TOPIC THREE - FIRE SUPPRESSION SPECIAL

CONTENTS

SECTION ONE - AIRCRAFT

CONTENTS

1 AIRCRAFT

1.1 Introduction

It is common for aircraft to carry more than 350 passengers and 200 000 L of fuel. In a crash situation, a commercial passenger aircraft combines a high life risk with a high fire risk. Because of the high safety standards in the Australian airline industry, there have been relatively few major incidents involving aircraft.

This means that many firefighters have had little experience in this type of fire fighting, and unless firefighters are members of airport fire services, they receive little training in fighting aircraft fires.

Aircraft accidents fall into two categories:

- an accident which occurs on or close to an airport. This type of accident is attended by airport and urban fire services, and resources are usually adequate;

- an accident which occurs away from an airport. This type of accident is attended by local fire services which are solely responsible. Depending on the area, resources may or may not be adequate, and back-up services may take some time to organise. Refer to *Standing Orders*.

In an aircraft accident, the problems firefighters face will depend on the size and type of the aircraft involved. In accidents involving larger aircraft, access to the aircraft may be difficult because the body shell is very strong and constructed to withstand the strains of flight and landing. In accidents involving military aircraft, armaments and ejection seats create additional hazards for the firefighters.

In all aircraft incidents, the large amount of fuel present is a major hazard because it is often spread over wide areas from burst tanks. There are many ways the fuel can be ignited and any one of them can spark off a major blaze.

1.2 Construction of Aircraft

To be effective in fighting aircraft fires, a firefighter must have an elementary knowledge of aircraft construction. Design and construction vary with different manufacturers, but the basic principles are standard.

There are three main types of aircraft:

- civil;
- military; and
- helicopters (civil and military).

1.2.1 Civil Aircraft

Civil aircraft are constructed in two ways:

- stressed skin; and
- braced girder.

Stressed Skin Construction

Most large modern aircraft are of stressed skin construction. The fuselage shape is formed by a series of vertical metal frames placed transversely from nose to tail, and only rarely are two frames identical in shape or size. Metal stringers that run the length of the fuselage are placed around the circumference of the frames to form the fuselage shape. Heavier stringers, called longerons, carry floor and other assemblies.

The skin covers the frame and forms part of the load bearing structure. The thickness of the skin varies with the amount of stress it has to absorb. The skin may be riveted or bonded to the underlying framework.

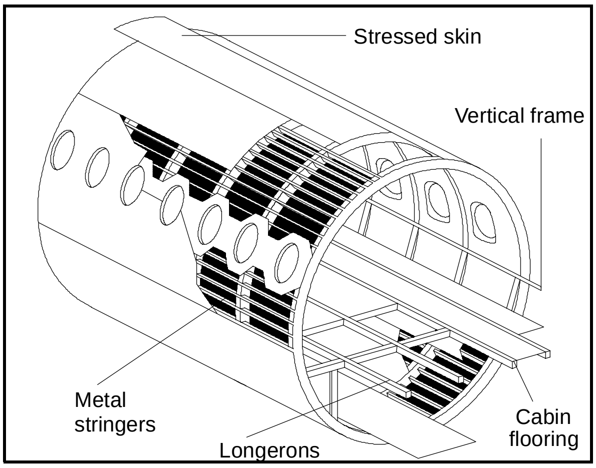


Fig 1.1 Stressed Skin Construction of a Fuselage

Braced Girder Construction

This form of construction consists of three or four lengths of steel tube running fore and aft, and braced by a pattern of struts. This form of construction is almost obsolete. In this type of construction, the frame takes all the load and stresses of the aircraft. The skin is usually made of fabric and is only for weatherproofing and streamlining. *Auster* and *Tiger Moth* aircraft are examples of this construction.

The number of spars in an aircraft wing varies with the area of the wing surface. Small aircraft may have only two spars, but larger aircraft may have several.

On some aircraft, the spars run from the centre section to the wingtip; on others, the spars run from wingtip to wingtip. The vertical height of the structural member depends on the wing profile, but all taper towards the wingtip. A series of ribs at right angles to the spars, forms the aerofoil shape of the wing. The metal skin of the wing is attached to the ribs and spars, and the skin provides rigidity, and bears some of the stress imposed on the structure.

The wings and fuselage meet in the centre section of the aircraft. This central section may be constructed as a separate unit, with the remaining portions of the aircraft built around it.

1.3 Metals Used in Aircraft Construction

Some of the metal alloys used in the construction of aircraft, are resistant to fire, impact, and/or cutting. This can have an effect on fire fighting and rescue operations.

Most aircraft are now constructed with aluminium alloys. Some of the most commonly used aluminium alloys are listed below:

- **Duralumin** - an alloy of aluminium with approx 4% copper and 1% each of magnesium, manganese, and silicon;
- **Alclad** - an alloy of duralumin with a surface finish of pure aluminium;
- **Magnalium** - a lighter alloy of aluminium with approx 2% copper and from 2 to 10% magnesium; and
- **Graphite - Magnesium** - an alloy from these two elements which is now in common use. It is light but extremely strong.

These alloys are used for skin surfaces, pressed sectional members, channels, spars, and stiffeners. Sheets made from these alloys are easily cut or pierced. Heavy sections may be cut with an axe or power cutting tools.

Magnesium alloys are used in sheets or casings to reduce mass where bulk is less important. They are rarely used where forced entry is likely. They are used in mounting brackets, crankcases, engine parts, and wheel assemblies. Magnesium alloys may ignite if heated to about 600° C.

Stainless steel and titanium alloys are used in the airframe where light alloys are not suitable. These are both resistant to heat, and are used in the construction of engine parts, leading edges of mainplanes, tubing for structural members, and airscrews. Titanium alloys will burn, but the temperature needed to ignite them is higher than that of the usual aircraft fire. These metals are extremely tough and hard to cut with normal equipment.

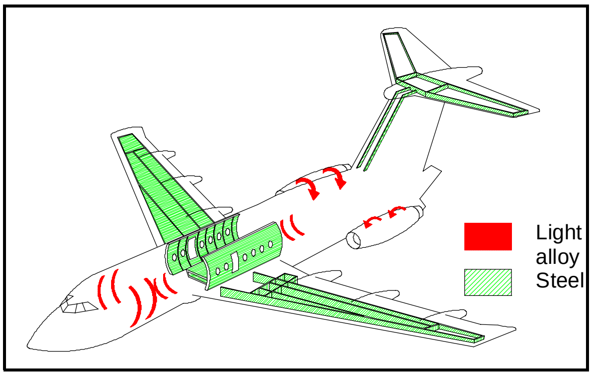


Fig 1.2 Structural Metals

1.4 Aircraft Engines

Aircraft engines use either a propeller or a turbine to accelerate a mass of air rearward - this movement of air propels the aircraft.

1.4.1 Piston Engines

Piston engines are manufactured in two forms:

- radial; and
- in-line.

In a radial engine, the piston assemblies are arranged around the crankshaft like the spokes of a wheel.

In an in-line engine, the piston assemblies are arranged one behind the other as in motor vehicles.

Large engines are usually of the radial type. This type of engine presents the greater fire risk. In larger engines, the cylinders may be banked in two rows, and the crankshaft is extended at the front to drive the airscrew, and at the rear to drive ancillary equipment.

The greater fire risk in this type of engine is in the ancillary equipment. This equipment is usually housed in a bay behind the cylinders. The fire risk in this area is in the oil pumps, generators, carburetors, and superchargers and in the pipework and wiring.

There is a fire-resistant bulkhead between the engine and the remainder of the plane structure. This bulkhead is made of two metal sheets with asbestos between them. Because the bulkhead is also used to support pipework and wiring, its effectiveness as a fire barrier is diminished.

Access to the engine is through removable metal cowls. In the event of fire, these cowls may become sealed by heat, and they should be pierced using a special nozzle or cut with an axe.

In piston engines, fires are often caused by rich fuel mixtures. Halons or CO_2 are most effective in controlling these fires.

⚠ **NOTE**

Foam should be avoided as piston engines must be completely dismantled if foam is used.

1.4.2 Turbine Engines

Turbine engines are now the most commonly used engines in aircraft. There are three types of turbine engines:

- turbo-props;
- turbo-jets; and
- turbo-fans.

In turbo-prop engines, the main turbine shaft extends in front to drive a variable pitch propeller by the use of a reduction gear.

In turbo-jet engines, the engine accelerates a mass of air through the tailpipe and propels the aircraft.

In turbo-fan engines, the engine has an extra compressor assembly fitted to the main shaft. This compressor acts as an internal airscrew supplying air to the main compressor. This main compressor acts as a turbo jet.

All three of these engines use the same principle. This principle has three stages.

- a compressor draws air into the engine. The air is forced into combustion chambers, where it is heated and then accelerated to drive a turbine located on a common shaft;
- fuel is then sprayed into the compressed air in the combustion chambers. Here it is ignited to provide heat to expand and to accelerate the air;
- the heated air and gases escape through the tailpipe, creating the thrust.

The normal engine accessories are placed in front of the combustion chambers. The whole unit is cooled by an air flow around it.

1.5 Aircraft Fuels

There are two fuels used in aircraft:

- petrol or gasoline, as used in piston engines; or
- kerosene or jet fuel, as used in turbine engines.

1.5.1 Petrol or Gasoline

Petrol, also known as gasoline, or *Avgas*, is supplied in three grades or octane ratings. These three grades each have a slightly different composition to suit the different engine compression ratios.

The three grades of petrol are:

- *Avgas* 115/145, dyed purple;
- *Avgas* 100/130, dyed green; and,
- *Avgas* 73, not dyed.

The different octane ratings and compositions have no bearing on the flammability of the fuels. All three grades have a flashpoint of about 40° C

1.5.2 Kerosene

There are three types of kerosene fuel used in turbine engines. These three grades all have different flashpoints and characteristics.

The three types of kerosene are:

- *Avtur*;
- *Avtag*; and
- *Avcat*.

Avtur has a flashpoint above 37.8° C. There are two grades of *Avtur* - *Avtur* 40 and *Avtur* 50.

Avtag has a flashpoint of -20° C. It has characteristics similar to gasoline.

Avcat has a flashpoint above 65° C. This kerosene fuel is specially distilled for use in naval aircraft.

1.5.3 Physical Properties of Fuels

Within certain limits, the following fuels will ignite at Normal Temperature and Pressure (NTP):

- *Avgas* (petrol fuels) - all three grades; and
- *Avtag* (kerosene fuel) - only JP5 or ATC.

Normally, *Avtur* will not ignite under these conditions, but it may do so if it gets sprayed on to hot engine parts in the event of a crash. Once ignited, a fire involving *Avtur* will burn as readily, and produce as much heat, as a fire involving *Avgas* or *Avtag*.

There is a difference, however, in the rate of flame spread. Controlled experiments have shown the following:

Fuel	**Rate of flame spread**
Avgas, Avtag	215-245 m/min
Avtur	30 m/min or less

⚠ **NOTE**

Flame propagation will be much faster if the fuel is in mist form.

1.6 Fuel Tanks and Power Systems

1.6.1 Fuel Tanks

Aircraft fuel may be contained in various types of tanks. All aircraft have several tanks. Usually these tanks are located in the wing structure. However, in some aircraft, the tanks may be located in the fuselage. Fuel tanks are inter-connected, and fuel may be transferred from one to another during flight.

There are four types of fuel tanks:

- rigid;
- integral;
- flexible; and
- auxiliary.

Rigid tanks are usually made of aluminium alloys. They have internal baffles to reduce the swirl of fuel in the tank. Rigid tanks are often covered in fabric, and they are set in cradles and secured by metal straps. Rigid tanks have an overflow, a fuelling orifice, and a sump to collect any water that may accumulate. They may have pressure fuelling valves fitted. Rigid tanks are bonded to prevent static electricity build up.

Integral tanks are compartments formed by the airframe itself. They are generally box sections, formed by the spars and ribs within the wings, and are sprayed with a rubber compound to make them fuel tight. They may contain semi-circular resurge sections. In an accident, distortion can cause splitting of the joints, and this in turn can cause fuel spillage.

Flexible tanks are plastic or rubber bags inserted into compartments in the wings or fuselage of the aircraft and held in place by press studs. These tanks are better able to withstand abnormal shocks, but they can be easily torn by jagged metal. The tanks themselves can burn. If ignited, they may emit toxic vapours.

Auxiliary fuel tanks can be fitted to most aircraft. They may be clipped under the wings or the fuselage and carried externally, or they can be carried in cargo spaces. External auxiliary tanks are aerodynamically shaped, and they can be jettisoned in an emergency. Small tanks with a capacity of up to 150 L are often made of fibreglass. Larger tanks with a capacity of up to 7500 L are usually stressed aluminium skin on a framework.

1.6.2 Power Systems

On small aircraft, the control surfaces are manipulated manually with a network of cables.

On larger aircraft however, the control surfaces cannot be manipulated manually, they require boost power systems. These boost power systems may be operated by hydraulics, electricity, or gas pressure, and considerable amounts of pipework and wiring are needed to operate them.

1.6.3 Hydraulic Systems

The aircraft hydraulic system is used to operate the undercarriage, flaps, brakes and certain lower assist systems.

The hydraulic fluids used in these systems are of three types:

- special mineral oils (red);
- a castor oil-alcohol mixture (blue); or
- synthetic (yellow or purple).

CAUTION

These fluids may exceed 7000 kPa and care must be taken to avoid cutting hydraulic lines accidentally. If the lines are cut, these fluids may cause injury as they are under high pressure.

1.6.4 Electrical systems

The aircraft electrical system powers lights, radio, intercom, booster pumps, hydraulic pumps, airscrew pitch gearing, heaters, and many other items. In an average aircraft, several kilometres of wiring are needed to operate these systems.

The primary source of power for the electrical system is the generator or alternator. Some jet aircraft have a small turbine engine with the sole purpose of driving the prime power source.

The standby power system can be either alkaline or lead-acid batteries. These batteries are either 12 or 24 V. They can be located in a central bank in the fuselage, or they may be in each individual engine nacelle (compartment).

The ignition systems that start aircraft engines are of the dual magneto type and do not rely on outside power.

Electrical switches in aircraft are normally of the toggle type. They are in the **off** position when pointed down. The main, or master electrical switch is normally found near the pilot's seat and/or the flight engineer's position. When activated, this main switch cuts electrical power to all systems.

In the event of an accident, the electrical system, with all its wires and cables, can be a source of fire hazards. If these wires or cables are damaged, a spark from any of them can ignite spilt or leaking fuel. In the event of an accident, the master switches should be turned to the **off** position, and, if possible, the negative terminal should be removed from the batteries.

De-icing Systems

In adverse weather, a fluid with a large alcohol content is used to prevent icing of wings and windscreens. This fluid is contained in tanks of up to 225 L. When required, the fluid is pumped through pipework and jets to spray on to these surfaces.

Compressed Gases

Compressed air is used as an emergency pressure source in the event of hydraulic pump failure.

Nitrogen is sometimes used to pressurise fuel tanks to assist in providing fuel flow.

Auxiliary oxygen supply is required in the event of cabin pressure failure, (for emergency breathing purposes) and for replacement of oxygen used up by normal procedures. The auxiliary supply of oxygen is stored in special cylinders. Some aircraft have up to twelve of these cylinders. Liquid-oxygen converters are also used in some modern aircraft.

1.7 Pressurisation and Air Conditioning

All large passenger aircraft are pressurised for passenger comfort. This means that the cabin atmospheric pressure can be kept at a pressure equivalent to that at sea level. A compressor maintains the pressure. Air conditioning units filter, refrigerate, and circulate air to the cabins at a comfortable temperature. A valve, known as a spill valve, allows a controlled discharge of pressure from the cabin so that an even atmospheric pressure is maintained. The system is regulated electrically from the cockpit.

1.8 Layout of Civil Aircraft

1.8.1 Seating

Seating in civil aircraft varies greatly with the size and type of the aircraft. Fig 1.3 shows one of the layouts that are used. All seats are fitted with lap strap seat belts with buckles locking in front of the passenger. Bassinets (Fig 1.4) are provided in certain locations for the carriage of babies.

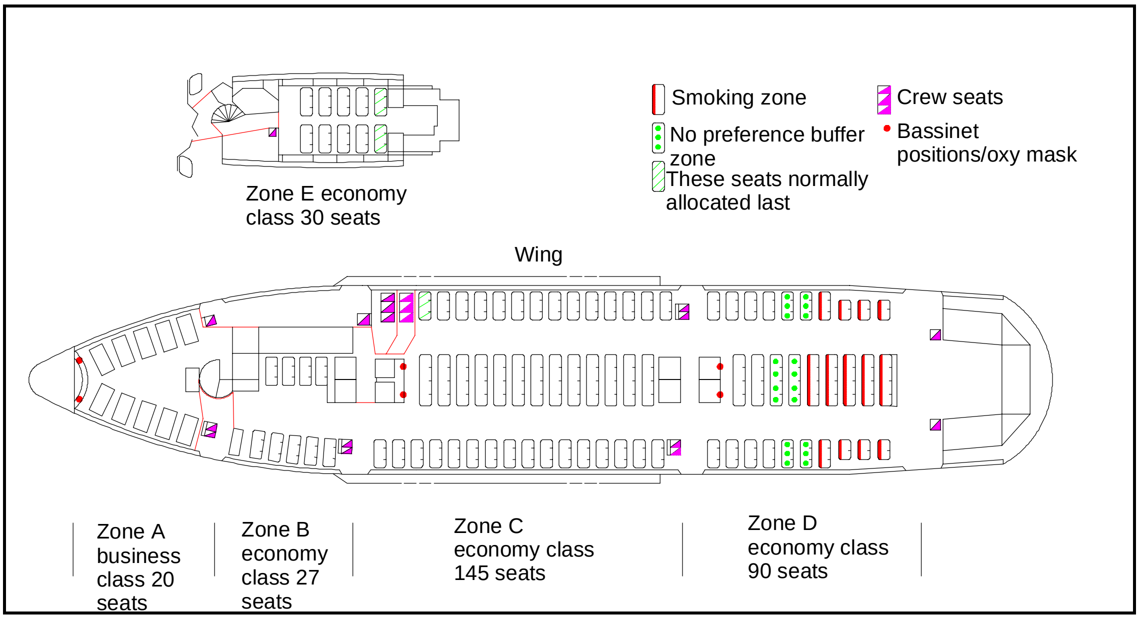


Fig 1.3 Typical Seat Configuration found in a Large Civil Aircraft

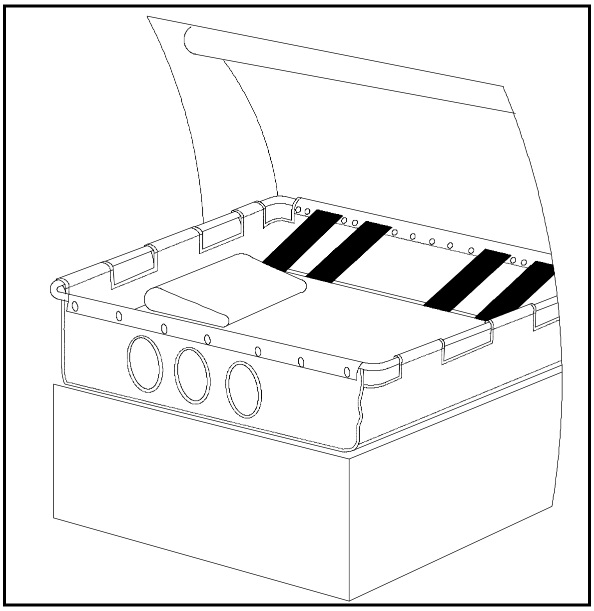


Fig 1.4 A Bassinet

1.8.2 Aircraft Access

Doors

The entrance to an aircraft is normally through doors on the port (left) side of the aircraft. Normally, a single door is located towards the rear of the aircraft, but many large aircraft have a door at both ends.

Aircraft doors open outwards, and operation is simple and direct. Instructions for opening the doors are printed near the latch on each door.

Access doors for cabin and galley service are located on the starboard (right) side of larger aircraft. These doors are in addition to the passenger access doors.

Windows

Windows are usually double-glazed, fixed and designed as small as possible. They are extremely strong. They do not provide a good point for forced entry in the event of an emergency.

1.8.3 Emergency Exits

Emergency Doors

All large aircraft have a number of emergency doors. These emergency exits are outlined by a thin line of paint to make them immediately obvious and noticeable. Emergency doors can be opened from either inside or outside the aircraft.

Emergency Hatches

Emergency hatches are usually selected window panels located above the wing roof. These hatches are opened by operating the handles and moving the hatch inwards into the aircraft interior (see Fig 1.5). The hatches must be removed in this way because the edges of the windows are wedge-shaped. This shape provides resistance to the internal cabin pressure while the aircraft is flying at high altitude. After moving the hatches inwards, the panels can then be turned on edge, withdrawn through the opening, and jettisoned outside the aircraft.

Cut-in Points

Cut-in points are areas on the aircraft that provide the least resistance to forced entry. These cut-in points are often located on the roof of the aircraft. They are usually marked by a dotted line on the outside of the aircraft. Except for these cut-in points, it is difficult to find an area clear enough to break into the aircraft by forced entry, because of the structural members and service ducts carrying pipes and wiring.

It is difficult to carry out rescue procedures through these cut-in points, they should be used only as a last resort. Every attempt should be made to enter through conventional means first, before using the cut-in points.

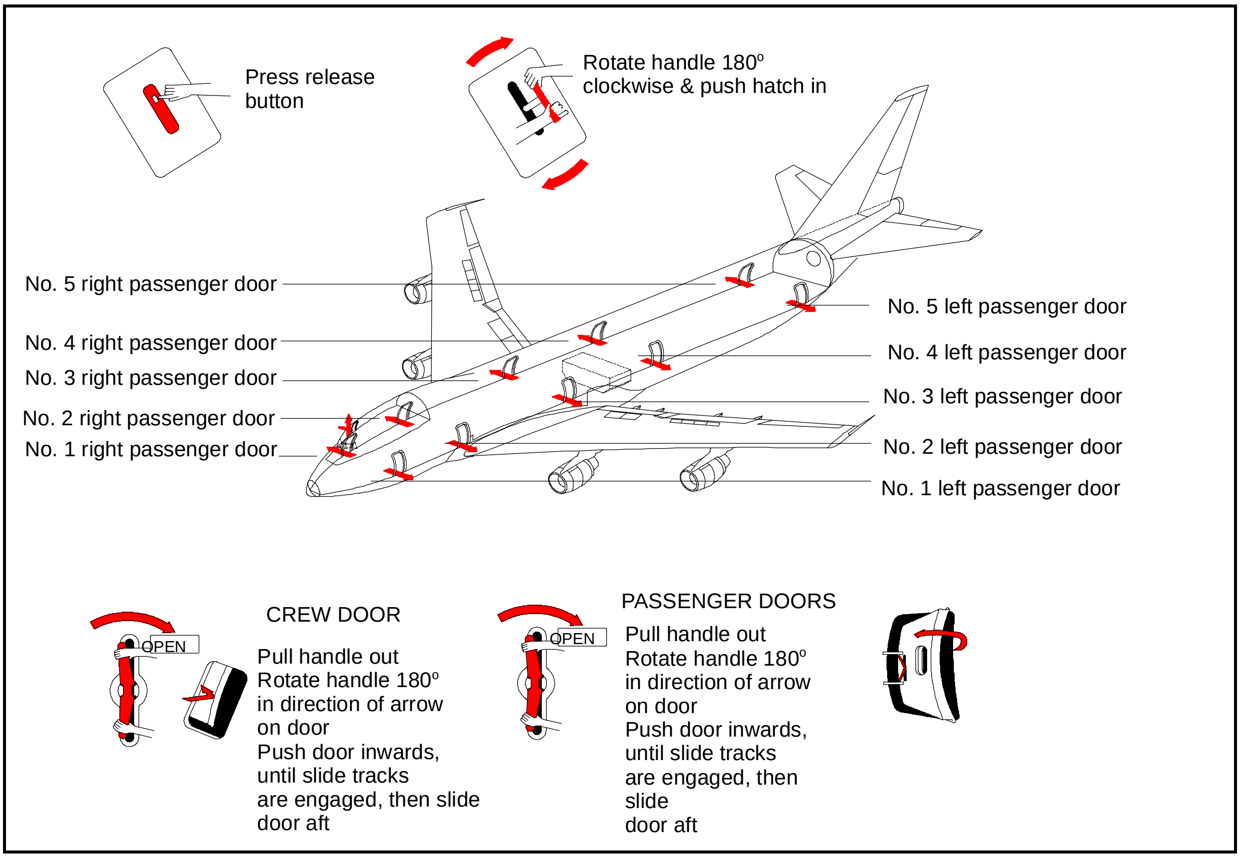


Fig 1.5 Typical Passenger Escape Facilities

1.9 Fire Protection Systems

Most large aircraft have automatic fire detection systems. These detection systems operate in the engine bays and sometimes in the fuel tank compartments. The fire extinguishing equipment is usually activated manually.

The fire detection system operates by electrical heat detection. This type of system consists of stainless steel piping with a co-axial central conductor wire. Between the wire and the pipe there is an insulating material. When this insulating material is heated over a certain temperature, it loses its resistance and allows a current to flow between the wire and the casing. This current causes a warning signal light to show in the cockpit, and this light indicates the area affected.

When the warning signal light is activated, the pilot can then manually activate the fire extinguishing system. This system discharges Halon gas into the affected area. The extinguishant is stored in cylinders under pressure. When the system is activated, the extinguishant is discharged by electrically firing a small detonator that blows the cylinder seals. Cylinders can be fired independently or together from the pilot's position. Discharge time in an individual cylinder is brief (about 5 secs). Where twin cylinders are fitted, firing each independently can extend the total discharge time.

If a crash occurs, impact or crash switches may fire the extinguishing agents. These impact switches may not work in crash conditions. However, inert gas may fill engine spaces enough to prevent the initial ignition of spilt fuel.

1.9.1 Flight Recorders

Flight recorders, or black boxes, are carried on most civil aircraft and are normally installed in the rear fuselage. They are often round in shape and painted fluorescent red. The function of the flight recorder is to record details of aircraft performance. The flight recorder is very important as its data can be essential after an accident. In the event of an accident, if you find a flight recorder, you should not interfere with it unless you suspect that it might become permanently lost. It is best to simply mark the position of the recorder and point out its position to the authorities as soon as possible. In the event that you must move the recorder, carry it very carefully. You should avoid shaking or tilting it, and you should jar it as little as possible.

1.10 Military Aircraft

1.10.1 Construction

The construction of military aircraft is very similar to that of civil aircraft, but there are some differences. Some of these differences are described below.

1.10.2 Auxiliary Fuel Tanks

Some military aircraft are fitted with one or more auxiliary fuel tanks to provide extended flight time. These auxiliary tanks are often metal saddle or cylindrical section tanks, and they are usually installed in the bomb bay. As the bomb bay may also contain a load of weapons or pyrotechnic stores, there is an increased risk of fire.

1.10.3 Auxiliary Power Engines

Large military aircraft often have small turbine engines installed on board to drive generators or compressors. These turbine engines are contained in enclosed compartments and are usually installed close to the main engines. They have their own air intake and exhaust systems.

1.10.4 Avpin (Isopropyl Nitrate)

In addition to normal aviation fuel, some military aircraft use *Avpin* (Isopropyl Nitrate) in liquid fuel engine-started systems. This unusual fuel produces its own oxygen, and this allows it to burn fiercely without an air supply. Additionally, this fuel has a low flash point (10° C), and this makes it extremely hazardous. It also has wide limits of flammability. When burning, this fuel emits toxic fumes.

1.10.5 Gases

Military aircraft may carry gas cylinders containing compressed CO_2, air, or nitrogen.

These aircraft may also have a liquid-oxygen converter. This converter is a spherical or cylindrical insulated container with evaporating coils and valves to regulate the oxygen flow. One litre of converted liquid oxygen can produce 862 L of gaseous oxygen. In smaller military aircraft, a liquid oxygen converter is normally fitted near the cockpit.

In larger aircraft, there may be additional systems in the cabin areas.

Pipework and components on military aircraft are coded with symbols; POL indicates petrol, oil and lubricants and the symbols are detailed in Fig 1.6

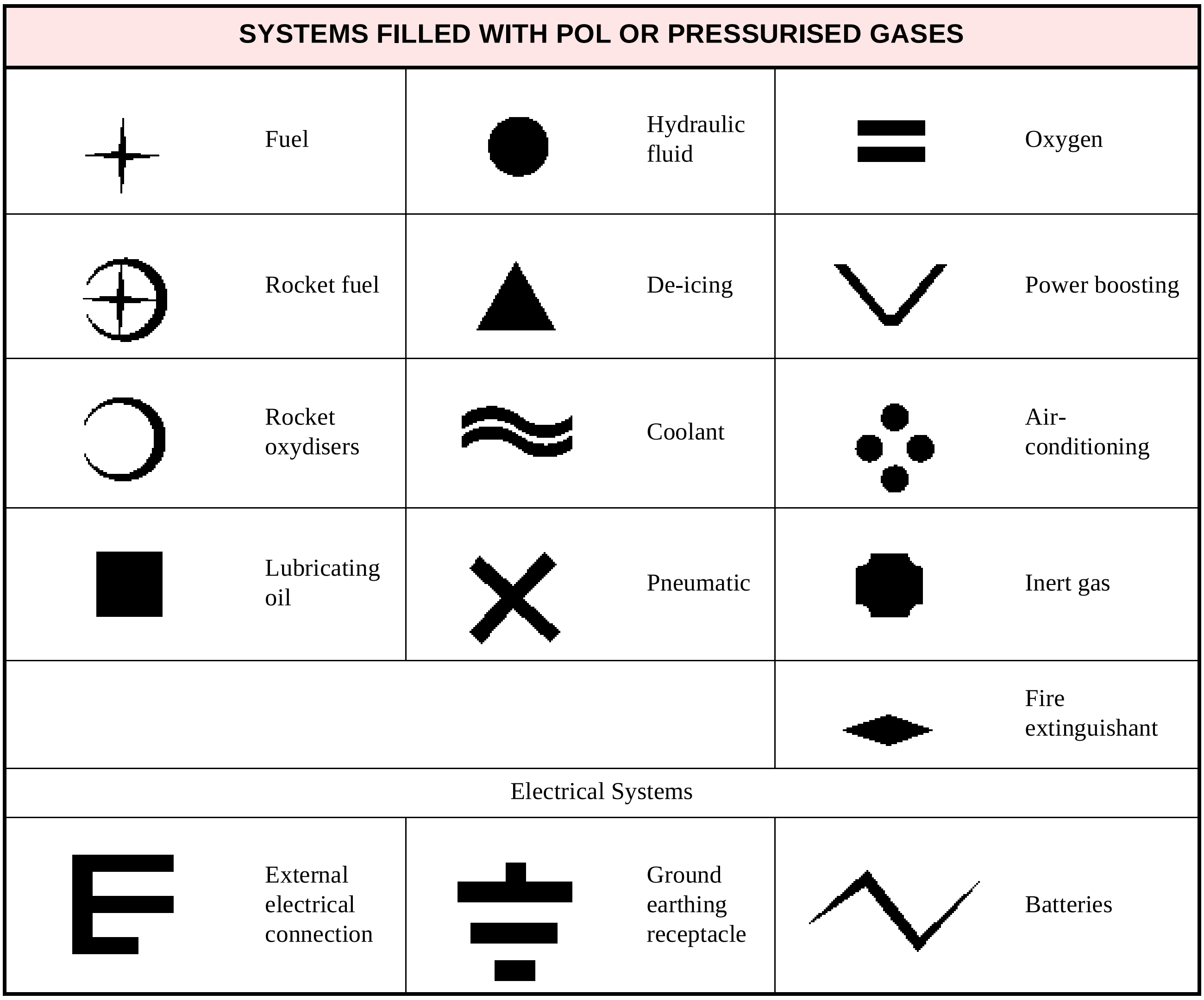


Fig 1.6 Military Identification Symbols

1.10.6 Cockpit Canopies

Fighter and bomber aircraft usually have canopies rather than doors or hatches. Canopies are domed hoods that hinge or slide over the seat positions. If the aircraft has tandem seats fitted, there may be single or twin canopies. In an emergency, on bomber aircraft, the canopy is jettisoned by small explosive charges. On smaller fighter aircraft, the canopy usually does not have an automatic explosive charge, and the canopy can be jettisoned manually. If ejector seats are fitted, the canopy jettison system may be interconnected to the ejector system.

CAUTION

Make no attempt to remove the pilot until the ejection seat is made safe with seat safety pins.

1.10.7 Layout of Military Aircraft

Passenger seats in military transport planes are often faced rearwards. The seats are usually removable to allow the aircraft to carry stores and equipment. Where the load consists of both passengers and cargo, the freight is placed to the front and passengers are at the rear of the fuselage.

In paratroop-carrying aircraft, seating for passengers consists of benches along both sides of the aircraft. Some of the larger aircraft that carry paratroopers may have an additional seat fore and aft, up the centre of the fuselage.

1.10.8 Pilot Ejection Seat

Most high speed combat military aircraft have ejection seats to enable aircrew to leave the aircraft quickly in an emergency. The ejector seats use an explosive charge that is detonated automatically in a particular emergency. When this charge is activated, it ejects both the pilot and the complete seat clear of the aircraft. If the ejection occurs while the aircraft is in flight, the seat then drops away, allowing the pilot's parachute to open.

Later model seats can eject from ground level and allow the pilot to land safely. Some military aircraft are now fitted with an ejecting capsule. This capsule acts as a safety landing area on land or sea. The *F111* is one such aircraft where the whole crew capsule is ejected.

Several types of ejection seats are in use. The main components of these ejection seats are:

- the seat, which is propelled vertically upwards by the explosive cartridge;
- a locking catch, termed a sear, which is connected to the firing pin for the cartridge; and
- a blind, to protect the pilot's face.

The operating handle connects with a gun that fires a steel bolt to open a drogue parachute. This parachute then steadies the seat after ejection.

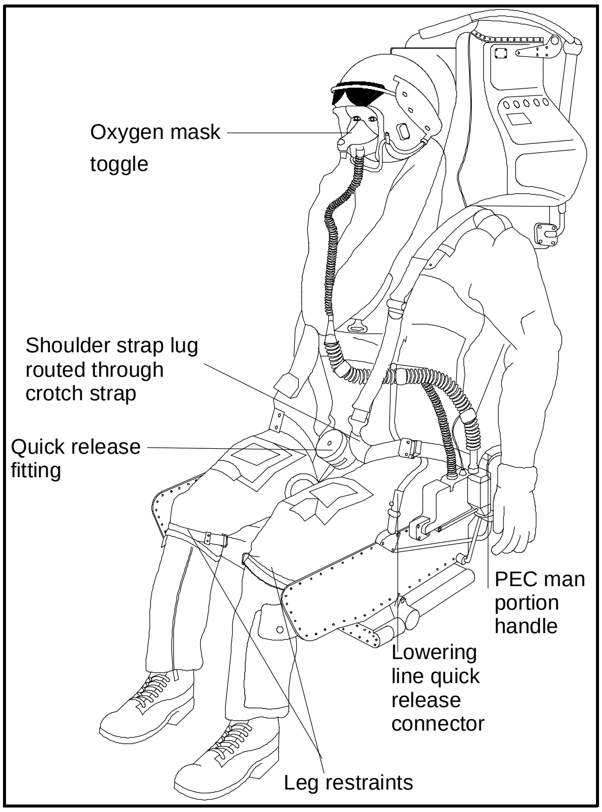


Fig 1.7 Example of an Ejection Seat.

1.11 Helicopters

Small Helicopters

Small helicopters generally have two to five seats and a single engine that drives both main and tail rotors.

Large Helicopters

Large helicopters generally carry from ten to thirty persons and have either one large single rotor with a single engine or twin rotors driven by twin engines.

1.11.1 Helicopter Construction

The airframes of helicopters can be similar in construction to the fuselage of fixed wing aircraft, but they are often much lighter because there are no wings to impose stress. The cabins of helicopters do not have to withstand pressurisation as they do not fly at high altitudes.

Helicopters that operate over water often have flotation equipment fitted, and this may impede rescue work in the event of an accident. This equipment may consist of inflatable plastic bags, about 1.5 m in diameter, that fit into containers on the undercarriage. These plastic bags operate when in contact with water, and so a hose stream in close proximity can easily activate the devices.

CAUTION

These bags will deflate if cut. The container will be blown free with considerable force.

1.11.2 Engines

Most helicopters have turbine engines. These are similar in construction to turbo-prop engines on fixed wing aircraft, and they are geared to the rotor. The position of these engines can vary from one helicopter to another. In smaller helicopters, they may not be enclosed. Large helicopters have the engines under cowlings separated from the cabin by fire resistant bulk heads. Twin engines are also normally separated one from the other by a fire resistant bulkhead.

1.11.3 Rotors

Single engine helicopters have one main rotor overhead and a small vertical stabilising rotor to the rear. The stabilising rotor presents the greater hazard of the two because it revolves at body height. Both rotors revolve for a considerable time after the engine is shut off. Some stabilising rotors are enclosed in a cage or are brightly coloured to draw attention and prevent accidents.

1.12 Emergencies at Airports

In NSW only international airports that operate scheduled services have an *Airport Fire Service (AFS)* to attend accidents or aircraft fires. This type of fire service generally operates within a designated area surrounding the airport.

Fires in airport buildings do not come within the jurisdiction of the *AFS*. However, if their own commitments permit them to do so, the *AFS* will often respond to emergencies in airport buildings. They may even commence fire fighting operations in airport buildings in emergency situations.

NSWFB have three responsibilities relating to airports:

- they attend to all building fires at airports;
- they attend airport emergencies as a backup to the *AFS*; and
- they attend airport emergencies as the *AFS*.

When called to an incident where there is no *AFS* available, the NSWFB will also carry the *AFS* regulations. The NSWFB will take charge, and when the incident is made safe will hand over to the relevant authority.

Emergencies at airports are declared by the air traffic controllers. Emergency services are normally alerted through the police operations room after the police have been notified by air traffic control of one of the following emergency situations:

- standby alert;
- emergency alert;
- crash or accident alert; and
- bomb alert.

1.12.1 Standby Alert

Air traffic controllers call a standby alert when an aircraft with a known or suspected defect is approaching an airport, and it appears that the defect will not affect the normal landing capabilities of the aircraft. Weather conditions may warrant an alert if an aircraft is making a forced landing due to a shortage of fuel or for some similar reason.

For a standby alert, the *AFS* may or may not take up position on the runway.

1.12.2 Emergency Alert

There are three levels of Emergency Alerts:

- Level 1 - up to 18 seats (Light Aircraft);
- Level 2 - up to 150 seats (Medium Aircraft);
- Level 3 - More than 150 seats (Heavy Aircraft).

Air traffic controllers call an emergency alert when an aircraft is approaching the airport and may have difficulty landing, and the aircraft controllers declare that an accident may possibly occur.

In an emergency alert, the *AFS* will take up pre-arranged standby positions on the side of the runway. Fire service appliances normally assemble at the crash fire headquarters or near the control tower. Urban fire service appliances and other emergency services may be called upon to attend the airport in an emergency alert. If called, they assemble at prearranged areas.

1.12.3 Crash or Accident Alert

Air traffic controllers call a crash or accident alert when an accident has occurred.

- Provincial Airports e.g. Kingsford Smith Airport - meet at an emergency entrance and wait until the Airport Safety Officer (ASO) arrives to escort the NSWFB to the accident.
- Regional Airports - the NSWFB can proceed straight to the accident scene.

If urban fire service appliances are called to attend, they proceed straight to the accident scene. However, before entering onto any taxiway or runway, they must obtain clearance from the control tower. This clearance is obtained by calling the air traffic controllers from a telephone which is located at the base of the control tower. Also, you can determine the clearance status by observing a system of signal lights shown from the tower, as set out in Table 1A below.

SIGNAL	MEANING
Steady Red	Stop immediately
Flashing Red	Move off runway or taxiway, and watch for aircraft
Steady Green	Move on to or cross runway or taxiway
Flashing Green	Increase speed in same direction
Flashing White	Report to control tower, moving by the perimeter

Table 1A Air Traffic Control Tower Signals

In a crash alert at provincial airports, the urban fire service performs two roles:

- to supply water to the *AFS* appliances, fire fighting; and

- the rescue of survivors.

If an urban fire service receives an aircraft crash alert outside normal channels, it should first immediately make contact with air traffic control. If required, it should then send appliances to the crash alert scene.

If the crash is outside the designated boundaries of an airport, the *AFS* may attend, but their attendance will depend on the following factors:

- the distance from the airport;
- the likelihood of survivors,
- the type of aircraft involved; and
- the ability of the nearest urban fire service to handle the situation.

Where a crash alert occurs near an airport that is surrounded by water or swamp, rescue boats or amphibious craft may be required. These rescue craft are generally provided by marine organisations or police search and rescue units. In such an alert, the *AFS* would normally receive survivors on shore and provide required urgent medical attention.

1.12.4 Bomb Alert

A bomb alert is called by the air traffic controllers when they know or suspect that a bomb is on board an aircraft. In a bomb alert, the aircraft is usually taken or directed to an isolated area to enable the bomb squad to carry out a search.

⚠ **NOTE**

NSWFB personnel take no part in the search for a bomb on an aircraft.

If the aircraft is in flight when a bomb alert is received, the air traffic controllers may not declare an emergency alert until after the aircraft has landed. A fire appliance and crew are placed outside the clearance limits of the search area. The driver of the appliance maintains radio contact with the control tower or NSWFB Communication Centre for further directions.

1.12.5 Airport Appliances

Airport fire fighting vehicles are usually much larger than normal fire service appliances. These special airport appliances are fitted with tanks that contain over 1000 L of foam compound and 8000 L of water. The foam can be discharged and applied to the emergency by using foam monitors or hand held branches. The most modern airport appliances can pump while the vehicle is moving. These special vehicles are fitted with all-wheel drive, and they are able to drive through gates or fences to enable them to take the shortest route to a crashed aircraft.

Old airport appliances operate foam pumps through which a compound of water and air are mixed and supplied to the monitor. In these appliances, the hand lines are supplied by a centrifugal pump with a variable inductor.

Modern airport appliances operate a separate power unit that drives a centrifugal pump fitted with an automatic proportioner that feeds all foam equipment.

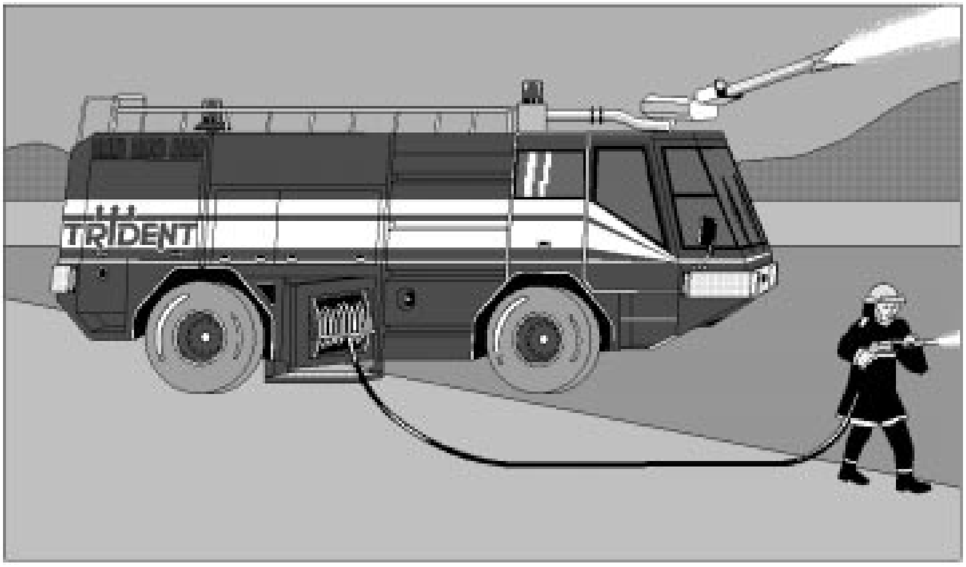


Fig 1.8 Typical Airport Fire Appliance

AFS also have rescue vehicles that carry cutting equipment, lighting equipment, and BA. They sometimes also have large appliances that carry dry powder. This dry powder can be applied using a monitor or a hose reel.

1.12.6 Water Supplies at Aerodromes

Most commercial airports have a ring water main system that is fitted with pit-type screwdown hydrants. The hydrants are fitted at intervals around the airport near the runways and taxiways. To feed the water mains, water may be drawn from the city reticulation system or from special reservoirs. Pressure through the hydrants may be by gravity or by mechanical pumps.

Where water mains are not available, static supplies of water are provided from tanks or hard-standing areas near ponds and rivers.

1.12.7 Military Aerodromes

Military aerodromes often provide their own fire services both for aircraft and other property. Local urban fire services may be called in when major incidents occur in these military aerodromes.

1.13 Aircraft Fire Fighting

The primary object of fighting fires in aircraft is to ensure so far as possible the survival and rescue of the occupants of the aircraft. Many aircraft fires ignite at the moment of impact however, ignition can occur at any time because of spilt fuel and broken wiring. In fighting aircraft fires, a foam blanket is generally laid to prevent ignition of vapours.

Most aircraft crashes occur on or near airports or on flat ground because a pilot will always attempt to find a suitable area on which to make an emergency landing. Aircraft crashes in built-up areas do occur, and when they do, these crashes have all the ingredients of a major disaster.

1.13.1 Features of Aircraft Fires

An aircraft fire usually breaks out suddenly, and it can swiftly reach maximum intensity. The highest danger in such a fire is due to escaping fuel, but the dangers caused by the mass of other flammable materials is always present. Large volumes of smoke are often created by aircraft fires. The fuselage is often rapidly distorted by the heat of the fire, and this can cause fracture of pipework resulting in the release of more fuel.

It is generally accepted that the emergency crews will have a maximum of 7 mins to reduce or contain an aircraft fire before total involvement occurs.

1.14 Fire Fighting at Aerodromes

In an aerodrome emergency, air traffic control will generally clear the emergency area of all aircraft until the emergency is over.

In aerodrome emergencies, fire fighting appliances position themselves according to local tactical plans. The Senior Fire Officer (SFO) is responsible for assessing whether the applicable tactical plan will work and be effective. In brief, the SFO looks for changing circumstances that may impede obtaining the overall objective and indicates a change of tactics.

If possible, firefighters should always mount an attack on the fire from upwind and uphill of the crashed aircraft. If firefighters proceed from a downwind or downhill position, the risk is greatly increased that fumes may blow towards the firefighters and impede the operation. Further, where the attack is mounted from downwind, spilt fuel may run to a point where a spark created by chance from the fire fighting appliance can ignite the fuel and add to the emergency.

