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BUREAU OF SHIPS
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14 October 1946.

From: E. H. BATCHELLER, Commander, U. S. Navy.
To : Chief of the Bureau of Ships.

Subj: Operation Crossroads - Personal Observations on the Atomic Bomb Tests at Bikini.

Ref: (a) BuShips Confidential Memo of 30 Sept. 1946.

I GENERAL OBSERVATIONS AND OVERALL IMPRESSIONS

1. The experimental explosion of two atomic bombs at Bikini this past summer has permitted an unparallelled opportunity to evaluate the potentialities of the Atomic Bo mb as a weapon and to determine from the results of the explosions on Naval vessel targets what changes in the design of Naval ships are desirable to increase their power to resist this form of attack.

2. The loading imposed on the target ships by the explosion of these atomic bombs differed from that imposed by conventional explosives in two major respects: first, the physical loadings (air blast, water-shock and heat) were far more severe than ever before experienced being of such magnitude as to act on a ship as a whole rather than against some portion or section of the ship; second, for the first time ships were subjected to large amounts of radiation from radioactive materials and to contamination from the radioactive by-products of the atomic explosion.

3. No one who witnessed the tests could fail to be impressed by the destructive power of the bomb. The explosions were spectacular and awe-inspiring. The visible material damage on vessels close to the point of burst was extensive. One fact, however, became apparent at once. This fact was that for both the air burst and for the subsurface burst the material destructiveness of the bomb fell off rapidly with the distance from the point of explosion. Although the bomb releases vastly more energy than conventional explosives its ability to do material damage is confined to a reasonably well defined range. This range though large when compared to that of other known explosives is not great when compared to the distances normally kept when naval vessels steam in formation.

4. To intelligently approach the problem of incorporating the lessons learned at Bikini in naval ship design it

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seems desirable to make first some sort of an assessment of the probable success of an atomic weapon attack against naval targets, the probability of its employment, and the nature or form of attack which may be expected. Such an assessment is necessary to determine the severity of the threat of the weapon and to justify for any given type ship such reduction in ability to perform its primary mission as may result from changes in characteristics designed to combat the threat.

5. The following overall impressions and opinions are based on observations at Bikini, on certain of the instrumentation data obtained during the tests and on conversations with other members of JTF-ONE. They are made in advance of a detailed study of all the data accumalated.

A. The atomic projectile is not an ecconomical weapon in a military sense for use against naval vessels at sea. At present the high cost of manufacturing atomic bombs and the apparently limited supply of raw material from which the bombs are made make them more expensive to use than their effectiveness against ship targets justifies. Even though future technilogical advances reduce the cost of the bomb and new sources of fissionable material are found it is believed that the supply of these bombs will always be relatively limited. Furthermore because of the mechanism of a chain reaction the charge of fissionable material in an atomic bomb has a definite minimum and a practical maximum size. This fact coupled with the need for elaborate mechanisms to initiate fission and to protect personnel will tend to set limits on the size and types of weapons in which atomic explosives can be used. Since the distance between naval vessels steaming in formation need be increased only slightly to limit the number of vessels within the lethal radius of an atomic explosion to one or two the value and desirability of this form of attack from a military stand point is seriously questioned.

The atomic bomb and atomic weapons which may be developed in the future seem much more valuable for employment against strategic targets in a country's industrial and population centers rather than for use tactically against a ship or a well dispersed formation of ships. The possible use of atomic weapons against ships at sea, however, cannot be discounted entirely.

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B. Naval vessels will be most suceptable to Atomic Weapon attacks when such attacks are made against port facilities and coastal industrial areas or on amphibious landing operations.

Fleets are supported from shore bases and vessels in port for fueling taking on stores or repairs will be incidental targets in attacks on such bases or on the industrial areas and population centers which in many cases are contigious to such bases.

A major amphibious operation in which large numbers of ships and personnel are concentrated in a relatively small area would be a worth while target for an atomic weapon attack.

It seems likely that such attacks will be by aerial bombings or by rockets and guided missiles. For the attack against waterfront areas and amphibious operations missiles which are designed for subsurface explosions appear to offer the best prospects of effectiveness.

C. The subsurface form of atomic weapon attack appears more effective in causing material damage to ship targets than the air burst attack.

The subsurface shot at Bikini this past summer was fired at a depth considerably less than the theoretical optimum for maximum damage range. The gas bubble formed by the explosion vented through the surface before it reach its maximum size. Even so its lethal range (i.e. the distance at which it sank ships) was almost as great as that of the air burst for surface ships and it sank submerged submarines at distances beyond its lethal range for surface ships. Although material damage to surviving ships was less wide spread than that caused by the air burst, it was in most cases much more severe in its effect of the ships military effectiveness.

