships can accept up to 20 bars); the tanks are normally cylindrical although some ships have spherical tanks or vertically mounted cylinders or a combination of both, ships carry two to six tanks which are arranged below or partly below deck, some might have more tanks; because of their working pressure, the tank weights are high; these vessels tend to be small with cargo capacities rarely exceeding 2000m^3 ; typical cargoes carried are LPG or ammonia in the shortsea or nearsea trade; an illustration of this type of carrier is shown in **Figure 8**;

Fully Pressurized LPG Carrier 7,000 cbm

Figure 8.   *An example of a fully pressurized LPG carrier*

- **semi-pressurized vessels**; these usually have tapered cylindrical or lobed tanks suitable for carrying cargoes in the temperature range of approximately -33^{0}C to-50^{0}C at a pressure range of 4-7 bars; vessels tend to be reasonable large with a cargo carrying capacity of 12,000m^3; they usually have four to six cargo tanks arranged in two groups of two or three tanks, each group having a port and starboard tank found below deck and when a third is present, it is found above deck along the centre line; the outer surfaces of the tank are insulated and vapour given off ("boil off") which collects in the head space (ullage) of the tanks is withdrawn via a vapour line to a reliquefaction system which cools, compresses and condenses the vapour which is then returned via a return line to the tanks; typical cargoes carried are LPG and other chemical feedstocks such as ammonia, butadiene, propylene and vinyl chloride; an illustration of this type of carrier is shown in **Figure 9**;

Figure 9. ***An example of a semi-pressurized LPG/NH₃ carrier***

- **fully refrigerated LPG vessels**: these are generally designed to transport large quantities of LPG at atmospheric pressure and at temperatures as low as -47^{0}C and -55^{0}C depending on the ethane content of the LPG; they may be equipped to carry ammonia; four different cargo containment design systems have been used in these vessels although the prismatic free-standing unit is the most common type of tank used; because of the low temperature carriage conditions, thermal insulation and reliquefaction equipment are fitted; there are normally between three and six cargo tanks extending almost the full beam of the ship; the cargo capacity is usually 5,000m^3 to 100,000m^3 so the ships can be quite large; an illustration of this type of carrier is shown in **Figure 10**;

Figure 10. ***An example of a fully refrigerated LPG carrier***

- **ethylene ships**: these are built for specific trades; the cargo is carried fully refrigerated at -104^{0}C and at about atmospheric pressure; insulation and reliquefaction equipment is fitted; the cargo tanks used are independent; the ships tend to be highly specialized having cargo capacities in the range of 1,000 to 12,000m^3; they are often equipped to carry LPG cargoes; an illustration of this type of carrier is shown in **Figure 11**;

Figure 11. ***An example of a semi-pressurized/fully refrigerated ethylene/LPG carrier***

- **LNG ships**: these are built to transport large volumes of LNG and are normally dedicated to a specific project where they will remain for their entire contract life; the cargo is carried fully refrigerated at -163^0C, at about atmospheric pressure; insulation is fitted but no reliquefaction equipment is fitted since "boil-off" gas is either vented to the atmosphere or used as propulsion fuel in the boilers; the ships are large having cargo capacities between 40,000m^3 to 135,000m^3 with four to six cargo tanks of either the self-supporting or membrane type; an illustration of this type of carrier is shown in **Figure 12**.
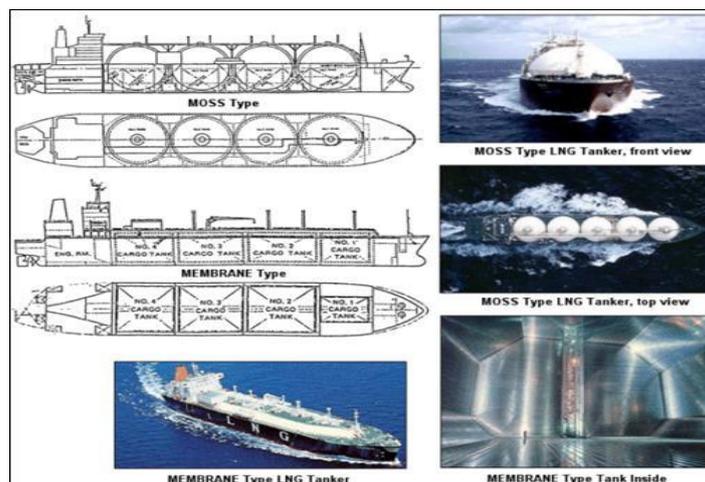
Figure 12. ***Overall view of a LNG carrier***

2.2 International regulations governing the carriage at sea of gaseous products in bulk

For the construction and equipment of vessels transporting gases in bulk, gas carriers must comply with the standards of the various gas codes of IMO i.e. the *Code for Existing Ships Carrying Liquefied Gases in Bulk* for ships built before October 1976; the *Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* for ships built after October 1976 but before July 1986 and the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*, for ships built after June 1986. The first two codes are known as the IMO Gas Codes whilst the last is known with the short title of the *International Gas Carrier (IGC) Code*. The IGC Code has been incorporated into the 1974 Safety of Life at Sea International Convention (SOLAS) as well as MARPOL 73/78.

Although it is beyond the scope of this short section to examine in details the contents of the Codes, it is worth nothing that the object of the codes is to recommend suitable design criteria, construction standards and other safety measures (e.g. fire protection, ventilation) for ships transporting liquefied gases in bulk and certain other substances listed in the Codes so as to minimize, as far as is technologically possible, the risk to the gas ship, to its crew and to the environment.

The possibility of a gas carrier experiencing an incident does exist (see Introduction - Table 1). This could lead to cargo tank damage and an uncontrolled release of the product resulting in evaporation and dispersion of the product and in some cases brittle fracture of the ship's hull. One of the basic aims of the Codes is that a ship built to the construction requirements of the Codes should be able to survive the normal effects of flooding following assumed hull damage caused by some external force, to protect the cargo tanks from penetration damage caused by minor incidents such as ramming a jetty, tug or some other hard object and to give a measure of protection to the ship from major damage caused by incidents such as collisions and groundings (see **Figure 13**). To this end, the construction and compartmentation of all gas carriers offer substantial protection of the cargo containment so that penetration damage is not transmitted to the cargo containment system.
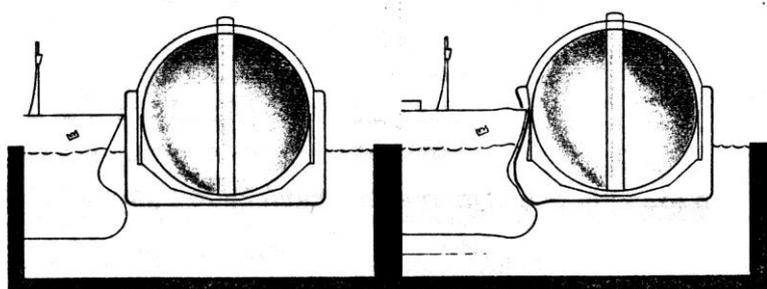
Figure 13. *One of the objectives of the Codes is to ensure substantial protection against accidental damage*

CHAPTER 3

RISK AND RESPONSE TO AN ACCIDNETAL GASEOS RELEASE

Within the context of a maritime emergency, risk can be defined as a characteristic or action wherein a number of adverse outcomes are possible, yet the particular outcome that will occur and the chain of events leading to the outcome cannot be determined precisely. Thus, In addition to understanding the way gaseous products are carried at sea, the background against which preparing for and responding to an accidental release of a gaseous product takes place, is a consideration of the pattern of events describing hypothetical but credible accident scenarios as well as a hazard evaluation of the product.

1. Accident scenarios

The objectives of such an exercise would be to assist decision-makers involved in preparedness activities appreciate the possible chain of events leading to such releases and the detrimental effects associated with such events as well as the response measures that might be taken. The following summarizes some of these events.

