U.S.S. RALEIGH

TORPEDO AND BOMB DAMAGE

December 7, 1941

Pearl Harbor

Class.....	6" Cruiser (CL7)	Length.....	550'
Launched.....	October, 1922	Beam.....	55'-4"
Displacement (standard).....	7,050 tons	Mean Draft (before damage).....	18'-3"
		Mean Draft (after damage).....	24'-0"

References:

(a) C.O. RALEIGH conf. ltr. to Cincpac, CL7/A16(0157), December 13, 1941.
(b) C.O. RALEIGH conf. ltr. to BuShips, CL7/S88/L11-1/A9(1202-C), January 14, 1942.
(c) N.Y. Pearl Harbor plan CL7-11/1-8 Alt. 0, Damage Investigation.
(d) Comdt. N.Y. Pearl Harbor conf. ltr. to BuShips, C-L11-1/CL7/NY10(Y-0464), March 12, 1942.

Circumstances of the Attacks

1. U.S.S. RALEIGH was moored with starboard side to interrupted quays at berth F12, eastward side of the north channel, Pearl Harbor, on the morning of December 7, 1941. The depth of water here is 45 feet. The weather was clear with scattered clouds. The ship was in Material Condition Xray. Two torpedoes were dropped from about 300 yards by the first wave of Japanese torpedo planes at 0756. One passed about 25 yards ahead of the ship and the other struck the port side amidships in way of No. 2 boiler room.

2. The torpedo apparently exploded at the instant of contact. A geyser of water rose over the quarterdeck. The sound of the explosion was muffled; no flash or flame was noted. The forward engine room filled with dark acrid smoke. No general flexural vibration of the ship was reported, but the shock was undoubtedly severe. The ship heeled to starboard under the force of the explosion and then gradually took a list to port. General Quarters was sounded at once and the A. A. batteries were in action within five minutes.

3. The two forward boiler rooms and the forward engine room flooded rapidly. Power was lost. It was feared that the ship would capsize, and men not at the guns were ordered to jettison topside gear. A barge was obtained and attached to the port quarter, which acted as an outrigger to steady the ship. Extra lines were run to the quays.

4. About 0900 a dive bombing attack was made. There were several near-misses, and at 0908 a bomb hit the after deck house at frame 112. The estimated height of release was 800 feet from a dive at an angle of about 65 degrees. The bomb passed through three decks and out the port side below water. The distance of the explosion from the ship is estimated at 100 feet in reference (b), but considering

the steepness of the descent, the nature of the damage to the shell plating, and the fact that the water is only 45 feet deep at berth F12, the bomb must have exploded much closer than 100 feet. It fortunately missed two full tanks (3500 gallons) of aviation gasoline on the main deck by 10 feet. The plane machine-gunned the ship.

5. Extensive flooding aft resulted from the bomb hit. Jettisoning of topside weights continued. At some time after 0900, steam was raised and the pumps were started. The list of the ship varied from port to starboard. The maxima are given in reference (a) as 11 degrees port (shown on Plate VII) and 8 degrees starboard. Photo 3, however, shows water nearly up to the airports on the main deck and thus indicates a starboard list of about 13 degrees. About midnight on December 7, the ship was upright and later steadied at a 4-degree list to port. Photos 1, 2 and 3 show the general condition after the two attacks.

6. The flooding resulting from the torpedo hit, and counterflooding which followed (see paragraph 32), put the bow down to a draft of about 30 feet. Flooding aft following the bomb hit resulted in a draft of about 20 feet at the stern.

7. No information is available at present with regard to the charges carried by the Japanese airplane torpedoes used at Pearl Harbor. It is believed, however, that the structural damage did not exceed that to be expected from a 500-lb. charge, and the torpedo may have contained even less explosive.

8. The bomb appears to have been of the 16-inch armor-piercing type used against other vessels on December 7.

9. RALEIGH and UTAH were near berths designated for LEXINGTON and ENTERPRISE. The carriers were fortunately not in. The severity of the attacks on RALEIGH and UTAH indicates that the Japanese either believed them to be the carriers, or that Japanese attack plans could not be changed to more vital objectives when the absence of the carriers was discovered by them.

10. The bomb hole aft was patched by means of a wooden caisson and life jackets by December 12, and by December 15 a semi-permanent concrete patch had been installed. Photos 12 and 13 show this patch. The ship was docked on January 3, and hull repairs were completed by February 5 as shown by Photos 17 and 18.

