CHAPTER 14

FIRE AND DAMAGE

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SECTION 1 - FIRE

1401. Fire Hazards

Fire is an ever-present risk in ships, with the risk being greater in war and upkeep periods. As always, prevention is better than cure and, accepting those caused by enemy action, clean and tidy living, keeping things in their proper places, being fire conscious and obeying the relevant regulations, can prevent most fires on board ship. Listed below are some of the more common causes and aids to propagation of fire:

a. Carelessness with naked lights; lighted pipes and cigarettes left about, and cigarettes thrown over the side. Clothing hung to dry on a hot surface or lying about when it should be stowed. Bunks left unmade, mattresses stacked in messdecks, and mattresses with their fireproof covers removed.

b. Rags left lying about, especially if oily; canvas, etc, stowed away wet (all materials of vegetable origin, if wet or oily, can generate enough heat to start a fire spontaneously).

c. The careless stowage of bundles of rags in the vicinity of hot exhausts and exhaust ducting such as funnel uptakes.

d. Papers and books left about in offices, cabins and messdecks, or tucked away near sleeping billets.

e. Paint and oil splashes in contact with heat; paint pots not returned to store at secure; too many coats of paint on surfaces; indiscriminate use and stowage of aerosols.

f. Cooking fat, especially in deep-fat fryers, allowed to overheat, left unattended, or contaminated with water.

g. Timber stowed near sources of heat or soaked with flammable liquid.

h. Bilges, flats, workshops, etc, allowed to remain oily, untidy and dirty.

i. Misuse of electrical apparatus or use of defective apparatus.

j. Non-observance of the requirement that all private electrical appliances must be checked safe in accordance with BR 2000(52).

k. Sparks from dirty incinerator uptakes.

l. The use of plastic containers as dustbins, waste-paper baskets or gash bins. Only metal bins should be used.

m. Servery, galley, food or other lift hatches/doors/shutters left open when not in use (tally plates reading **WHEN NOT IN USE, THIS HATCH IS TO BE CLOSED** should be fitted).

n. Non-observance of the regulations for handling flammable liquids, and for stowing and handling explosives (BR 1754 and JSP 862).

1402. Additional Hazards in War

Heat from an explosion, including the heat flash from a nuclear weapon, and unspent missile propellant can start ‘primary’ fires. ‘Secondary’ fires, as an indirect consequence of damage, may be caused by:

a. Hot splinters striking combustible materials.

b. Flammable liquid fuels brought into contact with hot surfaces (eg on the surface of rising flood water).

c. Combustible material thrown by blast or shock against a source of heat.

d. Damage to electrical circuits, causing sparks or overheating and ignition of insulation.

1403. Additional Hazards in Upkeep Periods

Fire precautions and firefighting in Upkeep Periods are covered in Chapter 24. The main hazards are:

a. Welding and burning operations, (the safety regulations concerning ‘open flame’ heating are contained in BR 2000(20)).

b. Numerous temporary electrical/air leads passing through doors and hatches.

c. Difficulty in maintaining control of smoking and the use of electrical equipment.

d. The arisings of waste material that would normally not be allowed to accumulate.

e. The use of flammable substances such as adhesives and paints.

f. Civilian personnel who are not familiar with the ship layout.

g. Possible disruption of normal firefighting equipment and communications.

1404. DIY Improvements

Despite general improvements in habitability in ships, there remains a desire to overcome minor deficiencies and provide personal touches, by DIY. However, DIY presents many potential fire dangers and it is essential that DIY installations be closely controlled. BRd 9467 provides guidance on the exercising of this control.

1405. Explosives and Fuel

It must always be borne in mind that fire in the vicinity of stowed explosives or fuel (including weapon fuel/propellant) is an immediate and grave risk to the safety of the ship.

1406. Flash Point and Ignition Temperature

a. Warships contain considerable quantities of flammable liquids, so it is important to understand the significance of the terms flash point and ignition temperature.

b. Heat raises the temperature of a combustible substance to the point where fuel in the substance gives off vapour. When enough vapour is formed to support a flame the substance is at its flash point. If the vapour is heated further, it ignites when combined with enough oxygen and the substance is then at ignition temperature. Flash points and ignition temperatures vary with different substances. Fuels such as Dieso and AVCAT are known as high flash point fuels because their flash point is above normal ambient temperature. However, low flash point fuels such as gasoline (petrol) have a flash point below normal ambient temperature, so must be handled with greater care to avoid sources of ignition.

c. Dieso and AVCAT in the form of an atomised spray (eg a ruptured, pressurised system) may ignite below their respective flash points when in contact with a flame.