1.1 Packages gaseous dangerous goods

With packaged gaseous dangerous goods, two scenarios will be described, both of which will assume that the gases released do not take place in circumstances which would change the internal and/or external temperature of the container such as in the case of a fire.

1.1.1 Scenario No. 1 – compressed gases

Gases which are compressed to high pressure and are contained in a receptacle such as a gas cylinder but which have not been liquefied will vent at high velocity from a puncture or from any other similar small opening. At some stage, the pressure within the receptacle will drop to the external atmospheric pressure and the intense venting will either cease or subside to a rate proportionate with the amount of heat that enters the receptacle from the external surroundings.

1.1.2 Scenario No. 2 – compressed liquefied gases

Gases carried as compressed liquefied gases would typically be in pressurized receptacles designed to withstand a certain amount of pressure and what may happen will very much depend on the location of the puncture or damage:

    i.   If the puncture occurs in the head space (ullage) above the liquid, the gas will vent at high velocity, possibly creating some liquid droplets in the process; as the temperature increases and reaches the boiling point of the cryogenic liquid, the liquid turns into vapour picking up heat from the surroundings which provides the latent heat needed to change the liquid into vapour (change of state); the receptacle can become quite cold and even frost around the area of the puncture due to this "thermodynamic cooling"; although the velocity of the venting might drop, it may still continue so that eventually no more material remains in the receptacle;

    ii   If the puncture occurs below the liquid, the liquid may jet from the opening due to the pressure in the head space above the liquid which forces the liquid out, large amounts of liquid may flash into vapour due to the warmer temperatures found on the exterior; this might result in the formation of a mist/aerosol (vapour mixed with small liquid droplets); if the cryogenic liquid has the chance to reach a surface, it will have a

tendency to form a rapidly evaporating liquid pool and, as in the previous case, pick up heat from the surroundings to evaporate, possibly causing brittle fracture of the material it has come in contact with, if the material is not designed to withstand low temperatures;

1.2 Gaseous products in bulk

With gaseous products carried in bulk, describing accidents scenarios is more complicated than for packaged dangerous goods since any scenario would need to incorporate all aspects of the marine casualty and not treat the cargo containment as an entity separate from the rest of the vessel.

1.2.1 Scenario No. 1 – collision

A high energy collision could lead to cargo tank damage, resulting in an uncontrolled release of the product. The pattern of events following a collision will depend upon on a number of factors:

- type and size of ships;
- speed of colliding vessels;
- locations of the penetrations of hull and cargo containment in relation to water line;
- geometry of rupture;
- pressure of a double side shell;
- presence in the cargo tank;
- angle of impact;

For example, penetrations above the water line in a double-hulled vessel, e.g. a LNG carrier, will subject those parts of the ship's structure which come into contact with the cold cargo to brittle fracture. Contact of the cold cargo liquid with the warmer ship structure will result in rapid vaporization. Any adjacent enclosed space receiving cargo vapour might inhibit further significant leakage due to the resultant build-up of back pressure from the vapour within the space. Assuming there is no propagation of the rupture of the hull to below the water line, liquid cargo may not escape to the sea. Cargo which does escape to the sea may spread, vaporize and dissolve, depending on its properties. A prolonged vapour release from the breached cargo tank might also occur.

Penetrations below the water line will probably result in an initial outflow of cargo until sea water and cargo heads balance, followed by alternating inflow/outflow of water/cargo respectively in the breached tank and eventually all the cargo in the tank would be lost.

A possible consequence of collisions and the associated release of cargo is ignition. A gas carrier or parts of it may be engulfed with gas vapour on impact due to the rapid vaporization of the escaping liquefied gas. If ignition does not occur on impact, the vaporization of cargo released by the impact may still maintain suitable conditions of flammability in the vicinity of the casualty although this threat could be offset for a very short time by the over-rich concentration of gas. In conditions of possible flammability, it is not only the gas carrier which has suffered the impact which is at risk but also the impacting vessel may be a likely source of ignition if the vapour cloud moves in its direction.

1.2.2 Scenario No. 2 – grounding

The double bottom construction found in the majority of gas carriers provides protection in the event of grounding. However grounding could result in build-up of water within certain enclosed spaces. If penetration through the hull leads to a major rupture of the cargo tank, there would be an initial outflow of cargo to the sea until a balance of heads (cargo/water) is achieved. Ice and vapour formation would also take place.

1.2.3   Scenario No. 3 – ramming

This scenario covers situations arising from gas carriers involved in low-energy impacts e.g. striking a structure on the dockside or a fixed navigational aid, e.g. beacon.

It would be accepted that a gas carrier striking a navigational beacon would do so at relatively high speed. On the other hand, the damage that may be sustained by the vessel would probably be superficial and it is unlikely to result in cargo loss directly. However, striking such objects may cause damage to the rudder or propellers resulting in some loss in steerage capabilities giving rise to possible grounding or collision possibility.

Berthing incidents are not likely to give rise to loss of integrity of the cargo containment, since the energy of impact is usually too low to result in enough damage to cause tank rupture. However these minor incidents may cause damage to deck pipework and valves which, whilst not causing immediate loss of cargo, could give rise to losses during cargo discharge. Furthermore any leakage of gas may tend to lie around the decks since many of the vapours originating from liquefied cargoes are heavier than air. These may enter doors and other openings near the cargo deck and may be drawn into machinery spaces and air intakes.

1.2.4   Scenario No. 4 – fire on board a gas carrier

Fires in machinery or accommodation spaces are unlikely to spread to the cargo area because of the totally closed and oxygen-free nature of a gas carrier's cargo system.

Fire or explosion in a compressor house, situated as it usually is on deck within the cargo area could result in damage to adjacent tank domes and connecting gas lines and to the ignition of gas which is released at the points of disruption.

1.2.5   Scenario No. 5 – spillage resulting from inadvertent disconnection piping failure or tank overflowing

Unexpected meteorological conditions e.g. high winds or the effect of another vessel passing at excessive speed, by a gas carrier which is secured alongside a berth may put extra strain on the mooring lines and fenders to the extent of damaging or severing the transfer cargo lines. Although automatic emergency shutdown systems come into operation if the integrity of the cargo transfer lines is at risk, a small amount of liquefied gas may still be spilled before the supply is shut off. In these circumstances, the liquid may find its way overboard and form a pool on the sea surface between the ship and the berth. If the ship is lying alongside an open-piled jetty, then the spacing between the piles will offer no containment for the pool. If on the other hand, the jetty is a continuous wall, the pool may be confined between the jetty wall and the ship's side. If fenders are spaced at the water level along the ship's side, they will have a "booming effect" on the pool (see **Figure 1**). If ignition takes place, and assuming rapid shutdown of the transfer operation has taken place, the fire could be quite intense but should be short-lived.
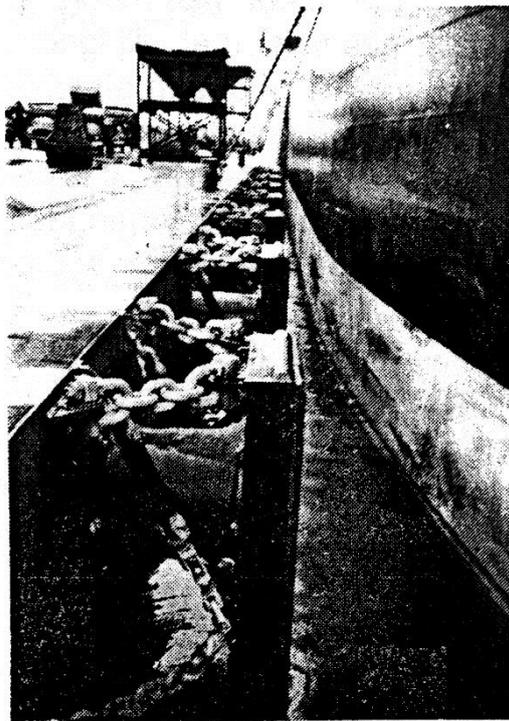
Figure 1. **Illustration showing possible booming effect "of fixed fender system positioned alongside a ship's hull**

Tank overfilling or piping failure (incl. failures of joints, seals etc.) may result in spillage on deck. Consequences may be minor if the leakage is detected quickly and corrective action taken immediately. Yet brittle cracking of adjacent steel structures and an accumulation of liquefied gas in void spaces with subsequent vaporization could still result.

