SECTION VIII
DAMAGE TO NAVAL EQUIPMENT

8.1 General

a. Damage Mechanisms. Mechanical damage to surface ships may be caused by air blast, water shock, and surface wave action. Submerged submarines may be damaged by water shock. Thermal damage to naval vessels and topside equipment is not considered a significant factor, in that it does not of itself cause sinking or immobilization.

b. Damage Classification for Surface Ships. The degree of damage to surface ships and surfaced submarines is separated into three categories—

   (1) Severe damage (probable sinking). The ship is sunk or is damaged to an extent requiring rebuilding.

   (2) Moderate damage (immobilization). The ship requires extensive repairs. This includes damage to certain shock sensitive components or their foundations, such as propulsion machinery, boilers, and damage to interior equipment.

   (3) Light damage. This category includes damage to electronic, electrical, and mechanical equipment; however, the ship may still be able to operate effectively.

c. Damage Classification for Submarines. For submerged submarines two degrees of damage are specified—

   (1) Lethal hull damage. Pressure hull rupture occurs.

   (2) Interior shock damage (surfacing damage). Extensive interior damage to equipment, machinery, and piping occurs with immobilization probable. Submarines are forced to surface.

8.2 Surface Ship Damage

a. Water Shock Damage. Water shock is the principal cause of damage to surface ships from underwater explosions. The directly transmitted shock, however, is not the sole damaging mechanism. When the water depth is of the order of 3,000 feet or less for a 1 KT underwater burst, it is possible that the shock wave reflected from the bottom may produce more severe equipment damage at a given range than the direct shock wave, even though the peak pressure of the reflected wave is less. This phenomenon results from the reflected wave propagating in a more vertical direction and hence being more effective in producing vertical velocities in the hull. In addition, certain bottom forms may focus the reflected wave, resulting in local areas of much higher pressures. It is therefore not possible to predict accurately the effects in a given case without extensive knowledge of the bottom structure in the vicinity of the detonation. To estimate the effects of the reflected shock wave in the absence of such knowledge, it is necessary to assume the bottom to be flat and a perfect reflector, and to use the image of the actual burst point as the apparent source of the reflected shock wave.

Refraction of the water shock wave, discussed in paragraph 2.3a(4), may act to reduce the range at which a given level of damage occurs. This reduction is not significant, however, except at the ranges for light damage, and the actual magnitude of the reduction depends upon the individual circumstances. Since this range reduction is of a small magnitude when considering severe and moderate damage levels and is in the conservative direction when considering possible effects against weapon delivery vessels, the influence of water shock wave refraction has not been included in the damage curves.

Water shock damage curves for surface ships are presented in figures 8–1 through 8–3. These curves are based upon several criteria. Severe damage to ships with multi-plate side protective systems (cruisers, carriers, etc.) is defined by bottom deflection, while for those with thin skin shells (transports, destroyers, etc.), it is defined by side deflection. Moderate and light damage to all types is related to the bottom plate velocity.
b. *Air Blast Damage.* As the depth of a burst is decreased, a transition from water shock to air blast as the primary damage-producing mechanism occurs. Peak overpressure is considered a satisfactory parameter for estimating damage to ships from air blast. Peak overpressures of 5 psi cause light damage to most types of surface ships, while overpressures required for severe damage vary from 25 psi for destroyers to 45 psi for battleships. Figures 8–1 and 8–2 present damage ranges for a 1 KT detonation for heights of burst less than 600 feet and depths of burst less than 800 feet, with means of scaling to other yields. A tabulation of peak overpressure required to cause ship damage is given in table 8–1 for use with burst heights greater than those shown in figures 8–1 and 8–2. For such burst heights, distances to which overpressures extend can be obtained from figure 2–17.

