U.S.S. YORKTOWN

Bomb Damage

May 8, 1942

Coral Sea

Class.....Aircraft Carrier(CV5)	Length (W.L.)...770'
Launched.....April 4, 1936	Beam (W.L.).....82'-3"
Displacement..20,000 Tons (Standard)	Draft (prior damage).....27'-2-1/2"

References:

(a) C.O. YORKTOWN letter CV5/S88/A9/(CEA-50-swg) Serial (003) of 20 May, 1942 (War Damage Report).

(b) C.O. YORKTOWN letter CV5/S88/(CEA-50-swg) Serial (004) of 20 May, 1942 (Information on Damage Control).

(c) Comdt. N.Y. Pearl Harbor letter C-L11-1/CV/NY10 Serial Y-01212 of 24 June, 1942 (War Damage Report).

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29. Bulkhead 106, between 3rd and 2nd decks, looking forward.

30. Fragment damage, starboard longitudinal bulkhead, second deck, FRS. 106-109, looking forward.

Section I - Foreword

1. U.S.S. YORKTOWN received damage from at least three bombs while in the Coral Sea on 8 May, 1942. Of these, one was a direct hit on the flight deck, the second struck and glanced off the outboard coaming of the forward starboard gallery walkway exploding off the bow and the third exploded in the water off the port side at about frame 108.

2. This report deals with the damage in detail, particularly that caused by the direct hit. This is the first case to be studied by the Bureau of a bomb explosion in a confined space aboard a modern carrier of the U.S. Navy.

3. This report is based on the excellent data supplied with the references. Photos were supplied by the Commanding Officer and Pearl Harbor. Plates were prepared from plans submitted by Pearl Harbor.

Section II - Narrative

(Plate I)

4. On the morning of 8 May, 1942, YORKTOWN was operating in the Coral Sea as part of a task force. Enemy action during the day was expected and at 0545 the crew was called to General Quarters and material condition Afirm established. Weather was clear with visibility excellent. The sea was calm with a moderate swell.

5. At 0835 contact was reported with the enemy about 150 miles distant. Attack groups were launched shortly after. At 1055 a large number of enemy planes was reported bearing 020° some 68 miles away. By 1058 the enemy has closed to 40 miles and at 1102 fighters were launched. At 1111 the enemy had closed to 15 miles. Speed was now 30 knots and various courses were steered to evade bombs and torpedoes.

6. At 1118 anti-aircraft fire was opened and enemy torpedoes were launched from the port beam and quarter. All missed. At 1124 dive bombing started. There were six or eight bombs observed to fall close to the vessel and explode on impact or just below the surface. During this attack the direct hit on the flight deck occurred as well as the damage to the starboard bow and port beam. Dive bombing and torpedo attacks continued until 1140 when action was finished.

7. Damage to the starboard bow and port beam was slight and had little effect on the combat efficiency of the YORKTOWN.

8. The bomb which struck the flight deck was released from a dive bomber at an altitude of about 1500 feet with the angle of dive estimated to be 60 degrees from the horizontal. The bomb struck slightly forward of frame 108, 6 feet and 6 inches to starboard of the centerline. It penetrated the flight, gallery, main, second and third decks and exploded in C-402-A, an aviation storeroom, at about frame 107, some feet above the fourth deck.

9. The detonation was of "high order". Blast did considerable damage to the third deck and adjacent bulkhead 106. There were some blast and fragment holes in the second deck. The fourth deck was undamaged beyond a slight deflection. A few bulkheads between third and fourth decks received damage of varying amounts. Doors and hatches on fourth, third, second and main decks were damaged. Flying fragments did considerable damage in the vicinity of the explosion on the third and fourth decks, particularly to medium steel bulkheads.

10. A fire started immediately in C-402-A among the crated stores. Two additional minor fires started and were immediately extinguished. The fire in C-402-A was quickly brought under control and later extinguished. Eleven hoses were lead down from the main or hangar deck. Of these, two were used to supply foam. The sprinkling system in C-402-A started automatically although the lines were pierced and shattered in many places.

11. The explosion produced dense black smoke and noxious gases. These were largely confined to the damaged areas. They passed slowly up through the damaged hatches and bomb holes and the number 2 Elevator Pit to the hangar deck. As hangar roller curtains were up at the time of attack, smoke and gas cleared quickly from the hangar.

