Hit 3 – Starboard side of Turret I

From the BuShips damage report:

> 16. The starboard side of Turret I was struck a glancing blow by a projectile, probably 6-inch, which exploded on the starboard sight port. The hinge on the sight port was bent and the closing device on the port was rendered inoperative. Seven strakes of wood deck planking between frames 44 and 48 were badly splintered by fragments.[26]

South Dakota's action report described the damage as follows:

> A shell struck starboard side plate #1 turret approximately parallel passed through the 25 man life raft* and exploded on the starboard sight port. Hinge on sight port bent and distorted. Closing device on port inoperative.
>
> 7 strakes on wood deck planking splintered and gouged by shrapnel between frames 44 and 48, main deck 4' to 6' inboard of shell plate.
>
> *Total of five (5) balsa wood life rafts destroyed, about the ship.[27]

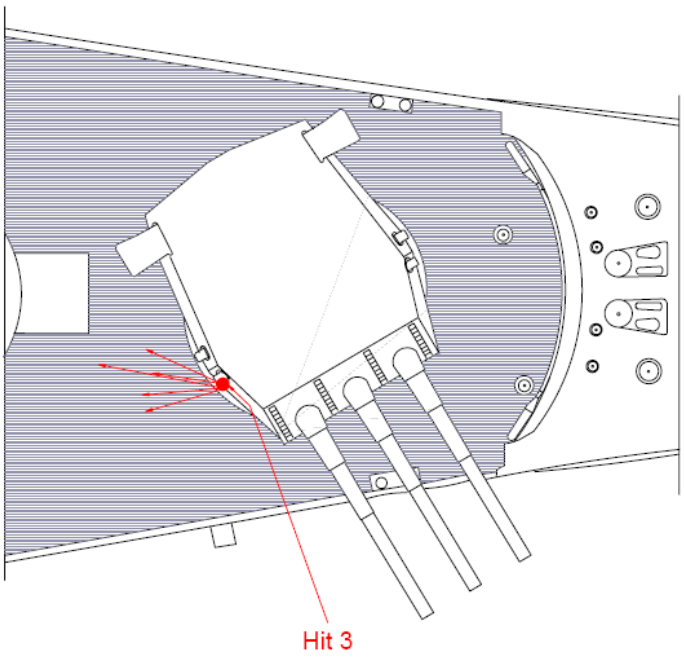

Figure 10 – Hit 3 – Impact Point on Turret I

[26] BuShips War Damage Report # 57, page 5
[27] USS *South Dakota* Action Report, Enclosure D, page 3

Analysis of impact

There are no inconsistencies between the reports for this hit and it probably was a 6-inch shell from Kirishima. Another possibility is a 5.5-inch shell fired by one of the light cruisers during the time between 0048 and 0054. The specific time of this hit is unknown and the exact bearing of Turret I at the time of the hit is also unknown, but it was certainly trained to starboard in the direction of the Japanese ships as shown above in Figure 10.

Hit 4 – Frames 46 and 47

From the BuShips damage report:

> 17. This hit struck between frames 46 and 47 about one foot above the third deck. It penetrated longitudinal torpedo bulkhead No. 2 and detonated on the 12.2-inch longitudinal armor bulkhead about 2 feet 2 inches above the third deck. The armor was not indented, but the projectile left a black circle about 6 inches in diameter within a partial black ring about 8 inches in diameter on the face of the armor. The force of the explosion blew the third deck down 3-1/2 inches over a 15 by 30 inch area and fragments penetrated the third deck between bulkheads No. 2 and the longitudinal armor bulkhead in two places. Torpedo bulkhead No. 2 above the third deck was blown outboard between frames 46 and 47 by the force of the explosion. The following tanks were reported flooded as a result of the hit; A-11-F, A-21-F, A-23-F, A-33-F and A-39-F. Although it was not mentioned in the report, A-27-V probably flooded also.
>
> 18. This projectile most likely landed short of *South Dakota* and was about to ricochet as the hit was below the waterline and the projectile was rising. From the black circles which the projectile left on the armor, it is estimated that this was an 8-inch AP projectile.[28]

South Dakota's action report simply lists this damage as a 12-inch hole located 2.5 inches below the waterline at Frame 46.[29]

[28] BuShips War Damage Report # 57, page 5
[29] USS *South Dakota* Action Report, Enclosure D, page 13

Figure 11 – Hit 4 – Entry Hole

The flat face of the shell body also left a mark on the outer shell as seen to the right side of the exterior hole in Figure 11. This flat face is unique to AP shells and the 12-inch hole plus the circular scar on the main belt as seen in Figure 11 really helps with the identification of this shell type.

