U.S.S. SAVANNAH (CL42)

Bomb Damage

Gulf of Salerno, Italy
11 September, 1943

Class.....Light Cruiser (CL42)	Length (W.L.).....600 ft.
Launched.....8 May, 1937	Beam (W.L.).....61 ft.-7 in.
Displacement.....9,475 Tons (Standard)	Draft.....23 ft.-1-1/2 in. (Before Damage)

Reference:

(a) C.O. SAVANNAH ltr. CL42/L11-1, Serial 009 of 14 October, 1943 (Report of Damage).
(b) Comdt. N.Y. Philadelphia ltr. S85;Ordship 12/L11-1/ S85(E3-2) of 10 February, 1944 (forwards photographs).

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24. Showing remains of A-533-C and A-531-M, second platform, frames 49 to 56, centerline.

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26. View looking to starboard, camera at frame 51 at second platform level. Note first platform is blown up, having torn through the scarfed riveted joint in way of bulkhead 49.

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30. General view of temporary framing and shell plating installed at Malta.

31. One of two 6-inch/47 H.C. projectiles that detonated in the gun room of No. 3 turret. Both are believed to have been stowed in the left projectile rack, 30 inches below the roof. Both went off 24 minutes after the bomb hit, during which time there was a fire in the gun room. Detonations were apparently low order. The left side plate of the turret was bulged outward in way of the stowage to a depth of 4 inches.

32. A 6-inch/47 H.C. projectile split open by impact. The filler did not detonate or burn. Recovered from the gun room of No. 3 turret.

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35. Blast effect to screen on vent trunk terminating at frame 55, above main deck. The lower vent trunk supplied air to A-533-C, second platform, demolished by the detonation.

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37. Electrical cables which permitted water to pass from forward emergency power switchboard (in A-532-E) to forward main distribution board (in forward engine room).

PLATE

I Bomb Damage

SECTION I - FOREWORD

1. The case of SAVANNAH is unique even when it is considered that practically every case of war damage has its unusual aspects. The bomb which struck SAVANNAH was the largest, both as to total weight and size of charge, to have scored a hit on a U.S. naval vessel. Further, the bomb also detonated in the midst of main and secondary battery magazines - a location usually regarded as certain to cause the immediate and violent destruction of the vessel. Finally, the hit was the first made on a U.S. naval vessel with a German radio-controlled bomb.

2. Heavy punishment was absorbed by SAVANNAH in such a manner that her survival was never in jeopardy. That this was so is attributable both to the ruggedness of the hull and to the general excellence of measures taken by SAVANNAH's personnel to control damage.

3. This report is based on reference (a), complete and detailed description of damage and of measures taken to control damage, and on an inspection of SAVANNAH, upon her return to this country, by representatives of this Bureau. Photos 1 through 4 present an unusual sequence of the visible effects of the bomb detonation. They are stills from movies taken by a Metro-Goldwyn-Mayer news cameraman who was covering operations from a vessel which happened to be adjacent to the SAVANNAH. Of the other photos some were taken by the ship's camera party, some by the staff at Malta and the remainder by the Navy Yard, Philadelphia. The plate was prepared by the Bureau from a plan drawn by the staff at Malta and submitted with reference (a).

SECTION II - SUMMARY

4. On 11 September, 1943, SAVANNAH was acting as a fire support vessel for amphibious operations in the Gulf of Salerno, Italy. At 0930 the ship was lying to, awaiting the assignment of a fire mission when an alert was broadcast by the fighter director ship. Almost simultaneously a report was received that 12 German planes were entering the area. Immediately upon receipt of the warning, material condition ABLE was set and the vessel went ahead at 10 knots. At 0941 speed was increased to 15 knots. A flat calm with a heavy haze prevailed in the area.

5. At 0944 SAVANNAH was hit on the roof of No. III turret by a large A.P. radio-controlled bomb. It penetrated the 2-inch STS roof plate and passed downward inside the barbette. The shell deck, of 1-inch STS, and the first platform, of 2-inch STS, also were penetrated. The bomb then detonated in the lower handling room for No. III turret, slightly above the second platform.

6. The blast obliterated adjacent bulkheads between the first and second platforms and demolished the second platform within a radius of 15 feet from the point of detonation. A fairly large hole was blown in the bottom to port of the centerline and the seam in the port shell just below the armor belt was ripped open between frames 41 and 52.

7. Blast and flash passed up through No. III barbette and turret, killing the entire crew. A fire was ignited in the turret which burned stubbornly before being extinguished. In the magazines a powder fire of very brief duration occurred prior to the inrush of water through the openings in the shell.

8. The blast blew out most of the doors in transverse bulkheads between the first and second platforms in the area from bulkhead 25 to bulkhead 61. Smoke and toxic fumes from the detonation and the burning powder almost instantly permeated the spaces of turrets I and II, causing heavy casualties to these magazine and turret crews. Almost all compartments between bulkhead 23 and 61 below the third deck flooded quickly. The third deck flooded to a depth of about 4 feet between bulkheads 39 and 61. An 8-degree list to port and a change of trim of 11 feet down by the bow quickly were assumed.

9. All electrical power was lost temporarily for a few minutes. All telephone communications went out and but a few of these were restored. Steering control between the pilot house and steering aft went out. General lighting failed but the automatic emergency battle lanterns functioned. Difficulties were experienced with smoke in No. 1 fireroom, low water for the boilers in No. 2 fireroom, and failure of fuel oil supply to the boilers in No. 3 and No. 4 firerooms. As a result, steam was not available to the main engines for a short period. The electric plant was quickly placed back in operation and in a short time normal service was resumed to all portions of the ship except the zone of damage.

