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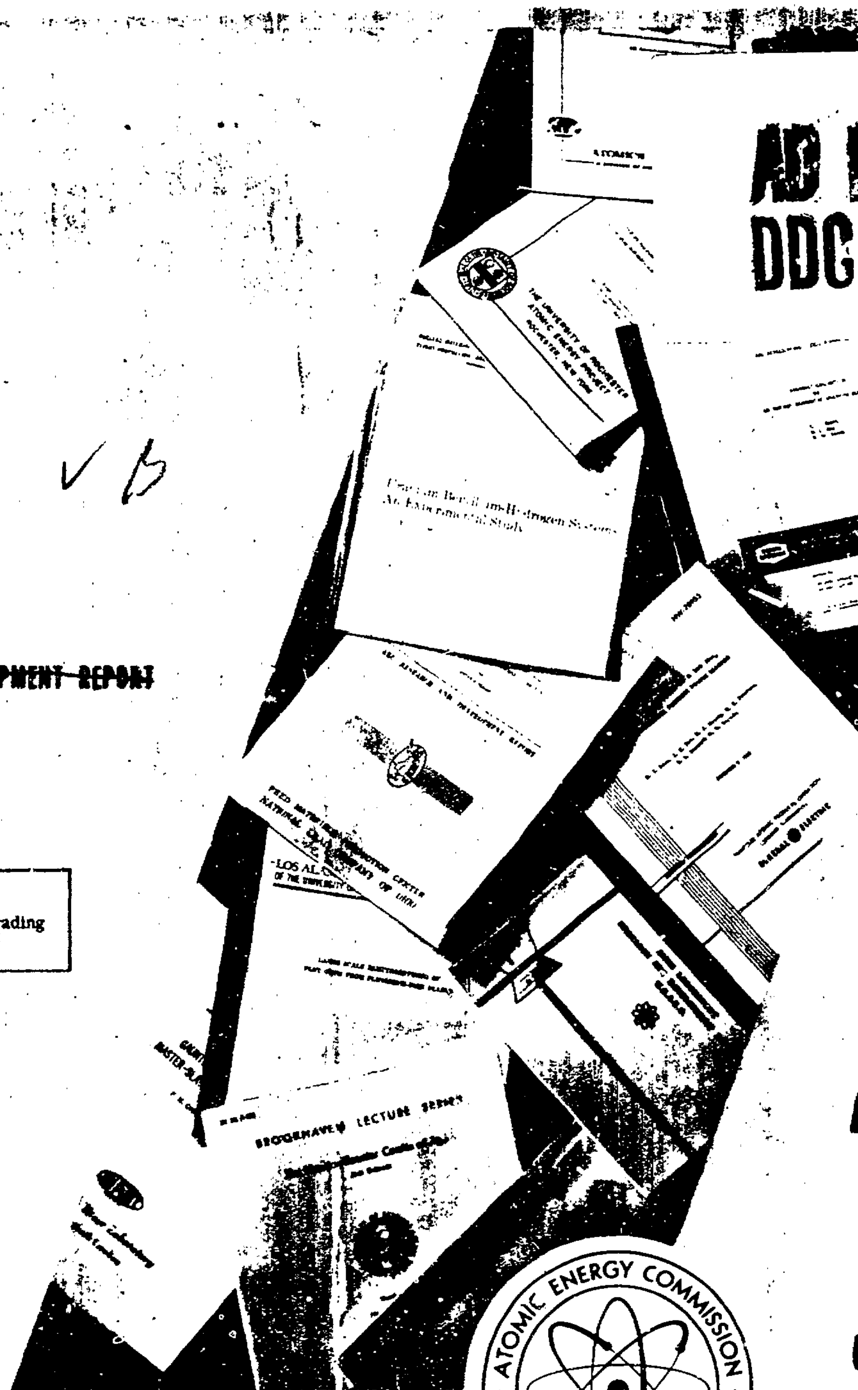

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EFFECT OF AIR BLAST ON SUPERSTRUCTURE

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EFFECT OF AIR BLAST ON SUPERSTRUCTURE [U].

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EFFECT OF AIR BLAST ON SUPERSTRUCTURE

SECTION I - PHYSICAL CHARACTERISTICS OF AIR BLAST

1. The properties of the air blast engendered by the detonation of an atomic bomb from the physicist's point of view are described in detail in other Crossroads reports. For purposes of evaluating the effects of air blast on ship structure, and, more especially, superstructures, a brief description and analysis of the characteristics of air blast from the engineer's point of view is of value.

2. Measurements of air blast during Tests A and B indicate that the air blast caused by the atomic detonation has the same essential characteristics as air blast caused by TNT and similar molecular detonations. The air blast results in Test A show that the atomic detonation was roughly equivalent in its blast effects to 20,000 tons of TNT exploded at the same point at which the bomb burst. The air blast results over the range of distance 500 yards to 1300 yards in Test B agree well with the air blast which would be produced by 4,000 tons of TNT exploded at ground level over smooth ground. The air blast is in the form of a spherical pressure wave. This wave moves outward from the center of detonation very rapidly. The speed of advance of the wave is a function of the peak or maximum pressure in the wave at any point. About 300 yards from the center of detonation, the maximum or peak pressure is about 150 pounds per square inch and the speed of advance of the wave is about three times the speed of sound at atmospheric pressure. At 50 pounds per square inch peak pressure, the speed of the wave is about one and three-quarters times the speed of sound at atmospheric pressure, the speed of advance of the wave is approximately sonic speed.

3. The physical effect of the impingement of the air blast on a ship's superstructure may be conveniently thought of as a static pressure accompanied by a high wind. That is, the pressure wave contains energy in the form of pressure and also in the form of velocity. The pressure head corresponds to the peak pressure of the wave and the velocity head corresponds to the particle velocity or wind velocity in the wave. Consider a gauge station mounted on board one of the target vessels as in Figure 1. The station

consists of two gauges for measuring maximum pressure, one mounted facing the center of detonation and the other situated at right angles to the first. The pressure wave would impinge directly on gauge "A" but would pass by parallel to the face of gauge "B". Gauge "B" would measure only the pressure head or "free field" peak pressure of the air blast, the free field pressure being that existing in the open air with no structure to impinge upon. Gauge "A" would measure not only the free field pressure head but also the velocity head caused by the impingement of the air particles put in motion by the wave. Gauge "A" would thus record a higher pressure than gauge "B".

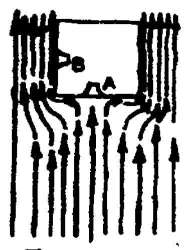

FIGURE 1

The increase in pressure recorded by gauge "A" would be influenced not only by the velocity of the air particles but also by the shape of the gauge and its surrounding structure. Certain shapes and arrangements of structure which allow the air particles to pass over and around them with a minimum of resistance and consequent minimum decrease in velocity would absorb a minimum amount of energy from the velocity head. Other shapes or arrangements of structure, acting as "blast traps", may prevent the diffraction of the air particles around them and hence absorb a maximum amount of energy from the velocity of the air particles. The design of superstructures to resist damage by air blast thus resolves itself into two principal problems; first, the introduction of adequate scantlings to resist the "free field" pressure head, and second, the shaping of the structure so as to provide a minimum interference with the velocity head of the air particles.

4. The air particle velocity or wind velocity in the wave is a function of the peak pressure and the speed of advance of the wave. The air blast in Test A had the following characteristics based on distance from the burst:

TABLE I

Horizontal radius in yards.	Peak pressure in pound per square inch.	Wind velocity in statute miles per hour.	Duration of positive pressure in seconds.
0	2000		
360	100	1350	0.42
500	53	950	0.46
600	34	700	
750	21	500	0.59
1000	11.0	300	0.75
1200	7.8	240	
1400	5.5	175	—
1600	4.5	145	—
2000	3.0	95	1.0

The air blast in Test B was very much less, being roughly 20 pounds per square inch about 500 yards from the center and decreasing to about 5 pounds per square inch at 1000 yards.

5. The forces of air blast are loaded on the superstructure in a very short interval and the loading is therefore an impact loading. Figure 2 indicates the shape of the air blast wave on a pressure-time basis. Po is the maximum or peak pressure. To is the duration of the positive pressure phase. The figure illustrates the values for the pressure wave at a point 360 yards out from the center of detonation. It will be noted that the peak pressure is reached almost instantaneously. The length of application of the load, To, varies from about 0.5 second to one second, according to Table I.

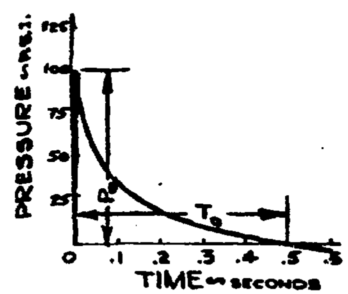

FIGURE 2

This time interval is generally in excess of the natural period of vibration of all ship structures except, possibly, the ship as a whole. Hence, the dynamic load factor by which the peak pressures given in Table 2 must be multiplied to obtain the equivalent static pressure head is approximately 2. In other words, the scantlings of a structure 750 yards from the burst must be designed to resist a static load of 42 pounds per square inch to resist the dynamic impact of the peak pressure of the atomic air burst.

6. An additional characteristic of air blast which stems from the compressibility of air is the nature of the accelerations imparted to the structure. Because of the great compressibility of air, air blast waves have small peak pressures compared to the peak pressures of underwater shock waves initiated by comparable detonations. The initial acceleration of the structure varies as the product of the peak pressure and the area of the structure divided by the mass of the structure. Initial accelerations due to air blast are thus small compared to those experienced with underwater shock. However, the compressibility of air allows it to follow the structure as it begins to react and thus the curve of accelerations falls off very slowly. The actual slope of the decaying acceleration curve is largely dependent on the shape of the structure and how much of the velocity head of the air blast wave is absorbed. Air blast thus tends to impart moderate accelerations sustained over a considerable interval of time in contrast to the high acceleration over a short interval imposed by underwater shock. This results in many characteristic failures under air blast. Masts and stanchions tend to bend rather than shear off. Bulkheads and bulwarks tend to deflect and dish rather than tear away at connections. Joint failures tend to be progressive failures from a point of initiation rather than a bodily rupture. Specific examples of these tendencies may be found in Section II.

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SECTION II - EFFECTS ON SUPERSTRUCTURE

1. Masts and Spars. A detailed study of the behavior of masts and spars is the subject of a separate report. It appears that serious damage to masts and spars extended out to 900 yards on heavy ships and to 1100 yards on light vessels. Sporadic minor deflections occur in ships further removed. In Test A, four vessels were located about 600 yards (horizontal distance) from the burst. These were INDEPENDENCE (CVL22), NEVADA (BB36), ARKANSAS (BB33) and CRITTENDEN (APA77). The peak pressure experienced at this range was about 34 pounds per square inch and the wind velocity in the wave was momentarily about 700 miles per hour. INDEPENDENCE (CVL22) took the air blast over the port quarter. The cage-type mast structure supporting fire control equipment and radar is completely missing from the upper level of the island as shown in Photo 2040-6, page 27. Photo 196-151-23, page 28 shows the mast structure before test. NEVADA (BB36) also received the blast from the port quarter. The effect on topmasts is shown in Photo 1832-9, page 29. The masts and radar antennae all failed at discontinuities. A close-up view of the main topmast, Photo 1897-10, page 30, indicates that the mast bent considerably before parting from the platform. On ARKANSAS (BB33), which received the air blast on the starboard quarter, a similar condition resulted (Photo 1774-11, page 31). The main topmast has been torn from its connection to the director platform (Photo 1775-12, page32). On the foremast, however, the radar pole mast is still connected to the radar platform although it is bent nearly double (Photo 2097-3, page 33). Signal yardarms are all bent forward. CRITTENDEN (APA77) was bow-on to the blast. Photo 227-49-116, page 34 indicates the effect of the air blast upon the pole masts. These are bent drastically aft but have not fractured. All three masts bent sharply at discontinuities or supports. (Photos 1921-10, 1922-8, and 1906-9; pages 35, 36 and 37).

2. PENSACOLA (CA24) was located about 750 yards from the detonation axis so that the air blast arrived over the stern and slightly on the starboard side. The peak pressure at this distance was

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about 21 pounds per square inch and the wind velocity in the wave was approximately 500 miles per hour. Photo 1860-3, page 38 shows the radar masts. The foremast, which is the more seriously damaged, shows the typical bending type of failure which results from air blast but the degree of bending is much less than on the vessels closer in. Note that the point of maximum bending occurs close to the uppermost support which constitutes a discontinuity in strength. Heavy masts, as represented by the main mast, show a more even deflection at this range. At 850 yards, the masts on DAWSON (APA79) show the same characteristics of a general deflection consistant with the decrease in peak pressure and wind velocity and the increase in length of application of the load (Photo 1773-3, page 39). Note that the radar array on the main mast shows that sharp deflections are still impressed on light structures. The peak pressure at 850 yards is about 16 pounds per square inch and the wind velocity is about 400 miles per hour. Photo 2104-10, page 40 shows the distortion of the stub mast on the forward stack of DAWSON and should be compared with the damage to identical structure on CRITTENDEN (Photo 1922-8, page 36). SALT LAKE CITY (CA25) and HUGHES (DD410) were located 900 yards from the burst and received the air blast over the stern and somewhat on the port side. Photos 227-91-47, 1869-5 and 1868-8; pages 41, 42, and 43 and illustrate the damage to SALT LAKE CITY. Photo 227-91-47, page 41 should be compared with Photo 1860-3, page 38 for damage to sister ship PENSACOLA. Blast conditions at SALT LAKE CITY were 14 pounds per square inch peak pressure and a wind velocity of about 365 miles per hour, about 2/3 as great as the forces attacking PENSACOLA. Photo 2198-4, page 44 shows the distortion in the foremast of HUGHES. The distortion is gradual and moderate.

3. Beyond the 900 yard range from the blast center damage to pole masts and spars is not serious. There is no apparent damage to the masts on BRULE (APA66), at 950 yards. RHIND (DD404), located about 1000 yards from the burst suffered a failure of the radar on the foremast (Photo 1771-10, page 45) but the masts themselves are essentially undamaged (Photo 2003-4, page 46). At 1100 yards, the foremast on RALPH TALBOT (DD390) is bent to port (Photo 227-50-41, page 47) but damage to masts beyond 1000 yards

is sporadic and is not easy to analyze. In general, the masts on the target ships appear to withstand satisfactorily peak pressure less than 15 pounds per square inch and wind velocities less than 350 miles per hour.

4. Mast equipment. The equipment mounted on the masts, especially radar and similar electronic devices, proved vulnerable at ranges beyond that at which structural damage to the mast itself disappeared (See Photo 2003-4, page 46 for an example). In general, serious damage (practically all radar and communication antennae lost) extended out to about 950 yards horizontal distance from the burst. Peak pressure at this range is about 13 pounds per square inch and the wind velocity is about 330 miles per hour. Moderate damage (roughly half of the radar and communication antennae inoperable) extended to about 1200 yards range (8 pounds per square inch pressure, 240 miles per hour wind velocity). Light damage extended to about 1600 yards. The peak pressure at this range is roughly 5 pounds per square inch and the wind velocity is nearly 150 miles per hour.

5. Tower structures. On the larger combatant vessels (battleships and cruisers), the major superstructure masses are in the form of towers, usually supported by tripod mast structures. The free field or peak pressure, operating over the tower as a whole, imparts a downward load on the tripod legs which is transmitted to the hull. The effects of the wind or velocity head in the air blast wave attack the tower from the approximate direction of the actual burst. The exact direction of this attack is not usually directly from the burst because of deflection of the wind by other targets, the water surface and, often, by other portions of the same target. The angularity of the air blast above the horizontal in Test A was quite small on surviving vessels having tower structures, being about 15 1/2 degrees above horizontal at 600 yards, 12 1/2 degrees above horizontal at 750 yards and about 9 1/2 degrees above horizontal at 1000 yards. Thus the forces imposed upon the tower structures by the velocity head of the air blast were largely horizontal, acting against the tower as a cantilever beam and tending to tilt the axis of the tower away from the blast center.

This action placed an additional compressive load on the tripod legs on the far side of the tower and tended to lift the leg or legs on the near side. Damage of this type was most evident on ARKANSAS (BB33) and NEVADA (BB36) which were the only vessels within 600 yards of the burst having tower structures. Damage on ARKANSAS was more severe than on NEVADA because the blast was received from broad on the starboard quarter, putting both the port and forward tripod legs of the main mast in compression and leaving only the starboard leg to resist the tilting action of the blast. NEVADA received the blast from more nearly over the stern and the port and starboard legs of the foremast both acted to inhibit tilting. The mainmast tower structure on NEVADA is small and, having much less sail area than the mainmast structure on ARKANSAS, was undamaged. Photos 2097-7 and 2146-5, pages 48 and 49 show the starboard mainmast tripod leg of ARKANSAS pulled away from the main and second decks respectively. The port and forward legs were crushed by the compressive load about five feet above the main deck (Photos 2111-7 and 2134-7, pages 50 and 51). In addition, a main longitudinal bulkhead between the enginerooms, on which the foot of the forward leg rests, was buckled by the load. The foremast tripod on ARKANSAS was undamaged and did not move. This was largely because of the relatively small sail area on the tripod proper and the large area of base of the forward superstructure. The foremast structure on NEVADA showed very slight evidences of movement. The effect of tension in the port and starboard foremast tripod legs is shown in Photos 2154-3 and 2137-12, pages 52 and 53 . In addition to the foremast and mainmast tripods, NEVADA has two 40mm director positions on tripods outboard of the stack, as shown in Photo 1910-11, page 54 . These tripods were tilted considerably despite the small sail area of the director tubs. Photo 2137-8, page 55 illustrates the upward movement of the after leg of the starboard director tripod. Photo 2137-10, page 56 shows the result of compressive loading on the forward leg of the same tripod. This is typical of the port tripod also. The wind velocity in the wave against ARKANSAS and NEVADA was approximately 700 miles per hour. PENSACOLA, located 750 yards from the burst (wind velocity 530 miles per hour), suffered damage to both mainmast and foremast. The after tripod legs of the foremast did

not show any tendency to pull from their deck connections but compressive loading on the fore leg resulted in the buckling of transverse bulkhead 43 which supports the foot of the forward leg (Photo 1762-2, page 57). The main mast is not a true tripod but rather is a pole mast with two strut supports angled aft, port and starboard. The main mast was moved forward by the blast, pulling the struts from the deck. Photos 2161-5, 1757-6, 2161-6 and 1757-7, pages 58, 59, 60, and 61 show the failures at the base of the struts. Sister ship SALT LAKE CITY (CA25), located about 900 yards from the blast, showed no indication of distortion or lifting of the tripod (Photo 1861-5, page 62). The structure supporting the fore leg was moderately distorted by excessive compressive loads. Tripods and towers on vessels further removed were unaffected.

6. Superstructure plating. The behavior of superstructure bulkhead plating under air blast loadings is dependent upon numerous factors. In general, the peak pressure component of the air blast wave acted indiscriminately over the entire structure. The thickness of plating, span between bulkhead supports and method of stiffening were the principal factors influencing the amount of deflection in the bulkhead. Access openings in the bulkheads were definite points of weakness. The effect of the velocity head upon the superstructure was extremely variable and appeared to be principally affected by the angle of attack upon the bulkhead, the physical dimensions of the bulkhead, the influence of other structures (including overhangs, armored structures, passages, etc.) and the shape of the bulkhead. The velocity head of the blast appeared to be easily deflected from strong structures to weaker structures and thus exhibited a pronounced "searching effect" which tended to concentrate loads on weaker elements. There were numerous cases of failures at marked strength discontinuities. By excluding as many of the variables as possible, it is possible to estimate roughly the performance of various plating thicknesses under the range of pressures and velocities encountered in Test A. In general, the critical plating weight (thickness at which deflection became apparent) for a flat superstructure bulkhead, typically stiffened and exposed in the open, normal to the blast, with little, if any, influence from surrounding structure, was between ten and fifteen pounds per square foot from 500 yards to 850 yards. That is, bulkheads having

plating heavier than this range of weights were generally undistorted while plating of lighter scantlings showed deflections of measurable amounts depending on the thickness of plating and distance from the blast center. The peak pressures encountered between 500 and 850 yards varied between 53 pounds per square inch and 16 pounds per square inch and wind velocities varied between 950 miles per hour and 400 miles per hour. Between the ranges 850 yards to 1250 yards, the critical plating weight, subject to the same conditions, appeared to lie between five and ten pounds per square foot. All plating of five pounds and over appeared to be relatively undamaged from 1250 yards to 1600 yards and beyond 1600 yards, only sheet metal and aluminum plating appeared to have suffered damage.

7. Effect of overhangs. Overhanging structure had, in almost all cases, a very deleterious effect upon the bulkheads below. The overhangs acted to trap the velocity component of the air blast wave which resulted in intensification of the forces on the boundaries of the "pocket". The overhangs were generally lifted upward and, where the bulkhead below was not parallel or nearly parallel to the blast, damage to the bulkhead was invariably greater than that to a similar bulkhead in the open. A very good example of the influence of overhangs occurred on ARKANSAS (BB33). Photo 2134-9, page 63 was taken from a point in line with the origin of the blast wave. Note that the blast has entered under the overhanging gun tub and has severely damaged the longitudinal bulkhead beyond. Photo 2090-3, page 64 illustrates the damage [illegible] clearly. The maximum damage to the bulkhead is displaced forward relative to the overhang because of the quartering direction of the blast. The intensification of damage caused by the existence of the overhang is evidenced by the condition of the neighboring bulkhead in a more exposed location, as shown in Photo 2097-12, page 65 . Note also the damage to the overhang proper. This is a typical result. Several excellent examples of damage intensification under overhanging platforms occurred on STACK (DD406). These examples are shown in Photos 2006-8, 1850-8, 2006-9 and 2006-11; pages 66, 67, 68, and 69 . There are also numerous examples of damage to overhangs proper. Photo 2095-9, page 70 shows the rangefinder platform on the rear of the foremast structure of ARKANSAS (BB33). This platform was lifted upward and warped by the pocketing of air blast below.

Note also that the house below is badly distorted. Photo 2135-3, page 71 shows a typical failure of the cantilever supports for the rangefinder platform where connected to the foremast tripod le[illegible]. An example of damage to overhanging platforms where the di[illegible]tion of blast was nearly parallel to the bulkhead is shown in Photo [illegible]742-7, page 72 . The damage occurred on NEVADA (BB36). The camera angle is very nearly the direction of blast at this point. The open bridge overhang has been blown upward, tearing the cantilever beams from the bulkhead. In addition, the bulwark below is blown outward and the door in the bulkhead (a weak point) is dished inward.

8. Effect of heavy structure. In many instances, heavy items in the superstructure or allied with it tended to channel the blast onto weaker elements, resulting in increased damage to the relatively weak structure. An excellent illustration of this action occurred on ARKANSAS (BB33). Photo 2091-5, page 73 shows the deck house located just forward of turret 3. The direction of the air blast wave was from the starboard quarter and, neglecting the influence of turret 3, the starboard and after sides of the house were equally exposed to the blast. Note that the starboard side is relatively undamaged. Photo 2095-11, page 74 shows the rear of the house which received the full force of the velocity head diverted by turret 3. Photo 2097-3, page 33 shows the relation of the house and turret 3 from another angle. Another striking example of the channeling or focusing effect of heavy superstructure items occurred on BARROW (APA61) and other APA's similarly situated. The damage occurred on the signal level, the uppermost superstructure level. At the forward end of the signal level, a heavy-scantling shoulder-high bulwark or shield surrounds the fire control station on the centerline. About ten feet aft of the station is the forward stack. The direction of the blast center was forward of the port beam. The wind generated within the pressure wave was channeled into the opening between the fire control station and the forward stack and operated on the starboard flagbag which was directly in line with the opening. The flagbag was demolished, torn from its supports and deposited in the lee of the stack (Photo 1740-6, page 75). The port flagbag, although located in the open closer to the blast center, was only slightly dished.