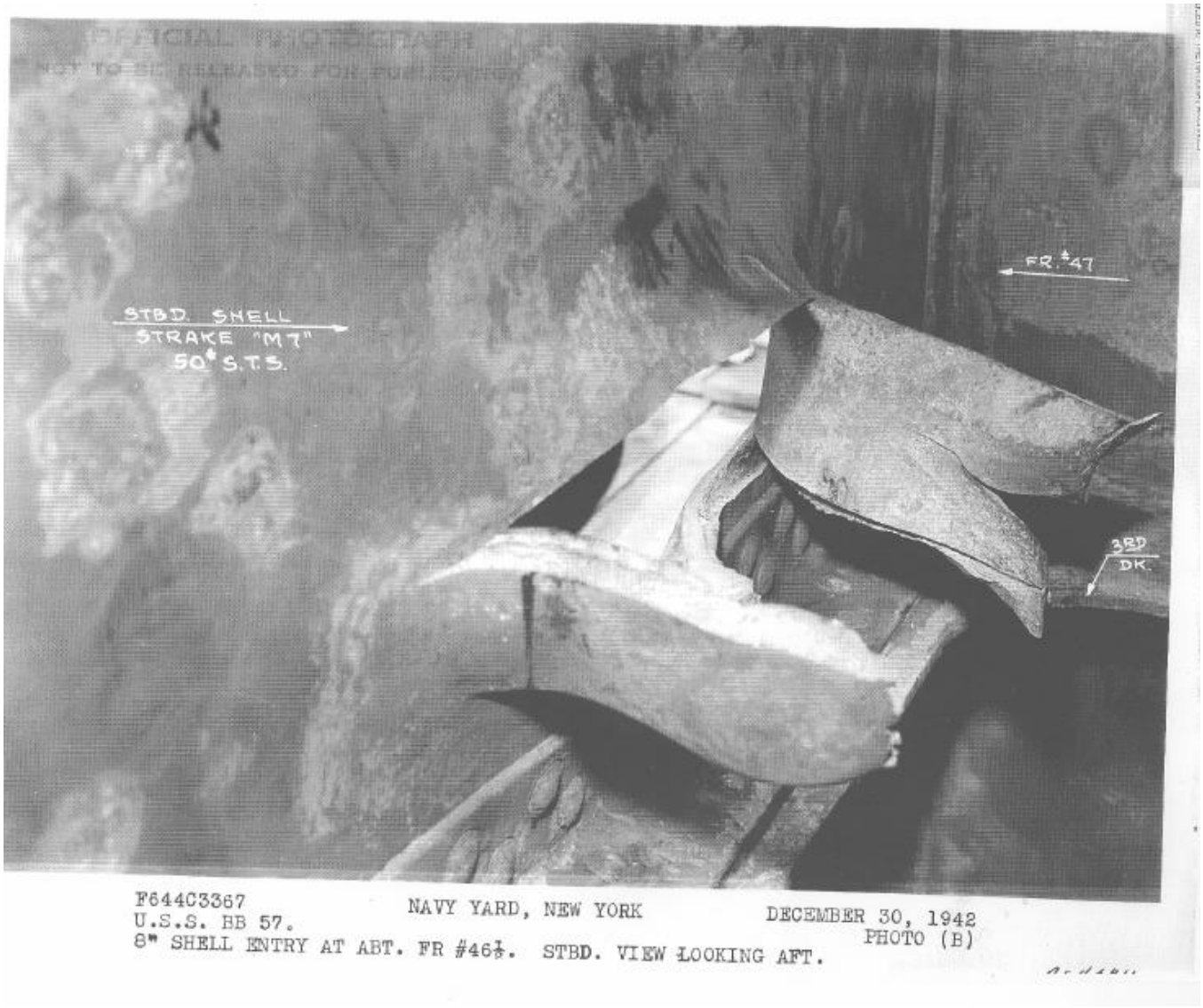

Figure 12 – Hit 4 – Inside view of Entry Hole

Figure 12 also shows a circular scar on the end of the extrusion closest to the camera which was caused by the flat head of the AP projectile.

