**ARMOR PLATE BALLISTIC ACCEPTANCE TESTS FROM U.S. NAVY BUORD ORDNANCE SPECIFICATION**

**O.S. 751, “STEEL ARMOR FOR U.S. NAVY”**

**(FINAL REVISION “K” OF 29 OCTOBER 1947)**

**By Nathan Okun (26 July 2011)**

**CLASS “A” ‘THICK CHILL’ (CIRCA 55% FACE) FACE-HARDENED ARMOR**

Class “A” armor was specified down to a minimum thickness of 2.25”. However, the minimum thickness of standard KC-type cemented and decrementally-hardened Class “A” armor--face hardness dropped in two or more steps or smooth curves from the face surface to the soft back layer–was either 4” in 4-6” tapered cruiser belt plates (lower edge) or 5” in uniform-thickness cruiser plates (barbettes and turrets for the most part). Thicknesses less than this were of composition similar to U.S. Army light face-hardened steel armor or 19th Century Harveyized face-hardened steel armor with a cemented (high-carbon or “case-hardened”) face of about 1-1.5” thickness and a soft back, having only a single step in hardness at their boundary. Little, if any, Class “A” armor under 4”/5” thick as specified above was ever used in the U.S. Navy. Class “A” armor was never used for horizontal protection where highly oblique impacts were expected to occur.

Two impacts by either the same projectile type or one of several alternate projectile types specified below for that given plate thickness at any of the allowed impact obliquity angles (normal = 0° obliquity) and striking velocities (in ft/second) can be used in testing any plate selected from a lot of contract plates, at the discretion of the U.S. Naval Proving Ground test conductor. Failure of one plate to pass the test may result in another plate being selected and tested, at the discretion of the test conductor. Failure of both plates will usually cause the entire lot to be rejected; even if the second one passes, a third plate may be required to confirm the results and it must always pass.

In addition to the standard metallurgical test criteria (hardness, toughness, tensile strength, etc.), the armor had to meet the following three ballistic criteria to be considered acceptable when hit by the specified projectile at the specified obliquity and striking velocity (plus/minus a small tolerance):

1. No more than half, if the projectile is broken, of the projectile body (not counting the AP cap and windscreen) may completely pass through the plate and become detached therefrom, ending up behind the plate on the ground. This is an absolute minimal form of the U.S. “Navy” Ballistic Limit (NBL), which usually requires all or almost all of the projectile body to pass through the plate to define the NBL. Failure here is usually a definite reason for rejecting the plate and, possibly, the entire lot. However, some U.S. Navy AP projectiles had become so good as armor penetrators by the end of WWII that failure to stop them merely meant that another, less-damage-resistant projectile type in the tables below should be used to retest the plate, with only this latter test being cause for accepting or rejecting the lot.
2. Except for shock-induced cracks radiating from nearby holes cut into the plate face, which are to be ignored, no cracks in the plate that are more than two calibers long measured radially from the edge of the impact hole are allowed, especially no cracks to the plate edge or to nearby other impacts that were previously made in the plate. Cracking is not an absolute reason for rejection, but is a negative point when considering all results of the various tests done to the plate, ballistic or metallurgical.
3. The armor shall show the ability to cause “serious” projectile NOSE DAMAGE (“projectile breakage criteria”) of some sort (shatter, breakage, chewing, shearing, or wiping) equal to the minimum previously allowed in accepted plates of the same gauge during ballistic tests (at least 1/3 of nose gone). Damage that rendered the projectile filler “ineffective” was not required; just nose and upper body damage of some minimal sort. This determination is somewhat subjective, but pictures of previous acceptable test results were used when there was any question of minimal performance in this criterion. As with criterion (2), one plate impact failure in criterion (3) of the two projectiles fired is not an absolute reason for rejecting the lot, but only one additional (third) impact can be ordered by the test conductor and failure of that third plate test to meet this breakage criterion will be cause for rejecting the lot. Thus, failure here is more-or-less of the same importance as criterion (1) in passing or rejecting Class “A” armor. Also, by the end of WWII, some U.S. Navy AP projectiles had become so damage resistant that criterion (3), as with criterion (1) with sometimes the same superior projectile type, was dropped for those particular tests, with further ballistic tests with other projectiles of less damage-resistant type being required to test this criterion.