12. Air intakes to numbers 7, 8 and 9 boiler rooms had been pierced between second and fourth decks permitting smoke to be drawn into the boiler rooms, and these three spaces were evacuated for a short period. However, speed was not reduced below 25 knots.

13. The bomb pierced and cut general and battle lighting and power cables under the second deck. Inasmuch as these served the damaged areas, darkness prevailed. However, floodlights were quickly rigged.

14. When fires were extinguished, four feet of water from the hoses and sprinkling system had accumulated in fourth deck compartments B-411-E, B-9-5AT, C-402-A and C-408-1A. Water spread throughout these by virtue of ruptured bulkheads and damaged doors. It was pumped out using six portable submersible pumps and the one 2-1/2 inch air-driven portable pump. Ten hours were required for this.

15. Blast and shock effects on operating equipment were not severe although some damage occurred. The most important units involved were the gyrocompasses, which oscillated erratically for some three hours, and the distant control operating gears to the main steam stop valves in the forward engine room which suffered considerable derangement.

16. Damage did not incapacitate the YORKTOWN to any great extent. The reduction in speed to 25 knots was by far the most serious immediate effect. The oil slick from leaky port oil tanks was extremely undesirable

Section III

A. Fragmentation Effect, Starboard Bow

(Plate I, Photos 4 and 5)

17. One of the bombs released during the dive bombing attack was seen to explode on contact with the surface about

50 feet off the starboard bow abreast frame 20. A bomb also struck and glanced off the starboard gallery walkway slightly aft of frame 42. Point of impact of the latter is shown in Photo 4. It is possible that both of these were one and the same bomb as there were no fragmentation effects aft of frame 25. In addition, the one which obviously struck the walkway was not observed at the time.

18. Fragments pierced the shell in four or five places. The largest hole was about 3 inches in diameter about 5 feet above the waterline at frame 22. There were numerous small dents in the shell. The "M" coil of the exterior degaussing cable was cut at frame 18. A gasoline line was cut at frame 20 but no fire resulted as gas lines had been drained prior to action.

B. Damage to Shell, Port Side, From Far Miss

(Plate II, Photos 1, 2 and 3)

19. Another of the bombs was observed to explode about 20 feet from the port shell abreast frame 108 some distance below the surface.

20. The shell was dished in at the seam between G and H strakes, frames 101 to 113. This is about 16 feet below the waterline. The lower edge of the armor belt was pushed in slightly with a maximum deflection of the order of 2 inches. Transverse frames and bulkheads inboard of the shell were wrinkled and torn from the shell in a few places. The tank between the shell and the first longitudinal bulkhead was full at the time and the distortion of the shell forced some oil from tanks C-4-F and C-16-F to escape through the pressure relief valves into C-404-L. Damage did not extend inboard of the first bulkhead, which, although slightly deflected, was uninjured.

21. The most serious consequence of this damage was the oil slick formed aft of the ship by oil escaping from the leaking seam.

C. Damage From Direct Hit

(Plates III and IV, Photos 6 to 30, inclusive)

22. Considerable structural damage resulted from the direct hit on the flight deck. Point of impact was between frames 107 and 108, 6 feet and 6 inches to starboard of the centerline. The probable path of the bomb, as deduced from the damage, is shown on Plate III. Prior to the impact it appears to have traveled slightly forward and from port to starboard. The flight, gallery, main, second and third decks were penetrated and the explosion occurred a few feet below the third deck about 12 feet to starboard of the centerline between frames 107 and 108.

23. Damage to the flight deck plating and planking consisted of a hole about 12 inches in diameter and distortion of

the deck longitudinal immediately outboard of the hole. The weld in the face plate of this longitudinal failed although the weld was not in the direct path of the bomb. Photo 6 shows the bomb hole and cracked weld.

24. At the gallery deck, Photo 7, the bomb, which had been deflected slightly inboard by the I-beam at the flight deck, struck and dented the side of a small safe which deflected it inboard still more. It then passed through the gallery deck tearing a hole about 12 inches fore and aft and 18 inches athwartships. It was thus turning slightly in its flight. Unde this deck a small transverse, intercostal between longitudinals, was completely severed.