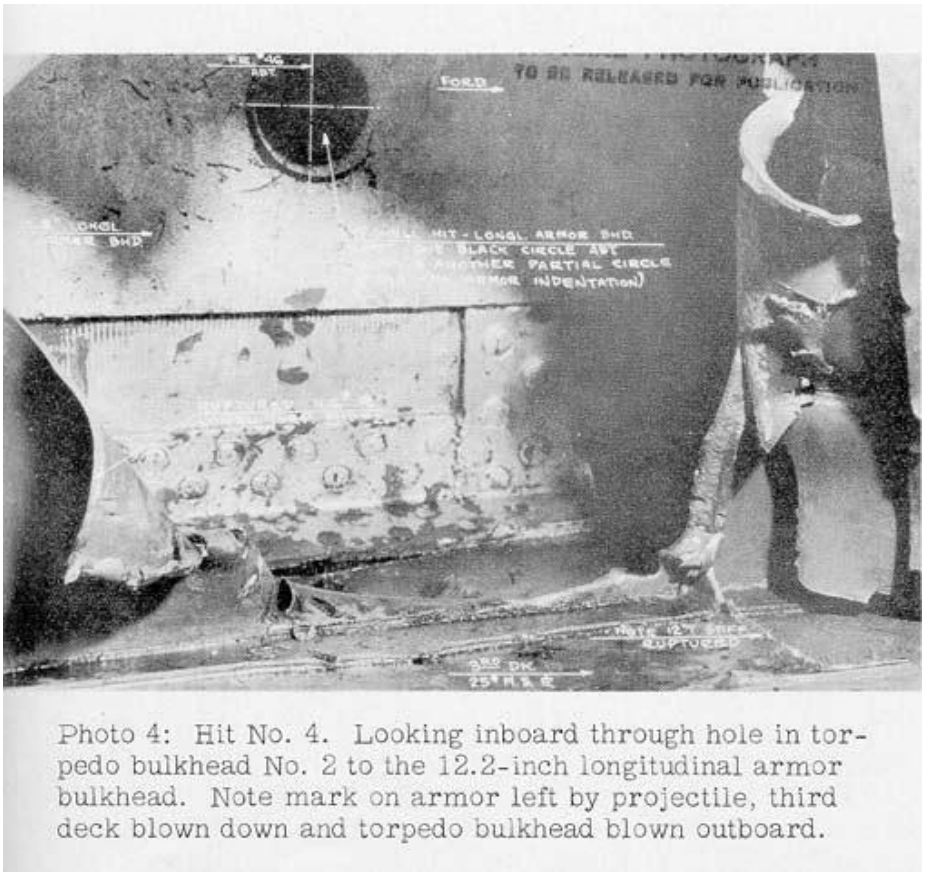

Photo 4: Hit No. 4. Looking inboard through hole in torpedo bulkhead No. 2 to the 12.2-inch longitudinal armor bulkhead. Note mark on armor left by projectile, third deck blown down and torpedo bulkhead blown outboard.

Figure 13 – Hit 4 – Main Belt Strike

Figure 14 – Hit 4 – Torpedo Bulkhead and Main Belt

Figure 14 shows how this projectile came in from the left through the Second Torpedo Bulkhead and then struck the Main Belt on the right.

Note that Figure 13 and Figure 14 also show that the main belt was not dented in any way; there is mainly just a "scuff" mark on the armor plate.

Analysis of impact

There are no inconsistencies with this damage or with BuShips' estimate of an 8-inch AP projectile.[30] Although this shell was slowed down by its underwater trajectory, it still had enough velocity remaining to penetrate the torpedo defenses and reach the main belt but not enough to significantly damage the plate.