NOTE: This minimal damage-causing criterion (3), which was not in British CA ballistic test specifications, at first seems reasonable until it is realized that trying to meet this criterion actually resulted in noticeable loss of the ability to meet criterion (1), if criterion (1) had been raised as high as it could have been with the metallurgical skill of U.S. armor manufacturers during WWII. Making criterion (1) the only absolute pass/fail criterion, reducing criterion (3) to the same importance as criterion (2), and raising the criterion (1) striking velocities to their highest possible values would have resulted in stronger, more resistant armor at all thicknesses. Obviously, there was a loss of focus as to what was the most important property in an armor.

Note that linear interpolation of the striking velocity (in ft/sec) is used for a plate thickness in-between those in the tables below.

The following projectiles were used for Class “A” armor ballistic testing in this Revision of OS 751, which represented the absolute best projectiles in U.S. Navy Service at the end of WWII:

PROJECTILE #1 = 3” AP Mark 29 Mod 2 (w/high hardness AP cap)

PROJECTILE #2 = 6” AP Mark 35 Mod 9 (w/super-hard AP cap)

PROJECTILE #3 = 8” AP Mark 21 Mod 5 (w/super-hard AP cap)

PROJECTILE #4 = 12” AP Mark 18 Mod 1 (only new 12” AP Mod)

PROJECTILE #5 = 14” AP Mark 16 Mod 8 (best all-round BB AP shell)

PROJECTILE #6 = 16” AP Mark 8 Mod 6 (best super-heavy BB shell)

**TABLE IA--Small Projectiles &/or Thin Class “A” Plates**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Projectile Number** | **#1** | **#2** | **#3\*\*** | **#4** |
| **Obliquity (º)** | **20** | **30** | **30** | **40** | **30** | **40** | **30** | **35** |
| **Thickness (inches)** |  |  |  |  |  |  |  |  |
| 2.25 | 1,510 | 1,715\* | --- | --- | --- | --- | --- | --- |
| 2.50 | 1,630 | 1,835\* | --- | --- | --- | --- | --- | --- |
| 2.75 | 1,755 | 1,955\* | --- | 1,075\* | --- | --- | --- | --- |
| 3.00 | 1,875 | 2,080\* | --- | 1,170\* | --- | --- | --- | --- |
| 3.25 | 2,000 | --- | --- | 1,265\* | --- | --- | --- | --- |
| 3.50 | 2,125 | --- | --- | 1,360\* | --- | --- | --- | --- |
| 3.75 | --- | --- | 1,310 | 1,455\* | --- | --- | --- | --- |
| 4.00 | --- | --- | 1,360 | 1,555\* | --- | --- | --- | --- |
| 4.25 | --- | --- | 1,415 | 1,650\* | --- | --- | --- | --- |
| 4.50 | --- | --- | 1,470 | 1,745\* | --- | --- | --- | --- |
| 4.75 | --- | --- | 1,525 | 1,840\* | 1,110 | 1,205\* | --- | --- |
| 5.00 | --- | --- | 1,580 | 1,935\* | 1,150 | 1,270\* | --- | --- |
| 5.25 | --- | --- | 1,635 | --- | 1,185 | 1,340\* | --- | --- |
| 5.50 | --- | --- | 1,690 | --- | 1,225 | 1,410\* | --- | --- |
| 6.00 | --- | --- | 1,800 | --- | 1,305 | 1,545\* | --- | --- |
| 6.50 | --- | --- | --- | --- | 1,385 | 1,680\* | --- | --- |
| 7.00 | --- | --- | --- | --- | 1,460 | 1,820\* | --- | --- |
| 7.50 | --- | --- | --- | --- | 1,540 | --- | --- | --- |
| 8.00 | --- | --- | --- | --- | 1,620 | --- | --- | 1,220 |
| 8.50 | --- | --- | --- | --- | 1,695 | --- | --- | 1,270 |
| 9.00 | --- | --- | --- | --- | --- | --- | --- | 1,325 |