When fighting an aerodrome fire, or any fire, you should never park an appliance in an area where fuel has been spilt.

At all times, you should maintain the appliance in a position and in such a condition, that a line of retreat from the fire is always open to you.

Refer to *Standing Orders*.

1.14.1 Methods of Attack

Your method of attacking an aircraft fire should always include a plan to isolate the fuselage in order to open safe routes for operations to rescue survivors. Under normal wind conditions associated with aircraft landings or take-offs, a tactical front-on or tail-on approach would be appropriate.

CAUTION

Radar is normally fitted in the nose section of aircraft.

If the fire is in the wings and engines, you should first make an attempt to stop the fire at the wing roots. Watch for fuel spillages, and make an attempt to sweep them away from the fuselage with water jets or cover them with a foam blanket.

Determine the wind direction and try to keep one side of the aircraft relatively free from smoke and radiated heat. To allow evacuation of passengers, you should protect all parts of the fuselage as much as possible because aircraft skin material is easily penetrated by fire. Additionally, fire will decompose sealants and plastic materials in the cabin, and this can cause a generation of smoke and fumes.

For the main attack, you should use foam monitors. For back-up and for fighting fire pockets, use foam branches or dry powder and vaporising liquids. These can also be used in inert spaces that you cannot reach with the foam.

The foam branches should be positioned as close as possible to the fuselage so that the foam drives the fire outward. But you should be very careful to ensure that fuel is not inadvertently flushed under the fuselage. Foam should be applied using a diffuser branch or by allowing the foam to strike an object and flow over the surface. Further, you should take care that waterjets do not disturb the foam blanket.

1.14.2 A Typical Tactical Plan

A basic tactical plan for the initial attack is generally designed so that vehicles can be deployed to set positions with a minimum of instruction or delay. The SFO on the fire ground may vary this plan if operational considerations dictate.

Considerations:

- approach upwind;
- approach diagonally;
- evacuation corridor.

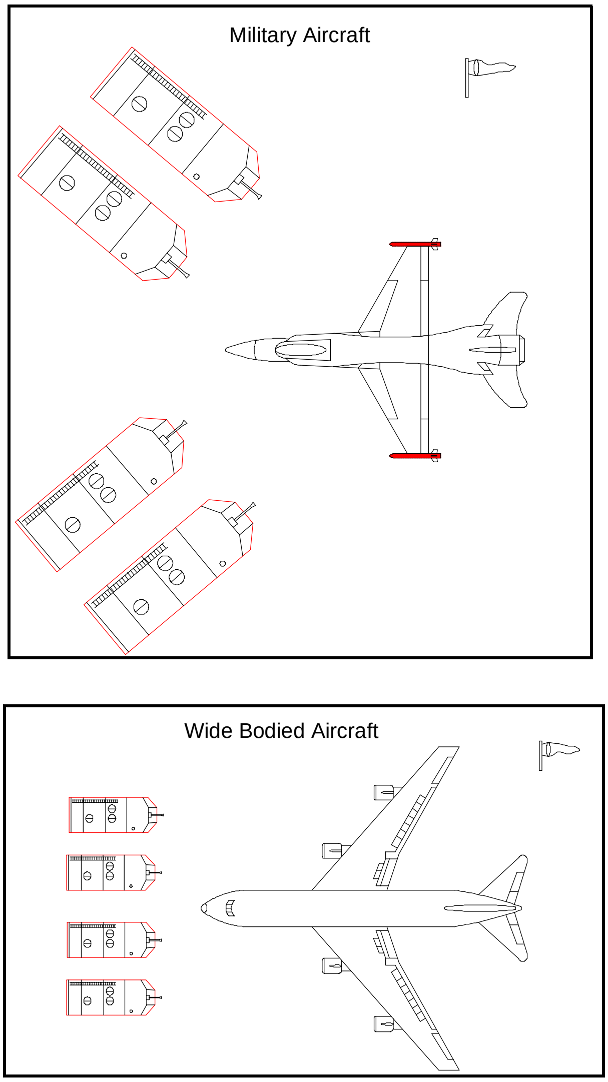


Fig 1.9 Positioning of Appliances

1.14.3 Ground Incidents

A ground incident fire can start in an aircraft while the aircraft is refuelling, starting up engines, or after it has collided with another aircraft or object while it is taxiing.

When proceeding to a ground incident, you must take great care if travelling through smoke, because persons may be present on the tarmac.

1.14.4 Low-Speed Incidents

Low-speed incidents are the most common incidents at aerodromes. A low speed incident usually occurs during take off or landing where the aircraft either under-shoots or overshoots the runway. The term **low speed** is relative to an aircraft moving at **low speed (**may be moving at a speed in excess of 160 km/h). Chances of aircraft passengers surviving in this type of incident are normally high, and rescue conditions are generally favourable.

A low speed incident also includes undercarriage failure. Where an aircraft lands with undercarriage failure, the aircraft is usually basically intact, and it is likely that doors and hatches can be opened and used. If the occupants are capable of escaping for themselves, you should not waste time attempting to enter the aircraft. When all able bodied people have left the aircraft, you can then enter and search for anyone left behind.

In an incident involving undercarriage failure, the main battery of the aircraft should be located, isolated, and disabled. This is done by removing the negative terminal. If there is no one present who is familiar with this procedure, you should not make any attempt to touch the controls, or switches.

1.14.5 Fires Involving Metals

Aluminium

Aluminium can ignite at 800° C. However, it rarely does ignite because at 600° C it melts and flows away from the heat.

Magnesium

Magnesium is not easily ignited, but it does start to burn on fine edges at 600° C. When it is ignited, it burns with an intense light and it can decompose water. This means that water can be ineffective in fighting a magnesium based fire unless copious amounts are used.

CAUTION

In a magnesium based fire, e.g. wheel and strut components, molten metal can be scattered when water is applied, but after cooling, the metal solidifies and the fire will go out.

Magnesium burns only in molten form. Special dry powders and dry sand can be effectively used to extinguish burning magnesium.

Titanium and Stainless Steel

Titanium and stainless steel do not normally reach high enough temperatures to become ignited in aircraft fires. If titanium does ignite, an extremely dense opaque vapour (titanium dioxide) is formed. This vapour is non-toxic, but its presence may hinder fire fighting by reducing visibility.

1.14.6 Brake and Wheel Assemblies

Heat build-up from excessive braking to stop an aircraft in an emergency, can cause fires in the tyres or in the brake assemblies. Some aircraft are fitted with fusible plugs in the wheels (see Fig 1.10). When these plugs fuse, the pressure in the tyre is released at a predetermined temperature. If the plug has fused or if the tyre is deflated, the danger of explosive disintegration of the wheel is greatly reduced.

In attending an incident involving tyres or wheel assemblies, you should standby with a dry chemical extinguisher. If fire breaks out, attack it with dry chemical. When the flames are extinguished, stand by until the wheel cools.

If the use of dry chemical extinguishant is unsuccessful, you should apply water in the form of a dense fog. However, you should take care to avoid causing a jet of water to directly strike the wheel.

CAUTION

Approach wheel incidents from the front of the aircraft.

Tyres are filled with nitrogen near the filler valve. There is a fusable plug (Fig 1.10) that can be jetisoned at high velocity when temperature is extreme.

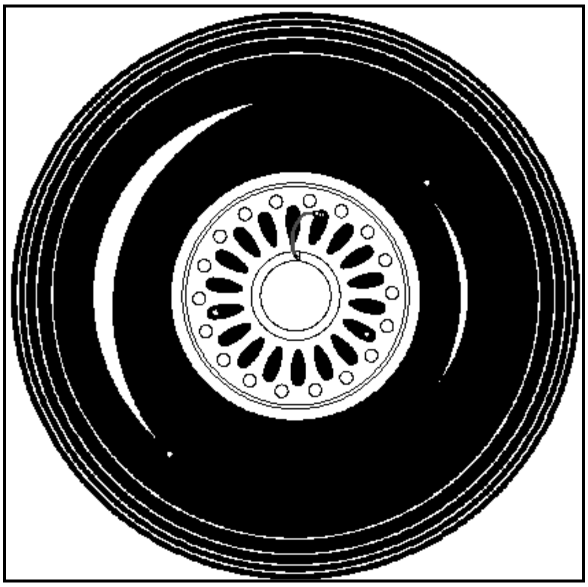


Fig 1.10 Aircraft Tyre Showing Fusable Plug

1.15 Fire Fighting Outside Aerodromes

Incidents involving fires outside aerodromes are usually the more serious because ground conditions may be unfavourable and crash speeds of the aircraft may be higher.

In such an incident, you should always approach a crashed aircraft by a safe route. If you use a short cut to the incident scene, your appliance may become bogged, and you can lose valuable time in approaching the aircraft.

As you approach the aircraft, try to position the appliance upwind and uphill of the aircraft. Keep clear of spilt fuel, and keep a watch for survivors who may have been thrown clear of the aircraft.

If the crash site is near buildings, the following steps are essential:

- check to see if the buildings are occupied, and evacuate the occupants if necessary;
- shut off power and gas supplies to the buildings to prevent accidental ignition of spilt fuel;
- recover any documents or valuables from the buildings and hand them to the police;
- avoid interfering with wreckage unless you must do so to rescue survivors;
- keep onlookers away from the incident site to prevent them from taking property for souvenirs;
- leave any controls or switches as you find them. If they must be adjusted, notify the Accidents Investigation Personnel as to what action you took; and
- cordon off area with barrier tape.

1.15.1 Crashes on Buildings

Crashes on buildings can cause many problems and complications. If an aircraft crashes on a building, the aircraft will normally break up, and there will be widespread and extensive damage. Fires may have broken out in several places and they may be spreading rapidly. Your first concern should be to rescue survivors, but such rescue operations may first involve fighting the fires to provide access to survivors.

Collapsed roofs and walls can hinder access, and persons may be trapped in both the buildings and in the aircraft. If possible, you should first disconnect all power and gas from the surrounding area, and you should evacuate all persons from nearby buildings. Cover all fuel spills with a foam blanket and, if possible, prevent spilt fuel from entering drains or sewers.

1.15.2 Nose Dives and Cartwheel Accidents

Nose dive accidents can occur at high speeds. A nose dive usually results from complete loss of control of an aircraft. A nose dive incident can result in a large crater if the crash occurs in soft ground. In a nose dive crash, there is little hope of survivors. You may be able to contain the fire by flooding the crater with water and covering it with a foam seal.

Cartwheel accidents can occur at high speeds. A cartwheel accident can occur when an aircraft wing touches a solid object. When this happens, the aircraft may career along for a considerable distance and disintegrate leaving wreckage over a wide area. Persons in the aircraft may be thrown out, and internal aircraft fittings may be torn free making rescue difficult. Small fires that do not endanger property or life may be left until more urgent tasks are completed.

1.15.3 Crashes into Water

When an aircraft crashes into water, the risk of fire is reduced, but fuel floating on the surface of the water can ignite. Large water jets can be used to break up floating fuel and reduce the fire risk. On calm surfaces, it may be possible for you to lay a foam cover on the fuel to reduce the risk of fire.

When the aircraft is floating after a crash on water, you should take care that its buoyancy is not disturbed. Survivors should be evacuated smoothly and quickly before the aircraft can fill and sink. If there is time before the aircraft sinks, divers can sometimes rescue persons trapped in air pockets within the fuselage.

Refer to *Standing Orders*.

1.16 Rescue From Crashed Aircraft

You should take great care in approaching a crashed aircraft if the engines are still running. Stay at least 7.5 m away from the jet intake and 45 m away from the jet stream behind the engine. Stay away from the arc swept by a propeller, even if the propeller is not revolving. Electrical short circuits can operate starter motors.

CAUTION

Never, under any circumstances attempt to turn or rotate the propeller of a crashed aircraft.

1.16.1 Civil Aircraft

When you are attempting to evacuate persons from a damaged aircraft, you should always make the first attempt through the passenger doors. The doors can be opened from the outside of the fuselage. Instructions for opening the doors are printed on the door near the handle. Doors normally have a contrasting line painted around their perimeter to make their position obvious.

Fig 1.11 illustrates the heights to the various exit points on a Boeing 747. Note the depth of the fuselage body below passenger compartments.

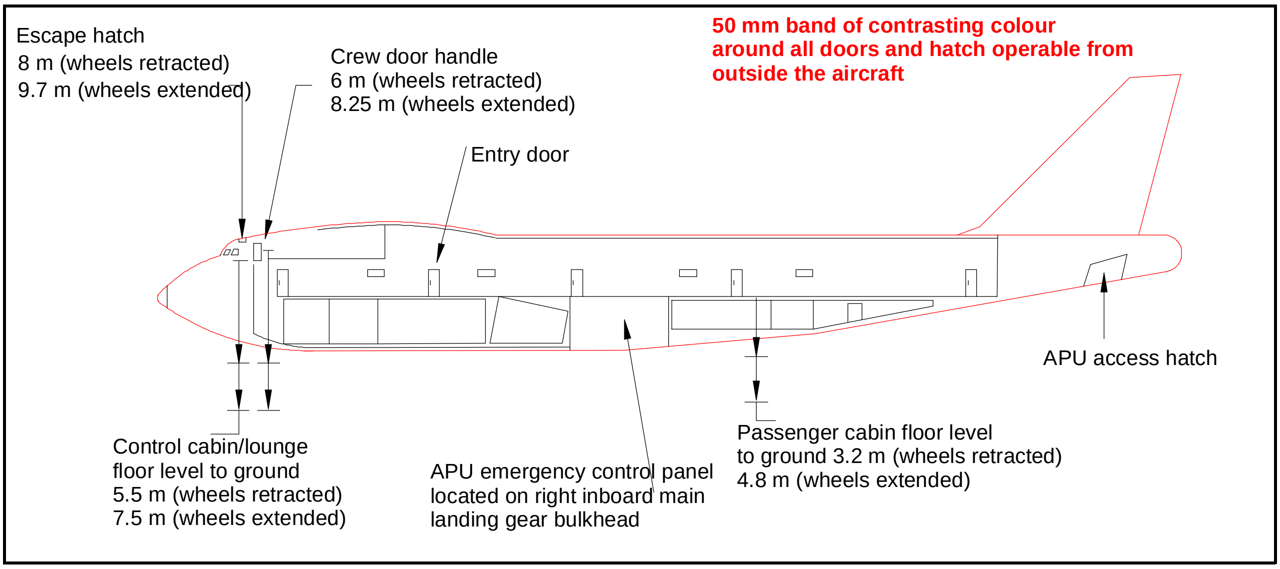


Fig 1.11 Boeing 747 Exit Points

Some aircraft have built-in staircases that are extended by hydraulic power. These staircases can be extended by a hand pump in an emergency. Sometimes the stairway must be extended to clear the doorway before you can enter through the door.

Entry Doors

When you open an entry door from the outside, you should stand to the side because emergency chutes or slides may be released when you open the door.

Escape Slides

Large passenger aircraft are fitted with inflatable escape slides of heavy quality nylon. These escape slides are located near all exits. Before using these slides in an emergency, passengers must remove their shoes to prevent injury. The passengers can then quickly slide to the ground.

When using the slides (see Fig 1.12) passengers jump into the slides rather than sitting down and pushing off. In some aircraft, these slides operate automatically when the door is opened in an emergency situation.

Once passengers have moved to the bottom of the slide, they should be helped clear of the base of the slide. This helps to speed up evacuation and prevent injury.

In an emergency situation, if a slide accidentally inflates inside the aircraft, you should try to remove the slide intact so that it remains functional. If you cannot remove the slide intact, deflate it by cutting or puncturing it, to allow access to the cabin.

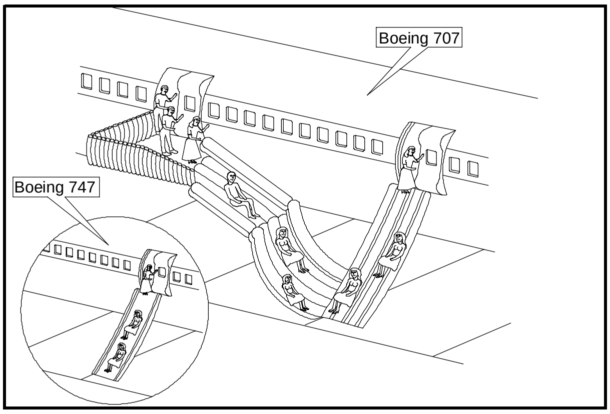


Fig 1.12 Various Escape Slides.

Emergency Methods of Escape

The emergency escape hatches are usually removable window panels. These hatches provide an exit from inside the cabin to the upper wing surfaces of the aircraft. These escape panels are well marked, and they can be opened from either inside or outside the aircraft. These panels are the next preferred means of emergency entry if entry through the doors is not possible.

Emergency exits for the crew are removable sections of the cockpit. These emergency exits are usually either removable windows or roof hatches.

Cutting In

Cutting into an aircraft is a last resort. You should attempt entry through cutting in, only if all other methods of entry fail. Certain areas on the aircraft are suitable for cutting in. These areas are well marked on the outer skin of some aircraft. If it is not possible for you to cut in at these specified points, then cut in at points where there is the smallest number of internal fittings, pipework, and wiring ducts. There are only a few of these areas, and they are not always in a convenient place to make rescue work possible.

⚠ **NOTE**

You should never cut into an aircraft unless you are sure you can gain entry.

Cutting in points are generally positioned 13 m above ground level.

Safety Belts

All passengers in civil aircraft wear safety belts of the lap strap type. The release for the belt is at the centre of the passenger's lap. A safety belt must be released before a passenger can move or be removed from their seat. If release is difficult, the safety belt should be cut.

Rescue Procedures

After you have gained entry to the aircraft, you may encounter a tangled mass of fittings and baggage. In an emergency situation, most of the passengers and crew will be in shock. They will be able to give only limited assistance and information.

For the most efficient rescue operation, only a small number of rescuers should enter the aircraft. It is essential that all passengers are cleared in the minimum of time, and if too many persons enter the aircraft, they may hinder rescue procedures.

If you must ventilate the cabin, you should do so on the downwind side of the aircraft.

If you are a rescuer who has entered the aircraft, immediately after you enter, you should clear an initial rescue area. You should then move through the fuselage and give help first to those persons who are mobile. Help them to leave the aircraft by forming a **human chain** system with some of the other rescuers. Pass the mobile passengers along the human chain to the point of exit. This is the most effective method of moving people out of a damaged aircraft where there is limited room available inside the aircraft, and limited time to achieve full evacuation.

When all mobile survivors are cleared from the aircraft, you can then turn your attention to those passengers who are trapped and/or injured. At this time, you should administer only limited first aid, and only to those passengers who most urgently require such attention. If you must use a stretcher to remove an injured passenger, pass the stretcher above shoulder height to clear the seats and passengers.

After you have evacuated all of the survivors whose positions are obvious to you, you should then make a detailed search of the aircraft to see that no one has been missed.

After you have evacuated all of the passengers, all survivors should be moved at least 50 m away from the crashed aircraft to an uphill and/or upwind position. You should try to keep the survivors warm, until a doctor can see them or until they can be removed to a hospital. No smoking should be allowed because a survivor's clothing may be impregnated with spilt fuel.

1.16.2 Military Aircraft

Rescue from military aircraft is much the same as it is for civil aircraft. One major difference with military fighter and bomber aircraft is that they may have a canopy, particularly if ejection seats are fitted.

Emergency opening instructions are printed near the canopy-opening handles, and certain emergency exit panels are marked with instructions for removal. Some aircraft also have ditching or parachute panels, which are light enough to be kicked out.

Canopies open in different ways on different aircraft. They normally open by sliding backwards or hinging upwards. In an emergency however, they are to be removed completely. There are two release handles to remove a canopy. One is for normal release; a second handle is for emergency release. It is very important that you know which handle is for which purpose.

When a sliding canopy is released in an emergency, it is lifted off complete with the guide rails.

When a hinged canopy is released in an emergency, it is usually jettisoned by a small explosive charge. There is usually no control over where it may fall. When released, a hinged canopy does not fly like a missile, but it may travel up to 10 m before striking the ground.

CAUTION

If you are attempting a rescue where a hinged canopy is involved, you should never put your arm through a hole in the canopy as you may accidentally fire the explosive charge.

A perspex canopy can be broken by force, but it is almost impossible to smash through laminated perspex. If you must attempt breaking into a perspex canopy, you should use the back of an axe and strike near the canopy edge. You must take care to avoid hitting the head of a crew member or the back of an ejection seat.

Removal of hinged canopy varies.

Ejection seats can be very dangerous unless the safety pins are in place. When you are attempting a rescue where a crew member is in the ejection seat, you should never lean over the ejection seat or interfere with it unless you are sure it is safe to do so. Check to see if the safety pins are in place. When not fitted into the ejection seat, safety pins are stowed together usually on the port side of the cockpit coaming. Locations do vary with different types of military aircraft.

Where a canopy jettison unit is fitted, a safety pin must also be placed in this unit to render it safe.

CAUTION

If the pilot has attempted unsuccessfully to jettison during an emergency, this will be indicated by either the face blind being pulled out, or the seat pan handle being pulled out. In such event, you should make no attempt to remove the canopy. If the canopy is removed in this situation, the ejection seat will activate unless the restrictor wire is first removed or cut, and the safety pin is placed in the seat. To do this, you must first cut a hole in the canopy to give you access. Then cut the restrictor wire and put the pin in place.

When the ejection seat is safe, the following steps should be taken to rescue a crew member:

- remove the oxygen mask;
- disconnect the main and emergency oxygen supplies;
- disconnect the communication lead;
- disconnect the parachute straps;
- disconnect the inflatable dinghy straps;
- disconnect the anti-G tubes; and
- disconnect the seat straps.

On some aircraft, there may be a multiple personal equipment connector (PEC) fitted. In this case, follow these steps:

- remove the oxygen mask;
- disconnect the personal equipment connector by pressing the release and lifting the handle;
- disconnect the dinghy straps, and
- disconnect the seat and parachute straps.

Special Hazards of Military Aircraft

Most military aircraft have armaments and/or pyrotechnics stowed on board. As a firefighter, you should stay clear of the gun muzzles or rocket missiles.

Missiles are normally carried in pods or racks under the wings of the aircraft. In an emergency, they will seldom fly, but they can explode like high explosive bombs. You should approach a military aircraft from the front at 45°.

Where nuclear weapons are present, fire fighting should proceed as for radioactive substances with firefighters wearing full protective clothing and BA. You should follow the decontamination procedures. All persons should keep clear of smoke or fumes.

1.16.3 Helicopter Accidents

Helicopters are of light construction, and they do not stand up well to the stresses of emergency landings. Usually the tail, rotors, and undercarriage collapse, and this leaves the cabin as the main wreckage. If the main rotor is damaged in flight, it is likely that the helicopter will have had a nose-dive type of accident. The fuel loads are normally smaller in helicopters than they are in winged aircraft, and hence, a fire involving fuel is not as likely to occur or to be as severe.

CAUTION

Be very careful if you approach a helicopter when the rotors are still turning. If the helicopter has capsized, access can be difficult. In such an emergency, the perspex around the nose can probably be broken to gain entry to the cabin.

Military helicopters can present additional hazards - they may have machine guns or missiles fitted, and they may have magnesium flares in special outboard racks.

1.17 Naval Aircraft Fire Fighting Arrangements

1.17.1 Hazards

The two main hazards with ship-board components are fire and explosion. This is particularly true of aircraft on board a ship.

A fire on a ship-board aircraft can be caused by the following:

- an impact spark or a spark from the aircraft's electrical system;
- contact with hot engine parts; or
- accident through negligence or ignorance.

An explosion on a ship-board aircraft can be caused by the following:

- overheating of fuel tanks, oxygen, or compressed air cylinders; or
- the detonation of explosive weapons by **cook-off** in a fire situation.

There are additional hazards involving ship-board aircraft. These include radiation hazard (**radhaz**) and special problems with ship-board helicopters.

Radiation from the aerials of high power communication and radar transmitters can cause hazardous situations, including fire, unless appropriate precautions are observed:

- personnel can be harmed by the heating effects of absorbed radio frequency radiation. Additionally, they can be shocked or burned by making contact with metallic objects excited by radio frequency radiation;
- combustible materials (fuels) can be ignited by the sparking from metallic objects excited by radio frequency radiation;
- explosive materials and propellants can be ignited or detonated by either the sparking between metallic contacts or by the induction of currents into the firing circuits of electrically initiated explosive devices; and
- permanent damage can be caused by induced currents in certain electronic equipment, particularly where semi-conductors are present. Additionally, the equipment can malfunction from unwanted voltages that come from external radio sources.

1.17.2 Helicopters

Firefighters should be fully aware of the general safety rules concerning helicopters. In particular, the dangers from rotor blades, blade sail, tail rotors, exhaust gases, and engine noise.

An additional hazard is the flotation gear that is fitted to some helicopters. Basically, this equipment consists of large bags placed at strategic points on the aircraft. These bags are housed in containers, and they can inflate almost instantaneously.

CAUTION

When the bags inflate, the housing canister is blown free with considerable force, especially when the canister is immersed in salt water.

1.17.3 Fire Protection Arrangements

Fire protection arrangements required for helicopter landings on navy ships and hangars include the following:

- two fire hydrants fully equipped with hoses, nozzles, and fog applicators. Each hydrant must be capable of providing complete coverage of the area;

- two foam points supplied from either one permanently installed foam station or from two portable stations. Each of these points must be complete with foam hoses and branch pipes or hose reels with AFFF nozzles. Each foam point must be capable of providing complete coverage of the area;

- several portable fire extinguishers including at least:

  - one x 25 kg BCF extinguisher
  - one x 50 kg Dry Chemical extinguisher
  - two x 9 kg Dry Chemical extinguishers
  - two x 5 kg BCF extinguishers

1.17.4 Fire Fighting Procedures

Hangars

In the event of a small fire in a hangar, attack it first with the portable/first aid appliance. However, if the fire has gained a firm hold, you should immediately activate the major foam and sprinkler systems. If there is a helicopter in the hangar at the time of the fire, you should make every effort to move the aircraft clear of the fire scene.

Fire on Deck

In the event of a fire on the deck, as a result of a helicopter crash, you should attack the fire immediately with large quantities of foam. You can support this attack with the large dry chemical extinguisher. Additionally, you can use the twin agent unit if there is one on board.

Modern helicopters sometimes have a high magnesium content in their structure. They can carry between 900 and 3200 L of *Avcat*. If the fuel tank ruptures, an extremely hot fire of massive proportions can develop. If a helicopter crashes with the engine still running, there is an additional risk of an explosion.

Precautions to be Observed

If there is an aircraft crash on deck, and you suspect or know that there is free fuel vapour present, you should take the following precautions:

- notify all personnel on board that smoking is prohibited throughout the ship;

- cover all spilled fuel immediately with foam until fuel cocks can be shut and fractured fuel lines blanked;

- avoid disturbing any electrical switches and leads on the crashed aircraft, but, if possible, disconnect the aircraft batteries.

⚠ **NOTE**

Disconnecting the batteries should be done only by a person qualified to do so, and they should take great care to avoid causing sparks from the batteries.

- seek out and locate all hidden pockets of fire within the fuselage of the crashed aircraft and blanket them with foam. These hidden pockets of fire constitute a great potential danger to fuel tanks, oxygen tanks, and compressed air cylinders.

When you have extinguished the fire in and surrounding the crashed aircraft, wash thoroughly the deck surfaces to remove all traces of spilled fuel.

The above instructions will be started by Naval personnel prior to your arrival.

SECTION TWO - SHIPPING

CONTENTS

SECTION TWO - SHIPPING

CONTENTS

2 SHIPPING

2.1 Introduction

Fire incidents on board ships can involve an unlimited variety of cargoes and an almost unlimited variety of ships. Fires, explosions, spillages and other incidents on board ships always present firefighters with problems.

In many regards, we can compare fires on ships to fires on land:

- a fire in a cargo vessel can be compared to a warehouse fire with the added risk of a basement and single access;
- a fire in the engine room can be compared to a major workshop fire in that an engine room on a modern container vessel or on a large tanker, may be as many as six levels in height; and
- a fire in the passenger and crew accommodation areas can be compared to a hotel or lodging house fire, except that this lodging house has no windows.

You should take every opportunity that presents itself to get on board a ship and familiarise yourself with the construction, layout, controls, and provisions for preventing and fighting fires on board ship. In this Section, we explore and discuss details of many types of cargo ships and cargoes. Clearly we cannot cover every kind of ship, every cargo, and every situation, but here we deal with the more common ones.

2.2 Construction

2.2.1 Introduction

The design of ships can vary. The design of a ship is determined by its age, function, the volume of goods, or the number of passengers it carries, and the requirements of individual owners. Most ships share these basic features and terms.

The construction of a ship is more easily understood if you consider a ship to be a huge box girder. The parts of this huge box include:

- keel;
- frames and beams;
- shell plating;
- main deck; and.
- bulkheads.

These main components are strengthened by various parts called keelsons, stringers, girders, pillars, lower decks, and transverse bulkheads. To appreciate the construction of a ship in its entirety, it helps if you have a basic understanding of the functions of each of its main components.

2.2.2 Keel

The keel is primarily the backbone of the ship. It consists of a rigid longitudinal timber or plate that extends along the centre of the bottom of a ship. The keel runs fore and aft along the centre line of the ship, and it often projects out from the bottom of the ship. The stem is connected to the forward end of the keel. The stern frame is located at the aft end. This stern frame supports both the rudder and the propeller.

2.2.3 Frames and Beams

The frames are the ribs of the ship. Their lower ends are attached at intervals along the keel, and their upper ends are attached through brackets to the beams which support the deck. Internal bracing is provided by keelsons and stringers running fore and aft. The frames determine the form of the ship, and they support and stiffen the shell plating.

2.2.4 Shell Plating

The shell plating is the principal strength member of the ship, and is also necessary for watertightness. The shell plating runs continuously from the stem to the stern frame and from the keel to the weather deck. The shell plating forms three of the four sides of the box girder. Together with the frames, the shell plating must be able to withstand the exterior water pressure, the stress from the buffeting of waves, and the rubbing and bumping of the ship against the wharf.

2.2.5 Main Deck

The main deck of the ship forms the fourth side of the huge box girder. It must be of strong construction. The plating is connected to beams which extend from side to side across the ship. The deck is strengthened by the doubling of plates in regions that are weakened by openings such as hatches, companionways, and areas under all deck machinery. The deck is supported from below by girders and pillars.

2.2.6 Bulkheads

The ship also requires internal strengthening to enable the shell (bottom, sides, and main deck) to withstand the stresses of an ocean voyage. This internal strengthening takes different forms in different types of ships.

- In a cargo vessel, this internal strengthening is provided by the lower decks and the main transverse bulkheads.
- In older tankers, this internal strengthening is provided by transverse and longitudinal bulkheads. These bulkheads extend from the keel to the main deck and separate the vessel into numerous cargo tanks.
- In newer tankers, including all chemical and gas carriers, double bottoms and sides provide the strength, and give added protection for cargo, in case cracks occur in the shell plating.

In addition to furnishing support for the shell and decks, the main transverse bulkheads are made watertight. These subdivisions of the vessel created by the bulkheads provide the extra safety of watertight compartments. In case of damage to the ship, any water that seeps in can be confined to one compartment. The doors in these bulkheads are made watertight by fitting gaskets. To ensure instant closure, doorways must be kept clear at all times.

Bulkheads also offer fire resistance, and can limit the spread of fire. While these compartments provide a degree of safety, they can complicate firefighting efforts unless firefighters know how a ship is laid out. In a fire incident or an emergency, you should examine the general construction layout of the ship so that you can locate access and egress routes for firefighting.

To limit flooding in case of a collision, the first bulkhead aft of the stem is known as the collision bulkhead. In the construction of the ship, no doors or other openings are placed below the main deck in this bulkhead.

In a cargo vessel, the engine and boiler rooms are usually located amidships.

In a tanker, the engine room is located in the aft section of the ship.

Special foundations are necessary to support heavy engines and boilers. To provide sufficient headroom for the propelling machinery located in the engine room, it is necessary to omit one or more of the decks in this region. To maintain the vessel’s strength in the absence of these decks, this area has several extra-heavy web frames and transverse beams around it.

The propeller shaft extends through the aft holds from the engine to the stern gland. Because the propeller shaft must be accessible at all times for inspection and lubrication, it is enclosed in a narrow shaft tunnel. This shaft tunnel is made watertight by watertight doors. Thus, if the tail shaft is fractured, only the tunnel is flooded.

The necessity for good drainage requires special attention in the design and construction of a ship. Free water on the decks, in a hold, or in the bilges of the ship can affect the stability of the vessel. Therefore, the drainage system must be as efficient as possible. The decks are cambered, or arched slightly upwards in the middle, to cause loose water to drain to the scuppers which release the water either overboard or into the bilges.

2.3 Types

A type of ship is defined by its use. The various types of ships include the following groups:

- cargo;
- container;
- roll on/roll off;
- tankers;
- chemical and gas carriers; and
- passenger.

2.3.1 Cargo Ships

Cargo ships are designed to carry the largest possible amount and variety of goods. They have certain characteristics including the following:

- normally from five to eight holds. The holds are numbered from bow to stern;
- oil, fuel, and water ballast tanks located at the sides of the vessel; and
- in older ships, the machinery is located amidship; in newer ships, the machinery is located towards the stern.

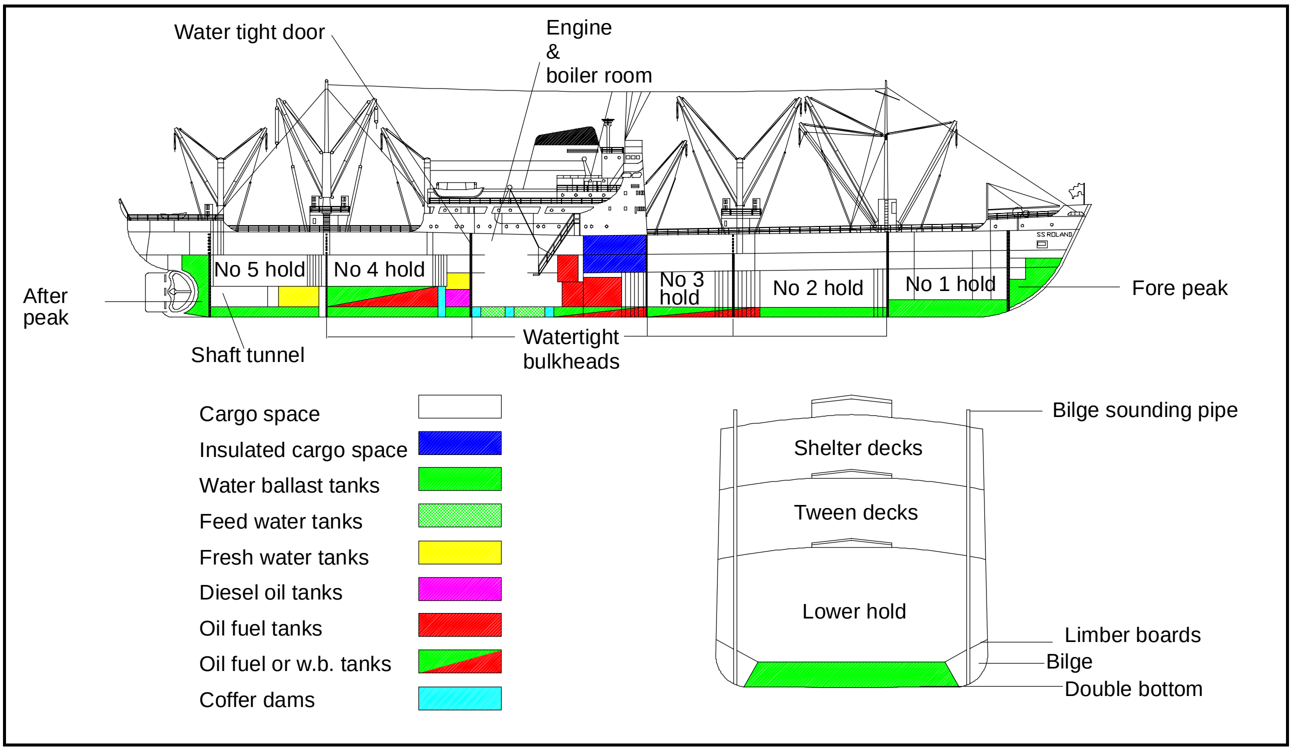


Fig 2.1 Section Through a Cargo Ship

The holds are separated one from another by watertight steel bulkheads. The openings in these bulkheads are fitted with watertight doors. On ships of a more basic design, each hold is a compartment between two bulkheads. Each of these holds extends from the inner bottom to the upper deck. On ships of a more complex design, there are additionally one or more tween decks. Some of these tween decks may exist only between specific bulkheads. The tween decks themselves may have longitudinal bulkheads running along the centre of the ship.

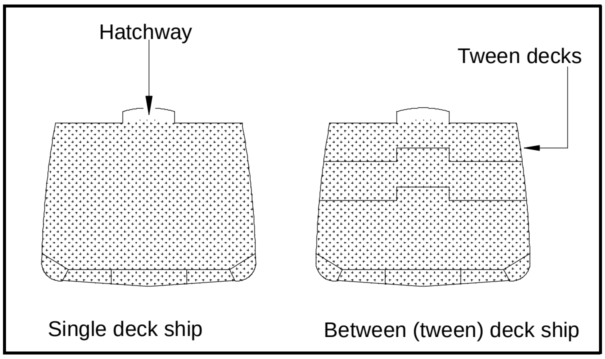


Fig 2.2 Single Deck Ship /Tween Deck Ship

Superstructure

The superstructure above the deck of a cargo vessel can vary from ship to ship. It will house the bridge, and it may also be used for cargo, stores, machinery, or passenger and crew accommodation.

Hatches

A large hatchway in the deck over each hold gives access for loading and unloading the cargo. These hatchway openings usually extend across the deck for about one third of the beam.

Tween decks have similar openings or hatchways. These are located in a vertical line so that cargo can be lowered down through hatches to the lower tween decks. All of these hatchways are protected by hatch covers. On the upper deck, the hatch cover is usually of watertight, steel construction and is operated either hydraulically or electrically.

All of the hatch covers are designed to withstand the weight of cargo. On the upper deck, this weight may consist of cargo containers stacked up to four high. Heat from a fire can distort the metal of hydraulically operated hatch covers and make them inoperable. If this happens, the hatch cover must be forced open manually.

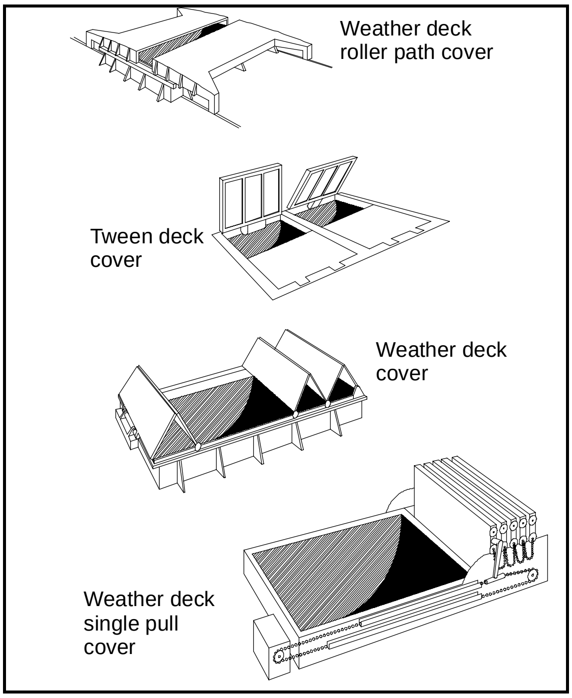


Fig 2.3 Various Types of Hatch Covers

Access to the Holds

The most common means of access to the hold areas are by the following:

- hatch ladders are usually located just inside the hatch openings. These ladders may be staggered at different deck levels;
- mast house ladders give access to each deck, the lower hold, and the double bottom of the ship. The mast houses may also act as ventilators with cowls on top of the mast house;

CAUTION

Ladders into the machinery spaces have a steep pitch and tend to be greasy.

- trimming hatches are small openings (approx 600 mm x 600 mm) located in the corners of the tween decks;

- bilge and saunding pipes give access to the bilges through hatches from the lowest deck; and

- ventilation shafts give access to all decks.

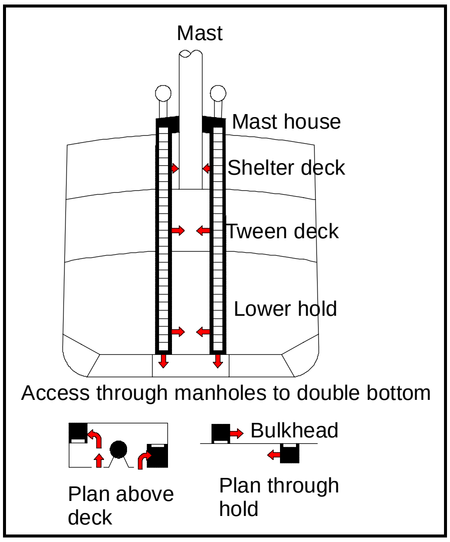


Fig 2.4 Section/Plan of a Mast House

2.3.2 Container

It is now common for cargo to be loaded into a container that is sealed and shipped to a destination aboard a container ship. The container is most often not opened during transport.

These containers are usually of single or double wall construction and made of either mild steel, stainless steel, steel and aluminium alloy, fibreglass or a combination of these materials. The design of the container can vary considerably. There is a standard model, but the standard model can be modified and insulated or refrigerated. It can open at the top, side or end. There are bulk models and tank models

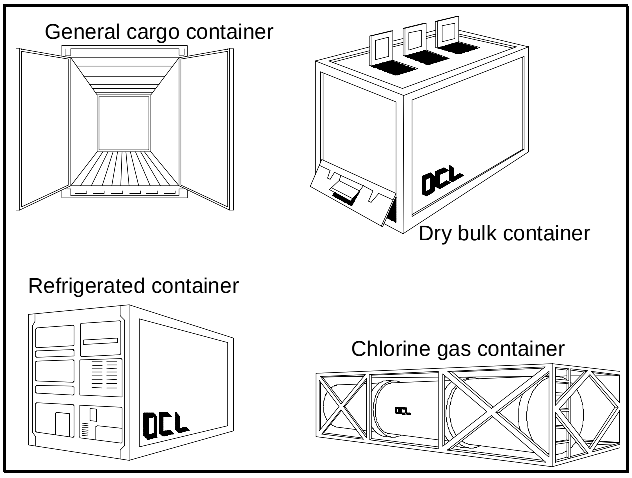


Fig 2.5 Containers

Standard container sizes and maximum capacities are:

- 6.1 x 2.44 x 2.44 m with a capacity of 20 t; and

- 12.2 x 2.44 x 2.44 m with a capacity of 30-40 t.

Container ships are designed to carry up to 3600 containers with a total cargo load of between 1000 to 100 000 t. A ship may carry only containers, or it may carry some containers and some other cargo. Some of the variations include the following:

- a full container ship carries containers in all available spaces, stacked in cells up to eight deep below deck and four deep above. Each cell is formed by four vertical guide rails. Heavy web frames separate all groups within a hold;

- a partial container ship has only part of its cargo capacity designed to carry containers. The remainder of the area on the decks and in the holds is for general cargo;

- a general purpose ship uses all or part of its capacity for containers or other cargo.

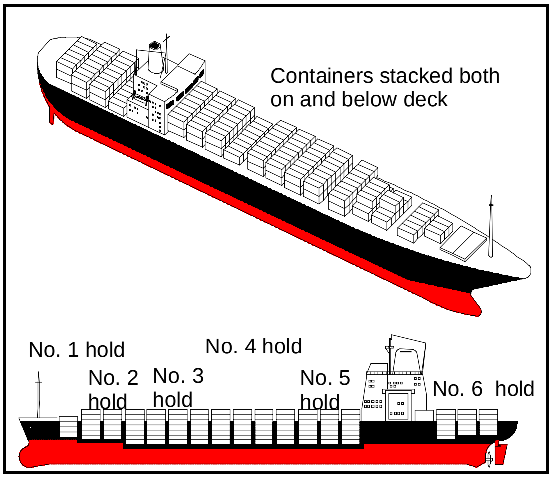


Fig 2.6 Container Ship

Construction

The design of container ships can vary from ship to ship and from purpose to purpose. The superstructure of a container ship can be located in different positions. It may have as many as twelve decks, one on top of another. The engine room casing may be in the middle of the ship and be surrounded by accommodation.

Access

Access to the holds of a container ship is through the large hatch covers provided for loading and unloading the containers. There is also access from a working alley below the main deck on both sides of the ship. Some of the holds are insulated and carry refrigerated containers that are attached by flexible pipes to the ship's refrigeration system.

Some container ships are being designed especially for use at ports where there is no conventional handling gear. These ships have access to the cargo spaces through doors in the bow. They carry equipment such as bogies and heavy duty fork-lift trucks for loading and unloading.

2.3.3 Roll-on, Roll-off (Ro-Ro)

General Characteristics

Ro-Ro ships are designed to have vehicles drive on and off them. A ro-ro ship can have as many as twelve decks. These decks are often suspended on cables and they can be raised, lowered, or removed for loading and unloading motor vehicles or carrying other cargo.

A vessel designed to carry general cargo or containers in addition to a large number of vehicles, is sometimes referred to as a sto-ro ship. Sto-ro ships have remotely controlled watertight doors in the holds which shut off part of the ship as a safeguard against water leaks.

Car Carriers

A ro-ro car carrier may carry as many as 2000 or more cars (Fig 2.7). Vehicles are usually driven onto the ship through bow or stern loading doors and into position via ramps where they are secured.

The decks are like large hangars but they have limited headroom. There are no bulkheads. Ventilation on each deck is usually mechanically controlled. The cars are tightly packed, and movement is severely restricted.

When the loading doors are closed, access to the car decks is through stairs and sliding doors in the accommodation section.