25. At the main deck, the hole measured 15 inches fore and aft and 3 feet 6 inches athwartships. The bomb passed through nearly on its side. It pierced a thin diamondette plate, two courses of medium steel (25 and 17 pounds) and a deep longitudinal I-beam under the deck. Photos 8 and 9 show this.

26. At the second deck, the bomb struck just above the inboard after corner of access trunk C-301-2T between second and third decks. It passed through the deck, making a hole about 15 inches fore and aft and 2 feet 6 inches athwartships, and ploughed down the corner of the trunk as shown on Photo 10. From the damage it appears that the bomb was deflected inboard and away from the trunk and that it then passed through the third deck exploding below the third deck about 12 feet to starboard of the centerline. The third deck plating in the area was destroyed obliterating the hole caused by passage of the bomb.

27. The thickness of decks pierced by the bomb was: (a) Flight deck - 3" pine and 4 pound medium steel, (b) gallery deck - 9 pounds medium steel, (c) main deck - two courses, one 25 pound and one 17 pound medium steel, (d) second deck - 9 pounds medium steel, (e) third deck - 10 pounds medium steel. In addition, a longitudinal under the flight deck, a transverse under the gallery deck, a longitudinal under the main deck and a vertical bulkhead of the access trunk, third deck, were either severed or damaged due to the fall. Thus, a minimum of 72 pound (1-13/16 inches) of steel plate was penetrated. Total travel of bomb from flight deck to point of explosion was about 50 feet.

28. Structural damage falls naturally into two categories (a), that caused by blast and (b), that caused by splinters and fragments.

(a) Damage Caused by Blast

29. The fourth deck, 60 pounds STS, suffered no damage beyond a slight downward dish in C-402-A. Photo 17 indicates only a slight deflection. Vertical bulkheads between the third and fourth decks were damaged over an area extending from frame 100 to frame 129. Bulkhead 106 was the most seriously damaged. It will be noted from Plate IV and Photos 11, 12 and 13 that it was demolished in way of the Laundry Storeroom. The demolished plating was of 9 pound thickness bounded inboard by 40 pound STS and outboard by 30 pound STS. The STS bulkheads were deflected

slightly forward by the blast. The inboard longitudinal 30 pound STS bulkhead of trunk C-401-T was blown outboard. The inboard 30 pound STS bulkhead of the ventilation trunk between frames 106 and 107 on the centerline was deflected outboard and ripped from the third deck. Forward of bulkhead 106 the forward and outboard bulkheads of the Laundry Storeroom were severely dished, in a direction outward from the center of the explosion. The door at frame 101 in the outboard longitudinal bulkhead of B-411-E was blown off its dogs and hinges, marking the farthest extent forward of damage. Bulkhead 118 (and trunk C-405-T) was undamaged except for the double door on the starboard side. This door was blasted out of the dogs and thrown aft to frame 128, some 40 feet. It had been tightly dogged. The frame was pushed aft about 3 inches as shown in Photo 23. Blast traveled up the long trunk, frames 119-125, and blew off the second and third deck hatch covers. The longitudinal refrigerator bulkhead, frames 127-129-1/2 starboard, was deflected inboard about 4 inches as shown in Photo 27.

30. Transverse web frame 109 under the third deck, with its connecting intercostals, was distorted and twisted. The starboard I-beam stanchion supporting it was lifted from the third deck. Photos 17 and 19 indicate this. The fragment damage will be discussed later. Attention is invited to Photos 21 and 22 which show failures at the weld in the butts in the corner brackets of the web along the starboard shell and inboard longitudinal bulkhead. Failure of these welds will be discussed in Section VII.

31. The blast blew a hole approximately 6 feet in diameter in the third deck. Plates around the periphery of the hole were curled upward. Photos 11 and 12 show the hole. The entire third deck in C-301-1L was deflected and received a permanent set. Deflection was almost entirely aft of the center of explosion as will be seen from Plate III bulkhead 106 effectively reduced damage forward of the explosion. Areas outboard of the longitudinal splinter bulkheads below were depressed. The center area was elevated about 5 inches. Aft of bulkhead 112 on the starboard side, the third deck was also bulged upward back to frame 117.