**TABLE IB--Large Projectiles & Thick Class “A” Plates**

|  |  |  |  |
| --- | --- | --- | --- |
| **Projectile Number** | **#4** | **#5\*\*** | **#6** |
| **Obliquity (º)** | **30** | **35** | **30** | **35** | **30** | **35** |
| **Thickness (inches)** |  |  |  |  |  |  |
| 10.0 | 1,345\* | 1,430 | --- | 1,265 | --- | --- |
| 11.0 | 1,450\* | 1,535 | 1,310 | 1,360 | --- | --- |
| 12.0 | 1,550\* | 1,640 | 1,410 | 1,460 | --- | --- |
| 13.0 | 1,655\* | 1,745 | 1,510 | 1,560 | --- | 1,420 |
| 14.0 | 1,760\* | --- | 1,610 | 1,660 | 1,435\* | 1,500 |
| 15.0 | --- | --- | 1,710 | 1,760 | 1,515\* | 1,580 |
| 16.0 | --- | --- | 1,810 | --- | 1,595\* | 1,660 |
| 17.0 | --- | --- | 1,905 | --- | 1,670\* | 1,735 |
| 18.0 | --- | --- | 2,005 | --- | 1,750\* | 1,815 |

**Notes for Tables IA and IB**

\* Failure to prevent a complete penetration--criterion (1)--is not cause for test failure for this projectile type and this obliquity. These test criteria are for a previous, weaker Mod of this projectile.

\*\* For these two projectile types only, failure to be damaged by the plate--criterion (3)--is not cause to fail this test. Retest plate with another tabulated projectile. These two projectiles have reached a zenith in damage-resistance ability.

**NOTE CONCERNING THICKER CLASS “A” PLATES**

Two plates (20.64-20.88” non-cemented Midvale Barbette Plate 8563 with a 41% face of only 522 Brinell Hardness at the face surface and an abrupt face/back boundary and 20.64” Bethlehem Barbette Plate 6C132A1 with a 52% face and a standard Thick Chill plate hardness contour) were tested in 1942 using 16” Mark 8 Mod 3 AP projectiles at 29-30.3° obliquity for the projected WWII MONTANA Class battleships. These were the thickest US Class “A” plates ever tested.

The Bethlehem plate was hit at 2,101 ft/sec and 29° obliquity and had the projectile completely penetrate except for its base around the driving band and base plug, which snapped off and remained stuck in the plate. The Midvale plate was hit twice: Once at 2,011 ft/sec and 30.3° obliquity and had the projectile break its nose and crack open its lower body and explosive cavity without penetrating, while the second projectile hit at 2,084 ft/sec and 29.3° obliquity had the same thing happen, except that its explosive cavity remained intact.

Extrapolating the 16” Mark 8 Mod 6 30° Table 1B 30° column above gives about 1,970 ft/sec at 30° obliquity, though with those somewhat weaker projectiles, the value is probably closer to 2,000 ft/sec for the 20.6” Class “A” acceptance test velocity at 30° with the 16” Mark 8 Mod 3 AP projectile. Both of these plates passed test criterion (3), since a lower impact velocity will cause even more damage as the projectile is deflected more and is subjected to the plate’s resistance for a longer time, and the Midvale plate definitely passed plate criterion (1). The Bethlehem plate is unknown concerning its ability to pass the criterion (1) requirement, but the actual impact was not a failure, since if the projectile which hit it had not broken off its base, the projectile would not have completely penetrated, but remained stuck in the plate.

**CLASS “B” HOMOGENEOUS CHROMIUM-NICKEL STEEL ARMOR**

This armor material is relatively soft and ductile and fails by tearing and deforming more than by brittle cracking or shearing, though projectile nose shape and impact velocity and obliquity have a distinct influence on how the plate behaves on impact. It has much less ability than Class “A” armor to damage projectiles except in very thick gauges. It is similar to BuC&R/BuShips Special Treatment Steel (STS) or Protective Deck Plating (PDP) (made only by Carnegie-Illinois Steel Company) used in hull armor, especially light armor and light and heavy deck armor. BuOrd Class “B” armor was made in very thick plates used in WWII U.S. battleship main armament turret faces and conning towers, though not in the rest of the vertical or near-vertical turret or barbette armor, being the thickest U.S. naval armor ever used in completed warships. (Only Japanese super-battleships IJN YAMATO and MUSASHI had thicker armor, up to 26” in the turret face plates.)