<table>
<thead>
<tr>
<th>Type of ship</th>
<th>Peak air overpressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Severe</td>
</tr>
<tr>
<td>Aircraft carriers</td>
<td>30</td>
</tr>
<tr>
<td>Battleships</td>
<td>45</td>
</tr>
<tr>
<td>Cruisers (heavy)</td>
<td>40</td>
</tr>
<tr>
<td>Cruisers (light) (AA)</td>
<td>30</td>
</tr>
<tr>
<td>Destroyers</td>
<td>25</td>
</tr>
<tr>
<td>Pontoon (for pier construction)</td>
<td>60</td>
</tr>
<tr>
<td>Transports</td>
<td>30</td>
</tr>
<tr>
<td>LST's, landing craft and landing vehicles</td>
<td>25</td>
</tr>
<tr>
<td>Submarines (surfaced)</td>
<td>80</td>
</tr>
</tbody>
</table>

8.3 *Subsurface Target Damage*

a. *Submarines.*

1. *Air blast damage.* Air blast damage to surfaced submarines is significant only for the case of surface, transition zone or air bursts. Peak air overpressures of 80 and 60 psi are expected to cause severe and moderate damage, respectively, to surfaced submarines.

2. *Water shock damage.* Water shock is the controlling damage-producing mechanism for a submerged submarine for any burst position, and also for a surfaced submarine subjected to an underwater burst. The criterion used for estimating lethal hull damage is a function of "excess impulse." This excess impulse is defined as the impulse delivered by that portion of the shock overpressure which is in excess of the static collapse pressure minus the hydrostatic pressure. In deep water when a sharp change in water temperature with depth exists (thermocline) and the weapon is fired in close proximity to this region, refraction may reduce the range for a given degree of damage on the order of perhaps 20 percent. This reduction will only occur when the weapon and the submarine are on opposite sides of the thermocline. For weapons fired well below or above the thermocline, there should be no reduction. Isodamage curves for the hull lethal range and interior shock damage range are presented in figures 8–4 and 8–5 for a submarine with a 600 psi static collapse pressure subjected to a 10 KT and a 30 KT surface or underwater detonation, with methods for scaling to other yields. No account of refraction has been taken in the damage curves presented. Non-linear effects as described in paragraph 2.3 have been incorporated. Initial translational

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velocity is the criterion used for prediction of shock damage to submarine equipment.

b. Underwater Mines. Underwater mines are expected to be neutralized when the peak pressure acting on the mines is equal to or greater than the mine case static collapse pressure, or when the mines are within the crater. Figures 8–6 through 8–8 show the neutralization ranges for mines with hydrostatic collapse pressures of 250, 500, and 1,000 psi in depths of water of 50, 100, and 200 feet and for a range of yields from 1 to 100 KT. These curves are computed for mines and burst both on the bottom.
SURFACE SHIP DAMAGE

Figure 8-1 gives estimated ranges for severe damage (probable sinking) plotted as a function of burst height and depth for surface ships for a 1 KT detonation. Figure 8-2 gives the ranges for moderate (immobilization) damage and for light damage as functions of burst height and shallow depths. Figure 8-3 is an extended plot of light damage vs. depth of burst. This latter figure enables an estimate to be made for the effect of the bottom reflection pressures on the predicted light damage range using the assumptions given in paragraph 8.2a (i.e., a flat perfect reflector bottom and a burst depth at the image of the actual burst point). For evaluation of light damage, a value should be found for both the direct shock wave and the bottom reflected shock wave and the larger value chosen.

Scaling. For yields other than 1 KT the following relations can be used to estimate ranges for a given degree of damage:

\[
\frac{d_1}{d_2} = \frac{W_1^{1/3}}{W_2^{1/3}} \times \frac{h_1}{h_2}
\]

where \(d_1\) = range for a given degree of damage for yield \(W_1\) KT at a depth \(h_1\), and \(d_2\) = range for a given degree of damage for yield \(W_2\) KT at depth \(h_2\).

Example.

Given: A 30 KT burst at a depth of 2,000 feet in 5,000 feet of water.

Find:

(a) The range at which an aircraft carrier suffers severe damage.