In either case, spillage of toxic cargo will result in health hazards to personnel in the immediate areas.

2. Hazards from spilled gases

In general terms, **harm** can be defined as injury or damage caused following exposure to the hazards of an accidental release of a product. The hazards faced by response pressure following exposure to an accidental release of a gaseous material could be due to:

- flammability;
- toxicity;
- reactivity
- corrosively;
- cold burns;
- a combination of the different hazardous properties.

### 2.1. Fire hazards of spilled gases

A spill involving a gaseous product may pose fire hazards. The ease with which a gas will ignite, either spontaneously from exposure to high temperature or from exposure to a spark or open flame is termed the **flammability potential of the gas**.

2.1.1   Measures of flammability potential

Some common measures quoted from the scientific and technical literature which can assist a responder in evaluating the flammability potential of a gas are:

- the **flash point** which is the lowest temperature of the material at which it will ignite and burn when exposed to an ignition source without self-sustaining combustion;

- the **fire point** which is the lowest temperature at which a substance, when once ignited will continue to burn without any additional source of heat (temperatures are available for a relatively few materials in the literature);

- the **flammable range or limit** which gives a measure of the ratio of flammable gas (or vapour) to air necessary for combustion; it is the difference between the upper and lower flammable (or explosive) limits; the lower flammable (or explosive) limit (LFL or LEL) is the minimum concentration of a gas in air that will ignite and propagate a flame and is usually expressed as a percentage by volume of gas in air whilst the upper flammable (or explosion) limit (UFL or UEL) is the maximum concentration of a gas in air that will ignite or propagate a flame. If the gas-to-air mixture is below the LFL, it is described as being "too lean" to burn and if it is above the UFL, it is ,"too rich" to burn; when the gas-to-air ratio is somewhere between the LFL and UFL, fires and explosions can occur and the mixture is said to be in the flammable range (see **Figure 2**).

The words "flammable" and "explosion" are used interchangeably here; the reasoning behind this is that the concentration of a gas that will burn in air can also be expected to explode given the right conditions in particular when the products of gas combustion including the heat produced, are not removed from the reaction zone.
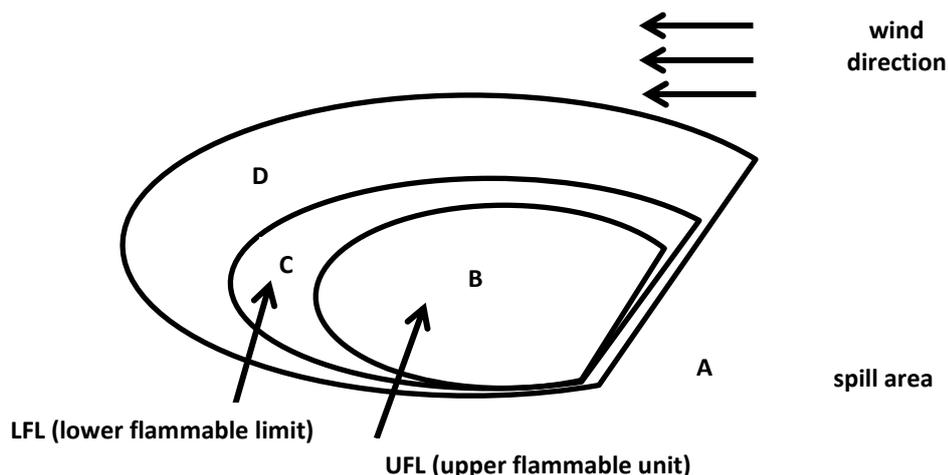
Figure 2.   ***Flammable range set up from a liquefied gas spill***

- the **autoignition temperature**: which is the ignition temperature required to cause self-sustained combustion in the absence of any source of ignition.(e.g. flame or spark).

Flammable properties of some gases which are commonly transported are shown in **Annex 2**.

2.1.2   Types of fire

Some of the types of fires associated with gaseous (or vapour) releases are:

- **flame jets** which can form when liberated gas (or vapour) encounters an ignition source whilst discharging or venting at high speeds entraining and mixing with air in the process;

- **fire balls** which can form following a <u>b</u>oiling <u>l</u>iquid <u>e</u>xpanding <u>v</u>apour <u>e</u>xplosion (BLEVE);

- **vapour cloud fires** which can form when a cloud or plume of flammable gas (or vapour) contacts an ignition source at a point at which the gas (or vapour) concentration is within the flammable range; the fire may flash back to the spill source engulfing anything and everything in its path.

2.1.3   Sources of ignition

Following an airborne release or likely release of a gaseous flammable product, it is essential to control all sources of ignition during the response since the occurrence of these sources whilst unexpected, their potential hazard is often underestimated. Sources of ignition could include:

- smoking including the use of cigarette lighters and matches;
- flash lights;
- safety tools which although may be "non-sparking" may have fragments of metal embedded in their heads;
- generators of static electricity such as helicopters used to transport response personnel to and from the stricken vessel;
- personal clothing such as shoes with metal cleats.

2.1.4   Hazards from the products of combustion

A **fire** is but one of the products of the chemical reaction initiated between a flammable gas and oxygen (from the air). This chemical reaction is also known as "combustion". There are three major products of combustion, all of which are produced in varying degrees. These are:

- **flame and heat** which give rise to thermal radiation causing burns of different intensity, i.e. first-degree burns affect the outer layer of the skin, second-degree burns cause blistering and penetrate further into the skin, third-degree burns penetrate even further and damage nerve endings;

- **smoke** which consists of airborne particulate material, mostly of a carbonaceous nature, which results from the incomplete combustion of material and causes irritation to eyes and lungs and even death;

- **fire gases** which are the products of combustion and the resulting chemical rearrangements produced by the fire; invariably they will consist of carbon dioxide and, depending on the amount of available oxygen, carbon monoxide; irritating, corrosive and toxic products, such as hydrogen chloride and phosgene may be generated depending on the chemical composition of the material.

2.2 Toxic hazards from spilled gases

Toxicity can be defined as the property of a substance to cause damage to living tissue, impair the function of the central nervous system, cause severe illness or even death when inhaled, ingested, injected or absorbed by the skin. It is also important to distinguish between **acute effects** of a substance which are those that occur immediately after exposure and **chronic effects** which are those that occur and remain apparent for some time after the exposure.

2.2.1 Factors affecting the toxicity potential

Undoubtedly, the release of a gaseous product can pose toxicological threats and the immediate concern during an airborne gaseous discharge should be the protection of human life and health. The toxic hazard posed by the released material will depend on:

- the amount spilled;
- the toxicological properties of the substance;
- the route of exposure;
- the duration of exposure;
- the life-stage of the exposed individual(s).

Two common routes of exposure following an airborne release of a gas (or vapour) are **inhalation** and **absorption**.

Inhalation of a toxic gas (or vapour) may:

- dull the sense of smell;
- cause dizziness;
- cause headaches;
- irritate the eyes;
- cause unconsciousness;
- cause internal damage to vital organs
- cause cessation of breathing;
- cause death.

Absorption of a toxic gas (or vapour) may:

- irritate the skin;
- cause blood poisoning;
- cause internal damage;
- cause death.

2.2.2 Exposure limits for airborne release

One of the key tasks in preparing for and responding to an emergency involving a gaseous release is to select the airborne concentration that can be tolerated by all exposed personnel, including people in the vicinity, since it is this "target" concentration that will determine the extent of the hazardous zone.