As with Class “A” armor, two projectiles are fired at one selected plate from each lot; however, with a somewhat different set of pass/fail criteria from Class “A” armor. The plate must pass the following criteria to be considered a success in ballistic test:

1. The NBL criterion is identical to Class “A” armor’s criterion (1), which is given above.
2. Except in the direction of projectile motion at oblique impact and directly caused by the projectile tearing the plate along its path through the armor, no crack or tear more than two calibers long shall radiate in any direction from the impact region. Shock-induced cracks are not acceptable here. As with Class “A” armor, failure of this criterion alone is not cause for rejecting the lot, but will be a negative point when the armor is evaluated.
3. In addition to the no-large-crack criterion, an additional requirement that no large plate splinters or fragments be thrown from the plate back larger than half-caliber in its maximum transverse dimension and close to full plate thickness in length, excluding only those relatively small pieces that are sometimes punched out of the plate by a blunt projectile nose directly in front of the projectile. This criterion is on a par with criterion (2) as to its effects on evaluation of the lot.

No additional projectile impacts are to be used on that plate if the plate fails due to the two impacts already made. As with Class “A” armor testing, a second plate can be chosen if the first one fails and, in some rare cases, the test conductor may allow a third plate if the second one fails, but he will more often require it to confirm the results if the second one passes, but that third plate must always pass to allow the lot to pass.

Again, linear interpolation is used for plates between the tabulated entries in thickness.

Class “B” armor is tested at a much wider range of obliquities than Class “A” armor, with some thinner plates being tested at 75° obliquity. More projectile types, including other than AP gun projectiles, and more than one Mod for some AP projectile sizes and Marks are used in Class “B” armor testing, too.

These projectiles used for Class “B” ballistic tests are:

PROJECTILE # 1 = 5” Special Common Mark 46 Mod 2 (70 lb w/Hood)

PROJECTILE # 2 = 3” AP Mark 29 Mod 2

PROJECTILE # 3 = 6” AP Mark 35 Mod 5 (std. 555-583 Brinell cap)

PROJECTILE # 4 = 6” AP Mark 35 Mod 9 (super-hard cap)

PROJECTILE # 5 = 8” AP Mark 21 Mod 3 (std. 555-583 Brinell cap)

PROJECTILE # 6 = 8” AP Mark 21 Mod 5 (super-hard cap)

PROJECTILE # 7 = 12” AP Mark 18 Mod 1

PROJECTILE # 8 = 14” AP Mark 16 Mod 8

PROJECTILE # 9 = 16” AP Mark 8 Mod 6

PROJECTILE #10 = 12” 1,000-lb AP Bomb Mark 33 Mod 2 (no AP cap)

**TABLE IIA--Small Projectiles & Thin Class “B” Plates**

|  |  |  |
| --- | --- | --- |
| **Projectile Number** | **#2** | **#1** |
| **Obliquity (º)** | **20** | **30** | **40** | **50** | **60** | **70** | **75** |
| **Thickness (inches)** |  |  |  |  |  |  |  |
| 0.25 | --- | --- | --- | --- | --- | 660 | --- |
| 0.30 | --- | --- | --- | --- | --- | --- | 780 |
| 0.40 | --- | --- | --- | --- | --- | --- | 910 |
| 0.50 | --- | --- | --- | 775\* | 935\* | 1,205 | 1,065 |
| 0.75 | --- | --- | --- | 1,005\* | 1,235\* | 1,760 | 1,450 |
| 1.00 | --- | 875\* | 970\* | 1,240\* | 1,535\* | --- | 1,820 |
| 1.25 | --- | 1,090\* | 1,200\* | 1,475\* | 1,840\* | --- | --- |
| 1.50 | --- | 1,300\* | 1,410\* | 1,695\* | --- | --- | --- |
| 1.75 | 1,435\* | 1,505\* | 1,600\* | 1,905\* | --- | --- | --- |
| 2.00 | 1,625\* | 1,690\* | 1,770\* | --- | --- | --- | --- |
| 2.25 | 1,760\* | 1,840\* | 1,925\* | --- | --- | --- | --- |
| 2.50 | 1,875\* | 1,960\* | 2,060\* | --- | --- | --- | --- |
| 2.75 | 1,980\* | 2,065\* | --- | --- | --- | --- | --- |
| 3.00 | 2,080\* | 2,155\* | --- | --- | --- | --- | --- |
| 3.25 | 2,180\* | 2,240 | --- | --- | --- | --- | --- |
| 3.50 | 2,280\* | --- | --- | --- | --- | --- | --- |

\* Failure to prevent a complete penetration--criterion (1)--is not cause for test failure for this projectile type and this obliquity. These test criteria are for a previous, weaker Mod of this projectile.