9. Effect of open passageways. Passageways between deck houses or open ended passages through deck houses also acted to trap the velocity component of the air blast wave with a resultant intensification of damage to the boundaries of the passage. Where passageways were open only at one end, thus forming a U-shaped trap, the principal damage generally occurred at the closed end of the passage. In passageways open at both ends, the bulkheads bounding the sides of the passage suffered severely. Photographs illustrating typical damage concentrations in passageways are Photos 1757-9, 1755-1, 2161-10, 2103-2, 1815-6 and 1848-12; pages 76, 77, 78, 79, 80, and 81. In all these cases, the damage shown was a radical increase over that sustained by structure in the open.

10. Shaped surfaces. The critical plating weights quoted in paragraph 2-6 have to do with flat plates, typically stiffened, when exposed normal to the blast. The reduction in degree of damage with angularity of the blast direction was marked. A sharp decrease in damage was apparent when the bulkhead was more than thirty degrees off the normal. The use of shaped surfaces rather than flat surfaces also resulted in a considerable decrease in damage. The principal shape encountered on the target ships was the cylindrical surface, as typified by masts, gun tubs and lookout shields. These items all manifested superior resistance to distortion or deflection by the air blast wave because they provided less resistance to the movement of the air particles in the air blast wave than did flat surfaces in corresponding locations and because the cylindrical shape is more efficient in resisting the effects of the pressure head. It is estimated that the critical plating weight for cylindrical surfaces was from two to five pounds less than for flat surfaces normal to the air blast under similar conditions of location and range from the blast center. Photo 1966-9, page 82 is view looking forward at the after side of the foremast on PENSACOLA (CA24). Note the forward deflection of the flat portion of the large shield just below the main director station. Since the blast center was located on the starboard quarter, this flat section was situated at an approximate angle of 45 degrees to the blast wave. The cylindrical shields are undamaged although elements of them were normal to the blast.

Photo 1755-10, page 83 , also of the PENSACOLA, shows a similar shield on the after superstructure which exhibits the same increase in damage in the flat portion of the shield. Photo 1894-3, page 84 taken on SALT LAKE CITY (CA25), shows the flat portion of a gun shield deflected inboard. The cylindrical portions are intact. Photo 1719-5, page 85 illustrates the condition of the after tower on the same vessel with flat portions of various shields either missing or severely deflected. Photo 2094-2, page 86 shows damage to the flat portion of the starboard shield on the fire control level of the foremast of ARKANSAS (BB33). Note that the cylindrical portion in the view is intact. Another example of similar damage to the ARKANSAS is shown in Photo 1775-12, page 32.

11. Performance of various materials. In general, there was no appreciable difference in the overall performance of medium steel, high tensile steel and special treatment steel. HTS and STS showed somewhat greater resistance to deflection than MS but this superiority was offset by a higher incidence of weld failures at connections. Aluminum and brass elements in superstructures showed poor resistance to deflection and a higher rate of failure at connections which were primarily riveted. Brass bulkheads tended to shear bodily at connections to stronger steel structures. Sheet metal items in the superstructure were extremely fragile and took permanent deflections at extreme ranges where peak pressures were of the order of one pound per square inch and wind velocities were less than 60 miles per hour. Light-gauge stainless steel structures, such as destroyer uptakes, were only slightly better than sheet metal in performance under attack by air blast.

12. Superstructure decks. Superstructure decks suffered considerable less damage than superstructure bulkheads. This was, in part, due to the predominately horizontal attack of the velocity head of the air blast wave. Deck scantlings are also somewhat heavier than bulkhead scantlings because of the higher loadings which decks must support under ordinary operating conditions. Decks usually have better support from bulkheads and stanchions below than have bulkheads. Deck access openings are fewer and stronger, generally. The principal cause of deck damage was the pressure head of the

air blast wave except in the case where superstructure decks were overhanging. Photos 1754-4, 2037-12 and 2094-12; pages 87, 88, and 89 show typical distortion and failure in overhanging decks where velocity head of the air blast wave also acted. The velocity head also was active against decks under low overhangs (Photo 1910-5, page 90) and in narrow "blast traps", especially if discontinuities such as access openings, etc., existed (Photo 1758-7, page 91). Damage to ordinary superstructure decks which did not overhang open spaces below or were not located in blast "traps" generally consisted of either general depression of the entire panel or a wave deformation between supports (Photos 2094-2, 1910-8 and 1737-12; pages 86, 92, and 93).

13. Access openings. Doors opening to the weather in the superstructure proved to be a serious weak point in the weather bulkheads. Where bulkheads were deflected by blast, the maximum deflection consistently occurred at a door, if one was present in the bulkhead (Photos 2006-9 and 1760-5; pages 68 and 98. Beyond 1200 yards from the blast center (peak pressure, 7.8 pounds per square inch and wind velocity 240 miles per hour) numerous examples were found of considerable deflection in doors and door frames while adjacent bulkheads were relatively undamaged (Photos 1755-1, 1737-12 and 2094-12; pages 77, 93 and 89. Several cases occurred in which doors and door frames on the protected or lee side of the vessel were dished although bulkheads on the exposed side of the vessel were intact. Oversized or double doors displayed an especial weakness under relatively light loadings. Photo 1824-2, page 97 shows the double doors to the carpenter shop on the BARROW (APA61), situated at 1350 yards (peak pressure 6 pounds per square inch, wind velocity 185 miles per hour). The blast center was on the port bow. Photo 1740-5, page 95 shows the damage incurred by ordinary watertight doors on BARROW which were more nearly normal to the blast. Photo 1738-9, page 96 shows the same doors on BUTTE (APA68). The blast angle was approximately the same but the range was 2100 yards. The peak pressure was only 3 pounds per square inch and the wind velocity was about 100 miles per hour. These doors absorbed considerable energy from the velocity head because of their location in a partially enclosed position. which acted as a "blast trap".

The foregoing examples indicate that doors and door frames constitute a serious weak point in superstructure weather peripheries. An analysis of the manner of failure of a large number of cases indicates that the principal source of weakness is the lack of rigidity in the door frame. The knife edge of the door frame forms a stiffening element. The nearest bulkhead stiffener to the door frame, which is generally from three to nine inches away, forms a line of strength in the bulkhead and the knife edge and the plating between the knife edge and the bulkhead stiffener tend to rotate around the bulkhead stiffener as a loading is applied to the panel containing the door. The panel takes the shape shown by dotted lines in Figure 3, permitting the door to slip past the knife edge. This action results in permanent distortion to the door and damage to hinges and dogs. A typical example of the above action is shown in Photo 1740-5, page 95. Another illustration can be seen in Photo 1824-2, page 97. Photo 1738-9, page 96 shows a damaged door in opened position and, as would be expected, the curvature of the door indicates that the long (vertical) knife edges have permitted the greatest deflection. In the case of the double door shown in Photo 1824-2, page 97, the length of the lower knife edge has resulted in the opposite effect. Hatches in the superstructure were relatively unaffected by air blast except when left in the open position. The small amount of damage to superstructure hatches is in part a result of the nearly horizontal character of the velocity component of the air blast wave. However, hatch construction is generally superior to door construction in that the hatch is more intimately connected to the deck by means of hatch girders and hatch end beams which are tied into the stiffening elements of the deck. In addition, many hatches are supported against deflection by bulkheads, trunks or stanchions below.

FIGURE 3

14. Ladders and railings. Access fittings, such as ladders, handrails, life lines, etc., suffered serious damage inside the 1000 yard range and moderate damage out to 1400 yards. Ladders containing aluminum treads were especially weak. Photos 1968-5 and 1967-8; pages 99 and 101 show damage to two such ladders on PENSACOLA (CA24) at 750 yards from the blast center. Ladders also were generally unusable where connected to overhangs which were damaged. Handrails were among the more rugged of the superstructure fittings because of their cylindrical shape and relatively small sail area. However, handrails were twisted and bent in exposed location inside 1000 yards of the blast center. Photo 2154-11, page 100 shows a typical damage on NEVADA (BB36).

15. Deck lockers and stowages. Deck lockers, flagbags and other light deck stowages fabricated of sheet metal, brass, aluminum and expanded metal proved utterly inadequate. Not only were such stowages damaged to such an extent that their utility was sharply reduced, but they were often torn from their moorings, blocking passageways and presenting hazards to personnel in the form of missiles. Some illustrations of typical damage are shown in Photos 2095-7-5, 2047-9, 1733-10, 1827-2 and 1828-6; pages 102, 103, 104, 105, 106, and 107. Photos 2095-7 and 2095-5; page 102 and 103 show damage to lockers on ARKANSAS (BB33) which was 600 yards from the blast center. Photo 2047-9, page 104 shows the deflection of the flagbag on NEW YORK (BB34) which was 1450 yards away. Damage to the flagbag on CARTERET (APA70) is shown in Photo 1733-10, page 105. CARTERET was located about 1550 yards from the blast center. Deflections to sheet metal flagbags extended out to the outer circle of the target array. Photos 1827-2 and 1828-6; pages 106 and 107 show damage to sheet metal and expanded metal structures on BRULE (APA66) which was located about 950 yards from the blast center.

16. Interior structure. Interior structure and equipment was generally damaged only by the movement and distortion of the weather surfaces. Such damage needs no special discussion. Blast damage was not apparent within closed compartments. Instruments and gauges to measure pressure intensities were installed in many target ships.

Records made on these instruments indicate that, on the whole, air blast did not penetrate closed compartments. An exception was BRULE (APA66), on which all weather doors were purposely left open. Damage to metal joiner work and furniture around these access openings was severe, as shown in Photo 1827-5, page 108. This damage disappeared rapidly with increased distance from the open access and except for long narrow passageways was confined to the immediate area around the access.

17. Personnel positions. Animals were placed on board a series of target ships to obtain data on air blast damage to personnel. All such animals on SALT LAKE CITY (CA25) which was 900 yards from the blast center was killed. The point usually referred to in calculating air blast casualties is the distance at which fifty percent of the animals were killed, known as the LD 50 point. This occurred on FALLON (APA81) which was 1300 yards from the blast center. The data just stated indicates that all topside personnel positions must be fully enclosed for blast protection on vessels designed to operate within 1000 yards of the blast center.

SECTION III - CONCLUSIONS AND RECOMMENDATIONS

1. Many conclusions can be generalized from the study of the effects of air blast on superstructure presented in Section II. They are developed in the following paragraphs along with general recommendations for ameliorating the unsatisfactory conditions encountered. All recommendations are to be treated merely as suggestions as to profitable avenues for design studies and research and not as specific solutions to the problems. It is expected that design agencies will develop further and, possibly, more feasible solutions.

2. Masts and spars. Pole masts appear to be unsuitable for vessels designed to resist the air blast of Test A within 1000 yards of the blast center. They should be dispensed with. Properly designed tower structures, similar to those on modern battleships, appear to be most suitable. Tripod masts on target vessels were not footed on adequate foundations to resist the compressive loads received and are not designed to resist the horizontal loading of the velocity head of the wave. It is recommended that where tripods are used, the legs be extended to the lower level of the ship. Every effort should be made to reduce the height and sail area of mast and tower structures. As a first measure in new designs, only action stations should be located in the mast structure. Spars have poor resistance to air blast. The use of spars should be reduced to a minimum.

3. Mast equipment. Mast equipment is extremely fragile, especially radar and other electronics gear. It does not appear feasible to design these items to survive air blast within 1000 yards and remain operable. Consequently, all fragile mast equipment should be eliminated insofar as possible. For equipment which is absolutely necessary, a possible solution is to mount a permanent set on the foremast and carry a duplicate emergency set on a telescopic mainmast which could be housed under adequate blast protection at all times. The emergency set would be raised to operating position only upon loss of the foremast facilities.

4. Superstructure plating. The results of Test A as described in Section II paragraph 6 indicate that exposed superstructure plating should be at least 15 pounds per square foot weight if the ship is to resist air blast within about 850 yards of the blast center. The overall dimensions and height of the superstructure would have to be radically reduced on all but the largest combatant vessels to accomplish this. However, other considerations (see paragraph 2 and 3 of this section) also indicate the desirability of such measures.

5. Overhangs. Overhanging structure is not only liable to severe damage in itself but acts to increase damage to structure below by acting to trap the velocity head of the air blast wave. Energetic efforts should be made to totally eliminate overhanging structures in the superstructure.

6. Heavy structure. The velocity component of the air blast wave appears to be easily deflected by heavy structures so as to increase damage to adjacent light structure. Efforts should be made to avoid sharp discontinuities in structural weights in the superstructure. Where this is not possible (and there will be many such instances) care should be taken in placing structure so as to avoid locating light but important structures in the path of such deflected air streams.

7. Open passageways. Passageways in the superstructure which are open to the weather act as very efficient blast traps, resulting in severe damage to passage boundaries. Such passageways should be enclosed or eliminated by substituting cross-deck passage through hatches and passages below the weather deck.

8. Shaped surfaces. Faired shapes, especially cylindrical surfaces, substantially reduce the damage sustained from the velocity component of the air blast wave. In addition, many of these shapes are more efficient in resisting the pressure component of the wave than are flat surfaces. Flat surfaces and sharp angles should be avoided. Fillets should be provided where decks meet bulkheads and deck edges should be rounded. The entire superstructure should be faired into a continuous surface wherever possible.

9. Materials. Aluminum and brass bulkheads have poor resistance to damage by air blast and should be avoided. There appears to be no concrete evidence of superiority of any of the various steels and their use should be governed by other considerations.

10. Decks. The comments on plating in paragraph 4 of this section apply. Care should be taken to avoid blast traps under turret overhangs, etc., and to avoid sharp discontinuities in strength of the deck panels.

11. Access openings. Weather doors are a major source of weakness in the superstructure. The most beneficial remedy is to eliminate as many weather doors as possible. Probably fifty percent of the superstructure doors opening to the weather could be eliminated in present design without reducing the fighting efficiency of the ship or seriously reducing the habitability and general operability. Hatches in the overhead can be substituted in many cases for emergency access. Doors which are considered necessary should be redesigned, locating bulkhead stiffening elements at the knife edges and extending these stiffeners to deck and overhead where they should be bracketed to deck stiffening elements (Figure 4). Stiffening elements might also be installed in line with the upper and lower knife edges similar to hatch end beams on hatches. This would be especially effective on double doors. It is not considered that remedial action is necessary on hatches. The provision of adequate support in the form of hatch end stanchions would improve the resistance of hatches whose locations are particularly exposed.

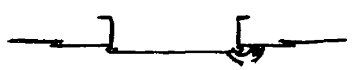


FIGURE 4

12. Ladders and railings. Ladders appear to be highly vulnerable to damage within 1000 yards. In addition, other aspects of the atomic bomb render exposed access and passage hazardous, hence new designs should be provided with ample vertical access entirely

within the superstructure. No radical redesign of hand railings, lifelines, etc., appears to be necessary.

13. Deck lockers and stowages. Light sheet metal structures are vulnerable to air blast damage at extreme ranges. Such structures should be eliminated completely and the necessary facilities built into the superstructure so as to protect the stowage and reduce the possibility that necessary ship functions might be impeded by mangled and displaced lockers and stowages.

14. Personnel positions. All exposed topside personnel will be incapacitated within about 1000 yards of the blast center. Serious personnel casualties will extend to much greater ranges. All topside personnel positions must be fully enclosed for protection against air blast. This points to the elimination of open bridges, gun tubs, lookout tubs, etc. Transparent hemispherical domes may be feasible for many of these positions.

15. A brief summary of the opinions and recommendations voiced by the Commanding Officers of the target vessels involved will be of value as an expression from the forces afloat. The following excerpts are taken from the Commanding Officer's Report following Test A for each major vessel, listed in order of distance from the blast center; CO, INDEPENDENCE (CVL22): "The pressure - - - generally affected flat areas facing to port and all overhangs on the port side. The port side of the hangar deck blew in and the deck above went up. Dogged doors and doors generally blew in before the surrounding walls. The two elevators apparently went straight up as there are no marks on the ship from them. The pipe-frame structure above the bridge with its searchlights, radars, yardarm and masthead must have offered much resistance to the blast. It is gone completely. If it had been strong enough to take the blast it would have been too heavy for the ship. It is recommended that this part of the CVL construction be kept about the same so that it will break off cleanly and so not take the bridge with it." CO, CRITTENDEN (APA77): "It was noted generally that frames around doors, hatches and the athwartship bulkheads, the topmasts, and the stacks, all of which suffered the most damages would require reinforcing, if it is desired to withstand the effects of the blast. Wherever a fore and aft frame

or support was used the bulkhead forward of that support seemed to withstand the pressure or shock - - - -. Exposed fittings were generally unsatisfactory of or weak construction. - - - - - - - - The desire to keep down topside weight is recognized but the atomic bomb will mean that more thought and care will be put into stronger and more durable metals." CO, ARKANSAS (BB33): "Several design changes are obviously desirable but may be discounted due to the age and material condition of the ship. However, it would seem that in the future the superstructure must be more streamlined, with vertical flat surfaces and overhangs eliminated; all topside personnel must be protected in some manner; the smoke stack must be much stronger and a method provided to prevent the blast's entering the firerooms via the stack; there should be fewer topside ventilation openings; radar and radio antennae must be improved in design to resist blast; protection must be provided for fire control devices; and provisions for automatic tending or remote control of boilers. The number of persons manning guns and control stations in exposed stations has to be reduced to an absolute minimum. In our service, much could be done along these lines almost immediately, but it now appears that atomic age design should be characterized by automatic and remote control of functions formerly performed by exposed personnel to a degree never before considered desirable or even practicable." CO, NEVADA (BB36): "Improvements in superstructure design, more protection for exposed personnel (shields or housing made of aluminum alloys, etc.) and housed or quickly replaceable radar antennae are items on battleships requiring study and improvements. Pockets where large vertical and horizontal surfaces intersect at right angles concentrate the force. An attempt should be made to streamline superstructure areas and eliminate such spaces." CO, PENSACOLA (CA24): "Existing ships must be redesigned to provide for spherical streamlined surfaces without projections of any sort. Vital areas such as control stations must be armored. Radar and radio antennae must be retractable or permanently installed in a protective housing. All vertical surfaces must be eliminated. Auxiliary masts similar to conning towers on submarines should be provided and it is strongly recommended that ships presently in commision be fitted with such devices now. In general, super-

structure construction must be uniform in strength as the blast tends to seek out weak points. Sharply defined shapes bore the brunt of the blast. Structures such as the masts, stacks, gun shields, crane davits and ladders were wholly or partially destroyed. If the air had a smooth armored surface to flow over, chances of damage would have been less." CO, DAWSON (APA79): "Bulkhead door frames should be strengthened also the area around bulkhead doors, so that should door fail, replacement will be simplified. Mast extension supporting radio antenna, radar, and other gear should be sufficiently substantial and braced to survive a shock such as experienced in test." CO, SALT LAKE CITY (CA25): "The superstructure needs to be streamlined and must prevent trapping of blast forces." CO, HUGHES (DD410): "Watertight doors must be of greater strength and door frames should be welded rather than riveted and supported by strength members as close to knife edge as possible. At least three hinges would add some strength. Door frames that had been strengthened by webs every six inches or so held up well and the doors were only dished slightly." CO, BRULE (APA66): "Antenna and signal halyards should have quick replacement features. Stacks should either be reinforced or made lighter, with a view to their sacrifice to a near miss. Present strength is a useless compromise. The desirability of reducing sheet metal partitioning to a minimum is suggested." CO, RALPH TALBOT (DD390): "Streamlining will reduce appreciably the effect of exposed blast pressure. Funnel shaped areas and open tunnel passageways should be avoided in construction because of the wave guide effect on the blast and its tendency to follow the path of least resistance." CO, NEW YORK (BB34): "Damage not sufficient to make generalizations. However, it is of interest to point out that curved surfaces in close proximity to dished flat surfaces showed no similar damage. It is believed that curved surfaces should be incorporated in future superstructure design where possible."

SECTION IV

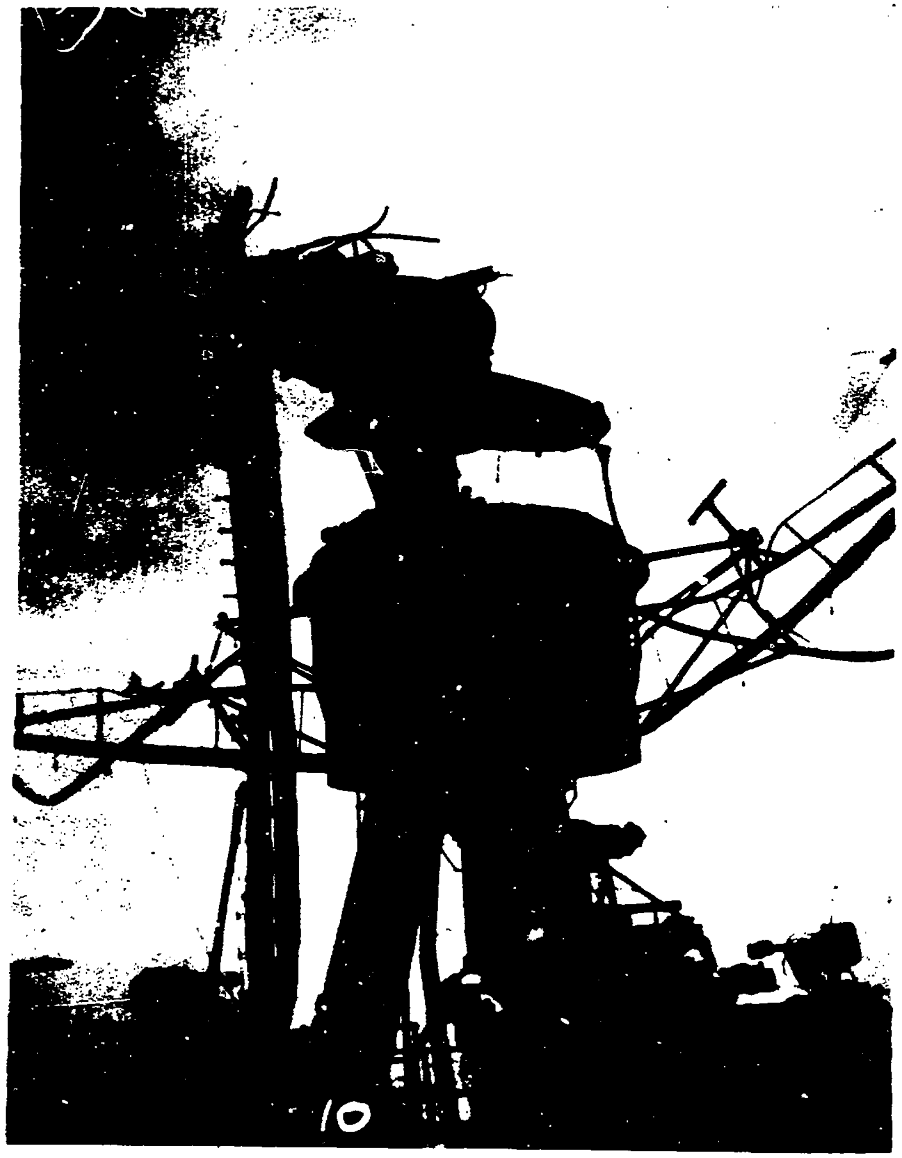
PHOTOGRAPHS

EFFECT OF AIR BLAST ON SUPERSTRUCTURE

AA-CR-175-2040-6. U.S.S. INDEPENDENCE (CVL22). Air blast damage to crane and island, looking to starboard. Stubs of missing pipe mast structure may be seen on house top.