[30] This may be a good place to note that *Atago*'s Direct Action Report claims no hits on *South Dakota* and gives credit to *Takao* and *Kirishima* for all of the damage inflicted on *South Dakota*.

The 8-inch AP projectile punched a rectangular hole out of the 1.25-inch STS outer hull which implies that it must have hit at a significant horizontal obliquity, but with minimal angle of fall. The windscreen was smashed flat and broken up by the impact with the outer shell, but the cap head remained on the projectile nose until it went completely through and even then did not have time to move much before the projectile eventually terminated its flight up against the belt armor. The projectile with the cap head still "riding" on its nose then punched through the HTS upward extension of the first internal anti-torpedo bulkhead and then it hit the main belt, where it destroyed itself, leaving only a 5-inch wide black circular disk on the face of the belt plate with an 8-inch wide narrow black ring surrounding it. What made the black color is unknown, but it might have been due to the impact shock of the 5-inch diameter flat nose under the crushed cap head and/or transmitted blast shock of the shell detonation removing paint and a very thin surface layer of the cemented part of the plate face, exposing the dark carburized layer that makes up about 1 inch of the plate thickness. The 8-inch ring might be due to the thick 8-inch diameter base hitting the armor after the projectile body in front of it had been destroyed. Other than this, the belt plate had no damage whatsoever.

Note that the hole in the upward extension of the anti-torpedo bulkhead is about 35 to 40 inches wide and was almost exactly in the center between two of the ship's vertical ribs, so nothing was there to modify the size of the hole in the horizontal direction. This portion, which is above the main 0.75-inch HTS anti-torpedo bulkhead, is thinner at 0.625 inches thick HTS. This plate was possibly still wrapped around the base of the projectile when the nose hit the belt armor and the shell detonated by impact shock. The internal cushion would not prevent such a detonation when the front of the shell shattered and the damage cut into the explosive cavity and the shell seems to have fully detonated high order, though this is not absolutely assured.

We can use Equation 1 from Hit 2 to calculate the hole size here. As mentioned in that section, "V" in Equation 1 is equal to zero when calculating damage for any plate other than the plate that actually sets off the nose fuze. This greatly simplifies the calculations for an HE shell:

$$Tphe(noADF) = (2.576 \times 10^{-20})(D)V^{5.6084}COS[2(Ob2 - 45^{o})] + (0.156)(D) \qquad (\textit{Equation 1})$$

$$= 0 + 0.156 \times 8 = 1.25 \text{ inches}$$

As the torpedo bulkhead is thinner than this value, we use Equation 2 to calculate the hole size as follows:

Hole Diameter (for an HE shell) = 8 x [1.25 / 0.85 / 0.625] = 18.82 inches

This shell, with only about 2.5% TNA filler (the rest of the 4% cavity was filled with inert cushion material), which makes it an AP-type shell. This reduces the hole-size calculation by 0.08/0.11 = 0.727:

Hole Diameter (for an AP shell) = 18.82 x 0.727 = 13.68 inches

Which is much smaller than the actual hole size of 35 to 40 inches.

What gives?

The only thing I can see is the fact that the blast is contained in the narrow space between the thin anti-torpedo bulkhead at its base, with the hole it made being partially blocked by the projectile base, and the essentially infinitely thick and rigid face-hardened belt plate in front of it. The blast pulse, which in a open area would only push up against the thin plate once as it moved outward from the projectile, is now

confined in a rather narrow space only about 36 inches deep where it can expand sideways, but not forward or backward. This containment and the impact and super-sonic detonation blast shockwaves in the air reflecting from the belt plate into the thin plate would greatly increase the maximum size and duration of the blast pressure pulse on that thin plate, coming from the inside of the space between the two plates backward toward the projectile base. Note that the thin plate edges are all bent outward away from the belt, indicating the pressure was from the inside outward. This seems to have increased the damage diameter by almost 300% over what would normally be expected for a Type 91 AP projectile detonating on a 0.625-inch HTS plate.