Fig 14-1. Fire Caused by an Anti-Ship Missile

1407. Toxicity of Smoke

The smoke produced by ship fires and burning weapon propellant (see Fig 14-1) is highly toxic. If inhaled, it will quickly become fatal. Smoke management procedures are detailed at Annex 21C.

SECTION 2 - DAMAGE

1408. Causes of Damage

a. Like fire, material damage can occur in a ship in peace as in war, though in war the chances are, of course, greater. A collision or a grounding may cause the underwater hull to be ruptured with the consequent flooding of compartments and damage to equipment in the immediate vicinity (Primary Zone damage) with possible additional damage remote from the incident (Secondary and Remote Zones of damage). In peace, explosions can normally be discounted, but if they do occur, they are generally internal. In war, explosions may occur outside and inside the ship. The extent of damage from an explosion cannot be forecast since it will depend on such variables as weight and nature of the explosive, the position of the explosion relative to the ship, the type and size of ship, her subdivision and hull strength. General information regarding the effects of weapon attack on surface ships is provided in CB 8844 - Weapon Effect. Damage posters (Form S.3075 (1)-(6)) show examples of damage sustained by ships in Operation Corporate in 1982. Reports on ship damage are in BR 8362 and CB 8362(2). Whenever damage is sustained in action, collisions or from any other cause, reports must be rendered in accordance with BRd 2.

Fig 14-2. Above Waterline Damage Caused by an Anti-Ship Missile

b. Explosive weapons are classed as conventional or nuclear. The term conventional normally refers to bombs, shells, missiles, rockets, mines or torpedoes that are filled with any type of chemical explosive which does not rely on nuclear reaction to produce its explosive power.

1409. Damage from Conventional Weapons Above Water

Weight for weight, weapons designed to explode on impact carry a larger charge than those designed to pierce structural protection. The explosion of a weapon above the waterline can cause extremely heavy local damage, with widespread secondary damage (by splinters, shock and whip) with probable loss of watertight and gastight integrity. Subsidiary effects of damage can be serious and some examples are:

a. Blast entering funnels and uptakes can cause damage to machinery.

b. Riddling, ie multiple holes in the freeboard from near-miss splinters, will cause loss of reserve buoyancy.

c. Fires may be started in the vicinity of the explosion and remote from it.

d. Heavy casualties may result from splinters and objects, including personnel being thrown violently by shock and blast.

Fig 14-3. Aircraft Cannon Fire Damage

Fig 14-4. Weapon Entry Hole, Showing Petalling of Plating

1410. Internal Explosions

The explosion of a weapon inside a ship will cause very heavy local damage with complete destruction of structure and services. The venting of explosion gases will create a formidable secondary zone of damage. In addition to the immediate primary and secondary effects, there will most probably be fire, loss of watertight and gastight integrity, failure of pipe systems, electrical and other services in other areas of the ship. Should the weapon explode below the waterline and rupture the outer hull plating, flooding can spread back through the compartments and spaces wrecked by its passage and detonation. The results of any accidental internal explosion will be similar, in type if not in degree, except that there will be no entry path.

Fig 14-5. Damage to Fully Clipped Door Caused by Internal Explosion

1411. Blast Routes

a. **Magazines**. Arrangements are made in magazines to allow for any build up of pressure, due to a rapid ‘burn-off’ of a weapon, to be vented off to atmosphere. In the event of a detonation this arrangement is inadequate, and will not prevent extensive damage.

b. **During Action**. Deliberately opening up blast venting routes prior to and during Action is not practicable, or advised, for the following reasons:

(1) The position of explosions cannot be predicted before the weapon enters the ship.

(2) Opening doors and hatches in the structure is detrimental to the watertight integrity of the ship and could facilitate the passage and spread of flash, fires, smoke, CBRN contamination and possibly floods.