**TABLE IIB--Medium-Size Projectiles & Thin-To-Medium Class “B” Plates**

|  |  |  |
| --- | --- | --- |
| **Projectile Number** | **#3 & #4** | **#5 & #6** |
| **Obliquity (º)** | **30** | **40** | **50** | **60** | **70** | **30** | **35** | **40** | **50** | **60** |
| **Thickness (inches)** |  |  |  |  |  |  |  |  |  |  |
| 0.75 | --- | --- | --- | --- | 885\* | --- | --- | --- | --- | --- |
| 1.00 | --- | --- | --- | --- | 1045\* | --- | --- | --- | --- | --- |
| 1.25 | --- | --- | --- | 945\* | 1205\* | --- | --- | --- | --- | --- |
| 1.50 | --- | --- | --- | 1075\* | 1365\* | --- | --- | --- | --- | --- |
| 1.75 | --- | --- | 980\* | 1205\* | --- | --- | --- | --- | --- | --- |
| 2.00 | --- | --- | 1085\* | **1345\*$** | --- | --- | --- | --- | --- | --- |
| 2.25 | --- | --- | 1190\* | --- | ***#10/30°@*** | --- | --- | --- | --- | 1,100\* |
| 2.50 | --- | 995\* | 1290\* | --- | ***435@*** | --- | --- | --- | --- | 1,195\* |
| 2.75 | 985\* | 1100\* | 1395\* | --- | --- | --- | --- | --- | --- | 1,290\* |
| 3.00 | 1,085\* | 1200\* | 1495\* | --- | ***520@*** | --- | --- | --- | --- | 1,390\* |
| 3.25 | 1,185\* | 1290\* | **1590\*$** | --- | --- | --- | --- | --- | 1,180\* | 1,490\* |
| 3.50 | 1,280\* | 1375\* | **1680\*$** | --- | ***610@*** | --- | --- | --- | 1,250\* | --- |
| 3.75 | 1,365\* | 1455\* | --- | --- | --- | --- | --- | --- | 1,320\* | --- |
| 4.00 | 1,440\* | 1525\* | --- | --- | ***695@*** | --- | --- | --- | 1,390\* | --- |
| 4.25 | 1,505\* | 1590\* | --- | --- | --- | --- | --- | 1,180\* | 1,465\* | --- |
| 4.50 | 1,565\* | 1650\* | --- | --- | ***785@*** | --- | 1,190\* | 1,245\* | --- | --- |
| 4.75 | 1,615\* | 1710\* | --- | --- | --- | --- | 1,255\* | 1,305\* | --- | --- |
| 5.00 | 1,665\* | 1765\* | --- | --- | ***870@*** | 1,265\* | 1,310\* | 1,360\* | --- | --- |
| 5.25 | 1,715\* | --- | --- | --- | --- | 1,320\* | 1,360\* | 1,410\* | --- | --- |
| 5.50 | 1,760\* | --- | --- | --- | ***960\*@*** | 1,365\* | 1,410\* | 1,455\* | --- | --- |
| 5.75 | --- | --- | --- | --- | --- | 1,410\* | 1,450\* | 1,500\* | --- | --- |
| 6.00 | --- | --- | --- | --- | ***1,050\*@*** | 1,450\* | 1,490\* | 1,540\* | --- | --- |
| 6.25 | --- | --- | --- | --- | --- | 1,490\* | 1,530\* | 1,585\* | --- | --- |
| 6.50 | --- | --- | --- | --- | ***1,135\*@*** | 1,525\* | 1,570\* | 1,625\* | --- | --- |
| 6.75 | --- | --- | --- | --- | --- | 1,565\* | 1,610\* | --- | --- | --- |
| 7.00 | --- | --- | --- | --- | ***1225\*@*** | 1,600\* | 1,650\* | --- | --- | --- |
| 7.25 | --- | --- | --- | --- | --- | 1,630\* | 1,690\* | --- | --- | --- |
| 7.50 | --- | --- | --- | --- | --- | 1,665\* | 1,725\* | --- | --- | --- |

**Notes for Table IIB**

**$Applies to PROJECTILE #4 only (is “---” to PROJECTILE #3).** Also, all “\*” NOTES (see next page) for **#3 & #4** in their columns apply to **PROJECTILE #4 only**; if PROJECTILE #3 completely penetrates, the lot will be rejected.