32. On the third deck, bulkhead 106, starboard side, in way of the explosion, was ripped from the deck and pushed forward about 18 inches and up 14 inches. Photos 11, 12 and 13 indicate the damage. Bulkhead 112 was bowed aft about 2-1/2 inches and port and starboard doors were deflected aft. Photo 24 shows the starboard door. Blast demolished the ships service stores on the centerline. The port store and the Laundry Receiving Room expanded and sheetmetal bulkheads were wrinkled. The expanded and sheetmetal bulkheads aft of bulkhead 112, both fore and aft and athwartships, were crumpled by the blast which came up trunk C-408-1A. The doors in bulkhead 112 were not opened by blast. Transverse trunk bulkheads 104 and 105 were blown out on the starboard side. The longitudinal bulkhead forming the inboard boundary of the long trunk between frames 119 and 125 was pushed inboard although not damaged severely. The inboard and after bulkheads to the engine room access trunk were crumpled somewhat but not extensively damaged, although at the edge of the hole in the third deck.

33. Damage to the second deck was confined between bulkheads 106 and 112. A few holes in the starboard center section

were caused by blast. A permanent set was taken although much less severe than that of the third deck. Stanchions between second and third decks on frame 109 did not buckle. Five deck longitudinals to starboard of the centerline were buckled severely The 6 inch pipe stanchion between second and main decks on frame 109, starboard, failed sharply, buckling in the middle. This stanchion was much lighter than the one below which did not fail. Structural bulkheads on the second deck were undamaged. The double hatch cover, frames 107 to 109, starboard, remained secure but the escape scuttle was blown up.

34. The main deck was slightly bowed up a maximum of 1-1/2 inches in the area to starboard of the centerline. The double hatch cover, frames 107 to 109, starboard was blown up and out of the dogs. Photo 25 indicates that hinges were not sheared.

(b) Damage Caused by Splinters and Fragments

35. Splinter and fragment effects were largely confined to third and fourth deck areas. The Commanding Officer estimated that 80 percent of the fragments were confined to the area immediately adjacent to the explosion on the fourth and third decks. Study of damage verifies this estimate. The after transverse bulkhead at frame 102, bounding uptake space B-413-1E, was the forward-most bulkhead to be damaged by splinters. It was dented but not pierced in several places in the area outboard of the 30 pound STS. The inboard STS portion was dented but not penetrated. The outboard medium steel bulkhead of the Laundry Storeroom was dented and pierced by several fragments. Transverse bulkhead 106 defeated almost all fragments in the STS portions. Photo 15 shows no fragment holes and Photo 17 shows a few small holes in the 40 pound section. The outboard longitudinal 30 pound STS bulkhead of trunk C-401-T was pierced by one fragment. The inboard bulkhead although STS was, of course, almost destroyed because of its proximity to the explosion. The few fragments which penetrated the 40 pound STS portion of bulkhead 106 pierced the medium steel boundaries of the air intake trunk to fireroom No. 7. Some fragments pierced the medium steel inboard bulkhead of the trunk to fireroom No. 9. Transverse medium steel bulkhead 118 and STS trunk C-405-T were pierced in only two places. The port and starboard longitudinal 25 pound STS splinter bulkheads defeated all fragments. There was no fragment damage to the 30 pound STS centerline vent trunk.

36. On the third deck, splinters, which carried through the blast hole and bulkhead 106 just above the deck, penetrated the boundaries of intake trunks to firerooms 7, 8 and 9.

37. There were several splinter holes in the second deck adjacent to the blast holes and directly over the center of the explosion. The main deck defeated all splinters and fragments although it was dented in some few places adjacent to the hatch.

Section IV - Fires

38. In storeroom C-402-A, where the bomb burst, a fire started immediately among the crated stores consisting of expeditionary gear, rags and target sleeves. The flash upward

caused a small paint fire on the overhead of the hangar above the explosion. A minor fire among the bedding in the marine compartment, C-201-L, on the second deck also broke out. The latter two fires were immediately extinguished.

39. Dense black smoke filled C-402-A, C-301-L and C-201-L. The general lighting, battle lighting and power cables for the damaged areas were severed by the bomb on passing through the main and second decks. See Photos 9, 10 and 30. Darkness prevailed.

40. The fire in C-402-A was fought with water from the firemain. From the hangar, where a large number of fireplugs and foam generators were located, eleven hoses were run, down through both the bomb holes and the elevator pit. Two of these were used to supply foam. The sprinkling system in C-402-A started automatically and effectively aided in extinguishing the fire. No damage to the firemain or risers occurred although one riser in C-402-A was believed to be ruptured at the time and was cut out in the forward engine room. The electric sprinkling control valve for C-402-A opened by the shorting of its power circuit. This started the automatic electric-driven damage control pump thus sprinkling in C-402-A and supplying water to fire plugs.