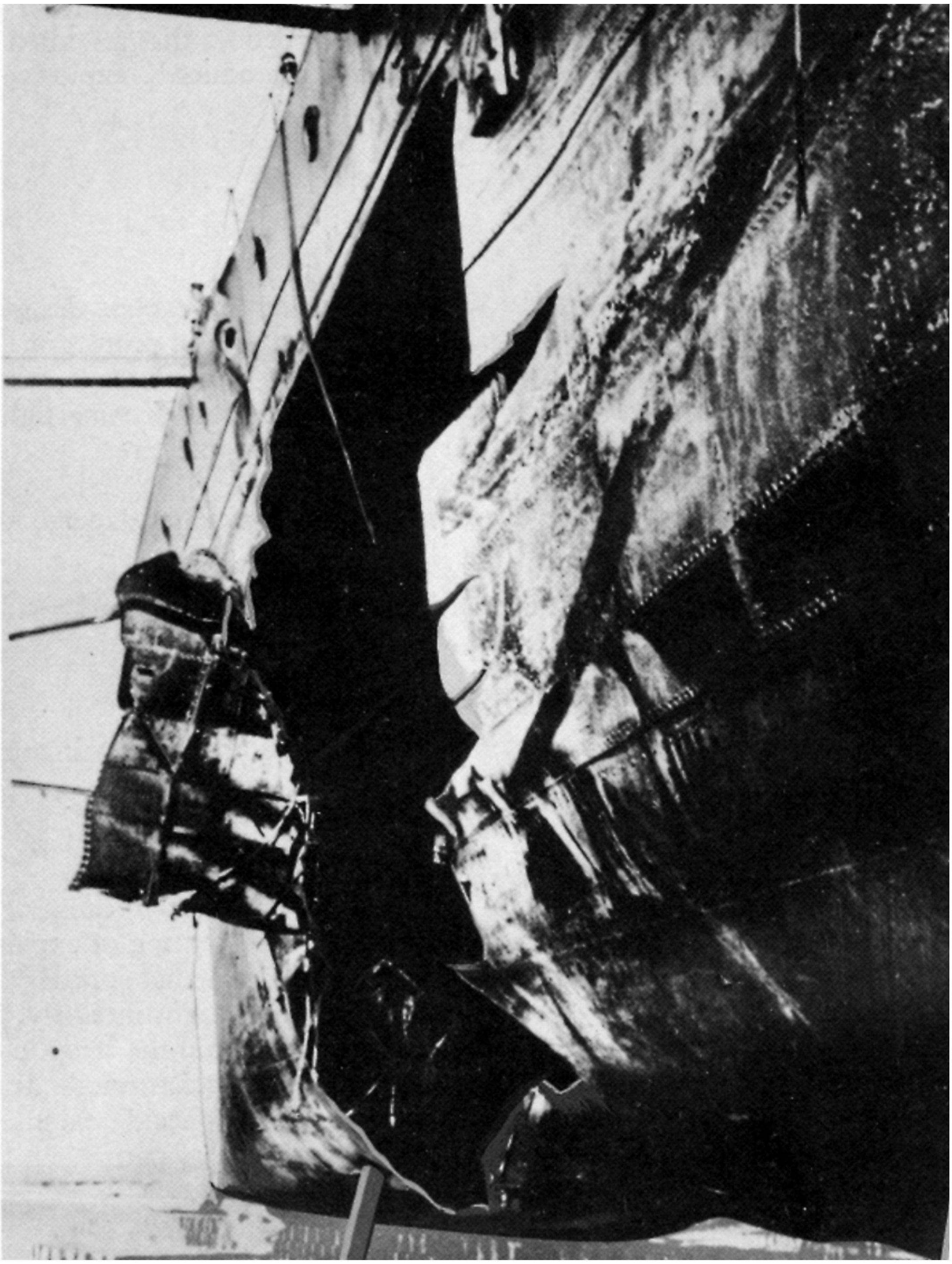
c. **Post Action**. When the presence of unexploded enemy munitions is confirmed in a ship post-action, opening up a blast venting route may be beneficial. While this will have little effect on the degree of damage at the point of an explosion, it may ameliorate the effects as blast spreads through adjacent compartments. In the case of a slower burn-off the opening of a blast route would be beneficial. The blast venting route should be arranged to take the most direct path to the weather deck. However, it should be borne in mind that the passage of the blast may cause damage to structure, systems and fittings as it passes along the venting route. Due account should be taken of any compartments adjacent to the venting route which might present a hazard by reacting adversely to the blast. Personnel are to be kept clear of the blast venting route until the munition has been dealt with.

d. **Improvised Explosive Devices (IEDs).** IEDs should be treated as unexploded ordnance. The ship should be brought to the highest state of watertight integrity and a blast venting route opened up as described in sub para c above.

1412. Underwater Contact Explosion

The water effectively tamps an underwater explosion and when it happens against the hull of a ship it causes very severe local damage (a charge of just one or two kilograms against the hull is generally enough to penetrate the plating). Outside the radius of severe damage there is normally little effect other than flooding and possible splinter damage. Shock is usually only of minor importance and fire is seldom caused directly by underwater explosion. A contact mine or torpedo exploding against the hull will destroy a large part of the hull structure, the internal structure, fittings and equipment. Fig 14-6 shows Second World War torpedo damage. The resulting flooded area may be extensive. Most of the structure in way of the hole will be seriously weakened and could result in the ship breaking in two. Flooding could result in a serious loss of stability and produce heel (loll or list) and/or trim.