(b) The range at which a destroyer suffers light damage.

Solution:

(a) The depth of 2,000 feet for a 30 KT burst corresponds for a 1 KT to

\[
\frac{h_1}{h_2} = \frac{W_1^{1/3}}{W_2^{1/3}} \times \frac{W_1^{1/3}}{W_2^{1/3}}
\]

\[
h_1 = \frac{2,000(1)}{(30)^{1/3}} = \frac{2,000}{(30)^{1/3}} = 640 \text{ feet.}
\]

From figure 8-1 the range at which an aircraft carrier suffers severe damage from a 1 KT burst 640 feet below the surface is 320 yards.

The range of severe damage to an aircraft carrier for a 30 KT detonation at a depth of 2,000 feet is then

\[
\frac{d_1}{d_2} = \frac{W_1^{1/3}}{W_2^{1/3}} \times \frac{h_2}{h_2} = \frac{(d_1 \times (W_2)^{1/3})}{W_1^{1/3}} = \frac{(320) \times (30)^{1/3}}{1} = 1,000 \text{ yards. Answer.}
\]

(b) From either figure 8-2 or 8-3 the range at which a destroyer suffers light damage from the direct shock wave of a 1 KT burst at 640 feet below the surface is 990 yards.

The imaginary burst point from which the bottom reflected shock waves are assumed to come is equal to the depth of the water plus the height of the weapon above the bottom, or 5,000 + 3,000 = 8,000 feet for the 30 KT weapon. The corresponding depth for a 1 KT is

\[
h_1 = \frac{W_1^{1/3}}{W_2^{1/3}} \times \frac{W_1^{1/3}}{W_2^{1/3}} = \frac{h_2}{h_2}
\]

\[
h_1 = \frac{8,000 \times (1)}{(30)^{1/3}} = \frac{8,000}{(30)^{1/3}} = 2,560 \text{ ft.}
\]

From figure 8-3 the range at which a destroyer suffers light damage from the shock wave of a 1 KT burst at 2,560 feet is 1,300 yards. Since this is greater than the range noted above (990 yards), the bottom reflected shock wave governs. Hence the range of light damage to a destroyer from a 30 KT burst at a depth of 2,000 feet in 5,000 feet of water is then,

\[
\frac{d_1}{d_2} = \frac{W_1^{1/3}}{W_2^{1/3}} \times \frac{d_2}{d_2} = \frac{(d_1 \times (W_2)^{1/3})}{W_1^{1/3}} = \frac{(1,300) \times (30)^{1/3}}{1} = 4,000 \text{ yards. Answer.}
\]

Reliability. Based on limited data. Predictions become less reliable as depth of burst decreases.

Related Material.

See paragraphs 8.1 and 8.2.

See also figures 8-4 and 8-5 for submarine damage.
LIGHT DAMAGE TO SURFACE SHIPS
BY 1 KT AS A FUNCTION OF
DEPTH OF BURST AND HORIZONTAL RANGE
Figure 8-4 presents isodamage curves of lethal hull range for a submarine with a static collapse pressure of 600 psi when subjected to a 10 KT or a 30 KT burst. For submarines of other structural strengths, the lethal range is assumed to be inversely proportional to the pressure hull thickness. For depths of submergence between those presented in the curves a linear interpolation may be used. Figure 8-5 presents isodamage curves for interior shock damage. While the ranges given in figure 8-4 are dependent upon hull strength, those in figure 8-5 are independent of hull strength. For shallow submarine submergence the range for interior shock damage is greater than the lethal hull range. However, for a depth of submergence greater than about 350 feet the lethal hull range predominates.

**Scaling.** Although direct scaling techniques are not applicable, useful data with sufficient accuracy may be obtained by these approximate procedures.