41. The Midship Repair Party, using the new type A rescue breathers, first entered C-301-L and cleared the wreckage and personnel casualties and used fire hoses down to C-402-A. Then C-402-A was entered and the fire extinguished. The time required to extinguish this fire was not reported, but it appears to have been reasonably short.

42. Electrical repair parties rigged portable lights which assisted materially in quickly controlling and extinguishing the fire.

43. When fire hoses were secured, water to a depth of four feet covered the fourth deck in B-411-E, B-9-5AT, C-402-A and C-408-1A. This water resulted from the eleven hoses used and the sprinkling in C-402-A. Spread of water fore and aft was through damaged doors. This water was pumped out in about 10 hours using six electric portable submersible pumps and one 2-1/2 inch air-driven pump.

Section V - Shock Effect

44. When the bomb exploded no general flexure of the ship girder or extensive vibration was reported. Rather, the shock was felt locally as a sharp blow.

45. The control drive shafting to number 2 elevator was sprung and gear boxes cracked. The foundation stiffening brackets for numbers 7 and 8 forced draft blowers were cracked at the bulkhead. Numerous small leaks developed in the economizer tubes of numbers 7, 8 and 9 superheater boilers. This was considered by the Commanding Officer to be merely an aggravation of a previous condition. The distant control operating gear to the three main steam stop valves in the forward engine room were damaged as follows:

(a) Starboard stop - out of line but still operative from the third deck.

(b) Center stop - demolished above the fourth deck. This was in way of the explosion.

(c) Port stop - out of line, wheel shattered, and gear pedestal bent. It was inoperative from the third deck.

In the forward engine room on the starboard side of the overhead, frames 106 to 112, insulation and light fixtures were broken loose from the deck and hangar supports for the main and auxiliary steam lines were sprung although the lines remained tight.

46. Both the forward and after gyro compasses started to oscillate erratically but soon settled on bearings that varied 3 degrees. In about 3 hours the forward compass settled to normal operation although the northsouth level showed slight unbalance. Bearing trouble developed in the south rotor of the after compass. This was manifested by high temperatures, excessive rotor current and a high frequency hum. The whole south rotor assembly was replaced by a spare.

47. Reference (a) reported that fifty fuel oil tank pneumercators on the port side were shattered and rendered inoperative. This damage was probably caused by the near-miss off the port beam.

Section VI - Repairs

(Photos 2 and 3)

48. The vessel was available at the Navy Yard, Pearl Harbor, for slightly more than 48 hours to allow temporary repairs. During this period demolished and damaged structure was replaced by material having equivalent weight, strength and section modulus. In way of the near-miss damage to the port side, frames and transverse floors between the shell and number 1 bulkhead were not replaced as enough material remained to hold the shell in place. The shell was repaired by caulking and welding the leaky seam and rivets as shown on Photos 2 and 3.

49. On the fourth deck the double door opening in bulkhead 118 was covered by a flat plate welded in place and a standard 26" x 66" watertight door installed. The demolished portions of bulkhead 106 were replaced. The heavy stanchions supporting transverse 109 were replaced and the web was replaced where twisted and riddled. The hole in the third deck had been previously covered by the ship's force with a 10 pound plate. Installation of this was completed by the Navy Yard and beams underneath replaced. The holes in the second deck were patched and damaged beams under the deck replaced.

50. All watertight doors and hatches below the main deck were repaired and tested for watertightness. Access trunk C-401-T was not replaced and miscellaneous partition and expanded metal bulkheads were not repaired. However, all essential watertight boundaries on second deck and below were restored.

Section VII - Discussion

A. Size of Bombs

51. The Commanding Officer, in reference (a), estimated the bomb to be a delayed action, armor-piercing type, weighing about 800 pounds and with a diameter of about 12 inches. He further stated that from examination of bomb fragments the bomb appeared to have been of the projectile type. This description does not fit any of the currently available data on Japanese bombs. The depth of penetration prior to detonation (1-13/16 inches of medium steel) and the extent of damage correspond with that observed on CURTISS. Damage on CURTISS was concluded to have been caused by a 250 kilogram (540 pound) bomb of the type recovered at Schofield Barracks after the raid of 7 December, 1941.