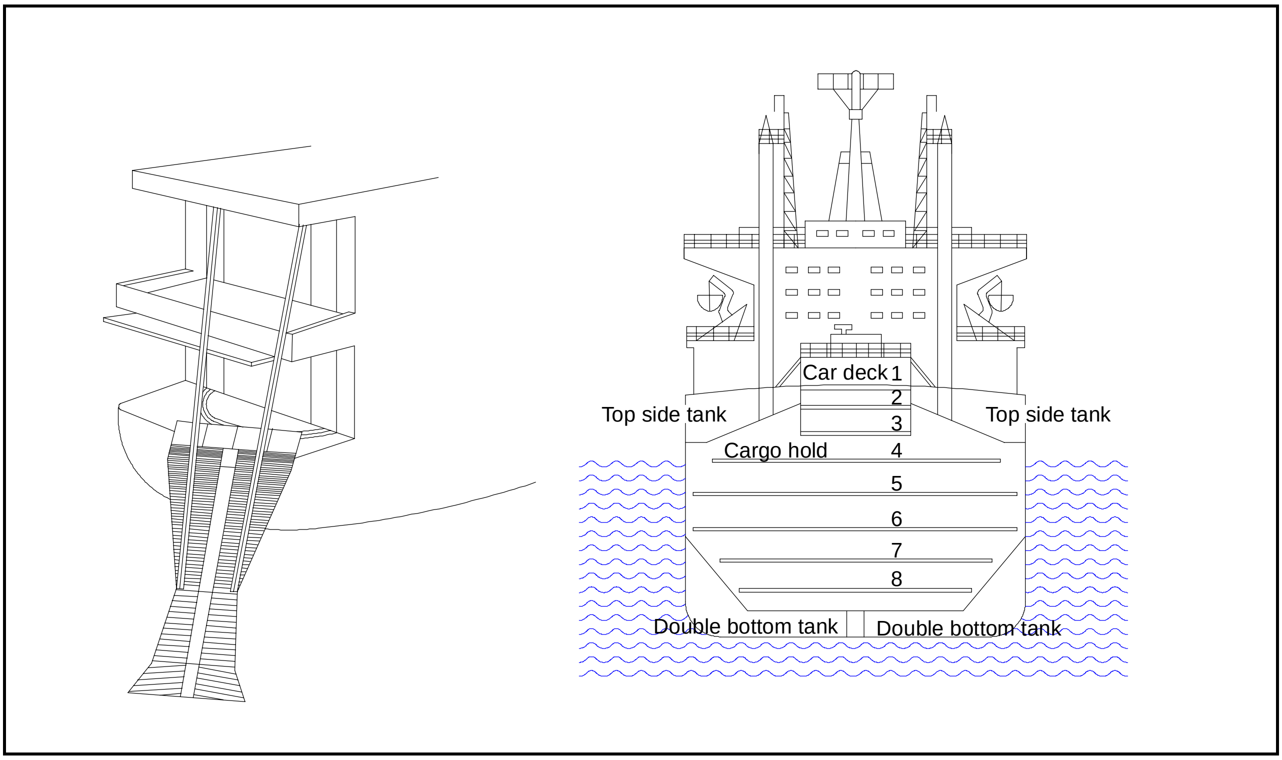


Fig 2.7 Ro-Ro Ship

2.3.4 Tankers

Tankers are designed to carry bulk oil.

Size

Tankers are either small or large.

Small tankers are usually about 20,000 t in size. They carry refined oil products from a refinery to another destination.

Large tankers are generally used for carrying crude oil. Large tankers are classified as follows:

- Large Crude Carriers (LCC's) 100,000 - 200,000 t
- Very Large Crude Carriers (VLCC's) 200,000 - 400,000 t
- Ultra Large Carriers (ULCC's) 400,000 t +.

Construction

In both small and large tankers, most of the hull is used to carry the oil. Small carriers are divided into many tanks. This improves their stability and enables them to carry different types of product.

The large oil tankers have fewer tanks within the hull, but each tank is very large. The tank section is divided by two longitudinal bulkheads into port, starboard and centre tanks. In most cases there is no double bottom. The longitudinals and transverse bulkheads strengthen the main deck and outer bottom. The shell is strengthened by transverse frames. A heavy transverse web is fitted at the half length of each tank. Fig 2.8 details an arrangement of tanks, pipelines and ballast tanks.

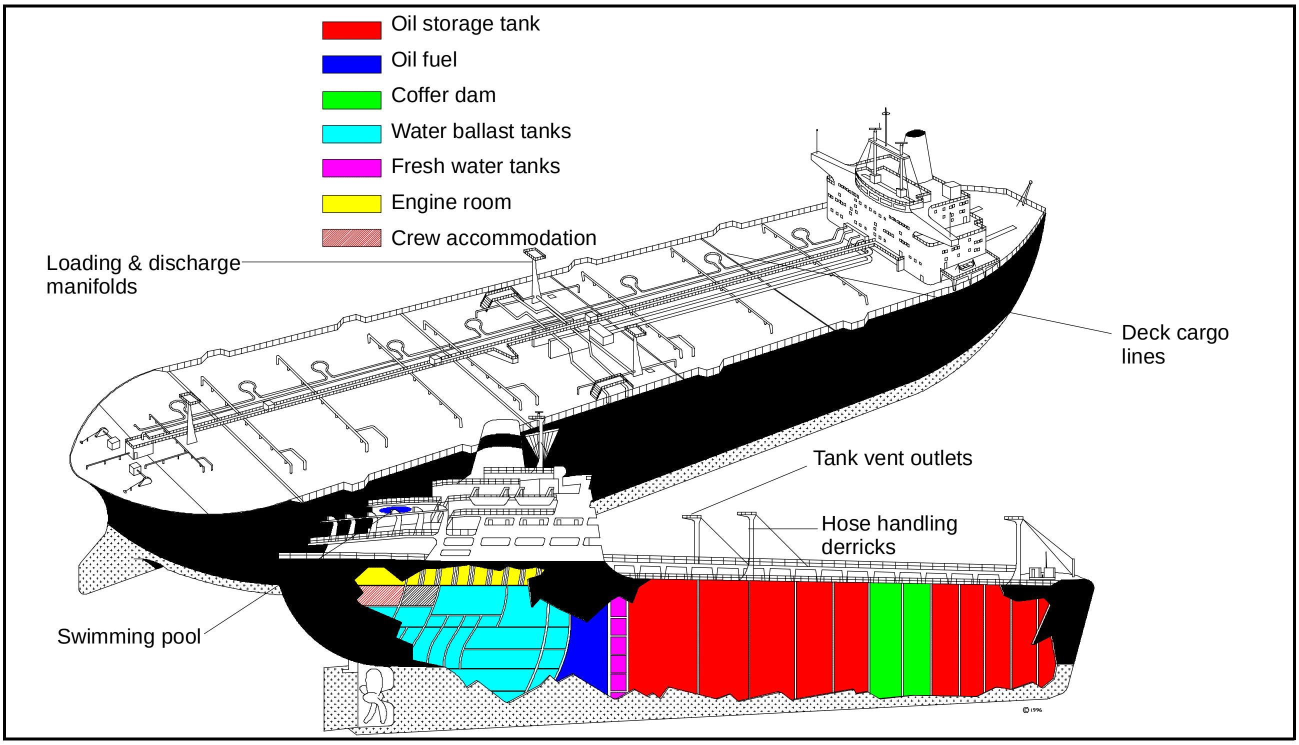


Fig 2.8 A Typical VLCC

Cargo Loading and Unloading

Oil cargo is loaded and unloaded through large hoses and hard-arms connecting the deck pipelines to the shore lines. Shore pumps are used to load the liquid cargo; ship's pumps are used to unload the cargo. Most large modern vessels have a free flow system for handling liquid cargo. This means that the oil can pass from one tank to another through bulkhead valves.

Inerting and Purging

Any oil discharged from the tanks of a cargo ship is usually replaced simultaneously by inert gas as a precaution against fire.

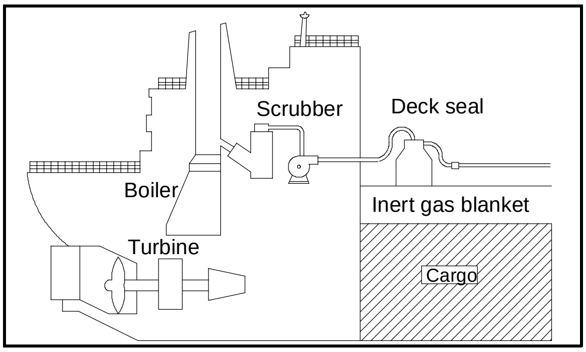


Fig 2.9 Inert Gas System - Main Components

- Inerting is the replacement of air or cargo vapour by inert gas before loading.
- Purging is the replacement of inert gas of unacceptable quality, or previous vapours, by nitrogen or other suitable cargo vapour before loading the main cargo.

The purpose of inerting is to prevent vapour/air mixtures from contacting combustible cargoes.

When the inerting or purging process is underway at a wharf, it is essential to prevent the concentration of dangerous vapours around the ship.

2.3.5 Chemical and Gas Carriers

Chemicals and gases, like plastics, are in use extensively in every part of modern life. Some chemicals and gases are harmless, but others are highly dangerous. Transporting chemicals is a very big business, and it can pose many fire hazards. Many chemicals are very flammable with a low ignition temperature. Many are toxic, corrosive or harmful in some other respect. The construction and operation of chemical carriers must take all of these hazards into account.

In this section, we discuss the two main types of ships that carry chemicals and gases:

- bulk chemical carriers;
- liquefied gas tankers, including
  - fully pressurised ships;
  - semi-pressurised / refrigerated ships; and
  - fully refrigerated ships.

Bulk Chemical Carriers

Bulk chemical carriers are ships that are designed to carry chemicals, usually oil, in bulk.
Some ships are specifically designed to carry one chemical. They are generally quite small. But many large ships are designed as parcel tankers. These ships can carry a number of different chemicals at the same time.

Before any cargo loading operation, the ship must be tested thoroughly and all safety checks must be completed. It is the Master's responsibility to present the vessel for loading/ discharging with all cargo tanks, equipment, and tank atmospheres ready for the operation. *The International Maritime Organisation (IMO)* has drawn up a code of safety provisions for ships that carry chemicals.

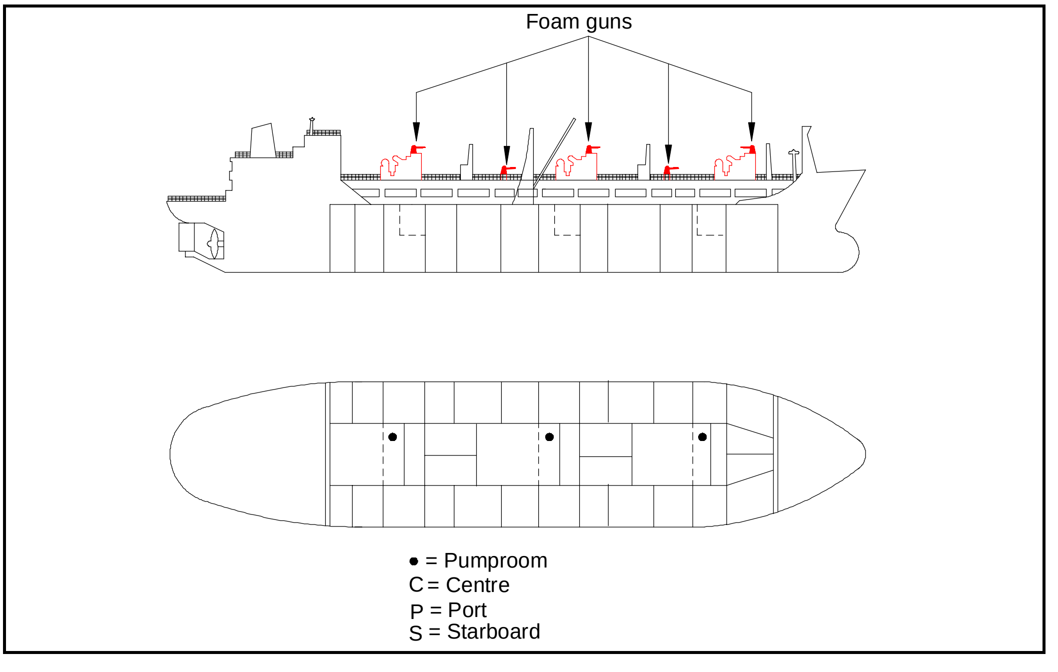


Fig 2.10 Bulk Chemical Carrier

Here is a list of some of the specified safety provisions.

Tank Location

A major safety provision is that all chemicals except those in the safest category must be carried in tanks located away from the sides and bottom of the ship. Minimum distances are specified for this purpose.

Cargo Separation

There are also requirements on cargo separation. Cargoes that react dangerously with other cargoes must be separated by a coffer dam, void space, pump-room, empty tank, or a mutually compatible cargo. These dangerous cargoes must have separate ventilation systems.

Types of Tanks

The tanks in which the chemicals are carried can be either integral, that is, forming an essential part of the ship's hull, or independent, that is, not forming part of the hull structure. In modern chemical-carrying ships, the tanks have linings of epoxy, zinc silicate, or stainless steel. The allocation of cargoes to the various tanks depends on the cargoes' compatibility with each other and with any residue from previous cargoes, and also on their compatibility with the tank linings, since the tank linings can be damaged by contact with certain chemicals.

Ventilation Systems

All chemical cargo tanks must have a ventilation system. Some substances require special ventilating arrangements. Some even require a controlled atmosphere in the cargo tank vapour spaces and in the spaces surrounding the tanks. These special ventilation requirements are often met by the following methods:

- inerting - filling the space with a gas which will not support combustion and which will not react with the cargo;
- padding - separating the cargo from the air by means of a liquid or gaseous filling; or
- drying - keeping the cargo free of water or steam with a moisture-free gas;
- pumping arrangements - Chemical carriers usually have two or three pump rooms, each with a number of high-capacity pumps. The rooms are arranged to give unrestricted access to cargo control valves and to give room to move for a person wearing protective equipment;
- access ladders - should be vertical, and individual platforms should be fitted with guard rails. Entries to void spaces, cargo tanks and other spaces in the cargo tank area should also be accessible for a person wearing SCBA. There must be direct access to the cargo tanks from the open deck.

Liquefied Gas Tankers

The development of refrigeration techniques and the use of metals that can withstand sub-zero temperatures, have made it possible to carry cargo at below ambient temperature. As well, the development of cargo containment systems and refrigeration plants, enable fully refrigerated vessels to carry liquefied petroleum gas (LPG) and liquefied natural gas (LNG) at above atmospheric pressures.

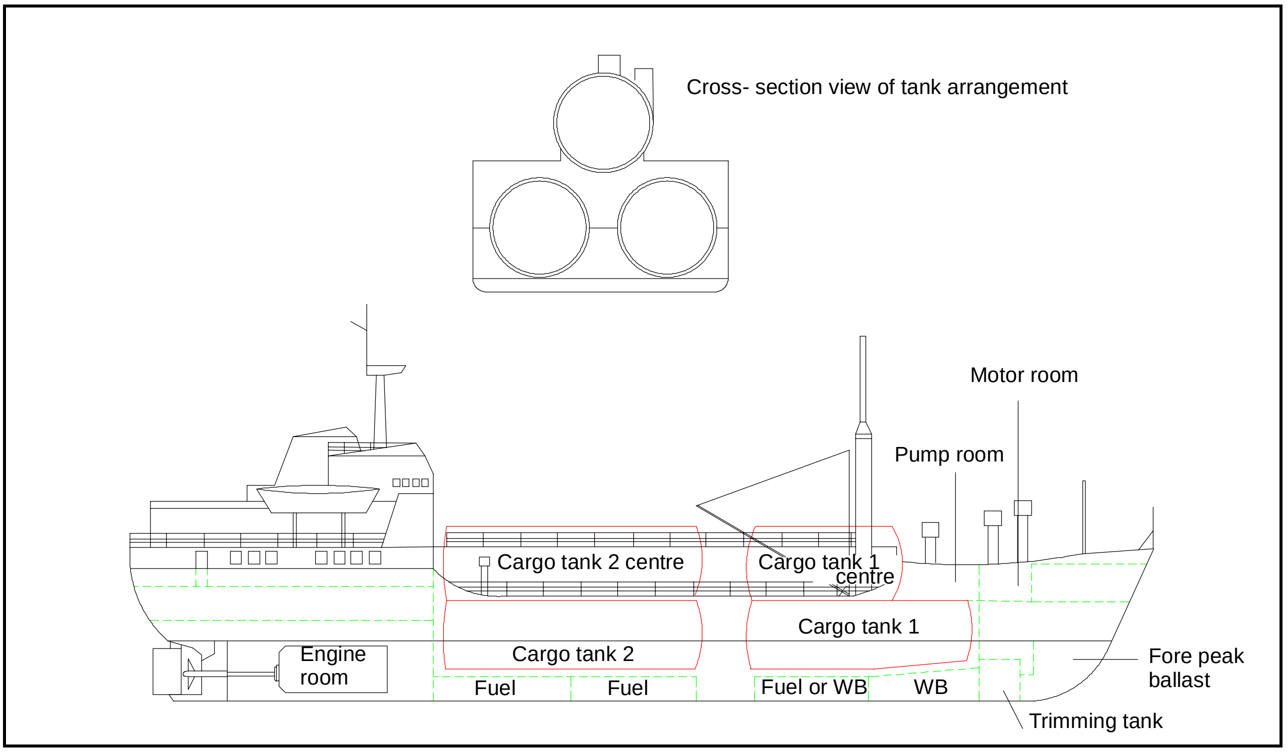


Fig 2.11 LPG Carrier Tanks - General Arrangement

There are currently three types of liquefied gas tankers in wide use:

- fully pressurised;
- semi-pressurised/refrigerated; and
- fully refrigerated.

Fully Pressurised Ships

Fully pressurised ships are designed to meet two requirements when carrying liquefied gas cargoes:

- to keep the gas at the relevant pressure; and
- to carry the gas safely at the highest ambient temperature the ship is likely to experience.

A maximum temperature of 45° C and a pressure of 17 kg/cm^2 are usually the criteria used in the design of these ships. These correspond to the vapour pressure of propane, the most volatile cargo carried at this temperature. These ships are usually fitted with double bottoms and topside ballast tanks, and they have ventilated spaces around the pressure tanks. They carry cylindrical or spherical pressure vessels, as these have been proven to be reliable and to be able to withstand the stress levels required by the gases.

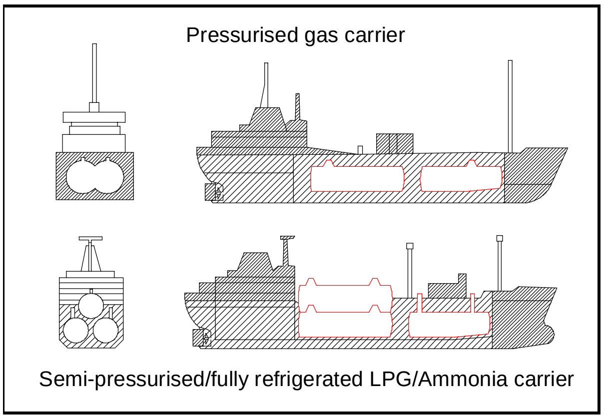


Fig 2.12 Pressurised/Semi-Pressurised Ships

Semi-pressurised/Refrigerated Ships

Semi-pressurised ships can increase cargo capacity and reduce cargo tank building costs. There is a wide range of semi-pressurised ships, and they carry pressure vessels that are suitable for carrying cargo at temperatures as low as -50° C.

With the reduction in design pressure, designers can make better use of the cargo space by building different shaped tanks including lobed tanks, tapered cylinders, and above deck tanks. To utilise the space available, the tanks are normally arranged in groups of three with the port and starboard tanks below deck and a third tank above deck, situated between the lower two and over the centre line.

These ships can carry many cargoes ranging from LPG to chemicals. These ships normally have full double bottom ballast tanks. The space around the tanks is usually filled with an inert gas. With greater use of cargo space, the vessels can carry up to 15 000 m^3 of cargo.

Fully Refrigerated Ships

A fully refrigerated ship has special insulated tanks of aluminium or carbon-manganese steel. These ships are 5000 m^3 to 100 000 m^3, and they can carry pressurised cargo at between 0° C and -55° C. They still use some spherical and cylindrical tanks, but most of them use tanks that have internally-stiffened, rectangular, flat walls. These tanks can be tailored to fit the ship's available hold space. These fully insulated cargo tanks are supported **on chocks keyed to the hull**, and this allows for expansion and contraction.

2.3.6 Passenger Ships

Passenger ships carry a large crew and can accommodate over a thousand passengers. They can have as many as twelve accommodation decks.

Decks

Accommodation decks are usually identified alphabetically with the A deck being the uppermost. The Sun, Boat, Games, and Promenade Decks may all be located above the A deck. The deck immediately above the water level is a statutory bulkhead deck. Below this statutory bulkhead, the hull is divided by watertight fire-resisting bulkheads.

The statutory bulkhead deck and above are divided by non-watertight fire zone bulkheads. A zone is 40 m, and each zone has fire doors at each opening.

Corridors

Corridors run the length of the ship on each side of the passenger decks. There are side passages leading from the corridors to the cabins. In the main corridors, at various intervals, there are halls with lifts and stairs leading to the other decks and public rooms. The stairways may be located in fire-resisting enclosures. There are also service passages, which run the length of the ship and provide the main access to service areas, such as kitchens and laundries.

Fire Risk

Passenger liners generally present a high fire risk. Passenger accommodation on these vessels is very extensive, and there are numerous large public rooms and facilities. The overall pattern of rooms and corridors is very complex. Decoration, furnishing, and fittings are generally elaborate and usually flammable. Panels and false ceilings create air spaces, which may carry piping and cables. Together with the steel decking, and insulation of accommodation areas, all contribute to rapid fire spread

Fire Alarm Systems

Generally, automatic fire alarms and detectors are used in the accommodation decks and the service areas. These areas are supplied with automatic sprinklers in the deckheads. They usually have non-combustible materials in the structural boundaries and partitions.

2.4 Stability

2.4.1 Introduction

The stability of a ship in the water can be very easily upset by the shifting of weight on the ship. This means that a shift in the position of cargo or ballast can tip a ship to one side so that it loses its balance. This is of major significance to firefighters. An event of this nature can increase fire danger and threaten life.

It is essential that you be aware of the principles of ship stability if you are involved in an incident on board a ship. This section examines and discusses these principles.

2.4.2 Terminology

To have an understanding of and to be able to converse about the principles of ship stability, it is essential that you have a working knowledge of the terminology of these principles. Here is a list of the main terms relating to these principles:

- Stability;
- Mass and Trim;
- List and Heel;
- Loll;
- Centre of Gravity;
- Centre of Buoyancy;
- Metacentre and Metacentric Height;
- Free surface effect.

Stability

The stability of a ship refers to its ability to float upright without listing, or tipping, to one side. There are many factors that can affect the stability of a ship.

Mass and Trim

The mass of a ship means the gross weight of a ship including everything afloat with it cargo, fuel, provisions, and crew. The mass of a ship varies. It depends on the loading at any particular time. It is important to acknowledge that any water applied in firefighting or any equipment loaded onto the ship during a firefighting operation increases the ship's mass.

Trim is the position of a ship or boat with reference to the horizon. This means that trim is the longitudinal inclination of a ship or its balance from side to side. A ship floating in the water with its decks parallel to the water is said to be in trim. Fig 2.13 illustrates a ship out of trim due to water in the forward holds.

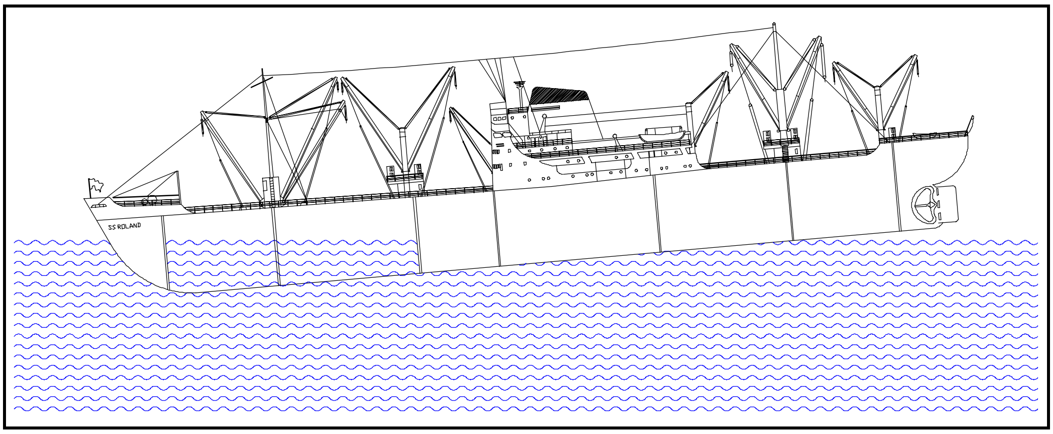


Fig 2.13 A ship out of Trim

List and Heel

These terms, list and heel, refer to the transverse, or side-to-side, inclination of a ship from a vertical position of balance. The term used is determined by the cause of the imbalance.

List is the inclination, or tilt, caused by some item of weight on a ship being placed in an off-centre position. A ship on a list can still remain stable in the water, but it will retain the list as long as the weight distribution remains unevenly placed.

Heel is the inclination, or tilt, caused by an external force such as wind or waves. The ship will heel when acted upon by the force of the wind or waves, but when the force is removed, the ship will return to its stable, balanced position in the water.

Loll

Lolling is the inclination of a ship to an unstable state caused by large volumes of water stowed high in the ship. Loll is commonly caused by free surface liquid. The sloshing of the water on the upper surface of a ship can cause the ship to flop from side to side. This can be a very dangerous situation. Loll can also be caused by weight being added to the top or upper areas of a ship, or by the removal of weight low in the ship.
If free surface liquid is added high up in the ship, it combines the dangerous effects of both free surface liquid and top weight.

Loll caused by free surface liquid can be reduced in any of the following ways, in order of priority:

(1) pumping or draining the liquid from the ship;

(2) draining the liquid from the higher to the lower and narrower compartments;

(3) reducing the free surface area by erecting longitudinal barriers; or

(4) filling up the compartment (this method should only be used for tanks or very small compartments low in the ship).

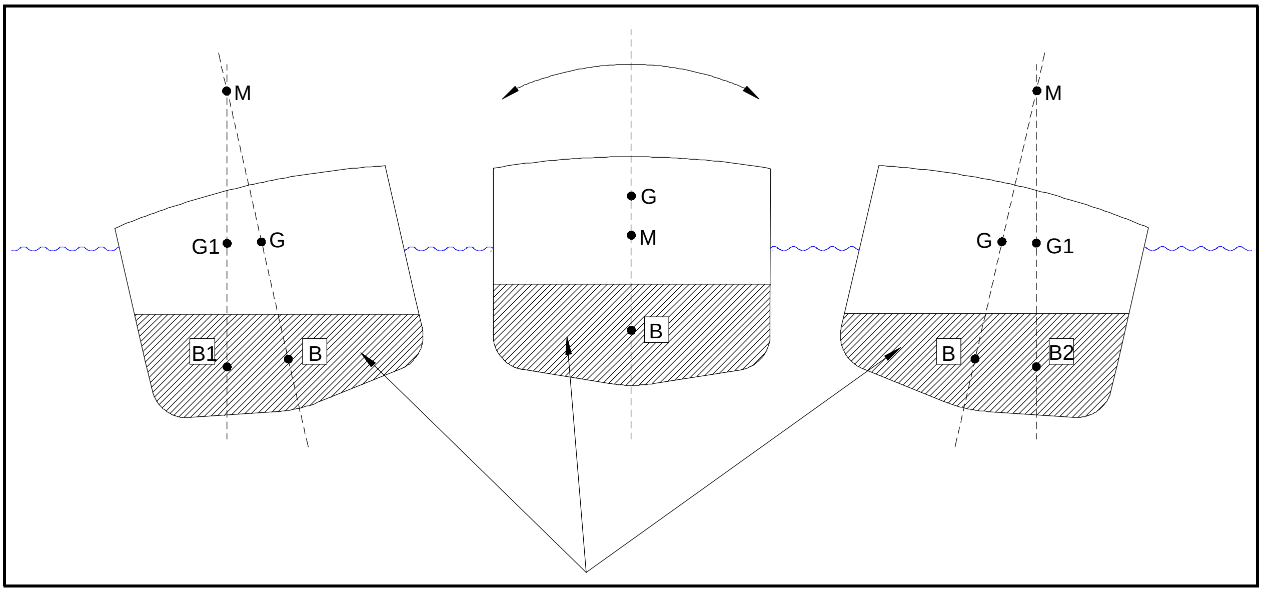


Fig 2.14 Loll Caused by Free Surface Water

NOTE

Before implementing steps in Items (2), (3) and (4), you must seek advice from the Master or senior officer of the ship. Liaison with these officers is most important because these operations may already be under way by the ship's crew.

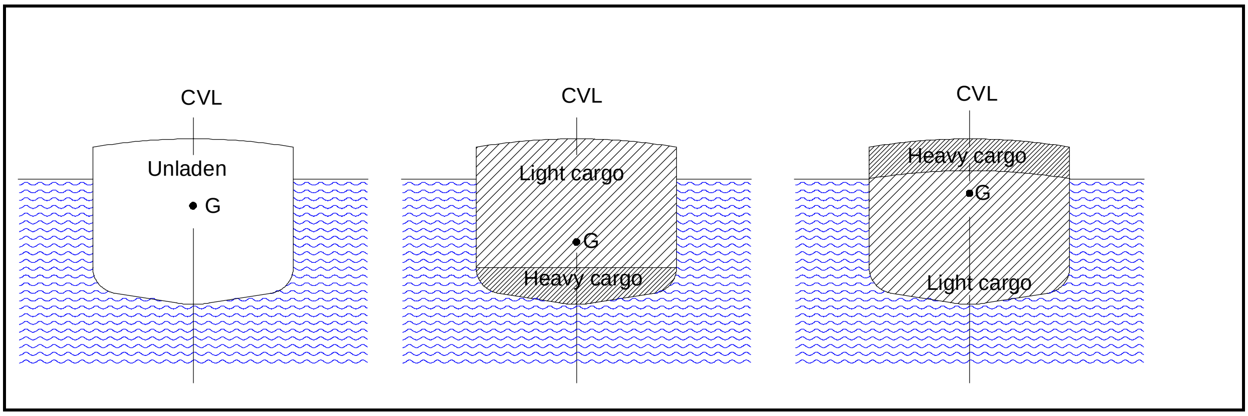


Fig 2.15 Effects of Loading on Centre of Gravity

Centre of Gravity

The centre of gravity (G) of a ship is the point through which the force of gravity acts with a force equal to the weight of the ship so that the ship stays afloat and balanced. The G is the balance point of the ship.

When a ship is loaded evenly and sits level in the water, the G lies on an imaginary vertical line drawn through the centre of the ship from the top down to the keel. This line is called the Centre Vertical Line (CVL).

The height of the G depends on the distribution of weight on the ship. Thus, when a heavy load is placed low in the ship, the G moves downwards from the point where it is located in an unladen ship. Conversely, when a heavy load is placed in the upper decks of the ship, the G is raised on the CVL.
If a cargo is loaded onto a ship so that the weight is unevenly distributed about the CVL, the G then moves sideways and creates a list in the ship.

Centre of Buoyancy

Due to the force of gravity, objects move downwards until they contact a resistance to their downward path. This resistance is most often the ground or the floor. This principle also holds true for any object placed into water.

When an object is placed into a liquid, the liquid exerts an upwards pressure on the object. This upwards pressure is equal to the weight of the fluid displaced by the object. When the weight of the displaced fluid equals the weight of the object, the object floats in the liquid.

Example

If you place a capped empty bottle into water, the bottle floats on the surface of the water. The bottle floats because it does not have to displace much water to equal its weight.

If you partially fill the same capped bottle with some water, the bottle will still float; but now it must displace more water to equal its weight. Hence, it floats partially submerged.

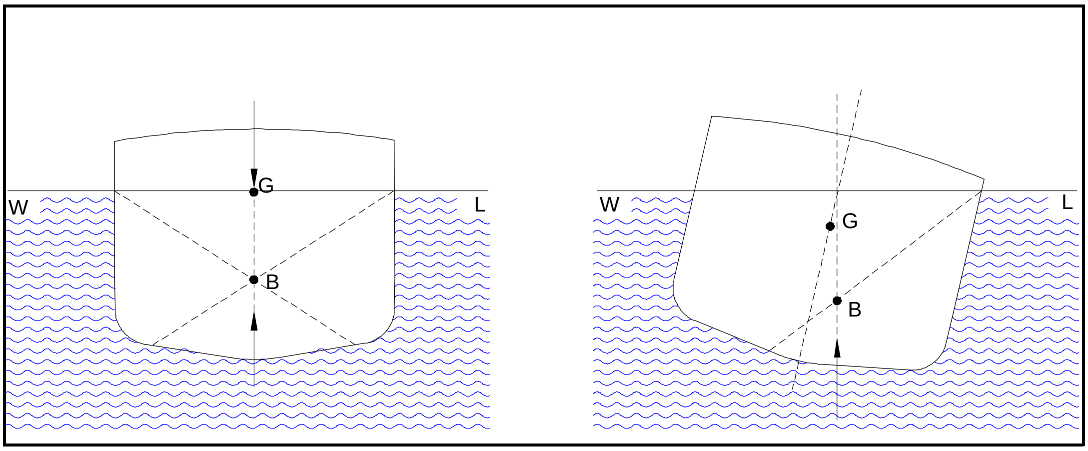


Fig 2.16 Change in Centre of Buoyancy due to a List

If you totally fill the same capped bottle with water, the bottle sinks. It will sink to a certain depth before sufficient water is displaced to equal the weight of the bottle and the water it contains. If you place the full bottle in shallow water, the filled bottle will sink to the bottom. But if you place the filled bottle in deep water, the bottle will sink only to a depth at which it displaces its weight. At this point it floats or becomes suspended in the water somewhere between the surface and the bottom of the water.

The resistance, or upwards thrust, of the water is called the **force of buoyancy**. As the filled bottle sinks in the water, when the force of buoyancy equals the force of gravity, the bottle floats or becomes suspended at that depth. The force of buoyancy acts along the CVL of a stable ship at a point called the Centre of Buoyancy (B).

The B is located at the geometric centre of the underwater volume. When the ship heels or lists, the shape of the underwater section changes, thus the centre of buoyancy moves away from the CVL to the new geometric centre of the underwater section.

Metacentre and Metacentric Height

The metacentre of a ship (M) is the point at which a vertical line drawn through the centre of buoyancy (B) intersects the CVL when the ship is heeling or listing.

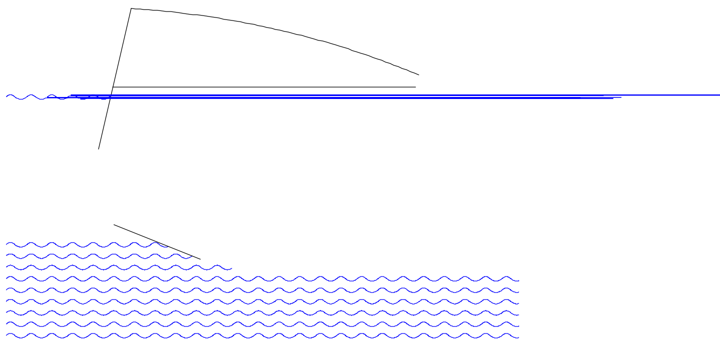


Fig 2.17 Metacentre of a Listing Ship

The Metacentric Height (MH) is the vertical distance between the G and the Metacentre:

- when the metacentre is above the G, the MH is positive; and
- when the metacentre is below the G, the MH is negative.

The MH of a ship determines whether a ship is stiff or tender.

- A stiff ship has a large positive MH. It strongly resists inclination and returns to the upright position quickly.
- A tender ship has only a small MH, inclines easily, and is slow to return to the upright position.

Weight distribution during the loading of cargo and equipment is critical for the stability of the ship. If the MH becomes negative, the ship loses its stability, and any inclination from the vertical can cause it to capsize:

- heavy cargo placed low in the ship gives a high metacentre; and,
- heavy cargo placed high on the ship gives a low metacentre.

A ship with too little MH becomes unstable as the MH approaches a negative value.

⚠ **NOTE**

Fire fighting systems applied to the upper areas of the ship reduce the MH, this can place the ship in danger of capsize.

2.4.3 Free Surface Effect

A ship has a fixed centre of gravity, when the ship's hold is totally filled, and no movement of liquid cargo can take place.

This situation changes dramatically if the hold is only partially filled with liquid. As the ship moves in a roll or list, the liquid in the hold flows to the low side of the ship. The centre of gravity of the ship shifts sideways with the flow of the liquid. This free surface effect is independent of the depth of liquid cargo and its location within the ship.

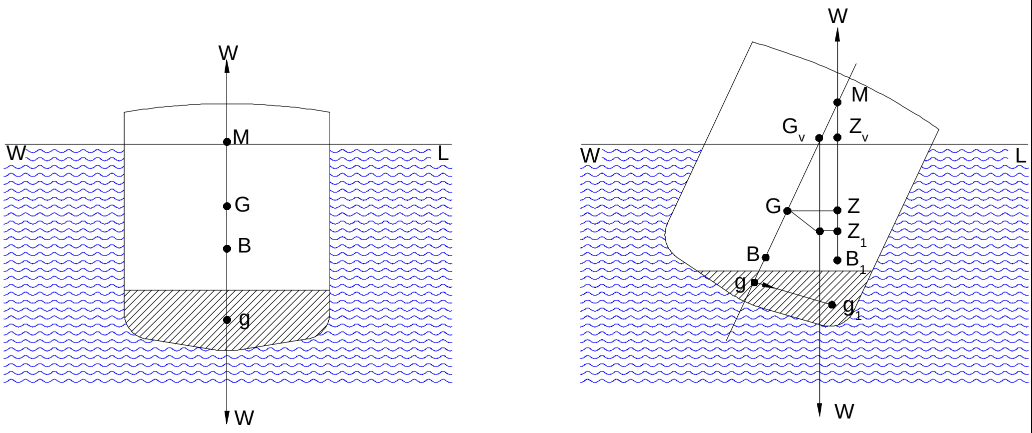
Example

Free surface effect can be demonstrated by considering a large flat dish partly filled with water. If the dish is not kept perfectly level, the free surface effect created makes it difficult to carry the dish from one place to another, without spilling the water.

Although the free surface effect shifts the centre of gravity sideways, the ship's stability is affected the same as if the centre of gravity were to be moved upwards along the centre vertical line. The MH is reduced, and this reduces the effect of the righting lever and consequently the stability of the ship is reduced. Fig 2.18 illustrates the free surface effect of a liquid in a partially flooded hold when a ship heels.

The illustration on the left shows the ship in an upright position.

The illustration on the right shows the ship in a heeled position.



Key:

G	Centre of gravity of the ship overall
g	Centre of gravity of the liquid
G_v	Centre of gravity created by free surface effect
M	Metacentre
B	Centre of buoyancy
GZ	Effective righting lever
No subscript	Original position
Subscript 1	Resulting position due to heel
Subscript v	Position created by total vessel weight

Fig 2.18 Free Surface Effect

NOTE

The G has risen, reducing the MH.

Free surface effect is an extremely important factor to consider when applying water to a fire. The presence of free surface effect depends on the total area of free liquids and not on the quantity or amount of water applied. Longitudinal bulkheads will break up the free surface liquid and reduce the effect.

2.4.4 Stability During Fire Fighting

When fighting a ship fire, all the water added and remaining in the ship, increases its draught, reducing freeboard and buoyancy. Thus, the following points effect the ship's stability:

- water in an outer compartment of the ship will result in asymmetric loading and cause a list;
- added water in the upper deck compartments will add top-weight and reduce stability;
- partially flooding a compartment will create a free surface effect;
- completely flooding a compartment low in the ship increases the righting forces, and a free surface is created while the compartment is filling; and
- loose water in a compartment must be removed as soon as possible.

CAUTION

When a ship lists away from the wharf, the hawsers holding it will be tightened up on one side, and if a hawser should break, the whiplash of the severed end is capable of killing anyone caught in its path.

2.4.5 Ships in Shallow Water

Both the depth of water and the profile of the bottom of the harbour may have an effect on a ship's stability. Where there is little clearance between the ship's keel and the bottom of the harbour, application of large quantities of water to a fire, may cause the ship to settle on the bottom unevenly.

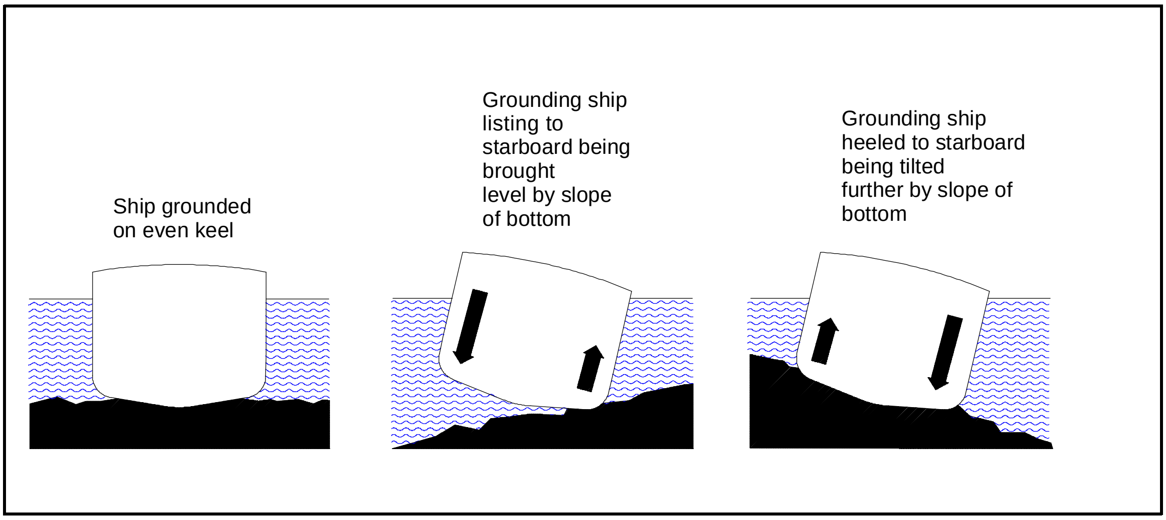


Fig 2.19 Examples of a Ship Settling

If the bottom of the harbour is even, the ship will probably settle into a stable position. A rising tide can then refloat the ship and cause a stability problem. If the bottom of the harbour is uneven, the ship may settle unevenly, and become unstable.

In Fig 2.19, listing ship is settling on an uneven bottom. The slope of the bottom is favourable, and it will tend to push the ship upright as it settles. This will reduce the stability problems. However, the heeling ship in Fig 2.19 presents a dangerous situation for the ship's stability as it is settling on a slope.

The bottom is sloping in the same direction as the list. As the ship settles, the list will be increased by the slope. If the ship were to slide off the slope, it could refloat with either a more pronounced list or it could begin to oscillate. In either case, the free surface water effect could cause the ship to capsize.

If the ship settles only on the stern or the bow, the stability will be reduced even further. This is due to the loss of buoyancy and the upward thrust provided by the bottom.

2.4.6 Capsizing

When a ship lolls due to the free surface effect of water, the ship moves slightly ahead of the water, as water will flow only downhill without assistance. As the ship reaches the extent of its loll to one side, the righting movement comes into effect to bring the ship back to level. The ship builds up momentum and does not stop in the upright position, but proceeds past the vertical upright position.

Normally, the ship would rock from side to side in decreasing degrees until it reaches equilibrium. Because the ship's movement is slightly ahead of the water, the water shifts across. This movement builds up momentum. By the time the ship has reached the end of its arc, the water arrives. If there is a sufficient amount of water flowing back and forth, the force of the water's momentum hitting the side of the ship, combined with the weight of the water, can cause the vessel to capsize.

In most instances, ships that have capsized in a port have capsized in the opposite direction to the initial movement. Thus, if the initial loll was to starboard, the ship would capsize to the port side.

⚠ **NOTE**

An important point for firefighters to note is that if a ship initially lolls severely away from the wharf, it is most likely to capsize towards the wharf endangering firefighters,

their appliances, and equipment. Severe damage can result as the superstructure, masts, derricks, and containers hit the wharf.

2.5 Fire Fighting Systems

2.5.1 Introduction

The requirements of a ship's on-board fire protection system vary with the type and size of the ship. There are international standards for fire protection systems on board ships. The responsibility for implementing these standards rests with the individual countries. The ship's master is responsible for the maintenance and serviceability of the equipment on any given ship.

Whilst firefighters can expect ships to have fire protection systems in place, the systems may not be in a serviceable condition. It is also possible that the CO_2 or Halon systems may have been depleted by an earlier fire incident at sea.

2.5.2 Fire Suppression Systems

Although all ships have fire suppression systems fitted, the type of system on board depends on the age, type, and size of the ship. Large modern ships carry a minimum crew. Much of the ship's activity and functions are monitored and carried out by computers. These ships have a competent fire detection system that monitors the conditions and activates gas discharges or sprinklers in the event of a fire.

Ships carry fire mains and sprinkler shore connection adaptors that adhere to international standards. These connection adaptors ensure that land-based firefighters are able to pressurise an activated on board system or main.

There are seven types of fire suppression systems used on board ships:

- steam injection;
- sprinkler;
- carbon dioxide flooding;
- halon;
- inert gas injection;
- foam; and
- water mains.

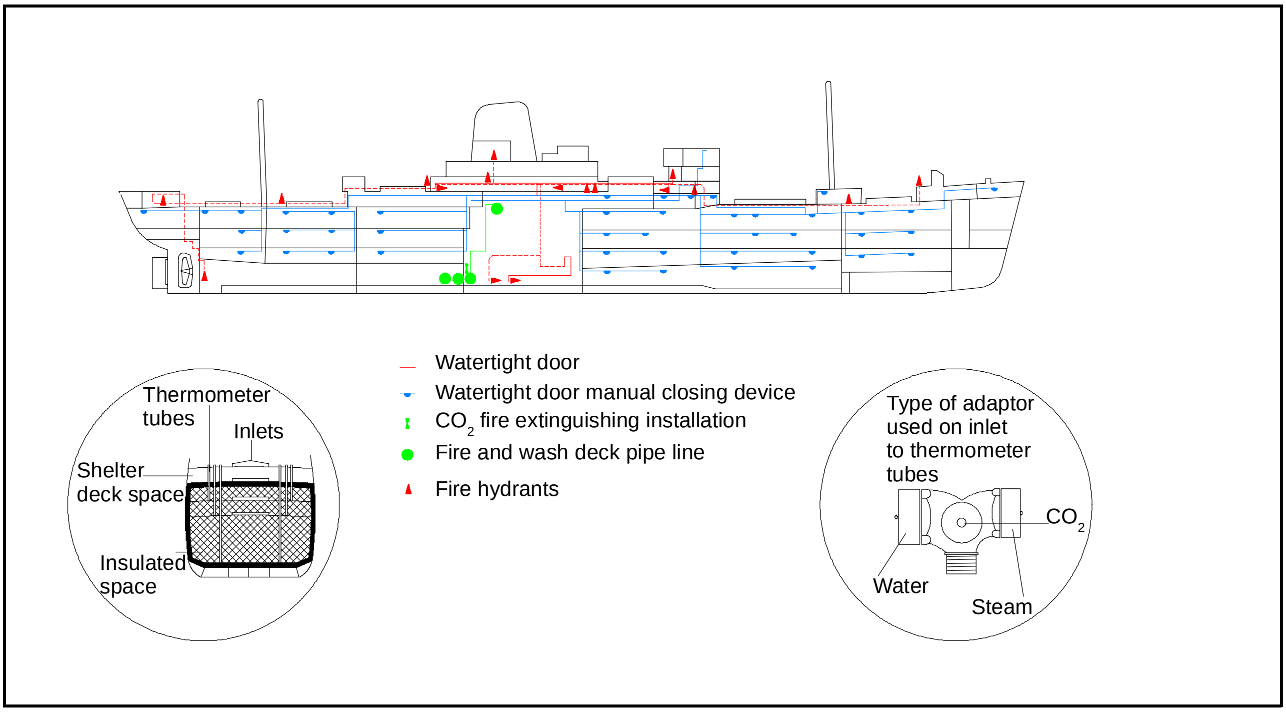


Fig 2.20 Fixed Fire Fighting System Carrying Water and CO_2

Steam Injection

Steam extinguishes a fire by displacing the oxygen from the air. As the moisture from the steam condenses, it slowly saturates the cargo. Steam is available in continuous large quantities on board some ships. If it is available, steam is a very suitable fire suppression system. However, marine boilers cannot normally use salt water. This means that the steam must be generated from fresh water. And this means that the effectiveness of a steam system is limited by the availability of fresh water.