Hit 5 – Flag Bridge Level

From the BuShips damage report:

> 19. The wind and spray shield at Frame 74 starboard on the flag bridge level was hit by an estimated 8-inch projectile that detonated on contact. The 10-pound STS splinter shield around the starboard 40 mm director was badly buckled and holed and the 40 mm director was extensively damaged. Fragments from this projectile penetrated the deck of the flag bridge in the vicinity of Frame 74 and the watertight door between the signal bridge and signal shelter. One fragment gouged a hole 3 inches in diameter to a depth of 3/4 inch in the 1-1/2 inch STS bulkhead of the signal shelter. Other fragments blew downward and sprayed the first super structural deck between frames 66 and 72 starboard and penetrated hatch 01-07-1 in eleven places. On the navigation bridge fragments from this projectile penetrated the spray shield and the starboard longitudinal structural bulkhead in two places and the deck in three places near Frame 75. Extensive blast damage was sustained by metal joiners, ventilation ducts, aluminum bulkheads, and metal furniture in the vicinity of the hit. Three glass panels on the flag bridge were broken by blast or fragments and the operating mechanisms rendered unserviceable.[31]

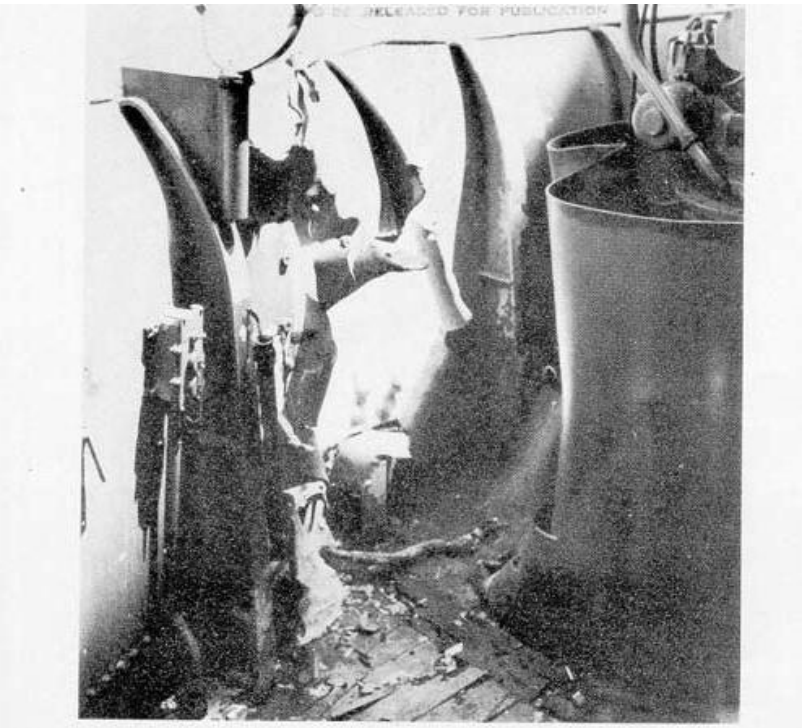

Photo 5: Hit No. 5. Damage to spray shield and splinter shield around 40mm director.

Figure 15 – Hit 5 – 40 mm Director

[31] BuShips War Damage Report # 57, page 5

The information on this hit covers multiple pages within *South Dakota*'s action report. Damage extended from the 1st superstructure deck level to the Navigation deck level. The only photograph in BuShips' report (shown above as Figure 15) is of fragment damage to the 40 mm director, but does not show the point of impact. However, a search of the archives did turn up a photograph of the entry hole as seen below in Figure 16.

Figure 16 – Hit 5 – Entry Hole

Damage from Hit 5 as described in *South Dakota*'s Action Report:

> [Flag Bridge level]
>
> 8" shell struck the upper edge of bulkhead plating of spray shield and Flag Bridge, Frame 72 1/2 starboard, resulting in the following damage:
>
> (a) Shrapnel blew downward penetrating wood and steel deck on first superstructure deck starboard between frame 66 and 72, approximately 45 holes ranging in size from ½" to 5".