52. The Schofield Bomb has been classified in previous reports as a "general purpose" bomb. In light of recent classification of U.S. Navy bombs by the Bureau of Ordnance, it appears proper to place this bomb in the "semi-armor piercing" category. The Schofield Bomb had a fairly heavy case with a thickness of about 3/4 inches, about 25 percent by weight of explosive (133 pounds) and a diameter of 12 inches. While the term "semi-armor piercing" has not been closely defined it is used to describe a bomb with about 30% by weight explosive charge, a medium weight case, delay action fuse or fuses and the ability to penetrate moderately armored decks (such as the decks of cruisers or carriers) when dropped from about 12,000 feet in horizontal bombing or light armored decks in dive bombing from about 2,500 feet.

53. With the above in mind it has been concluded that the bomb which struck the YORKTOWN was of the "semi-armor piercing" type with the characteristics of the one recovered at Schofield Barracks. The bomb which caused the slight damage to the port shell was probably of the same type. This is based on the minor damage suffered, although the bomb exploded quite close (20 feet) to the shell. "Semi-armor piercing" bombs below 1000 pounds in weight produce negligible underwater effect, unless in very close proximity to the shell, because of the relatively small explosive charge. On the basis of Bureau of Ordnance charts it is estimated that the bomb which struck the flight deck would not have pierced a 70 pound STS deck.

B. Explosion in Confined Space

(Plate III)

54. The bomb explosion occurred in a completely confined space, deep in the interior of the vessel. It is the first case to be studied of such an explosion aboard a U.S. Navy vessel of recent design. One somewhat similar case aboard a British vessel, the H.M.S. ORION, has, however, been studied.

55. On ORION a 500 Kg. German bomb of the thick-walled type and carrying about 165 pounds of explosive penetrated six decks and exploded in a comparatively small compartment just above an 80 pound armored deck. The bomb penetrated 47 pounds

of medium steel and 24 pounds of D quality (similar to our H.T.S.) steel and ricocheted off the armored deck prior to explosion. A good sized hole was blown in the armored deck, the deck immediately above was ruptured over a large area and the second deck above was bulged upwards about one foot. Vertical bulkheads, both longitudinal and transverse, on three decks were blown out, severely warped or otherwise damaged so that watertight integrity was completely destroyed throughout an area extending between stations 53 and 77, about 50 feet, completely across the ship and vertically from the keel through three deck heights. Structural damage on ORION, as compared to that on YORKTOWN, was thus far more extensive and far out of proportion to the relative weights of explosive concerned.

56. It is difficult to definitely ascertain the reasons for the disproportionate amount of damage on the two vessels, particularly as very little is known about the physics involved in a bomb explosion. However, the following factors may partially account for the relative amounts of damage:

(a) Size of compartment in which explosion occurred. On ORION the compartment was very much smaller than on YORKTOWN, the ratio being about 1 to 20 by volume. Experience so far indicates that local structural damage will be more severe in small compartments than in large ones for similar weights of explosive.

(b) Presence of hatches left deliberately open. On ORION several deck hatches were deliberately left open in order to "vent" possible interior explosions. One of these was located in the deck overhead and just aft of the explosion. Still another was located on the second deck level above the explosion. The vertical extent of serious structural damage on ORION leads to the suspicion that these open hatches not only did not reduce the blast effects but served rather to extend them. On YORKTOWN all doors and hatches were tightly dogged. However, the double door in bulkhead 118 and the hatch cover on the third deck to the long hatch between frames 119 and 125, both of which were blown off, seemed to have served as involuntary "vents". The minor damage which occurred aft of bulkhead 118 on the fourth deck and aft of bulkhead 112 on the third deck resulted from blast through these openings. The only positive evidence existing that blast from bombs can be successfully vented (from small scale model tests) indicates that extremely large open areas, such as the open sides of hangar decks on aircraft carriers, are required. Such areas cannot be provided on other types of vessels. In view of the limited extent of serious damage on the YORKTOWN as compared with the much greater extent of serious damage on ORION, there no longer seems to be any reason for believing that the effects of bomb explosions in confined spaces can be reduced by deliberate "venting". Indeed, it appears that "venting" will extend the damage to remote areas which would not otherwise be damaged and will not correspondingly lessen the damage in the vicinity of the explosion.