Steam systems have some disadvantages in that:

- much of the steam is likely to condense quickly when steam is first applied to a fire. This means that large quantities of steam are required to fight a fire;
- steam produces effects similar to water. If the use of water is inappropriate, then likewise the use of steam is also inappropriate. For instance, steam cannot be used on cargo where water may produce dangerous gases or cause a cargo to swell. Additionally, water may render explosives unstable;
- the use of steam can cause a vacuum, especially where steam is used intermittently. Steam can cause a rush of air, and this can intensify the fire. The air may be sucked into the fire during the early stages of the application of the steam when the steam is condensing into water; and
- steam can cause as much damage as water.

Firefighters are unlikely to use the steam themselves. The OIC of a fire fighting operation may request the ship's master to arrange the use of steam. Steam in quantities sufficient to flood a hold would be available only on old steam-driven ships. These older style ships have the capacity to deliver a continuous supply of low pressure steam. Modern ships use only small quantities of high pressure / high temperature steam. This type of steam is unsuitable for fire fighting.

Sprinklers

Some ships use permanently charged automatic sprinkler systems in accommodation and service areas. These systems include a pressure tank that contains a standing supply of fresh water and a pump that draws sea water automatically if the tank pressure drops. Sprinklers that have been activated are indicated in control areas.

Ships have fire **main** inlets fore and aft. You can connect your appliances to these inlets. This enables you to pump water from the shore directly into the sprinkler system. A ship's sprinkler system is used by firefighters similarly to how you would use them to fight a fire in a building.

In addition to the sprinkler system, some ships have a water-spray system. This system is located over the bilges and the tank tops and over areas of special risk in the machinery spaces. Ships carrying bulk liquefied gases generally have more extensive systems.

Sprinkler systems have some disadvantages in that:

- the water from sprinkler systems can cause flood damage;
- the water from the system can create instability of the vessel by flooding it;
- the system may need to be fed from fresh water tanks, and this can limit the supply of water;
- the system can become inoperative if the power system fails; and
- the water from the system can damage the cargo.

Carbon Dioxide Flooding

A carbon dioxide system may form part of a ship's fixed fire fighting installation. This system is generally recognised as more efficient than a steam system for smothering a fire. It is supplied from an on board battery of cylinders.

In the event of an on board fire incident, the NSWFB can obtain additional supplies of carbon dioxide gas from the manufacturers. The manufacturers will supply the gas in bulk tankers directly to the incident.

Carbon dioxide extinguishes a fire by reducing the proportion of oxygen in the air around the fire. When oxygen is reduced to a certain level, combustion can no longer be supported. The level of oxygen that must be reached to eliminate combustion varies according to the cargo involved. If you need to calculate the amount of required gas to be used in an incident, you should make allowance for any gas that may escape through openings around the fire.

There are two types of fixed CO_2 systems used on board commercial ships:

- CO_2 Systems for fighting cargo fires

Class A fires in cargo holds usually start with smouldering. This can produce large quantities of smoke. Rapid burning of the cargo usually does not occur until a high temperature is reached at which combustibles in the cargo will support the fire. Until that temperature is reached, the rate of combustion is slow.

It can take as much as 20 mins for flaming combustion to occur after a smouldering fire is discovered in a ship's hold. This delay can give sufficient time to prepare for fighting the fire. You should first seal the cargo hold. You should then release several cylinders of the CO_2 simultaneously. This multiple release helps to reduce the oxygen level below the rate required to support combustion.

- Total Flooding

Fires that occur in a ship's engine room and machinery spaces are generally **B** Class fires. This type of fire produces an intense build-up of heat. The safety of the ship depends on the timely introduction of available CO_2 gas. This rapid action also prevents heat from causing the failure of the bulkheads. If the bulkheads fail, it is virtually impossible to maintain a sufficient concentration of carbon dioxide in the hold. Quick release of the extinguishing CO_2 agent also prevents heat updraft from the fire carrying away the carbon dioxide. This rapid action also helps to limit the extent of damage to the equipment.

If you are using CO_2, you should try to discharge 85% of the required quantity within two minutes. However, if you are attending an incident involving roll on/roll off cargo, you should attempt to discharge 100% of the contents within the two minutes. If the CO_2 is released too slowly, the extinguishing gas may have very little or no effect on the fire.

To avoid the unintentional release of the CO_2 gas, you must activate two separate controls. One control releases the minimum amount of carbon dioxide required, and the other control operates the stop valve or direction valve.

Advantages

The use of CO_2 gas has two main advantages in that:

- CO_2 leaves most cargoes undamaged and unaffected; and
- it is carried as a liquid under pressure and does not require special pumps for application.

Disadvantages

The use of CO_2 gas has some disadvantages in that:

- cargoes that require a very great reduction of oxygen to eliminate combustion e.g. cotton or that generate their own oxygen e.g. celluloid cannot be extinguished by CO_2;
- CO_2 gas can be slow to penetrate to some parts of a cargo hold or the cargo itself e.g. areas blocked off by cargo or if the fire is in the centre of a tightly packed bale;
- CO_2 gas at its initial release temperature is heavier than air and falls to the bottom of the hold. The bottom of the hold may be below the fire. Although the gas will eventually fill the affected area, there may be a delay in the extinguishment of the fire; and
- CO_2 gas has little cooling effect, and the cargo affected can remain hot for a long time. This increases the risk of the fire re-igniting.

NOTE

Where bulk CO_2 is required to fight a ship fire, the gas can be ordered only by the authorised Fire Officer. The owner, or the ship's agent, may incur the cost of the operation. Refer to *Standing Orders*.

Halon

Halon gas is supplied from a bank of cylinders on board the ship in the same manner as CO_2. Halon systems are used to protect engine rooms and oil pump rooms.

Advantages

Halon systems have advantages in that:

- only small quantities of Halon are required to extinguish a fire (5% by volume);
- Halon has a low toxicity;
- Halon is non-corrosive;
- Halon is chemically stable at normal

temperature and pressure, it is suitable for prolonged storage;

- the small quantity required for Halon to be effective allows the ship to carry more weight and to have more cargo space available; and
- Halon causes only a minimum reduction in visibility when it is in use.

Disadvantages

Halon systems have some disadvantages in that:

- Halon breaks down when it is exposed to flames. By-products of this break-down are sharp, acrid, and irritating;
- Halon has no cooling effect; and
- Halons are destructive to the ozone layer.

NOTE

The following special precautions must be observed when using CO_2 or Halon gas flooding:

- **the area to be affected by the release of these gases must be evacuated before the system is discharged. A predischarge alarm is required;**
- **the containers that store these agents must be located outside the area to be protected;**
- **in order to avoid accidental release on manual systems, you must perform two separate and distinct actions to discharge the agent;**
- **manual type stop devices are required on automatic systems;**
- **there must be an alternate means of discharging the system, and detailed instructions of the procedure for this release must be provided at the remote release station.**

CAUTION

There may not be any warning that a Halon system has operated.

Inert Gas Injection

Most ships run on diesel oil. When the diesel oil burns, it produces inert exhaust gases in the combustion process. This inert gas is 85% Nitrogen and 15% CO_2. When this inert gas is introduced into a fire area, it depletes the oxygen content of the air. The absence of air smothers the fire.

This inert gas can be also produced by specially designed burners using either coolers and water scrubbers or the main engine's exhaust system.

Advantages

The use of inert gas to fight fires has some advantages in that:

- it is non-toxic and non-corrosive;
- it does not damage the cargo;
- large quantities can be produced in a short time; and
- it is cheap to produce.

Disadvantages

The use of inert gas to fight fires has some disadvantages in that:

- the engine needs to be in working order;
- the gas has no cooling effect; and
- the gas is asphyxiating.

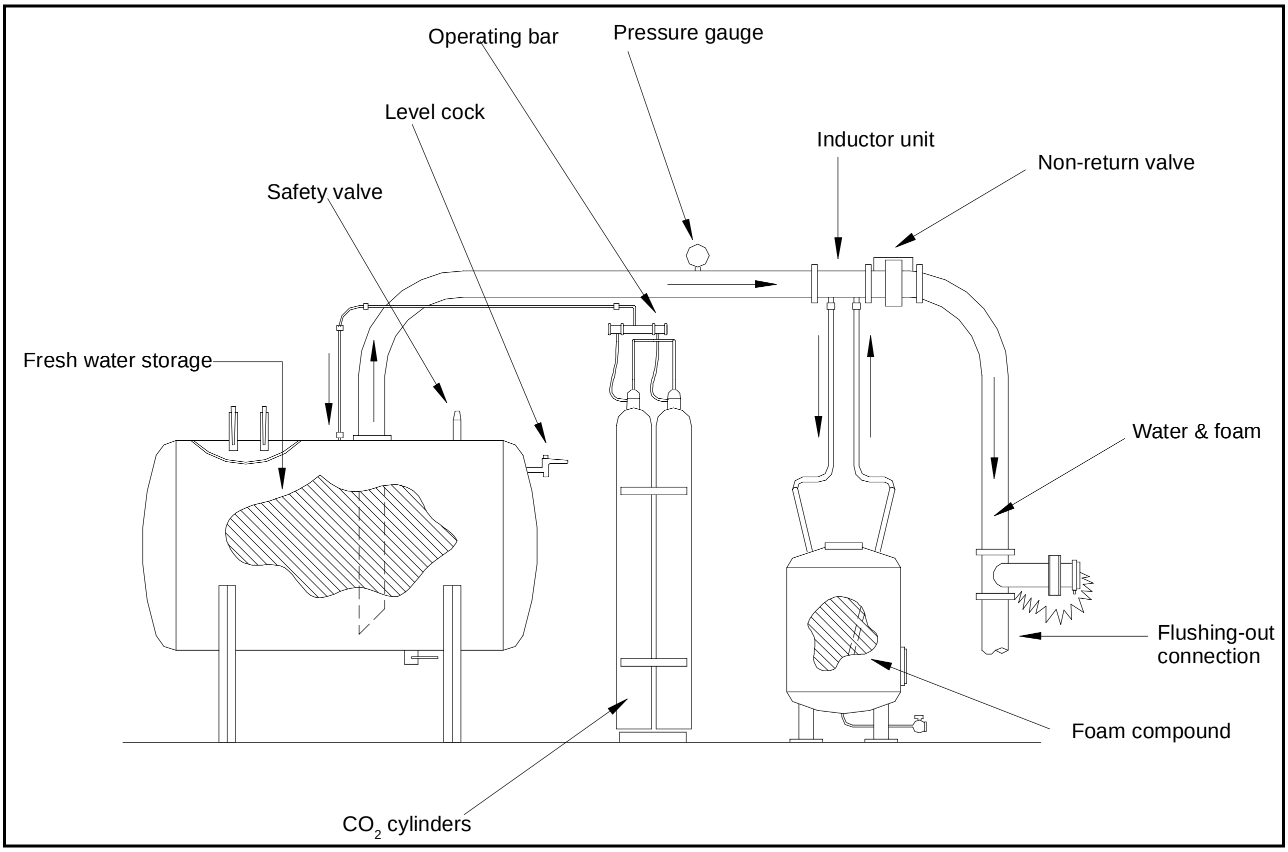


Fig 2.21 Self Contained Pressurised Mechanical Foam Installation

Foam

The foam used on board ships for fire protection is called a Fixed Deck Foam system. All tankers that carry combustible liquids or chemicals must have this system. It must be capable of applying foam over the whole cargo tank area and into all tanks and holds. The system comprises monitors, foam applicators, and valves. Various sections of the pipework can be isolated to treat a given affected area. The control stations are located outside the protected zones.

The foam used by these systems for fighting flammable liquid fires must be Low Expansion Foam, such as AFFF. High Expansion foam (Hi-Ex) is an ideal extinguishing media for use in ship fires carrying conventional cargo, but it is not appropriate for use on liquid cargo ships. Hi-Ex foam works well on conventional ships because it easily fills a hold space: there is no pressure to overcome above the foam. The foam flows into a hold under gravity.

Advantages

The use of foam has some advantages in that:

- it is effective on flammable liquid fires;
- it has a cooling effect;
- large quantities can be produced quickly;
- it uses less water than fire fighting water streams and this helps reduce cargo damage; and
- does not create problems with the ship’s stability.

Disadvantages

The use of foam has some disadvantages in that:

- cargo clean-up is more difficult;
- it is not as effective when used with salt water;
- it can conduct electricity; and
- foam bubbles absorb toxic gases.

Water Mains

Water is the most common fire extinguishing medium used by the NSWFB to combat fires and to cool exposures. All ships have water pumps and fire mains. The fire mains on a ship are commonly called Fire Services. These fire services are available on all decks. The fire main has a connection to supply water from a pump on the wharf. The inlet connections are normally both fore and aft and may have threaded couplings.

The fire main system provides fire fighting and flushing water throughout the ship. This system is the backbone of all fire fighting systems aboard. The quantity of water available for fire fighting is limited only by the capacity of the pumps supplying the system. Each vessel must have two fire pumps with suction inlets. The sources of power for the pumps are each located in separate spaces. This ensures that one fire incident does not put all of the pumps out of operation.

The size of the pumps required depends on the size of the ship, the type of service it provides, the arrangement of the pumps, and the system of piping aboard the vessel. Hydrants on the firemain system are located to allow two hose streams to be directed into those parts of the vessel that are accessible to passengers and crew.

Water can be applied to a fire incident on a ship by several means including lines of hose, monitors, in-built sprinkler systems, or by complete flooding of a hold. Flooding, however, should be considered only after consultation with the ship’s master and engineer.

Advantages

The use of water has two main advantages in that:

- the supply is unlimited; and
- it has a high cooling ability.

Disadvantages

The use of water has some disadvantages in that:

- it is likely to damage cargo;
- it may react dangerously with cargo;
- it can affect a ship’s stability;
- it always presents a danger of flooding; and
- NSWFB equipment may not fit ship-board connections.

2.5.3 Use of Systems

It is essential that you become familiar with a ship’s in-built fire suppression systems. Familiarity with the systems ensures that you will not waste time attempting to locate the controls for the in-built suppression systems. During an incident, it is very important to maintain liaison with the master and the engineer of the ship. If firefighters and the ship’s master and engineer all agree that a particular system can be used, firefighters can enlist the help of a crew member and can then activate the appropriate system.

2.6 Fire Fighting Techniques

2.6.1 NSWFB Powers

With a few exceptions, The NSWFB Act is applicable to most localities and in most incidents. Among the exceptions are docks that are private property and HMAS Dockyards. Even though the NSWFB jurisdiction does not extend to these exceptions, most of the organisations that have jurisdiction over the excepted areas still rely on local brigades. These organisations generally agree that the NSWFB can exercise firefighting powers in the event of a fire. Where there is a problem with the exercise of the powers of the NSWFB, the NSWFB should try to reach an agreement with the relevant organisation.

There are certain cases of special service incidents. For example, in the event of the leakage of hazardous materials, the NSWFB powers are more limited. If such an incident happens in a port, the harbour master is formally in charge. But he or she may wish to delegate some operational responsibility to the NSWFB. The delegation of this authority should be decided during preplanning. If such an incident happens while a ship is at sea, the master of the ship has overall responsibility and authority.

NOTE

For more information refer to Topic 11 Hazmat.

2.6.2 Responsibilities

Ships in Port under Construction or Refurbishment

Ships under construction are the responsibility of the ship builder. Ships under repair or refurbishment are the responsibility of the shipowner unless this responsibility has been delegated to the person or organisation doing the repair or refurbishment.

Ships at Sea

Ships at sea, in port, or in a harbour are the responsibility of the master of the ship. He or she is responsible for the ship, the cargo, the crew, and the passengers. In the event of a fire incident (even with fire fighting operations under way), the master of the ship can request that fire fighting operations cease and that the ship leave the moorings.

Ships Entering the Harbour

The harbour is under the responsibility of the harbour master. He or she has the ultimate right to refuse entry to a ship into the harbour if the ship is on fire or in some other dangerous condition. If the harbour master considers that a vessel is a danger to the port and dock installations, he or she can have the ship towed to a pre-planned beaching area accessible to the NSWFB.

Fire Fighting on Ships

When the NSWFB arrive at the scene of a fire incident involving a ship, the NSWFB officer-in-charge first contacts the ship's master or duty officer, and the engineer to obtain from them the ship's plans, manifest and other important details of the incident.

Here is a list of questions to which the NSWFB officer-in-charge will seek answers:

- Is anyone missing and/or injured?
- Where is the fire?
- What is burning?
- Have electrical supplies to the ship/ fire zone been isolated?
- How long has the fire been burning?
- How did the fire start?
- What action is being taken by ship staff?
- What is the condition of the ship's salt water service?
- Are there any dangerous compartments adjacent to the fire area?
- What is the condition of the ship's Fire and Emergency Team?

- Are there any problems with the stability of the ship?

- Is timber docking affected?

⚠ **NOTE**

This question is for ships in dry dock only

- Has a smoke boundary been set up?

- Are the main and auxiliary engines operating?

- Where is the manifest?

- Where is the plan of the ship?

The ship's on-board fire fighting installations, such as sprinkler systems, will probably be operating. If they are not operating, the NSWFB should deploy its own equipment and use the facilities on the ship as necessary. The ship's personnel can probably assist firefighters by operating doors, pumps, and valves. If ventilation equipment is running, consult the master or the engineer about turning it off.

Modern ships use computers and electronic apparatus to manage data and operate systems. In the event of a fire, these systems may not be operating. This can cause problems, e.g. if there is a fire, you may not be able to use the computer to get a printout of the cargo manifest.

2.6.3 Fire Fighting Precautions for Various Types of Ships

Container Ships

Containers to be carried by container ships are packed and sealed before being transported to a wharf for loading onto the container ship. Fire inside a container is very rare because there is very little oxygen inside the container. There are some exceptions; spontaneous combustion or a reaction between leaking chemicals can cause a fire in a container. However, since there is very little oxygen available inside the container, the fire will probably be a very slow smouldering fire. It may not burst into flame until the container is unloaded and opened.

Nonetheless, a fire involving containers on board a ship can pose difficulties. Containers are tightly packed on board container ships. Access to specific containers in a fire incident is all but impossible. Therefore some rearranging of containers adjacent to the burning containers is usually required. Sometimes the containers will need to be unloaded.

Guide Rails

Each stack or cell of containers consists of eight containers below deck and four containers above deck. Each cell is held in position by four vertical guide rails. If these guide rails become distorted by heat during a fire incident, the containers cannot be moved from their position or removed from the ship. The guide rails must be kept cool by water sprays. Damage to either the containers or to the guide rails on deck can cause the containers to slip. If this happens, firefighters and other persons in the vicinity may be injured.

Partial Container Ships

Partial container ships often carry motor vehicles as well as containers. These ships have very low deckheads. The lashings used to secure the vehicles can limit access to the container storage area. Access onto these ships can be very difficult because they often have a very high freeboard and narrow gangplank.

Refrigerated Containers

Refrigerated containers are refrigerated either by a self contained plant or by connection via ducts, to the ship's refrigeration system. The holds that carry refrigerated cargo are insulated. Both the ducting and the insulation can promote vigorous fire spread.

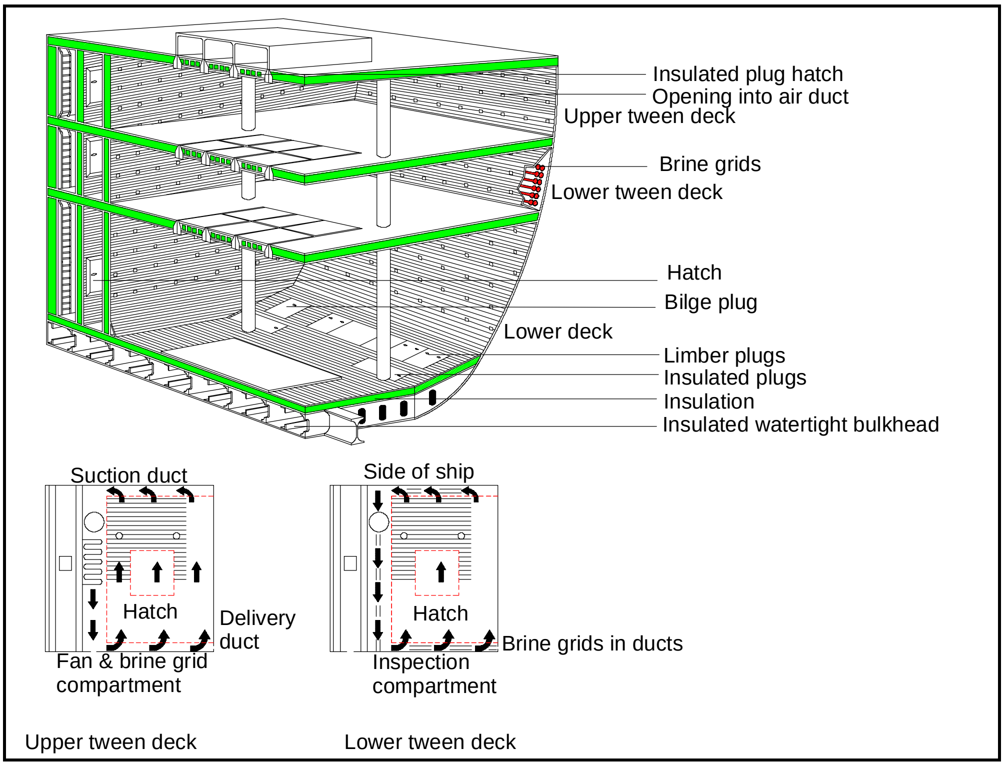


Fig 2.22 Sectional View of a Type of Insulated Ship

Ducting Samplers

Samplers are fitted where connecting ducts pass through a bulkhead. To prevent fire spread in these areas, these samplers must be closed and secured. In the event of a fire in the refrigerated area, you should close down the refrigeration plant and watch for signs of heat on the bulkheads and on the partitions adjacent to the fire. Fig 2.22 illustrates the insulator, brine grids and plug hatches

Passenger Ships

In the event of a fire incident on board a passenger ship, the passengers will most probably need to be evacuated. As a firefighter, you may not be involved in the actual evacuation exercise. However, if the passengers are distressed or panicked, your immediate tasks of locating the fire and manoeuvering equipment on board, may be made more difficult.

Several factors contribute to the confusion in a fire incident on a passenger ship. The names and locations of the decks, passageways, cabins, public areas, and service areas are even more confusing in a time of emergency. People lose their orientation, and you may have trouble locating the fire. Additionally, the long corridors, stairwells, and lift shafts can all create strong draughts and increase the difficulty of containing the fire spread.

Tankers

When you attend a fire incident on a tanker, you deal with it in much the same manner as you would deal with an incident involving an oil tank on shore. If there is a fire in more than one tank on board concentrate on one tank at a time. When the fire has been extinguished, you should maintain a thick foam blanket on the affected area for several hours until the ship’s plates and affected oil has cooled. Any water applied to the side plates of the ship to cool them must not be allowed to enter the tank. Water in the tank can cause the burning oil to overflow.

Bulk Chemical Carriers

Bulk chemical carriers often carry materials that are incompatible. These materials can react with each other to cause a fire or increase the dangers of a fire risk. Although stringent safety regulations cover the handling of these materials, problems do arise and incidents do occur. In dealing with incidents regarding these materials, you must be guided by the expertise of the owner or manufacturer of the products and by specialists familiar with the product.

Gas Carriers

With gas carriers, the ship's stability and the presence of slack tanks are two factors that can affect your ability to deal with an incident on board.

The stability of the ship is of the greatest concern when you are fighting a fire on a gas carrier. Configuration of the tanks usually does not provide good ballast capacity. The stability of the ship is easily disturbed. It is essential to maintain a close liaison with the harbour master, the ship's engineer, and the fire officer-in-charge throughout the fire fighting operations.

Ship Stability

The design of a refrigerated gas carrier requires that ballast water and cargo must be handled simultaneously. Given that liquids can shift and slosh, all care must be taken to maintain the ship's positive stability.

In the pre-planning stage, when you are considering emergency procedures, you should be aware of the possible need to move the ship away from the berth at short notice. In an emergency, this could be essential.

Slack Tanks

The design of a refrigerated gas carrier provides only a low margin of positive stability at any given time. This means that even small errors in loading of cargo can affect stability. Partially filled tanks further reduce the margin of stability. It is therefore essential for some ships that the tanks be fully laden before it can put to sea. The sloshing effect in partially filled tanks, especially during loading operations, can cause violent movement in the ship and affect its stability. This movement can prevent the ship from leaving its berth.

2.6.4 Fire Fighting Routines

Establish Contact

Immediately on arrival at a ship fire incident, you must contact the ship's master or duty officer to determine details of:

- the ship's configuration and structure (from the ship's plan);
- the cargo carried (from the manifest);
- any fire fighting measures that have been initiated;
- the fire suppression systems that are installed on the ship; and
- the state of the ship's stability.

Steps to Take

Immediately after making contact with the ship's officers, you should take the following steps:

- establish communications;
- establish source of water supply;
- connect pump to water supply;
- connect pump to ship's main supply;
- put on BA and establish BA control; and
- use guide lines.

Connect Auxiliary Electrical Power

On most modern ships, the ship's manifest is held in a computer system. To access the manifest through the computer, you will need electrical power. To ensure the availability, you should always use your own electrical power equipment, even though it may take a little longer to get it on board.

Interim Action

If the ship is operated by a minimum number of crew, it may take some time to gather the necessary information. This can be especially true if communication is hampered by language barriers.

While you are gathering the necessary information, you can take some interim action. You can remove combustible materials from the deck areas nearest the fire Also, you can use sprays or jets to cool the decks and bulkheads affected by heat.

Locating the Fire

If the ship's officers or crew know where the seat of the fire is located, they can advise you of the best route to reach it. If they do not know where it is, you must locate it before you can make an attack on the fire. To help you in your search for the seat of the fire, watch for the presence of smoke, see where the smoke is at its most dense, and search out parts of the ship's structure where there are high temperatures.

Opening Compartments

Hatches and hold covers on a ship are most often designed to be air tight as well as water-tight. Because of the danger of backdraught, you must be very careful when you open a hatch.

⚠ **NOTE**

The hatch size determines the number of fog streams required to effectively seal the opening.

You should use the following procedure to open a compartment or a deck hatch leading to a compartment:

- inspect the door for heat and heat damage by feeling it with the back of a gloved hand; this will give you an indication of the size of the fire;
- run out two hose lines. Use one to apply the fog stream to cool the door and bulkhead and the second for fire attack;
- direct the fog branch at the centre of the opening when you are ready to open the door;
- assume a crouching position before opening the door;
- open the door slowly and be prepared to close it quickly again if necessary;
- protect the fire fighting team by sealing the opening with fog as you open the door.
- with the fog still sealing the opening, attack the fire from behind the protective fog with the second hose line using a spray or jet; and
- as the fire is controlled, advance both teams into the compartment to extinguish the fire.

Fire Fighting in Specific Areas

A ship is similar to a small town in that it must sustain the crew for long periods of time. A ship provides accommodation areas, engine rooms, cargo spaces, galleys, recreation areas, food stores, freezers, fuel stores, and more. Fires can occur in any one of these areas of the ship. Each one presents a different scenario for firefighters. We will deal with some of these areas below.

Accommodation Areas

If the ship's crew has not attacked the fire by the time firefighters arrive, the fire probably has developed to the stage where portable fire extinguishers are of little use and you will have to use water. You should use a combination attack of a fog stream and a spray or jet for quick extinguishment.

Cabins

All cabins on a ship contain furniture, carpets, bedding, and wooden doors. All of these items must be attacked quickly to prevent the spread of the fire. You should check all areas adjoining the fire area for signs of fire spread.

Doors and Portholes

To prevent draughts and breezes feeding oxygen to the fire, all doors and portholes should be closed in areas not affected by the fire. Keep all doors of burning compartments closed until the fire fighting teams have their equipment ready to enter the affected area.

Breathing Apparatus

You must use Breathing Apparatus. Until the fire area can be thoroughly ventilated, the smoke will be extremely thick and dangerous.

Electrical Power

If the electrical power is still turned on, you should contact the ship's engineer and request isolation of the affected area. You must obtain confirmation that the power is off before you commence your attack on the fire.

Engine Rooms

Fires in the engine room of a ship can be very dangerous. You should make a rapid attack on an engine room fire to ensure that all firefighters spend as little time as possible in an engine room fire area.

First Steps

A fire in the engine room will probably involve fuel oil. A small fire may be extinguished using portable extinguishers. In a large fire, you should shut-down the fuel supply, close down the ventilation system, and close the hatches, doors, and skylights to restrict the oxygen flow to the fire. You can then effectively attack the fire with fog streams. To attack a fire in an engine room that has developed to a more serious stage, you will need to use fixed installations such as sprinklers. Once you have extinguished the engine room fire, then open the area for ventilation.

Use of Carbon Dioxide

You should not use carbon dioxide flooding while firefighters are in the area, and it is unlikely to be effective if heat builds up before it is introduced. If you do use $CO_{2,}$ leave the affected area closed for at least ten minutes to allow the burning materials to cool below their ignition temperature.

Entrance to Engine Room

You should enter the engine room through the shaft tunnel. All ships have a hydrant outlet at the shaft tunnel entrance. Gases and smoke rising to the top of the engine compartment and the likelihood that the stairs will be slippery, make entrance through the engine room doors dangerous.

Electrical Power

The ship's electric power is produced by generators in the engine room. Many electrical cables run through the bulkheads. When you are fighting an engine room fire, the generators must be shut down.

Cargo Spaces

To attack a fire in a cargo space, you will need information about the type of cargo involved and the way it is stowed that is, whether it is stowed as bulk or in containers. For instance, if you are fighting a fire in a container, you must first take steps to isolate the container from the rest of the cargo.

Breathing Apparatus

Use of BA is essential, as extreme heat can reduce the time you will be able to work in a fire on board ship. As you open the hold area, be aware of the initial risk of hot gases and smoke.

Use of Water

An attack on the seat of the fire will provide the greatest chance of rapid extinguishment and minimal water damage. Where possible, you should apply the hose streams from within the hold use adjustable pattern branches. If you cannot apply hose streams from within the hold, you can direct them into the hold from the hatch above, in the direction of the seat of the fire. While the fire is being attacked, crews should apply cooling sprays to heated bulkheads. This helps contain the fire.

If you are going to use water on a fire on board a ship, you must notify the ship's officers. One of these officers must be appointed as the ship's Stability Control Officer. You must keep this officer constantly informed of the amount of water you are applying and of its precise position.

Firefighters measure water application in litres per minute (L/min). You must furnish this information to the Stability Officer, but the Stability Officer needs this information in tonnes per hour (t/hr) of water being applied. You need to know the water output of the branch you are using in L/min and you then convert that information to t/hr:

Example:

One AWG Branch with 22 mm nozzle at 700 kPa delivers:

768.311 L/min

46,098.66 L/hr

46.098 t/hr.

Use of Flooding

You should flood a ship's fire only as a last resort. Although flooding the lower holds can be practical and efficient, you must control this operation very carefully. You must determine whether there is sufficient depth of water beneath the keel so that stability and fore trim and aft trim of the ship can be maintained. You should seal the flooding area and see that all connecting water tight doors are closed. This helps to ensure that other areas will not be flooded as well.

Sinking the Ship

If the fire is too advanced to be extinguished by flooding the individual holds, it may be necessary to sink the ship. If this is necessary, you should contact the Harbour Authority. They will arrange to have the vessel towed to a point where there is sufficient depth of water to sink it.

Getting Water Aboard

All ships over 1000 t are required by *International Maritime Law* to provide an international shore connection on both sides of the ship. The purpose of the International Shore Fire Connection is so that local firefighters can connect the water supply from shore to a ship's fire main or to the fire mains of two ships. This shore fire connection provides a standardised joint between two systems of possibly non-matching couplings.

Use of Carbon Dioxide

CO_2 gas can be effective in fighting a fire in a cargo hold. Flood the hold as you would flood the engine room in the event of an engine room fire. Shipboard supplies of CO_2 may be insufficient to successfully extinguish a fire in a cargo hold. Be aware that the on board supply of CO_2 may require topping up.

If you flood a cargo hold with carbon dioxide, you must then completely seal the area to prevent the entry of oxygen. You will then need to monitor the heat output in the holds adjacent to the affected area. If the bulkheads, decks, and hull adjoining the flooded hold begin to show consistent cooling, you can assume that the fire has been extinguished. You can then prepare to open the hold. Prepare charged lines of hose in case the fire re-ignites.

Extinguishing the fire and cooling of the adjacent areas may take several days. To ensure the maintenance of an inert atmosphere during this time, you will need additional supplies of CO_2. Equipment used to deliver bulk CO_2 is kept at HAZMAT Fire Stations.

Use of Foam (Hi-Expansion)

If you decide to use foam stocks, you should consider whether the first applications of foam may break down because of the heat in the hold. Convection currents also can prevent the foam from initially settling. You will probably need to vary the rate of application and the ratios so that you can make an extra-heavy attack of foam in the first instance.

The use of foam may be effective only as an interim measure. This initial application of foam can enable you to penetrate the area with water jets to extinguish the fire. In some cases, however, the foam may be successful without any back-up.

A cargo fire can take several days to become completely extinguished. The length of time required will depend on the type of cargo, the depth of the fire, and the length of time the fire has been burning.

Handling Cargo

It may be necessary to move cargo to reach the seat of a fire. If this need arises, you and your team must be prepared to move the cargo yourselves. To move the cargo, you should seek advice and assistance from a skilled stevedore. If a dispute arises about who should handle the cargo, the stevedores should handle the cargo. This leaves you and your team free to carry out damping down. As the cargo is moved, you should inspect it for signs of fire and extinguish the fire as necessary. You should also take particular care with the equipment that is used for moving the cargo e.g. A grain conveyor belt may draw up fire along with the grain. Partially burnt bales should be opened up only after they have been moved onshore, and the fire must be extinguished using jets.

Galley Spaces

Most galley fires involve either fuel used to power the ovens and stoves, or burning fat. On these fires, you should use foam, CO_2, Halon, or dry chemical extinguishers. Gas fires are extinguished by shutting off the supply.

Firefighters called to attend a galley fire can usually expect one of two conditions:

- the fire has been extinguished by the crew, and it will then require a careful inspection of the area for signs of fire spread; or
- the fire has intensified, and it involves a much larger area than it occupied originally.

After you size up the situation, you should apply normal fire fighting procedures. You may find that the best procedures are those you would use for a fire in an accommodation area.

Oil Fires

In attacking an oil fire, you should first ensure that tank covers are in place and all openings are sealed. You can then inject inert gas or foam into the tank. Use water sprays to cool the surrounding deck area. Remove all flammable and combustible materials from the area. Fog streams are effective in fighting oil fires as they create an emulsion and cool the oil.

Electrical Fires

For fighting an electrical fire, you will probably use normal fire fighting procedures. However, when you are attacking an electrical fire on a ship, you must pay special attention to the fact that both salt water and foam are effective conductors of electricity.

CAUTION

It is essential for the safety of the fire fighting team to ensure that the electrical power supply is disconnected to all areas involved in the fire.

2.6.5 Important Points to Remember

- Remember that every ship is different: no two ships are alike. The different types of cargo require that you consider each incident individually.
- Consult with the ship's officers and crew for construction details of the ship and to identify the locations of dangerous cargo and hazards.
- Seek advice from the ship's officers and crew on access and escape routes to and from the ship and on the state of the ship's stability.
- Provide first for escape for personnel below deck. Immediately upon arrival, establish at least one escape route.
- Find out as much as you can about the type of vessel, its cargo, and the state of loading.
- You will normally gain access to a ship board fire from the top. For access to the seat of a fire in the bilges, you must first penetrate the areas of the greatest heat.
- A fire can spread very quickly through the air conditioning ducts. The ducts can carry the fire great distances from the point of origin. Bulkheads made of steel can be dangerous as they can transfer heat very rapidly.

2.7 Fire Fighting and Emergency Tugs

In NSW, we have only a few fireboats that are built for the sole purpose of fighting fires. However, some authorities and industries have access to fire tugs. Some of these authorities and industries maintain their own fire tugs; others have them available on call in an emergency. In many instances, these fire tugs are normally employed as ordinary tugs in the port area, but they are equipped to assist the NSWFB when an emergency arises.

Port Authority Emergency Tugs

The *Port Authority* has tug boats for emergency services in the ports of Sydney and Botany Bay. All of these tugs are equipped with water and foam-based fire fighting equipment.

The vessels are Class 2C vessels. They are built as Class A fire fighting ships, outfitted to the highest marine standard, and fully air conditioned. They are fitted with twin screws and *GM* marine diesel main engines that produce 700 BHP. A 100 hp transverse-tunnel bow thruster is driven from the starboard main engine. Each tug is equipped with a quick release towing hook, hydraulic crane, and equipment for dealing with oil spills.

Dimensions

Table 2A details the principal dimensions of a fire fighting and emergency tug.

DIMENSIONS	MEASUREMENT
Length overall	24.5 m
Length waterline	23.5 m
Breadth	8.0 m
Depth	4.0 m
Design draught	3.0 m
Trials speed	11.0 kts
Bollard pull	18.0 t

Table 2A Tug Dimensions

Capacities

Table 2B details the appropriate capacities of a fire fighting and emergency tug.

CAPACITIES	MEASUREMENT (L)
Fuel oil (95 %)	33 000
Drinkable water	10 000
Salt water ballast	40 000
Foam concentrate (alcohol resistant)	14 000

NOTE

At 6% concentration, that is sufficient to supply monitors for approximately 25 mins; at 3% concentration, 40-50 mins.

Oil pollution dispersant/ concentrate 5000 L.

Table 2B Tug Capacities

The Primary Monitor

A primary fire monitor is capable of producing 10 200 L of water or 60 000 L of foam per min and two secondary monitors have a capacity of 3000 L of water or 18 000 L of foam per min.

Each primary monitor is supplied by a diesel-driven pump while a pump driven from the port main engine supplies the secondary monitor, deck hydrants and a self-protection spray system.

The primary monitor is telescopic. It is controlled automatically from the wheel house of the vessel. It has a maximum range of 90 m when using water. Fully extended, it is 17 m above water level. The secondary monitors can be directed manually.

Additional Equipment

Secondary Fire Monitors

The secondary fire monitors are two *Skum* MK-80. They are controlled manually. They have a water delivery capacity of 50 L per second each, and a foam delivery capacity of 300 L per second, with fog-jet nozzles available for fitting if required. Operation is by a pump driven from port main engine. This pump also supplies fire hydrants and a self-protection spray. The pump doubles as a salvage pump when it is not being used for fire fighting.

Fire Hydrants

On each fire tug, there are seven fire hydrants, six fitted on deck and one fitted in the engine room.

Self Protecting Spray System

Each fire tug has two searchlights. They are controlled remotely from the wheel house.

Portable Equipment (minimum quantities):

- seven fire hoses, 15 m x 64 mm (threaded couplings) stowed in boxes adjacent to hydrants;
- six fire hoses, 30 m x 64 mm (threaded couplings);
- seven *Quell/Ajax* No.2 fog/jet nozzles (one for each hydrant) stowed in boxes adjacent to the hydrants;
- three *Quell/Skum* MLR 400 hand-held water-foam branches;
- two *Storz* adaptors (male) 70mm;
- two *Storz* adaptors (female) 70mm;
- one international shore connection;
- two *Quell/Sabre* CABA plus four spare cylinders;
- two hemp covered steel life lines each 36 m and 1 t capacity;

- two close proximity suits;
- two insulated handle fireman's axes with belt and pouch;
- two safety lamps and charger;
- one automatic oxy-resuscitation unit;
- one set oxy-acetylene cutting equipment;
- one pair bolt cutters;
- one aluminium boarding ladder (extending to 7 m); and
- six pairs fire-proof overalls as crew protective clothing.

Private Emergency Tugs

Private tug companies provide the primary port protection for *Port Kembla* and *Newcastle* ports.

Table 2C summarises the private emergency tugs in various ports.

PORT	TUG
Sydney/Botany Bay	Wonga
	Wallace
	Manly Cove
Newcastle	Warrawee
	Botany Cove
Port Kembla	Korrimul

Table 2C Private Emergency Tugs

Communications

Radios on the *Port Authority* tugs have access to the NSWFB frequency. Privately owned tugs do not have access to this frequency. Therefore, a fire-duty radio is necessary on the privately owned tugs during emergencies. The fire-duty radio should be used during training exercises.

2.8 Pre-planning

2.8.1 Introduction

Ship-board fires create many hazards for firefighters, crew, passengers, and cargo. Pre-planning inspections of ships help to prepare the firefighter for an emergency prior to the incident and will assist the fire fighting team at the scene. The amount of information generated by an emergency can be overwhelming. No individual can be expected to remember all of the details, especially when they are working in an emergency situation. Ship inspections and pre-planning for such incidents ensure that the firefighters are equipped with critical information about the ship, its specific layout and likely cargo.

The structure of a ship can be very complex with tight spaces, passageways, stairways and a confusing layout. on board a ship, a fire has many avenues through which to spread. You can be better prepared to fight a fire in this complex environment if you pre-plan your approach to the emergency.

The NSWFB has no authority to inspect ships. To carry out an inspection of a ship, you must have permission from the ship's master or representative.

2.8.2 Elements of Pre-Planning

Pre-planning for fire incidents on board ships comprises three elements:

- identify threatening situations;
- identify variables of fire control;
- communication with ship's personnel

Identify Threatening Situations

During your inspection of the ship, you identify the areas that present the greatest risks to life, limb, and property. You then prioritise these risks to determine which ones pose the greatest threat in terms of origin and spread of fire.

In this step, you should evaluate the following potentially threatening situations:

- the location of vertical and horizontal openings such as open stairways, long passageways, and hatches;
- the range of combustible materials on board and where they are located in relation to the avenues of fire spread;
- the status of the occupants of the ship and the extent of their knowledge of the ship;
- the sources of potential ignition such as flammable liquids, electrical hazards, and processing methods; and
- the construction details of the ship including combustibles used in accommodation and recreation areas.

Identify Variables of Fire Control

If you carry out an inspection of a ship with a logical sequence in mind, you will probably identify most of the variables of fire control. These variables include:

- the most likely areas of origin of a fire;
- the most likely path of fire spread in the interior;
- the potential hazards to life for occupants, bystanders, or firefighters such as explosives and hazardous materials;
- the best available means of entry and exit;
- the factors that affect and influence the behaviour of a fire such as vertical openings, horizontal openings, interior finishes, wall coverings, flammable liquids, and excess fuel loads;
- the factors that affect and influence the severity of a fire, such as fuel load, type of fuel, fuel distribution;
- the factors that can hinder fire fighting operations such as bolted doors, extra heavy roofs, and cargo stacked to roof level;
- the factors that can affect response time such as response routes, water supply, traffic problems, access limitations;
- the factors on site to provide early warning and reduce the fire spread such as built-in fire protection devices (smoke detectors, alarms and sprinkler systems), and structural features like fire walls; and
- the factors that may change on board after pre-plan inspections have been conducted and which affect operations such as personnel changes and rearrangements to the layout of the vessel.

In your inspection, you should also assess the possible avenues that a fire spread might follow. For example, in your inspection, ask if a fire starts at point A, will it spread to points B and C, or will it spread directly from A to C?

⚠ **NOTE**

Firefighters should familiarise themselves with the existing *Port Authority Fire and Counter Disaster Plan*, and *SOP* for ship fires and other port emergencies.

Communication with Ship's Personnel

Communication and co-operation between firefighters and the ship's personnel are absolutely essential. Often, the best way to establish good communication is to arrange for inspections and drills. These exercises give the firefighter the opportunity to compare theoretical and conceptual information with the real life situation on board ship. These exercises should be conducted on the ship and on the shore adjacent to the ship.

Ship Inspections

To familiarise yourself with the various types of ships and their specific features, you should make regular inspections of ships. Firefighters do not experience many ship fires. Hence, regular visits can help enhance your familiarity with the ship and the procedures on the ship. Without this familiarity, you may find yourself in a strange environment if you are called upon to attend a fire incident.

In your inspection of a ship, pay attention to the following areas:

- loading equipment;
- access to cargo areas;
- engine rooms;
- accommodation areas;
- operation of doors and hatches;
- firefighting installations;
- internal access ways;
- location of manifest;
- methods of isolating areas; and
- means of taking equipment aboard.

Practice Drills

As well as inspections, practice drills on board the ship can help enhance your skills and perception of the operations you will follow in the event of an incident.

In a practice drill, you should do at least the following:

- enter the engine room via the shaft escape and shaft tunnel;
- descend the stairs into the engine room and note the condition of the stairs they can be steep, narrow and greasy. During a fire, the metal railings and threads can heat up and pose a hazard;
- descend the hold ladders and ensure that the ladder hatches below are closed before you step off the ladder; and
- carry equipment such as hoses and branches aboard the ship by way of the gangplank.

Search and Rescue Drills

By arrangement with the ship's master, you can conduct search and rescue drills on board a ship. During these drills, use blacked out SCBA masks and guidelines to simulate moving about a ship in thick smoke. During the exercise, you can develop techniques for locating hatches, ladders, and doors. The experience you gain under these conditions can greatly enhance your effectiveness and your safety under fire conditions.