Commonly available exposure limits for airborne contaminants which have been published by various advisory bodies as guidance to the operational handling of chemicals are the **Threshold Limit Values (TLVs)**. The TLVs can be of different types and include:

- **TLV-TWA** which is the time weighted average concentration for an 8-hour workday and 40-hour workweek to which workers can be repeatedly exposed without suffering adverse effect;

- **TLV-STEL** which is the time weighted average concentration to which workers can be exposed for no longer than 15 minutes duration provided the exposure is not repeated more than four times per day, allowing a minimum of 60 minutes between each exposure;

- **TLV-C** which is the ceiling concentration in air that should not be exceeded under any circumstance in any part of the working exposure.

In addition to the TLVs, another useful airborne concentration value is the **Immediately Dangerous to Life or Health (IDLH)** level which is the maximum airborne concentration from which one could escape within 30 minutes without any escape-impairing symptom or any irreversible health effect.

It must be recognized that:

- any toxicological value is continually being revised and updated and the latest revision of these values should be consulted;

- the intended use of these values are for the occupational hazards where the exposed person is presumably a "healthy worker" and not an elderly person, young child or an individual with pre-existing health problems, all of whom might be more sensitive than a healthy worker to the ill-effects of a toxic airborne release;

- the values provide "guideposts" for identifying exposure limits in an emergency situation and should not be regarded as sharp dividing lines between what is safe and what is a dangerous concentration;

- the application of any value to an emergency situation requires specialist interpretation and any advice should be taken following a formal and total review of the toxicity of the substance.

2.3 Cold and chemical burns

Two possible additional health hazards from contact with gases are **cold** and **chemical burns.**

Cold burns are very much related to the way a gas cargo is carried rather than to the inherent properties of the cargo and are caused as a result of the direct contact with an extremely cold liquid. The mechanism that applies to brittle fracture of a steel structure on board a ship following a spillage of a cryogenic liquid would also apply to the production of cold burns. In this case, heat from the skin is taken to provide the latent heat the cold liquid needs to be able to evaporate.

On the other hand chemical burns are related to the corrosively of the gases (or vapour) which causes visible destruction or irreversible alteration in human skin tissue at the site of contact. Chemical burns can be caused by ammonia, bromine, chlorine, ethylene oxide and propylene oxide.

2.4 Reactivity hazards of spilled gases

Reactivity is the ability of a material to change chemically, either by combination, replacement or decomposition. Reactivity hazards involve the release of energy in quantities and at rates too high to be absorbed by the reacting system. This results in possible adverse consequences such as the generation of toxic gases, heat, rupture of cargo tanks with an

overflow of material, fire and explosion. In the case of a spilled gas some of the basic types of reaction which could give rise to potentially hazardous situation are:

- **reactions with water** or air: for example ammonia will dissolve rapidly and exothermically to produce ammonium hydroxide whilst if any cryogenic gas spills onto the sea, large quantities of vapour will be generated by the heating effect of the water which if flammable may ignite in the presence of an ignition source;

- **polymerization reactions**: for example vinyl chloride monomer (VCM) has a strong tendency to polymerize (self-react) under certain conditions and is therefore carried with a phenol inhibitor;

- **reactions with other materials**: for example methane and propylene are considered reactive with mild steel which is a common material of construction on most ships.

3. Behaviour airborne release

Because of the high vapour pressure of gases and rapid vaporization of spilled liquefied gases, response organization will frequently have to deal with how the liberated gas (or vapour) will spread and what the resulting airborne concentrations will be in the downwind location. The following will refer to airborne gas releases but equally applies to vapours.

3.1 Types of gas dispersion

Dispersion is a term which incorporates advection (moving), diffusion (spreading) and mixture with air. An air borne release of gas will generally move in downwind direction and spread in a crosswind (perpendicular to the wind) and vertical direction. Releases of gases into the atmosphere can be classified as:

- **instantaneous** which are those releases that take place over a short period of time and then stop; the result of such a type of release is a puff or a distinct cloud; as wind pushes the puff in the direction of the wind, air will begin to mix with the surface of the puff, thus diluting the surface concentration although the volume of the contaminated air space will become larger;

- **continuous** which are those releases which take place over a longer time and produce long stretched-out plumes; the results of such a type of release is that points downwind will eventually be exposed to a relatively constant airborne contaminant concentration for a period of time equal to the duration of the discharge as long as there is no shift in wind.

Illustrations of the two different types of gas dispersion are found in **Figure 3**.
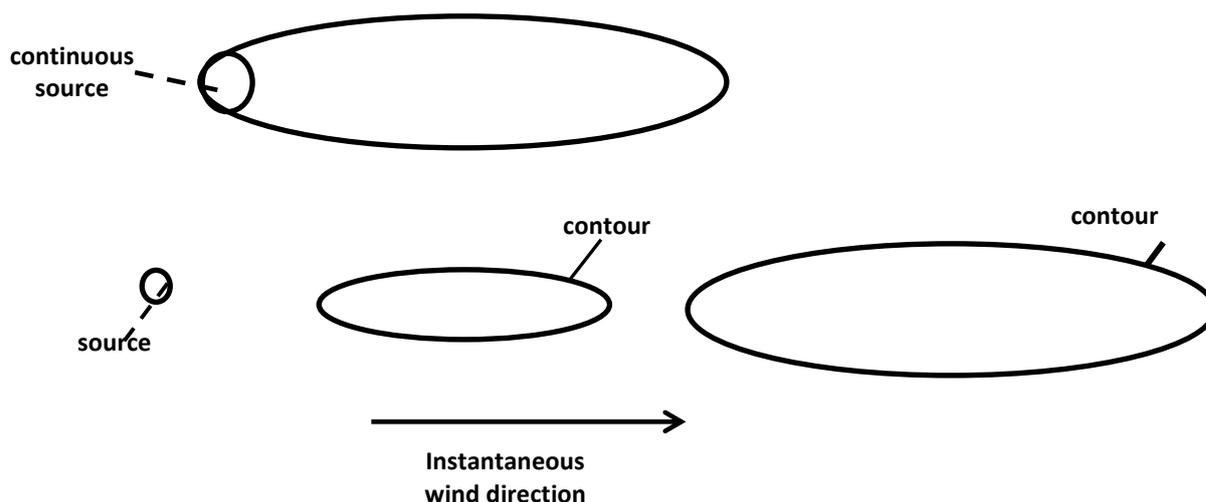
Figure 3.   *Illustration of plume (top) and cloud formation (bottom)*

Purely instantaneous or continuous spills do not readily occur in practice since many spills may be of too long duration to be characterized as truly instantaneous, yet too short in duration to establish a continuous plume. However this type of theoretical categorization enables simulated models to be developed which assist in assessing how a gas will dispersed over time and therefore help a responder in determining the extent of the hazard zone affected by the gas.

3.2   Variables influencing atmospheric dispersion

Generally, a cloud or plume of a gas will drift in the direction of the prevailing wind, dispersing and becoming diluted as it mixes with the air, tending to broaden and becoming more diluted as it travels further.

There are a number of factors that influence the shape and size of a downwind zone affected by an airborne gaseous release. Although these variables will be discussed individually, several of them interact with each other so that the resultant hazard zone is a function of the combination of the different variables.

3.2.1   Effects of sources strength

In general larger release amounts or higher release rates will produce longer and larger downwind hazard zones. "Jet" momentum effects will also be experienced in the vicinity of a source if a gas is vented under high pressure. These effects become less significant as the gas moves away from the source.

3.2.2   Effects of fire

Thermal energy from a fire will cause a gas cloud or plume to rise. Furthermore a flammable gas, once released, will provide fuel for the fire and can itself be consumed in the process. This may result in a smaller overall hazard zone of the original released substance, especially if the fire is close to the source of release.