(c) Presence of armored bulkheads. On YORKTOWN a considerable number of STS bulkheads were included in the peripheries of the compartment in which the explosion occurred. These are shown on Plate III. On ORION there were none. The limited extent of serious structural damage on YORKTOWN presents further evidence, in addition to that of NEVADA [1] and PENNSYLVANIA [2], of the ability of STS to sharply limit blast damage in addition to limiting fragment damage.

C. Effect of STS in Limiting Fragment Damage

(Plate III)

57. In general, STS bulkheads between the third and fourth decks were fitted to reduce fragment damage to vital trunks, air intakes, and other important spaces. By reference to Plate III it will be noted that fragment damage was sharply limited. Damage by fragments between third and fourth decks was very small although, as pointed out previously, this area was well covered with fragments. Such was not the case above the third deck where medium steel air intakes to the three after firerooms were badly holed and permitted considerable smoke to be drawn into the firerooms. The 60 pound STS cable trunk, B-419-T, containing all vital cables to the after director, was not pierced although located quite close to the explosion. It is, of course, armored throughout its vertical extent.

58. It has long been felt that the fitting of any thickness of STS will pay large dividends in the form of limitation of damage from fragments and splinters. This case will certainly serve to emphasize the correctness of this theory. No vital damage was done although the bomb exploded deep in the vessel in close proximity to installations of major importance to continued efficient operation. Thicknesses as great as 25 or 30 pounds of STS cannot always be fitted, but lesser thicknesses have been shown in other cases to be well worthwhile.

D. Welding

(Photos 6, 20, 21 and 22)

59. The YORKTOWN was a comparatively modern vessel employing quite recent design features in her construction. Extensive use was made of welding, particularly in the fabrication of beams and stiffeners. In general, the performance of welds was satisfactory, although minor defects were noted. For example, Photo 6 shows a cracked butt weld in the face plate of transverse 109 under the flight deck. This was probably due to a poor weld. Since the YORKTOWN was built, the quality of welding has greatly improved through the development of high grade materials, thorough training of welders and close supervision of work. The rupture in the brackets joining transverse 109 to the starboard 25 pound STS bulkhead and to the starboard shell, Photos 21 and 22, is indicative of both poor welding

[1] Buships War Damage Report No. 19 (not yet issued).
[2] Buships War Damage Report No. 14 of 6/1/42.

technique and incorrect design. The locations of the butts in the web and face plate were such as to invite trouble when large bending moments were applied to the joint. Since the YORKTOWN was designed the design of girders and beams for ships has been greatly improved by the Bureau and such weak points at the bracketed connections have been eliminated.

E. Doors and Hatches

(Photos 23, 24, 25 and 27)

60. The single doors and hatches involved performed satisfactorily. This was not the case with the double door in bulkhead 118 on the fourth deck. Photo 23 illustrates what happened although it should be added that the remains of the door were found 40 feet aft of the bulkhead. It is a maxim that installation of doors and hatches should be held to a minimum consistent with adequate access. Further, the size of such openings should be a minimum. The size of the particular door in question was the subject of some debate at the time of design. It was installed to permit the stowage of large objects in C-402-A. The door frame was the particular source of weakness inasmuch as lack of stiffness permitted rotation aft. It will be noted from Photo 23 that two vertical bulkhead stiffeners above the frame actually did act as anti-tilting brackets and did serve to reduce rotation of the overhead portions of the frame. However, it is doubtful if any reasonable number of brackets on the frame would have prevented the door blowing out because of the large opening presented.

61. The performance of the double door should be compared with that of the single doors in bulkhead 112 on the third deck. Photo 24 shows the starboard door. The door was bulged aft about 4 inches but remained watertight as evidenced by test at Pearl Harbor. This door was actually about 20 feet closer to the explosion than the double door below although the latter was in the same compartment with the explosion. Both doors were hinged forward, toward the explosion.

62. The Bureau has given the subject of doors on aircraft carriers much study in recent years. For carriers subsequent to the YORKTOWN class, double doors have been omitted completely. Single doors in transverse bulkheads have been greatly reduced in number. Furthermore, the longitudinal bulkheads, fitted between third and fourth decks on YORKTOWN, have been extended up to the second deck on carriers now under construction or in the design stage. These longitudinal bulkheads have very few single doors inasmuch as such bulkheads are highly important members of the system of watertight subdivision and openings in them are held to an absolute minimum.