Structural Damage Caused by Torpedo

11. Damage to the hull is shown on Photos 4 to 9 and on Plates I, II and III, prepared by the Navy Yard, Pearl Harbor. The following remarks are based mainly on a study of the photographs and plans, and on the repairs reported by reference (d).

12. The point of impact appears to have been near frame 55 just below the lower edge of the armor belt on 'E' strake, which forms the turn of the bilge and carries the bilge keel. The side was blown in a maximum of about 8 feet between frames 54 and 58. The area of indentation of the shell was about 50 feet long by 35 feet measured around the girth; see Plate II. 'E' strake vanished in this region, leaving a twisted

length of bilge keel behind as shown in Photo 6. 'D' strake split longitudinally and was pulled up to meet the bottom of the armor belt. The split was probably along the connection of No. 3 longitudinal, which would mean that about 9 feet of the original girth was lost when the remains of 'D' strake met the armor as shown in Photos 5, 6 and 7. 'C' strake, in pulling up over the 14 ft. length, was knuckled over No. 2-1/2 longitudinal; see Photos 5, 6, 7 and 8.

13. 'C' strake was broken near frames 54 and 58. At frame 54 (Photo 8) the split was not along rivet holes, but apparently along the toe of web frame angle, and it extended nearly all the way across 'B' strake also. The split at frame 58 was along a butt (Photo 9) and 'B' strake was torn here as well.

14. The hull above 'E' strake consists of 40-lb. STS to which the 80-lb. STS plates of the main armor belt are attached; this construction extends up to the main deck as seen in Photo 4. The bottom strake of armor was blown in, breaking all its connections over a considerable length. The lower edge of the middle strake was dished and the upper strake was apparently unharmed. Not much can be seen of the 40-lb. shell behind the armor, but it was no doubt extensively damaged. One plate is visible at the separation of plates in the lower strake of armor, and the plate above it is torn as seen at the tops of Photos 5, 6 and 7.

15. The comparatively undistorted portion of 'D' and 'C' strakes between the fractures at frames 54 and 58 is most unusual. Probably this area is more rigid than its surroundings due to the foundations of No. 6 boiler. It would seem that the torpedo exploded at the instant of contact, carrying in and destroying a width of about 9 feet of plating around the turn of the bilge, pushing in the lower strake of armor, and blowing up the bottom to close the hole. The 14-foot section of bottom was apparently pulled up by the sudden inward movement of the plating above (the split in 'D' strake looks like a tension failure in the photographs) as well as pushed up by the pressure of the explosion. The unusual appearance of the damaged area suggests that the torpedo either had a small charge or that the detonation was of a low order.

16. Extensive failures of rivets are noticeable in this case, as well as in other ships damaged at Pearl Harbor.

17. Bulkheads bounding No. 2 boiler room, frames 53 and 59, were severely crumpled adjacent to the shell and penetrated by numerous fragments.

18. The three vent trunks in No. 2 boiler room were damaged, presumably by gas pressure from the explosion. Bulkhead 70 dished about 5 inches, but this was undoubtedly due to hydrostatic pressure in the flooded engine room. There was a small bulge in the after port corner of the first platform deck at frame 47 which was probably a consequence of flooding pressure against bulkhead 47.

Structural Damage Caused by Bomb

19. The bomb passed through the ship from starboard to port at an angle of 28 degrees from the vertical in the transverse plane and 4 degrees from the vertical, toward the bow,

in the fore-and-aft plane, as indicated on Plate IV. It penetrated the following plating:

Upper deck	10 lb. M.S.
Carpenter shop bulkhead. .	15 lb. M.S.
Main deck.	25 lb. H.T.S.
First platform	10 lb. M.S.
Hull (at a butt)	2 x 38 lb. H.T.S.

or in all, nearly 3.5 inches of metal. The path through the ship was 46 feet. The point of detonation was estimated at 100 feet from the hull; but see paragraphs 4 and 21.

20. The holes made had minimum diameters of about 1-1/2 feet, with jagged edges turned in the direction of the bomb path. Photos 10 and 11 show the holes in the upper and main decks. The exit hole in the shell had a minimum diameter of 16 inches and a maximum of 2-1/2 feet. The tail fin was stripped off and was found on the first platform deck, which probably accounts for the larger holes in the plating penetrated above. The bomb demolished three type B crew's lockers and three aluminum bunks.