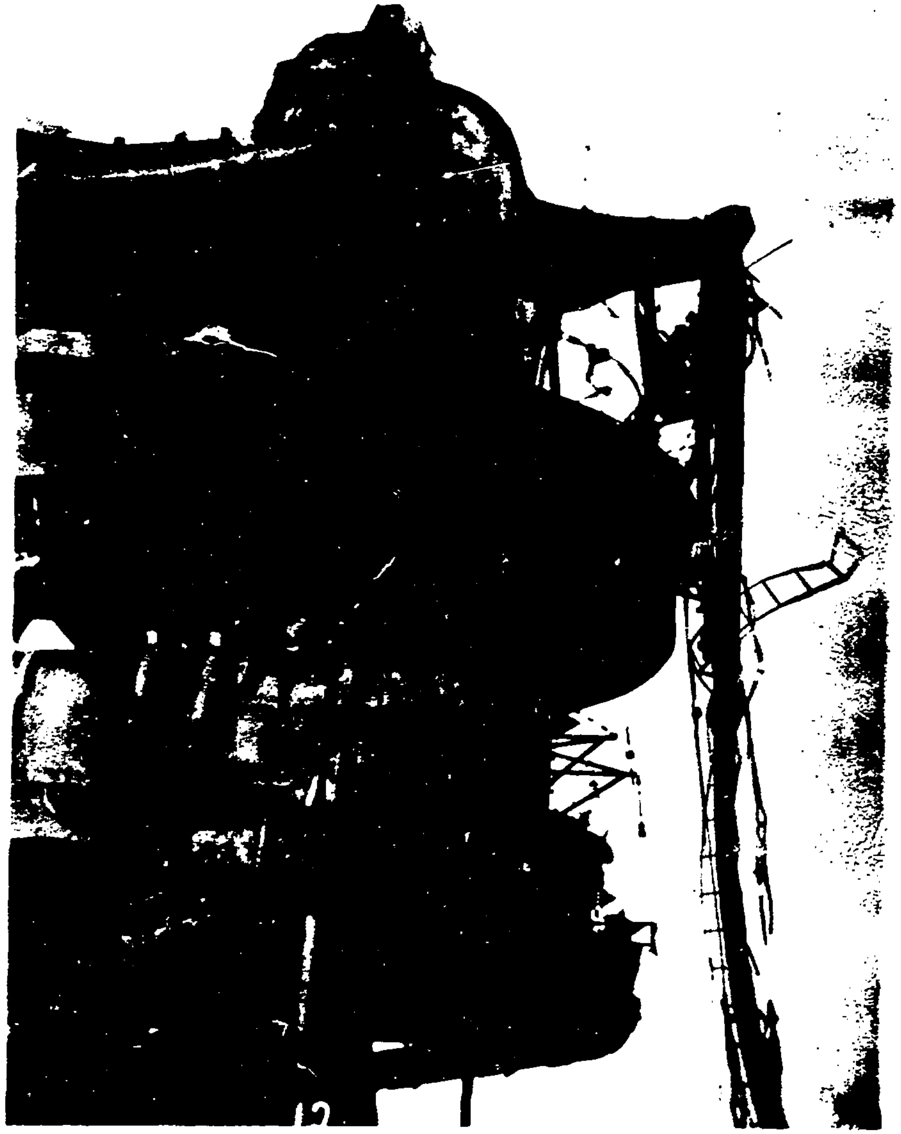
BA-CR-196-151-23. U.S.S. INDEPENDENCE (CVL 22). General view of flight deck and island before Test A, showing extent of pipe mast structure and radars.

AA-CR-62-1832-9. U.S.S. NEVADA (BB36). General view of superstructure from starboard. Mainmast radar pole mast is hanging over forward side of mainmast. Pole mast on foremast is missing.

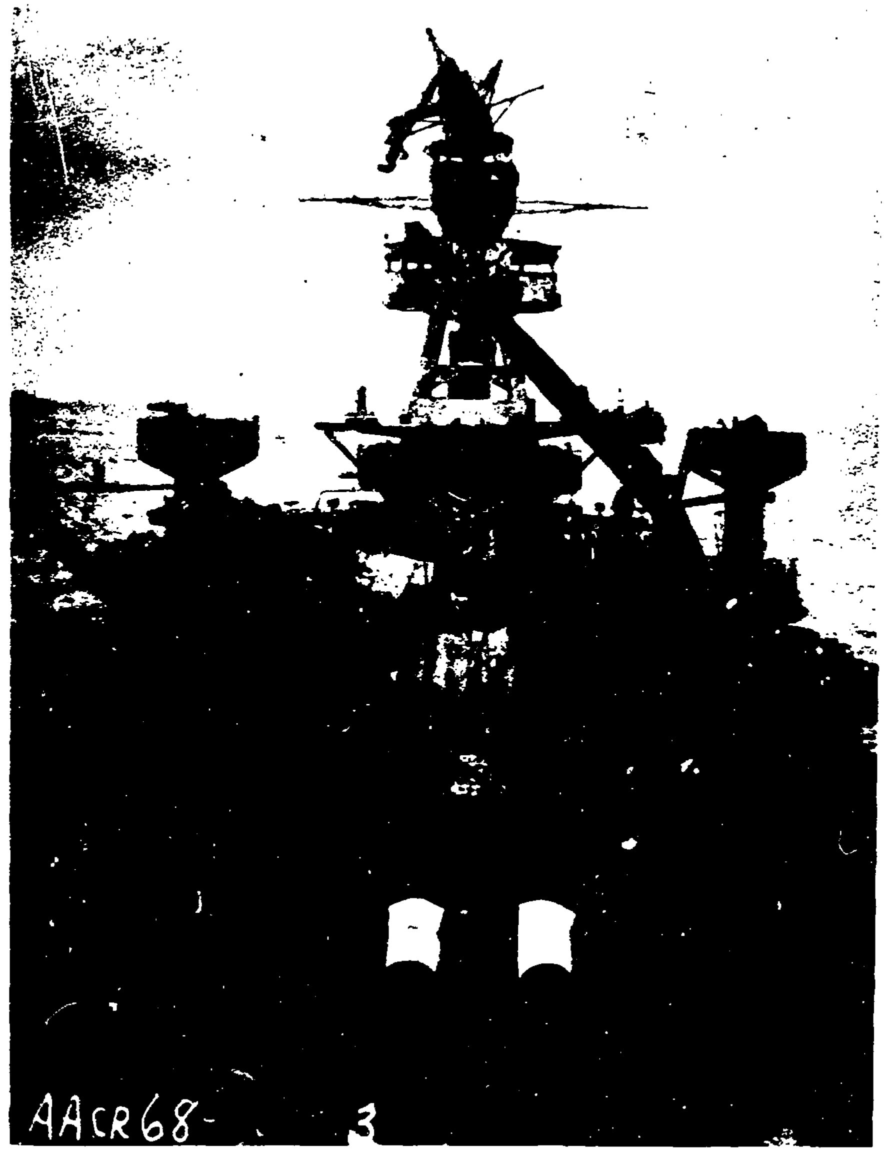


AA-CR-80-1897-10. U.S.S. NEVADA (BB36). Close-up of mainmast damage from port. Damage to pole mast indicates that mast bent considerably before failure. Note damage to yardarms also.

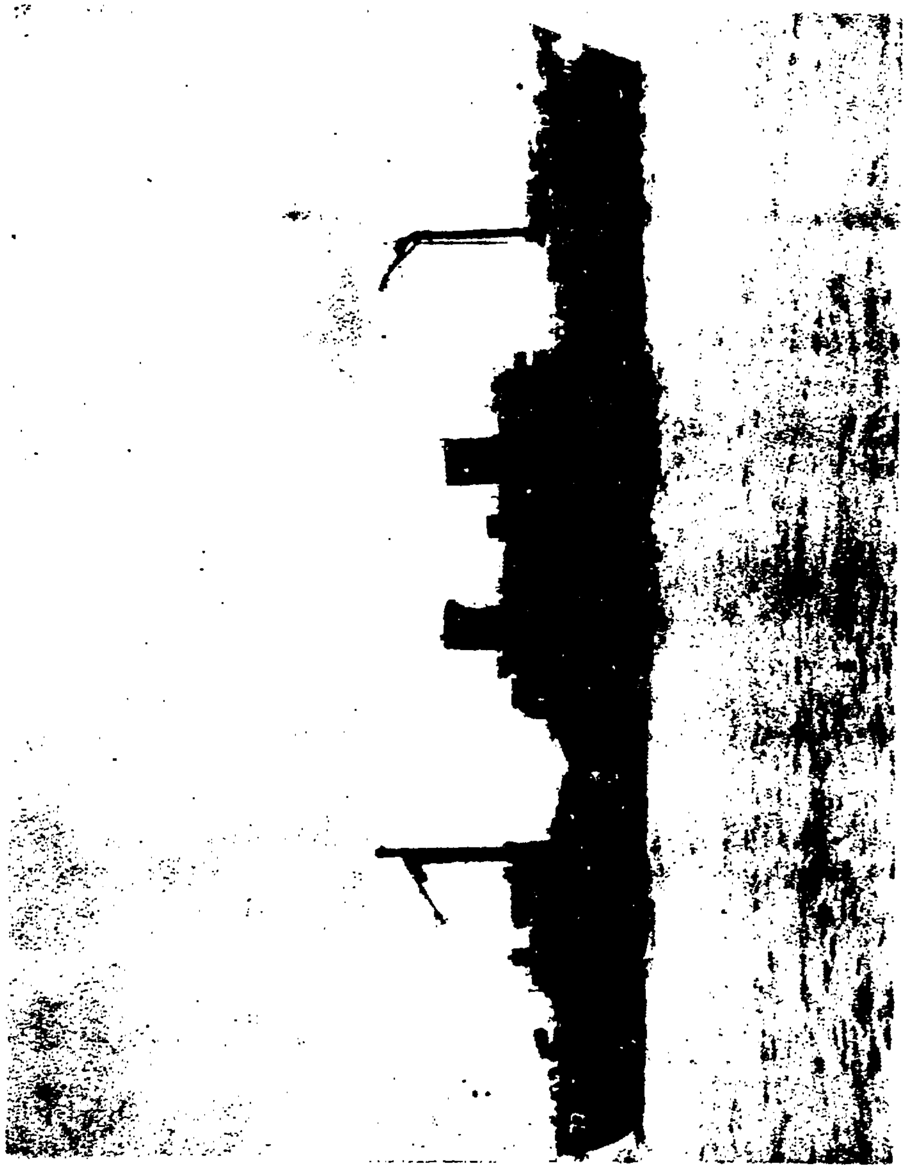
AA-CR-92-1774-11. U.S.S. ARKANSAS (BB33). General view of superstructure from port. Mainmast radar pole mast is hanging over forward side of mainmast. Pole mast on foremast is bent double.



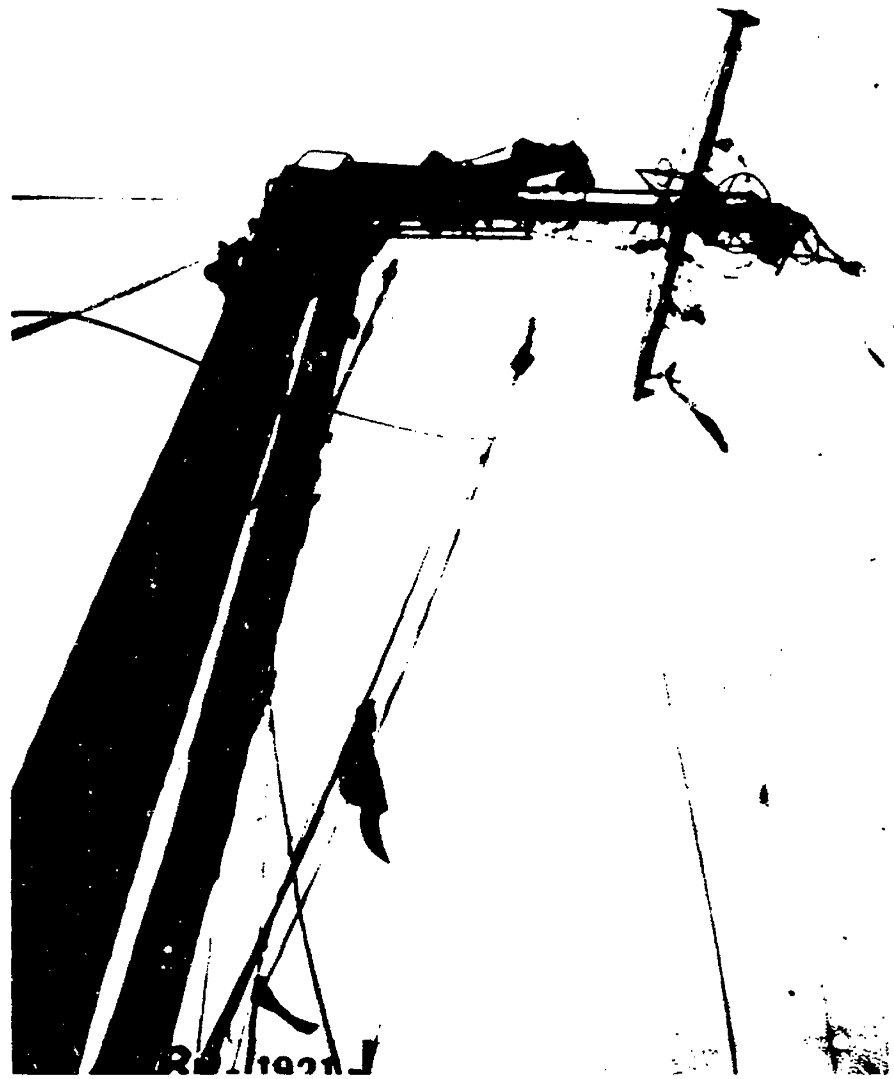
AA-CR-92-1775-12. U.S.S. ARKANSAS (BB33). Close-up of failure of main top mast, looking from starboard. See also damage to flat portion of upper shield.



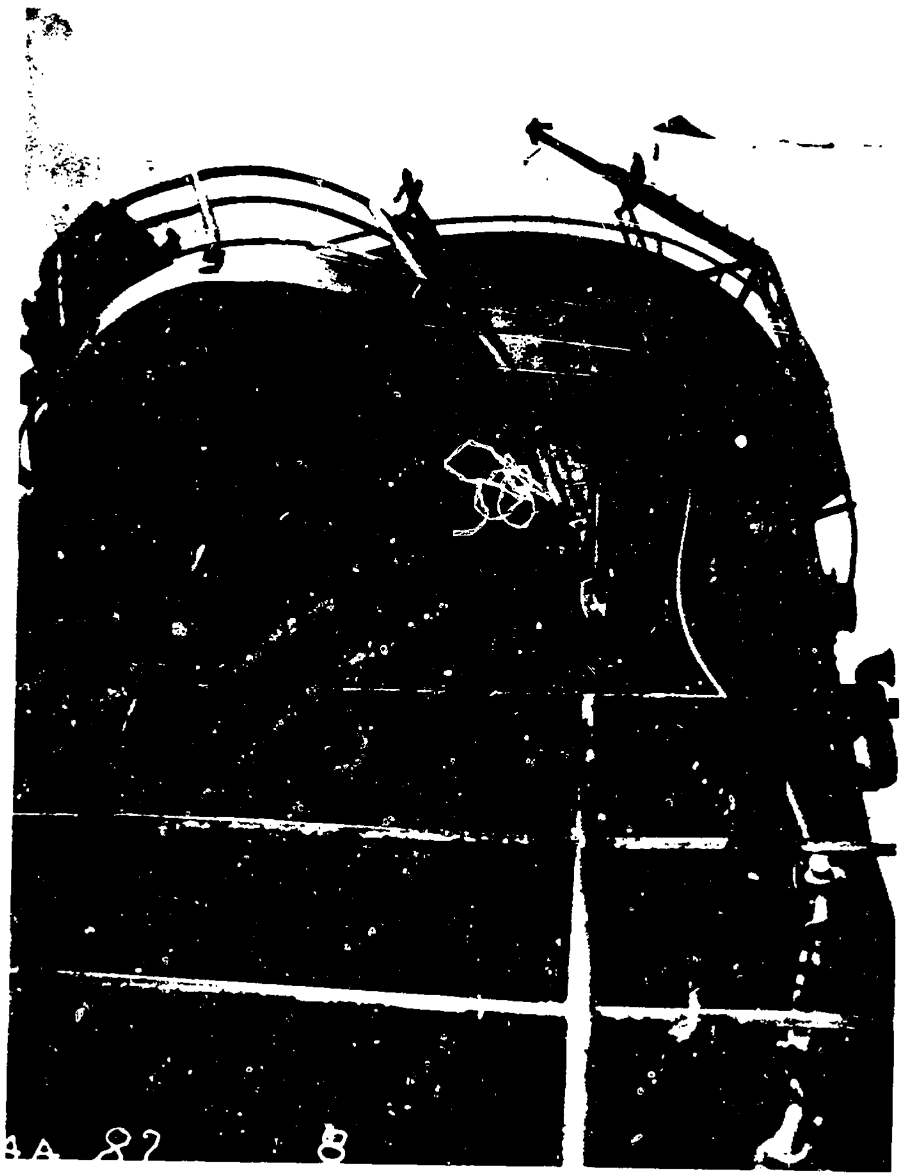
AA-CR-68-2097-3. U.S.S. ARKANSAS (BB33). Damage to foremast structure viewed from mainmast. Radar pole mast is bent radically forward and to port. Yardarms are bent forward.



AA-CR-227-49-116. U.S.S. CRITTENDEN (APA77). General view of superstructure, showing air blast damage to pole masts.



AA-CR-82-1921-10. U.S.S. CRITTENDEN (APA77). Air blast damage to fore top mast.

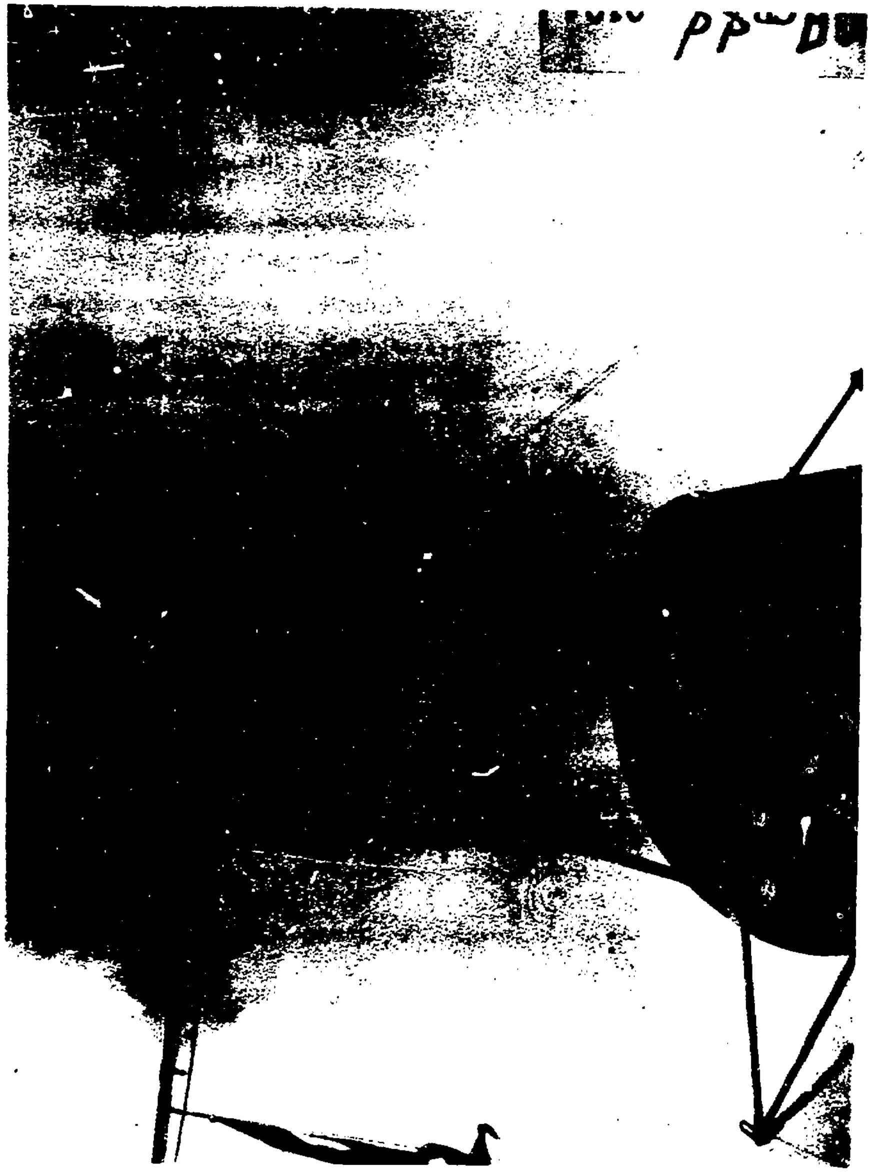


AA-CR-82-1922-8. U.S.S. CRITTENDEN (APA77). Air blast damage to stub mast on leading edge of forward stack.

AA-CR-80-1906-9. U.S.S. CRITTENDEN (APA77). Air blast damage to main top mast, looking upward and aft. Note radar array fallen to house top.

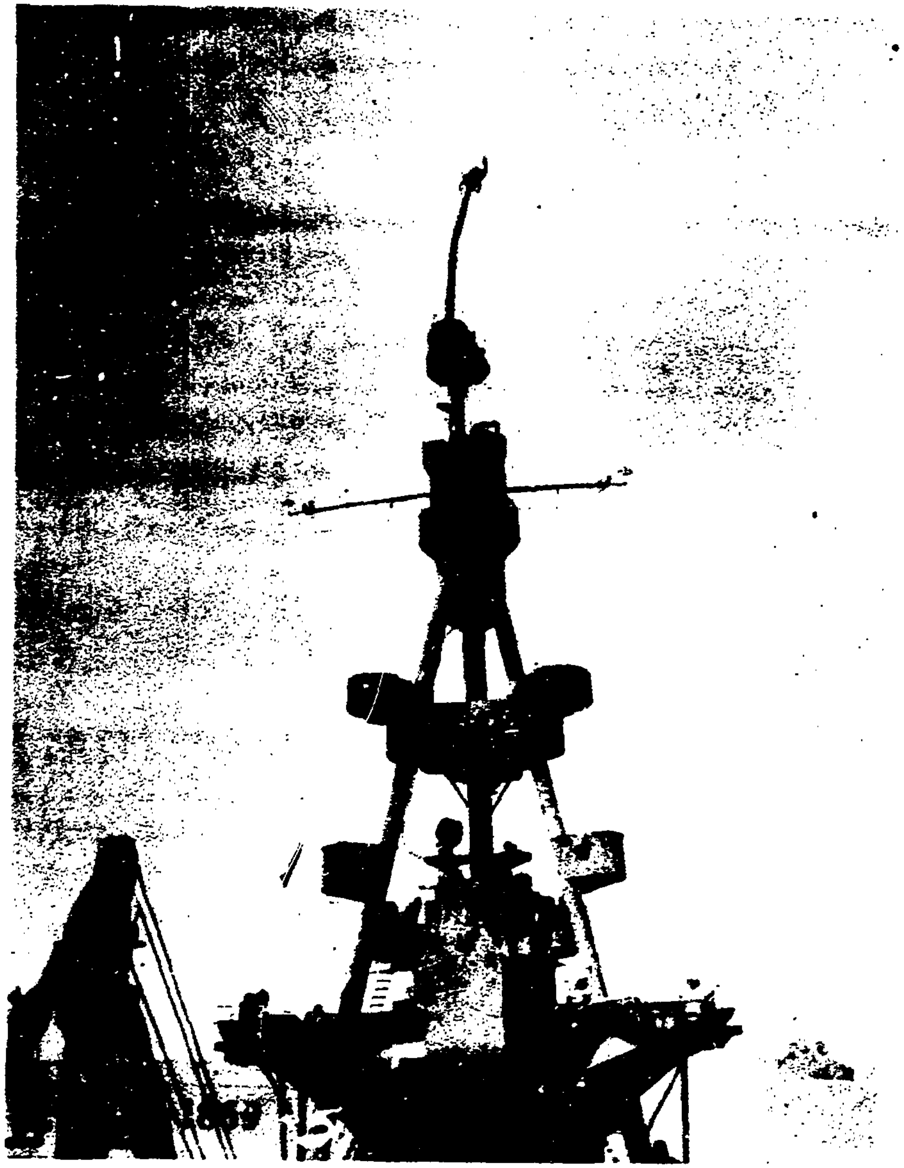
AA-CR-62-1860-3. U.S.S. PENSACOLA (CA24). General view of super-structure from port, showing damage to top masts.