%The “\*” NOTE in the **#5 & #6** column for 35° obliquity **do not apply to PROJECTILE #5**, so a complete penetration by PROJECTILE #5 at 35° will cause the lot to be rejected. Also, **PROJECTILE #5 was used only at 35° obliquity** in this version of OS 751; all Class “B” ballistic tests at any other obliquity using 8” projectiles are **for PROJECTILE #6 onl**y.

***@The velocities given from here down in the 70° column apply to PROJECTILE #10 (bomb) at 30° obliquity, \*\*NOT\*\* to #3 or #4 projectiles at 70°.***

**TABLE IIC---Large Projectiles & Thick Class “B” Plates**

|  |  |  |  |
| --- | --- | --- | --- |
| **Projectile Number** | **#7** | **#8** | **#9** |
| **Obliquity (º)** | **30** | **35** | **40** | **30** | **40** | **30** | **35** | **40** |
| **Thickness (inches)** |  |  |  |  |  |  |  |  |
| 8.0 | --- | --- | 1,335\* | --- | --- | --- | --- | --- |
| 8.5 | --- | --- | 1,395\* | --- | --- | --- | --- | --- |
| 9.0 | 1,365\* | 1,400\* | 1,450\* | --- | 1,315\* | --- | --- | --- |
| 9.5 | 1,415\* | 1,450 | 1,510\* | --- | 1,380\* | --- | --- | --- |
| 10.0 | 1,460\* | 1,505 | 1,565\* | 1,330 | 1,435\* | --- | --- | --- |
| 11.0 | 1,555\* | 1,605 | 1,675\* | 1,425 | 1,550\* | --- | --- | --- |
| 12.0 | 1,650\* | 1,705 | 1,780\* | 1,520 | 1,655\* | --- | --- | 1,445\* |
| 13.0 | 1,745\* | 1,805\* | --- | 1,615 | 1,760\* | 1,420\* | 1,455\* | 1,530\* |
| 14.0 | 1,845\* | 1,905\* | --- | 1,705 | 1,865\* | 1,490\* | 1,540\* | 1,620\* |
| 15.0 | --- | --- | --- | 1,790 | --- | 1,560\* | 1,620\* | 1,705\* |
| 16.0 | --- | --- | --- | 1,880 | --- | 1,635\* | 1,695\* | 1,790\* |
| 17.0 | --- | --- | --- | 1,965 | --- | 1,705\* | 1,765\* | 1,865\* |
| 18.0 | --- | --- | --- | 2,055 | --- | 1,770\* | 1,830\* | --- |
| 19.0 | --- | --- | --- | 2,140 | --- | 1,840\* | 1,890\* | --- |
| 20.0 | --- | --- | --- | 2,225 | --- | --- | --- | --- |

\* Failure to prevent a complete penetration--criterion (1)--is not cause for test failure for this projectile type and this obliquity. These test criteria are for a previous, weaker Mod of this projectile.

**HOMOGENEOUS CHROME-NICKEL STEEL ARMOR UPTAKE GRATINGS**

The boiler creates very hot exhaust gasses that are passed up well above the deck by the funnel uptakes (smokestacks). This requires large holes in the armored decks of armored warships and something must cover these holes to prevent enemy weapons from entering the ship, yet still allow the exhaust gasses to exit the boilers. The original method when low-angle fire was the only threat was to put a cylindrical or multi-sided prism-shaped armor box around the base of the funnels at the armored deck level that were tall enough to prevent a projectile from passing at a shallow angle into the uptake. Crisscrossing steel bars were placed across the opening at the armored deck level to stop fragments of a projectile that exploded above the opening near the top of the box--these being called “the armored grating.”

With the advent of long-range plunging fire and aircraft bombs, the side box lost much of its usefulness and was rather heavy, wasting weight that could be used more effectively elsewhere. It was replaced by making a very thick homogeneous armor plate of usually the same material used in the armored deck and drilling many holes in it to let the gasses through when this plate was fitted as an extra-heavy deck plate over the uptake hole. Thus, the armor grating was now merely a part of the armor deck, though much thicker than a regular armor deck plate. Tests usually showed that this grating had about 40% of the effective thickness of a similar plate with no holes in it--so for example a 15” thick one-piece multi-holed armor grating would roughly equal a 6” solid plate of the same homogeneous armor material in ballistic resistance. Of course, blast and small fragments could pass through the holes, so the armor grating was still a potential point of weakness, but by sloping the uptake pipes under the armor deck and thus keeping the boilers and engines as far away from the armor grating hole(s) as possible, the effects of such external weapon hits would be minimized. The Japanese YAMATO Class battleships also added a very high, sloped, roughly 3”-thick homogeneous armor shield wrapped around the base of the funnels and going up into the superstructure so that aircraft bombs would usually hit this shield first and explode well above the armor deck level near the uptakes, further reducing the threat to the gratings and the hull spaces below them.