3.2.3 Effects of gas buoyancy

From a buoyancy perspective, gases can either be classified as lighter-than-air (e.g. LNG) or heavier-than-air (e.g. chlorine). Lighter-than-air gases, when released, will rise and mix with air. The rate at which a gas will rise as it moves downwind will, in part, be a function of the difference between the density of the gas and that of air as well as the prevailing wind speed. Strong winds tend to keep a lighter-than-air gas plume or a cloud closer to the ground for longer periods.

Heavier-than-air gases will have a tendency to initially collect at ground level. As the gas moves away from the point of discharge, it will become diluted as it mixes with air. As its density approaches that of air, it will begin to behave more like a neutrally buoyant gas. A gas that is lighter-than-air under normal ambient conditions, but is shipped as a cryogenic (low temperature) liquid, forms a heavy gas cloud on initial spillage because at the time of the release it is cold and therefore dense.

3.2.4 Effects of Terrain

Topographical features will influence the manner in which a gas will disperse. Topographical features are usually expressed as <u>surface roughness</u>. A rough surface causes more turbulence than a smooth surface promoting vertical mixing of gas. A rough surface tends to create obstacles thereby reducing the wind speed near the ground as is the case in an urban area near a port. Wind flowing around large obstacles will also create eddies and unstable wind-shifts which can influence the behaviour of gas release. This is of particular importance when air flows swiftly pass a ship's hull and its superstructure, swirling around the ship in the process (see **Figure 4**). The passing air causes a slight drop in pressure, drawing in currents of air (eddies) which can then drag the released gas onto the ship's deck.
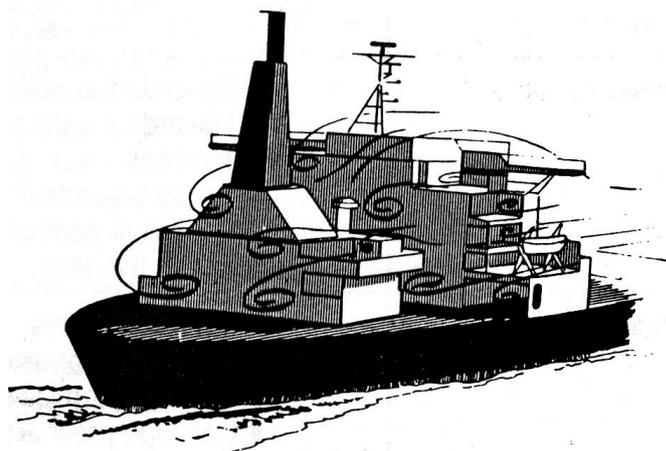
Figure 4. *Formation of swirling currents (eddies) as air flows past a ship's superstructure*

3.2.5 Effects of atmospheric stability

The time of day, cloud coverage, wind speeds, strength of sunlight determine the level of turbulence in the atmosphere and how a parcel of air will behave when it is displaced in the vertical direction. Unstable atmospheric conditions, characterized by strong sunlight and clear skies contribute to high levels of thermal turbulence in the atmosphere and promote rapid mixing. On the other hand, stable conditions characterized by light winds and night time cooling conditions contribute to low levels of thermal turbulence and would not promote mixing of the gas. When there is very little wind or when wind speed decreases, the wind direction may also become very inconsistent. The practical significance of this is that under low wind conditions, sudden shifts in wind direction may take place and the possibility exists that the gas cloud or plume may "hop" from one position or direction to another. At the other end of the

scale, high wind speeds contribute to the generation of mechanical turbulence and hence rapid mixing. Thus, weather conditions will determine the direction of the plume or cloud and the amount of dilution in the plume as it moves downwind.

4. Response measures applicable to gaseous releases

Response measures are those actions which will minimize the risk to both life (including human health) and the environment in the early, critical stages of a spill or leak of gas. These actions could be directed to:

- the ship;
- the cargo;
- the released substance.

In responding to an emergency situation, any response action to be taken has to be evaluated on the basis of the circumstances of the particular incident and whether the action can be accomplished safely without detriment to those responding. The following paragraphs contain possible response options, giving an indication of what might be undertaken in the event of a gaseous release or likely gaseous release resulting from a maritime incident. These lists should not in any way be interpreted as a recipe to response operations for gaseous releases from accidents involving the transportation by sea in bulk or in package form of such products but should only act as guidance.

4.1 Response options – the vessel

The following is a list of response options focusing on the vessel.

ACTION	THE VESSEL
	MODE OF ACTION
Move (or tow) the ship	No. Towards the open sea
	No. Towards a safe anchorage
	No. Towards a safe haven
	No. To the prevailing wind direction, with accommodation upwind (if possible)
	No. Beach the ship
Extinguish fire	No. Use water spray
	No. Use high expansion foam
	No. Use dry chemicals
	No. Use high pressure CO_2 gas
	No. Use sand
Reduce potential for fire	No. Eliminate ignition sources
	No. Eliminate heat sources
	No. Flood area of contact to cool hot metal (applicable mostly to collisions)
	No. Spray down deck/piping
	No. Spray down tanks
Scuttle the ship	
Instruct and warn approaching vessels as to safe approach and to remain upwind	
No direct action	No. Monitor the situation

4.2   Response options – the cargo

The following is a list of response options focusing on the cargo.

THE CARGO	
ACTION	MODE OF ACTION
Move the cargo	No. Transfer cargo from damage a tanks No. Lighter the vessel (STS; STT) No. Remove containers/receptacles
Stop the spill	No. Close valves No. Seal/plug the leaks/ruptures
Protect the cargo	No. Isolate damage tanks No. Cool adjacent areas No. Add inert gas
Immobilize the cargo	No. Bury the containers/receptacles, (capping) No. Anchor the containers/receptacles
Release the cargo	No. Intentional jettison with mechanical air dilution No. Intentional jettison with water spray dispersion No. Controlled explosion of sunken containers No. Controlled flare-off
No direct action	No. Monitor the situation

4.3   Response options – the released gas

The following is a list of response options focusing on the released gas.

THE RELEASED GAS	
ACTION	MODE OF ACTION
Chemical treatment	No. Use foam for vapour suppression No. Use water fog to knock down gas clouds using neutralizing agent to avoid pH overdosing, if necessary No. Make cloud visible
Restrict access to dangerous zone	
Evacuate non-response personnel from hazard zone	See Section 5
Shelter-in-place non-response personnel	See Section 5
Do nothing	No. Monitor the situation allowing the substance to evaporate and disperse naturally

5.   Behaviour airborne release personnel (the civil protection)

There are essentially two ways to protect the civil population. One is **evacuation** and involves relocation of a threatened population to shelters in safer areas. The other involves giving people instructions to remain inside their homes or places of business until the danger passes (**shelter-in-place**).
Both of these options have been used to protect the community from the effects of maritime-related accidents (see **Table 1**).

TABLE 1

CASES OF EVACUATION/IN-PLACE SHELTERING METHODS IN
MARITIME RELATED ACCIDENTS INVOLVING HAZARDOUS SUBSTANCES

DATE	LOCATION	VESSEL	SUBSTANCE	DETAILS
20/4/95	Corpus Christi, Texas, USA	barge, DC-304	cumene/VCM	Bow of LPGC Maersk Shetland loaded with VCM struck barge near Ingleside naval station: small release of cumene: **locals evacuated**; VCM cargo intact
9/01/93	nr Mandal, Norway	Stawfjord	explosives	Listing ship with 200 tonnes of dynamite in hold and deck containers of percussion caps overturned when tow broke: grounded; **100 evacuated**; explosion
22/8/91	Coode Island, Australia	bulk liquids storage tank	methyl ethyl ketone	Explosion and fire in storage tanks spread to others. Port and railroad closed, **hundreds evacuated**. Workers and residents in nearby suburbs **were warned to stay indoors**, switch off air conditioners and seal windows to prevent entry of toxic fumes
3/05/91	Norfolk Coast, UK	Nordic Pride	ethyl acrylate	Two 24,000-litre ethyl acrylate tank containers beached; one leaked 1000 litres, **1000 residents evacuated**
27/7/89	Rotterdam, Holland	tank container	calcium hypochlorite	About **7000 people evacuated** from vessels and homes in port district following fire in container of calcium hypochlorite: chlorine given off