Fig 14-6. Underwater Damage - Contact Torpedo



1413. Underwater Non-Contact Explosion

The pressure pulses from this type of explosion cause damage to an extent depending on the size of charge, its distance from the hull and, to some extent, the depth of water (Fig 14-7 shows Second World War non-contact mine damage). If the explosion is outside the hull-splitting distance, dimpling or buckling of the plating between frames and distortion of the frames is probable. Successive pressure pulses striking the ship may lead to longitudinal bending, known as 'whip' (Fig 14-8), with the possibility of breaking the ships back.

Fig 14-7. Non-Contact Mine Damage

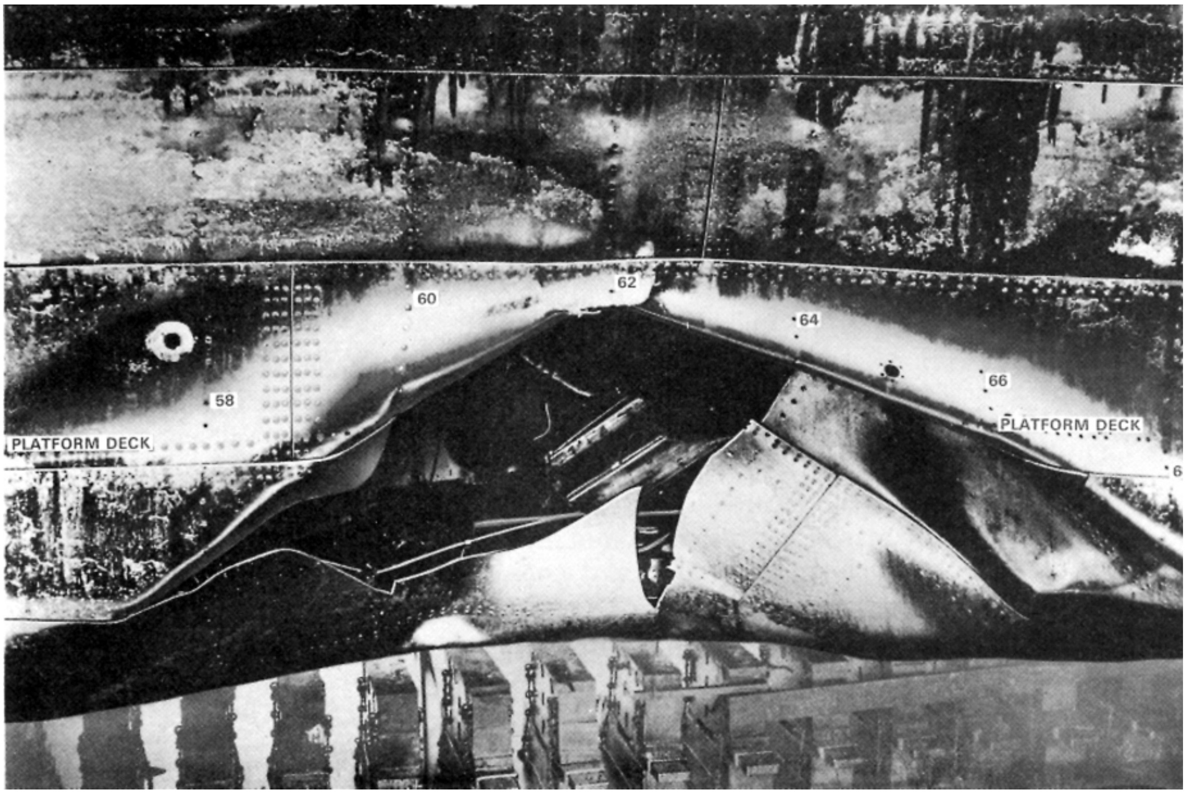
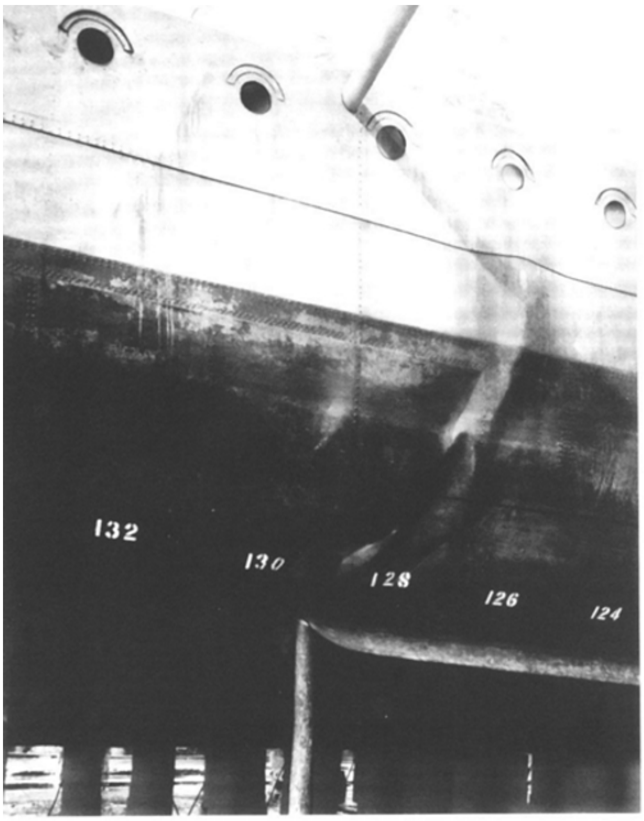