AA-CR-92-1773-3. U.S.S. DAWSON (APA79). General view of super-structure, showing damage to top masts.



AA-CR-88-2104-10. U.S.S. DAWSON (APA79). Air blast damage to stub mast on leading edge of forward stack.

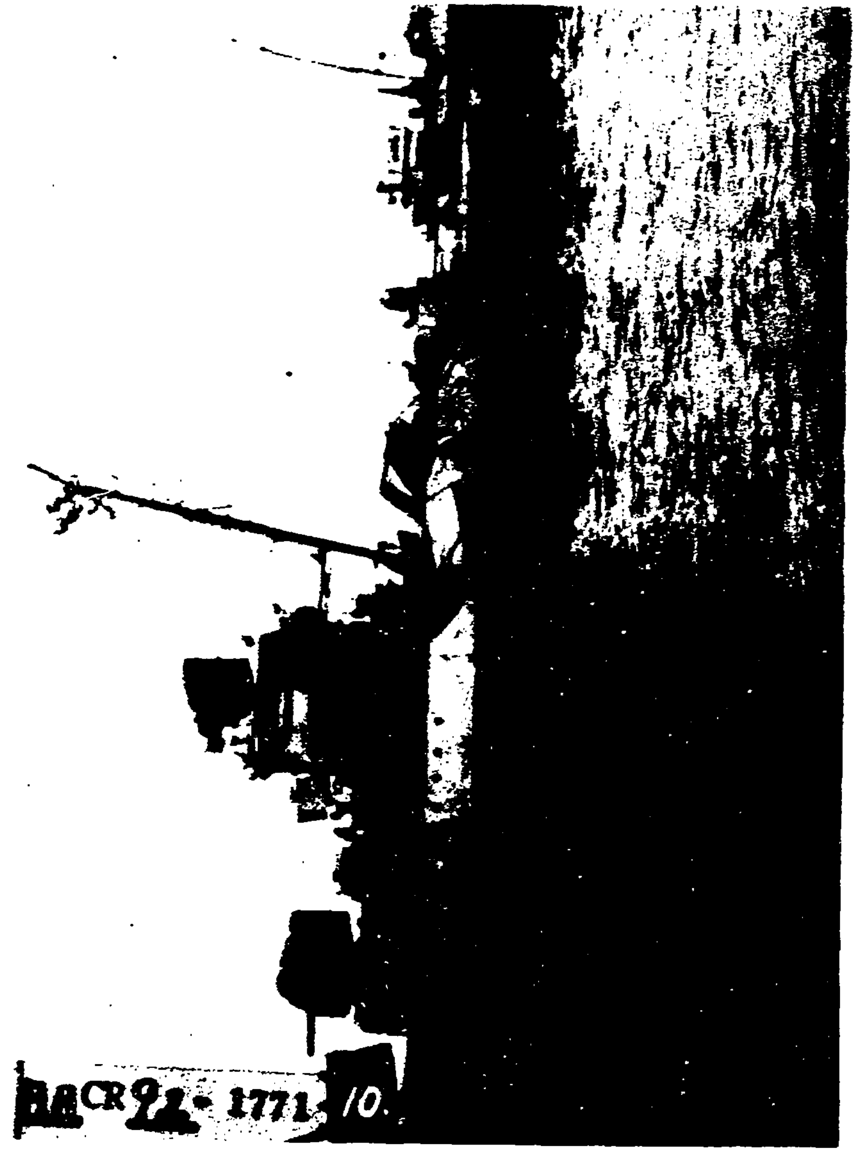
AA-CR-227-91-47. U.S.S. SALT LAKE CITY (CA25). General view of superstructure from starboard, showing damage to top masts.



AA-CR-1869-5. U.S.S. SALT LAKE CITY (CA25). Air blast damage to foremast and radar polemast, looking forward from frame 74.

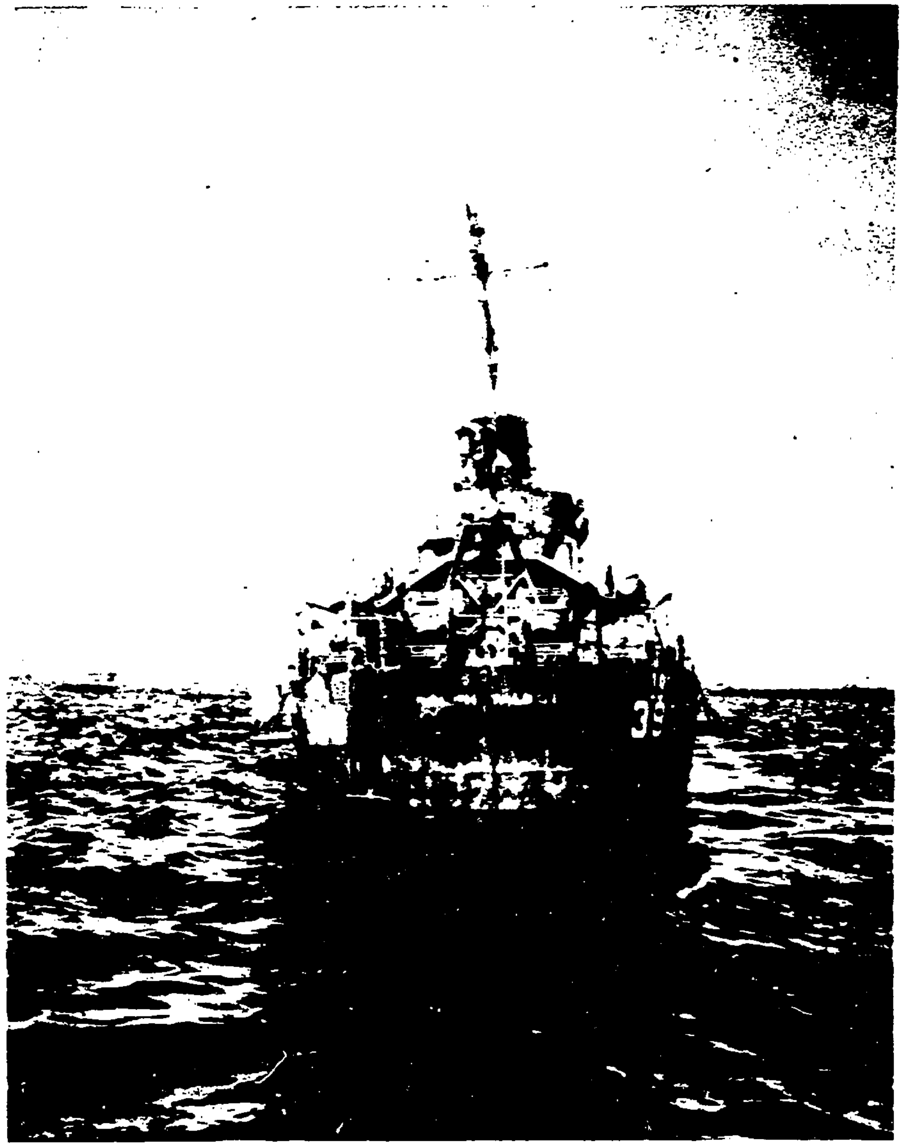
AA-CR-62-1868-8. U.S.S. SALT LAKE CITY (CA25). Air blast damage to radar mast and rigging on mainmast, looking forward from frame 94.

AA-CR-100-2198-4. U.S.S. HUGHES (DD410). Air blast damage to foremast, looking up, to starboard and slightly forward.



AA-CR-92-1771-10. U.S.S. RHIND (DD404). General view of superstructure from port side, showing damage to masts.

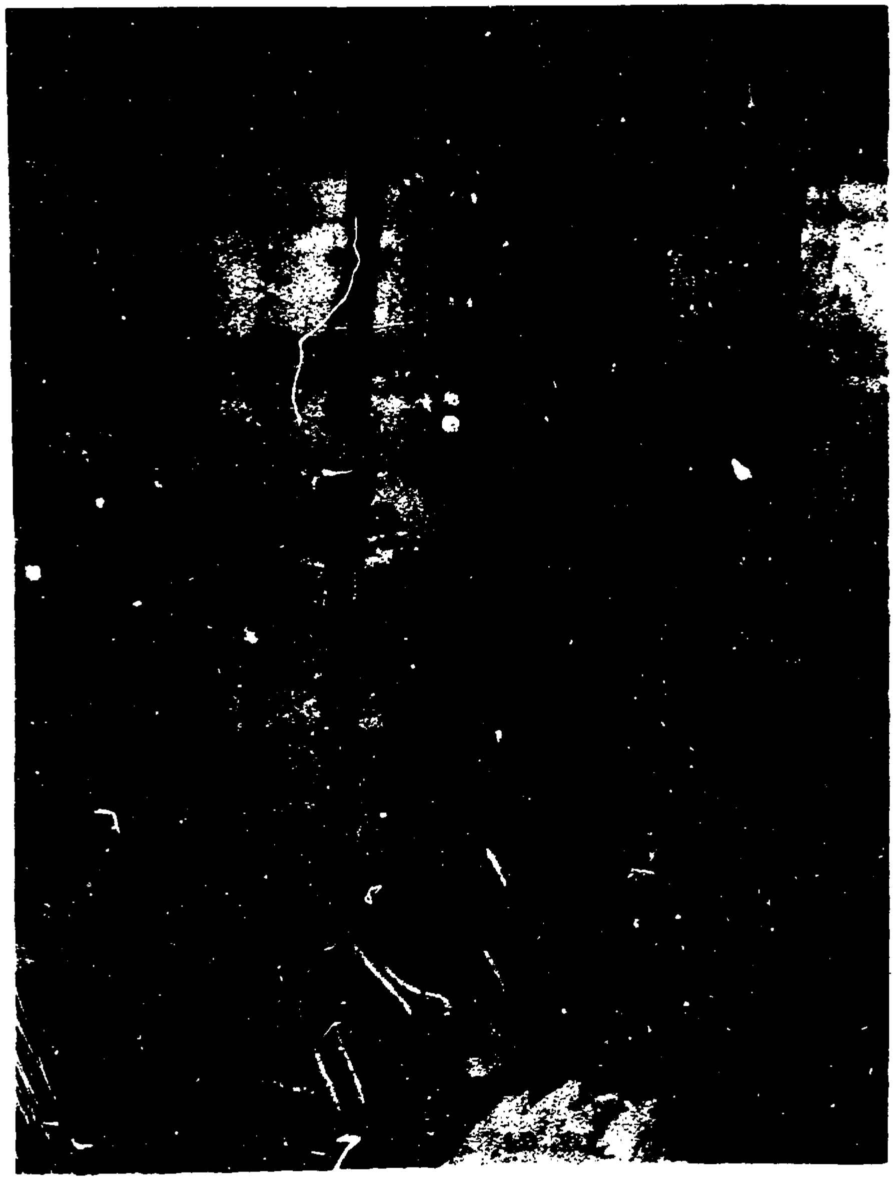
AA-CR-58-2003-4. U.S.S. RHIND (DD404). Air blast damage to foremast top as viewed from director platform.



AA-CR-227-50-41. U.S.S. RALPH TALBOT (DD390). General view from directly astern, showing bend in foremast.

AA-CR-68-2097-7. U.S.S. ARKANSAS (BB33). Failure of connection of starboard leg of mainmast tripod to main deck.

AA-CR-68-2146-5. U.S.S. ARKANSAS (BB33). Second deck, frame 103, showing base of starboard leg of mainmast tripod pulled away from deck.

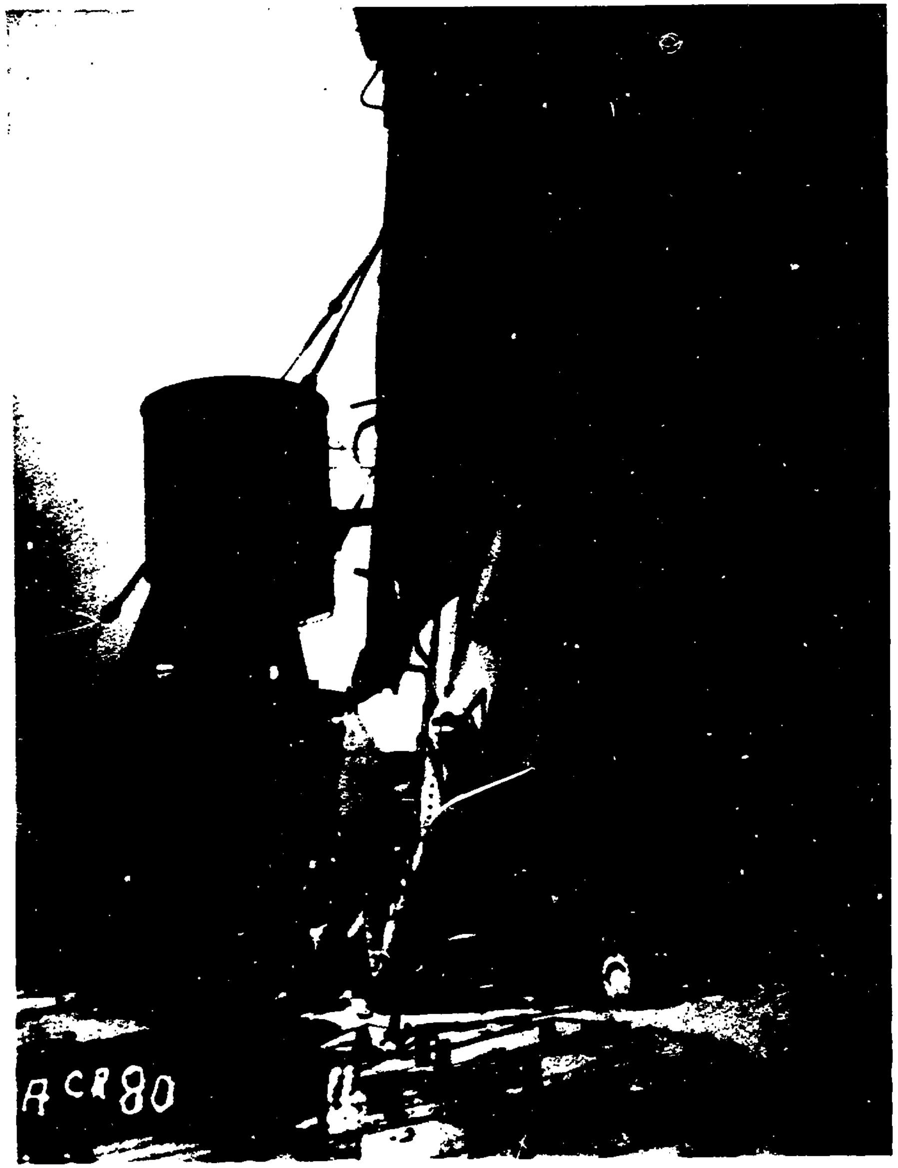


AA-CR-68-2111-7. U.S.S. ARKANSAS (BB33). Compression failure in foreleg of mainmast tripod as the result of air blast.

AA-CR-175-2134-7. U.S.S. ARKANSAS (BB33). Port leg of mainmast tripod, looking to starboard, showing evidence of compressive loading under air blast.

AA-CR-175-2154-3. U.S.S. NEVADA (BB36). Looking upward and aft at port leg of foremast tripod, showing distortion of superstructure deck from slight lifting of tripod leg under air blast loading

AA-CR-175-2137-12. U.S.S. NEVADA (BB36). Looking aft at starboard leg of foremast tripod, showing distortion of deck from slight lifting of tripod leg under air blast loading.



AA-CR-80-1910-11. U.S.S. NEVADA (BB36). Looking to port at frame 73 on the superstructure deck, showing location of 40 MM director tripods, port and starboard.

TCP SECRET

AA-CR-175-2137-8. U.S.S. NEVADA (BB36). Outboard after leg of the starboard 40 MM director tub tripod at frame 73. Note that deck is pulled up by leg.

TOP SECRET

AA-CR-175-2137-10. U.S.S. NEVADA (BB36). Looking upward and inboard at the forward leg of the starboard 40 MM director tub tripod, showing damage under superstructure deck from compression of leg.

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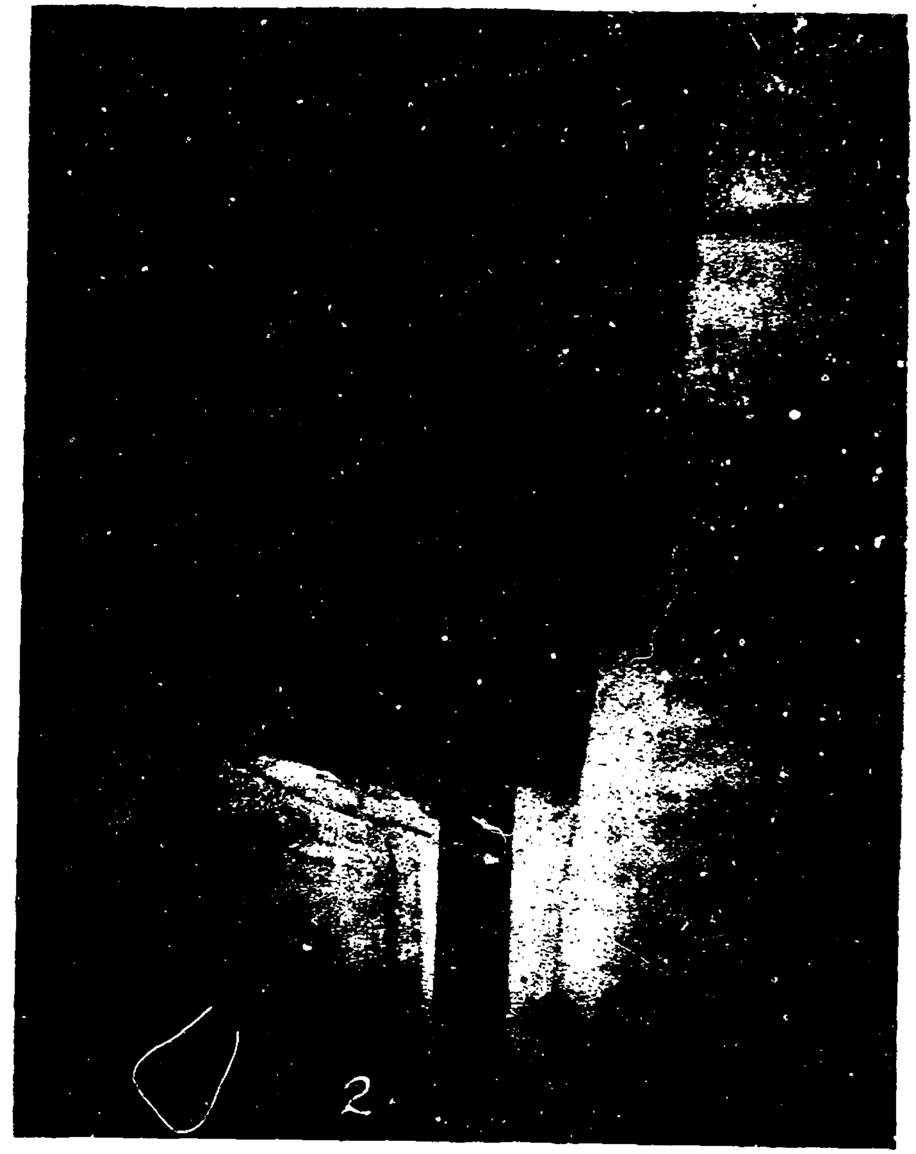
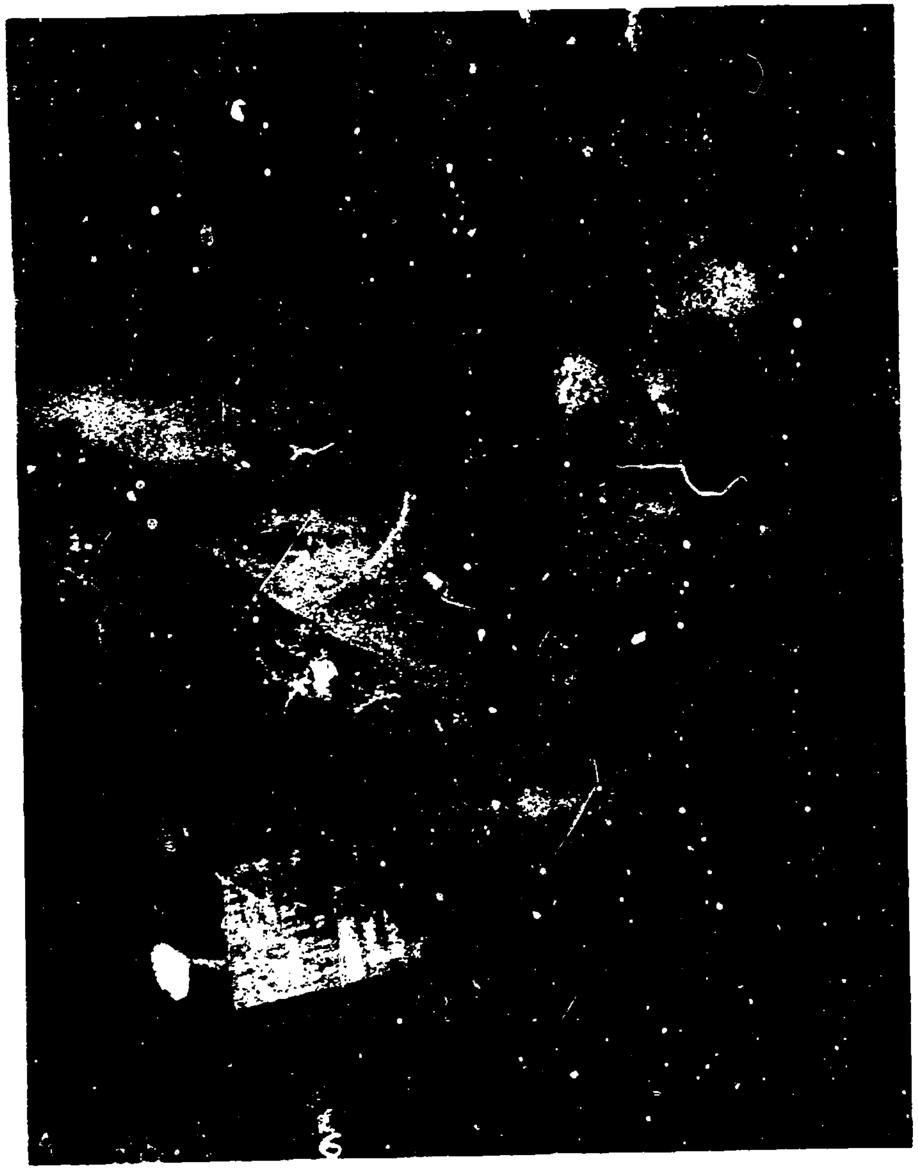


AA-CR-65-1762-2. U.S.S. PENSACOLA (CA24). Looking aft and to port at bulkhead 43, showing crushing under forward leg of forward tripod as the result of compressive loads applied by air blast.