21. The explosion resulted in typical near-miss damage; see Photos 11 and 12 and Plates III and IV. The indentation was about 1-1/2 feet maximum. This suggests that the explosion was much closer to the hull than the 100 feet estimated in reference (b), a point commented on in paragraph 4. Swash plates and decks in oil tank D-109 were buckled. The first platform deck was dished upward a maximum of 5 inches over an area about 10 by 10 feet in D-302, probably by the transmission of explosion pressure through the oil in the tank beneath. Compartment boundaries between D-109 and D-108, D-109 and D-202, D-109 and D-110 (i.e., boundaries of the oil tank D-109) were sprung from stiffeners with broken rivets, and rivets in boundary bars were sheared, W.T. door frames in bulkhead 109 showed signs of stress at the corners and the bulkhead was slightly crumpled at the outboard corner in D-302. All this can be ascribed to the transmission of explosion pressure to the boundaries of D-109 via the contained oil.

Damage to Machinery

22. No details of damage to the machinery are available. It was most serious in No. 2 boiler room, where boiler No. 6 was demolished (Plate III) and boilers 4 and 5 were badly damaged. Piping ruptures on the port side of No. 2 boiler room included the main and auxiliary steam lines, the auxiliary exhaust line, fire main, fuel oil suction and recirculating lines, high-pressure air lines and the fresh water filling line. Fuel oil heaters Nos. 4, 5 and 6 were demolished. Blower No. 6 was wrecked and No. 5 was damaged. Fuel oil service pumps Nos. 3 and 4 were wrecked, as were fuel oil booster pumps Nos. 1 and 2, together with the service and booster manifolds. This equipment was all, presumably, in No. 2 boiler room. Photos 14, 15 and 16 show wreckage in this space.

23. Certain auxiliaries in No. 1 boiler room were also damaged, including the fuel oil heaters and service pumps;

but the distribution of damage to auxiliaries in the boiler rooms is not entirely clear.

24. The main engine on the port side of the forward engine room (driving No. 4 shaft) was pushed out of line, and the other main engine (No. 1) in this room was reported as probably out of line. The two turbo generators were damaged, and so were the auxiliary condenser and its circulating pump.

Electrical Damage

25. Many circuits were out of action due to rupture of cables or short-circuits from flooding. Sixty-three damaged circuits are listed in reference (b). Those which were most important from a readiness-for-action standpoint included:

(a) Steering gear supply.
(b) Main radio supply.
(c) Forward twin 6" mount.
(d) Ammunition hoist forward.
(e) Power and lighting bus feeders between forward and after boards.
(f) Degaussing motor generators.
(g) 1.1" guns.
(h) Fire control motor generator.

These circuits were all from the distribution board in the forward engine room. Presumably power was still obtainable from the after turbo generators.

Shock Effects

26. The shock of the torpedo explosion threw personnel about, and though there is no report of general flexing of the ship, this must have occurred to some degree. Both main battery directors were put out of commission (no details reported). Both bridge repeaters tumbled from the peloruses.

Liquid Loading and Subsequent Flooding

27. The liquid loading before damage and the subsequent flooding are shown on Plates VI and VII. There is uncertainty as to the condition of some tanks, which are outlined in green. The reserve feed bottoms, for instance, must have been partly full; and those to port under the forward boiler rooms were certainly opened to the sea.

28. The torpedo hit resulted in immediate flooding of the two forward boiler rooms and the forward engine room. The wiring trunk leading from the forward boiler room to the I.C. room (A-116) evidently flooded and there was slow leakage into A-116 and thence to central station (A-120). This must have been through cables or cable stuffing tubes, or both. It was controlled by intermittent use of a submersible pump.

29. There was some leakage into the main deck passageways in way of the torpedo hit. The deck edge went under alternately to port and starboard as the list reversed. Free water on the main deck was later controlled by pumping at about 120 gallons per minute.

30. The bomb passed through the full tank D-109-F, which then flooded into adjacent compartments, the tank boundaries

having been damaged by the shock of the hit, or the underwater explosion which followed, or both. The 6-inch magazine and handling room, and the port storeroom and shaft alley (D-111-M, D-112-M and D-108) flooded rapidly. On the second platform, the provision and refrigerated storeroom, D-202, flooded; and D-302-L flooded through the bomb hole in the first platform deck.

31. D-301-L, just forward of D-302-L, was flooded, as the bulkhead between them at frame 109 is non-watertight. D-303-L, just aft of D-302-L, was partially flooded, apparently via a flush hatch which could not be properly secured (Plate V).