5.1   Options facing a person caught in a toxic gas vapour

A person has a range of options at his disposal on whether he stays in or outdoors when faced with a toxic gas or vapour release (see **Figure 5**).
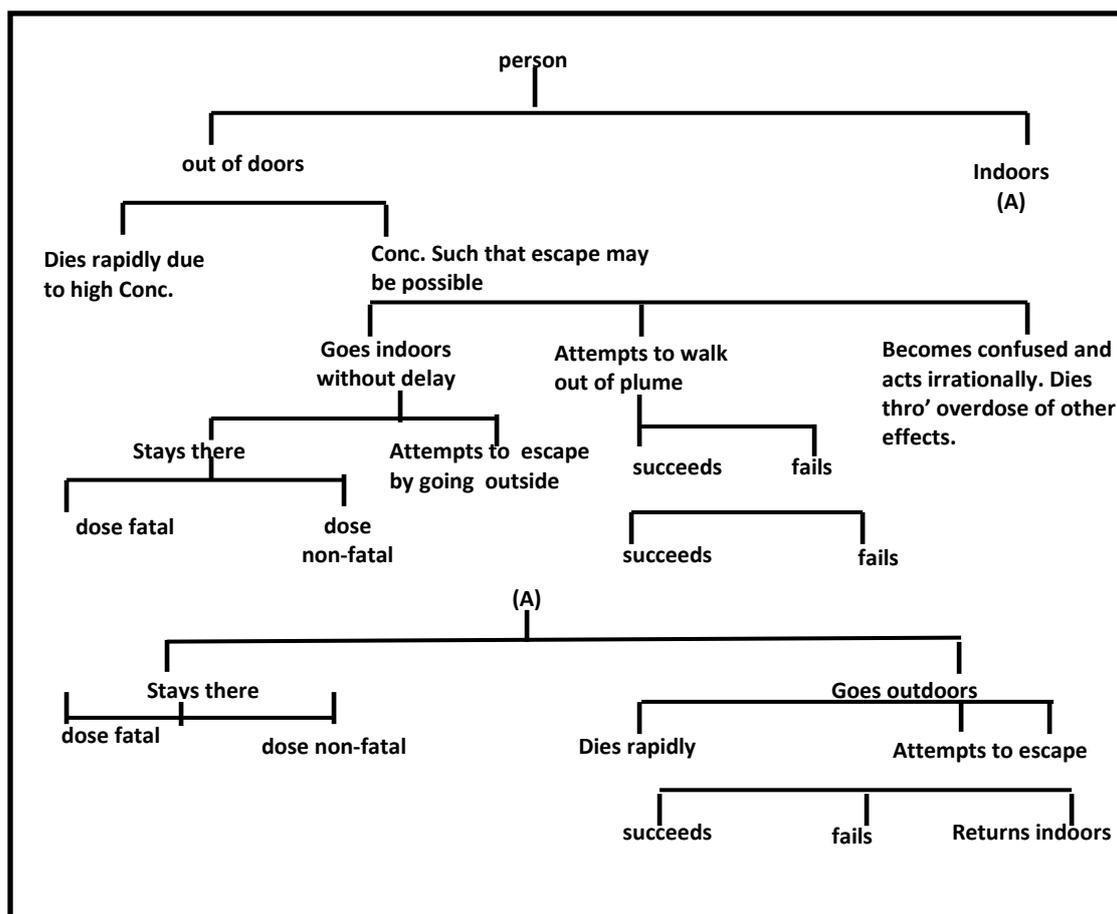
Figure 5. *Options facing a person caught in toxic gas cloud or vapour*

- The options in Figure 5, when extrapolated to a whole population can be summarized as follows:

- the remain-indoors option and the use of the reservoir of clean indoor air to dilute contaminated air that infiltrates indoors;

- the evacuation of the area before the toxic release occurs (pre-incident evacuation);

- the rescue of people after the hazard reaches the area which involves supplying protective equipment to ensure their safety;

- the evacuation of the area after the outdoor concentration has decreased to a level lower than indoors (post-incident evacuation).

5.2 Aspects of a evacuation

Evacuation is a complex operation and is considered one of the most sweeping and aggressive response measures taken in an accidental chemical release. It is also important to distinguish between mass evacuation of an entire area and the selective evacuation of part of the area at risk.

5.2.1 Factors to consider for evacuation

There are a number of factors to consider when deciding on an evacuation;

- the optimum starting time;
- the number of evacuees (evacuation of the entire area or a selection of the area);
- the location and whereabouts of evacuees;
- the mobility of evacuees;
- the reaction of people who are informed that they are to be evacuated.

5.2.2 Resources required for evacuation

To accomplish a safe and effective evacuation operation, <u>certain resources are imperative</u>, such as

- evacuation assistance personnel;
- vehicles to move people out of the stricken area;
- equipment;
- agreements with nearby jurisdictions to receive evacuees.

5.2.3 Conducting an evacuation

An evacuation operation itself must be conducted in a well co-ordinated, thorough and safe manner and making prior arrangements (**at the preparedness level**) to ensure the availability of resources prior to the emergency will result in a more efficient evacuation operation.

5.3 Aspects of in-place sheltering

<u>An alternative</u> to evacuation <u>is to seek shelter indoors</u>. This could be a viable option to protect the public from the effects of toxic gas or vapour discharges into the atmosphere. The exposure of people inside a building to a toxic gas or vapour release which has taken place on the outside is a function of:

- the airtightness of the building;
- the rate of entry and exit of the contaminated air;
- the indoor mixing of the toxic load with the indoor clean air.

5.4 Summary – evacuation vs. shelter-in-place

It can be said that the decision to evacuate and/or shelter in-place is very incident specific and the use of judgement is necessary. **Evacuation remains a viable option of protecting the public when:**

- there appears to be time to relocate people;
- the discharge has already taken place but people are sufficiently far downwind to permit evacuation;
- long term releases take place, and the release is expected to occur over an extended period of time;
- a fire has also occurred which can get out of control;
- people not yet in the direct path of a cloud or plume are threatened by a future shift in wind direction;
- risks associated with in-place sheltering might not fully protect the people from the deleterious effects of the hazardous material release.

On the other hand, **in-place sheltering is also a viable option of protecting the public when**:

- the air borne contamination is moving so fast that there is no time to evacuate;
- a short-term release takes place and the toxic plume is expected to pass over quickly;
- climatic changes and duration of toxic plume movement are difficult to predict;
- it is anticipated that the most vulnerable populations such as the elderly and sick, may sustain injury during evacuation;
- risks associated with evacuation might not fully protect the evacuees from the deleterious effects of the hazardous material release.

Further detailed information on the aspects to consider in evacuation and in-place sheltering can be found in **Annex 3**.

6.   Conclusion

Gases are distinguished from other hazardous cargoes in that their vapour pressure at ambient conditions exceeds that of the atmosphere. This characteristic imposes special requirements in their carriage at sea. Because of the volatility of gases together with their inherent toxic, flammable, corrosive and reactive properties, the possibility of spillages and accidental releases require special consideration. Preparing for maritime related accidents involving gaseous products whether they occur at a terminal facility or while a ship is on route requires an understanding of the chemistry of gases, the type of ships which carry such products, the type of accidental releases that might occur, the possible consequences from such releases and the countermeasures that may be feasible. Undoubtedly, once a spill of gas takes place it is very hard to combat.