A good way to improve communication with the ship's crew is to do combined fire drills and to have a conference with the crew. These exercises can improve the co-operation between you and the crew and should not impose any operational delays on either the terminal or the ship. A joint exercise also helps to make the ship's personnel familiar with the firefighting equipment available ashore. In this exercise, you also have the opportunity to become familiar with the types and locations of firefighting equipment on board the ship. The crew can also instruct you on any design features of the ship which may require special attention in case of a fire.

2.8.3 Emergency Removal of a Ship from Berth

If a fire on a ship cannot be controlled, you may need to arrange to move the ship from the berth. You can improve conditions for a safer working environment in an emergency by practising and experiencing the tasks you may have to perform in this situation.

The removal of a ship from berth requires careful planning if you are to minimise the damage to the ship, the terminal, other ships berthed nearby, and other adjacent installations.

In your planning process, you should provide for several options. The nature of the emergency may mean that the crew of the ship is unable to assist in moving the ship.

The planning process must involve the Manager Port Services, the Harbour Master, the Ship's Master, and the Senior Fire Officer.

In the consultation to develop the emergency plan, you should provide for the following:

- designate the person or persons, in order of priority, who have the authority to decide whether to remove a ship which is on fire;
- determine the actions to be taken to protect ships at other nearby berths;
- designate the locations to which a ship on fire can be safely moved under controlled conditions.

In the emergency plan, you should provide for the following actions to be taken:

- closing shore valves,
- disconnecting hoses or arms,
- unmooring the ship, and
- operating fire fighting equipment without assistance from the ship's crew.

In your planning process, you should patrol local areas for a favourable firefighting site to which a ship could be moved in an emergency. It is far better to be able to work from a site that you have selected and with which you are familiar than to have to work under strange conditions.

Table 2D details beaching sites in the Sydney Harbour area to which a ship can be moved in an emergency. The nature of the bottom of each location is mud.

NO	LOCATION	AVERAGE DEPTH OF WATER
1	Spring Cove	10 m
2	South West of Sow and Pigs	8 m
3	Rose Bay	7 m
4	Double Bay	8 m
5	Little Sirius Cove	9 m
6	Farm Cove	10 m
7	Lavender Bay	10 m
8	Ball's Head Bay	10 m
9	Off Clarke's Point	9 m
10	Five Dock Bay	5 m
11	Hen and Chickens Bay	4 m

Table 2D Sydney Beaching Sites

2.9 NAVAL SHIPS

2.9.1 Introduction

Most fires that occur on *Royal Australian Navy* (RAN) ships are discovered by the crew soon after the fire starts. Generally, the crew is able to extinguish these smaller fires with fire extinguishers. However, some fires grow very large very fast. This may be due to the nature of the fire, such as a fuel fire in a machinery space. Or it may be because the fire was not discovered early enough to extinguish it with the smaller appliances. In an emergency on a naval ship, you need to be aware of the action already taken by the crew before your arrival and what action you should take when you arrive.

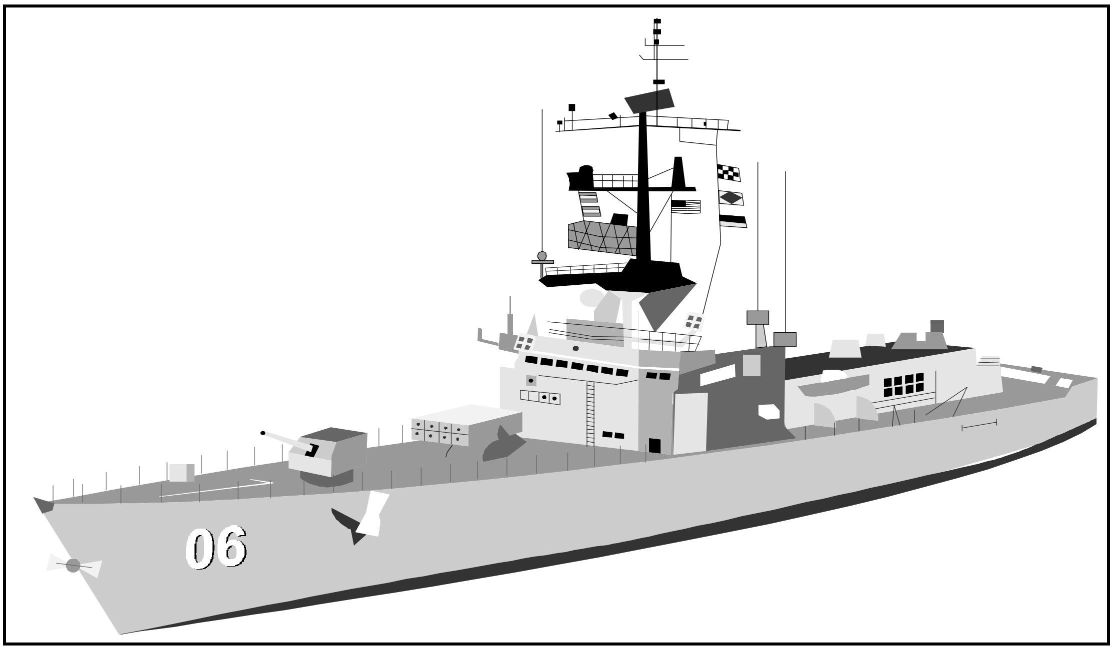


Fig 2.23 FFG Class Naval Frigate

2.9.2 Construction of Naval Ships

The configuration of naval ships is different from other ships. Naval ships are divided into more areas than other ships. They have many more watertight compartments than merchant ships.

These divisions, or compartments, are both transverse and longitudinal. The compartments are lettered alphabetically from stem to stern. The decks are numbered from the uppermost continuous deck down to the lower deck. Decks in the superstructure are numbered from the main deck upwards.

The extensive use of light alloys in the construction of naval ships makes it possible for these ships to have large superstructures. Naval vessels are generally well supplied with mobile and fixed firefighting equipment.

2.9.3 Responsibilities in Emergencies

Fires at Sea

If an RAN ship has a fire on board while it is at sea, the naval personnel on board are responsible for dealing with the fire.

Fires at the Dock

If a RAN ship has a fire on board while it is at the dock, the responsibility for the ship still rests with the Commanding Officer (CO) and the crew of the ship. However, the CO can delegate that responsibility to the NSWFB.

2.9.4 Arrival at the Dock

If the CO of a naval ship requests help from the NSWFB and delegates responsibility to the NSWFB, a clear area of 8 m of jetty space is made available for the NSWFB use. If there are multiple gangways on the jetty, a red flag is posted to indicate the gangway that is most suitable for the NSWFB use to gain access to the ship.

In such an emergency, RAN personnel meet NSWFB personnel at the dock and direct them to the RAN main control point. There, the ship's officers brief firefighters on the actions taken prior to the NSWFB arrival. Together, firefighters and ship's officers develop a strategy to manage the emergency.

Tactics Employed by RAN Personnel

Prior to the arrival of the NSWFB, the ship's personnel have probably already taken some action. Here is a list of some of the actions they may have already taken:

- they will lay out a guideline to the fire area;
- they will have shut down the ventilation systems. These can be restarted in selected areas to clear some of the smoke;
- they will have shut down the electrical power, but you must not assume that they have done so;

CAUTION

Where there is a risk from voltages in excess of 440 V the equipment should be isolated. You MUST always assume that electrical power is live until certain it is turned off.

- one of the RAN fire fighting teams will have performed some search and rescue in the affected area;
- a fire fighting team will have begun an attack on the fire using hose-lines and /or foam;
- these fire fighting teams are equipped with a thermal imaging camera (TIC) which provides clear vision through smoke to enable them to detect the location of a fire or heat source. The TIC operator (usually the team leader) is equipped with a damage control radio;
- these teams will have monitored the bulkhead temperatures and cooled the bulkheads where required;
- they use large supply fans to build up pressure to blow the smoke from the ship;
- they take steps to minimise the dangers to personnel from electrical equipment and to minimise damage to electronic and electrical equipment from the effects of fire fighting or boundary cooling; and
- they remove or drain down free surface water.

Withdrawal of RAN Personnel

Once the decision has been made to hand over the task of fire fighting and rescue to NSWFB, RAN personnel will be gradually withdrawn from within the smoke boundary as they are replaced by NSWFB personnel. This transition requires close communication and co-operation between you and the person in charge of the RAN firefighters.

The RAN fire fighting teams will have equipment and personnel available to you for the transition, including:

- TIC and operators;
- guide lines from a safe area to the fire scene;
- communication links from the RAN main control point to the fire scene; from the NSWFB control point to the fire scene; and between both control points. These communication lines will be operated by RAN personnel.

CAUTION

You must liaise with RAN personnel before using mobile phones and hand held transmitters. These instruments may be inappropriate in a warship environment. In some cases, the associated radio hazards prohibit their use.

2.9.5 Hazards of Fires on Naval Ships

Here is a list of some of the hazards you may encounter while fighting fires on naval ships:

- steam drenching;
- gas cylinders;
- fires in electrical equipment;
- explosive ordnance;
- explosive ordnance in fuel fires;
- aluminium structures involved in fire; and
- aircraft fires.

Steam Drenching

If a fire occurs in a compartment, it may have been necessary for a fire fighting team to drench that compartment with steam. When you re-enter that compartment, you must be aware of the following points:

- check the temperatures of the boundaries they can be a good guide to compartment conditions;
- remember the compartment itself and the fittings in the compartment will be hot for some time after the drenching is completed; and
- exercise great care when you first open the door/hatch charge your hose lines with a jet/spray branch in case the fire in the compartment re-ignites.

Fires in Electrical Equipment

You must maintain a safe working distance from areas where you suspect that there may be live electricity.

For voltages up to 440 V AC or 800 V DC, a safe working distance of 1.8 m is required.

Explosive Ordnance

Explosive Ordnance (EO) is a general term used to describe all stores with explosive components. These items may be stored in a magazine compartment or magazine locker.

EO includes the following materials:

- ammunition;
- pyrotechnics;
- guided weapons;
- torpedoes;
- mines, bombs, and demolition stores.

Modern naval ships have automatic spray systems fitted to magazine compartments, particularly those compartments containing missiles. Some ships have flooding arrangements fitted to some of these magazine compartments. Flooding arrangements are also fitted to some magazine compartments in older ships.

Most ships are required to have flooding capability in the magazine lockers unless the locker contains water reactivated EO.

CAUTION

If fire fighting teams are carrying out a boundary cooling exercise in a magazine fitted with an automatic (quartoid bulb) spray system, and if a high proportion of the spray heads are suddenly activated, all personnel not wearing BA must vacate the magazine immediately. The volume of fine spray of water makes the compartment uninhabitable without BA.

Explosive Ordnance in Fuel Fires

Many of the naval ships carry sophisticated and highly explosive and dangerous weapons. If one of these modern weapons is involved in a fuel fire, there is a grave danger that the weapon may cook-off (explode). The cook-off may occur very quickly (in one or two minutes).

NOTE

The need for rapid fire fighting in these areas is vital. Therefore, AFFF is to be applied immediately. This will have the combined effect of cooling the weapon while bringing the fuel fire under control.

Explosives remain in danger of **cooking off** for at least 30 mins after the fire has been extinguished. Thus, you must take full advantage of every structure and fitting which might give you shielding.

Aluminium Structures Involved in Fire

Aluminium is used in modern ship construction for bulkheads, decks, ventilation trucking, hangers, cabling and other services. Aluminium is a potential source of great danger in a fire situation. Heat can radically affect the strength of aluminium and its capacity to bear a load.

At 250° C, aluminium is weakened; at 600° C it melts.

When an aluminium structure melts it will:

- open a path for the spread of fire;
- allow additional air to reach the fire and increase combustion;
- cause further fire by dropping (in its molten state) on combustible material; and
- create sudden and possibly unexpected danger to the firefighters e.g. the deck on which you are standing may collapse or molten metal may drop on you.

If fire breaks out and involves an aluminium structure, it is essential that you spray-cool the structure immediately. You must continue the cooling until the fire is extinguished and the structure is no longer subject to heat.

Aircraft Fires

Some RAN ships are capable of carrying aircraft which add complications to fire fighting.

The hazards of aircraft fires fall into two main categories:

- explosion; and
- fire.

Explosion can be caused by the overheating of fuel tanks, oxygen or compressed air cylinders or by the detonation of explosive weapons by cook-off in a fire situation.

Fires are generally caused by free fuel vapour being ignited by:

- an impact spark or spark from the aircraft's electrical system;
- contact with hot engine parts;
- an accident through negligence or ignorance;

NOTE

For more information refer to Section 1 - Aircraft Fires.

2.9.6 Recommended Equipment

Table 2E details the recommended equipment and the actions to be taken to fight fires in naval ships:

TYPE	EQUIPMENT/ACTIONS	TYPE	EQUIPMENT/ACTIONS
Structural and general fires	AFFF Foam stored pressure type extinguishers. Hose lines.	Magazines and shell rooms	Spray (and floor if needed). Spray surroundings.
Fuel fires in boiler rooms	AFFF Foam stored pressure type extinguishers. Main foam appliances. If boiler room has to be evacuated, steam smothering or foam inlet tubes.	Other machinery spaces (generally)	AFFF foam stored pressure type extinguishers. Foam inlet tubes. Main Halon installation; form or steam smothering. High level foam sprinkler system.
Liquid fuel fires (generally)	Hand or main foam appliances.	Methylated spirit, alcohol and the like	CO_2 or dilution by water/AFFF.
Aircraft fires on deck	AFFF Foam stored pressure type extinguishers. Dry chemical backed up by main foam appliances.	Fires in hangers	AFFF foam stored pressure type extinguishers. CO_2 and main foam appliances. Dry chemical appliances. Fixed hangar spray.
Fires involving electrical/ electronic equipment	Switch off current and attack according to the substance burning. CO_2 and DCP is safe for us on all live equipment. Foam stored pressure type extinguishers with fresh water, safe at 0.5 m or more at normal ship voltages. Spray/jet nozzle set to spray, safe at 1.8 m from live equipment at normal ship voltages.	Galleys	Switch off master supply switch to electric galleys. Foam stored pressure type extinguishers. Smother ignited fat or cooking oil with metal cover, fire blanket. Fight a developed fire with FB5X foam branch, foam-making nozzle through a pre-determined opening. Operate Galley Fire Suppression system if fitted.

Table 2E Recommended Equipment and Actions

2.10 Safety Considerations for Firefighters

Here is a list of points that relate to your safety when you attend a fire incident on a ship:

- You may have difficulty in moving about the ship and accessing the fire. You will have to negotiate many levels, ladders, walkways, and machinery spaces. Return escape routes will be complicated and dangerous.
- You must wear gloves at all times to protect yourself from hot metal bulkheads, handrails, walkways, etc.
- You must wear BA at all times. You will almost invariably attack a fire on ship from the top.
- You must protect yourself from the copious amounts of smoke that are always present in a fire on board a ship.
- You must remember that oil is an integral part of a ship's engine room fire.
- You should be aware of the many electrical cables that will be present along the bulkheads.

- You will find difficulty in attacking bilge fires. These fires are difficult to extinguish, and you must ensure that there are various effective means of attack.

- You should ensure an adequate supply of expansion foam and CO_2: these are most useful for fighting ship fires.

- You will find search and rescue measures extremely difficult, time consuming, frustrating, and exacting.

- You must maintain your concentration to stay oriented as to your vertical and lateral position on the ship.

- You must plan ahead to ensure access to the fire area and to successfully attack the fire and provide rescue support if it is needed.

- You should provide for closed circuit communications for crews fighting the fire below decks.

SECTION THREE - TRAINS

CONTENTS

3 TRAINS

FRNSW personnel should not enter the RailCorp corridor without advising the RailCorp Rail Management Centre (via the Communication Centre) of their intention. The RailCorp Rail Management Centre will arrange the following, as necessary:

- trains to be stopped;
- overhead power to be removed, via a Rescue Power Outage (RPO), or 1500 V isolation procedure
- appropriate RailCorp to the incident site; and
- suitable protection for personnel entering the RailCorp corridor

RailCorp will operate the incident site and all personnel on site via a Rail Commander.

NOTE

RailCorp operates CityRail passenger train systems and CountryLink long distance passenger train services. RailCorp controls the Greater Sydney Metropolitan electrified network bounded by Nowra, Macarthur, Lithgow and Newcastle. Rail tracks outside these areas are controlled by Australian Rail Track Corporation (ARTC).

3.1 Introduction

As a firefighter, you must be aware of the hazards that trains present, the dangers in these hazards, and how you can carry out your responsibilities when you address these hazards and dangers.

Like ships and aircraft, trains have their own terminology. To be able to understand the nature of your work around trains, it is essential that you be familiar with train and railroad terminology.

3.2 Track Safety

When you must enter RailCorp property or running lines, you should be aware of certain safety issues and communications procedures. Here are a few key issues and a description of how to handle them.

Access to RailCorp Property

Access is restricted in most areas. These areas are protected by 2 m chain link wire fencing. Entrance gates are strategically located however, emergency service personnel are not issued with access keys.

Communication with RailCorp Representatives

Prior to entering onto the tracks or RailCorp property, you, and all emergency services, must make contact with a RailCorp representative. In this initial contact, you should find out where the incident is and request that the persons operating trains in the area of the incident be made aware of your presence. You may need to request that services be temporarily suspended. Every signal post within the RailCorp system has a telephone that can connect you to the RailCorp 24 hr Rail Management Centre. When you inform this centre of your presence, the signals can be placed at stop, or other arrangements can be made for your safety. Some railway stations are staffed 24 hrs a day.

Protection for Emergency Services

RailCorp will provide you with protection upon request.

This protection is by controlled signals or lookout persons. Your exact location is signalled to RailCorp personnel by the yellow plate fixed to every overhead wire support post or by paint stencilled to culverts, bridges, and tunnel entrances. This indicates your distance from Sydney Terminal station and allows RailCorp employees to:

- warn train drivers of your exact location;
- direct other emergency services to the most suitable access gate; and
- protect your location and operate trains outside of your immediate area.

3.2.1 Visibility

RailCorp regulations require all persons who work within 3 m of the track to attend a training course and to wear high visibility retroflective clothing. RailCorp personnel wear high visibility orange clothes, emergency personnel wear high visibility yellow safety clothing.

3.2.2 Train Safety

Today's trains are fast, heavy, and quiet. Unless some form of warning or protection is provided, these fast, quiet trains regularly surprise even the most experienced railway employees. Trains normally run in only one direction on a track designated for that direction that is, either up or down. However, some tracks are designated to allow trains to travel in either direction over both tracks at normal speed. The normal speeds can be from 50 kph to 115 kph. At these speeds, trains can take a considerable time to stop.

3.2.3 On-Track Precautions

If you must enter RailCorp property or go on track, you must advise RailCorp personnel. You must notify them even if the RailCorp called for your assistance.

When you arrive on site, you should advise the Station Manager or other responsible RailCorp officer of your presence and what you intend to do. These officers will arrange for trains to be stopped if necessary.

If there are no RailCorp personnel present, you should advise the RailCorp Rail Management Centre (via ComCen) of your presence.

Walking on the Track

If you must walk on or about the track, always be alert for trains. Always wear **reflective** vests, especially at night and always walk in the cess. The cess is the area on the outside edge of a railway track.

If you are walking on Multiple Lines when a train approaches on the track either side of you at the same time, and you cannot get clear, lie **face down** in the six foot and **protect your head**. The six foot is the area between the sets of railway tracks.

3.3 Sydney Underground System

FRNSW personnel are not to be in any tunnels unless supervised, or have agreement from RailCorp Rail Management Centre (via ComCen) that all trains have been stopped.

Tunnel Lights

In the tunnels of the Sydney Underground System, a lunar white light is fixed to the side of the tunnel.

Walking through Tunnels

When you are walking through an underground tunnel, you must keep an eye on the lunar white tunnel light. This light is attached to the side of the tunnel or in the four foot. When this light is on, it indicates the absence of trains in the section. When the light is off, it indicates that a train is approaching.

Refuges

When a train approaches, you will have sufficient time to walk to a refuge. Refuges are recessed into the side of the tunnel wall. Refuges are located every 20 m on both sides of the tunnel.

⚠ **NOTE**

A refuge will fit only three persons; but, if they are wearing BA, it will fit only two persons.

Before the train approaches, remove your cap and stand as close to the wall as possible.

3.4 Track and Location Identification

For track and location identification, there is a number on every structure within RailCorp, eg Signal, post, staunchion etc. Quote the number to RailCorp Rail Management Centre (via ComCen) and they will identify the exact location.

3.5 Emergency Stop

There are will be times when you may have to alert approaching trains to an incident on the track and you may require that these trains make an emergency stop.

If you need to signal a train to make an emergency stop carry out the following actions as shown in Fig 3.1.

- during daylight hours wave both arms or a coloured cloth vigorously (a red cloth if possible);
- during night hours wave a light vigorously.

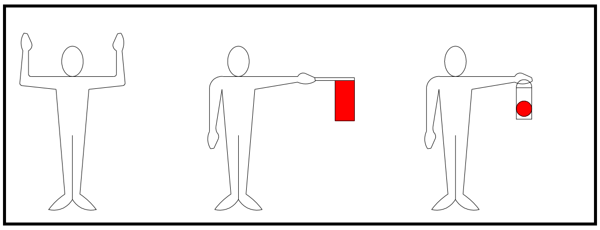


Fig 3.1 Emergency Hand Signals

NOTE

FRNSW personnel are not to be on the track, or in a tunnel, unless supervised by RailCorp staff, or have agreement from RailCorp Rail Management Centre (via ComCen) that all trains have been stopped.

3.6 Detonators

A detonator is a red disc-shaped explosive device that attaches to the rail and explodes under the wheel of a moving train. This device is used to attract the train driver's attention. All detonators are marked with the year of manufacture. Their usefulness expires after five years.

3.7 Hoses Across Rail Tracks

You should take hose across rail tracks only when you are quite certain that trains have been stopped and any electrified track has been isolated.

Modern methods of laying ballast make it impracticable to dig out under the sleepers and lay hose under the track. This is still done only if the incident requires a prolonged fire fighting presence and yet there is an urgent need to reactivate the track.

CAUTION

If a train approaches a section of track with hose across it, there is no danger of derailment. Do not attempt to remove the hose as you may place yourself in a dangerous situation.

3.8 Train Fires

When you are called to a train fire, any fixed fire fighting installations will probably have already been operated. The train crew will already have used their portable extinguishers. The detailed procedures for dealing with train fires does, of course, vary according to the circumstances, but here are two points for you to consider regarding train fires:

- on diesel locomotives, ensure that the engines have stopped and the battery isolation switch is open;
- on electric trains, ensure that all the pantographs have been lowered and the isolation switch is open.

Grass Fires

Small grass fires on railway embankments are common. They do not normally present any serious problems to firefighters.

Flammable Freight Fires

Flammable freight fires can have serious consequences and cause a major incident that can affect the surrounding area. In these circumstances, you should take action appropriate to the risks involved.

⚠ **NOTE**

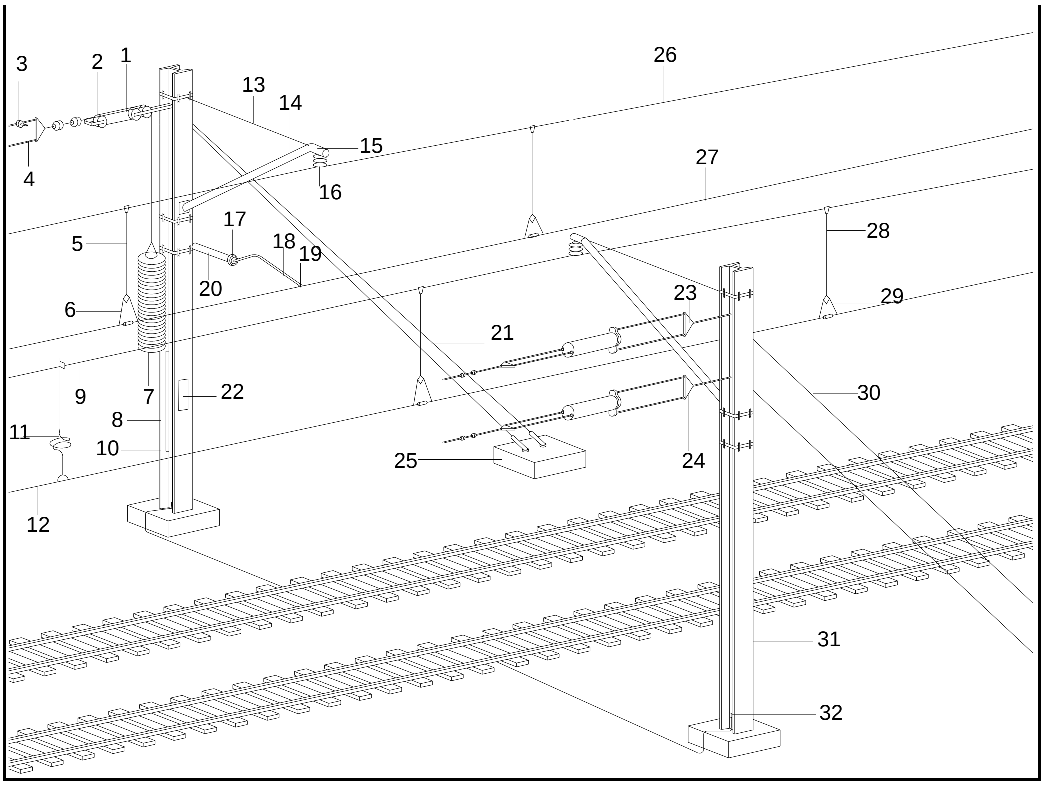
Freight trains operating within NSW are operated by Australian Rail Track Corporation (ARTC), not RailCorp.

3.9 Electrical Power

Electricity Supply

Electric power for RailCorp's operations is supplied from the State electricity generation system through the local supply authorities. This power carries voltages from 11 000 V to 132 000 V.

RailCorp transmits this electrical power through high voltage transmission lines and underground cables to a number of substations. At these substations, the electricity is transformed into 1500 V DC. It is then transmitted through the overhead wiring system to supply electric traction to the trains.



1	Wire rope	11	Span Feeder	21	Guy arrangement	31	Mast
2	Pulley arrangement	12	Contact wire	22	Identification number	32	Spark gap arrangement
3	Catenary termination clamp	13	Tie rod	23	Catenary gas device		
4	Contact anchor	14	Cantilever jib	24	Contact gas device		
5	Dropper top	15	Insulator & tie rod end	25	Anchor block		
6	Dropper bottom	16	Suspension insulator arrangement	26	Catenary wire		
7	Weight	17	Post type insulator	27	Contact wire		
8	Weight rod	18	Pull off arm	28	Dropper top		
9	Catenary wire	19	Contact clamp	29	Dropper bottom		
10	Mast	20	Insulator post	30	Guy		

Fig 3.2 Overhead Electrical Power Cables

Low Voltage Power

In addition to high voltage power for electric traction, lower voltage power is also supplied to railway stations, offices, workshops, and depots. This low voltage power is supplied from substations in the high voltage system. It supplies power for lighting, buildings, workshops and signalling operations. This power is distributed by aerial conductors (wires on poles) and cables.

In some cases, low voltage supply is also taken from the local supply authority. High and low voltage cables are often used near substations, sectioning huts, stations, signal locations, and throughout maintenance centres.

1500 V Equipment

In the case of fire near 1500 V equipment, you must take care to prevent any person from coming into contact with the electrical equipment. Contact can occur through falling material, through water from hoses, or from broken pipes.

If a major fire occurs in a vehicle standing on an electrified line, you must contact the RailCorp Rail Management Centre (via ComCen) to have the supply removed from the 1500 V overhead wiring via a Rescue Power Outage (RPO) or 1500 V overhead power isolation, before you begin fire fighting procedures.

3.10 Electric Trains

3.10.1 Introduction

Electric trains obtain their power from the overhead wiring that carries a current of between 1500 and 1600 V. This current operates various components throughout the train ranging from 1500 V to 120 V. These components are located mainly in the roof and under the train.

CAUTION

You should never attempt to remove anything from under any part of an electric train until the action has been authorised by the RailCorp representative.

You should also be careful that no object, such as fire fighting equipment, comes into direct contact with the underside or topside of a carriage of an electric train, until the train has been made safe and isolated from the overhead wiring.

Before you begin fire fighting procedures on an electric train, you should ensure that RailCorp personnel have taken precautions to render the train safe. These precautions may require the isolation of the train from the overhead wires. This can be done by the train driver. More serious incidents require the complete isolation of the overhead wiring section via a Rescue Power Outage (RPO) or 1500 V power isolation.

3.10.2 Fires

The RailCorp electrical system operates on 1500 V DC. This can cause problems for firefighters. Contact with this voltage will cause severe injuries or death.

3.11 Tunnel Fires

A fire in a tunnel presents specific problems including:

- divided attendance e.g. fire fighting, rescue and casualty assistance
- deep penetration into the earth;
- difficult rescue and evacuation situations;
- limited lengths of hose lines available;
- logistical control of moving fire fighting equipment;
- restricted communications facilities;
- limited BA control;
- difficult underfoot conditions;
- excessive heat; and
- thick smoke.

3.11.1 Air Shafts

Tunnels of any length may have one or more air shafts. These shafts can provide ventilation into the tunnel, but they also can act as flues. As a flue, the shaft releases hot air out into the open air above the tunnel. In moving this hot air, it also can draw in large amounts of fast-moving air from the tunnel entrances. As this fast-moving air moves through the tunnel from the entrance to the shaft, it can fan and feed a fire. The Sydney tunnel system needs the movement of trains to force air through the tunnels, this system of ventilation is called the push pull method. If the trains are stopped, positive pressure fans are required for ventilation.

⚠ **NOTE**

Sydney Underground and Eastern Suburbs Railways do not have smoke management systems. The Airport Line and Epping to Chatswood Rail Link tunnel systems are provided with a smoke management system that can be controlled by RailCorp Rail Management Centre.

3.11.2 Passenger Trains

In the event of a fire on a train in a tunnel, the train crew will contact RailCorp Rail Management Centre, who will contact FRNSW for assistance.

If the incident in the tunnel involves a passenger train, evacuation of passengers will be the first priority of RailCorp staff. The crew will try to evacuate passengers towards both ends of the tunnel. Available light for the evacuation may be limited if the tunnel is long and if the train is in the middle of the tunnel. All of this can cause panic. The call to the FRNSW will probably be delayed while the train crew attempts to evacuate passengers.

3.11.3 Freight Trains

The dangers from a freight train fire in a tunnel depend on the type of wagons and their contents. A fire in a tank wagon is likely to be extremely hazardous in the confined space of a tunnel. The extremity of the danger can depend on the diameter of the tunnel, the position and size of any air shafts, and access to the incident site.

⚠ **NOTE**

Freight trains do not operate in the Sydney Underground.

3.11.4 Pre-Planning

FRNSW pre-plans for incidents in major tunnels. Here is a list of some of the important points to remember about tunnel fires:

Tunnel Traffic

All traffic through the tunnel should be stopped and the power cut off. This should be done before firefighters enter the tunnel. Officers-in-charge at the site should ensure that there are adequate places of safety inside the tunnel.

OLE

If overhead live electricity (OLE) is present in the tunnel, the lines may have been brought down by the fire. This will pose a substantial hazard to firefighters. Most tunnels carry two OLE lines, and an incident of any size will affect both.

Personnel Movements

It is vitally important to restrict the number of personnel who enter the tunnel and to control their movements once they are in the tunnel.

Exhaust Fumes

Any portable pumps, generators, and motorised rescue equipment generate exhaust fumes. The air flow in a tunnel usually relieves this problem to some extent. If a fire occurs in a tunnel in the Sydney underground system, portable air blowers are essential to create a flow of air if the trains are stopped.

Evacuation

Rapid evacuation of firefighters may be necessary at some stage of the operation. Officers-in-charge at the site should keep the number of personnel in dangerous areas to a minimum. An effective emergency signal is essential. All personnel should know of and be able to recognise this emergency signal in the event that it becomes necessary to evacuate personnel from the tunnel.

Conclusion of Operation

When FRNSW operations have finished, the Officer-in-charge should inform the RailCorp that FRNSW personnel and equipment are leaving the area.

3.12 Freight Trains

Freight trains are owned and operated by Australian Rail Track Corporation (ARTC), not RailCorp.

3.12.1 Types

Freight trains consist of one or more locomotives hauling a series of wagons.

A diesel electric locomotives has a fuel capacity of 10 000 L and a weight of up to 140 t.

Wagons consist of three main types:

- tank wagons (Fig 3.3) with a capacity of 60 000 L and a tare weight of up to 75 t;
- hoppers (Fig 3.4) with a capacity of up to 100 T and a tare weight of 25 t; and
- flat top wagons used to carry containers of up to 40 t per container.

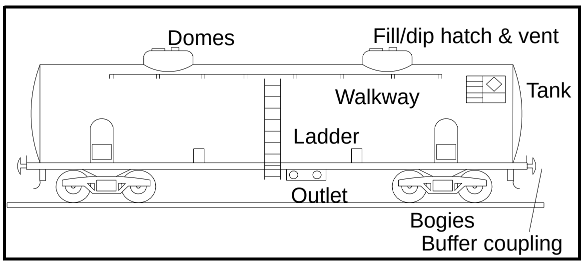


Fig 3.3 A Typical Rail Tank Wagon

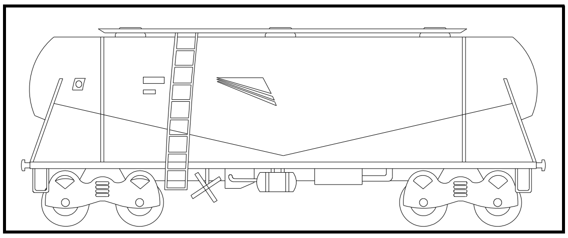


Fig 3.4 A Typical Hopper

⚠ NOTE

A freight train can consist of a mixture of different types of wagons and/or containers. This can create additional problems in the event of a derailment.

To minimise the problems that this mixture of wagons can cause, wagons carrying incompatible substances are separated one from another by a safe distance. For instance:

- explosives must be separated from flammable gas by at least 24 m; and
- flammable gas must be separated from oxidizing agents by at least 12 m.

3.12.2 Derailment

A derailment of a freight train can present many problems, including:

- danger from 1500 V overhead power wires;
- danger from other on-coming trains;
- danger from any ruptured freight wagon or container, especially one carrying dangerous goods;
- danger from fire;
- danger from the locomotive fuel leakage; and
- danger from hazardous materials.

3.12.3 Overhead Wires

If the overhead wires are brought down and are resting on the train, remain a safe distance until the RailCorp has isolated the power.

3.12.4 On-coming Trains

If you attend a derailment incident, you should inform the ComCen of the location of the derailment, so that this information can be relayed to the relevant rail authority.

In the RailCorp area track (ie with electric overhead wires), contact the RailCorp Rail Management Centre (via ComCen) to have trains stopped and assistance provided.

If the incident occurs in a country area, firefighters should proceed up-track and down-track for a minimum distance of one km to warn approaching trains of the incident.

CAUTION

Depending on weather conditions and terrain, you may need to increase this distance of notice up-track and down-track.

3.12.5 Dangerous Goods Documentation

In a derailment situation, you need to know what dangerous materials are involved. A list or manifest of the dangerous materials carried on a train is kept in a bag in the front locomotive. This bag is white with red stripes and marked **Dangerous Goods Documentation** (Fig 3.5). If you are unable to retrieve this manifest, contact the RailCorp Rail Management Centre (via ComCen). RailCorp keeps a copy of the manifest, and they can tell you what dangerous goods are on the train.

Fig 3.5 Dangerous Goods Documentation Bag

3.12.6 Damaged Locomotive

If the locomotive is damaged in the incident, it can present dangers because it is capable of carrying 10 000 L of fuel. It can cause additional problems if it has come to rest in a dangerous position and if it is still running.

3.13 Express Passenger Train

Express Passenger Train (XPT) can consist of up to 7 passenger cars and 2 locomotives, with three hundred and fifty passengers and a staff of 5. The XPT travels to *Brisbane*, *Melbourne*, and *Dubbo* and can travel at speeds of 193 km/h but is governed to a speed of 160 km/h.

The following tables detail the general specifications that relates to an XPT.

ITEM	SPECIFICATIONS
Basic construction	Steel, aluminium and fibreglass
Fuel tank capacity	4500 L (2 x 2250 L tanks) each equipped with a vent that acts to cut off the air supply to the rank in the event of an internal fire
Engine lubricating oil capacity and type	360 L 20W/50 multigrade
Cooling group oil capacity and type	36 L 20 W/50 multigrade
Fire extinguishers	Inner gas system with electrical operation and manual release on bottle CO_2 and dry chemical hand extinguishers located in driver's cabin
Electrical voltages on unit	2100 V - Traction 415 V - Train Supply 110 V - Control

NOTE

Signal detonators are stored in the driver's cabin.

Table 3A Locomotive Specifications

ITEM	SPECIFICATIONS
Basic construction	Fibreglass, laminated plywood, stainless steel, and foam rubber
Fire extinguishers	CO_2 and Dry Chemical hand extinguishers mounted in the end of each car. Note: Two CO_2 hand extinguishers are located in the buffet car.
Electrical voltages on unit	415 V - Train Supply 415 V - Control 24 V - Auxiliary Control

CAUTION

There is no alarm on the outside of the power car to show if the halon system has activated.

Table 3B Passenger Car Specifications

SECTION FOUR - FLAMMABLE LIQUIDS

CONTENTS

4 FLAMMABLE LIQUIDS

4.1 Introduction

Flammable and combustible liquids present many hazards to firefighters. This topic discusses the properties and characteristics of flammable and combustible liquids, their storage, fire protection, and fire fighting techniques and how you can best deal with incidents that involve these dangerous substances.

4.2 Physical Properties

Generally, flammable liquids belong in the class of organic compounds. They contain the elements carbon and hydrogen. Combustion converts both of these elements to their oxides - carbon to a mixture of carbon monoxide and carbon dioxide, and hydrogen to steam.

There are several organic compounds. For classification, it is useful to group them into a series of similar compounds such as the Kerosene Series, the Alcohol Series, etc. In each series, the chemical properties vary little from one another, but the physical properties vary significantly. The physical properties of each liquid determine how it is stored, how we protect against hazards, and how we fight fires involving each liquid.

4.2.1 Specific Gravity

If a liquid is not soluble in water, its specific gravity (SG) determines whether that liquid floats or sinks in water. The SG of a liquid is determined by the following formula:

$$SG = \frac{\text{Density of Liquid}}{\text{Density of Water}}$$

Most flammable liquids have a SG of **less than one.** If a flammable liquid has a SG of less than one, it floats on water e.g. petrol. If you have to fight a fire involving flammable liquids, you must use special techniques such as fogs, emulsifiers, and sprays. Do not use running water as there is always the risk that running water will carry a burning liquid away on the surface of the water spreading the fire.

Some flammable liquids are heavier than water. Carbon disulphide is one such liquid. If carbon disulphide is burning, you can usually extinguish the fire by running a layer of water over its surface to cut off the oxygen supply.

4.2.2 Water Solubility

Soluble Liquids and Water

Although most flammable liquids do not dissolve in water, there are some exceptions. Soluble flammable liquids include those in the Alcohol, Acid Ketone, and Phenol Series. These dissolve easily in water. If one of these liquids is burning, you can put out the fire by adding water to the burning liquid, and you will dilute the flammable liquid.

Soluble Liquids and Foam

If a fire involves a liquid that dissolves in water, the use of foam can cause difficulties. The burning liquid tends to mix with the water in the foam, and it breaks down the foam.

4.2.3 Vapour Density

One danger of flammable liquids is that they give off vapours that have a density that is greater than the density of air. The vapour density (VD) of a flammable liquid is determined by the following formula:

$$VD = \frac{\text{Density of Vapour}}{\text{Density of Air}}$$

The vapours that are heavier than air sink in air, and they tend to accumulate near ground level. Thus, a large spill of a flammable liquid can result in the formation of an extensive cloud of flammable vapour e.g. Liquid Petroleum Gas (LPG).

NOTE

The properties and characteristics of LPG are discussed in detail in Section 5.

4.2.4 Melting Point and Boiling Point

Melting Point

When heat is supplied to certain solids, they melt and turn to a liquid at a definite temperature. This is the melting point for that solid.

Boiling Point

If more heat is applied to the liquid, that liquid will eventually begin to boil at another definite temperature - the boiling point of the liquid. If a liquid has a low boiling point, it evaporates at ambient temperatures. This creates a high fire hazard. When a liquid burns, it is actually the mixture of vapour and air above the liquid which burns. The closer a liquid approaches its boiling point, the more vapour it gives off and the greater is the possibility of ignition. This is why flammable liquids stored in the vicinity of a fire should be kept cool while you deal with the fire.

4.2.5 Flash Point

This is the lowest temperature at which a liquid gives off sufficient flammable vapour into the air to cause a flash when an ignition source is applied to the vapour.

Classification of Liquids by Flash Point

Liquids are classified according to their flash points into two categories, flammable and combustible:

- Flammable liquids have a flash point below 61° C
- Combustible liquids have a flash point above 61° C

Combustible liquids are not classified as dangerous substances for transport e.g. lubricating oil.

4.2.6 Fire Point

This is the lowest temperature at which vapour in air will flash and continue to burn.

4.2.7 Spontaneous Ignition Temperature

This is the temperature at which a substance ignites spontaneously without ignition by an external spark or flame.

4.2.8 Flammable Range

This range defines the upper and lower limits of concentrations of vapour-air mixture that can be ignited. This is also known as the explosive range. For instance, the flammable range of petrol is from 1% to 6%. If the concentration of petrol vapour in air is less than about 1%, the mixture is too lean for combustion; if the concentration is more than 6%, the mixture is too rich for combustion.

In a closed tank, the vapour from kerosene is usually too lean for combustion while that of petrol is usually too rich. In a petrol spill, the entire range of vapour concentrations are present, the mixture close to the spill is too rich, and the mixture farther away from the spill is too lean. Ignition occurs only where concentrations are within the flammable limits. An empty used petrol can actually contains residual petrol. This residual petrol can have a vapour and air mixture that is within the flammable, or explosive, range for petrol.

Whether or not a liquid gives off enough vapour to form a mixture within these limits depends on its flash point.

4.2.9 Toxicity

Many flammable liquids give off toxic vapours which are harmful if inhaled. Some toxic liquids pass through the skin, into the blood stream and throughout a person's system. Benzene and Phenol are examples of such substances.

Most flammable liquids are organic compounds. The carbon in the compound breaks down as the compound burns. Even if a liquid is non-toxic, as it burns, its carbon content forms a toxic mixture of carbon monoxide and carbon dioxide.

4.3 Behaviour of Burning Liquids

4.3.1 Surface Area and Combustion

The rate of combustion of a flammable liquid is determined by the surface area that is available to burn. Given a wide surface area, a flammable liquid burns very quickly.

The rate of combustion of a flammable liquid is substantially reduced so long as that liquid is stored in a confined space, such as a storage tank. While the flammable liquid remains in a tank, combustion will reduce its level by between 150 mm and 300 mm/hr. The rate of combustion is restricted by the relatively small surface where evaporation can take place. The surface area, and the rate of combustion, increase enormously once a leak or spill occurs. For this reason, storage tanks are surrounded with bund walls to restrict the flow of escaping liquid.

4.3.2 Oil Boil-over

Boil-over occurs when heat from the fire of burning oil in a tank unites with water at the bottom of the tank to form steam. This steam increases the volume of the oil, and the oil boils over.

This happens because some crude oil and some unrefined oil form a heat wave as they burn. This heat wave, which is similar to a convection current, can reach a temperature of 300° C. After it is formed, the wave moves down through the oil at approximately 300-400 mm/hr. When the wave reaches water in the bottom of the tank, the water immediately flashes to steam. This increases the volume of the contents of the tank up to 1700 times. If the steam cannot escape easily, frothing occurs. The sudden increase in volume can throw large quantities of burning oil over a wide area. This phenomenon is known as boil-over.

Four conditions must be present at the same time for boil-over to occur:

- water must be present;
- the oil must contain free carbon;
- the burning oil must produce a heat wave; and
- the oil must be viscous enough to form a froth when the heat wave hits the water and turns the water into steam.

When the oil is burning, it can form a series of heat waves. So long as water remains in the tank, a boil-over can occur each time a wave reaches the bottom of the tank and unites with the water.

Boil-over can occur only if there is free carbon in the oil. Distillates, such as petrol or light lubricating oils, do not contain free carbon and cannot produce the necessary heat wave.

⚠ **NOTE**

A boil-over can occur if there is water in an oil storage tank. Most storage tanks do contain some water. If you are fighting a fire where you know the conditions exist for a possible boil-over, you must prepare to withdraw when the heat wave is within 1.5 m of the bottom of the tank. Boil-over can be prevented if the water can be drained from the bottom of the tank.

You can see where the heat wave is at any given moment by looking at the discolouration of paint on the wall of the tank. Some storage tanks have special heat-sensitive paint strips for this purpose.

CAUTION

Boil-over is preceded for some minutes by an increase in the intensity of the fire. At the first sign of an increased intensity, you must immediately withdraw a considerable distance from the tank.

4.3.3 Oil Slop-over

Slop-over occurs in oils with flash points below 61°C. Water applied to the surface of these oils sinks without turning to steam. The water has little cooling effect. The water is unlikely to extinguish the fire. Water that enters the tank and sinks to the bottom of the oil can cause the oil to overflow. The fire can then spread on the slop-over oil.

Heat Expansion and Frothing

Slop-over can occur during a fire when a tank is nearly full of a volatile oil and heat expands the oil. The water present causes the oil to froth. This slop-over is preceded by quantities of whitish smoke. You may also hear a sizzling sound. This is a signal for you to withdraw beyond the bund.

Slop-over vs Boil-over

Slop-over is less violent than boil-over. Slop-over does not throw as much oil as boil-over. Also, it does not throw the oil as far as boil-over does. Water fog/spray usually extinguishes any fires in the compound caused by slop-over.

NOTE

You can prevent slop-over by removing sufficient liquid from the tank to increase the ullage. The ullage is the space between the top of the liquid and the top of the tank.

4.3.4 Alcohol

Alcohol has an affinity for water and absorbs water in large quantities. If you use normal foam compounds to fight a fire involving alcohol, alcohol can break down the foam by absorbing water from the walls of the bubbles of the foam. To prevent this from happening, you should use either special foam compounds or apply normal foam at five times the usual ratio.

Using the Ullage

If sufficient ullage is available in an alcohol storage tank, you can often extinguish an alcohol fire by adding water until the alcohol is too diluted to burn.

CAUTION

Alcohol burning in an abundance of air has a flame that is almost colourless. Often, only the heat will indicate the presence of fire. Even if you cannot see a flame, be certain that the fire is fully extinguished.