Fig 14-8. Whip Damage

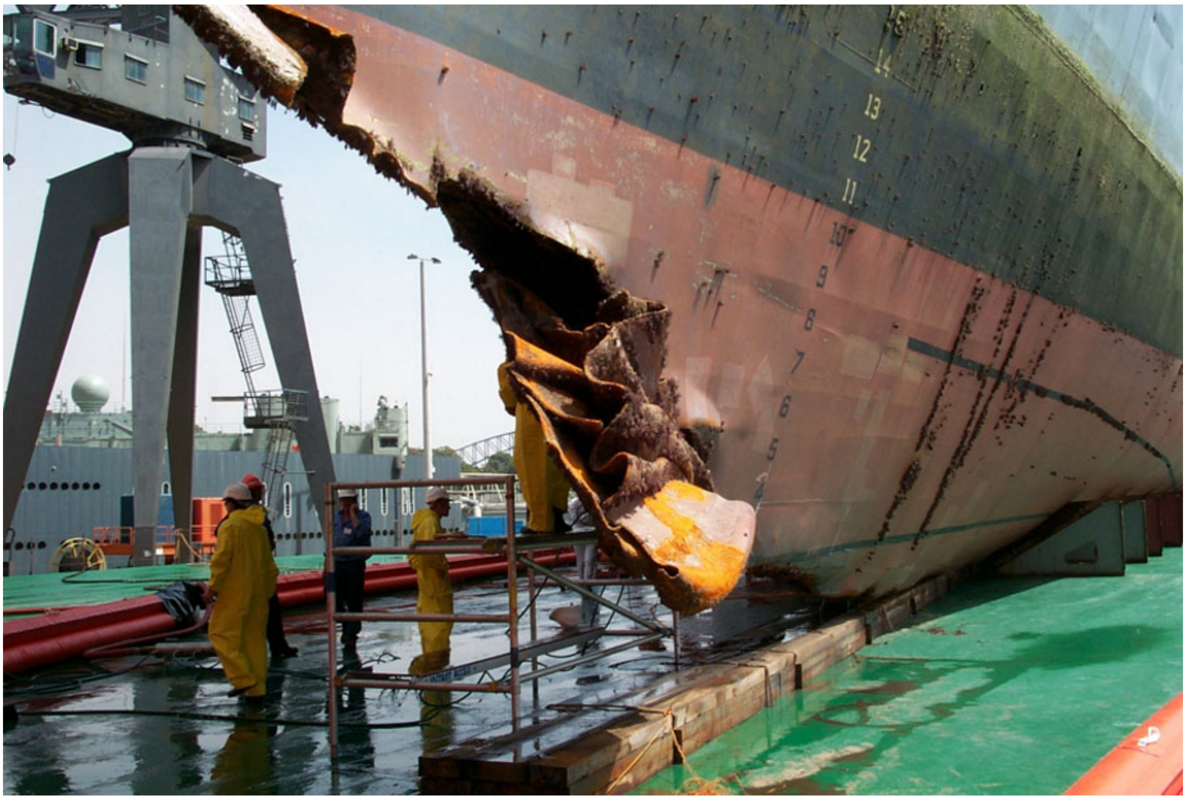


1414. Collision and Grounding

Ships are constantly at risk of damage from navigational incidents, but prompt damage control measures will normally save a ship in these circumstances. Fig 14-9 shows typical collision damage and Fig 14-10 shows typical grounding damage. Effective Damage Control methods, in both cases, resulted in the ships being made safe and enabled their safe return to port for repairs.