D. The Radiological aspects of an atomic weapon attack presents a serious problem because of its effect on personnel.

Perhaps the most significant and threatening single feature of an atomic weapon attack brought to light by the tests at Bikini was the heavy and persistant radiological contamina-

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tion of the target vessels surviving the subsurface burst. Fission products entrapped in the water were carried up in the plume and disseminated throughout the lagoon. Although measurements indicated that the portion of the fission products so entrapped was relatively small only a few ships most of them on the up wind fringe of the array escaped. Radioactivity was so intense on many of the ships that they could be boarded for only brief intervals over a period of weeks and in some cases months.

E. The Performance of the Target Vessels in withstanding the attack was generally good.

The overall ability of the target ships to withstand the loading imposed by the atomic bombs was up to the most optomistic expectations. Ships were not atomized; they did not disintegrate; nor did they glow with induced radioactivity. With the exception of the NAGATO which sank from progressive flooding five days after the subsurface shot all the vessels sunk were subjected to loadings greatly in excess of that which they were designed to withstand. The above is not intended to imply that no improvements in design were indicated by the tests. Much valuable information and data was obtained on the relative ability of the various components of naval vessels to defeat the imposed loading. Weak points were brought to light and lines of investigation for further study were indicated. It is felt, however, that no radical or major change in the design of the types exposed as targets was demonstrated as being necessary. In general it is believed that the tests indicated our current design of ships structure is sound and adequate and that future developments should be evolutionary rather than revolutionary.

II COMPARISON OF THE AIR AND SUBSURFACE BURSTS

1. A comparison between the air burst and the subsurface burst in relationship to their effect on the target vessels is complicated by the fact that the air burst was several hundred yards away from the point intended. The character of loading imposed by each shot, however, was clearly discernable.

2. In the case of the airburst the primary cause of damage was the air blast or air shock associated with the explo-

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sions. The air blast peak pressure as measured by various instruments at Bikini was on the order of 100 lbs. per square inch at 400 yards from the foot of the burst (i.e. the point on the surface directly below the burst); dropped to about 55 p.s.i. at 500 yards; was about 20 p.s.i., at 900 yards and 7.5 p.s.i. at 1200 yards. Extensive above-water damage was general on target ships within 900 yards of the foot of the burst. Beyond that distance the damage was for the most part superficial and did not greatly affected the fighting efficiency of the ships. The nature and severity of the damage varied depending on the type of ship and upon the ship's orientation with respect to the direction of blast.

3. Five vessels were sunk by the air burst. Of these the GILLIAM (APA57) at about 100 yards sank within one minute of the time of the explosion. The CARLISLE another APA at about 400 yards sank within a half hour of the explosion. The ANDERSON ((DD411) at about 600 yards rolled over and sank within about 8 minutes after the explosion. The LAMSON (DD367) at about 700 yards capsized within 30 minutes after the explosion and sank some hours later. The SAKAWA an ex-Japanese CL lying stern to the explosion at a distance of about 450 yards sank 26 hours after the explosion.

4. Of the surviving ships the damage to the following vessels is perhaps the most significant:

(a) The submarine SKATE at about 380 yards was a shambles topside with such of her superstructure as was not wiped off distorted and twisted. The strength hull, however, was intact, and the vessel was gotten underway on both engines without difficulty when the crew returned aboard.

(b) The YO 160 a concrete oil barge at about 450 yards was demolished topsides but the hull suffered no serious damage.

(c) The INDEPENDENCE CVL22 at about 550 yards, was heavily damaged above water along the port side and on the flight and hangar decks with serious structural distortion down through the third deck.

(d) The PENSACOLA at about 750 yards, the SALT LAKE CITY at about 900 yards, the ARKANSAS at about 650 yards, and the NEVADA at about 600 yards, suffered incapacitating stack, uptake and boiler damage, general topsides damage and serious distortion of the main deck and supporting structures.

(e) The CRITTENDEN an APA at about 600 yards suffered topside damage and considerable distortion in the way of number one hold but was not immobilized.

5. In addition to the damage cause by air blast, fires ignited in army quartermasters material exposed for test and in cordage and fenders by the flash heat were wide spread throughout the array; some occuring as far as 2400 yards from the point of burst. Because the target ships were unmanned these fires burned unchecked and in some cases caused moderate secondary damage. The effect of the flash heat on exposed personnel would probably have been serious out to ranges of about 2000 yards but any screening at all would have materially reduced casualties. Standard Navy flash proof clothing is believed to be a satisfactory measure to protect against this heat.