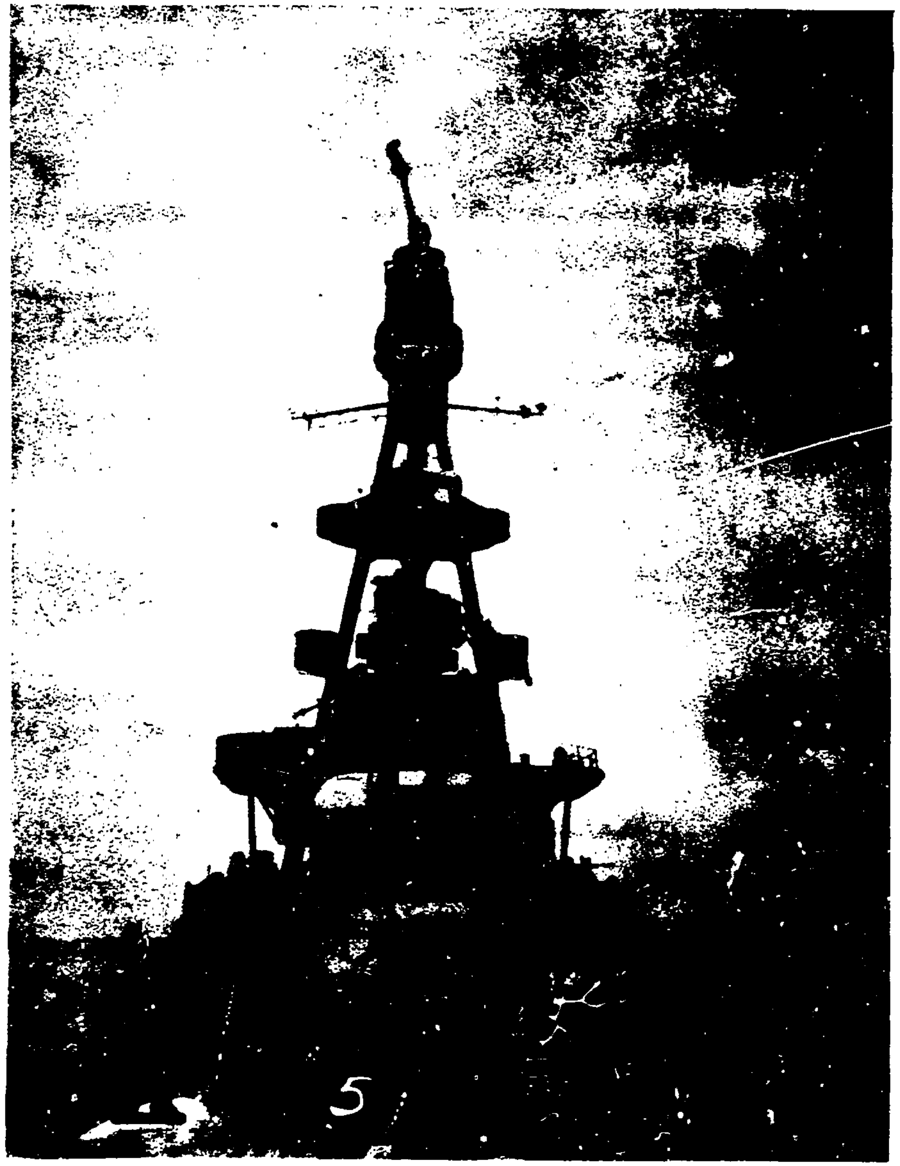
AA-CR-88-2161-5. U.S.S. PENSACOLA (CA24). Lifting of base of port strut of mainmast under action of air blast.

AA-CR-63-1757-6. U.S.S. PENSACOLA (CA24). Looking upward and aft at underside of superstructure deck in way of damage to base of port mainmast strut. See photo No. 32.

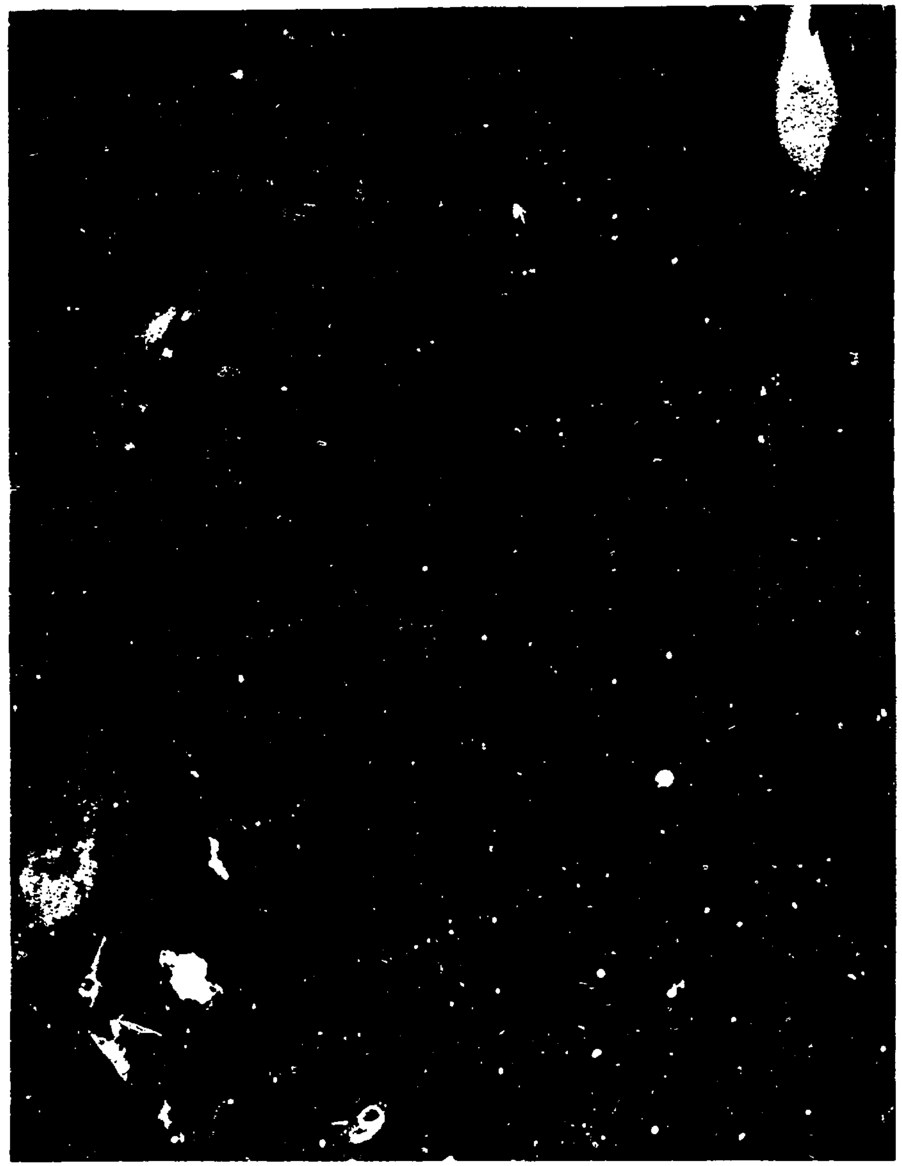


AA-CR-88-2161-6. U.S.S. PENSACOLA (CA24). Lifting of base of starboard strut of mainmast under action of air blast.

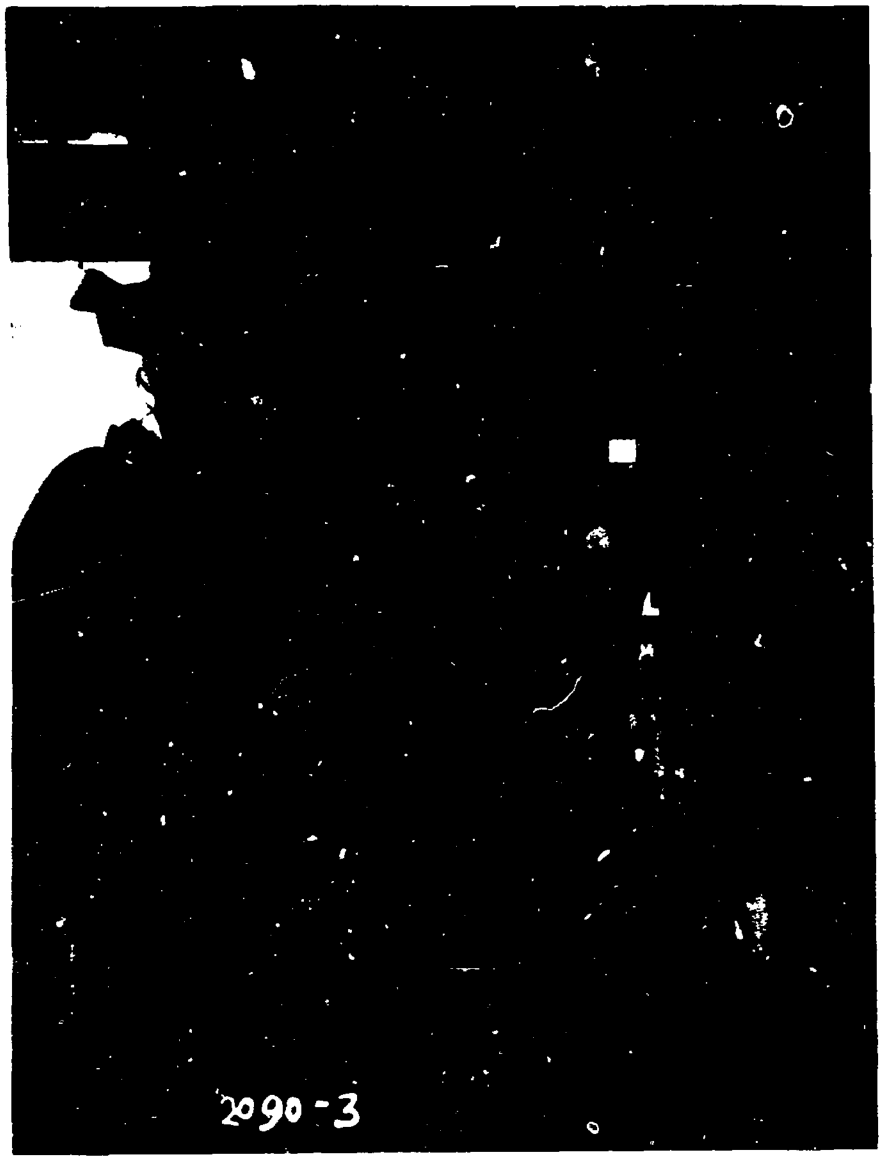
AA-CR-68-1757-7. U.S.S. PENSACOLA (CA24). Looking upward and aft at underside of superstructure deck in way of damage to starboard mainmast strut.



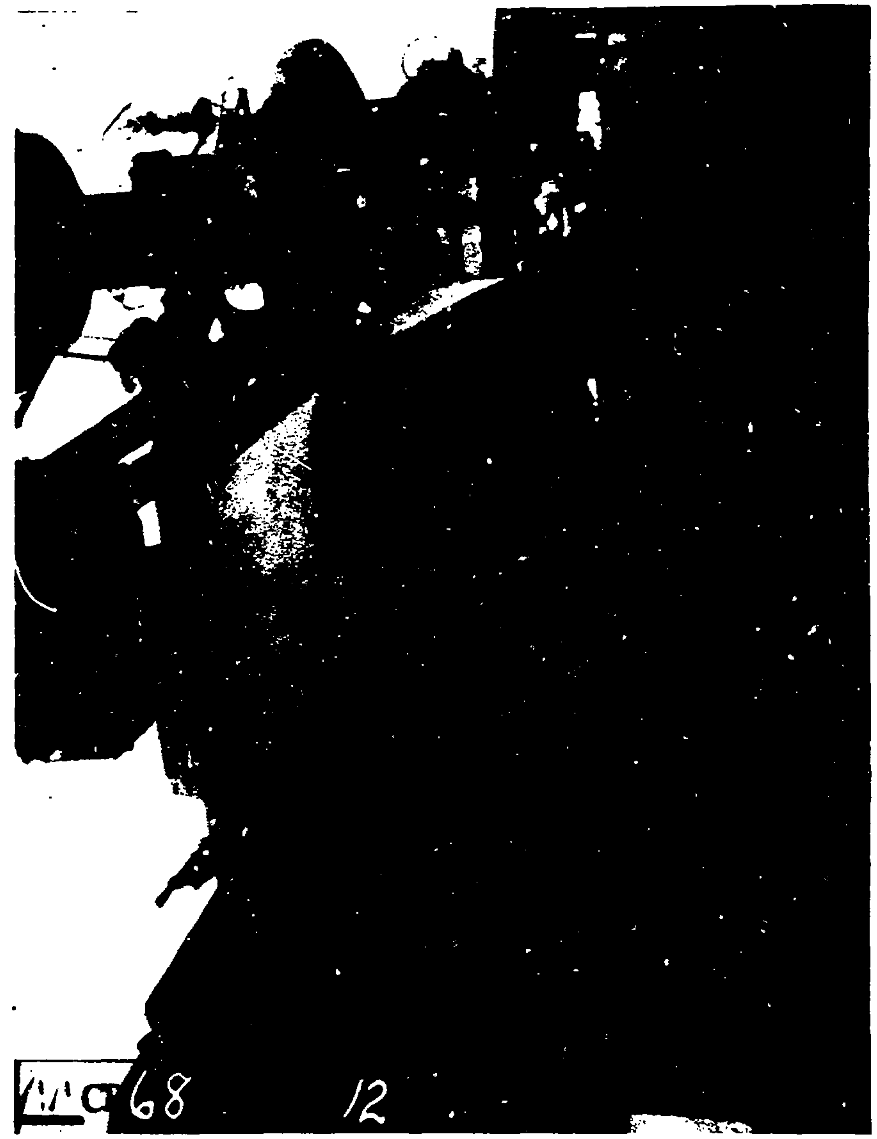
AA-CR-62-1861-5. U.S.S. SALT LAKE CITY (CA25). Looking aft at foremast structure, showing damage to top mast and intact condition of tripod.



AA-CR-175-2134-9. U.S.S. ARKANSAS (BB33). Looking forward and to port under overhanging gun platform, showing heavy damage to bulkhead beyond. View taken from approximate angle of approach of the air blast.



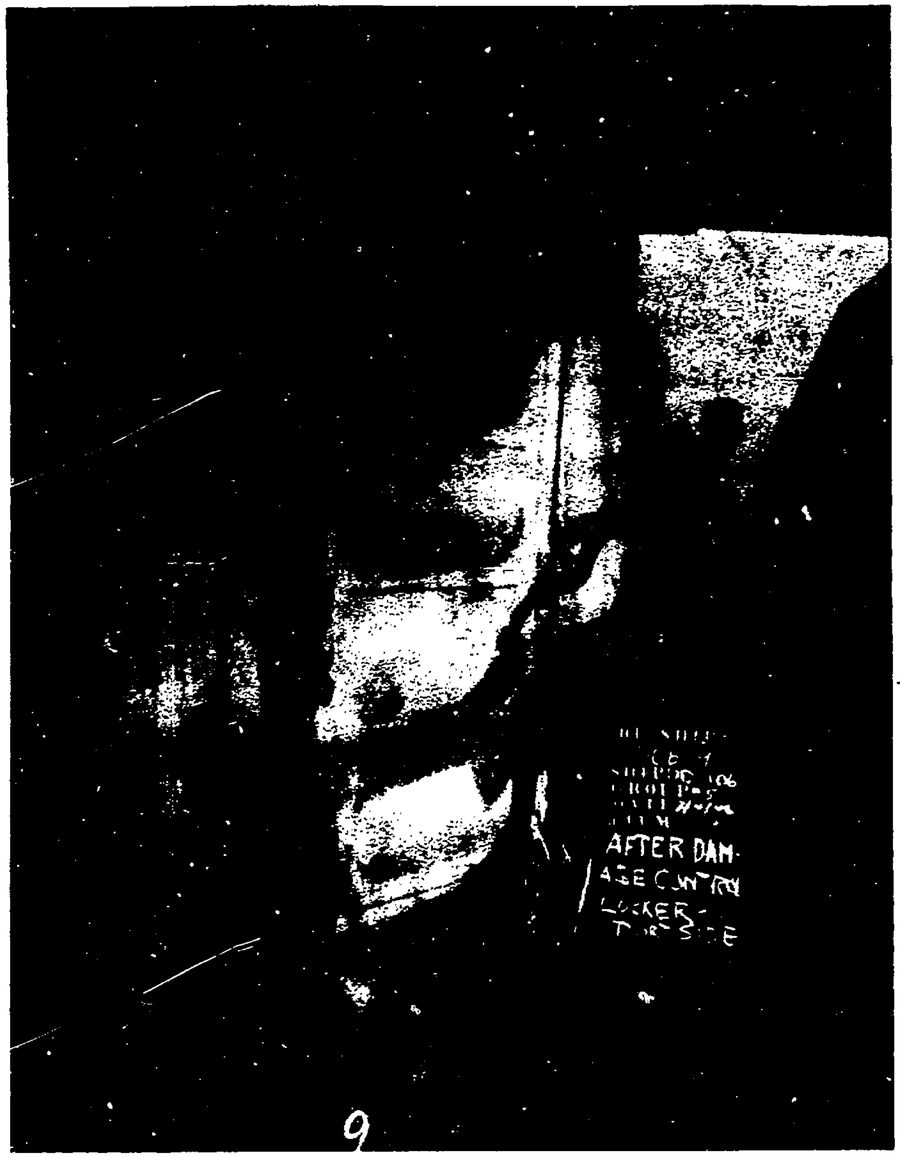
AA-CR-68-2090-3. U.S.S. ARKANSAS (BB33). Looking inboard at starboard deckhouse bulkhead on main deck, frames 63 to 68, showing heavy air blast damage because of overhanging gun platform.



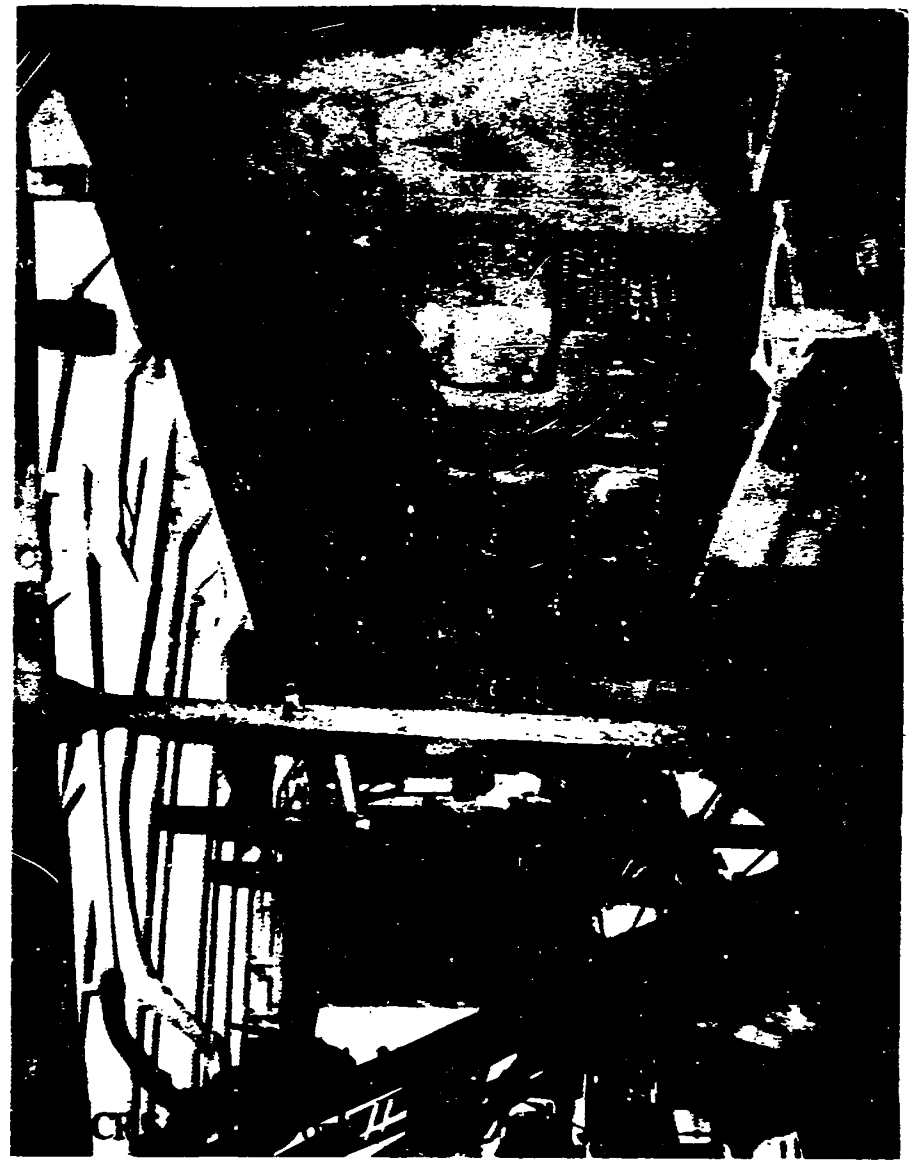
AA-CR-68-2097-12. U.S.S. ARKANSAS (BB33). Looking forward on main deck starboard side, from frame 80, showing damage to overhanging structure. Note relatively undamaged condition of exposed portion of bulkhead.

AA-CR-58-2006-8. U.S.S. STACK (DD406). General view of damage to bulkhead and door of engineer's log room, main deck, frame 100, starboard side. Note also deflection of gun shield.

AA-CR-65-1850-8. U.S.S. STACK (DD406). Air blast damage to bulkhead and door under overhanging gun tub, main deck, starboard side, in way of engineer's log room. See Photo 40.