Damage Control Measures
(Refer to Flooding Diagrams, Plates VI and VII)

32. Condition Zed was completely set and counterflooding started within fifteen minutes after the torpedo hit. The forward starboard compartments A-107-M and A-115 were counterflooded. A-108-M was unintentionally counterflooded through a jammed valve. Bulkhead 70 (after bulkhead of forward engine room) was shored. Leaking flush-deck hatches on the main deck were shored down tight.

33. Jettisoning of topside weights was undertaken almost at once. All this work was done by hand; there was of course no power available for some time. The airplanes were hoisted out and taxied to Ford Island. The jettisoned gear amounted to about 60 tons, and included:

(a) four sets of boat skids,
(b) the 6-inch and 3-inch loading machines,
(c) torpedo tubes, starboard and port,
(d) both catapults,
(e) the port gangway,
(f) both anchors and chain,
(g) the airplane boom,
(h) oxygen, acetylene and CO_2 bottles,
(i) four vent cowls,
(j) alcohol locker,
(k) supply locker,
(l) blocks, ladders, and miscellany.

34. The barge mentioned in paragraph 3 was obtained from BALTIMORE. It carried four 80-ton salvage pontoons. This appears, from reference (a), to have been secured to the ship before the bombing attack. As there was no equipment or power to handle the pontoons, the entire barge was attached by passing four two-inch wire hawsers completely around the ship and barge. Wire straps were passed around the top and bottom parts of the hawsers, in the gap between ship and barge. The barge was securely fixed to the hull by tightening up these straps. Extra wire and manila lines were also run to the quays.

35. Following the bomb hit, the forward compartments A-117, A-118-M and A-119-M were counterflooded; later the starboard forward shaft alley D-103 was counterflooded. Three flush-deck type hatches in D-301 and one in D-303 in the first platform deck were shored down.

36. It appears from reference (b) that the counter-flooded compartments forward were pumped out after steam had been raised. Mention is also made of pumping the forward port shaft alley (D-102), although it is not clear whether this was flooded by damage or intentionally. Other pumping is mentioned in paragraphs 28 and 29.

37. At some later time, 3500 gallons of aviation gasoline were transferred to a barge. Oil soaked gear and bedding were removed and compartments wiped down to reduce the fire hazard.

Bureau Comment on Stability and Damage Control

38. The case of RALEIGH is unusually interesting from the standpoints of stability and damage control, and a special study of these features has been made by this Bureau.

39. Before proceeding to the RALEIGH case, however, the general problem of ships with little or negative stability after damage will be discussed. No simple rules can be stated, but there are certain definite principles to guide the Damage Control Officer in making his decisions.

40. This discussion applies to ships damaged so extensively that the initial stability becomes negative. This reduction in stability is due primarily to the effect of free surface of liquids. Such a situation will almost certainly develop on destroyers and cruisers having more than two main compartments flooded.

41. A ship with negative stability will list even though there is no transverse listing moment due to flooding or to distribution of weights unbalanced about the fore-and-aft centerline. The degree of list depends on the amount of negative metacentric height. It is useless to try to right the ship by shifting weights or counterflooding unless these operations restore positive stability, and this in turn will not result unless the center of gravity is lowered.

42. If, in a ship listing due to negative stability, a compartment on the high side is counterflooded, the ship will suddenly reverse her list to an even greater degree on the opposite side. This is due to three reasons (1) a ship with negative stability is not in stable equilibrium when upright; (2) stability is further decreased by free surface in the compartments being counterflooded; and (3) the counterflooded compartment represents an unbalanced added weight or a loss of buoyancy on the previously high side. These arguments, with obvious modifications, also apply to shifting liquid or solid weights.

43. Under some circumstances, however, deliberate flooding or weight-shifting operations may be desirable in ships with basically low stability such as cruisers and destroyers even though there is no unsymmetrical damage flooding (the ship being listed because stability is negative). The list will be decreased if stability is increased. The procedure

is to lower the center of gravity, and this can be done by: (1) jettisoning topside weights; (2) lowering weights; or (3) flooding compartments of relatively small width, low in the ship, near the centerline, until completely filled. The compartments deliberately flooded should be selected to improve the trim if possible. But it should be emphasized that deliberate flooding in these circumstances is a last resort and should not be undertaken until a full survey of the condition of the ship has been made. It can seldom do very much good and will always have the transient ill effects of free surface until the compartments are filled, and of reducing still farther the reserve of buoyancy. Nor can one be certain that the compartments will fill completely, as the list may produce air pockets which cannot be vented.