6. There was no evidence of significant water shock and no persistant radiological contamination of target ships. As evidenced by its effect on the animals exposed for the test the radiation from the burst itself appears to have been lethal chiefly to animals which were not screened from direct attack. No indication of missile damage was noted.

7. It is interesting to note at this point that even the worst damaged ships surviving the airburst were able to steam under their own power after only moderate repairs.

8. Material damage from the subsurface burst was predominantly from water shock, with no evidence of flash heat and only minor indications on surviving ships of air blast damage. The SARATOGA at about 400 yards the ARKANSAS at about 250 yards the YO 160 at 600 yards and the submerged submarines PILOTFISH at 400 yards, APOGON at 850 yards and SKIPJACK at 800 yards were sunk in this test. The LCT 1114 at about 500 yards was capsized but floated bottom up until sunk by demolition charges. The NAGATO at 800 yards also sank five days after the explosion from progressive flooding which because of radiological condi-

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tions could not be controlled. The watertight integrity of the NAGATO was not good. There was some flooding during the air burst from which the ship suffered no underwater damage.

9. Swamping by the tons of water descending from the plume possible contributed somewhat to the rapidity with which the SARATOGA and the YO 160 sank.

10. The fact that the APOGON and SKIPJACK were sunk while the GASCONADE, FALLON, HUGHES and LST 133 at considerably lesser distance remained afloat substantiates the instrumentation data that the peak water shock wave pressure is affected by the air-water interface and that beyond a zone defined by a specific angle of incidence of the shockwave with the water surface the pressure is reduced considerably below that which might be expected from an accoustical theory. This affect on the peak pressure extends to greater depths below the surface with an increase in distance from the critical zone.

11. Material damage suffered by the surviving ships was confined to ships within the 1000 yard range and for a given distance from the burst was most severe on deep draft ships. The PENSACOLA at about 800 yards, the HUGHES at about 650 yards and the GASCONADE and FALLON at 550 and 500 yards respectively all suffered major machinery derangements which would have required extensive overhauls to repair. For the depth of explosion used at Bikini the range of incapacitating damage to surface ships was about 800 yards.

12. The radiological contamination of the target vessels which followed the underwater burst was the most startling and threatening aspect of either test. Whereas indications of radioactivity on target vessels after the air burst were confined to vessels close to the point of burst and dropped to within the permitted tolerance on all vessels within three days, the radiological contamination which followed the subsurface burst extended to vessels beyond the 4000 yards radius and was so heavy and persistent that most target vessels could be boarded for only brief interval over a period of weeks. Although the effects of exposure to radioactivity are not immediate they are none the less certain and had the target ships been manned the eventual loss of life and consequent loss of military efficiency would have been high.

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13. As might be expected the heaviest concentrations were topsides but not inconsiderable amounts found their way into the interior of the ships. This penetration probably would have been increased had the ships been manned because of radioactive matter drawn in through ventilation systems and carried into the interior spaces on the shoes and clothing of the crew. On the other hand had the crews been aboard and aware of the dangers present the degree of contamination might have been considerably reduced by prompt action in washing down the exterior of the ships before the radioactive matter had opportunity to adhere to the surface.

14. The nature of radioactivity is such that natural or induced radioactive elements can not have their rate of radiation altered by chemical or physical means. Every substance looses radioactive properties at a specific rate which determines its "half-life" (i.e. the time required for its radioactivity to decrease by half). The half life of some elements is a few minutes while other elements have a half life of many thousand years. Thus radiological decontamination requires the mechanical removal of the radioactive material. This is rendered doubly difficult by the extremely small size of the particles involved.

III DESIGN CHANGES INDICATED AS A RESULT OF THE BIKINI TESTS

1. The only really new factor introduced by the Bikini Tests into the problems of designing naval ships is that of the radiological contamination which followed the subsurface burst. As has been mentioned earlier decontamination is difficult because of the very small size of the radioactive particles and the fact that their radioactivity cannot be reduced or eliminated by chemical or physical means. Studies of this problem are underway at the present time. What lines they are following is not known but it would seem desirable to include the following broad catagories:

A. Prevention of ingress of radioactive material into the ship by:

(1) Screening of openings in the structure.
(2) Use of filters.
(3) The use of air purification and recirculation systems to permit closing off vital spaces from the outside atmosphere

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(4) Indoctrination of Personnel.