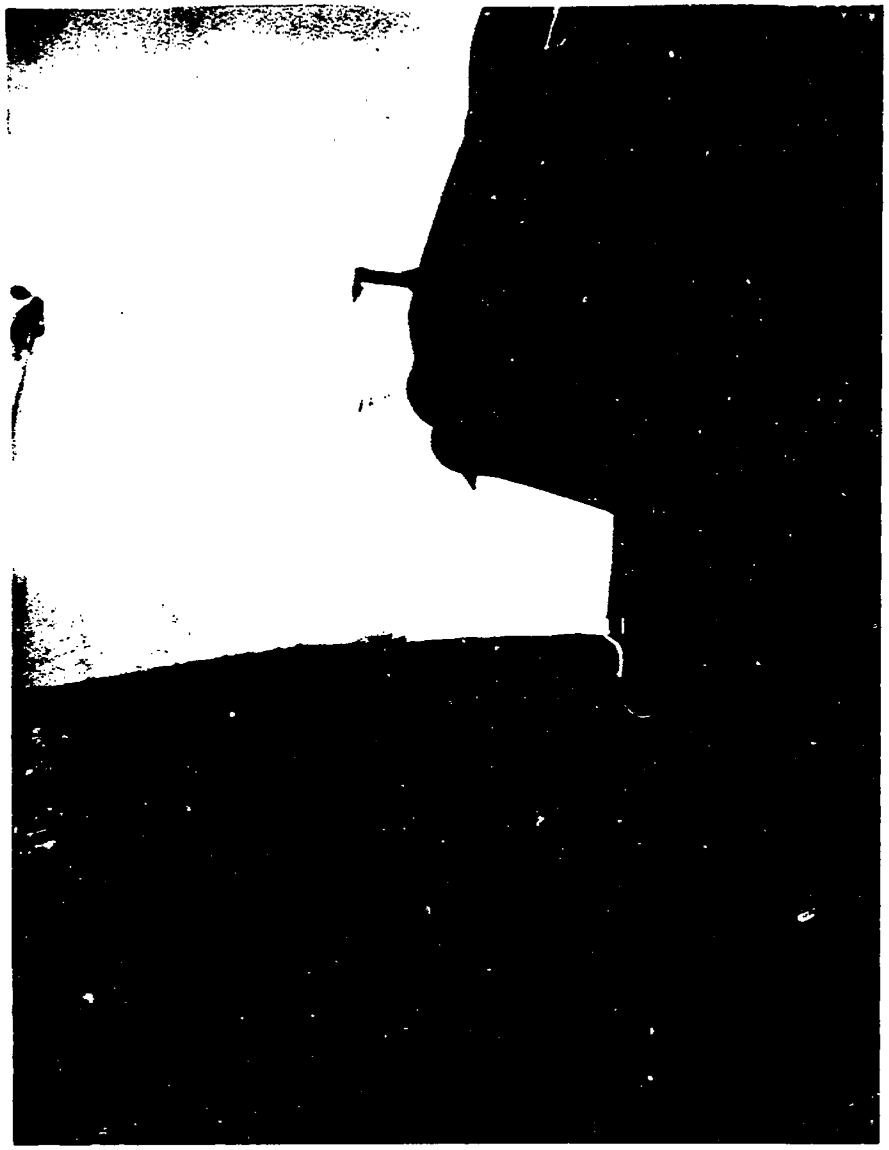
AA-CR-58-2006-9. U.S.S. STACK (DD406). Air blast damage to bulkhead and door under overhanging platform, main deck, frame 123, port side.



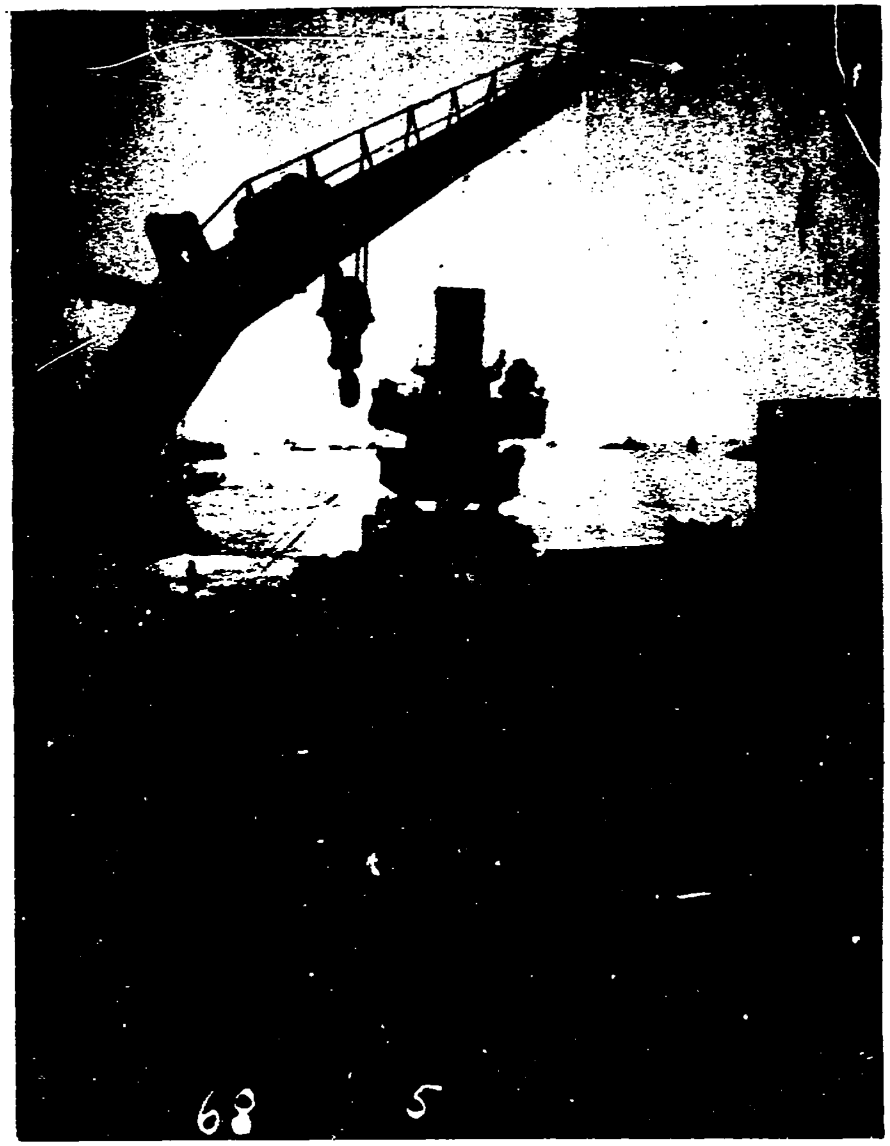
AA-CR-58-2006-11. U.S.S. STACK (DD406). Air blast damage to bulkhead and door under overhanging platform, superstructure deck, starboard side, in way of C.I.C. room.

AA-CR-68-2095-9. U.S.S. ARKANSAS (BB33). Looking forward and to port at after side of foremast, showing rangefinder platform lifted by air blast. Note distortion of house under platform.

AA-CR-175-2135-3. U.S.S. ARKANSAS (BB33). Fracture of starboard foremast tripod leg in way of contilever support for rangefinder platform, looking upward and outboard.

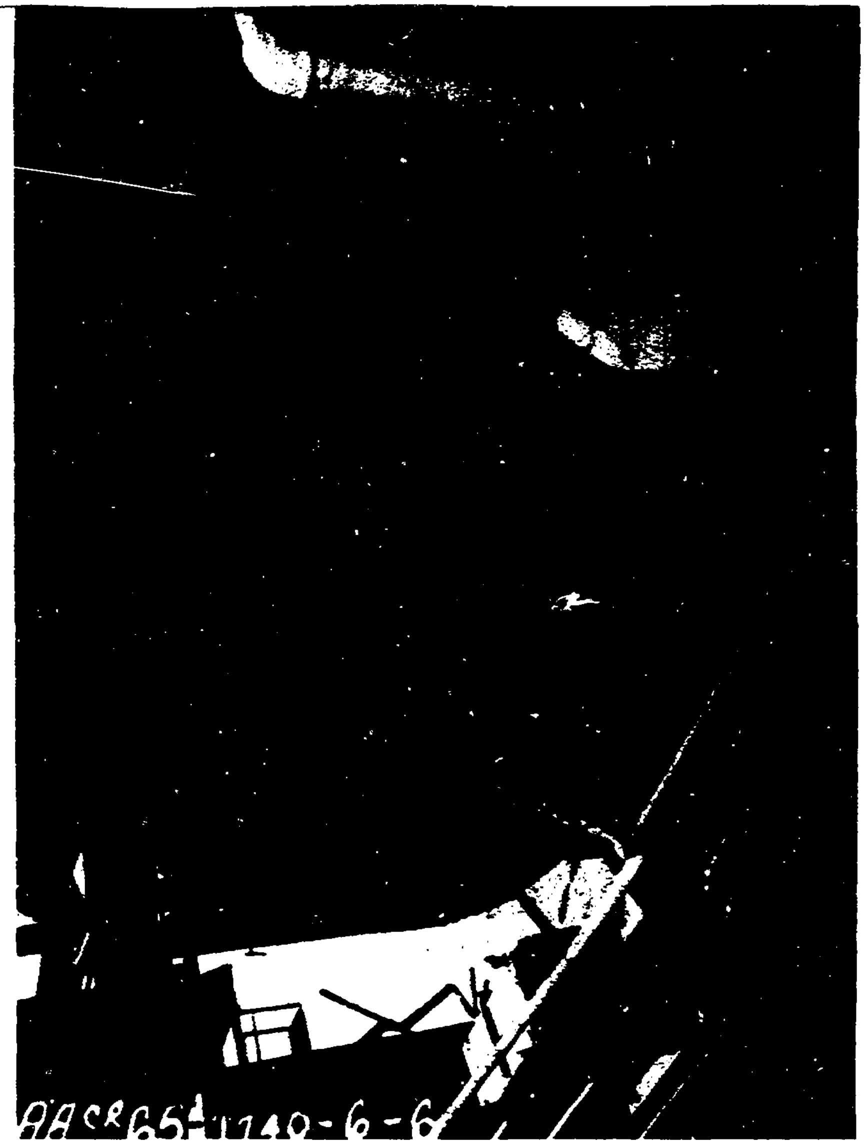


AA-CR-65-1742-7. U.S.S. NEVADA (BB36). Looking forward on port side of superstructure, showing open bridge wing lifted up by air blast, tearing supports from bulkhead. Note bulwark below blown outward and door dished in.

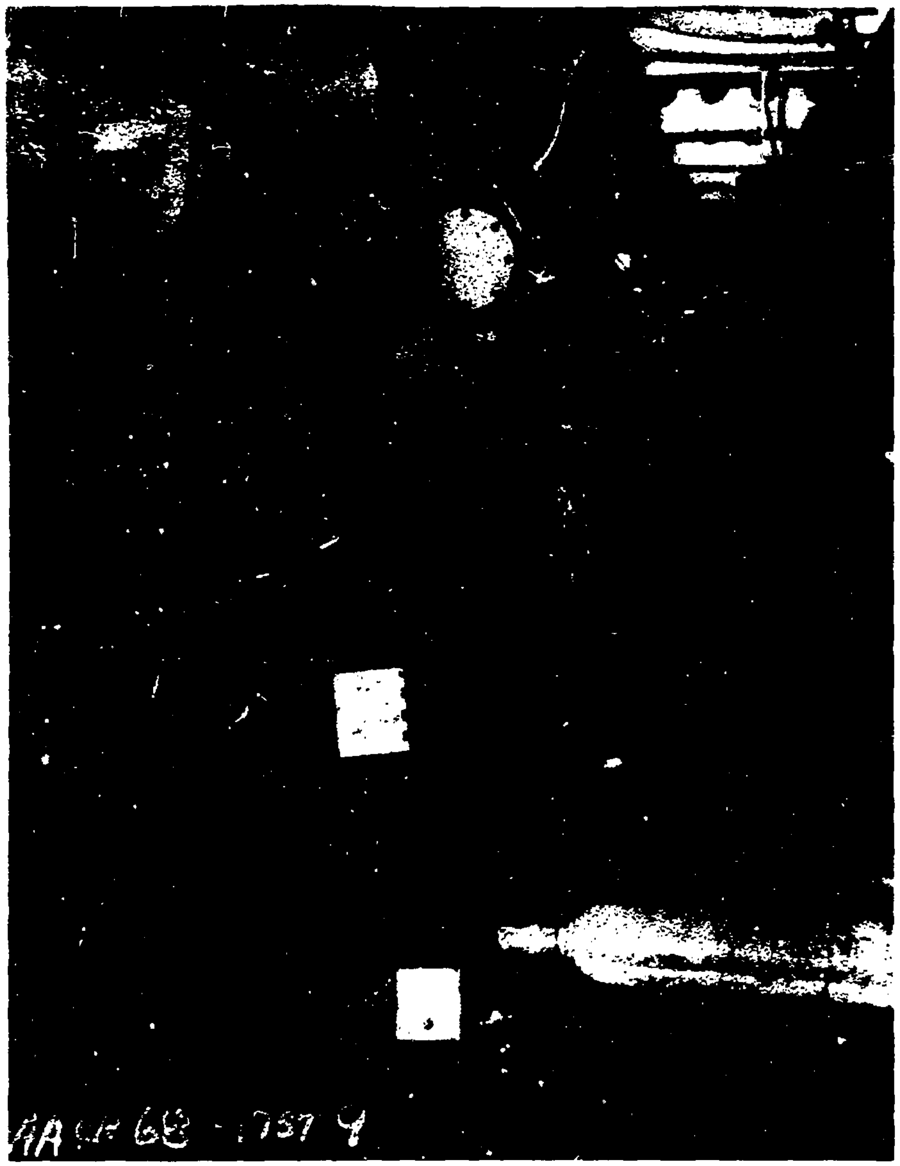


AA-CR-68-2091-5. U.S.S. ARKANSAS (BB33). Looking aft on starboard side of superstructure deck, showing deck house and Turret 3. Note that starboard side of deck house is only slightly damaged.

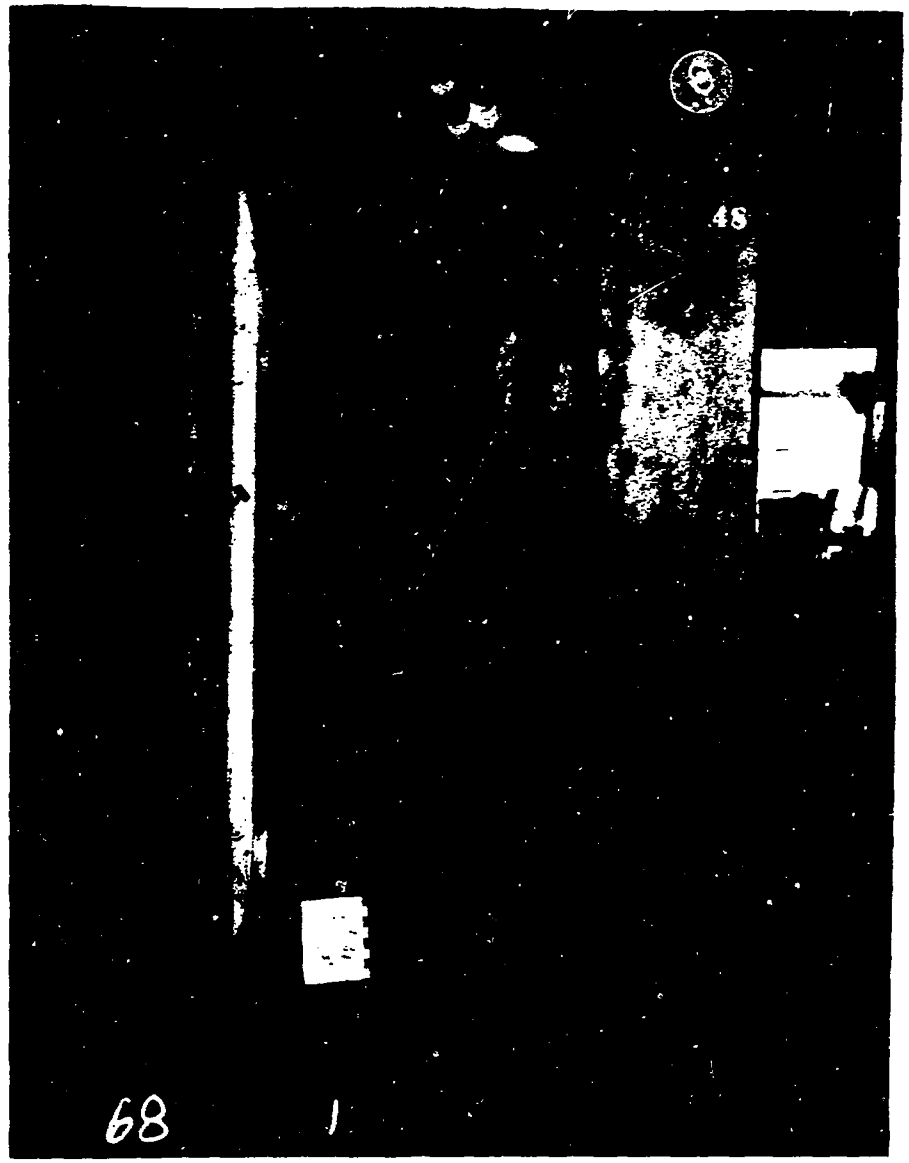
AA-CR-68-2095-11. U.S.S. ARKANSAS (BB33). Looking forward and to starboard at after face of deck house on superstructure deck, frame 68, showing heavy damage from air blast deflected by Turret 3.



AA-CR-65-1740-6. U.S.S. BARROW (APA61). Air blast damage to starboard flag bag on signal bridge level. Flag bag has been torn from supports and thrown in lee of forward stack.

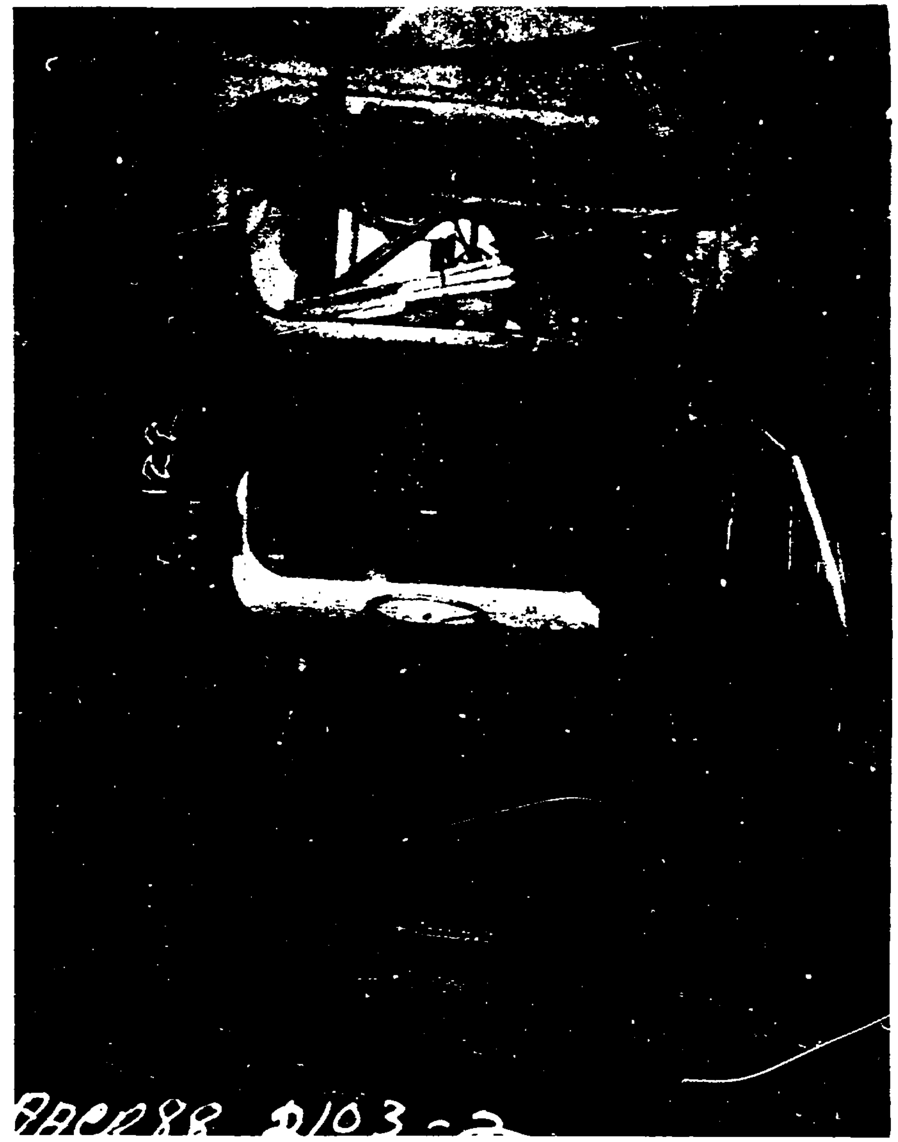


AA-CR-68-1757-9. U.S.S. PENSACOLA (CA24). Looking forward from frame 83 in the port main deck passageway, showing damage resulting from air blast.

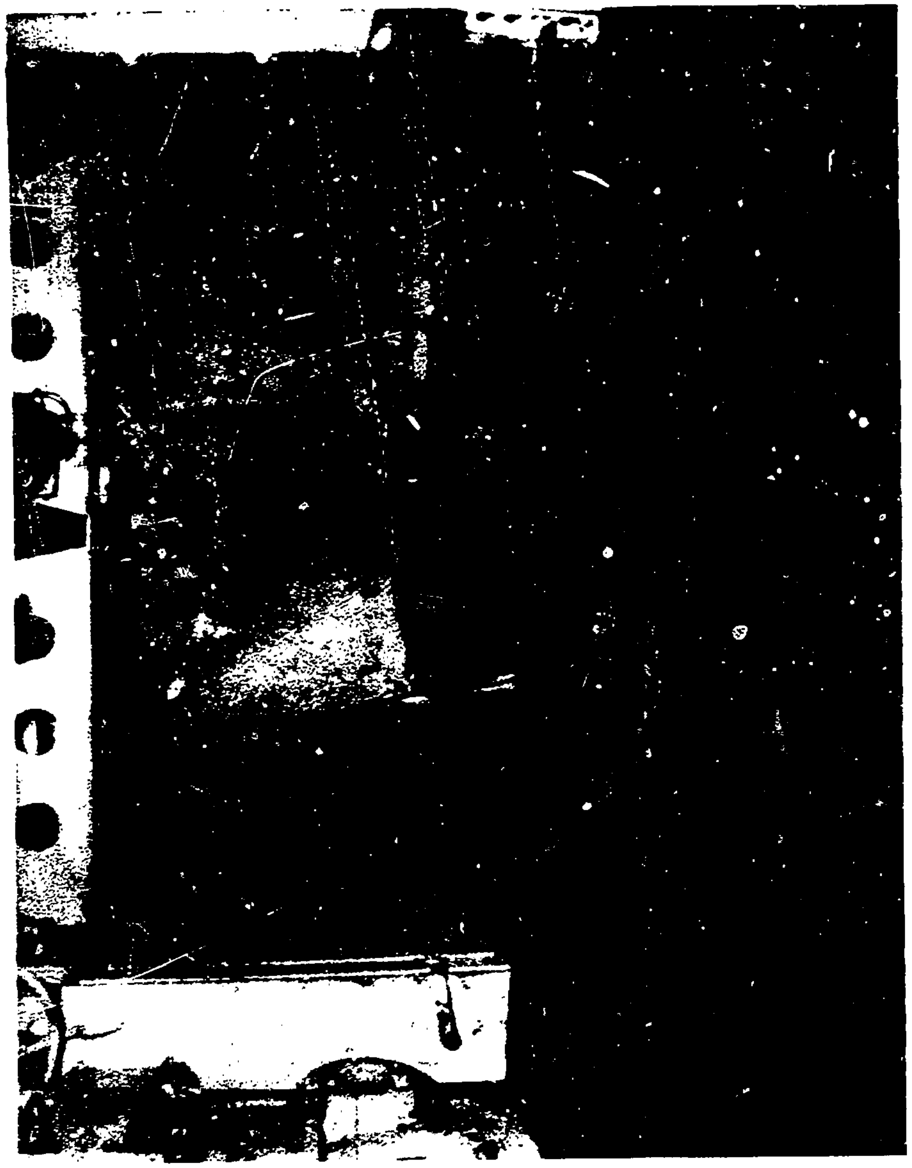


AA-CR-68-1755-1. U.S.S. PENSACOLA (CA24). Looking to port on main deck in transverse passageway, frames 46 to 49, showing air blast damage to passage boundaries.