F. Deflection of Third Deck and Transverse 109

(Plate IV, photos 14, 17 and 19)

63. Transverse 109 under the third deck, by virtue of its position, received the brunt of the explosion. It is a

built-up welded member 15 inches deep. The design of such structural members ordinarily follows the theory of continuous beams. Inasmuch as the problem of design presents a number of indeterminate features, the deflection of the beam and the manner in which it resisted damage are of some interest.

64. The explosion occurred 4 or 5 feet forward of, and a few feet below, transverse 109. From Plate IV and the photos it will be noted that the contour assumed by the beam (and that portion of the third deck which moved with it) is one of long easy curves. Directly over the explosion the beam and deck were lifted about 5 inches. From this point deflection tapered to zero at the port longitudinal bulkhead and to a depression of about 3/4 inches at the starboard longitudinal bulkhead. Between the longitudinal bulkheads and the shell, on both sides, the beam and deck were depressed a maximum of 2-3/4 inches.

65. In addition to the load imposed by the explosion underneath, it is apparent that the blast wave above the third deck spread to the shell imposing an unbalanced downward load on the third deck outboard of the longitudinal bulkheads below. This resulted in the depression of the deck and beam between the shell and longitudinal bulkheads. The 25 pound STS bulkheads, of course, stopped the blast wave on the fourth deck

66. Considering the destruction of the third deck, with its longitudinal members, just forward of transverse 109 and the damage to the web caused by fragments (photo 17) the performance of the beam and that portion of the deck acting in conjunction with it was eminently satisfactory. With the exception of the bracketed connections to the longitudinal bulkheads, discussed in paragraph 59, design was of high order. The ability of all welded built-up structural members to resist damage was effectively demonstrated.

F. Comments on Equipment

67. The Commanding Officer, in reference (a), furnished some notes and recommendations. Some of these are briefly discussed below:

a. "The new type A Rescue Breather assisted materially in aiding the quick work of the fire parties below deck.

In view of some adverse criticism of the new apparatus this comment was received with interest. The major criticism has been centered on the ease and rapidity with which the breathing bag could be deflated. Bureau of Ships letter S93-(6)(3688) of July 24, 1942, outlined modifications to the relief-valve exhaust to be made by the operating personnel which will remedy the defect. Apparatus now being manufactured will have this modification incorporated. The modification consists essentially of reducing the diameter of the relief-valve exhaust

b. "A 2-1/2 inch air-driven portable pump, the only one on board, was used to assist the electric submersible pumps, and was discovered to be much

more efficient than the latter. It is recommended that 10 of the pumps be added to the allowance list and distributed to the lower deck repair stations."

This pump was assigned to the vessel primarily for the purpose of handling gasoline where sparkless features are required. It is considered that supplying a large number of these pumps for general service about the ship in case of emergency is not warranted because of the susceptibility to damage of compressed air lines and the large amount of compressed air piping which would be required to provide such service. In addition, the quantity of air required to operate one pump (about 87 cu. ft. per minute) precludes the use of a large number of such pumps with existing air compressor capacity.

c. "Anti-flash clothing should be worn during battle by all personnel below decks as well as topside."

The need for this has been recognized and the Bureau intends to supply one suit per man plus 5 percent spares when the material is available.

d. "Rubber boots should be furnished fire parties to prevent electric shocks."

The shortage of rubber prevents supplying these in needed quantities. The Bureau is investigating the use of substitute material of proper characteristics.

e. "Compartment lighting switch panels should be painted a color distinctive from that of the surrounding bulkheads."

There is no established policy governing the color of switch panels. In general, they have been painted to match surroundings. However, the recommendation is worthy of adoption and the work involved is considered to be within the capacity of the ship's force.

G. Effectiveness of Fire-fighting Methods

68. As battle damage data from the forces afloat accumulates, the importance of quickly controlling and extinguishing fires continues to be clearly emphasized. It is, accordingly, gratifying to note the increased efficiency with which such fires are combatted in cases where fire fighting facilities remain available. This example of the YORKTOWN typifies the progress being made in prompt and effective fire-fighting.