4.4 Principal Products of an Oil Refinery

An oil refinery processes crude oil into refined, usable products. In this process, the refinery generates several principal products.

Table 4A details the products.

PRODUCT	USAGE	PRODUCT	USAGE
Autodiesel	a fuel used in automotive diesel engines	Bituminous	a product used for road construction, roofing and waterproofing materials
Butane	a liquified petroleum gas used as a fuel for heating and cooking, air-conditioning on farms	Butadiene	a product used in the manufacture of synthetic rubber
Butyl rubber	a product used for car inner tubes, shock absorbers, and cable insulation	Cancined coke	a substance used for the manufacture of electrodes for aluminium production and electrodes in electric arc steel-producing furnaces
Ethylene	a chemical used in the manufacture of polyethylene, and an essential chemical for ethylene glycol, which is used in the manufacture of terylene and anti-freeze	Fuel oils	a fuel for home heating, industrial furnaces, ship propulsion, and electricity generation
Gas	a by-product used for fuel in the refinery's own furnaces	Heptanes	a product for use in the manufacture of plastics, such as PVC
Kerosene (paraffin)	a fuel for portable domestic heaters	Lubricating oil	a lubricant for all kinds of machinery
Lubricating oil additives	products for the improvement of engine performance and reduction of wear	Marine diesel	a fuel for marine diesel engines
Naphtha	a product used in its raw state in the manufacture of town gas; also widely used as a petrol-chemical feedstock and for reforming to petrol	Petrol	a fuel for motor cars and internal combustion engines
Propane	a gas for heating, metal cutting, flame welding, lighting for caravans, etc	Sulphur	an essential chemical in the manufacture of sulphuric acid and fertilisers
Tractor vaporising oil	a kerosene fuel	Turbo-jet fuels	fuels for civil and military jet aircraft
White spirit	a solvent used in the manufacture of paints, varnishes, enamels and polishes; also used for dry cleaning.		

Table 4A Principle Products of an Oil refinery

4.5 Bulk Storage Tanks

General Description

Tanks that store large amounts of bulk flammable liquids deserve special attention because of the potential hazards they present to firefighters. Bulk storage tanks are located at oil refineries, ports, and rail and road terminals. Oil refineries are by far the largest storage facilities.

Tanks can be up to 90 m in diameter and 20 m in height. They can contain up to 125 000 000 L of flammable liquid.

Because of the potential hazards, the confines and walls of a bulk storage tank compound must be kept free of rubbish and combustible materials.

Tank Environment

Bulk tanks are usually set in groups and surrounded by impervious earth dams or bund walls. In the event of a spill, the confined area is designed to contain the entire amount of liquid in the largest tank plus 50% of the capacity of the remaining tanks in the compound.

Tank Location

Depending on the tank size and the type of goods being stored, bulk tanks must be located at least 15 to 30 m away from the compound boundary. They must also be located at least 15 m away from each other.

Contents

The tanks located in oil refineries usually all have similar contents within the same compound; however, the tanks located at port and rail tank farms often have a wide range of products within various tanks in a single compound.

Air and Water in the Tanks

Air and water must be removed from the tanks to prevent them from mixing with the flammable liquid contents of the tanks.

Air can be removed from flammable liquid storage tanks by using floating roofs to limit the space above the liquid or by storing the flammable liquid under an atmosphere which will not support combustion. i.e. ether is usually stored under nitrogen, and petrol and carbon disulphide are stored under carbon dioxide.

Water must be removed from the tanks and from the compound. Means to remove water from the compound must be provided so as not to impair the ability of the Bund wall to retain spilled liquid. Usually pumps or traps controlled by a gate valve remove the water.

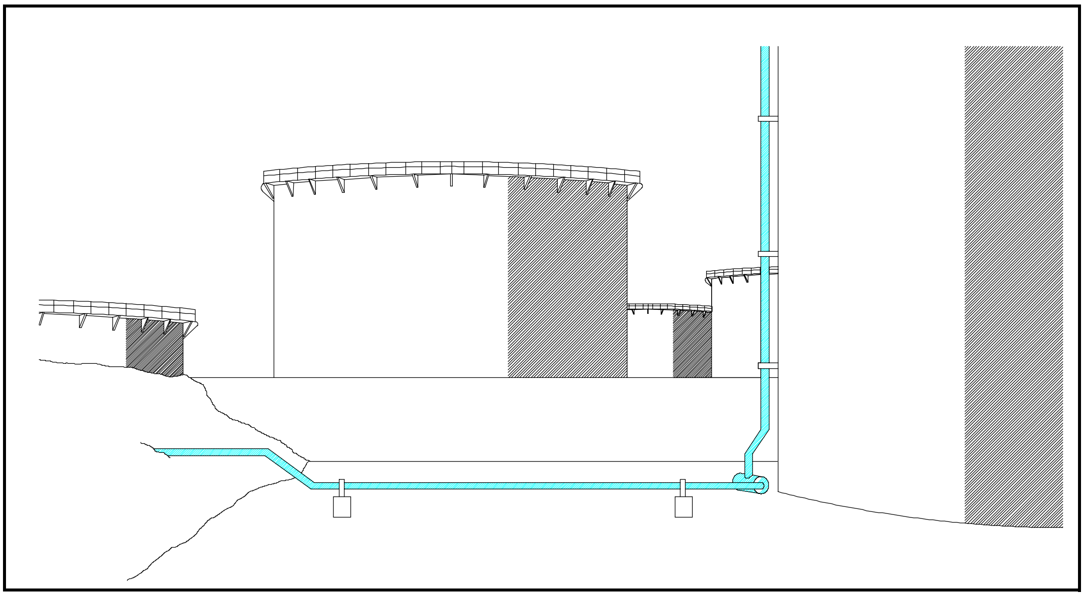


Fig 4.1 Storage Tank Showing Bund Wall

Empty Tanks

As the vapour and air mixture in empty tanks can be within flammable limits, tanks that are presumed to be empty can be dangerous. The danger is substantially reduced if the tanks are steamed and ventilated to remove all traces of flammable liquid.

4.5.1 Tank Types

A bulk storage tank is described by the kind of roof it has. The type of tank depends on the classification of the product it contains. Four common types of tanks are listed below.

Type A - Non-pressure fixed roof with atmospheric vents

Type B - Non-pressure fixed roof with internal floating decks

Type C - Pressure-fixed roof

Type D - Floating-roof

They are classified by their roof designs and according to the flash points of the liquids for which they can be used.

Type A

This is the most common form of bulk flammable liquid storage tank. This type of tank is made of curved steel plates that are welded together. The plates are thicker at the bottom of the tank than they are near the top. The roof of the tank is made of a covering of thin plates fitted over a rigid framework in such a way that the plates will blow off and vent the tank should there be an explosion. This protects the walls of the tank from damage and provides the best chance to contain the flammable liquid.

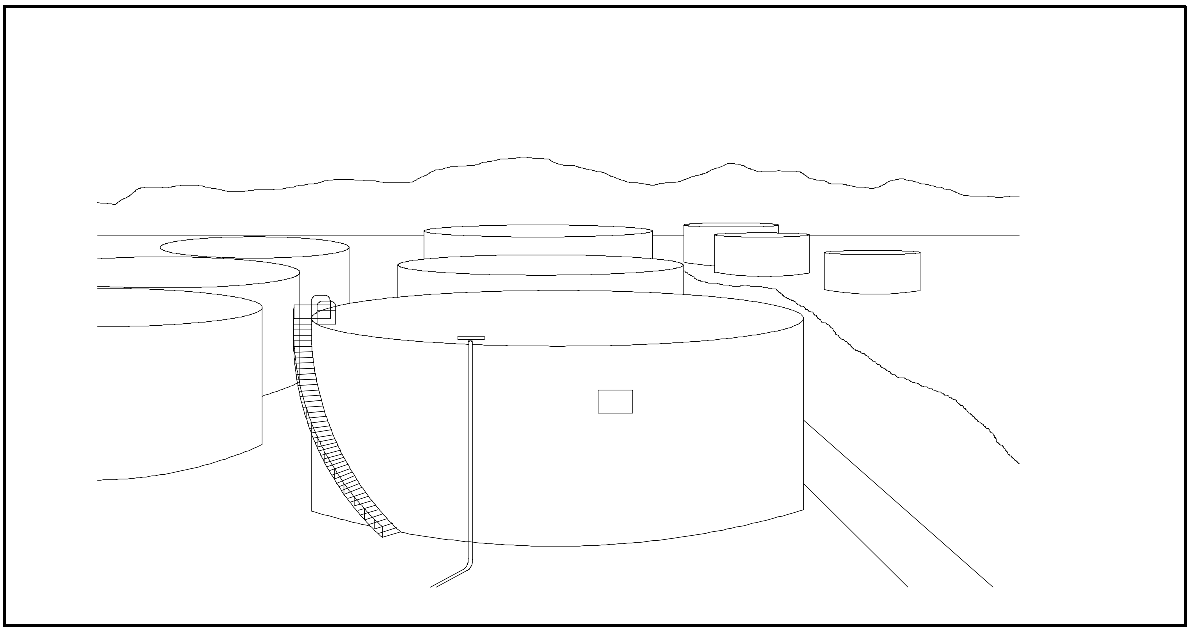


Fig 4.2 Type A Bulk Storage Tank

This type of tank has atmospheric breather vents. These vents are covered with a fine stainless steel gauze. The mesh prevents flame entering the tank if vapour from the contents ignites.

This type of tank is used to store flammable liquids with a flashpoint of 23° C and above.

Type B

This tank is similar in construction to the Type A with a floating deck inside.

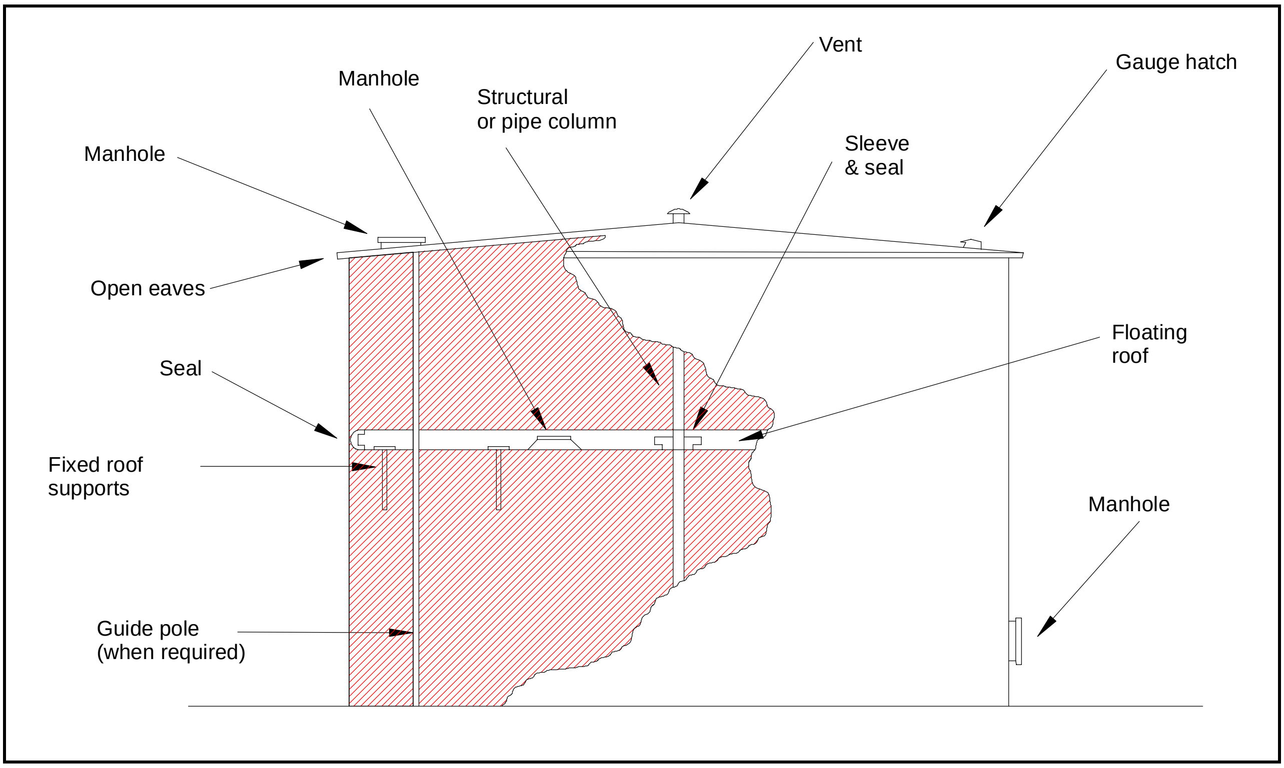


Fig 4.3 Type B Bulk Storage Tank

This type of tank is used to store flammable liquids with a flashpoint of 61° C and below.

Type C

This type of tank has a pressure-fixed roof to provide a different kind of ventilation. Except for this feature, this type of tank is similar in construction to the non-pressure types. This tank uses spring-loaded vent valves to control both pressure and vacuum levels within the tank as the contents are pumped in or out. The vents seal the tank when the contents are stable.

This type of tank is used to store flammable liquids with a flashpoint of 23° C and below.

Type D

Floating-roof tanks have either a pontoon or a double deck roof. This roof floats directly on the liquid contained in the tank. Depending largely on the climate of the area, the tank may be open or have a roof with side vents.

The floating-roof tanks with open tops have a strengthening girder around the upper perimeter of the tank. Without this girder, the wind can distort the casing. If this happens, the contents can possibly leak past the seals.

This type of tank is used to store flammable liquids with a flashpoint of 61° C and below.

The danger of fire or explosion is reduced by eliminating the air space above the flammable liquid. With no air space, vapour cannot form. To eliminate this air space, the sides must be sealed.

Two types of seals are used for a floating-roof tank, fabric and pantograph seals. They provide a flexible gas-tight seal between the pontoon and the tank walls to prevent the contents evaporating.

NOTE

If liquid or vapour escapes past the seals to the tank top or if the pontoon is grounded in an empty tank. The free air can create vapour that can cause a fire or explosion.

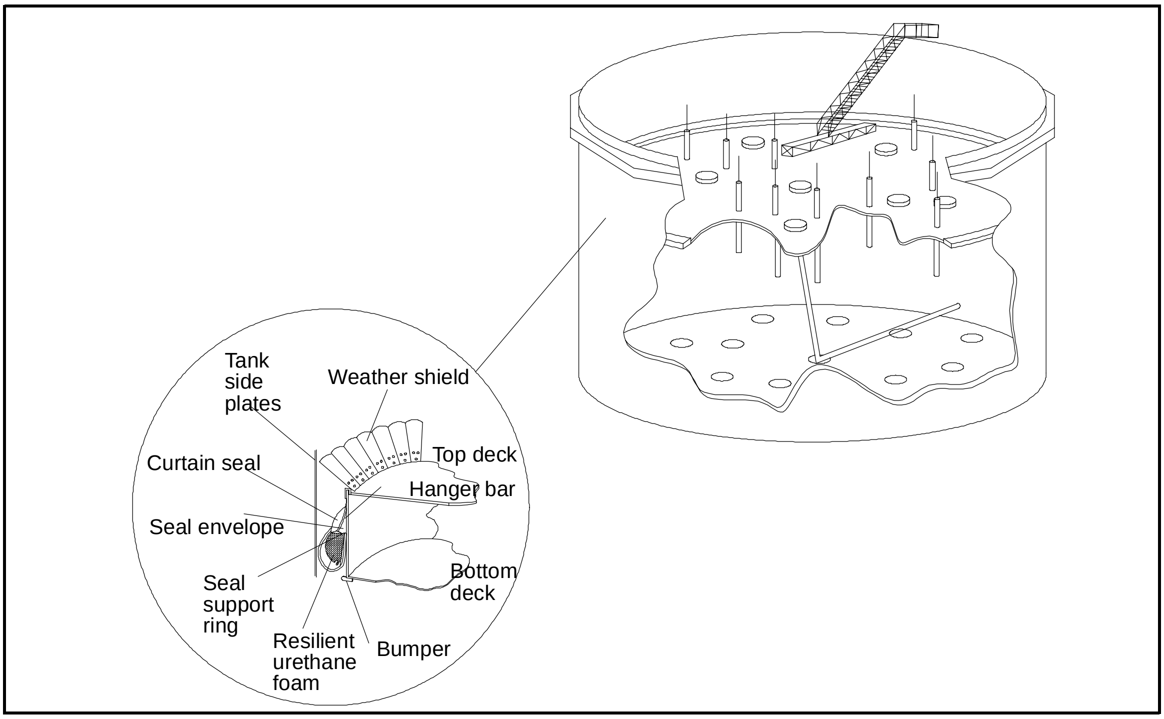


Fig 4.4 Type D Bulk Storage Tank

4.5.2 Tank Fittings

Staircases

Most bulk storage tanks have a spiral staircase that wind upward around the outside of the tank. Open-top tanks with floating roofs have an additional ladder that gives access to the pontoon. This ladder is hinged at the top. It has rollers on the bottom so that it can move and adjust to the height of the roof.

Access Holes

Access holes in the tank roof allow a person to enter the tank through the roof. Additionally, smaller hatches in the tank top allow personnel to measure the level of the contents and obtain samples.

CAUTION

If you enter a tank, you must wear BA and use a safety line.

Pipelines

Several supply pipelines can be connected to one tank. Each pipeline is fitted with an emergency shut-off valve. Some pipelines have a swinging arm that enables them to draw from different levels of the tank.

Pipelines may be filled with water. Some residual water can enter the tank when pumping next occurs. This accumulated residual water is removed from the pipelines by drain valves located below the tank outlets.

Pumping Stations

Pumping stations shift stored liquids around the compound. Pumping stations are usually located outside the bund walls in a central location in the compound. During a fire, they can be used to pump away the contents of burning tanks. If the volume of liquid can be sufficiently reduced, slop-over will be prevented, the danger of the tank splitting can be reduced, and fire losses can be avoided.

Shut-off Valves

Shut-off valves within the bund wall may be out of reach under fire conditions. When the pipelines are heated by fire, you should ensure that pipelines in the bund have at least one valve open to allow the contents to expand. If a valve is not open, expansion of the liquid can rupture the pipe and spread the fire.

CAUTION

Opening and closing of all valves and pumps is to be carried out under the direction of the site engineer.

4.6 Fire Protection Devices

Bulk storage facilities have various fixed fire protection devices. You should familiarise yourself with the types of devices in the facilities in your response area.

Some of the different types of fixed fire protection devices are drenchers, foam pourers and base foam injection devices. Drenchers are a great aid in cooling tanks adjacent to a tank that is burning. Drenchers can cool the entire surface of a tank or selected parts of it. If drenchers are not fitted in the compound, you will need branches to direct water onto exposed tanks.

4.7 Fighting Bulk Storage Fires

Fires involving flammable liquids in bulk storage areas pose special hazards because of the explosive nature of the liquids. There are several kinds of fire situations that deserve attention.

4.7.1 Spill Fires

Spillages cause most fires in and around areas where flammable liquids are stored.

First Action

If you attend a fire in a bulk storage area, the first action is to isolate the flow of liquid, cut off the flow, and prevent the fire from spreading.

Extinguishants

Dry powder is particularly effective on flammable liquid spillages, but its low capacity for heat absorption will not prevent re-ignition. You should use a foam back-up.

Foam

A foam blanket should be used to cover any spillage whether the spillage is ignited or not. If ignition has not occurred, a foam blanket will provide protection against accidental ignition. If the liquid does ignite, you can usually rapidly knock down the flame with fog, carbon dioxide, vapourising liquid, or dry powder.

Difficulties with Foam

Foam can sometimes be ineffective against a spillage fire if the flammable liquids have spilled amongst plant and equipment. This can make satisfactory foam cover difficult to achieve particularly if a pipe or flange above floor level is leaking. Not only is the fire spreading, but areas of the floor may be sheltered by equipment. This can prevent the foam from covering all of the spilled fuel. If the foam is thin and wet enough to flow into gaps, it will not stick on vertical surfaces. If it is too stiff, it will not flow to cover sheltered areas.

The OIC has the responsibility to decide which type of foam to use e.g. AFFF or Fluoro-protein.

⚠ **NOTE**

Most large terminals and refineries carry stocks of protein or fluoro-protein foam as well as AFFF.

Road Tankers and Spills

Spills are common in the vehicle loading bays of oil terminals. Road Tankers are earthed to prevent static electricity build-up during the loading operation. **Vehicles are connected to the plant by delivery equipment while they are loading.** Automatic valves are fitted that are designed to shut off the flow when a certain level is reached, but sometimes the valves malfunction, and the road tankers overflow. If a fire occurs, it generally involves both the road tankers and the filling tanks in their steel framework above the loading area.

When fire occurs in the loading bay of an oil terminal the first action is to isolate the flow of liquid and prevent the fire escalating. Provided the fuel supply can be shut off, water spray or fog is an effective extinguisher in this type of spill fire

4.7.2 Bulk Stores

Sometimes, flammable liquids are stored in large drums instead of in bulk storage tanks. These large drums are often piled in stacks or placed on racks or pallets and kept in the open. In severe climate areas, these drums are sometimes placed in open-sided sheds. Identification of the contents of the drums can be a problem. The drums are not always marked to identify their contents. Trade names are often used instead of chemical names.

Drums can explode if a fire occurs. If a drum explodes, it can often fly a considerable distance into the air. You should use water spray to cool the drum stacks to keep them from exploding. You should shelter behind substantial cover while applying water to storage drums.

4.7.3 Transport Spillages, Fire and Product Recovery

Spillages of flammable liquids in transport present hazards to the general public as well as to firefighters. The priorities in incidents involving a road or rail tanker are to:

- protect life and property;
- extinguish any fire or at least prevent it from spreading;
- prevent spilled product from entering drains;
- contain spilled product for subsequent

removal; and

- prevent or minimise further spillage.

Protecting Life and Property

Before police arrive at the scene of the incident, you must make every effort to stop or divert approaching vehicles. Warn people to remain at a safe distance. Take into consideration the topography of the area and prevailing weather conditions.

Extinguishing the Fire

You can use water from a fog nozzle to cool equipment and to shield firefighters.

⚠ **NOTE**

Water streams or coarse sprays should never be directed onto a petroleum fire. They can splash the petroleum around and spread the burning fluid. The water streams can also carry the burning petroleum to the entrance of drains and create a new hazard.

If you use foam to blanket the spilled product or equipment, do not hose it off as this may increase the risk of ignition or re-ignition.

Protecting Watercourses

You must make every effort to prevent spilled flammable liquid from entering drains or watercourses. The liquids can cause damage by pollution and can increase the risk of fire and explosion far away from the scene of the accident.

Inlets to drains can be blocked effectively with paper, rags, old clothing, sacks or similar material. If you are using hoses, you can direct them to create a water dam to contain the spilled liquid. If you cannot prevent the spilled flammable liquid from entering drains, you can use foam to minimise the fire risk.

Containing the Spilled Liquid

Dams of shovelled earth or sand are very effective in containing the spilled liquid. You can also use plastic sheets to prevent seepage and to make dams more liquid-tight. Alternatively, you may be able to channel the liquid to a low, safe area.

If you see a risk of fire from any source of ignition, you should blanket the flammable products, such as petrol, with foam. If there is no such risk of ignition, thin slicks and small quantities of flammable liquid on open waterways can be left to evaporate.

There is no advantage in foam-blanketing products such as diesel fuel, because the risk of ignition is small unless a hot flame is applied directly to the surface.

Recovery and Transfer of Product

Recovery of spilled liquid and the pumping out of a disabled tanker can be hazardous because of the risk of ignition. The portable pumps and pump-equipped road tankers that oil companies use for these tasks do not have spark-ignition engines. This reduces the risk of ignition. Road tankers that are modified do not have conventional electrical systems, they have specifically designed systems conforming to special safety standards. If it is not practicable for a vehicle of this kind to attend (as is often the case in country areas), hand pumping into drums is the best alternative.

Experts on the site should determine the safest and most effective method of recovery and transfer.

The NSWFB OIC will take charge of the recovery operation and HAZMAT.

4.8 Extinguishing Media

You must be familiar with the various media used to extinguish flammable liquids.

4.8.1 Water

Water Soluble Liquids

If the flammable liquid is soluble in water, you can use water to dilute the burning liquid and extinguish the fire. Water soluble flammable liquids such as alcohols, acids, and phenols can usually be extinguished by diluting them with water. How practical this is depends on the space available for the additional water.

Non-soluble Liquids

An example of this kind of liquid is carbon disulphide. If the liquid is not water-soluble and if it is more dense than water, you can smother the fire by means of a layer of water that will float on top of the liquid.

Most flammable liquids are not water soluble i.e. they will not dissolve in water. The most likely case is that a liquid will be less dense than water and will not dissolve in it. Such liquids include petrol and paraffin. You can use water, but the water must be applied by fog and diffuser branches.

⚠ **NOTE**

Fog is particularly effective in extinguishing flammable fuel fires but the application of a foam blanket should be applied to prevent re-ignition.

- do not use jets as they will only spread the fire;
- if the flammable liquid has a flash point below that of the water temperature, extinguishing the fire by cooling is not possible;
- if you use water to extinguish a flammable liquid fire, seal it with foam where practicable to prevent the escape of vapours and prevent re-ignition; and
- be careful to avoid boil-over in fires involving heavy combustible liquids such as fuel oils. Boil-over may occur if water is applied to these liquids.

4.8.2 Foams

Fire fighting foams are created by the mechanical mixing of foam concentrate, water, and air. Foams are well suited for use against flammable liquids because of their low density, high water content, blanketing tendencies, and resistance to rapid breakdown. These properties allow foam to float on burning liquids. The foam smothers the fire and cools any hot objects that may be located near the flammable liquids.

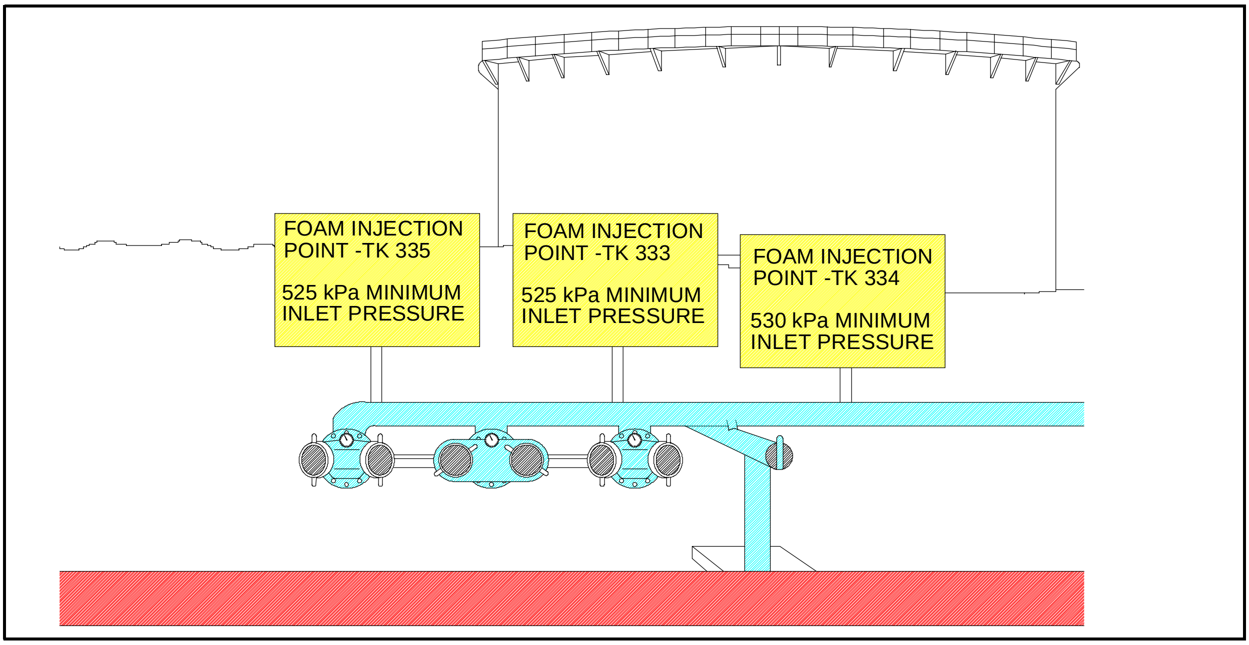


Fig 4.5 Foam Injection Points

CAUTION

Foams are not suitable for water-reactive fires, for three dimensional fires (such as leaking flanges), or for rapid-flowing flammable liquid fires, unless the flow can be dammed, because the foam cannot flow as quickly as the flammable liquid.

There are two basic types of foam:

- mechanical foams and
- chemical foams.

The mechanical foams include the protein and synthetic foams. These are distinguished from chemical foams. All three foams can be used with fresh or salt water. (For further information on foam compounds and foam-making equipment see *Topic 2 Section 3*)

4.8.3 Carbon Dioxide

This medium has a general application in fighting fire in flammable liquids. See *Topic 2 Section 3*.

4.8.4 Dry Powders

Dry powders also have general application for extinguishing flammable liquids. See *Topic 2 Section 3*.

4.8.5 Smothering Techniques

There are several techniques you can use for smothering flammable liquid fires. Two of the most common methods are:

- metal or asbestos blankets - these are suitable for dealing with small fires in containers; and
- steam - if injected into the space in a tank above a liquid, steam will eventually reduce the oxygen content so that combustion can no longer take place. This method is used in many oil refineries.

SECTION FIVE - LIQUID PETROLEUM GAS

CONTENTS

5 LIQUID PETROLEUM GAS

5.1 Introduction

Liquid Petroleum Gas (LPG) presents special hazards to firefighters. Because of the nature of LPG, problems can occur in storage and transport by leakage, fire, container failure, and boiling-liquid-expanding-vapour explosions (**BLEVE**). If LPG is involved in an incident, it can release a large amount of very destructive energy. In this section, we discuss the nature of LPG, its properties, the problems it presents, and how you can best deal with incidents involving LPG.

5.2 LPG Properties

LPG is a by-product of refining oil. LPG remains in a liquid state only so long as it remains in storage tanks under pressure. LPG vapourises rapidly when the tank in which it is stored is opened to the air. When it vapourises, it forms large volumes of gas.

Propane and Butane

The two most common forms of LPG are propane and butane. Table 5A details the properties of propane and butane.

SPECIFICATION	PROPANE	BUTANE
As a Liquid		
Specific Gravity at 15.60° C	0.5	0.58
Litres per tonne	1960	1740
As a Vapour		
Specific Gravity	1.5	2.0
Boiling point at atmospheric pressure	-40° C	-1.1°C
Vapour Pressure		
at 0° C	506 kPa	193 kPa
at 37.8° C	1553 kPa	400 kPa
Limits of Flammability	2-9% gas in air	2-10% in air

Table 5A Propane and Butane Properties

Weight

In its liquid form, LPG weighs about half the weight of an equivalent volume of water. As a gas it is 1.5 to 2 times heavier than air.

Odour

LPG is odourless in its original form as it comes from the refining process. An odourant is usually added to the gas before distribution. The most common odourants are ethyl mercaptan or dimethyl sulphide. The odourant is not added to the gas if the odourant would interfere with the purpose for which the gas is to be used. An example of this would be its use as the propellant in aerosol cans. If a container holds LPG that does not have an odourant added, the container is labelled accordingly.

LPG Mixing with Air

When mixed with air, LPG forms a flammable mixture. This gaseous mixture has a risk of explosion if the gas concentration is between 2% and 10%. Outside this range of concentration, the mixture is too lean or too rich to burn. However, over-rich mixtures can become hazardous as they become diluted with more air. In still air, LPG vapour disperses slowly.

Small quantities of **liquified LPG gas** give large volumes of gas vapour. When mixed with air, 1 L of liquid LPG produces 250-275 L of gas. When this amount of gas is mixed with enough air to come within the flammable range, the resulting volume could be as much as **2500 - 13 750 L**. It is possible that these conditions could exist in large LPG storage containers that are presumed to be empty.

LPG vapour is heavier than air. If LPG is released into the air, it may flow along the ground. It can flow into depressions and into drains, much like water. It will sink to the lowest level of its environment. It can flow over a considerable distance, and it may be ignited some distance from where the leak occurred.

Wind conditions can cause LPG to flow away from the point of release and accumulate in obscure places. For instance, if the wind conditions are just right, LPG may flow some distance and then accumulate behind a hedge or a fence.

CAUTION

LPG vapour is slightly anaesthetic. If LPG is present in sufficiently high concentration, it can cause asphyxiation by displacing the air.

Detection

LPG vapour can be hard to detect. It is not readily visible in the air. However, it can refract light. This means that sometimes you can see LPG in the air shimmering in the form of a fog, due to condensation of water vapour in the air. On a very hot dry day, however, you may not be able to see this fog because of the lack of water vapour in the air. This means that the fog cannot form and the gas will not be visible.

Under suitable conditions, if LPG is released into the air, you can hear the hiss of escaping gas.

A suitable, properly calibrated gas detector is required to test concentrations in the air. Here is a list of some of the appropriate LPG detectors:

- JW Sniffer Model G;
- Combustible Gas Detector;
- Danger Multi Gas Detector;
- TMX 412; and
- Gas Detector 13/14.

CAUTION

You should never use a naked flame to detect an LPG leak. Use soapy water, or a safe gas detector.

5.3 Storage and Transport Containers

The material used in the construction of LPG containers is approximately twice as thick as that used in petrol containers. The containers on LPG transport tankers have internal baffles to control the surge and flow of loose liquid.

Labelling

Cylinders and tanks that contain LPG display a hazard class label. This is a **red diamond with the words flammable gas.** This classification complies with Class 2 labelling of dangerous goods.

Internal Pressure

All LPG containers are tested to withstand internal pressures in excess of 1750 kPa. Each LPG storage or transport container has a pressure relief valve fitted. This valve relieves internal pressure when the LPG in the container is heated and the internal pressure rises above a safe working limit. The relief valve normally operates to release pressure when that pressure exceeds 1750 kPa. Cylinders should always be positioned so that the relief valve is free of obstruction, the liquid contents should never cover the relief valve.

CAUTION

If flame is applied to the outside walls of the container of the gas space, the heat can weaken the metal walls, and the tank may rupture at a pressure below that at which the relief valve operates.

Container Filling

LPG storage tanks are filled only to a level of 80% liquid and 20% gas. If the tank were full of liquid, a slight rise in temperature can produce an increase in the hydrostatic pressure. If this happens, the relief valve may open and discharge liquid.

NOTE

For every 20° C rise in temperature, there is a 6% increase in liquid volume.

5.3.1 Container Failure - BLEVE

A container of liquefied gas has a very high level of potential energy. If the container fails or breaks apart, this energy is released in a very violent way. It may even be an explosion. If this happens, the liquid and gas contents and pieces of the container are propelled rapidly and violently into the surrounding environment.

Boiling Liquid, Expanding Vapour Explosion (BLEVE) is the name that describes the result of such a container failure if the container fails when it is exposed to fire.

For a BLEVE to occur, the contents of the container need not even be flammable. For example, in the USA, a central heating boiler system became a BLEVE which totally destroyed the eight storey building it served. This happened when the pressure relief valve failed to operate after a faulty thermostat allowed overheating to occur in the tank.

How a BLEVE Occurs

At a normal storage temperature, liquefied gas is stored under a pressure ranging from less than 1 kPa for some cryogenic gas containers to several hundred kPa for non-cryogenic liquefied gas containers. Any rise in temperature of the liquid within a container increases vapourisation. If the rise in temperature, as in a fire, is great enough, a rapid rise in pressure occurs as well. This rise in pressure can overcome the coping capacity of the pressure relief valve. If this happens, the valve does not allow enough vapour to escape fast enough. The pressure can then build to a point at which container failure can occur.

When a container does fail, the pressure suddenly drops to atmospheric pressure. The heat stored in the liquid causes the liquid to boil very rapidly. A large part of the liquid then becomes gas. This causes an increase in volume within the container.

The amount of liquid which vapourises is relative to the difference in the temperatures of the liquid when the container fails at the normal boiling point of the liquid - for propane the latter is -42° C.

For many liquefied flammable gasses stored at normal atmospheric temperature, that is if the temperature is not increased by fire, about one third of the gas in the container would vapourise if the container were to fail. With fire, the temperature difference is greater and the result more violent. This means that in the presence of fire, the liquid can reach boiling point immediately. The result is an expanding vapour explosion. Most BLEVE's occur when containers are filled from slightly less than half full capacity to about three-quarters full of liquid.

BLEVE Characteristics

A BLEVE involving LPG produces a large fireball and atomises the remaining liquid. This reaction can happen so rapidly that it is not uncommon for cold liquid to be propelled from the fire zone so quickly that it does not even ignite. In one incident in the USA, a BLEVE propelled droplets of liquid 1 km from the fireground. In other incidents, firefighters have been cooled by cold liquid as it passed them.

The magnitude of a BLEVE depends on three factors:

- the size of the container;
- the quantity of liquid which vapourises when the container fails; and
- the weight of the pieces of the container.

In a violent BLEVE, the pieces of the container are propelled like rockets for distances even up to 1 km. Projectiles from larger containers have been known to cause death at distances of up to 200 m. The fireball from a violent BLEVE can be several hundred m in diameter. Fatal burns have been received by persons as far as 75 m away from the exploding container.

The time between the first flame contact and a BLEVE is variable. The time lag depends on several factors such as the size and nature of the fire and the size and nature of the container itself. In the absence of water cooling the container, a small uninsulated container located above the ground, can produce a BLEVE in a few minutes. A large container can take several hours before heat application causes a BLEVE.

A study of LPG storage containers ranging in size from 4500 to 125 000 L has revealed that some of these tanks have BLEVED in 8-30 mins. 54% of the BLEVEs occurred within 15 mins or less. Data on insulated containers is scarce. The only containers that are insulated are cryogenic containers and some reactive gas containers. Research shows that there is no doubt that insulation designed for fire exposure can extend the time significantly in which a BLEVE will occur.

In one case, an insulated LPG railroad tank car withstood 20.5 hrs of fire exposure before the BLEVE occurred. This was probably an extreme example. In comparison, fire tests on several other insulated LPG railroad tank cars caused a BLEVE to occur in 93 mins. Similar tests on an uninsulated tank caused a BLEVE in 25 mins.

The best practice is to treat all LPG cylinders with great caution. A BLEVE is always possible when LPG containers are involved in a fire. The fireground tactics of the OIC should always include a plan to deal with a BLEVE.

5.4 Major Leaks

A leak of LPG from a large storage vessel or a road tanker can be a very serious matter.

If you attend an incident where a major leak is suspected or confirmed but where ignition has not occurred, you should take the following action immediately:

- evacuate all persons from the immediate area with a radius of at least 200 m, especially those down wind of the escaping gas;
- instruct everyone in the area surrounding the incident to eliminate all sources of ignition by turning off gas appliances, gas pilots, refrigerators, washing machines, hair dryers, electric stoves, heaters etc;
- if the leak is from a storage tank, consult plant personnel to locate any valves that could be used to stop the flow; and

- if the leak is from a mobile tanker, consult the driver to locate the valves to reduce or stop the flow.

LPG vapourises very quickly. When it does vapourise, the temperature of the LPG drops dramatically. As a result, LPG, particularly liquid LPG, can cause severe frost burns if it comes into contact with the skin. If exposure to liquid LPG is possible, you must wear protective clothing such as gloves and goggles, especially while you are trying to close valves.

Dealing with an Empty Container

A container that has held LPG and is thought to be empty can still contain LPG as vapour. This container can still be very dangerous. The internal pressure of an LPG container is approximately that of the surrounding atmosphere. If a valve is leaking or left open, air can diffuse into the container. If air enters the container and mixes with the LPG vapour, it forms a flammable mixture and creates the risk of an explosion. Alternatively, the vapour may diffuse into the atmosphere where it can ignite.

Dealing with an Open Leak

If you cannot shut off the leak, you should attempt to disperse the emission of gas with fog streams of high pressure water. You should approach and apply the water across the vapour stream if possible but do this from a safe distance. You should keep a second fog branch alongside to give you protection if the vapour cloud ignites. Always position appliances and personnel on high ground up wind of the incident.

CAUTION

LPG vapour is heavier than air. If it is not actively disturbed, it can form pockets of gas that may explode.

Danger of a Cool Vessel

The use of water is generally effective on an LPG vessel from which gas is escaping and fire has not yet occurred. However, you should consider whether the vessel itself may be cooler than the water being applied to it.

Escaping LPG vapour causes rapid vapourisation of the liquid LPG. This vapourisation takes heat from both the body of the vessel and from the surrounding air. This can happen so fast that ice can form on the lower portion of the vessel holding the liquid. You can actually see how much liquid is in the vessel by observing the frost line on the outside of the vessel. In this situation, it is unwise to continue to use water spray for cooling the vessel.

Dispersing the Vapour

The most important action you must take now is to disperse the vapour. The rate at which the vapour disperses can depend on the weather conditions:

- in cold and still conditions, the gas will lie close to the ground. You can actually see the gas cloud if the ambient temperature is low enough. Expansion of the gas will reduce the temperature of the surrounding air, and will cause water vapour to condense and produce a fog-like phenomenon;

- in warm and windy conditions, the vapour is most likely to disperse. There is no control over direction and strength of the wind.

Flowing LPG Vapour

LPG vapour is heavier than air, but it can flow like water. LPG vapour can find a way into basements and into drains. Even thick vegetation or grass can hold explosive mixtures. These pockets of gas-air mixture can explode violently if ignited. If ignition occurs, the radiant heat, or even the flame itself, can ignite the gas coming from a leak. This causes further damage and raises the temperature. The vapour pressure in the vessel also rises.

Consequently, a different type of hazard is created namely, an escape with fire - an extremely dangerous condition.

5.5 Fire and Major Leaks

Ignited Leak

If a leaking stream of escaping gas is ignited, you must assume that a BLEVE can occur. In this event, you must request assistance to organise the evacuation area. It should have a radius of at least 1 km around the site of the incident.

⚠ **NOTE**

A BLEVE can occur in as little as ten minutes. Container failures can cause damage to property up to a 1 km radius around the incident.

Pressure Relief Valve

The operation (or non-operation) of the pressure relief valve does not necessarily mean that a BLEVE is imminent. However, if the valve is operating, the internal pressure of the cylinder may be rising. This can be indicated by the following:

- any increase in the noise level from the valve; or
- any sign of bulging or blistering on the outside of the tank or cylinder.

If either of these occurs, immediately evacuate all personnel from the area. BLEVE's have been known to cause fireballs of up to 300 m in diameter.

5.5.1 Evacuation of the Area

In the event of an incident involving LPG, you must always consider the possibility that the area needs to be evacuated. Whether evacuation is necessary depends on the nature of the incident.

Conduct of the Evacuation

You may be fully committed to attacking the fire, and it may be necessary for you to leave the evacuation operation to Police. The evacuation is conducted under the direction of the OIC at the incident.

Criteria for Evacuation

The decision on whether to conduct a wide area evacuation of personnel outside the fireground is based on five factors:

- whether flame from another source is threatening an LPG tank or container;
- whether the flame deflected from the leak is burning back against the container wall;
- whether there is flame threatening the container from other than the LPG source;
- whether radiant heat from any source is affecting an LPG tank or container; and
- whether the estimated size of the LPG container is sufficient to warrant an evacuation.

⚠ **NOTE**

The decision on the final area of evacuation rests with the OIC.

5.5.2 Fire Fighting Procedures for an LPG Leak

Implementation of a Fire Fighting Plan

Once the fireground is defined, (refer to SOP's), you should determine the potential danger to the general public, the environment, public facilities, livestock, or property. If substantial danger exists, implement a plan of attack according to SOP.

Position of Appliances

The ultimate positioning of the appliance will depend on the decisions you make following your assessment of the situation. Your decisions should include the following considerations:

- whether water pumping appliances are close enough to the incident to provide speedy access;
- whether you can maintain cover behind a building or natural ground feature; and
- whether you can set up covering sprays or monitors during the initial stages of the plan which can enable evacuation of firefighters if that becomes necessary.

Possible Container Failure

Container failure is always a danger in an LPG incident. Container failure is most often due to the weakening of the container metal as a result of flame contact. Water must be directed onto affected containers and nearby pipe works and structures.

It is extremely difficult for the metal of the container to heat significantly where it has contact with the liquid within, because the liquid acts as a heat absorber. For this reason, the biggest danger of a BLEVE is caused by a flame impinging on the upper portion of the tank where the vapour is located.

Guidelines for Minimising Container Failure

When attacking a fire caused by an LPG leak that is likely to involve a container failure, you follow these guidelines:

- avoid creating rivulets of water on the container. Rivulets of water may cause the temperature of the steel skin between the rivulets to rise rapidly. This can cause the skin to reach failure temperature;
- distribute the water evenly over the entire surface of the LPG vessel. Place your hose lines carefully and consider the angle of attack and the curvature of the vessel;
- attack the LPG cylinders from the side. Maintain a good water supply. If possible, you should use spray, but you can use a straight jet if you have to consider distance or wind effects;
- concentrate on the areas exposed to heat rather than on the entire container. Concentrate particularly on those upper areas that are less likely to benefit from the heat-dispersing effects of the liquid on the inside of the container;
- remember that cooling water applied to the upper surface of a cylinder or spherical tank is not likely to be effective below its equator;
- apply the water at the point of flame contact. The most critical area of the container is the vapour space, the area above its liquid level. This is the high priority area for cooling. (However, it is not always possible to identify the exact level of the liquid.);
- if water supplies are inadequate, consider constructing dams and re-using the water which is draining away;
- if you have access to a valve to cut off the flow of LPG and if that valve is still functioning, it may be possible for a crew to approach the container from the side (not the ends). If this approach is undertaken, the members of the crew must wear protective clothing and they must proceed under protection of water fog;

- it is important to spray jets of water continuously on the cylinder from hose lines throughout the entire operation; and
- allow only the minimum number of personnel in the combat zone. Control is at the discretion of the OIC.

⚠ **NOTE**

Flame should not be extinguished until valve shut-down has been completed, otherwise a more hazardous situation would be created.

5.6 Pre-Planning

You can best pre-plan an attack on an LPG incident by simulating an incident at a premises that stores LPG.

Here is a brief checklist of some of the points to consider when you carry out a simulated exercise.

5.6.1 Evacuating the Area

Here is a checklist of things to consider as you anticipate a need to evacuate an area:

- define the area where an incident may occur;
- determine the probabilities of the occurrence of an incident;
- consult with Police, Ambulance, suppliers of LPG, and other Authorities;
- determine the population of the area; and
- carry out regular tactical exercises.

5.6.2 Attacking the Fire

Here is a checklist of things to consider as you prepare to attack the fire:

- determine the water supplies available for prolonged use;
- conduct regular exercises on fixed installations in your station area; and
- remember time is not on the side of the firefighter. Container failures have occurred within 10 mins of ignition.