1. For yields in the range of 30 to 100 KT, a given depth of burst and a given submarine depth, the following relation can be used with the 30 KT curves to estimate ranges for a given degree of damage:

   \[
   \frac{d_1}{d_2} = \frac{W_1^{1/3}}{W_2^{1/3}}
   \]

   where \(d_1\) = range for a given degree of damage for a yield of \(W_1\) KT, and \(d_2\) = range for a given degree of damage for a yield of \(W_2\) KT.

2. A similar relation should be used for yields in the range of 3 to 10 KT using the 10 KT curves. For yields between 10 and 30 KT, compute a range using the 10 KT curves as the basis for cube root scaling and a second range using the 30 KT curves as the basis for cube root scaling, then linearly interpolate between these two computed ranges.

**Example.**

*Given:* A 20 KT weapon burst at a depth of 400 feet.

*Find:* The lethal hull range for a submarine (600 psi static collapse pressure) submerged to a depth of 100 feet.

*Solution:* From figure 8-4, the lethal hull range for a 10 KT burst at 400 feet is 1,040 yards. The scaled range is then

   \[
   \frac{d_1}{d_2} = \frac{W_1^{1/3}}{W_2^{1/3}} \quad \text{or} \quad d_2 = \frac{d_1}{W_1^{1/3}}
   \]

   \[
   d_2 = \frac{(20)^{1/3}}{(10)^{1/3}} \times 1,040 = 1,300 \text{ yards}.
   \]

The lethal range for a 30 KT bomb burst at 400 feet is 1,300 yards. The scaled range is then

   \[
   d_2 = \frac{W_1^{1/3} \times d_1}{W_2^{1/3}}
   \]

   \[
   d_2 = \frac{(20)^{1/3}}{(30)^{1/3}} \times 1,300 = 1,100 \text{ yards}.
   \]

The lethal hull range for a 20 KT bomb burst at a depth of 400 feet is then

   \[
   d_2 = 1,300 - \frac{1}{2}(1,300 - 1,100) = 1,200 \text{ yards}.
   \]

*Answer.*

**Reliability.** Based on limited data.

**Related Material.**

See paragraphs 8.1c and 8.3a.

See also figures 8-1 through 8-3 for surface ship damage.
SUBMARINE LETHAL HULL DAMAGE BY 10KT AND 30KT AS A FUNCTION OF DEPTH OF BURST AND HORIZONTAL RANGE
SUBMARINE INTERIOR SHOCK DAMAGE BY 10 KT AND 30 KT
AS A FUNCTION OF DEPTH OF BURST AND HORIZONTAL RANGE
Figures 8–6 through 8–8 give ranges for underwater minefield neutralization as a function of yield for collapse pressures of 250, 500 and 1,000 psi with both the burst and mines on the bottom. Figure 8–6 is for a 50-foot water depth, figure 8–7 for 100 feet, and figure 8–8 for 200 feet. Linear interpolation between these curves can be used for intermediate water depths and mine case static collapse pressures.

Example.

Given: A 30 KT burst on the bottom in 100 feet of water.

Find: The range at which mines with a 500 psi static case collapse pressure located on the bottom are neutralized.

Solution: The range at which the mines are neutralized is taken directly from figure 8–7 to be 400 yards. Answer.

Reliability: Based on limited data.

Related Material.

See paragraph 8.3b.
FIGURE 8-6

UNDERWATER MINEFIELD
NEUTRALIZATION
RANGE VS. YIELD

50 Feet Depth of Water,
Burst and Mines on Bottom

Mine Static Collapse Pressure
1,000 psi
500 psi
250 psi

Horizontal Range (yards)

Yield (kilotons)
UNDERWATER MINEFIELD NEUTRALIZATION RANGE VS. YIELD

100 Feet Depth of Water, Burst and Mines on Bottom
UNDERWATER MINEFIELD NEUTRALIZATION RANGE VS. YIELD

200 Feet Depth of Water, Burst and Mines on Bottom

Mine Static Collapse Pressure

1,000 psi
500 psi
250 psi

Yield (kilotons)

Horizontal Range (yards)