44. Next consider the case in which flooding due to damage is not symmetrical, still assuming negative stability. Unless the list is serious - such that freeboard is so little that flooding over the deck is imminent, or (in action) the guns cannot be engaged - it will generally be best not to counterflood. If the list is serious, counterflooding or liquid-shifting operations may be undertaken such that the inclining moment due to the damage is neutralized, but no more. Again it should be emphasized that free surface in the counterflooded compartments is dangerous, and only compartments with small transverse dimensions should be utilized. The ship will then be in the condition of paragraph 41 above, and any further steps should be governed by the considerations discussed in paragraph 43.

45. In cases of low or negative stability it will not be easy, generally speaking, to decide when to stop in neutralizing the inclining moment due to unsymmetrical flooding. Compartments available for counterflooding will usually not be symmetrically placed with respect to those flooded by damage. And if too much righting moment is created, a sudden reversal of list will almost certainly occur, and the ship may be worse off than before. It is wise to stop counterflooding well before the ship comes to the vertical.

46. Turning now to the particular case of RALEIGH, the metacentric height of this ship was about 22 inches before damage. This is for a displacement of 9900 tons, corresponding to the reported mean draft, which incidentally is about 150 tons over the emergency load condition given in the Inclining Experiment.

47. Two boiler rooms and an engine room flooded as a result of the torpedo explosion. There was free surface in all these compartments. A rough calculation gives a residual metacentric height of only two inches, and it may well have been slightly negative. The ship took a list to port; how much is not reported. This list may have been due to negative stability, or to some slight unsymmetrical buoyancy (such as an intact feed and filter tank, or an air lock), or both. The draft forward increased to nearly 30 feet.

48. Forward compartments were then deliberately flooded. This action unnecessarily increased trim by the bow. Fortunately the compartments are small and had small free-surface and listing moment effects. It is doubtful that any advantage accrued from the counterflooding at this time.

49. The flooding following the bomb hit was unsymmetrical, and the considerations of paragraph 44 apply. The list to port was now appreciable and the ship was in such a critical condition that counterflooding was justified. The Damage Control Officer had little choice in selecting compartments to counterflood. He improved the freeboard aft by more flooding forward, and flooded a low starboard compartment aft to reduce list. It is estimated that the flooding from bomb damage resulted in a negative metacentric height of 7 to 10 inches, and that the counterflooding and jettisoning of topside gear restored this to a negative value of perhaps 4 to 6 inches.

50. The condition of RALEIGH would have been considerably more critical if the ship had been at sea. The freeboard to the main deck was so low that rolling would have spread water over it, and this deck is not subdivided except at the ends. Counterflooding as conducted after the bomb hit would have improved the situation by reducing list and increasing the freeboard aft; but it is quite probable that the ship would have been lost, in spite of all corrective measures, had she been out in a moderately rough sea.

51. The other measures - jettisoning topside weights, attaching a barge, and shoring bulkheads and hatches - were correctly taken and insured survival of the ship. The expeditious accomplishment of these tasks was highly commendable.

52. The precarious situation can be seen in Photos 1, 2 and 3. Photo 2 shows the ship listing to port, with practically no freeboard to the main deck. Photo 3 shows the ship with a list to starboard with the main deck airports just out of water. As stated in paragraph 5, the ship's list varied from side to side, a proof of negative stability.

53. The leakage through flush-deck type hatches should be particularly noted. This has been mentioned in paragraphs 31 and 32. Ten of these hatches were faulty, six forward and four aft. Those in the first platform deck aft (armored) permitted flooding of D-301 and D-302, which added considerably to the seriousness of the ship's condition. Reference (b) states that all these hatches had been given routine chalk and air tests during the preceding year, but all had to be shored down in this emergency. *

54. In conclusion, with the exception of the initial counterflooding which was of doubtful advantage, the damage control measures were completely and skillfully carried out under very difficult conditions. Without them, the ship might have sunk.

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* Difficulty with hatches was also experienced in the case of HONOLULU; see War Damage Report of Bomb Damage, December 7, dated February 14, 1942. An alteration for all ships in service has subsequently been approved in BuShips confidential letter C-EN28/A2-11 of March 26, 1942. The improvement consists in substituting hexagonal box wrenches for T-wrenches and modifying the dogs as necessary.

Repairs at Pearl Harbor

55. Damage to the hull itself was completely repaired at the Navy Yard, Pearl Harbor in a period of about a month. The repairs in way of the torpedo damage are shown by Photos 17 and 18.