Grating ballistic test criteria are as follows:

1. The NBL is defined as with Class “A” and Class “B” armor tests. See the Class “A” armor criterion (1) for details.
2. The grating itself must not break across through more than one triangular group of holes outward from the area directly struck by the projectile, which will usually punch out the armor web between the holes directly under it if it hits at near the NBL velocity or greater.

There is a special table of projectiles and impact conditions for retesting a grating that has failed the primary ballistic test. Failure of the grating to pass this retest will result in a second grating being chosen from the contract lot and tested again as with the first plate. If this second grating also fails or, if it succeeds and a third plate is required to confirm the results, the failure of this third grating will always result in all of the grating plates of the affected lot being rejected.

As with Class “A” and Class “B” armor testing linear interpolation between tabled values will be used for gratings with unusual thicknesses. Note that armor gratings are tested at as high an obliquity angle as is practicable to subject them as closely as possible to enemy weapon impact conditions in a battle.

Some different projectile types are used in armor grating tests and retests than for Class “A” or Class “B” armor testing. However, the range of possible obliquities for a given grating thickness with all but two of these various alternate projectiles is more limited than with Class “B” armor testing.

The projectiles used for armor grating ballistic tests are:

PROJECTILE #1 = 6” AP Mark 35 Mod 5

PROJECTILE #2 = 8” AP Mark 21 Mod 1 (narrow cap & long windscrn)

PROJECTILE #3 = 8” AP Mark 21 Mod 3

PROJECTILE #4 = 12” AP Mark 18 Mod 1

PROJECTILE #5 = 14” AP Mark 16 Mod 8

PROJECTILE #6 = 16” AP Mark 8 Mod 6

PROJECTILE #7 = 12” 1000-lb AP Bomb Mark 33 Mod 2

PROJECTILE #8 = 6” Special Common Mark 27 Mod 7 (2.4% cavity)

PROJECTILE #9 = 8” AP Mark 19 Mod 6 (short body & long windscrn)

**TABLE IIIA--Initial Tests Part 1**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Obliquity (º)** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
| **Thickness (inches)** |  |  |  |  |  |  |  |  |  |
| 3.0 | --- | --- | --- | --- | --- | --- | --- | --- | 1,005@ |
| 3.5 | --- | --- | --- | --- | --- | --- | --- | 1,010@ | 1,160@ |
| 4.0 | --- | --- | --- | --- | --- | --- | --- | 1,140@ | --- |
| 4.5 | --- | --- | --- | --- | --- | --- | 1,105@ | 1,270@ | --- |
| 5.0 | --- | --- | --- | --- | --- | 1,055@ | 1,220@ | --- | 1,220% |
| 5.5 | --- | --- | --- | --- | --- | 1,140@ | --- | --- | 1,330% |
| 6.0 | --- | --- | --- | --- | 1,070@ | 1,210@ | --- | 1,180% | 1,445% |
| 6.5 | --- | --- | --- | 1,035@ | 1,140@ | --- | 1,110% | 1,270% | --- |
| 7.0 | --- | --- | 1,045@ | 1,100@ | --- | --- | 1,195% | --- | --- |
| 7.5 | --- | 1,065@ | 1,105@ | 1,160@ | --- | 1,105% | 1,280% | --- | --- |
| 8.0 | 1,085@ | 1,125@ | 1,160@ | --- | --- | 1,160% | --- | --- | --- |
| 8.5 | 1,145@ | 1,180@ | 1,215@ | --- | --- | 1,205% | --- | --- | --- |
| 9.0 | 1,205@ | 1,230@ | --- | 1,010% | --- | 1,255% | --- | --- | --- |
| 9.5 | 1,255@ | --- | --- | 1,055% | --- | --- | --- | --- | --- |
| 10.0 | --- | --- | --- | 1,100% | --- | --- | --- | 1,270$ | --- |
| 10.5 | --- | --- | --- | 1,140% | --- | --- | --- | 1,325$ | --- |
| 11.0 | --- | --- | --- | 1,185% | --- | --- | --- | 1,380$ | --- |
| 11.5 | --- | --- | 1,160% | 1,225% | --- | --- | --- | --- | --- |
| 12.0 | --- | 1,160% | 1,195% | --- | --- | --- | --- | --- | --- |
| 12.5 | 1,165% | 1,195% | 1,230% | --- | --- | --- | --- | --- | --- |
| 13.0 | 1,200% | 1,230% | 1,265% | --- | --- | 1,235# | --- | --- | --- |
| 13.5 | --- | --- | 1,300% | --- | --- | 1,265# | --- | --- | --- |
| 14.0 | --- | --- | 1,330% | --- | --- | 1,290# | --- | 1,400& | --- |
| 14.5 | --- | --- | --- | --- | --- | 1,320# | --- | 1,445& | --- |
| 15.0 | --- | --- | --- | --- | --- | 1,350# | --- | 1,490& | --- |
| 15.5 | --- | --- | --- | --- | --- | 1,380# | --- | 1,535& | --- |
| 16.0 | --- | --- | --- | --- | --- | --- | --- | 1,580& | --- |
| 16.5 | --- | --- | --- | --- | --- | --- | --- | 1,625& | --- |
| 17.0 | --- | --- | --- | --- | --- | --- | --- | 1,670& | --- |