AA-CR-88-2161-10. U.S.S. PENSACOLA (CA24). Looking to starboard on main deck in transverse passageway, frames 46 to 49, showing air blast damage to passage boundaries.



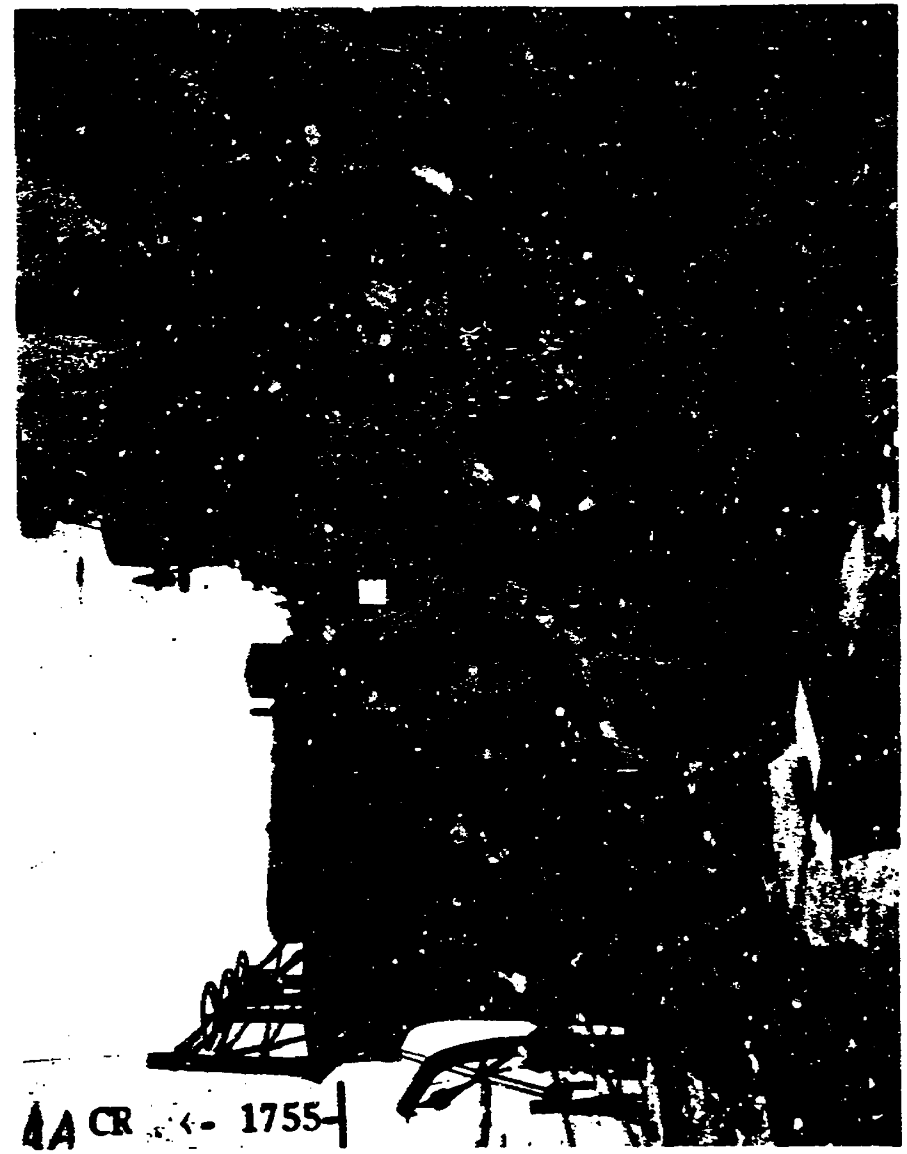
AA-CR-88-2103-2. U.S.S. DAWSON (APA79). Looking aft in the port main deck weather passageway, showing damage to doors in bulkhead 122.



AA-CR-79-1815-6. U.S.S. RALPH TALBOT (DD390). Looking to port in transverse passage at frame 60, main deck, showing air blast damage to wardroom pantry bulkhead and door.

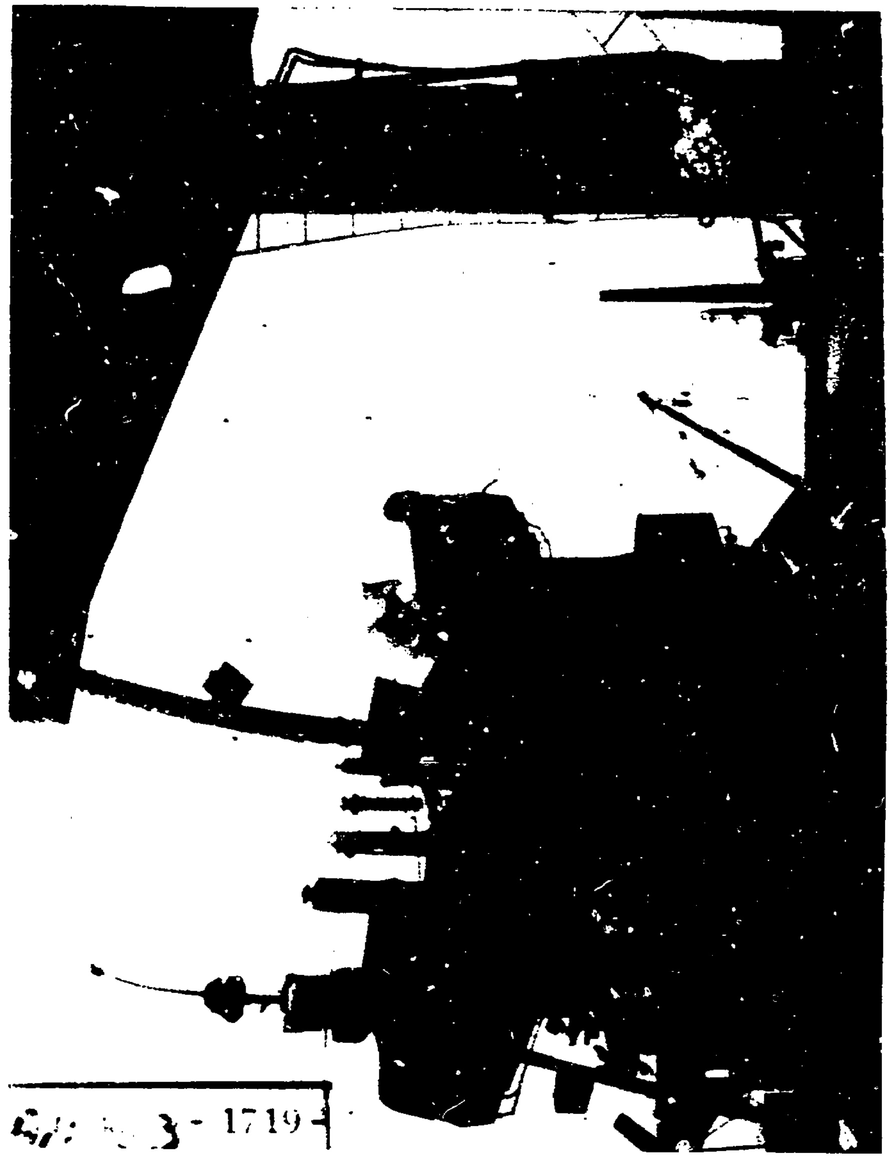
AA-CR-65-1848-12. U.S.S. RALPH TALBOT (DD390). Close-up of air blast damage to inboard bulkhead of wardroom pantry, main deck, port side, frame 60. This bulkhead is at far end of open transverse passageway.

AA-CR-98-1966-9. U.S.S. PENSACOLA (CA24). View of after side of forward superstructure, showing damage to flat portions of platform shields.

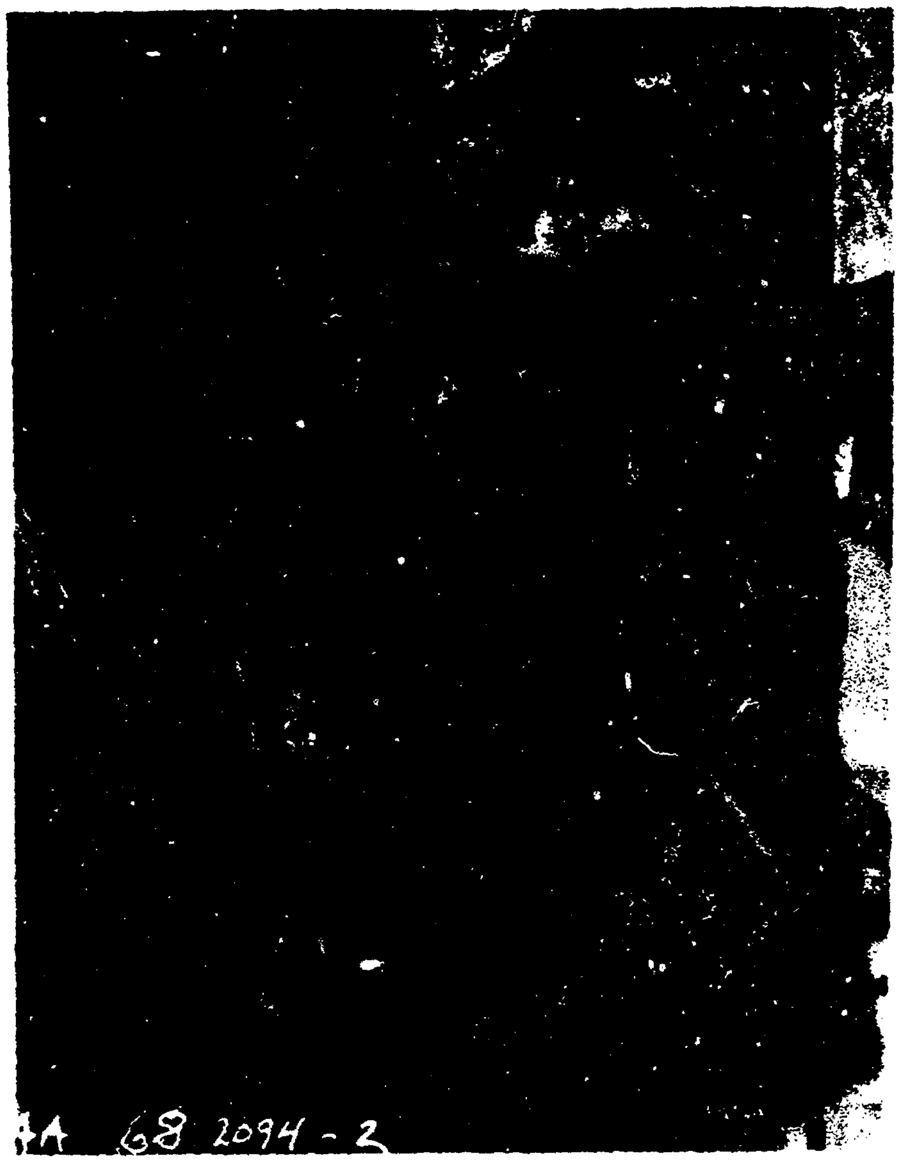


AA-CR-68-1755-10. U.S.S. PENSACOLA (CA24). Looking aft on starboard side, showing air blast damage to flat portion of shield on searchlight platform.

AA-CR-80-1894-3. U.S.S. SALT LAKE CITY (CA25). Looking aft from frame 51, port side, showing air blast damage to gun shield.



AA-CR-63-1719-5. U.S.S. SALT LAKE CITY (CA2:,. Looking forward from port side near stern at mainmast tower, showing air blast damage to flat portions of shields.



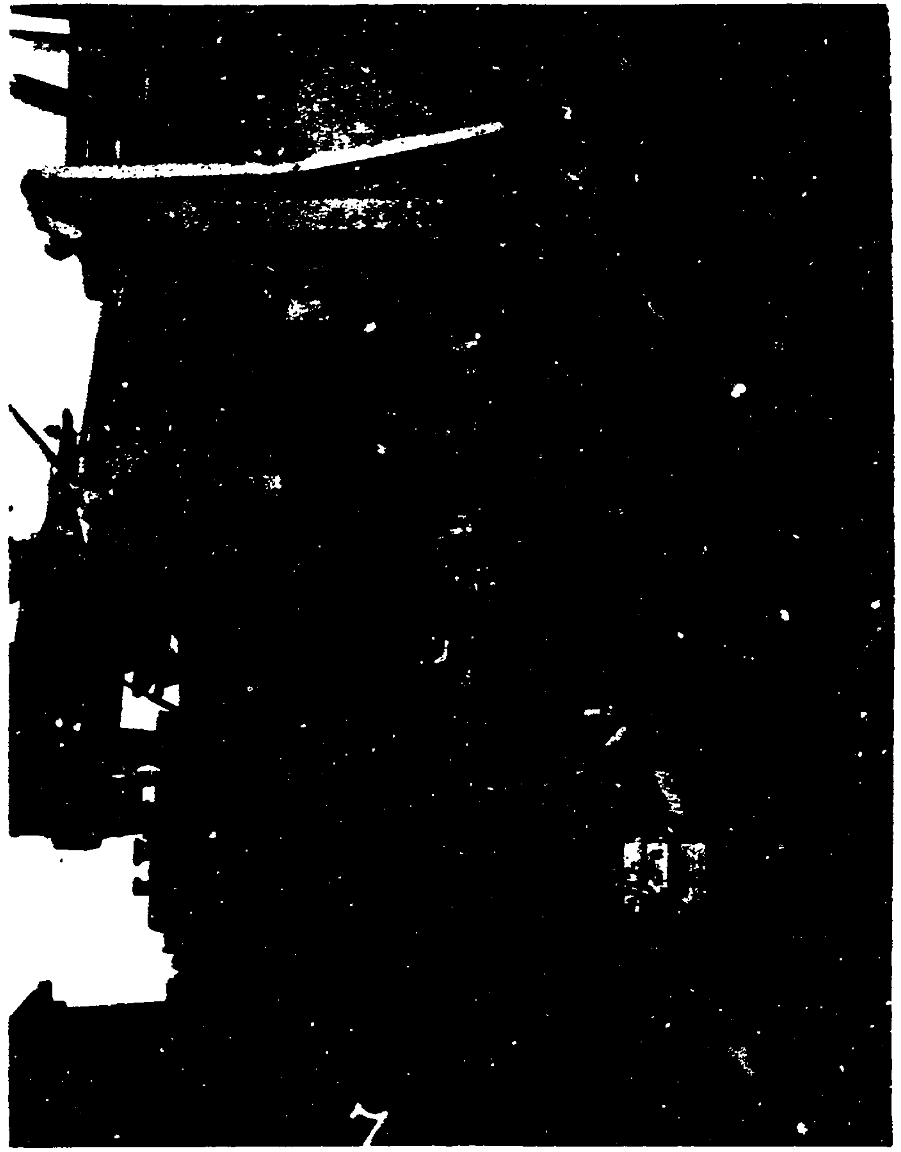
AA-CR-68-2094-2. U.S.S. ARKANSAS (BB33). Looking down on starboard side of top of fire control station, showing deflection inboard of flat portion of shield. Note also the panel deflection of the deck.

AA-CR-68-1754-4. U.S.S. PENSACOLA (CA24). Looking upward at air blast damage to underside of superstructure deck in athwartship passageway, frame 46 to 49.

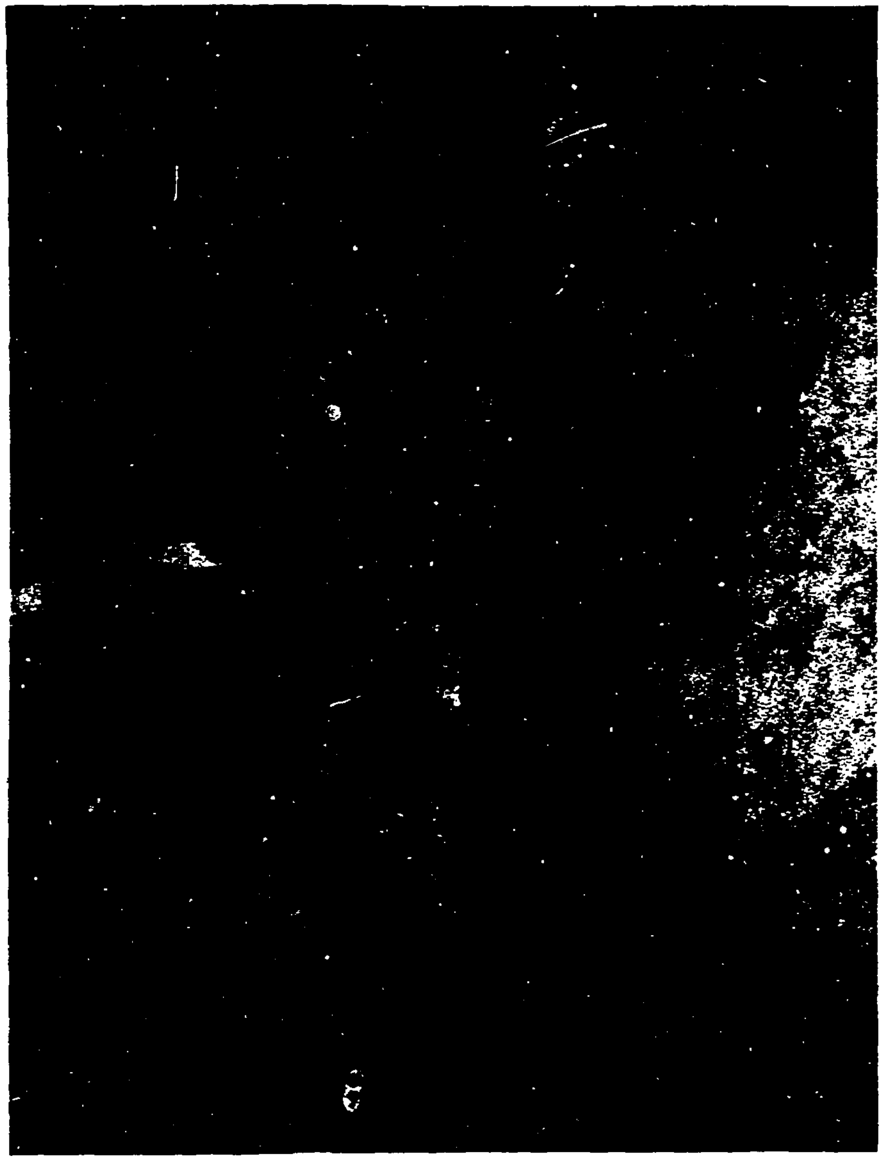
AA-CR-175-2037-12. U.S.S. INDEPENDENCE (CVL22). Looking aft on flight deck, showing damage to deck over hangar space.

AA-CR-68-2094-12. U.S.S. ARKANSAS (BB33). Failure of deck girder connection under fire control station in foremast.

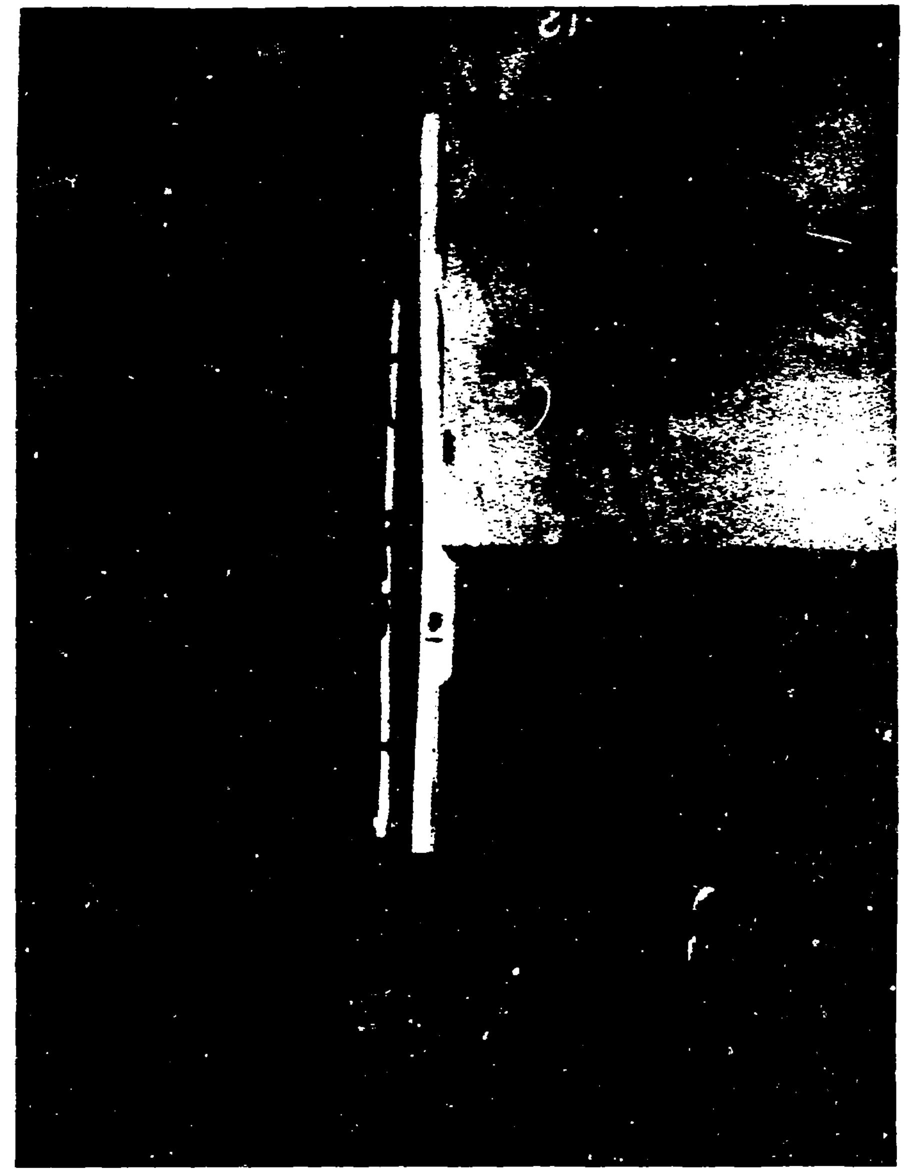
AA-CR-80-1910-5. U.S.S. NEVADA (BB36). Deflection of superstructure deck at frame 50 under overhang of turret 2, looking forward and to port.