5.7 LPG as a Motor Vehicle Fuel

5.7.1 Identifying LPG Vehicles

If you are called to an incident that you suspect may involve LPG in a motor vehicle, your first task is to determine if LPG is in fact involved. This can be difficult, and you could be well advised to assume that LPG is involved until you determine that it is not involved.

Labelling Standards and Compliance

Australian Standard 1425, Automotive LP Gas Code, requires the labelling of LPG powered vehicles with a 25mm reflective red square fixed to both front and rear licence plates. Compliance with this code is controlled by the *Vehicle Engineering Branch of the Department of Transport*. This Branch of the Department also monitors the standard of workmanship of those who hold a current LPG fitter's permit.

Currently, plastic stick-on labels are used to indicate that a motor vehicle is fitted with LPG operation. This label may not be evident in a fire situation. There is little other external evidence to alert firefighters to an LPG cylinder in the boot.

LPG Change-over Switch in Vehicle

If the LPG cylinder or the red stick-on labels are not visible, look to the right of the steering column inside the vehicle to see if there is a petrol LPG change-over switch. Also look to see if there is a second fuel filler cap on the outside of the vehicle. Usually this second fuel filler cap will be on the opposite side to the petrol filler cap.

Safety Valve Discharge Outlet and Vent Pipes

Other indicators of LPG installation are the safety valve discharge outlet and vent pipes. If the safety valve discharge outlet is present, it will probably be fitted with a rubber plug and located at the rear of the vehicle in the wheel arch area. The *Vehicle Engineering Branch* encourages fitters to install this valve behind the mud flap under the rear mudguard. Placement of vent pipes may vary depending on make and model of the vehicle and the regulations at the time of its conversion.

5.7.2 LPG Equipment

LPG Cylinders

LPG container cylinders must be installed correctly by an auto-gas licence holder. The installation and the cylinders must comply with the *Automotive LP Gas Code*. All LPG cylinders, including those on automobiles, must be fitted with safety valves, including relief valves, that operate at approximately 2500 Kpa. These valves are vented to the outside of the boot and covered by a protective seal. Cylinders have a capacity of 60-90 L for cars and up to 350 L for trucks.

Location of Cylinders

In sedans, the cylinder is situated in the boot. In station wagons and vans, it may be in the luggage area near the spare wheel. The location of the cylinder filling facility depends on the regulations in force at the time of conversion and installation of the cylinder. The filling facility is often located externally.

Cylinder Fittings

In general, cylinders have the following fittings:

- service valve;
- contents gauge;
- fixed liquid level gauge;
- safety valve;
- filler valve

Service Valve

The service valve is a manually operated valve connected to the outlet of the container. It controls the LPG fuel flow. An excess flow valve is also fitted at the service valve to stop the flow of liquid in the event of rupture or breakage of the service line.

Contents Gauge

The contents gauge shows the approximate amount of liquid in the container.

Fixed Liquid Level Gauge

This gauge is also called an ullage gauge. This device indicates when the container is filled to the correct level. It is also used to test the accuracy of automatic fill limiters.

Safety Valve

The safety valve allows LPG to be released if the pressure reaches a dangerous level.

Filler Valve

The filler valve provides an attachment point where the container is filled. The latest design containers also incorporate an automatic 80% fill limiter.

5.7.3 LPG leaks in Motor Vehicles

Problem Areas

If you have determined that LPG is installed in a vehicle that has been involved in an accident, one of your first concerns should be whether there is gas escaping from the LPG installation. You should consider the following as problem areas:

- the pipeline;
- the fittings in the engine compartment;
- the cylinder; and
- the cylinder connections.

Approaching the Vehicle

Here is a list of precautions you should take as you approach a vehicle that may have LPG installed and that may have a leak or a rupture:

- approach the vehicle from up-wind where practical;
- eliminate all ignition sources;
- evacuate all persons from the surrounding area as necessary and up to a distance as directed by the OIC (this could be a radius of up to 200 m depending on the situation.);
- allow no one to come within the area of the vapour cloud;
- attempt to break up any vapour cloud by high pressure water sprays; and
- locate the source of the leak and stop it.

Dealing with the Leak and the Vehicle

Here is a list of precautions and procedures you should observe as you attack the leak in the vehicle:

- turn off the service valve at the cylinder. If the leak is in the line from the tank to the carburettor it may be either liquid or gas. The leak may not be strong enough to activate the excess flow valve;
- if the leak or rupture is excessive and the excess flow valve has not worked, you can stop the flow by turning off the service valve;
- if the valves are damaged or not accessible, and you cannot stop the leak or rupture, then disperse the cloud with high pressure water spray. Direct the spray into the vapours or across the leak. The spray action will draw the LPG into the water-air stream and break up the cloud. This also drops the condition of the gas vapour to below its flammability limit;
- apply the spray until all gas has been dissipated and you have rendered the incident safe; and
- avoid creating sparks from the vehicle's electrical system, do not open vehicle doors, do not turn on the ignition or the lights, and do not attempt to remove the battery.

5.7.4 Fire and LPG Leaks in Motor Vehicles

If you attend an incident involving a motor vehicle in which LPG may be installed, the fire at first may involve only the vehicle and not the LPG fuel. In this event, you must assume that the LPG fuel may become involved in the fire especially if you cannot isolate the fire from the LPG cylinder, fuel lines, and equipment.

Your first priority is to cool all equipment associated with the LPG and to keep the fuel itself below the pressure at which **the relief valve** operates.

⚠ **NOTE**

Once the relief valve operates, more fuel becomes available for combustion, this greatly increases the problem. Deploy a second line to keep the cylinder and the fuel lines cool by spraying them with large quantities of water.

Dealing with the Leak

In actually dealing with the leak, your first priority is to determine just where the leak is located. Here is a list of examples of leaks that can cause problems or fires at various points in the system:

- fire at the carburettor - make an assessment and then approach with caution. Turn off the ignition. This should isolate the gas flow and stop the fuel fire. Deal separately with other combustibles which may be ignited. Proceed to the cylinder and turn off the service valve. At the same time, disperse any LPG with high pressure spray;
- fire at the second-stage converter - make an assessment and then approach with caution. Turn off the ignition. This should isolate the gas flow and stop the fuel fire. Deal separately with other combustibles which may be ignited. Proceed to the cylinder and turn off the service valve. At the same time, disperse any LPG with high pressure spray; or
- hose rupture between the cylinder and the converter issuing liquid fuel. Any large flow should activate the excess flow valve. Then you must deal only with the residual gas.

⚠ **NOTE**

If the rupture is not strong enough to cause the excess flow valve to operate, the escape of fuel will be continuous. Protect yourself adequately and isolate the fuel flow by turning off the service valve at the cylinder. Disperse any LPG with high pressure spray.

5.7.5 Accidents Involving LPG Fuelled Motor Vehicles

Finally, here is a list of general precautions you should take in dealing with an accident involving LPG fuelled motor vehicles:

- keep all unauthorised personnel at a distance of at least 75 m from the fire;
- cool the vehicle with fixed hose streams before fire fighting crews approach the fire;
- position all firefighters behind adequate cover during cooling down operations;
- approach the vehicle from the sides; and
- take extra care if the vehicle has been burning for a prolonged period

⚠ **NOTE**

The pressure relief valve should be activated.

SECTION SIX - NATURAL GAS

CONTENTS

6 NATURAL GAS

6.1 Introduction

The Natural Gas (NG) network in NSW services households, businesses, and major industries. In all, there are over 550 000 connections to the gas network in NSW. Each of these connections can represent a potential incident.

Occurrence

NG occurs naturally in the earth. After cleaning and drying, NG is approximately 95% methane. A comparison of NG and LPG properties is detailed in Table 6A.

Distribution

NG is generally distributed by pipeline and mains at pressures starting at approximately 15 kPa in the trunk pipeline. NG can be compressed to higher pressures in cylinders for use as a vehicle fuel.

6.2 Combustion

Combustion can occur in three ways:

- stoichiometric combustion;
- complete combustion; and
- incomplete combustion.

Stoichiometric Combustion

Stoichiometric combustion, also called perfect combustion, occurs when the mix of air and fuel are in precisely the right combination in relation to each other. Stoichiometric combustion is generally achieved only in a laboratory.

Complete Combustion

Complete combustion occurs when the mix of air and fuel contains more air than is required to complete the combustion process. This results in complete combustion of all the gas present. Complete combustion is the combustion process used for most gas burners.

Incomplete Combustion

Incomplete combustion occurs when the mix of air and fuel contains more fuel than air, and the amount of air present is insufficient to complete the combustion process.

⚠ **CAUTION**

Incomplete combustion produces poisonous carbon monoxide. This is an extremely dangerous condition.

The ignition temperature of NG is approximately 680° C. (This is a higher temperature than a lighted cigarette.)

If you encounter escaping gas under field conditions, it can be difficult to tell what kind of gas it is, and therefore what its ignition temperature is. It makes good sense to isolate any area from which gas is escaping.

6.2.1 Air-Gas Ratio for Combustion

This is the ratio, or proportion, of air to gas that supports stoichiometric (or perfect) combustion. If the air to gas ratio is lower than this when a gas burner is operating, then incomplete combustion occurs and poisonous carbon monoxide is produced.

A gas burner must have an adequate supply of air to mix with the gas so that it can operate safely. Stoichiometric combustion is not usually desirable because a slight reduction in available air will result in incomplete combustion.

When a gas burner is operating correctly, it produces carbon dioxide, water vapour, and nitrogen. All of these by-products are non-toxic. However, if these products are allowed to accumulate in the vicinity of the burner, then incomplete combustion will occur.

Flammability Range

For combustion to occur with gas; the gas must mix with air in the proper concentration. Gas will not ignite if air is not present. For instance, it will not ignite inside gas pipework. The flammability limits define the range of concentration of gas to air in an air-gas mixture. Within the flammable range of concentration, combustion will continue after the ignition source is removed. When the air-gas concentration is below the flammable range, no combustion will occur at all in the absence of an ignition source. For concentrations above the range, combustion will occur, if additional air is made available.

6.2.2 Air-Gas Ratio for Stoichiometric Combustion

NG 9.95 parts air - 1 part gas.

Gas appliances are carefully designed to ensure that burners have an adequate supply of air so that by-products cannot accumulate. NSW *Plumbing Regulations* specify where gas appliances can be installed, what ventilation is required for them, and whether a flue is required to remove the products of combustion from the vicinity of the appliance.

Flammability Range

NG is limited between 5% and 15%.

In a confined space, the intensity of the pressure wave that results from ignition is approximately 700 kPa. This pressure is the same when the air-gas concentration is anywhere within the flammable range. After ignition, a lean mixture (that is, more air and less gas) will burn very rapidly in comparison to a rich mixture (that is, less air and more gas).

The sound of combustion of a lean mixture is more audible than the sound of combustion of a rich mixture. Audibility, however, is not necessarily a good measure of the danger that results from combustion. Combustion of a rich mixture, although less audible, will burn for a longer period and therefore presents more potential danger, especially from radiant heat.

6.3 Common Causes of Gas Escape

6.3.1 In a House or Building

The main causes of gas escape in a house or building are:

- gas appliances have been installed incorrectly;
- gas appliances have been tampered with; or
- regulations have been ignored when the gas appliances were installed.

6.3.2 In the Front Yard or around the House

The main causes of gas escape in the yard or around a house are:

- use of whipper-snippers (power weed and grass cutters);
- use of lawn mowers;
- disturbance of gas mains by digging in the earth; and
- damage by motor vehicles.

6.3.3 Escapes from Gas Mains in the Street

The main cause of gas escape in the street is disturbance of the gas main by improper excavation.

PROPERTY	NATURAL GAS	LPG
Relative Density	Dissipates The relative density of NG is 0.59. The relative density of air is 1.00. This means that when compared with air, NG is 41% *lighter* than air. Since NG is lighter than air, when NG is released into the air the gas disperses rapidly.	Accumulates The relative density of LPG propane in vapour form is 1.55. The relative density of air is 1.00. This means that, when compared with air, LPG is 55% *heavier* than air. Since LPG is heavier than air, when LPG is released into the air, *especially when ventilation is inadequate*, the LPG can accumulate at ground level particularly in any depressions such as pits or drains.
Flame Spread	0.4 m/sec	0.5 m/sec
	The *flame spread* is the speed at which flame will travel through a stoichiometric mixture of air and gas.	
Toxicity	Non-Toxic	Non-Toxic
	Both NG and LPG in sufficient quantities can cause suffocation if there is no air available to breathe. However, NG is *less likely* to cause suffocation because it is lighter than air. This means that in the presence of air, NG tends to disperse.	
Odour	Artificial	Artificial
	Both NG and LPG are naturally odourless. To make them safer, both gases are *artificially odourised*. This means that an odourising agent is added to the gas as a safety measure. Both of these gases can be detected at a concentration of 0.05% in air. This is well below the level that will support combustion. If you can smell gas in the air, it does not mean necessarily that the situation is hazardous. But if you can smell gas, you should take some action promptly to stop the release of the gas into the air.	
Hazard Information	UN No: 1971 Hazchem: 2SE	UN No: 1075 Hazchem: 2WE

Table 6A Comparison of NG to LPG Properties

6.4 Responding to a Gas Escape

If you are called upon to respond to a gas escape incident, you should first take action to make the area safe:

- clear all persons from the area affected by the gas escape;
- look for and prohibit all sources of ignition . This includes vehicles, naked flames, smoking, helicopters, cameras, electrical equipment, or electronic equipment, and devices with electronic switches. Electrical switches should be taped shut to prevent their use; and

- check all equipment being used to be sure that it is intrinsically safe.

If you are called upon to respond to a gas escape incident **in a home or building**, carry out the following actions:

- immediately find the gas supply and turn it off at the meter control valve. (Generally, the gas meters are located on the side of the house or just inside the front fence);

- if the gas meter control valve cannot be turned off, immediately clear the area of all unauthorised persons and ensure that the NG Company has been notified of an emergency;

- if you must enter the building, remember that toxic gas such as carbon monoxide may be present; and

- if knobs or controls need to be disturbed take note of their positions as this information will be needed for technical reports.

If you are called upon to respond to a gas escape incident involving NG, carry out the following actions:

- dampen the ground around the site of the gas escape to prevent static electricity igniting the gas;

⚠ **NOTE**

In a NG incident, you should use water in moderation. The presence or use of excessive water can hamper repair work and can cause major gas supply problems.

- if the escaping gas is on fire, generally you should let the gas continue to burn while the NG Company crew works to control the gas supply. This can help to prevent the escaping gas from becoming a hazard.

⚠ **NOTE**

You should let the gas continue to burn, but be aware of the dangers of radiant heat.

Never ignite escaping gas to locate the escape point.

SECTION SEVEN - EXPLOSIVES

CONTENTS

7 EXPLOSIVES

7.1 Introduction

An explosive is defined as:

A substance that is capable of developing a sudden high pressure by the rapid formation of large volumes of gases at high temperature.

Of all the common materials which can be involved in a fire, explosives present the highest and most immediate danger to life and property. Explosives are treated with great respect, and the persons responsible for the manufacture, handling, and transport of explosives practice a high standard of care and precaution.

A highly regulated and complex system of legal safeguards controls all aspects of the use of explosives. For this reason, fortunately, large fires rarely occur in explosives installations. To ensure your safety, however, you must be aware of the nature and properties of explosives.

Deflagation

Sudden and rapid combustion in which the flame speed is less than the velocity of sound in the gaseous products.

Flame speed 1-10 m/sec but the compression waves travel faster, about 330 m/sec giving some advance warning which may allow the operation of explosive vents. Temporary pressure can be very high.

Detonation

Violent explosion in which flame speed is equal to the velocity of sound in the gaseous products and is accompanied by a shock wave. The velocity is 1000 m/sec. Temporary pressure can be very high.

Brisonce

The ability to hit so fast that things cannot move out of the way.

7.2 Nature and Properties

Explosives are substances which can be transformed directly into gases at high temperatures. These substances include the following:

- common commercial and military explosives,
- coloured fires;
- fog signals;
- flares;
- fireworks;
- rockets;
- fuses;
- percussion caps;
- detonators; and
- various other explosive devices.

Some explosives are basic chemical compounds such as fulminate of mercury. Others are mixtures of common ingredients. For instance, gunpowder is a mixture of saltpetre, sulphur, and charcoal. The explosives industry handles an enormous variety of mixtures. These in turn are manufactured, processed, and packed into many different explosive products.

WorkCover Authority of NSW defines the sub-classes of explosives as shown in Fig 7.1

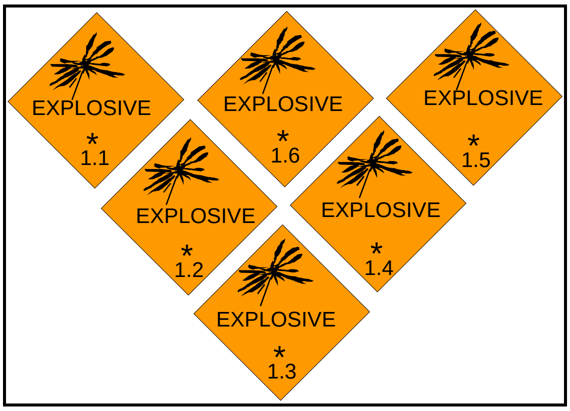


Fig 7.1 Sub-classes of Explosives

7.3 Types, Characteristics and Uses

Here is a list of the main types, characteristics, and uses of some common high explosives:

7.3.1 Nitroglycerine

Nitroglycerine is a powerful and sensitive explosive. Its qualities make it difficult to use this explosive in unmixed form. It is commonly combined with other explosives. Nitroglycerine is commonly the basic ingredient of dynamites and blasting gelatines.

7.3.2 Dynamites

Dynamite is not a single substance, it is a group of powerful explosives. Dynamites include nitroglycerine and absorbents in their structure. To add substance to the explosive material, the manufacturers often add gelatines and other ingredients such as ammonium nitrate.

7.3.3 Nitrates

The nitrates group comprises different substances.

- Ammonium nitrate is one of the most common constituents of nitrate mixtures, yet it is not classed as an explosive itself. When combined with other specific substances, ammonium nitrate has a wide variety of civil and military uses. For instance, Amatol is a combination of ammonium nitrate and trinitrotoluene (TNT).
- Cellulose nitrate, nitrocellulose, comprising guncotton, pyrocotton, and nitrocotton, burns very quickly and is a powerful explosive when compressed and initiated. Cellulose nitrate is used as a propellant mixture for shotgun and small arms ammunition and in nitroglycerine explosives.

7.3.4 Trinitrotoluene

Trinitrotoluene (TNT) is used mainly in mixtures for blasting. It is also used for charges in some types of ammunition. It is relatively safe to handle, but in large quantities may burn and detonate.

7.3.5 Chlorates

Chlorates are the salts of sodium or potassium. They are not used in blasting explosives, but they have a limited use in cap and detonator compositions. The principal use of chlorates is in firework compositions.

7.3.6 Fulminates, Azides, Styphnates

These compounds form sensitive explosive compounds when mixed with sulphur, phosphorous, and carbonaceous materials. They are predominantly used with other substances as initiators in the form of caps or detonators.

⚠ **CAUTION**

Fulminates, azides, styphnates are sensitive and dangerous and they can cause a short and violent explosion.

7.4 Classification

Detailed below is a list of the classifications of explosive materials:

- primary or initiating high explosives;
- secondary high explosives; and
- low explosives or propellants.

7.4.1 Primary or Initiating High Explosives

Primary or initiating high explosives **are very hazardous materials**. They are an important ingredient in the manufacture of explosive materials.

Typical primary or initiating high explosives include:

- mercury fulminate;
- lead styphnate; and
- lead azide.

Because of the hazardous nature of primary or initiating high explosives, they are seldom used alone. Their major function is to initiate detonation in less sensitive explosives. These primary explosives can be detonated very easily by heat or by the application of a mild mechanical shock such as the hammer of a firearm. They are used almost exclusively as the initiating agent in detonators.

7.4.2 Secondary High Explosives

Secondary high explosives are relatively insensitive to mechanical shock and heat, but they are easily detonated by a primary explosive. Secondary high explosives are more powerful than the primary or initiating explosives, and they are often used in commercial blasting operations. Secondary high explosives, unlike blasting agents, are cap sensitive.

Secondary high explosives include:

- dynamite;
- nitroglycerine;
- TNT;
- RDX; and
- pentaerythrital tetranitrate (PETN).

⚠ **NOTE**

Because of its sensitivity, nitroglycerine is never used alone.

7.4.3 Low Explosives or Propellants

Low explosives or propellants are used mainly for propulsion purposes. They normally operate by burning rather than by detonation, however, many low explosives or propellants are initiated by detonation. Fire is the primary hazard in the manufacture and use of propellant explosives.

Low explosives or propellants include:

- black powder;
- smokeless powder; and
- solid rocket fuels.

7.4.4 Blasting Agents

Blasting agents are often used because they are safer than nitroglycerine. Almost 90% of all blasting operations use blasting agents that consist of non-nitroglycerine materials. The most preferred blasting agent is a fuel oxidizer system which is made of ammonium nitrate and a fuel. One of these preferred blasting agents is made by adding approximately 60% fuel oil to ammonium nitrate pellets. This blasting agent has the advantage of low production cost, and it is safer than nitroglycerine in dynamites. Blasting agents do not burn readily, but they may detonate in a well established fire.

7.5 Storage

A storage facility for explosive materials must protect those materials from their surroundings. The safety of the general public and of the workers in the storage area is also of primary importance. Employees of the explosive manufacturing companies are aware of the hazards of their occupation, and safety is an integral part of their work. Most explosive materials are used by the mining and construction industries.

Security of stored explosives is also a matter of great concern. In recent years, the illicit use of explosives has increased, and the world wide increase in terrorism has made security of explosives a very important consideration.

The storage of explosives is a very specialised business. It requires knowledge of the materials, and skills in dealing with those materials. The control and storage of these materials is under the scrutiny of the *WorkCover Authority.*

Explosive materials are stored in specialised types of buildings or in storage areas below ground. These storage facilities are located a minimum distance from houses, highways, railways, and other public places. In some cases, protective mounds are used.

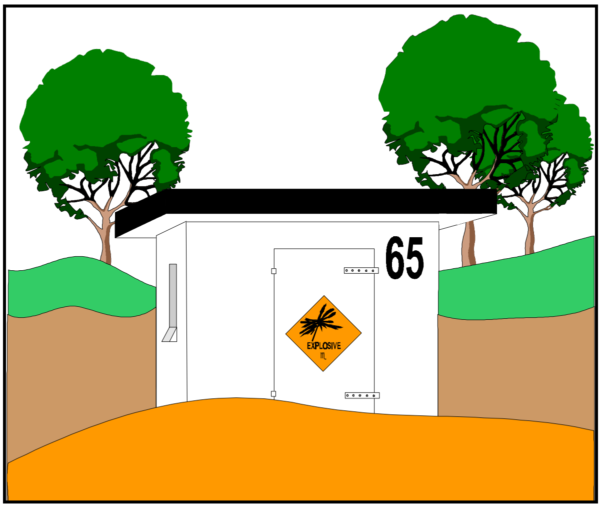


Fig 7.2 An Explosive Storehouse

Special requirements are imposed on all facilities relating to access, ventilation, and general tidiness. All of these stringent requirements relating to storage apply to large civil and military installations, as well as the small explosives stores of a quarry, and the registered premises of a fireworks shop.

If an explosion occurs in an explosives storage facility, the facility cannot be expected to fully contain the explosion. But the facilities must be blast resistant so that they deflect and reduce the effects of an explosion blast, reduce the shock waves generated by the explosion, and contain (as much as possible), the missiles that would be propelled by the explosion. Full containment within the facility is possible only for potentially small explosive elements.

7.6 Fires

Fires that occur in the use, manufacture, and storage of explosives and fireworks generally start with the ignition of a material or component containing the explosives. This ignition can induce a rapid, intense fire for a short duration or a steady fire of variable intensity. The incident may start with a primary explosion or series of explosions. The flying debris produced by the primary explosion can then start other fires. If the incident occurs in a building, damage can vary from minor effects within the building to complete destruction of the building and contents. Fortunately, serious outbreaks of fire incidents with explosives are rare.

The cause of ignition during manufacture is often impossible to determine. However, ignition may be due to the inclusion of foreign bodies such as grit or dirt in the manufacturing materials or in the processing machinery. Poor quality control in the composition, friction, or handling of the explosives can also cause an incident. If someone drops or strikes one of the dangerous materials, the materials may ignite or explode. In the industries that have a high fire risk, safety precautions are usually well observed and enforced. Hence, the incidence of accidents due to neglect of fire precautions is very low.

These elaborate and complex safety procedures play a large part in the storage and manufacture of explosives. The safety procedures depend on a high standard of control, cleanliness, and fire safety.

Persons who work with these materials reduce the chance of an incident by wearing special clothing and footwear. The areas where they work have special flooring material. The tools and other equipment they use are specially made to eliminate or reduce risk. These areas do not normally use fixed fire fighting installations, since, in most cases, the use of these installations would be too late to be of any benefit. Means of quick escape from the work area play a larger part in the safety of the workers than any of the normal fire extinguishing measures can provide.

7.7 Fire Fighting Procedures

Each incident involving explosive materials must be treated in a unique way. The practices prescribed for ordinary risks simply do not cover the risks involved with explosives. The correct fireground tactics and procedures depend on an intimate knowledge of the behaviour of explosives. The staff of explosives establishments are experts in this field and they have this specialised knowledge.

If you attend an incident involving explosives, you should consider three main factors upon arrival at the scene:

- identify the substance involved;
- identify the type of hazard involved; and
- determine the appropriate action to take.

⚠ **NOTE**

Advice about explosives is available from *Datachem.*

In the event of an incident, the NSWFB OIC at the incident must work in close co-operation with the officer of the explosives installation.

If you investigate an incident in a facility that is used to manufacture or store explosives, you must be very careful not to disturb the site of the incident or the remains of the buildings or facilities involved. Investigations into the cause and nature of these incidents can be seriously hampered by disturbing the remains at the site of the incident.

7.7.1 General Considerations

The fire fighting procedures you use at the site of an incident involving explosives greatly depend on the classification and the quantity and quality of the explosives present or involved in the incident. Each sub-class of explosives has certain points of procedure that you must observe if you are dealing with that sub-class. However, here are some general points of procedure that you should observe in any incident where explosives may be present:

- you must carry out all fire fighting procedures from behind substantial cover and protection;
- you must make every effort to prevent explosives becoming involved in an incident;
- you should use water streams to protect exposures;
- you should evacuate all personnel from the area once explosives have become involved;
- you should consider all substances in the incident potentially toxic; and
- you should consider using BA.

7.7.2 Specific Considerations

Table 7A details the sub-classes of class 1 explosive materials with a description of their characteristics. Following the table, there are procedural guidelines for you to follow if you attend an incident involving that sub-class of explosive material.

SUB-CLASS	DESCRIPTION
1.1	Explosives with a mass explosion hazard.
1.2	Explosives with a projection hazard but not a mass explosion hazard.
1.3	Explosives with a fire hazard and a minor blast hazard or minor projection hazard, or both, but no mass explosion hazard.
1.4	Explosives with no significance.
1.5	Explosives which are not very sensitive, but when initiated have a mass explosion hazard.
1.6	Extremely insensitive detonating substances

Table 7A Class 1 - Explosives

7.7.3 Mass Explosion Hazard - Sub-Class 1.1.

If you attend an incident involving sub-class 1.1 explosive material, you should observe the following procedures:

- your first action must be to prevent explosives from becoming involved in the incident;
- you must carry out all fire fighting operations from behind protective cover such as earth mounds, suitable buildings, or natural features; and
- you should follow the advice of the explosives industry staff member or the *WorkCover* Officer at the incident site.

If the fire reaches the explosives, an explosion is imminent. The external effects of any explosion depend on the quantity and type of explosive materials present and the design of the facility in which they are stored.

Your top priority at the site is to prevent other fires from starting from the effect of the explosion. To prevent the incident becoming more serious, you can cool the roofs and walls of nearby structures with solid streams, fogs, or sprays.

The OIC must evaluate the risks of cooling the explosives in the building. Drenchers and sprinklers should be operated when there is an apparent risk of further explosions due to burning embers falling on the ground.

7.7.4 Projection Hazard - Sub-Class 1.2

If you attend an incident involving sub-class 1.2 explosive material, you should observe the following procedures:

Once explosives have become involved in a fire:

- you should evacuate all non-essential personnel from the area;
- you should continue to apply water from behind substantial cover such as brick buildings;
- you should fight this kind of fire with large quantities of water, but try to avoid the use of hard striking solid streams; and
- if the fire spreads to neighbouring buildings, you should deal with the fire as for sub-class 1.1 explosives fires.

7.7.5 Minor Blast or Projection Hazard - Sub-Class 1.3.

If you attend an incident involving sub-class 1.3 explosive material, you should observe the procedures described in the paragraphs above relating to sub-classes 1.1 and 1.2.

7.7.6 No Significant Hazard - Sub-Class 1.4

If you attend an incident involving sub-class 1.4 explosive material, where there is no risk of mass explosion, the NSWFB have the responsibility to fight the fire, irrespective of the substances involved.

⚠ **NOTE**

Some of the explosive substances may have a toxic effect. You should consider the use of BA if the density and colour of the smoke suggest the presence of a toxic material.

7.7.7 Low Sensitivity Presenting a Mass Explosion Hazard When Initiated - Sub-Class 1.5.

If you attend an incident involving sub-classes 1.5 and 1.6 explosive material, and you arrive at the incident before any explosions have occurred, proceed to extinguish the fire as quickly as possible. Use the maximum amount of cover available.

If explosions have already occurred or if an explosion is imminent, you should follow the procedures outlined for sub-class 1.1.

7.8 Explosives in Transit

When explosives are transported from one place to another, the transportation itself can create additional hazards.

7.8.1 Transport by Sea

If the explosives are being transported by sea, certain controls are imposed on the activity of the vessel. To ensure that the information on the quantity and location of explosives in ships is readily available to the fire officer, the movement of ships carrying the explosive materials is strictly controlled.

Internal controls are also imposed and strictly enforced:

- the explosives must be correctly labelled and recorded; and
- the explosives must be classified and the classifications recorded along with a description of the expected behaviour of the substance in case of fire.

If an incident occurs on board a ship carrying explosive materials, you must co-ordinate any fire fighting efforts in close co-operation with the *Port Authority* of NSW and the *WorkCover Authority.*

7.8.2 Transport by Train

The transportation of explosives by train is controlled by railway legislation and the *WorkCover Authority.*

Explosives carried by rail must be clearly identified and carried in specially approved railway wagons. With the exception of small quantities of specified types of explosives, all explosive materials are transported by goods trains and are subjected to strict safety precautions.

The fire fighting procedure that you follow to fight a fire involving explosives on a train depends on the type of explosive materials carried. Early arrival on the scene and early attack is usually the best method. If an early direct attack on the fire is impossible, you should make an effort to move the train clear of inhabited areas.

⚠ **NOTE**

A primary concern at such an incident is the safety of firefighters and railway personnel.

7.8.3 Transport by Road

If explosives are being transported by road, the greatest risk of hazard is the possibility of a traffic accident. This type of incident presents an extreme risk to road users and local inhabitants. These factors may require an urgent and large scale evacuation procedure to be implemented. Procedures will vary greatly with the type and quantity of explosives carried.

SECTION EIGHT - DUST EXPLOSIONS

CONTENTS

8 DUST EXPLOSIONS

8.1 Introduction

Dust held in suspension in the air can be a fire hazard. Heat can cause dust to explode if the dust in the air is from a combustible material.

The fire danger in dust comes from the greater surface area that it exposes to the air. If the dust is very fine, it is even more likely to remain in suspension in the air and even more likely to explode. The suspension of fine dust in the air increases its danger. If suspended dust comes into contact with a suitable source of heat, it will explode, especially if the dust is in a confined space.

In this section, we will discuss the fire dangers that dust can create and how we can deal with those dangers.

8.2 How Dust Explosions Occur

A dust explosion is in fact a rapid movement of fire from one dust particle to another. When dust is in the right combination with air, the condition is similar to the right combination of gas and air. If an ignition source is introduced, the combination can explode.

When an explosion occurs, the fire moves rapidly from one particle to another. This rapid fire movement from one particle of dust to another is due to the very high surface area of the particles. Each particle burns very readily because oxygen is amply available. The small mass of each particle is rapidly consumed. If the concentration of particles in the air is just right, the heat of combustion of one particle brings the next nearest particles to their ignition temperature, and the process spreads with the rapidity of an explosion.

If the concentration or ratio of dust to air is less than perfect, that is, if the particles are too far apart in the air or if they are too close to one another, the possibility of an explosion diminishes.

In a factory or warehouse, combustible dust can accumulate on beams, machinery, and other surfaces. In the event of a fire, the combustion process can accelerate considerably.

The degree of concentration of the dust particles is critical both to the likelihood of the explosion occurring and to the severity of the explosion if it does occur. If the concentration of dust to air is too high, the particles do not have free access to oxygen. This will lower the possibility of an explosion. If the concentration of dust to air is too low, then the particles are too far from one another to pass on the heat of combustion, and, again, the likelihood of combustion is lowered.

A dust explosion usually does not produce a severe fire except in those premises where flammable materials are kept in large quantities.

8.3 Factors to Consider

Manufacturing plants and storage warehouses that are likely to have dangerous dust should have explosion vents and reliefs. If the vents and reliefs are properly installed, any dust explosions will probably be confined within the plant. A fire from an explosion will probably subside once the explosion is over if there are no other combustible materials in the vicinity.

There are, however, some dangerous characteristics of these explosions that should be noted.

Small Fires

When an explosion occurs, the movement of fire from one particle to another is very rapid. In fact, the fire may move so fast through the particles that it is unable to ignite large masses of combustible material stored in the vicinity of the explosion. But the explosion may leave a number of small fires burning. These fires can soon become serious if they are not extinguished immediately. In a larger fire, more dust clouds are created by falling debris. These dust clouds can then cause further dust explosions.

Sources of Ignition

The source of ignition for a dust explosion can be different from the ignition needed for gas-air mixtures. A dust explosion can be caused by a moderate heat environment such as over heated equipment.

Intensity

Dust explosions are frequently of greater intensity than gas explosions because dust explosions can have larger amounts of combustible matter contained in a given volume, and the explosion can move very fast through fine dust.

Presence of Foreign Matter

When combustible materials are being processed, particularly in the grinding or pulverising process, foreign materials such as particles of steel or stone can create sparks that act as sources of ignition.

Electricity as a Source of Ignition

Dust explosions can occur in dust extraction ducts. The dust moving through these ducts can be ignited by machinery that has overheated, by friction, or by the breakdown of electric motors or electric wiring.

Static electricity is another well recognised source of ignition. As the hot, dry dust moves through trunking and ducts, it can generate static electricity in the air within the ducts. This static electricity can ignite the dust in the ducts. The best way to prevent this ignition is to earth the ducts and surrounding equipment.

Successive Explosions

Dust explosions can occur successively, that is, in two parts:

- the first explosion, or pilot explosion, occurs when the air-dust mixture is ignited. It is often not very violent, but can be serious enough to agitate dust lying on the floor, beams, and other surfaces;

- the second explosion occurs when this newly agitated dust is ignited by the first explosion or by a continuous ignition source such as the overheated machinery. This second explosion can be of much greater intensity.

Successive explosions occur in industrial premises where combustible dust is present and house keeping is poor. Dust collects on horizontal surfaces of walls, on machinery, along roof girders, on floors and furniture, on window sills, and in niches of brickwork. When disturbed, this dust will become suspended in the air.

The pilot explosion disturbs the dust lying on the exposed surfaces, and this same ignition source can then set off a devastating secondary explosion. This type of incident has been described by employees who have experienced dust explosions. They say they have observed a small explosion just before the second, more violent, explosion.

Ignition

Dust clouds ignite at temperatures between 300° C and 600° C. They require 20 to 50 times more ignition energy than flammable vapours. To prevent the danger of a dust explosion, all ignition sources must be removed.

The main sources of ignition for dust explosions include:

- open flames;

- open lights;

- cigarettes;

- cigarette lighters;
- electric arcs;
- hot filaments of light bulbs;
- sparks from friction grinders;
- high pressure steam pipes;
- sparks from static electricity;
- spontaneous heating;
- overheated machinery;
- welding and cutting torches; and
- other sources of heat.

Inaccessible Machinery

Inaccessible electric motors and machinery can be a major source of dust explosions. When a piece of machinery is in a confined or inaccessible space, dust can accumulate on shafts and bearings. These shafts and bearings can heat up due to the friction of the machinery. This danger can even be increased by more friction caused by the dust itself.

Spontaneous Combustion

Spontaneous combustion can be a source of dust explosions. Fortunately, the number of substances is small in which spontaneous combustion of dry dust has been known to occur. Coal, rubber, and zinc sulfide are the only substances that have been known to cause spontaneous combustion. But the possibility does exist, and it should not be overlooked as a possible indirect cause of dust explosions.

Fires have been caused in dust heaps by spontaneous combustion. Such a fire can in turn ignite a dust cloud and a consequent explosion will occur.

Combustible Materials

Certain industries use combustible materials that are likely to cause dust explosions. Building inspections of factories and service industries that use these materials can reveal situations in which a dust explosion could occur. Those materials that are most likely to cause dust explosions include:

- grain;
- wood;
- metal;
- plastic;
- cotton;
- paper;
- fertiliser;
- spray painting overspray; and
- panel beating body filler.

⚠ **NOTE**

The manufacturing process generates a combination of several of these combustible dusts.

Table A details substances that can produce potentially hazardous dusts.

METAL DUSTS	PLASTIC DUSTS	MISCELLANEOUS DUSTS
Chromium	Cellulose Acetate	Spices
Copper	Methyl Methacrylate	Cocoa
Iron Ore	Phenolformal - dehyde	Grain Dusts
Lead	Polystyrene	Rice
Tungsten	Urea Resins	Soya Beans
Manganese	Melamine	Starch
Tin	Venyl Butryal	Yeast
Aluminium		Coffee
Magnesium		Graphite
Magnesium alloys		Leather Tea Powdered drugs Pyrethrum Shellac Silicone Sulphur Sawdust

Table 8B Hazardous Dust Substances

8.4 Conditions Required

For a dust explosion to occur, four conditions must exist simultaneously:

- a combustible solid in the form of dust must be dispersed in the air;
- the concentration of the dust in the air must be within the explosive range;
- a source of ignition must be introduced of sufficient energy and duration to initiate the explosive chain reaction for that particular dust; and
- the explosive chemical reaction must occur in a confined space.

Flash Fire vs Dust Explosion

A flash fire results if the first three of these conditions are present. A dust explosion requires the first three conditions plus the fourth condition. A dust explosion is thus a flash fire that occurs in a confined space. A dust explosion includes a rapid build-up of excessive pressures.

8.5 Factors Determining Intensity

The character and intensity of any dust explosion will be affected by the following factors:

- turbulence;
- ignition source;
- dust type;
- particle size; and
- concentration of particles.

Turbulence

Turbulence speeds up the diffusion of oxygen to the reacting surfaces and promotes stronger explosions.

⚠ **NOTE**

The smaller the particle size and the greater the turbulence, the more the dust resembles a gas or vapour in its explosive characteristics.

Ignition Source

Ignition source can affect the character of the dust explosion:

- the size of the ignition source affects the explosion. An increase in the size of the ignition source increases the severity of the explosion;
- the nature of the ignition source also affects the explosion:
  - heated coils more readily ignite organic dusts;

- spark ignition more readily ignites metal dusts.

Dust Type

Experiments show that some dusts produce stronger explosions than others. Strongest explosions are caused by metallic dusts such as:

- stamped aluminium powder;
- milled and stamped magnesium;
- atomised aluminium.

Milder explosions are caused by organic dusts such as:

- phenolformaldehyde resin;
- cornstarch;
- soybean protein;
- fine sawdust; and
- coal dust.

Particle Size

Particle size greatly affects dust explosions. The smaller the particle of dust :

- the easier it is to ignite the dust cloud;
- the higher the pressure rise in an explosion;
- the lower the ignition temperature required to cause an explosion;
- the lower the ignition energy necessary to ignite the dust;
- the greater the danger of electrostatic discharge;
- the larger the dust explosion;
- the greater the destruction; and
- the less concentrated they need to be to effect an explosion.

Concentration of Particles

Concentration of particles affects the nature and severity of a dust explosion. Lower Explosive Limits (LEL) of dust clouds define the lowest percentage of concentration by volume of dust mixed with air that will burn.

The LEL of dust clouds is lowered by the following factors:

- the purity of the sample i.e. removing foreign substances from the mixture;
- the oxygen concentration i.e. by introducing a higher level of oxygen;
- the strength of ignition source i.e. by increasing the intensity of the ignition;
- the turbulence of the cloud i.e. by increasing the movement of particles; and
- the uniformity of dispersion i.e. by making each particle equi-distant from each other.

8.6 Minimising Factors

Precautions can help to minimise the risk of dust explosions. These include minimising the formation of dust clouds and eliminating ignition sources.

Minimising the Formation of Dust Clouds.

Formation of dust clouds can be reduced by isolating the machines or items of plant from which dust is produced. These items of plant equipment should be enclosed, or arranged, to prevent the escape of dust. They should be so arranged that ventilation is adequate.

Dust material should be removed from the machines gently through removal chutes so that dust clouds are not allowed to form. If these machines produce dust in large quantities, dust extraction equipment should be provided.

Dust should not collect on ledges, floors and machinery. Accumulations of settled dust can be dislodged by even a small draught of air. If settled dust is disturbed, an explosion may occur. A small explosion may cause little damage in itself. However, it can dislodge sufficient settled dust to form dust clouds. These larger clouds can result in a more serious secondary explosion. Vacuum plants should be installed to remove dust and to prevent its accumulation.

Limiting the Potential Damage of an Explosion

When a dust explosion takes place in a confined space, its intensity is increased. Even in confined spaces, the potential damage of an explosion can be reduced by the introduction of lightweight relief panels. These panels on grinding machines, elevators, and other equipment that produce or are in contact with dust will allow the expanding gases to escape more easily, once an explosion has occurred.

Whenever possible, grinding machines and other equipment that produce dust, should be installed in separate fire-resistant rooms that have adequate relief panels and ventilation.

Good Housekeeping Theory and Practice

Good housekeeping in plants where dust is produced can help a great deal to reduce the risk of dust explosions. A good housekeeping program includes attention to the less complex aspects of reduction of risk, including:

- tidiness and order;
- waste control ;and
- regulation of smoking.

Poor housekeeping contributes to the risk of potential loss by increasing fire and explosion hazards:

- it provides more places for a fire to start;
- it provides a greater combustible loading for the initial fire to feed upon;
- it creates the potential for flash fires or dust explosions when layers of lint or dust are allowed to accumulate;
- it creates a greater continuity of combustibles so that it is easier for fire to spread; and
- it increases the potential for spontaneous ignitions.

8.7 Precautions when Fire Fighting

If you are called upon to attend an incident where dust accumulation may present the risk of a dust explosion, you should do the following:

- avoid the use of jets and sprays that strike harshly against layers of dust. Use only a fine spray or fog at low branch pressure when working near accumulated dust. Even a fog or a spray should be applied with care to avoid stirring up clouds of dust;
- use only powdered talc, graphite, soda ash or dry sand to extinguish dust fires involving metal powder.

CAUTION

Avoid the use of water, foam, chemical, and vaporising liquid extinguishers;

- avoid handling bins, cartons, drums or open containers of any flammable dust or powder in such a way that a dust cloud could be produced. If you must move these containers, cover them before moving them. If they are already on fire, carefully drench or flood the containers before moving them;

- use high expansion foam to minimise dust disturbance, to attract and absorb dust, and to cool and extinguish the fire;
- use care to minimise dust disturbance when walking or moving around in areas where there is accumulated dust.

8.8 Other Characteristics

Here are some other matters to remember regarding dust fires.

- deposits of dust or finely divided solids on horizontal surfaces can cause fire to spread through a building with exceptional speed;

⚠ NOTE

This applies particularly to dust fires inside trunking and ducts. For this reason, it is vital to shut down the extractors, exhaust systems, or any machinery creating a draught in trunking systems or ducts. In cases where a flammable dust is being fed from, produced in, or passed through machinery, the product supply must be cut off.

- where fire has been caused by a dust explosion, small pockets of dust may still be alight on horizontal surfaces. These pockets may not be readily visible. If this condition exists, you should make a search for these pockets in any adjoining compartments and linked conveyors. These small fires should be extinguished by using spray or fog;
- where dusts or powders of organic materials are lying in heaps, it is common for a smouldering fire to start in them;
- when the layer or pile is thin, you can detect the fire fairly easily. In a large or deep heap, however, a fire can smoulder for as long as a week with little external evidence;

it is particularly important to treat such fires with special care. Often a slight disturbance can cause the upper layer to fall into the cavity which has been burned away, and this can cause a minor explosion.

⚠ NOTE

You can extinguish these fires with a spray or fog branch if you take care to avoid disturbing the heap of accumulated dust.

SECTION NINE - METALS

CONTENTS

9 METALS

9.1 Introduction

In this section, we examine the various metals that can pose a fire hazard. For each metal, we list its characteristics and discuss the appropriate extinguishants to be used for fires involving each metal.

Exposure to Air

Most metals will burn in air under certain conditions. These conditions vary from one metal to another. To burn freely, a metal, like other substances, must reach a temperature at which it will ignite. Some metals can reach this ignition temperature when in reaction with oxygen in air or moisture. Aluminium and steel can ignite and burn in a finely divided form e.g. clean, fine steel wool can ignite and catch fire. Some metals react with oxygen to form a surface oxide coating that protects the metal from further reaction. Aluminium, zinc, and lead fall into this category.

Exposure to Water

Some metals react vigorously with water. Some react more slowly in air or moisture e.g. rust formation on iron. For each metal, we discuss the reaction to exposure to water.

Extinguishants

Fires involving metals require some techniques not commonly used to fight other types of fires.

⚠ **NOTE**

All metals have a Hazchem Code 4 allocation.

Dry sand is the only common extinguishant that can be safely used on all metal fires. However, specific extinguishants are recommended for fires involving specific types of metals.

9.2 Alkali Metals

9.2.1 Sodium

UN Number: 428

Class 1: 4.3 Dangerous when wet

Hazchem: 4W

Non-Pyrophonic (Does not ignite very easily on exposure to air)

General Characteristics

Metallic sodium is very soft, you can cut it with an ordinary knife.

Exposure to Air

When metallic sodium is exposed to the air, the surface immediately discolours. This is due to the formation of an oxide as the sodium reacts with the oxygen in the air. Metallic sodium will burn in the air at a temperature slightly below its melting point of 99° C. When sodium burns, it gives off a small flame and a caustic, choking smoke.