ANNEX I

CRITICAL TEMPERATURES AND PRESSURES OF SOME COMMON GASES

Substance	Critical Temperature ^0C	Critical Pressure (bars)	Substance	Critical Temperature ^0C	Critical Pressure (bars)
Methane	-82.5	44.7	δ-Butylene	144.7	38.7
Ethane	32.1	48.7	Butadiene	161.8	43.2
Propane	96.8	42.6	Isoprene	211.0	38.5
n-Butane	153.0	38.1	VCM	158.4	52.9
l-Butane	133.7	38.2	Ethylene oxide	195.7	74.4
Ethylene	9.9	50.5	Propylene oxide	209.1	47.7
Propylene	92.1	45.6	Ammonia	132.4	113.0
			Chlorine	144	77.1

VCM = Vinyl chloride monomer

ANNEX II

FLAMMABLE PROPERTIES OF SOME GASES

Gas	Flash point (^{0}C)	Flammable range (% by vol. in air)	Auto ignition temperature (^{0}C)
Methane	-175	5.3 - 14	595
Ethane	-125	3.1 - 12.5	510
Propane	-105	2.1 - 9.5	468
n-Butane	- 60	1.8 - 8.5	365
i-Butane	- 76	1.8 - 8.5	500
Ethylene	-150	3 - 32	453
Propylene	-180	2 - 11.1	453
α-Butylene	- 80	1.6 - 9.3	440
ß-Butylene	- 72	1.8 - 8.8	465
Butadiene	- 60	2 - 12.6	418
Isoprene	- 50	1 - 9.7	220
VCM	- 78	4 - 33	472
Ethylene oxide	- 18	3 - 100	429
Propylene oxide	- 37	2.8 - 37	465
Ammonia	- 57	16 - 25	615
Chlorine	Non-flammable		

EVACUATION VS IN-PLACE SHELTERING

1.   Aspects of evacuation

Evacuation is a complex operation and is considered one of the most sweeping and aggressive response measures taken in an accidental chemical release.   The physical difficulties of large scale evacuation should not be underestimated whilst in considering or carrying out an evacuation operation, care must be taken not to put people at risk by bringing them outdoors and being caught in the open when they might be more effectively protected by in-place sheltering.   It is also important to distinguish between mass evacuation of an entire area and the selective evacuation of part of the area at risk.

1.1   Factors to consider for evacuation

Issues to be considered are whether:
- people are evacuated before the release occurs and if there is enough time to permit relocation;
- people are sufficiently downwind to permit time for evacuation;
- people not yet in the direct path of a cloud or plume but threatened by a future shift in wind;
- the release has already taken place, in this case the best time to leave is after the outdoor concentration has decreased below the indoor level;

- number of evacuees (evacuation of the entire area or a selection of the area);
- the location and whereabouts of evacuees such as:
- private residences;
- educational institutions;
- medical institutions;
- health care facilities;
- child care facilities;
- correctional facilities;
- offices;
- commercial establishments;
- industrial establishments;
- sporting and recreational facilities;
- parks and similar open spaces;
- roadways;

- the mobility of evacuees with special consideration to:
- persons lacking their own transport;
- the elderly;
- the children;
- disabled persons;
- the infirm;
- prisoners;
- persons not speaking the "local" language;

- the reaction of people who are informed that they are to be evacuated (Note: with the realization that a person is to be away from home for a considerable time, there is a tendency for a person to return to pick up valuables and supplies whilst relatives and friends concerned about the safety of people evacuating have a tendency to converge on

the area compounding the whole operation the latter group of people should not be allowed in the stricken area. Persons with domestic pets may be unwilling to leave their homes unless arrangements include their pets).

1.2   Resources of required for evacuating

- To accomplish a safe and effective evacuation operation, <u>certain resources are imperative</u>, such as:

- evacuation assistance personnel;

- vehicles, to include:
    - lift-equipped vehicles for disabled persons;
    - ambulances for the infirm;
    - transport means for moving people lacking their own transport;

- equipment, to include:
    - protective equipment for evacuation assistance personnel;
    - protective equipment for evacuees who may have to be taken through a heavily contaminated area;

- communication equipment, such as:
    # portable and mobile radios;
    # mobile public address systems;
    # bull-horns;
- evacuation tags or markers to indicate the occupants of a building have already been notified and the building has been evacuated;
    - maps (drawn to scale) with evacuation routes and alternatives
    - protective shelters for evacuees;

- agreements with nearby jurisdictions to receive evacuees.

Making prior arrangements (<u>at the preparedness level</u>) to ensure the availability of resources prior to the emergency will result in a more efficient evacuation operation.

1.3   Conducting an evacuation

<u>An evacuation operation itself must be conducted in a well co-ordinated, thorough and safe manner</u>. This involves a number of sequential steps.

STEP 1:   Assigning tasks to evacuation assistance personnel such as their specific area of coverage.

STEP 2:   Alerting the people that they must evacuate and give them with accurate instructions. This step could be accomplished by:
    - door-to-door notification;
    - public address system e.g. mobile unit, broadcast system;
    - a combination of the two.

STEP 3:   Moving the people and providing them with transport assistance. Consideration will need to be given to traffic control and the provision of alternate traffic routes. Traffic control involves auditing vehicle movement in and out of the evacuation area.

STEP 4: Sheltering the evacuees and providing them with a safe and comfortable building. When selecting the location of the building, it is imperative that the location is chosen beyond the current and anticipated area of contamination. If in the extreme case, the building has to be evacuated, alternate locations would need to be previously identified. A number of buildings should have been pre-identified which could function as shelter/rest centres in any emergency. Some characteristics, facilities and services which should be available at shelter/rest centres are listed in **Appendix 1** to this <u>Annex</u>.

STEP 5: Securing the evacuated area to prevent unauthorized activities (e.g. looting, vandalism). Security personnel patrolling the area must be equipped with appropriate protective clothing.

STEP 6: Re-entering the evacuated area which can be considered as an evacuation operation in reverse. In this regard, once re-entry has taken place, it is important to advise people to report any lingering vapours or other hazards to emergency services as well as advise people to seek medical treatment for any unusual symptoms that they may experience (e.g. rashes, difficulty in breathing).

2. Aspects of in-place-sheltering

<u>An alternative</u> to evacuation <u>is to seek shelter indoors</u>. This could be a viable option to protect the public from the effects of toxic gas or vapour discharges into the atmosphere.

2.1 Factors to consider for in-place sheltering

If a building or other structure is airtight i.e. like a sealed box, anyone inside will not be exposed to any outside toxic gases or vapours. On the other hand, if severe leakages of contaminated air take place into a building, people will be exposed to the same level of contamination "indoors" as they would be if they were "outdoors". Therefore, the exposure of people inside a building to a toxic gas or vapour release which has taken place on the outside is a function of the **"airtightness" of the building**, the **rate of entry and exit of the contaminated air** and the **indoor mixing of the toxic load with the indoor clean air**.

2.1.1 Air-tightness

Three ways air enters (and exits) structures are:

- <u>natural ventilation</u> which can be described as the entry of outdoor air into a building through open windows or doors without assistance; obviously, the more openings in a building, the greater the rate at which outdoor air can pass through; closing and opening the various windows and doors regulates the rate of entry/exit;

- <u>forced-air ventilation</u> which can be described as the entry of outdoor air into a building through the use of fans and other equipment, possibly heating, cooling, filtering the air and even circulating it several times and then exhausting it to the outside; regulation of the rate of entry and exit is done through the control of the system;

- <u>infiltration</u> which can be described as the air leakage into building through cracks and crevices around the openings around the windows and doors and through floors and walls; this type of infiltration is divided into two: <u>background</u>

leakage which would include sources at the joints between the walls and the foundation, perforations such as electrical outlets and plumbing; and