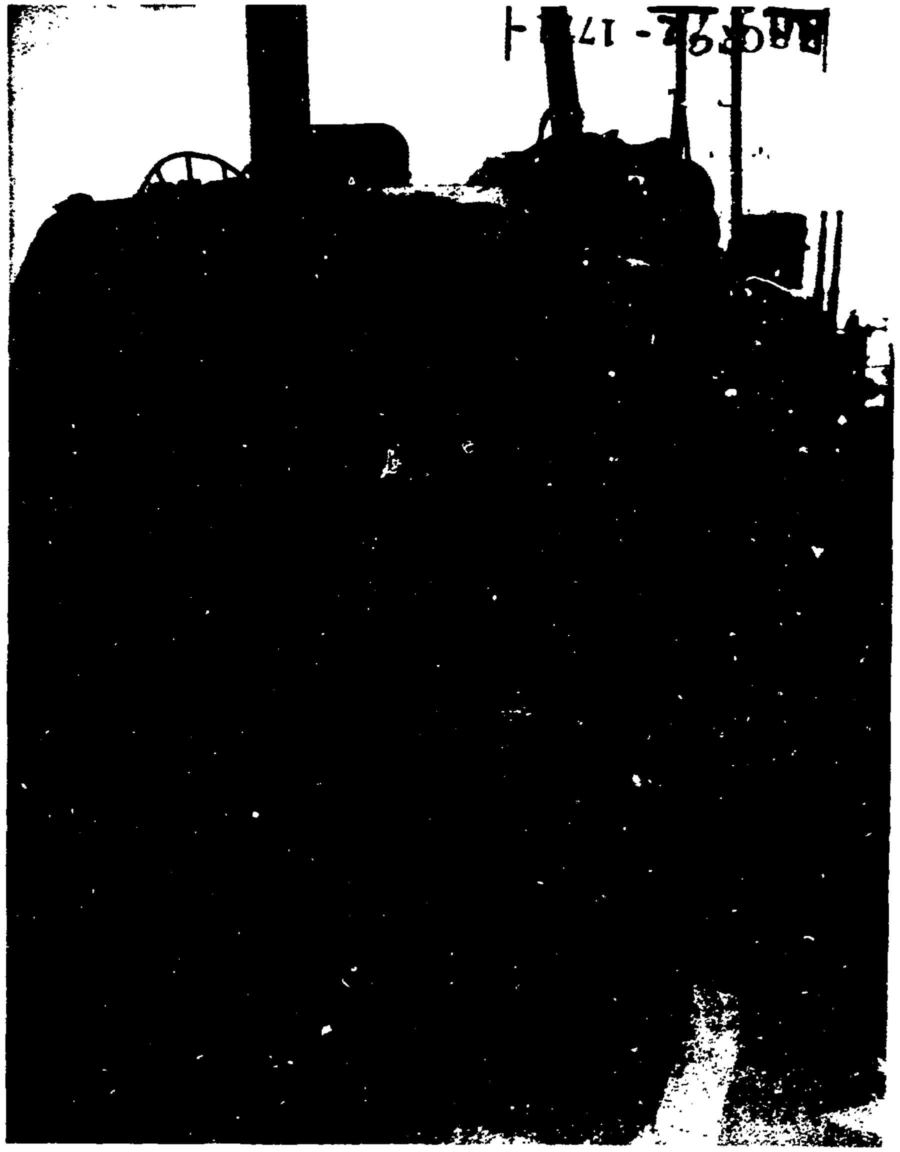
A A-CR-68-1758-7. U.S.S. PENSACOLA (CA24). Looking to starboar on superstructure deck level at frame 85, showing depression of deck around galley skylight.



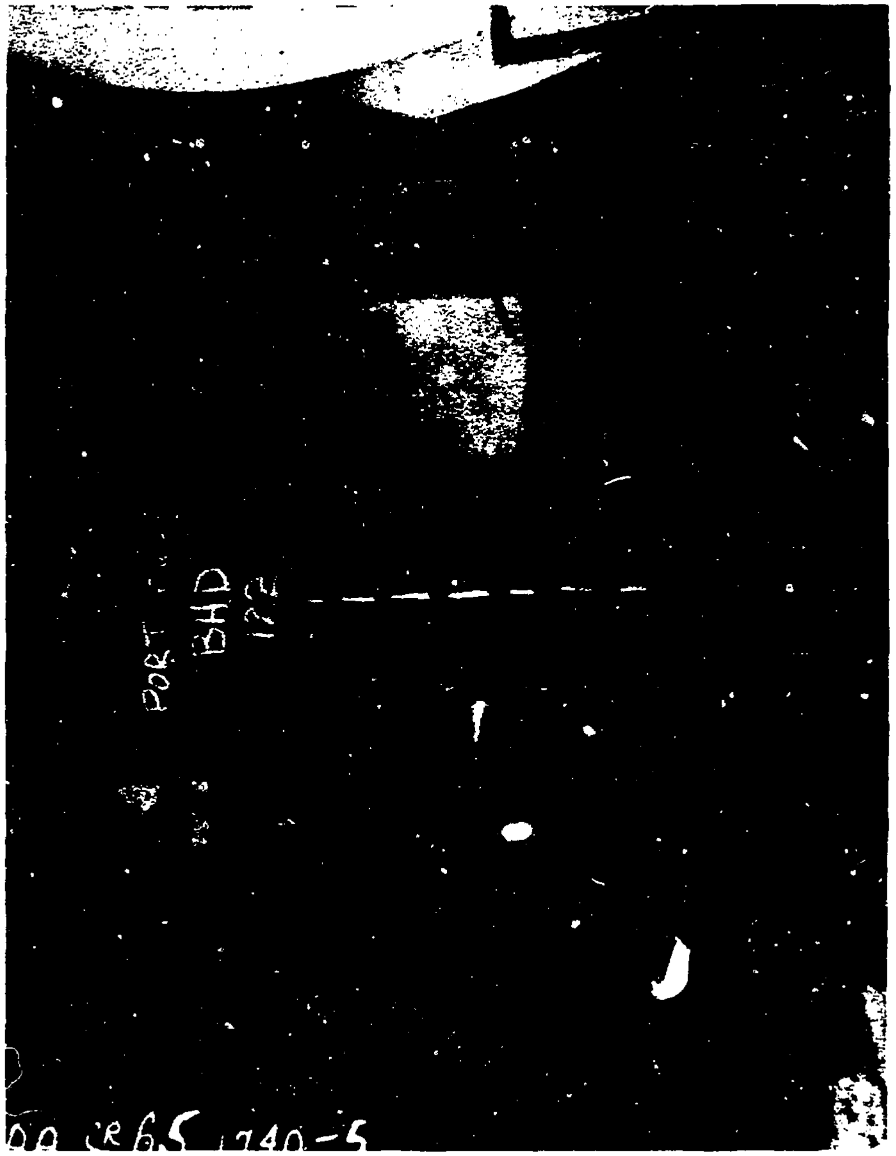
AA-CR-80-1910-8. U.S.S. NEVADA (BB36). Looking forward and to starboard from frame 65 on superstructure deck, showing distortion of deck from air blast.



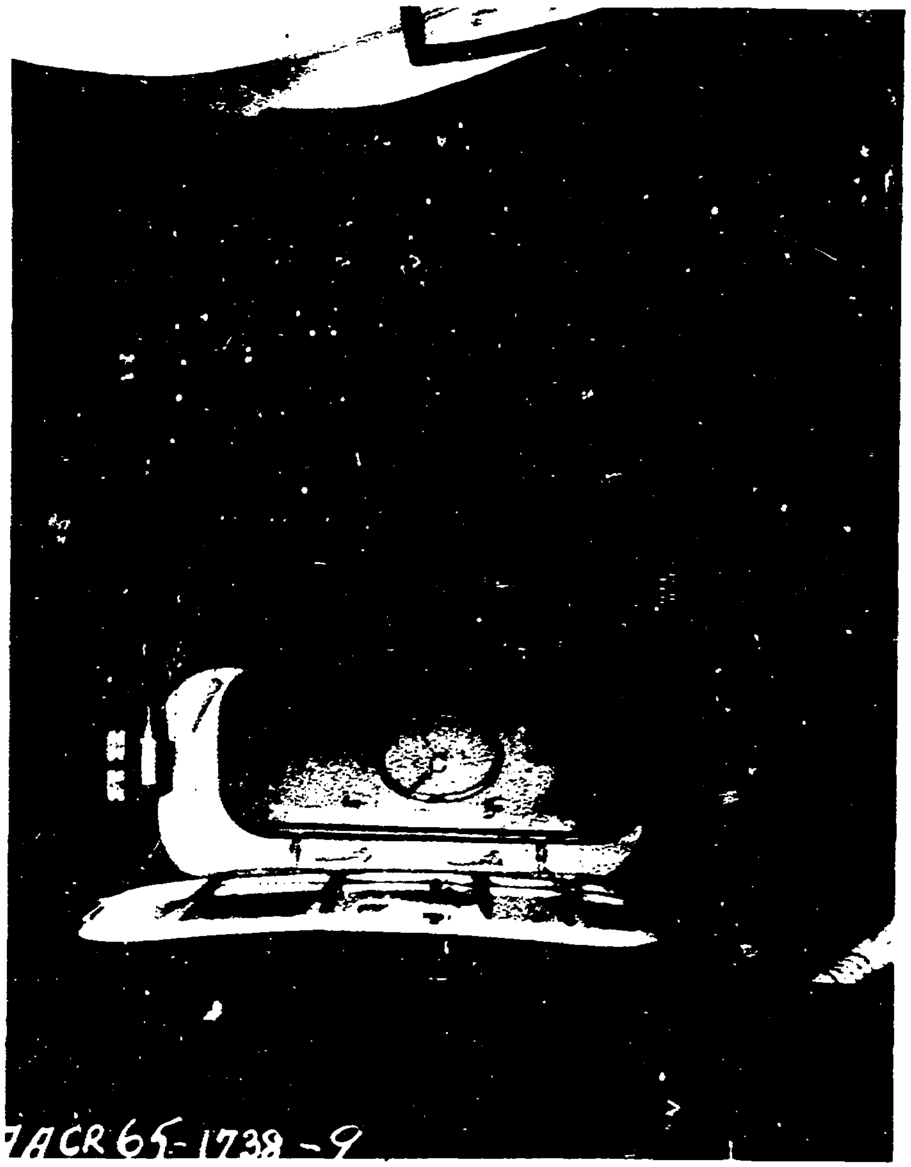
AA-CR-65-1737-12. U.S.S. BUTTE (APA68). Air blast damage to door 03-41-6. Note that bulkhead is relatively undamaged.



AA-CR-92-1771-11. U.S.S. RHIND (DD404). Air blast damage to superstructure, looking forward on starboard side from stern, showing dished door in diagonal bulkhead.



AA-CR-65-1740-5. U.S.S. BARROW (APA61). Looking aft in port main deck weather passageway at air blast damage to doors in bulkhead 122.

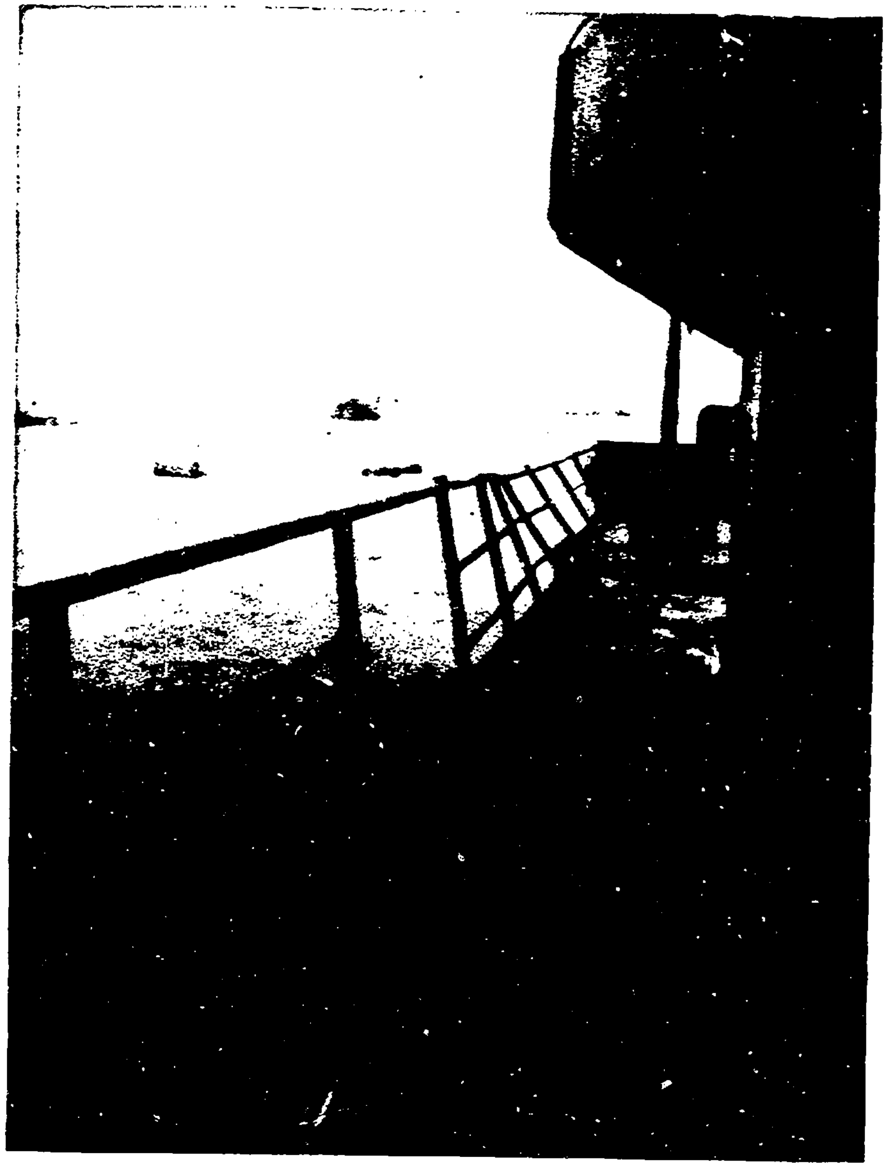


AA-CR-65-1738-9. U.S.S. BUTTE (APA68). Looking aft in port main deck weather passageway at air blast damage to doors in bulkhead 122.

AA-CR-82-1824-2. U.S.S. BARROW (APA61). Air blast damage to double doors to carpenter shop, upper deck, frame 130, port side. The air blast originated off the port bow.

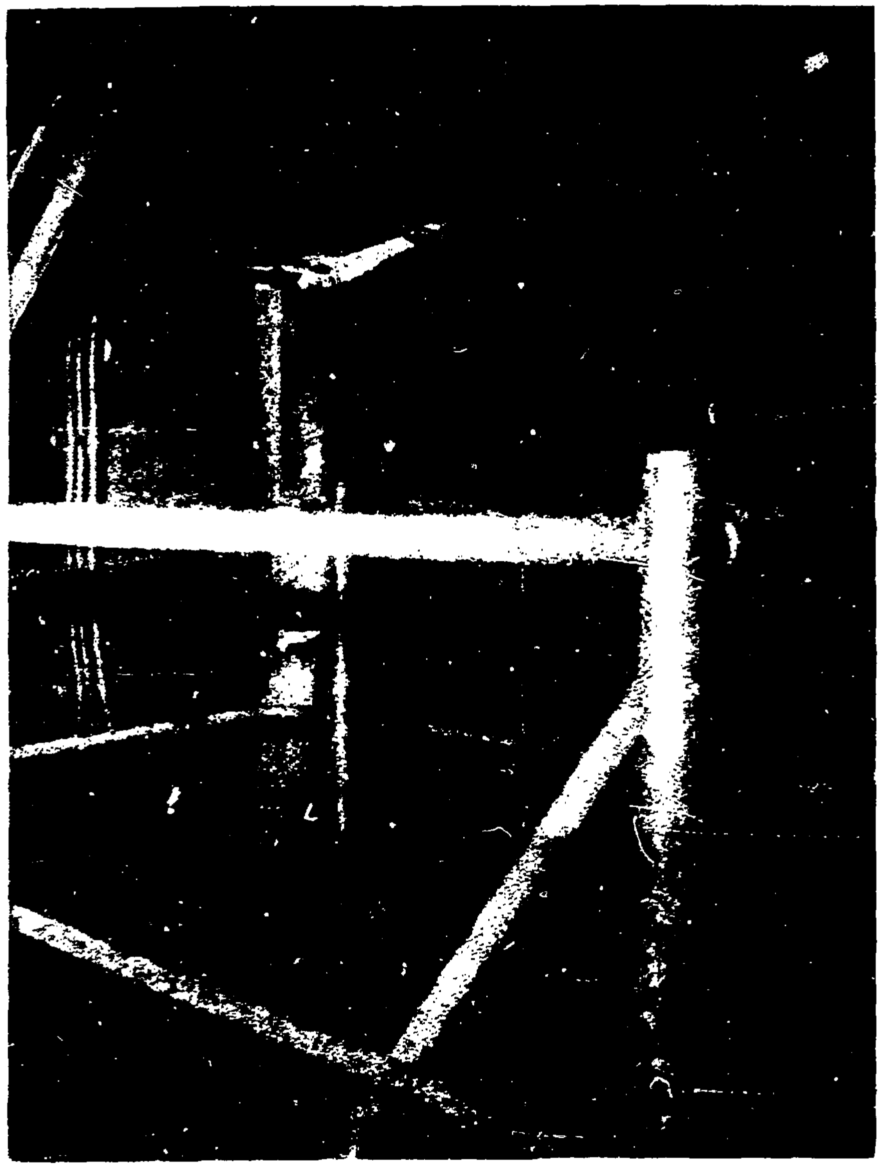
AA-CR-68-1760-5. U.S.S. PENSACOLA (CA24). Diagonal after starboard face of deck house on navigating bridge level, showing extreme damage to door. This door was about normal to the direction of the air blast.

AA-CR-68-1968-5. U.S.S. PENSACOLA (CA24). Air blast damage to ladder between radar control room house top and forward fire control station. Cast aluminum treads failed at connections.

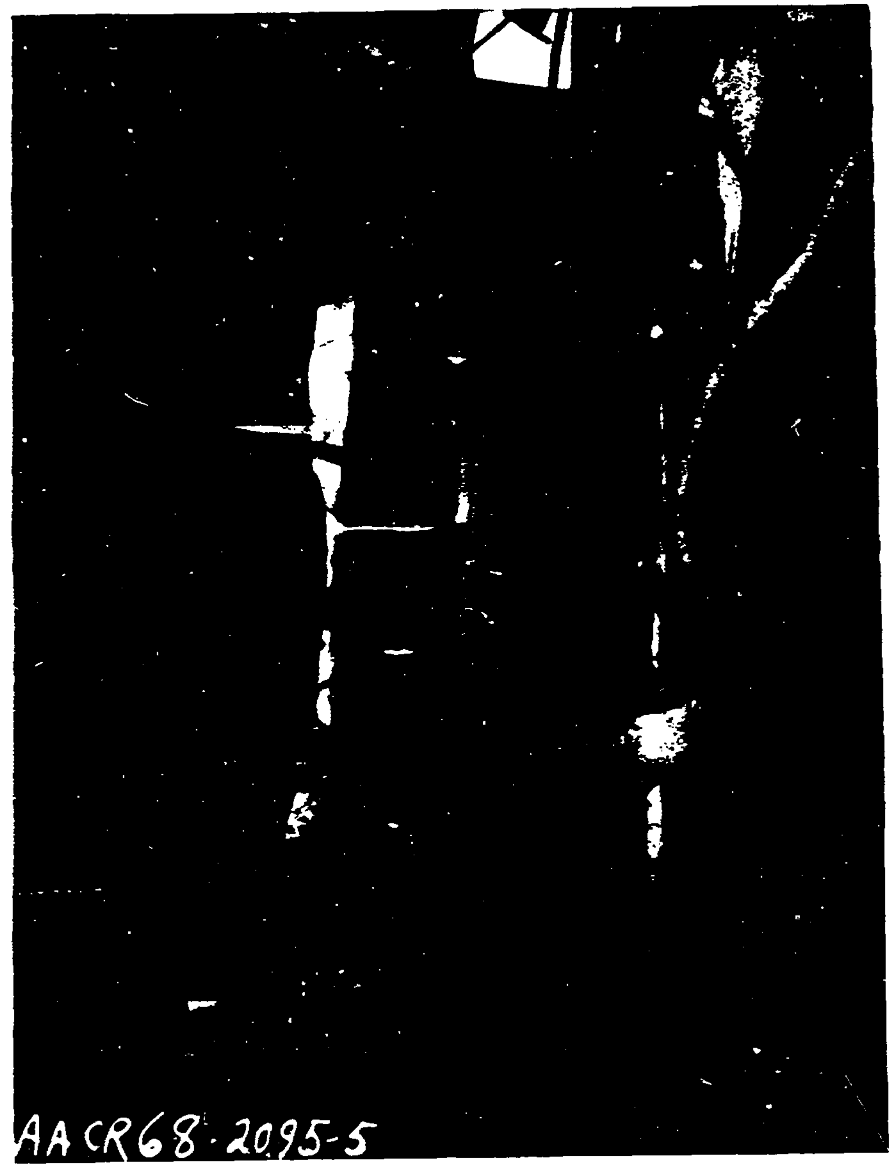


AA-CR-175-2154-11. ***U.S.S. NEVADA*** **(BB36). Looking aft along starboard side of superstructure deck from frame 62, showing damage to the hand rail.**

AA-CR-98-1967-8. U.S.S. PENSACOLA (CA24). Air blast damage to ladder between communication platform and emergency platform, starboard side. Cast aluminum treads failed at connections.



AA-CR-68-2095-7. U.S.S. ARKANSAS (BB33). Air blast damage to after side of ready service locker on the bridge deck, starboard side, frame 48



AA-CR-68-2095-5. U.S.S. ARKANSAS (BB33). Lookingaft on bridge deck at air blast damage to life jacket lockers.

AA-CR-66-2047-9. U.S.S. NEW YORK (BB34). Air blast damage to port flag bag, looking forward and inboard.

AA-CR-65-1733-10. U.S.S. CARTERET (APA70). Air blast damage to starboard flag bag. Note heavier structure is intact.

AA-CR-82-1827-2. U.S.S. BRULE (APA66). Looking downward and forward from starboard searchlight platform at air blast damage in fire control and signal station.

AA-CR-82-1828-6. U.S.S. BRULE (APA66). Looking aft at blast damage to gear locker on starboard wing of navigation bridge.

AA-CR-82-1827-5. U.S.S. BRULE (APA66). Air blast damage to metal joiner bulkheads around ladder 1-68-1, main deck, frame 68, starboard. Doors were left open for test.

CAUTION

This Document Contains
ATOMIC WEAPONS INFORMATION

NOTICE

This document contains atomic weapons information. Distribution is limited to recipients authorized by the Defense Atomic Support Agency (DOD) and/or the Division of Military Application (AEC)

Defense Special Weapons Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

TRC

10 April 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of Reports

The Defense Special Weapons Agency (formerly Defense Nuclear Agency) Security Office has reviewed and declassified the following reports:

AD-366718	XRD-32-Volume 3	
AD-366726	XRD-12-Volume 2	
AD-366703	XRD-16-Volume 1	
AD-366702	XRD-14-Volume 2	
AD-376819L	XRD-17-Volume 2	
AD-366704	XRD-18	
AD-367451	XRD-19-Volume 1	
AD-366705	XRD-20-Volume 2	AD-366705
AD-376028L	XRD-4	
AD-366694	XRD-1	
AD-473912	XRD-193	
AD-473891	XRD-171	
AD-473899	XRD-163	
AD-473887	XRD-166	
AD-473888	XRD-167	ST-A 28 JAN 80 made target
AD-473889	XRD-168	

TRC 10 April 1997

SUBJECT: Declassification of Reports

AD-B197749	XRD-174
AD-473905	XRD-182
AD-366719	XRD-33 Volume 4
AD-366700	XRD-10
AD-366712	XRD-25 Volume 1
AD-376827L	XRD-75
AD-366756	XRD-73
AD-366757	XRD-74
AD-366755	XRD-72
AD-366754	XRD-71
AD-366710	XRD-23 Volume 1
AD-366711	XRD-24 Volume 2
AD-366753	XRD-70
AD-366749	XRD-66
AD-366701	XRD-11
AD-366745	XRD-62.

All of the cited reports are now **approved for public release; distribution statement "A" applies.**

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center

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