Fig 14-9. Collision Damage

Fig 14-10. Grounding Damage



1415. Nuclear Explosions - Above Surface

Nuclear Weapon yield is explained in BRd 2170(2). Table 14-1 gives a rough approximation of the ranges at which damage of different degrees of severity will be likely for a 20 kT and 10 MT airburst, assuming that the weapons are exploded at the height that gives the greatest blast effect for the weapon yield. The table also gives approximate distances at which exposed combustibles are likely to ignite. Table 14-1 is only a generalisation because blast effect depends on such variables as height of burst, direction of the ships head relative to burst, atmospheric conditions (which modify the effects of heat) and the nature of materials. As used in the table, 'severe damage' means that the ship could be sunk, or put out of action with damage enough to require major reconstruction; 'moderate damage' means the ship will be immobilised and need much repair, especially to shock sensitive machinery and electronic equipment; 'light damage' means that although the ship may be still capable of operating, there will be damage, especially to electronic and other equipment, even though it may be repairable with ships resources.

Table 14-1. Approximate Range of Effects - Nuclear Airburst

Damage Sustained	Range (km)	
	20 kT	10 MT
Severe	0.8	3.2
Moderate	1.2	6.4
Light	2.0	11.2
Damage to aerials and parked aircraft	3.2	12.8-16.0
Exposed combustibles ignited	2.4	24.0

The significant part of the intense heat pulse lasts for about one-and-a-half seconds from a 20 kT weapon and 30 seconds from a 10 MT weapon. As weapon yield increases, the distance at which the heat is effective increases more than the ranges of other effects. The arrival of the heat pulse is virtually instantaneous so that some of the fires caused by it may be extinguished by the following blast. However, the indirect or secondary fires that are almost certain to follow will offset this. A low airburst or surface burst will cause similar damage, but the ranges of effects will be less.

1416. Nuclear Explosions - Underwater

The shock wave from this type of explosion lasts much longer than from a conventional non-contact weapon; long enough, in fact, for the pressure to be exerted all round the hull at once (crushing or squeezing effect). This will cause widespread damage to the whole of the underwater hull, the amount and severity of which will vary with the yield of the weapon, distance of explosion from the ship, depth of burst, depth of water, strength of structure and the attitude of the ship to the explosion. Water waves developed after an underwater explosion may cause damage to structure, flooding through weatherdeck openings and loss of external fittings and equipment. Wave formations will vary with the yield and depth of explosion, the depth of water and the topography of the seabed.

1417. Zones of Damage

Damage to a ship can be divided into three zones:

a. **Primary Zone**. This is in the immediate vicinity of the cause of damage (explosion, collision, grounding) and, particularly in the case of explosion, will be the zone of complete destruction. That part of the Primary Zone below the waterline will probably be completely flooded and nothing can be done except to try to contain the floodwater within its original bounds.

b. **Secondary Zone**. The area surrounding the Primary Zone will most probably suffer from split and leaking structure, doors and hatches, fractured pipes, damaged electrical circuits and fittings, fires, smoke and possibly toxic fumes. It is unlikely that this zone will flood immediately, but slow and progressive flooding is probable because of damage to hull and bulkheads/decks surrounding the Primary Zone.

c. **Remote Zone**. Explosion, collision or grounding, particularly explosion, will cause a shock wave to travel through the ships structure and may cause a violent whip, with resultant damage and possibly fire. Whip can cause extensive rippling and distortion of structure, damage to equipment, fittings and services, and often slow flooding over a large area.