B. Development of surface paints or coatings which will inhibit the adsorbtion or absorbtion of the radioactive particles by exterior surfaces.

C. Development of liquids which will take the radioactive substances into solution and enable washing them away.

D. Provision of reliable indicating and measuring devices suitable for general shipboard use in determining the locations and concentrations radiological hazzard.

2. Analyzing the material damage done to the target ships at Bikini in connection with the air and water shock-loading data from the instrumentation program it appears that the minimum distance from an atomic explosion that a ship can be without suffering incapacitating damage is not suceptible to much reduction without making such drastic changes as would seriously handicap a given type in the performance of its mission. Since at the present time there is no reason to doubt the validity of the missions for which our naval types are designed such changes appear unwise and unwarranted. The danger radius of an air explosion for most types appears to be in the neighborhood of 900 yards where the air pressure is about 20 p.s.i. To reduce that radius to 500 yards where the air pressure is about 55 p.s.i., would require a tremendous amount of strengthening. This would mean on the same displacement less guns, less armor, less cargo, fewer planes, fewer troops or smaller cruising radius or a combination of the above reduction. Although some improvement is possible the most effective way of meeting the bomb's destructive threat, certainly the cheapest from the standpoint of effect on a ship's ability to carry out its mission, is to so dispose ships tactically that only one or two will be exposed to an atomic attack at a time.

3. There were however, many lessons to be learned from the results of the tests at Bikini and a number of local weakness in our ships were highlighted. The more salient of these are discussed briefly below:

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(a) The wide spread damage to stacks, uptakes, and boilers resulting from the air burst merits close study. Damage to stacks was in many cases transmitted down to the uptakes while boiler air casing were in some cases ruptured where other damage to the ship was of a minor nature. In general the pressure parts of the boilers suffered no damage from air blast.

(b) Weather doors and door frames were a point of weakness. Developments should continue to produce a door assembly which will be as strong as adjacent panels of plating.

(c) Clean-up topsides: Reduce the amount of clutter on the upper decks. Gear lockers, movies booths and similar flimsey work is an unnecessary hazzard under air blast. It readily becomes a missile hazzard to personnel and may block vital accesses when they are needed most. Cordage, hawsers, fenders, etc., are a fire hazzard but a topsides stowage for them is considered preferable providing they are not near other flamable materials. The fires which followed the air burst would have been negligible had crews been aboard the target vessels.

(d) Rounded surfaces performed much better under air blast than flat surfaces and should be worked into designs where practicable. Topsides plating should be as heavy and as well stiffened as weight and stability considerations permit.

(e) Aircraft elevators on carriers should be made more rugged. The SARATOGA which was outside the 2000 yard circle for the air burst suffered a derangement to the automatic follow up mechanisim of her elevator which prevented its operation until the defective part was removed. Although the elevator could then be operated satisfactorily by hand the removal of the part required about four hours. The elevator was similar to the type installed in ESSEX class carriers. The derangement was caused by minor distortion of the elevator platform. Although elevators now being developed for the heavier planes will doubtless be more rigid consideration in their design should be given to air blast loading.

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(f) Studies should be continued in the shock mounting of machinery and equipment. In general the performance of shock mounted equipment exceeded expectations. The transmission of shock through the ships structure to locations remote from the areas of loading did not prove to be a major source of damage in either test. Heavy equipment and machinery mounted on or close to the hull structure below the waterline suffered heavily in surviving ships close to the subsurface burst, and the shock protection of such equipment requires improvement.

(g) Electronic equipment stood up well where any screening or shielding was present. Antennas and radar spinners can be improved to withstand higher air blast pressures. Whip antennas appeared superior to string antennas.

(h) The most effective means of bottom protection for large ships should be vigorously sought. The balance between multiple bulkhead side protection and double bottoms compartmentation should be reviewed. This question is already under study in connection with influence exploders for torpedo warheads and mines and the lessons learned from these studies will be equally applicable in combatting the water shock pressure of a subsurface atomic explosion.

(i) The hatch pontoons on the target APA are too easily dislodged. Moderate to minor shock sent them cascading down into the holds where they did considerable damage to test equipment and instruments.

(j) The design of sea chests and shell connections below the water line with their attendant sea valves should be the subject of close scrutiny. These are points of discontinuity and hence of possible weakness under water-shock loading. They should be designed to be at least as strong as the adjacent panels of plating but should not form hard spots around which the plating will rupture or tear.

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