**KEY:**

@ = PROJECTILE #1

% = PROJECTILE #2 & #3

# = PROJECTILE #4

$ = PROJECTILE #5

& = PROJECTILE #6

**TABLE IIIB--Initial Tests Part 2 & Retests**

|  |  |  |
| --- | --- | --- |
| **Test Type** | **Initial Tests** | **Retest** |
| **Obliquity (º)** | **30** | **35** | **40** | **45** | **50** | **55** | **60** | **65** | **70** |
| **Thickness (inches)** |  |  |  |  |  |  |  |  |  |
| 1.0 | --- | --- | --- | --- | --- | --- | --- | --- | 550+ |
| 2.0 | --- | --- | --- | --- | --- | --- | --- | --- | 850+ |
| 3.0 | --- | --- | --- | --- | --- | --- | --- | --- | 900? |
| 3.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 4.0 | --- | --- | --- | --- | --- | --- | --- | --- | 1,100? |
| 4.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 5.0 | 420! | --- | --- | --- | --- | --- | --- | --- | 1,300? |
| 5.5 | 440! | --- | --- | --- | --- | --- | --- | --- | --- |
| 6.0 | 460! | --- | --- | --- | --- | --- | --- | --- | 1,520? |
| 6.5 | 480! | --- | --- | --- | --- | --- | --- | --- | --- |
| 7.0 | 500! | --- | --- | --- | --- | --- | --- | --- | 1,750? |
| 7.5 | 520! | --- | --- | --- | --- | --- | --- | --- | --- |
| 8.0 | 540! | --- | --- | --- | --- | --- | --- | --- | 1,950? |
| 8.5 | 560! | --- | --- | --- | --- | --- | --- | --- | --- |
| 9.0 | 580! | --- | --- | --- | --- | --- | --- | --- | --- |
| 9.5 | 605! | --- | --- | --- | --- | --- | --- | --- | --- |
| 10.0 | 625! | --- | --- | --- | --- | --- | --- | --- | --- |
| 10.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12.0 | --- | --- | --- | --- | --- | --- | --- | --- | 1,590$ |
| 12.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 13.0 | --- | --- | --- | --- | --- | --- | --- | --- | 1,700$ |
| 13.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 14.0 | --- | --- | --- | --- | --- | --- | --- | --- | 1,800$ |
| 14.5 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 15.0 | --- | --- | --- | --- | --- | 1,305$ | --- | --- | 1,900$ |
| 15.5 | --- | --- | --- | --- | --- | 1,330$ | --- | --- | --- |
| 16.0 | --- | --- | --- | --- | --- | 1,355$ | --- | --- | 2,000$ |
| 16.5 | --- | --- | --- | --- | --- | 1,385$ | --- | --- | --- |
| 17.0 | --- | --- | --- | --- | --- | --- | --- | --- | --- |

**KEY:**

$ = PROJECTILE #5

! = PROJECTILE #7

+ = PROJECTILE #8

? = PROJECTILE #9