1418. Shock

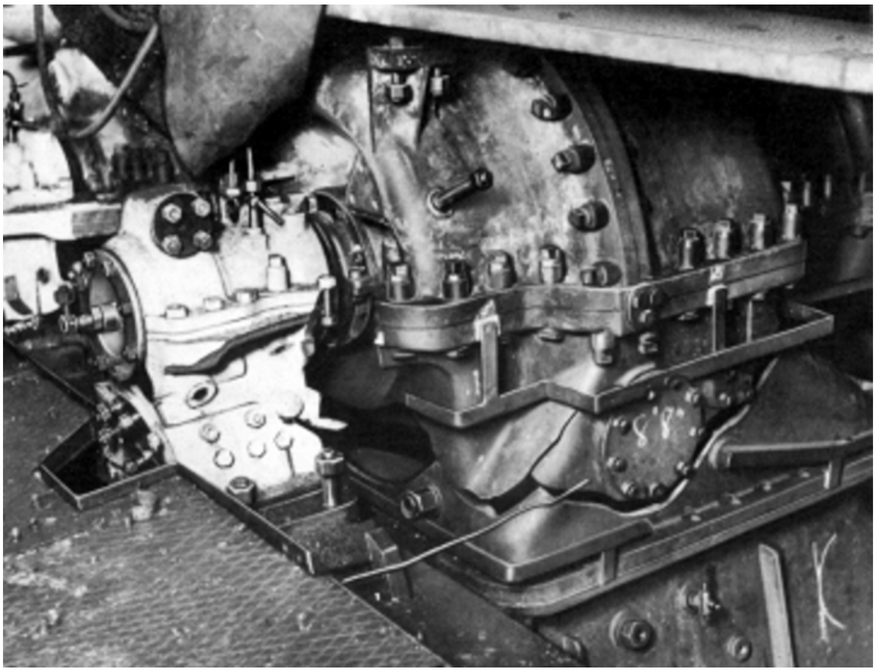
a. The large accelerations and decelerations imparted to equipment directly or indirectly connected to the hull may result in shock damage (Fig 14-11). Most of the important machinery and equipment in warships is either designed to be shockproof or is fitted with shock-resistant mountings. Even so, the shock forces may overcome these features and cause failure in an item of equipment because of fracture (usually in the securing arrangements). Damage from shock may be caused by:

(1) **Relative Movement between Separate Components.** This may lead to collision between components, failure of mechanisms, opening or closing of contacts. Extensive power failures may result from the accidental opening of switchgear. Damage to electronic equipment and displacement of fuses, telephone handsets and similar fittings may also occur.

(2) **Relative Movement between Different Parts of the Same Item**. Excessive strain caused by large bending moments may result in distortion of fittings that are made of ductile materials or fracture in those which are brittle. This is the most frequent cause of damage to machinery.

(3) **Passage of Stress Wave.** An intense stress wave, with its associated strain, passing through the material may cause failure in its path.

Fig 14-11. Shock Damage to Machinery



b. All portable and semi-portable equipment, fittings, ladders, stores etc must be properly secured or stowed as a precaution against shock or whip effects. Warships incorporate the following design features to reduce the effects of shock or whip:

(1) The use of non-brittle materials.

(2) The support of overhanging masses.

(3) Special securing arrangements to absorb accelerating and decelerating forces.

1419. Destruction

Structure, services and equipment may be completely destroyed by the force of an explosion and may be severely damaged by collision or grounding. In addition, the area of explosion damage may be greatly extended by fragmentation and the projectile effect of debris. Splinters may cause fragments of plating and equipment to act in turn as splinters. The effects of flying debris vary greatly, depending on whether the explosion occurs, how near it is to vital equipment and power supplies and the thickness of interposed structure. The penetration of decks and bulkheads always destroys watertight and/or gastight integrity. The limitation of damage from blast and splinters, and from a bows-on collision is in the first place a matter of design (eg collision bulkhead). Vulnerable equipment is protected as far as possible by structure and other equipment and, in large ships, side and deck protective plating. Whenever possible, alternative power supplies are provided for important machinery and services, and arrangements are made to enable systems to be isolated from damaged areas. According to size and type of ship, main machinery and associated systems are designed as far as practicable to operate as separate units. Provision is made for emergency power to be supplied if alternative supplies fail.

1420. Reduction of Splinter Hazards

The fitting of anti-shatter film to all glass mirrors and the removal of unbacked melamine laminates will reduce the splinter hazard to personnel. Covers for TV and VDU screens should be available to be fitted at State 1.