(b) Cover of watertight hatch 01-70-1. 11 small holes ranging from ½" to 1 ½".
(c) Two steel ladder rungs on longitudinal bulkhead 70 starboard cut out and broken.
(d) Light lock bracket to door 01-72 loading from 1st superstructure to Captains cabin broken off.

Senior staff officer's cabin, starboard longitudinal structural bulkhead and stiffeners between frame 72 and 74 buckled inboard approximately 3" over entire area. Two aluminum battle ports, frame 72-73 broken beyond repair. Metal book case 4' x 6', doors, hinges, and shelving distorted beyond economical repair. Supply ventilation duct torn and crushed. Metal joiner door and frame to linen locker broken. Metal joiner door access from passageway to stateroom bent and distorted beyond repair. 3' x 6' panel of after inboard divisional bulkhead blown out. Metal joiner door and frame to Admiral's cabin blown out. Metal joiner door access to first super structural deck blown out. Metal joiner door and frame between cabin and stateroom blown out. The transverse aluminum panel bulkhead between cabin and stateroom was blown out. Transverse aluminum panel bulkhead between cabin and bath blown out. Senior staff officer's stateroom, metal joiner door with full length mirror distorted and buckled. Confidential safe blown from bulkhead. Metal book case distorted and blown from bulkhead. 6' section of 1½" voice pipe leading to Flag Plot broken off at joint. Door of #1 Wardroom locker torn from hinges. Longitudinal aluminum panel division bulkhead between stateroom and bath blown out. Aluminum panel division bulkhead between bath and passageway completely blown out. Drainage valves to wash basin broken.[32]

- - -

FLAG BRIDGE LEVEL

Watertight access door 03-79, to B-0305E is badly distorted.
6' section of exhaust vent duct, compartment B-0305E, completely blown out.
1 section vent duct leading to pre-heater supply system 03-79-1 blown out.
Sides, drawers, and fastenings to signal bridge desk torn and distorted beyond repair.
Hole, 12" x 36" in outboard corner of starboard flag bag.
3" fragment hole 3' above bottom starboard end.
Light metal tissue blown out.
5' section of 4" drain line severed at frame 83, starboard.
2" drain line pierced and severed by shrapnel, frames 72 and 73 starboard.
1 1/2" voice tube, starboard alidade to conn, severed at frame 73.
6' square of wind and spray shield and stiffeners at frame 73 starboard demolished by salvo.
1/4" STS splinter shield around the starboard 40 mm director at frame 74 demolished
40 mm director demolished.
5 square feet areas of wood deck planking and margin steakes [sic] splintered and broken. Steel deck plating beneath wood deck in this area penetrated by several pieces of shrapnel.
1 1/2" inch STS armored signal shelter bulkhead starboard is gouged to a depth of 3/4" over a 3" circular area.
Watertight access door, access from signal bridge to signal shelter frame 71 starboard, pierced in 6 places by shrapnel. Holes ranging from 3/4" to 4" to 4" [sic]. 3/8" heat treated glass panel blown out.
3 36" x 42" heat treated glass windows broken. Raising and lowering mechanism broken and distorted. Unserviceable. Frame 68 starboard.

[32] USS *South Dakota* Action Report, Enclosure D, page 3

Metal joiner door leading from signal shelter access to flag plot blown inward and distorted.
Frame 72, centerline.
Hood for starboard signal light blown from fastenings and broken.
Doors to signal locker desk broken and distorted. Frame 79, centerline.[33]

The damage continued on up to the Navigation Bridge level:

NAVIGATION BRIDGE LEVEL

Wet and dry bulb thermometer casing demolished, frame 77 stbd.
4" hole in wind and spray shield 3' above deck level at frame 75, starboard.
1 6" hole, 1 3" hole and 1 4" hole in deck from shrapnel at frame 75 starboard.
1 3" and 1 2" shrapnel hole located in longitudinal structural bulkhead 1' above deck level at frame 75, starboard.
4" hole in spray shield 3' above deck at frame 75, starboard. [Ed's note: This may be a duplicate of above entry.]
1 3" and 1 2" shrapnel hole in longitudinal structural bulkhead 1' above deck level at frame 75, starboard.
1 6" shrapnel hole in circular base of starboard alidade.
1 section 3' by 5' in spray shield between frames 70 and 71 starboard blown inboard and distorted.
Swivel base scat (mess stool) on spray shield at frame 72, starboard demolished.
Watertight door access from pilot house to catwalk bent and distorted at frame 71, starboard.
Pipe rail and fittings supporting canvas windbreaker around catwalk port and starboard broken and unserviceable. Canvas windbreaker blown out.
20" x 36" heat treated glass panel in watertight access doors leading from catwalk to Navigation Bridge, port, blown out.
10" x 20" hole in deck overhead in upper section of longitudinal structural bulkhead at frame port. (Chart House)
6' x 8' panel of aluminum dividing bulkhead between Captain's sea cabin and Navigator's sea cabin demolished.
1 section of longitudinal panel bulkhead in navigation washroom and water closet blown out.
[Illegible] section of 4" ventilation duct broken off at the joint near washroom and water closet.
Natural exhaust ventilation closure for chart house to atmosphere at frame [illegible] port blown out.
1 4" shrapnel hole in wind and spray shield 4' above the deck level at frame 74 port.[34]

[33] USS *South Dakota* Action Report, Enclosure D, page 5
[34] USS *South Dakota* Action Report, Enclosure D, pages 5 and 6