Exposure to Water

When sodium makes contact with water, it floats because it has a density of -0.97. The water causes sodium to react violently and melts, almost explosively. In this melting process, sodium gives off hydrogen and oxygen, and it self-ignites. When this occurs, it sputters vigorously. Metallic sodium must be kept immersed in kerosene.

The combustion reaction of metallic sodium can be stopped only by blanketing the burning material with nitrogen gas or by smothering it with a non-reactive material that slowly reduces the oxygen access to the metal.

Extinguishants

The following extinguishants can be used with metallic sodium:

- dry sand;
- G-1 graphite powder;
- soda ash (anhydrous sodium carbonate);
- powdered sodium chloride (table salt); and
- dry limestone (calcium carbonate).

9.2.2 Potassium

UN Number: 2257

Class: 4.3 Dangerous when wet

Hazchem: 4W

General Characteristics

Metallic potassium is a soft, highly reactive metal similar in almost every respect to sodium.

Exposure to Air

Potassium is lighter than sodium. It has a density of -0.86, and it melts at 620° C. When exposed to air, metallic potassium usually ignites near its melting point.

Exposure to Water

When metallic potassium is exposed to water, it reacts rapidly. It melts and self-ignites, with vigorous sputtering. It gives off a caustic, choking white smoke. Metallic elemental potassium must be kept immersed in kerosene. Combustion of the potassium can be stopped by removing its access to oxygen.

Extinguishants

A fire involving potassium is extinguished by blanketing the burning material with nitrogen gas. The following extinguishants can be used with metallic potassium.

- dry sand;
- G-1 graphite powder;
- soda ash (anhydrous sodium carbonate);
- powdered sodium chloride (table salt); and
- dry limestone (calcium carbonate).

9.3 Aluminium

UN Number: 1309

Aluminium powder, coated (With not less than 20% of powder having a particle size of less than 250 microns).

Class: 4.1 Flammable Solid.

Hazchem: 4Z

UN Number: 1396 Aluminium powder, uncoated. Non-Pyrophonic.

Class: 4.3 Dangerous when wet.

Hazchem: 4Y

General Characteristics

Aluminium powder is transported under two UN numbers as dangerous goods - 1309 and 1396. Only the powdered or other finely divided form of aluminium present special fire problems. Aluminium powder in bulk is ignitable only with difficulty.

Small particles of aluminium have a greater tendency to form explosive dust clouds. These clouds can constitute a hazard when you are trying to extinguish aluminium powder fires.

Exposure to Air

In bulk, aluminium dust presents almost no fire hazard. However, if aluminium dust is suspended in a dust-air cloud, it is readily ignited and very explosive. Hence, when you are fighting an aluminium powder fire, you should avoid stirring the dust either with water sprays or by mechanical agitation. All electric power in the area should be shut off to prevent an electrical spark ignition of the dust.

If aluminium powder is burning in a place where you can safely isolate it, you should use sand as an extinguishant. Place the sand in a ring around the fire, but avoid dropping sand on the burning powder. When you place the sand in the ring, take care to avoid fanning the dust into the air. When aluminium powder burns quietly, it forms a crust which excludes oxygen, and it will gradually extinguish itself. So, as soon as you have isolated the fire, the room or area where the fire is located should be sealed and the bottoms of the doors sealed with sand. The fire should then be allowed to burn itself out.

Exposure to Water

Water streams or liquid sprays that vaporize quickly are highly dangerous to aluminium dust, since the dust can be thrown into the air. When suspended in the air, the particles can cause a violent dust explosion.

CAUTION

Water reacts with hot aluminium dust to form hydrogen and this can spread the fire.

Extinguishants

Dry chemical powder and sand.

9.4 Calcium

UN Number: 1401

Class: 4.3 Dangerous when wet

Hazchem: 4W

UN Number: 1855 Calcium Powdered, Pyrophoric, or Calcium Alloys, Powdered, Pyrophoric.

Class: 4.2

Sub Risk: 4.3 Dangerous when wet

Hazchem: 4W

General Characteristics

Calcium can be transported under either of the UN numbers listed above. Calcium is a moderately soft, silver-white metal that oxidises in air to form a dull protective coating. It can be machined, extruded, or drawn, and it has a melting point of 845° C.

Exposure to Air

Finely divided calcium ignites spontaneously in air. Calcium burns in air at a rate slightly slower than the rate at which sodium burns.

Exposure to Water

Calcium reacts with water to form calcium hydroxide and hydrogen, which can burn.

Extinguishants

Dry sand, soda ash or lime.

9.5 Iron and Steel

UN Number: 2793

Iron Shavings (Borings, Cuttings, Drilling, Filings, etc.)

Class: 4.2

Hazchem: 4Y

General Characteristics

Iron and steel in massive form, such as structural steel or cast iron parts, will not burn under ordinary conditions. Fires have been reported in piles of steel turnings and other fine scrap, but it appears that these fires were due to the presence of oil or other contaminants. However, there have been enough incidents of iron scrap being ignited in this way, to justify a special UN Number allocation for the purposes of transport.

Exposure to Air

In the form of fine steel wool or dust, iron and steel will ignite in air in the presence of excess heat such as the heat from the spark of a welding torch.

Exposure to Water

There is no apparent danger from exposure of iron and steel to water.

Extinguishant

Dry sand, graphite powder or dry sodium chloride based extinguishers.

9.6 Magnesium

UN Number: 1869

Magnesium or Magnesium Alloys

(With more than 50% magnesium in pellets, turnings, and ribbons.)

Class: 4.1 Flammable solid.

Hazchem: 4Y

UN Number: 2950

Magnesium granules, coated.

(Particle size no less than 149 microns.)

Class: 4.3 Dangerous when wet.

Hazchem: 4Y

UN Number: 1418

Magnesium powder or Magnesium alloys, powder.

Class: 4.3 Dangerous when wet.

Sub-risk: 4.2 Spontaneously combustible.

Hazchem: 4Y

General Characteristics

Magnesium is a silvery, moderately hard metal with a melting point of about 650° C. The ignition temperatures of magnesium alloys are about 575° C with flame temperatures in the region of 560° C. The flame region is very small, usually about 5 - 10 cm in height above the burning surface of the metal. While magnesium in massive form such as large castings and machined parts does not require it to be transported with a UN number, smaller sections and powder forms do.

Pure magnesium metal is almost always alloyed with aluminium, manganese, copper, or zinc in small amounts. It can be alloyed with aluminium for use in structural parts, die-cast automotive parts, missiles and space vehicles. In powder form, it is used in flares, pyrotechnics (fireworks), and flash photography.

In large castings or machine parts, magnesium will not generally ignite because of its high heat conductivity and its ability to radiate heat away from the area being heated. Near its melting point (which will vary depending on the type of alloy with which it is mixed), the surface of the metal becomes blackened due to oxide formation. This oxide formation accelerates the oxidation reaction, and the reaction produces the familiar dazzling bright flame.

Thin chips, turnings, or ribbons of magnesium alloys ignite more rapidly than do thick sections.

Exposure to Air

Finely divided powders can ignite with a flashing brightness. White smoke is produced if fine magnesium powders are heated and mixed with air by some process of falling or agitation. The metal foils and wires in certain photographic flashbulbs consist of magnesium enclosed in an envelope of oxygen. Such flashbulbs are ignited by an electrical filament. The brilliant pyrotechnic search flares utilise mixtures of magnesium powder in an oxidising composition to give steady combustion and light.

CAUTION

Never look directly at burning magnesium as this can result in eye damage.

Exposure to Water

Magnesium combines readily with oxygen. Under some conditions, water applied to a magnesium fire can decompose into its constituent elements, oxygen and hydrogen. The oxygen combines with the magnesium and the hydrogen released adds to the intensity of the fire.

Extinguishants

Magnesium and its alloys present special problems in fire fighting. Some of these problems include the following:

- none of the commonly available inert gases are suitable for extinguishing magnesium fires. Magnesium combines so easily with oxygen that it will burn in an atmosphere of carbon dioxide;
- magnesium can also burn in an atmosphere of nitrogen to form magnesium nitride;
- none of the common fire-extinguishing methods that depend on water solutions or inert gases are effective for use on magnesium chip fires; and
- halogen-containing extinguishing agents (the Halons) react violently with burning magnesium. The chlorine and other halogens combine with the magnesium.

The method of extinguishing magnesium fires depends largely upon the form of the material:

- burning chips, shavings, and small parts must be smothered and cooled with a suitable dry extinguishing agent;
- magnesium dust must be treated carefully because a magnesium dust cloud can cause an explosion;
- solid magnesium can be dealt with fairly easily if the fire can be attacked in the early stages. It is best to remove surrounding material, leaving a small quantity of magnesium to burn itself out harmlessly;
- because of the importance of prompt attack on magnesium fires, automatic sprinklers are desirable to provide immediate notification and control of fire. While the water from the sprinklers may have the immediate effect of intensifying combustion of the magnesium, it will serve to protect the structure and other materials from serious damage;
- an excess of water should be applied to fires of solid magnesium. This cools the metal below the ignition temperature and the fire will probably go out rapidly. A small, finely divided water spray, may actually intensify the fire.

The following extinguishants can be used with Magnesium.

- dry sand;
- Met-L-X powder; and
- G-I graphite powder

9.7 Zinc

UN Number: 1435

Zinc powder or Zinc dust

Class: 4.3 Dangerous when wet

Sub-Risk: 4.2 Spontaneously combustible
(if required)

Hazchem: 4Y

General Characteristics

Zinc is a shiny white metal with a bluish-gray lustre. It is widely used for galvanising iron. Zinc requires a UN number only when it is in powdered form. Massive pieces of zinc, although difficult to ignite, will burn vigorously once ignited.

Exposure to Air

Thin pieces of zinc, such as zinc foil, are easily ignited. Zinc dust can readily form explosive dust clouds.

Exposure to Water

Zinc dust, when exposed to water, can react with water to form hydrogen.

Extinguishant

Dry sand, lime and soda ash.

SECTION TEN - PLASTICS

CONTENTS

10 PLASTICS

10.1 Introduction

Of all materials for both domestic and industrial purposes, plastics are by far the most widely used. It appears that there is no limit to the uses for modern plastics in the home, shop, office, institution, and warehouse.

When plastics are in the raw material state, and are stored in warehouses and factories, they pose the greatest risk of becoming a fire hazard.

In this section, we will list the various types of plastics and examine their characteristics. We will also discuss the hazards specific to plastic related fires.

10.2 Development

Plastics produce toxic fumes and a characteristic black, acrid smoke when they burn.

One of the earliest plastics was **celluloid**. Its basic ingredient is the highly flammable **cellulose nitrate**. When celluloid burns, it can cause a multitude of hazards.

Plastics have undergone considerable development and refinement over recent years. Processed plastics now contain fire retardants to reduce their fire risk, but most plastics are still highly flammable in their raw material state.

Because of the great variety of plastics and the various degrees of hazards they present, it is advisable for firefighters to visit plastics manufacturing and storage facilities to evaluate potential local hazards.

You should treat all fires involving plastics as hazardous materials fires, and you must use BA when dealing with a plastics fire.

10.3 Composition and Characteristics

Although many chemicals are added to a finished product, most modern plastics are basically a compound of carbon plus hydrogen, oxygen, and/or nitrogen. Plastics are of two main types:

- semi-synthetics, such as cellulose derivatives; and
- synthetics such as the modern polymers.

10.4 Modern Plastics - Products and Gases

Table 10A and 10B detail many of the modern plastics now in use, some typical products that are made from them, and the various gases that these plastics produce when they burn.

PLASTIC	TYPICAL PRODUCTS	FIRE GASES
ABS (Acrylonitrile- butadienestyrene)	Piping Luggage vehicle dash panels Calculator housings Refrigerator liners Margarine tubs	Carbon Monoxide Carbon Dioxide Hydrogen Cyanide Oxides of Nitrogen
ACRYLICS (Polymethylacrylate)	Aircraft canopies Aircraft windows TV shields Skylights Camera lenses Outdoor signs Vehicle tail lights Name plates for home appliances	Carbon Monoxide Carbon Dioxide
NYLON (Polyamide)	Electronic connectors Brushes Appliance housings Gears and bearings Combs Sporting goods	Carbon Monoxide Carbon Dioxide Alehydes Hydrogen Cyanide Oxides of Nitrogen Ammonia Formic Acetic Acids
PHENOLICS	Circuit breakers Distributor caps Vehicle steering wheels Fuse blocks Pot handles Appliance knobs	Carbon Monoxide Carbon Dioxide
POLYCARBONATE	Helmets (firefighters) Power tool housings Battery cases Safety glass Moulded products	Carbon Monoxide Carbon Dioxide
POLYETHYLENE (High Density)	Seats Waste baskets Disposable syringes Pallets Shipping pails	Carbon Monoxide Carbon Dioxide
POLYESTER	Corrugated panels Boat hulls Bowling balls Shirt buttons	Carbon Monoxide Carbon Dioxide
POLYPROPYLENE	Battery cases Carpet packing Radio/TV/Stereo housings	Carbon Monoxide Carbon Dioxide
POLYSTYRENE	Foam and non-foam cups Margarine tubs	Carbon Monoxide Carbon Dioxide

Table 10A Plastic Products and Gases (Part 1)

PLASTIC	TYPICAL PRODUCTS	FIRE GASES
POLYETHYLENE (Low Density)	Rubbish bags Packing lids Communications cables Bowls Garment bags Wire/cable coatings	Carbon Monoxide Carbon Dioxide
POLYURETHANE (Flexible)	Cushioning for furniture Mattresses and bed pillows Laminated to fabrics in wearing apparel for insulation Used on carpet pads and on foam backed carpets	Carbon Monoxide Carbon Dioxide Hydrogen Cyanide
POLYURETHANE (Rigid Foam)	Building insulation - spray on, foamed in place or slab type Refrigerator and freezer insulation Chair frames Tables Cabinets Picture frames Decorative Beams and Wall Panels Swimming pools Sporting goods Flotation articles	Carbon Monoxide Carbon Dioxide Hydrogen Cyanide Oxides of Nitrogen
POLYVINYL CHLORIDE (PVC)	Gramophone records Bottles Piping and wiring Wall covering Upholstery	Carbon Monoxide Carbon Dioxide Bensene Hydrogen Chloride

Table 10B Plastic Products and Gases (Part 2)

10.5 Gases Emitted from Burning Plastics

When plastics burn, they produce various hazardous gases. Some of those gases and their characteristics along with some safety precautions you should take if you are dealing with a plastics-based fire are described below.

⚠ **NOTE**

As we have so many uses for plastics now, you can safely assume that many fires will have some plastics burning in them.

10.5.1 Hydrogen Cyanide (Hydrocyanic Acid)

Hydrogen cyanide is a clear, colourless gas with a faint odour of bitter almonds. When you work with hydrogen cyanide present, you must wear a full-body gas suit.

The characteristics of hydrogen cyanide include the following:

- it is lighter than air - it will dissipate when released into the air and is very dangerous in a confined space;

- it is lighter than water - it will bubble up through water;
- it is soluble in water - it can mix with water and can change the properties of the water with which it mixes;
- it is extremely toxic - a few breaths can cause death; and
- it can be absorbed through the skin. This is why a full body suit is required.

10.5.2 Hydrogen Chloride (Hydrochloric Acid - Spirit of Salts)

Hydrogen chloride is a clear, colourless gas with a pungent odour. When you work with hydrogen chloride present, you must wear a full-body gas suit.

The characteristics of hydrogen chloride include the following:

- it is soluble in water;
- it is non-combustible, but when it comes into contact with metal, it can form hydrogen which, in turn, can form an explosive mixture when in contact with air;
- it is toxic; and
- it irritates eyes, skin and the respiratory tract.

10.5.3 Carbon Dioxide

Carbon dioxide is a clear, colourless, and odourless gas. When you work with carbon dioxide present, you must use BA.

The characteristics of carbon dioxide include the following:

- it is non-flammable;
- it is heavier than air - it can accumulate in pits or depressed surfaces;
- it is soluble in water; and
- it is toxic in high concentration and can cause asphyxiation and death if breathed in concentrated form.

10.5.4 Carbon Monoxide

Carbon monoxide is a clear, colourless, tasteless, odourless, non-irritating gas.

CAUTION

Carbon monoxide gas is extremely poisonous.

When you work with carbon monoxide present, you must use SCBA.

The characteristics of carbon monoxide include the following:

- it is flammable - it burns with a blue flame that is almost invisible;
- explosive limits in air - 13 - 75%;
- it is extremely toxic;

  0.1% concentration is dangerous for even just a few minutes.;

  0.3% concentration will cause a person to collapse in 15 minutes;

  1.0% will cause a person to collapse in 3 minutes;

  1.28% in the air is regarded as lethal.

10.5.5 Nitrous Oxide

Nitrous oxide can be stable as either a gas or as a liquid. Nitrous oxide is also known as laughing gas. When working with nitrous oxide, you must use BA.

The characteristics of nitrous oxide include the following:

- it can appear as a gas which is heavier than air;
- it can appear as a colourless liquid under slight pressure. As a liquid it is heavier than water, and it has a faint sweetish smell;
- it is a soluble, toxic, oxidant; and
- it can be explosive when mixed with hydrogen.

CAUTION

There are many different plastics with a wide variety of compositions. When plastics burn, they can produce many different gases. All of these gases should be considered hazardous to firefighters, but some of these gases present a greater hazard than others. In all cases where you are dealing with a fire involving burning plastics, you should use BA and you should consider wearing a full-body gas suit.

10.6 Fighting Celluloid Fires

10.6.1 Introduction

CAUTION

Celluloid fires are the most dangerous of all plastics fires.

Celluloid fires have the following characteristics:

- they are extremely fierce;
- they can cause explosions within the fires themselves;
- they produce potentially lethal nitrous fumes, oxides of nitrogen;
- they can cause a human being long-term problems because the effects of these deadly nitrous fumes are usually delayed;
- they are very difficult to extinguish;
- they require very large amounts of water to extinguish them;
- they require the use of BA.

10.6.2 Why Celluloid Fires are so Dangerous.

Decomposition

Celluloid can begin to break down or decompose at a relatively low temperature at about 100° C. Celluloid can explode at about 120° C. This decomposition process can be very violent in itself.

Dangerous Fumes

Celluloid begins to give off dangerous fumes as soon as it begins to decompose. These fumes have the following dangerous characteristics:

- they can explode if they collect in a confined space and then are exposed to air;
- they can travel away from the fire and cause a remote explosion;
- they are flammable in themselves;
- they are heavier than air, and they can accumulate in pits or depressions; and
- they contain carbon monoxide, nitrous oxide and hydrogen cyanide.

Problems in Extinguishing Fires

Celluloid has a very high oxygen content, and this means that very large quantities of water are needed to fight celluloid fires:

- you can extinguish a small fire by the prompt application of $CO_{2;}$

- you must use large quantities of water for cooling purposes and to inhibit fire spread. A celluloid fire can spread very easily because of the low decomposition temperature;

- you should avoid inhaling the nitrous fumes, and you should use BA (even in the open air); and

- fumes can be made less noxious and less liable to flame by the use of water spray.

Storage of Celluloid

If a fire occurs where celluloid is stored, the heat of the fire can cause a hazard because of the low decomposition temperature of celluloid. You should take the following precautions:

- use water to cool the celluloid in the vicinity of the fire to reduce the chance of decomposition;

- separate any stacked sheets of celluloid to dissipate the heat;

- use water to cool the storage sacks that contain celluloid cuttings and scrap. These sacks contain an added danger in that celluloid flakes can leak through the fibres of the sacks and can increase fire spread; and

- be aware that finely divided celluloid is liable to cause a dust explosion.

Processing of Celluloid

The processing of celluloid requires the use of large quantities of acid. This acid is usually pumped through pipes from one area to another. If the pipes are fractured, acid may be sprayed over a wide area. The appropriate precaution is to locate and turn off the pumps that move the acid through the pipeworks.

Rolling and Seasoning Process

The rolling and seasoning process can create certain fire risks including the following:

- the process uses solvents, and these solvents produce solvent vapour. The vapour in the atmosphere presents a constant risk and a fire hazard;

- the process produces fine particles of hardened plastic. These particles can ignite as a result of becoming heated by the friction in the machinery.

10.7 Behaviour of Plastics in Fires

Ignition Point

Plastics generally have a higher ignition temperature than wood and other cellulosic materials, but many are easily ignited and burn vigorously. Flames can spread very rapidly across plastics surfaces often as much as ten times faster than flames spread across most wood surfaces.

Melting

Many plastics tend to melt and flow when heated. This can cause the material to melt away from the fire and inhibit further burning. It may also produce tar-like flaming drip. This tar-like drip can start secondary fires some distance from the primary fire.

Gases

When plastics are burning they can produce toxic gases including hydrogen cyanide, hydrogen chloride phosgene, carbon monoxide, and carbon dioxide.

Some plastics, such as PVC or ethylene sulphide, can generate hydrogen chloride or sulphur dioxide. These gases are highly toxic. Additionally, they are corrosive to metals and electrical equipment. Ventilation will help to reduce damage to equipment.

Plastics have three distinct rates of burning:

- materials that will not burn at all or that cease to burn if the ignition source is removed;
- materials that are combustible but have a relatively slow rate of burning. These materials may or may not cease to burn when the ignition source is removed; and
- materials that burn without difficulty and are capable of being consumed after the source of ignition is removed.

The rate of burning can be affected by several factors, including:

- the state, form, and process of manufacturing. The flammable characteristics of the product can vary from one manufacturer to another; and
- the size of the plastic and the way it is stored. Plastics in a thin sheet or in powder form are more flammable than plastics in a thick, block state.

10.8 Personal Hazards

CAUTION

You must use a BA in all plastics fires.

Most burning plastics produce thick smoke. Some produce carbon dioxide and carbon monoxide gases, and other toxic fumes. In a plastics fire incident, it is often difficult to distinguish what plastics are burning and what gases are produced.

EFFECT	SAFE FOR SEVERAL HRS	SAFE FOR 1 HR	DANGEROUS AFTER 1/2 HR	FATAL IN 1/2 HR	RAPIDLY FATAL	LEAST AMOUNT CAUSING IRRITATION TO THROAT	LEAST DETECTABLE
Carbon Monoxide (CO)	100	400-500	1500-2000	4000	10000		
Chlorine (CL)	0.35-1.0	4	40-60		1000	15	3.5
Hydrogen Chloride (HCL)	10	50-100	1000-2000		1300-2000	35	
Carbonyl Chloride ($COCL_2$)	1.0	10	25		50	3.1	5.6
Hydrogen Fluoride (HF)	1.5-3.0	50-60	50-250	200-450			
Hydrogen Cyanide (HCN)	20	100	100-240		3000		
Ammonia (NH_3)	100		2500-4500	600	5000-10 000	408	5.3
Hydrogen Sulphide (H_2S)	20		200		1000	100	10*
Nitrous fumes (NO_2)	10-40		100-150		200-700	62	

NOTE

*** Sense of smell lost after exposure to 100 - 150 ppm for from 2 to 15 mins.**

Table 10C Quantitative Physiological Effects of Toxic Gases

10.9 Manufacturing Plants

Plastics are highly flammable, and plastics fires spread very rapidly. If you are called upon to attend a fire incident in a plastics manufacturing plant, the fire may be well established by the time you arrive. The entire scene will probably be covered with heavy smoke and the air will be heavy with fumes. Upon arrival at the scene, you should do the following:

- approach the fire from upwind;
- consider evacuating the area immediately;
- call for an ambulance to be placed on standby;
- use BA at all times.

⚠ **NOTE**

The use of protective clothing should be considered.

The fumes in the air are probably highly toxic. Some fumes will be odourless, some carry delayed effects and some may be narcotic i.e. formaldehyde, chloroform. Ventilation can help reduce the hazards of toxic fumes.

Use water sprays in fighting most plastics fires. Solid streams may be the best attack on burning cellulose nitrate plastics. However, avoid solid streams on heated pressure vessels, piping, and stocks of powdered chemicals - fog streams may be required.

Use foam where flammable liquids are involved in a fire (i.e. aniline, styrene or ethylene).

⚠ **NOTE**

Small fires involving these liquids are often easily extinguished with water.

Seek guidance from a representative of the manufacturing plant or a work chemist:

- moulding powders and granules are completely ruined when they are mixed with water. You should make an effort to salvage existing stocks and reduce water damage. Work chemists can advise which fire fighting methods will work best;
- acids may have been used in the manufacturing process, turn off pumps and pipelines and release pressure in sealed tanks;

⚠ **NOTE**

The representative can help you turn off pumps and electric power.

Determine if radioactive isotopes are present*:*

- some processes involve an irradiation of plastics constituents using radioactive isotopes. This process is fairly rare, but it does exist. This process is more likely to be used in a research laboratory than in a plastics production plant;
- building inspections are very important to determine the presence of radioactive isotopes. Seek guidance from the company’s representatives, chemists or physicists during both inspections and operations.

Keep a special watch out for unusual dangers from certain plastics materials used in manufacturing:

- find out if cellulose nitrate stocks are present;
- determine if corrosive phenol or fluorocarbons are present.

10.10 Conclusion

Fires involving plastics and plastic substances in industrial situations can be extremely hazardous:

- they have a great heat output;
- they emit dense black smoke;
- they have a heavy concentration of gases and fumes; and
- they have an ever present danger of explosions from dust and flammable liquids.

The OIC of fighting the plastics fire should be aware of the potential hazards and should:

- gain as much knowledge about the materials as possible (Refer to *Datachem* and company’s representatives or chemists);
- prepare plans of high risk locations within the station area;
- conduct inspections of high risk areas at regular intervals;
- approach the fire from upwind;
- ventilate if possible;
- work in BA and protective clothing if chemicals are involved and attend to decontamination of all personnel;
- consider evacuation and have an ambulance on standby; and
- use water fogs, sprays and high expansion foam.

SECTION ELEVEN - ELECTRICITY

This topic has been rescinded. Refer to current Standard Operational Guidelines, Recommended Practices and SIMS Worksheets.

SECTION TWELVE - RADIATION SAFETY

CONTENTS

12 RADIATION SAFETY

12.1 Introduction

Discovery of X-rays

X-rays were discovered by Roentgen in 1894. He announced his discovery on Christmas eve of 1895 and produced the first x-ray photographs - a view of the bones of his hand. Within three months, x-rays were being used for diagnostic work in a Vienna hospital. The benefits gained from the diagnostic use of the x-ray technique had a great impact on the medical world. So large was the effect of the discovery of x-rays that very little consideration was given to the possibility that x-rays might have harmful effects.

Development of X-rays

About a year after the discovery of x-rays, Becquerel discovered natural radioactivity. This discovery helped to accelerate the development of knowledge about radioactivity. A few years later, Ernest Rutherford named three distinct types of radiation:

- gamma;
- beta; and
- alpha.

For reasons associated with its physical properties, the generic name given to all three types of radiation is ionising radiation. Ionising radiation can displace electrons from their energy shells in the target material. This can cause changes to occur in the target material. The target material does not become radioactive from being bombarded with ionising radiation.

Gamma Radiation

Gamma radiation is the name given to the long range, highly penetrating type of radiation. Gamma radiation, like x-rays, has a very short wave length and travels at the speed of light. Heavy dense substances such as lead, concrete, and iron are required to shield against gamma radiation.

Beta Radiation

Beta radiation is the name given to the shorter range, less penetrating radiation. Beta radiation takes the form of sub-atomic particles, identical to electrons. These particles travel at velocities close to the speed of light. Most beta radiation can be stopped by 3 mm of aluminium or an equivalent thickness of materials of lesser density.

Alpha Radiation

Alpha radiation is the name given to the extremely short range, low penetrating radiation. Alpha radiation consists of heavy atomic particles. It can be stopped by a thin sheet of paper. Alpha radiation cannot penetrate the skin and is not a hazard if kept outside the body.

12.2 Sources of Radiation

As a firefighter, you are called to attend many different kinds of incidents. At each incident that you attend, you encounter hazards. These hazards are almost unlimited in type and number. One of the hazards of which you must be aware is the danger of radiation. Radiation is used in many industries for many purposes. The more you know about its application, the more ready you will be to anticipate the dangers of radiation when you attend an incident.

12.2.1 Manufacturing

In manufacturing, radioactive materials are used in many applications. Here is a list of some of these applications:

- to measure the density of material;
- to measure the thickness of material;
- to determine the weight of material;

- to detect and measure the presence of moisture;
- to calibrate instruments for fine measurement;
- to analyse alloys and determine their content;
- to eliminate static electricity; and
- to sterilise instruments and surfaces with gamma irradiators;

12.2.2 Hospital and Health Facilities

Radioactive materials play a big part in the health sector. In hospitals, x-rays and radiation treatment are widely used for diagnostic and treatment purposes. Here is a list of some of the applications of x-rays and radiation in hospitals and the health sector:

- radiation oncology for treatment of cancer;
- medical clinic diagnostic programs;
- x-rays for therapy or imaging purposes;
- various radioactive sources for other therapy; and
- nuclear medicine diagnostic procedures.

12.2.3 Transport

In the transport industry, radioactive materials are used for many purposes. If you are called to an incident involving transport vehicles, you should be aware of the possibility of radiation danger in the accident. Here is a list of some examples of the applications of radiation relating to transport:

- transporting medical imaging materials from *Lucas Heights Research Laboratory* by car to Sydney hospitals and airports;
- transporting medical isotopes on domestic and international air flights;
- transporting industrial, road building, and agricultural devices;
- transporting materials and products of the nuclear industry by road, rail, and air;
- transporting mining products and materials by freight train and trucks; and
- transporting radioactive waste from universities and hospitals to disposal sites.

12.2.4 Research Establishments

In research establishments, radioactive materials are used for existing forms of research and in research to find new applications. Here is a list of some of the applications of radiation in research establishments:

- research in biomedicine and health laboratories;
- research in many CSIRO laboratories;
- research in government institutions including defence related activities; and
- research in universities for medical and health applications.

12.2.5 Others Sources of Radiation

Here is a list of some other sources of radiation:

- dangerous goods management premises (radioisotopes in transit);
- large farms and environmental management authorities, e.g. nuclear-type soil moisture and density

gauges used in road building and construction industries;

- oil and NG industries, e.g. pipeline and rig construction, industrial radiography, and tracers; and
- linear accelerators.

12.3 Radiation Hazards

You need to be aware of two kinds of hazard from radiation - external and internal.

External Radiation

External Radiation is radiation such as gamma, x-rays or beta from a device or a radioactive substance outside of the body. This type of radiation does not make us radioactive or contaminate our bodies, but large doses of external radiation can harm us.

Internal Radiation

Internal Radiation is the radiation we experience when foreign radioactive materials or substances are introduced into our bodies, usually in finely divided or liquid form. These radioactive materials, and the effects they carry, can enter the body by breathing, from swallowing, through open wounds, or by absorption through the skin. Internal radiation can have serious consequences.

12.3.1 Unit of Measurement for External Radiation

The Standard International (SI) unit of equivalent dose of external radiation is the sievert (Sv).

The Sv is a measure of the energy absorbed per unit of mass plus a weighting factor that is added to account for different types of radiation having different effects on the body.

⚠ **NOTE**

As a firefighter, this is the unit of radiation that you will use to determine the presence of danger to yourself and your fellow firefighters. All instruments that measure external radiation read in this unit, or they have a simple conversion chart printed near the dial.

The measurements of accumulated doses of radiation are in micro-sieverts (uSv - millionth of a sievert). A Sv of radiation is a very substantial amount of radiation for a human being to receive. The rate of dose is measured in micro sieverts per hour (uSv/h).

12.3.2 Unit of Measurement for Radioactive Contamination

Counts Per Second

Although there is no standard unit of measurement for radioactive contamination, the most common unit is counts per second (CPS).

Levels of Contamination

Low levels of radioactive contamination can exist in laboratories when people are working with radioactive materials in powder or liquid form. It is unlikely that sealed radioactive sources (such as those found in factories and in some medical applications) would be breached during a fire. However, the possibility does exist that an incident could create hazards to firefighters, and you should be aware of this danger.

Breaching of a high level sealed source of radioactivity can have serious consequences.

Dose Rate Meter

A Dose Rate Meter is used for contamination monitoring (usually in industry).

12.3.3 Biological Effects

Penetration of Body Tissue

Gamma rays and X-rays are long range rays. They have a strong ability to penetrate into body tissue. Beta rays can travel a few metres in air, but they can have effects similar to those of exposure to gamma rays and X-rays. The damage they do depends on the energy of the beta rays. All of these radiations can penetrate the body causing damage to a person. However, some rays pass through without any apparent effect.

Serious Effects

If a person is exposed to high levels of radiation in a short term, the effect can be severe radiation sickness and even death. High levels in the short term means several million micro sieverts for a period of hours or days.

Maximum Safe Exposure

The maximum amount of exposure a person can endure without detectable clinical effects is about 250 000 uSv. This exposure could take place over a short or long term without the person being aware of any biological damage. The risk of contracting cancer at a later stage in life may, however, be slightly increased.

Radiation and Cancer

Normal expectation of contracting cancer, without any more than average background radiation, is about one in four persons. It is difficult or impossible to determine if specific low doses of radiation actually increase the risk of cancer.

EXPOSURE (uSv)	EFFECTS
6 000 000 or more	Severe radiation sickness with up to 100% deaths for exposed individuals. Rapid emaciation and death as early as second week.
3 000 000 - 6 000 000	Severe radiation sickness with up to 50% deaths for individuals exposed to 4500 mSv and over.
2 000 000 - 3 000 000	Moderate radiation sickness. Recovery likely in about 3 mths unless complicated by poor previous health, superimposed injuries, or infection.
1 000 000 - 2 000 000	Slight radiation sickness. Blood changes with delayed recovery. Delayed effects may shorten life by 1%.
250 000	No radiation sickness expected. Slight temporary blood changes.
0 - 250 000	No radiation sickness. No detectable clinical effects. The exposed person would be unaware of any biological damage. Slight increased cancer risk.

Table 12A Radiation Effects

12.3.4 Protection Against External Radiation

There are three main factors involved in protection against the effects of external radiation - time, distance and shielding.

Time

If you control the amount of time that you are exposed to radiation, you can control the effects of that radiation i.e. we limit exposure of our skin to the sun to protect us against sunburn. If an operator is required to work in an area where the radiation dose rate is 100 uSv/h, the effect that he/she experiences in 2 hrs is 200 uSv.

Distance

External radiation decreases as the square of the distance from the source.

This means that if the radiation from a source is 4000 uSv/h, at a distance of 1 m from a source, the dose decreases to 1000 uSv/h. At a distance of 2 m from the source, the dose decreases to 250 uSv/h at a distance of 4 m from the source.

This relationship is known as the Inverse Square Law. If you are interested in photography and have used a flash gun, you may be familiar with this relationship even though you don't think of it in the same way.

Shielding

Heavy dense materials provide effective shielding against long range penetrating radiation such as gamma radiation and X-rays. The more dense the materials, that is, the more mass per unit volume, the better the shielding effect for a given thickness of material. Water, iron, and concrete, as well as lead, are commonly used as protective shielding. However, water is not a very good shield against gamma radiation or X-rays.

12.3.5 Measurement of Accumulated Dose

Personal Radiation Reading

Your personal radiation exposure to gamma rays, X-rays, or beta rays can be measured by a thermo-luminescent dosimeter (TLD). TLD's are centrally issued and processed and can only be read by special equipment. They are usually issued on a term basis for a period of some months. The results of analysis of a test are sent to the user, in the mail. Attention is drawn to any readings that indicate a serious problem from the effects of radiation. There are several TLD services in Australia. They are operated by various government agencies.

Digital Adding Dosimeters

If you require an instantaneous readout of an accumulated dose of radiation, an electronic device is available that analyses the dose and gives an audible alarm at a pre-set level. These devices are known as Digital Adding Dosimeters or DAD's.

DAD's are battery operated and usually incorporate a solid state detector. Some models are capable of telemetry interface so that doses received by individuals can be monitored at a distance.

Quartz Fibre Electrometers

If you need periodic readouts, you can wear a Quartz Fibre Electrometer (QFE). This device calculates the dose, but it does not give an alarm. The device must be checked from time to time to find out the level of the dose you have received.

QFE's operate on the principle that a quartz fibre that is given an electrical charge can be made to assume a position on a scale. This position is observed through an eyepiece. The fibre is gradually discharged by ionising radiation. This indicates the dose received. A charger is required to set the QFE to zero.

⚠ **NOTE**

QFE's are now being replaced by DAD's.

12.3.6 Radiation and Contamination

Radiation and Contamination are two terms with which you should be familiar.

- Radiation is the process of emitting radiant energy in the form of waves or particles.
- Contamination is the process of soiling, staining, infecting, or making unfit for use by the intrusion of an external agent or something from an outside source.

These terms can be confusing. Any radioactive material emits radiation to some degree. The term contamination, or more properly, radioactive contamination, describes circumstances in which radioactive material has found its way onto a surface or into a substance or material which is normally expected to be clean. Radioactive contamination is not visible to the naked eye.

The fact that a surface or substance is radioactively contaminated does not necessarily mean that a hazard exists. Whether a hazard exists depends on the amount and type of radioactive material involved.

If you attend an incident and you are dressed in your protective clothing and wearing positive pressure BA, you are protected from inhaling radioactive contaminated substances, i.e. dust or particles. But you are not protected from radiation. Radiation can penetrate your protective clothing.

We have natural background radiation all around us. Natural radiation is of two kinds - cosmic and terrestrial. Cosmic radiation comes from the atmosphere; terrestrial radiation comes from the earth.

All substances are made up of atoms. A nuclide atom is a species of atom that is characterised by the constitution of its nucleus and hence by the number of protons, the number of neutrons, and the energy content. A radionuclide is an atom that is radioactively charged.

Many different kinds of radionuclides are produced continuously by the interaction of cosmic rays within the atmosphere. These radionuclides include 3 H (Helium), 7 Be (Beryllium), 14 C (Carbon) and 22 Na (Sodium). Each of us continuously ingests these radionuclides from the air we breathe and the food we eat. The strength of radionuclides is measured in half life. A half life of a material is that amount of time in which a substance will reduce its volume by half due to the emanation of radioactive particles. Uranium has a short half life; lead has a long half life.

Cosmic Radiation

Primary high energy cosmic radiation is almost completely absorbed in the upper atmosphere. It produces secondary radiations which reach the earth in varying degrees of intensity. The intensity of this radiation depends on latitude and altitude i.e. in Sydney, at sea level, you could expect an annual dose of secondary cosmic radiation of about 300 uSv. In Canberra, at an altitude of 580 m, the dose would be about 400 uSv; for Katoomba, at an altitude of about 1000 m, the dose would be about 500 uSv; and for residents of Wyoming, USA, at an altitude of about 2.5 km, the dose would be about 1300 uSv.

Another common way in which we can be subjected to higher doses of cosmic radiation is to fly in a jet airliner at high altitude. For instance we would receive an additional 30 uSv of cosmic radiation by flying from Sydney to Perth and back.

Terrestrial Radiation

Terrestrial radiation comes mainly from exposure to the ground and to building materials such as sand and granite. Radionuclides such as 40 K (Potassium), 238 U (Uranium) and 232 Th (Thorium) have half-lives of about a thousand million years or greater. These materials are believed to have existed since the formation of the earth about four and a half thousand million years ago. Such materials give annual doses of radiation that range from an average value of about 450 mSv up to 25 000 uSv. In India, some locations have a high thorium content in their soils and can produce these upper range exposures.

Some substances, such as 222 Rn (Radon) and 220 Rn (Radon), produce certain decay products that have short half lives. Inhalation of these substances constitutes the major source of internal radiation to people living in most areas of the earth. Exposure to these substances tends to increase with the use of structural materials and processes such as brick, stone, or concrete materials and closed ventilation systems like continuous full cycle air conditioning.

Additionally, the use of well water can introduce a direct pathway for radon and radon daughter products to find their way into the home. Radon is a heavy radioactive stable gaseous element formed by the disintegration of radium. Water from natural sources in some parts of the world, notably North America, has been found to have high levels of radium. In some instances, the level of radium is so high that it must be removed before the water is fit for human consumption.

Ordinary food and drink can also be sources of internal radiation. Many things we eat and drink contain 40 K (Potasium) and 210 Pb (Lead) (plus its decay product 210 Po [Polonium]). These can add substantially to the radiation exposure received internally. We also receive minor contributions of 3 H (Hellium), 14 C (Carbon) and 22 Na (Sodium).

At ***Lucas Heights Research Laboratories*** in Sydney, a person can undergo a whole body monitor check to detect the presence of internal radiation. In this check, you can clearly see the 40 K gamma radiation peak at 1.46 MeV on the gamma spectrometer screen. An average adult male contains 140 to 160 g of potassium of which 18 mg or so are 40 K. This contributes an average internal dose of 170 uSv y-1. An analysis of the total radioactivity in a typical human body shows that this typical body produces some 8200 disintegrations per second from its contained radioactive material.

12.4 Working Guidelines

Here is a list of some of the guidelines and precautions you should follow if you are called to attend an incident where you suspect that radioactive materials may be present or where the area may be contaminated:

- refer to *Standing Orders*;
- gather immediate intelligence;
- seal off the area;
- use dose rate meters;
- use BA;
- approach from upwind;
- monitor dose rate;
- use standard fire fighting methods;
- check personal decontamination; and
- obtain full EPA clearance.

Immediate Intelligence.

During transit to and immediately upon arrival at the site of the incident, try to get as much information as possible from the people in charge of the incident site about the radioactive materials held at the site.

- Where are the radioactive materials located?
- Are the materials sealed or unsealed?
- What is their assessment of the level of severity of the radiation hazard?

Seal off the Area

Immediately upon arrival, secure the area for both entry and exit. Ensure that no material or personnel can exit the defined zone without being checked for contamination.

Use Dose Rate Meters

Ensure that all personnel going in to fight the fire have an operational dose rate meter worn on the belt clip, that the meter is switched on, and that the personnel are familiar with the operation of the meter. (Refer to 12.5)

Use BA

Ensure that all personnel attending the incident at a site involving radioactive materials are wearing spillage suits and positive pressure BA sets.

Approach from Upwind

If the incident is in an open space, approach the incident or fire from upwind if possible. This approach helps to minimise the chance of airborne contaminated material settling on clothing or exposed skin areas.

Monitor the Dose Rate

As you approach the site of the radioactive material, check the dose rate continuously by observing the digital scale. The maximum dose that you should accept is 10 uSv/h. If the reading on your meter goes higher than this, do not approach any closer to the site of the incident.

Move undamaged packages. If undamaged portable packages or devices that contain radioactive material can be moved from the area, use remote means to remove them i.e. instead of touching these materials and lifting them by hand, use a shovel, a wheel barrow, or drag the materials along on a sheet of tarpaulin.

Prevent the spread of contaminated materials. If you see an obvious leakage of material from a device or package that may be radioactive, use absorbent material to prevent the contaminated material from spreading.

Use Standard Methods

Carry out normal fire reduction methods using standard fire fighting agents.

Check Personal Contamination

When you leave the immediate site of the incident, ensure that you are checked for contamination at the periphery of the secured area. This check is not to be regarded as a final clearance.

⚠ **NOTE**

When you are undergoing the check, you must not personally touch or use the monitoring device, for you may contaminate it. A colleague wearing a clean spillage suit and BA will carry out this check. The procedure is described in 12.5.

Disposal of Personal Contamination

If you or other personnel are contaminated under the guidelines specified in 12.5, use wet swabs with detergents and water to remove the contamination. Change the cleansing swabs frequently. Retain the swabs in plastic bags for later examination.

⚠ **NOTE**

Do not attempt plant decontamination.

Obtain Full Clearance

When any personnel or equipment leave the controlled zone, they must be checked for contamination clearance by EPA nominated radiation protection specialists. The screening test mentioned above allows only for exit from the control zone to a safe area that is used as a holding point for final testing.

12.5 Dose Rate Meters

12.5.1 Introduction

Dose rate meters are used to measure the magnitude of ionising radiation fields. The information they produce helps control the amount of personnel exposure to radioactive contamination.

The meters vary in their performance characteristics, and no one instrument is capable of taking satisfactory measurements of all forms of ionising radiations. For the type of application required by personnel attending an incident involving radioactive material, instruments have been chosen that will measure everything except neutrons. Neutron radiation emanates only from certain kinds of devices. Neutron radiation is always accompanied by X-rays. There is no occasion envisaged where personnel operating under the conservative guidelines given would unwittingly be exposed to dangerous levels of neutron radiation.

12.5.2 Response Time (time constant)

Instruments vary in the time it takes them to display a reading of the ambient radiation dose rate. If you are using an instrument and you are unaware of the response time required, you can get an inaccurate reading if you move the instrument too quickly through the beam of radiation you are trying to measure. It will help if you can get some experience using these devices so you can learn about the response time required by each one.

12.5.3 Calibration

Radiation dose rates are a standardised measurement. Instruments used for dose rate measurement are calibrated, or adjusted, against this known standard. This calibration should be performed on each instrument once a year. An instrument should be calibrated more frequently if it has been subjected to a sudden shock such as falling on to a hard surface. A shock can interfere with the internal settings of the instrument. Most dose rate meters are calibrated with the radiation entering from the front of the chamber. If you use one of these instruments, ensure that the radiation tested enters from the front of the chamber.

12.5.4 Ram Gam-1 Radiation Monitor

This instrument is used to measure dose-rates in uSv/h to the operator. The monitor is worn on the belt with the scale upside down. In this way, when the operator bends down and lifts the front of the instrument, the scale can be easily read.

You would use this instrument when you approach an area where you suspect radioactive material is present. Here is how it operates.

- ensure that a fresh battery (9 V) is in the instrument;
- fit the instrument into the belt case with the scale upside down;
- press the on/off button once. The instrument will emit a long beep followed by an irregular chirping sound corresponding to the dose rate being detected. The dose rate detected as background will vary but will usually be of the order of 0.1 to 0.2 uSv/h as displayed in the digital readout. Use the check source at contact to the front of the instrument to further verify that the instrument is detecting radiation. The instrument should indicate the presence of an increase in dose rate;
- move at a slow walking pace and observe the instrument as you approach the area suspected of having a radioactive source; and
- when the instrument reads 10 uSv/h **STOP** - do not proceed any further towards the source. You should conduct fire reduction measures from this point or a distance further back if you can do so and still be effective with the fire fighting effort.

NOTE

You should not be alarmed if you have been in higher dose rate areas during the operation. Radiation controls are based on accumulated dose rather than dose rate. The figure of 10 uSv/h has been chosen as it represents a rate suitable for continuous occupancy over a whole working life rather than just a few minutes or hours spent in putting out a fire. Your training course will give you a proper perspective on radiation exposure.