- component leakage which would include localized sources such as for example cracks around window frames and openings for dryer vents (**Figure 1** illustrates the air infiltration and exfiltration leakage paths); this type of air entry is different from natural and mechanical ventilation in the sense that occupants are generally considered to exercise very little control over the rate of entry.
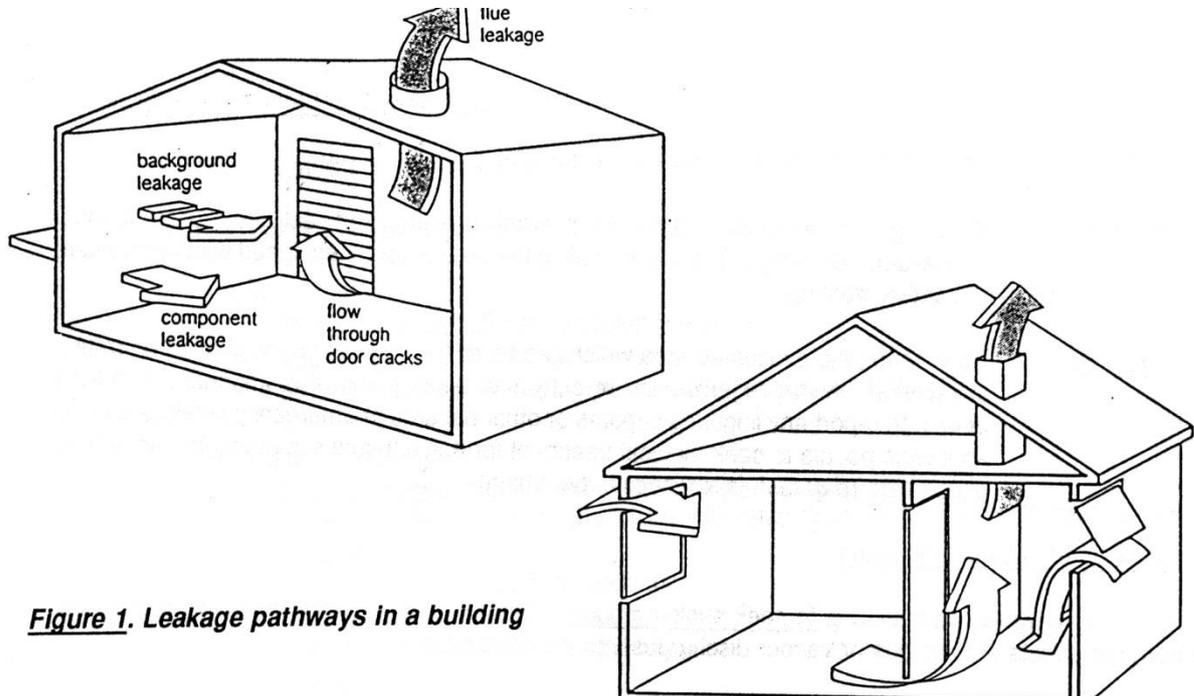
Figure 1. Leakage pathways in a building

2.1.2   Total infiltration rate of buildings

The rate of entry of a toxic gas into a building is dependent on:

- different types of ventilation;
- wind and temperature conditions;
- air exchange rate of the building;
- terrain roughness;
- path of the toxic plume in relation to the buildings.

2.1.3   Indoor mixing

Certain factors that need to be borne in mind when considering indoor mixing of contaminated air in a building are:

- the dilution of contaminated air with indoor air which means that person sheltering indoors will be exposed to a diluted outdoor concentration;
- the direct displacement of indoor air due to the entry of an unmixed flow of cooler contaminated outdoor air which would be in direct conflict with the dilution effect;
- the potential for build-up of hot spots within a given space;
- the physical state of the airborne substance (gases and vapours travel greater distances and pass through smaller spaces than dusts and other aerosols).

2.2   Recommendations to follow when in-place sheltering

In order for in-place sheltering to be effective, minimization of the indoor toxic air load needs to take place. The following are a set of suggested instructions which can assist in making in-place sheltering an effective protective measure:

- doors to the outside should be closed, windows should be closed and locked (windows seal better when locked). Gaps under doorways and windows should be sealed with wet towels/clothes and those around doorways and windows with ducting (electrician's) tape or equivalent thick tape;
- ventilation systems should be set fully to the recirculation mode to avoid outside contaminated air being drawn into the building. A ventilation system should be turned off where this is not possible;
- heating systems and air conditioners should be turned off;
- the use of lifts should be minimized since they tend to "pump" outdoor air in and out of a building as they travel up and down a building;
- extractor and exhaust fans in kitchens, bathrooms, toilets should be switched off;
- obvious gaps to the outside around window-type air-conditioners, exhaust fans, kitchen hoods, dryer vents should be sealed using plastic sheeting, wax paper or aluminium foil wrap;
- internal doors (as many as is feasibly possible) should be closed;
- if the information available on the substance indicates that the material is soluble or even partial soluble in water, advise to hold a wet cloth over the nose and the mouth. Advise to move to the bathroom, to seal the door and any other openings, to turn on the shower, and to set the shower head to a strong spray "to knock-down" any contaminated air;
- if there is a chance of explosion outdoors, advise to close curtains and shades, to lie low and to move away from external windows to avoid being hit by flying glass and other shrapnel;
- open windows and ventilation systems as soon as the danger has passed to help in "flushing-out" any contaminated air lingering or trapped in the building;
- turn on the emergency broadcast system on the radio or television and follow the guidance given.

**CHARACTERISTICS, FACILITIES AND SERVICES OF
SHELTERS/ REST CENTRES**

The Appendix will cover some broad guidelines, which are considered necessary for establishing a shelter/rest centre. They are by no means comprehensive but concentrate on the most important features. The Annex is divided into two parts. <u>Part A</u> deals with the characteristics, facilities and services that should be provided by the shelter/rest centres whilst <u>Part B</u> lists in point form the stress induced to those accommodated within these places.

PART A – Characterises, facilities and services

<u>Layout of building</u>:
- a single entrance and exit should be arranged even though more than one could be present in the building;

- entrance/reception area must be large enough to allow people to enter without having to wait outside especially at night or during inclement weather;
- a main living/sleeping area with sufficient space to avoid overcrowding;

- a room to store valuables and any other personal belongings evacuees may wish to protect;
- sufficient car park area and access to the premises which are large enough for buses or ambulances with easy access for the disabled;

- separate room for pet owners and their animals;

- rooms for medical examination and counselling.

<u>Facilities</u>:
- food preparation facilities;

- telephone or other communication facilities (e.g. two way radio);

- shower/washing/toilet facilities;

- basic furniture (e.g. chairs, tables, bedding);

- adequate lighting, temperature control, ventilation and uncontaminated water supply;

- provisions for the monitoring of hazards in and around the building.

<u>Management and organization</u>:

- a person to serve as a shelter/rest centre co-ordinator;

- provisions for registration and accountability of the whereabouts of the evacuees once received;

- arrangements to limit access where entry to parts of the premises is prohibited due to possible danger;

- provisions where regular, accurate and up-to-date information is displayed and given to the evacuees;

- provisions to have interpretation where necessary, this is particularly important in areas where evacuation has taken place of foreign nationals (e.g. hotels);

- provisions for medical prescriptions to be picked up and medical treatment continued for any chronic ailments suffered by evacuees;

- provisions to have assistant staff and workers to be relieved;

- provisions for certain basic items to be available (e.g. soap, towels, toothbrushes and toothpaste).

PART B – Possible Sources of Stress in Rest Centres

- **Loss of dignity**:
  - lack of privacy
  - loss of false teeth, spectacles, etc.
  - "being grateful"
  - "having to ask"
- **Strange and unsatisfactory surroundings**:
  - sanitation
  - washing
  - other people

- **Strange neighbourhood, loss of neighbours (social network):**
  - news
  - babysitting
  - support

- **Disruption of services**:
  - food
  - information

- **Uncertainty**:
  - how long here?
  - what next?

- **Bureaucracy**:
  - loss of control
  - delay
  - fading sympathy of others

- **Life changes**:
  - work
  - education
  - culture

- **Continuing psychological problems**:
  - encounter with death

- bereavement
- need to adapt

- **Family tension**:
  - crowding
  - no privacy
  - no communication (fear of memories and distress)
  - overuse of alcohol (tension release)
  - worries over children (behaviour)

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