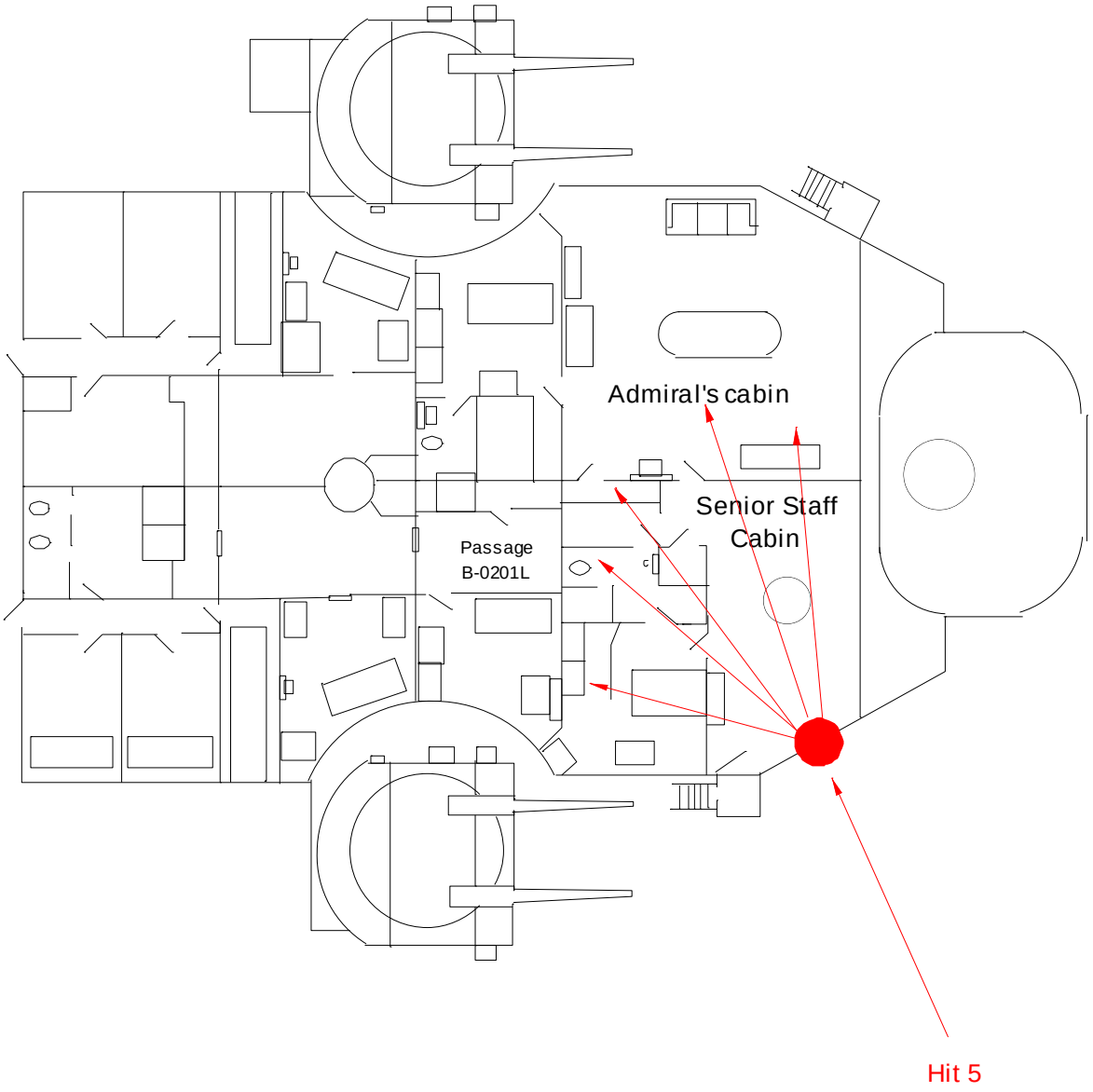

Figure 17 – Hit 5 – Path of Shell and Splinters

Analysis of impact

This shell is certainly a nose-fuzed projectile. The original crew estimated it to be an 8-inch projectile and this appears to indeed be the case. Despite the level of description in *South Dakota*'s Action Report about this hit, there was not a good sense of the hole it produced in the exterior bulkhead of the Flag Bridge until I found the photograph in Figure 16 which shows about a six foot hole in the Flag Bridge windscreen. The thickness of the exterior bulkhead on the Flag Bridge windscreen is 0.25 inches of STS steel. This projectile appears to have detonated on impact and blasted inboard into the Senior Staff Officer's stateroom and Admiral's cabin. The door to the Senior Staff Officers cabin was blown off due to blast overpressure from Turrets I and II, and the fact that it is missing is not associated with the 8-inch HE projectile hit above.

This is an actual case of a Type 91 Mod 1 fuze detonating on a 6 mm thick plate just as the Technical Mission Report documented that it would.[35]

The steel used for the superstructure was more likely to be HTS and not the STS that is listed in her original report. Using the figures established in Hit 2, an 8-inch HE projectile would produce a caliber size hole in 2.52-inch thick HTS plate. Using Equation 2 for the 0.25-inch HTS plate found here:

Hole Diameter = 8 x [2.52 / 0.25] = 80.64 inches

This calculated hole diameter is about 6.7 feet, which is close to the 6-foot hole size documented in the report.

To confirm this, we now look at the damage a normal World War II 14-inch HE projectile would have produced. This size shell will make a caliber size hole in a 4.54-inch thick HTS plate. We then can use Equation 2 as follows to calculate for the 0.25-inch thick HTS plate:

Hole Diameter = 14 x 4.54 / 0.25 = 254.24 inches or 21 feet

Even taking into account the smaller explosive filler of the 14-inch Type 0 HE projectile; 254.24 x 0.864 = 219.66 inches or 18.3 feet, this size projectile would have resulted in the bulkhead completely disappearing! Clearly, this hole was not made by a 14-inch projectile and the best estimate is an 8-inch Type 0 HE projectile.

The large number of shell fragments of relatively small size for this hit is typical of a HE shell due to the large cavity and thinner sides of that kind of projectile. The only heavy cruiser to fire Type 0 HE projectiles was *Atago* as *Takao* fired only AP ammunition during this battle. *Atago* was the last heavy cruiser to open fire at 0103 and there is only a brief period of time during which she is ahead of *South Dakota*, as she was in the lead of the Japanese formation. Since *Atago* was part of the bombardment group, she may very well have been loaded with Type 0 HE shells for her first salvo. Her ammunition report says that she fired a total of six HE shells during the battle.[36]

[35] Japanese Technical Mission Report 0-19 Japanese Projectiles General Types
[36] *Atago* Direct Action Report and *Takao* Brief Action Report JT1, although this report also says that she did not hit *South Dakota* during the battle.