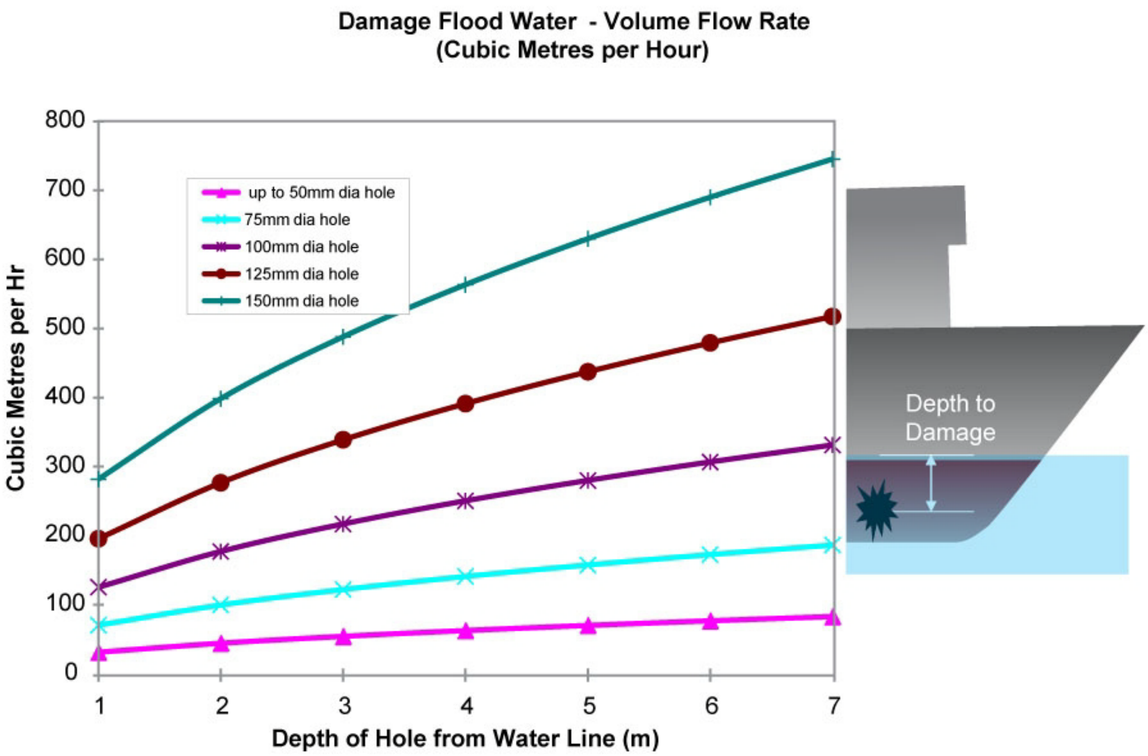
1421. Flooding

Flooding causes loss of buoyancy and the failure of non-watertight equipment in the flooded spaces. It impairs ship stability and may cause heel and/or trim. In a small ship the heel will probably be loll that may lead to capsize, and excessive trim may cause a small ship to plunge. Excessive heel (which may be list or loll) in a large ship gives serious risk of capsize. In all ships, a large heel impairs the operation of weapons and other equipment and has a serious effect on flying operations. Immediate measures are necessary to restore a ship to a stable and upright condition (see Chapter 15, Chapter 16, Chapter 29 and Chapter 30). Countermeasures such as leakstopping, pumping and shoring must be promptly applied and the main flooding boundary quickly established (see Chapter 20 Section 6). Extension of flooding to large spaces high in the ship has a most adverse effect on stability, and the forming of free surface in any compartment will give a loss of initial stability. As heel and trim increase, it is likely that further holes in the freeboard are brought below water; the effects are cumulative and hence the need for prompt action. Shock or whip damage may cause flooding in spaces removed from the actual incident (Remote Zone) and a careful search must be made after damage, with particular attention given to compartments low in the ship.

1422. Rate of Flooding

The speed with which a compartment will flood can be appreciated from the fact that, for example, a hole 150 mm in diameter and 1.8 m below the waterline will admit about 30m³ of water in 5 mins. In other words, this small hole would lead to the complete filling of a compartment 6 m x 3.7 m x 2.4 m in less than 10 mins. To estimate how much water will enter the ship due to a hole below the waterline, the graph at Fig 14-12 can be used. The size of hole and the depth below the waterline need to be known in order to determine the rate of flooding. This can then be used to assess the number of pumps required to reduce the flood or determine if the ships eductors can cope with the incoming water.

Fig 14-12. Flooding Rates



1423. Flooding Definitions

The categories of flooding in ships are defined as follows:

a. **Slow Flood**. Ingress of water/liquid into a compartment from either an internal or external source, which can be controlled by fixed or portable pumping equipment or by the same on completion of first or second stage leakstopping.

b. **Free Flood**. Ingress of water/liquid into a compartment from either an internal or external source, which cannot be controlled by fixed or portable pumping equipment and where first aid leakstopping actions have failed or have not been attempted due to the rate of ingress. A free flooded compartment will not necessarily become completely filled with water/liquid; this is dependent on several factors including the source of the flood and the position of the compartment with respect to the waterline.

c. **Free Surface**. A description of free surface and its effects are at Para 2916.