10. There was no flooding beyond that which occurred in the first 5 minutes other than some minor leaks. The efforts to fight the fire in No. III turret were handicapped initially due to failure of both electrical power and steam supply which caused loss of pressure on the fire main. The diesel fire pumps were quickly placed in operation, however, and five portable gasoline handy billies with fog nozzles were in use within 6 minutes. Within 10 minutes 80 pounds pressure from steam-driven pumps was on the fire main. About two hours were required to completely extinguish the fire, although it was under control within 15 minutes. The transfer of fuel oil to correct list was started almost immediately, and the list was removed in about 1-1/2 hours. The forward fresh water tanks were emptied, raising the bow about 1 foot.

11. Shortly before 1200, SAVANNAH anchored and two salvage tugs came alongside to assist in efforts to unwater forward compartments. This proved to be impossible and at 1800 SAVANNAH departed for Malta at a speed of about 12 knots, which was later increased to about 18 knots. She arrived at sunset the following day, and preparations for docking were immediately begun. She was docked on 19 September.

While in drydock the shell was made watertight and the longitudinal strength of the vessel was restored. The structure installed was of a temporary nature but adequate to permit her return to this country for permanent repairs. She was undocked on 5 December and departed Malta on 7 December. She arrived at the Navy Yard, Philadelphia, on 23 December after an uneventful crossing, although some heavy weather was encountered. At Philadelphia permanent repairs are being made, including the replacement of No. III turret with a battle spare. Many important alterations, including the installation of blisters and the replacement of the secondary battery with twin 5-inch/38 cal. D.P. mounts, also are to be completed.

12. One of the outstanding features of this case was the failure, when subjected to blast, of the lightweight watertight CRS-type doors located in the transverse bulkheads between the first and second platforms. The extent of blast damage, followed by some fire and then by flooding, was greatly increased by the failure of these doors, particularly those in bulkheads which were otherwise essentially undamaged. No. I turret, its lower handling room and the magazine abreast of the handling room would have been undamaged except for the presence of these light doors. Obviously the best remedy in new cruiser design is to provide sufficient vertical access so that the main watertight bulkheads can be carried intact at least to the second deck. This measure was recognized as being of great importance and was put into effect in cruiser designs some time before SAVANNAH was damaged. All recent cruiser designs beginning with the CL106 class have this feature. With respect to SAVANNAH and some of the other older cruisers, it has been possible to eliminate some of these doors. In addition, it is possible to rearrange the 6-inch ammunition supply in some of the cruisers now in service so that additional transverse bulkheads can be installed when availability permits. Finally, a comprehensive test program has been inaugurated with the objective of developing a type of door which will more effectively resist blast.

13. Large A.P. bombs are capable of penetrating an armored deck of any thickness which it is practicable to install on cruisers. This case, however, indicates that some reduction in the extent of blast, fragments and flooding would have been obtained by the presence of heavy STS bulkheads. The effectiveness of STS in limiting blast and fragment damage is well known and was emphasized in the case of YORKTOWN*. Even in the case of SAVANNAH, the 2-inch STS first platform had an appreciable effect in protecting spaces above this level from blast and fragments. Weight limitations and interior arrangements prohibit the installation of vertical STS bulkheads on most cruisers. However, the CA139 class, of much larger size, will have 3/4-inch STS transverse bulkheads continuous from the keel to the second deck in seven locations. These bulkheads, in addition to restricting the effects of bomb or projectile detonations within the hull, also will reduce the fore and aft extent of structural damage and flooding resulting from underwater explosions.

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* Buships War Damage Report No. 23.

14. SAVANNAH's crew was extremely well-trained in all aspects of damage control. Although damage and flooding were extensive and all normal services were completely disrupted temporarily, within a very short time after damage was received the situation was completely under control and SAVANNAH could have continued in action had this been required. Many problems were faced and all were solved effectively. For these reasons damage control measures are reported in considerable detail in Section III.

SECTION III - NARRATIVE

(All Photos, Plate I)

15. On 11 September, 1943, SAVANNAH was in the Gulf of Salerno, Italy. She was acting as a fire support vessel for amphibious operations being conducted by U.S. and British forces. Prior to dawn SAVANNAH cruised in the transport area and had undergone some sharp air attacks. These ceased about one hour before sunrise. At sunrise preparations were made to furnish main battery fire support to the Army upon call from the Shore Fire Control Party. Material condition ABLE had been modified to provide ventilation for certain below-deck spaces and a few hatches and doors had been opened to permit access to washrooms and heads. The crew had been at General Quarters almost continuously since the evening of 8 September.

16. The day dawned clear and warm. A flat calm with a heavy haze spreading out from the beaches prevailed in the gulf. Depth of water was about 30 fathoms. At 0930 SAVANNAH was lying to in the transport area about 5 miles from the beach, awaiting the assignment of a fire mission, when a RED ALERT was broadcast by the headquarters and fighter director ship. Simultaneously a report was received that 12 German planes were entering the area from the southward.

17. Immediately upon receipt of the alert, condition ABLE was ordered set, all hands went to battle stations, the gun batteries were alerted and the ship went ahead at 10 knots. At 0941 speed was increased to 15 knots.

18. At 0944 a twin-engined bomber was sighted almost overhead coming out of the sun on the port quarter and the A.A. director tracked it at an altitude of 18,700 feet. At the same instant a bomb struck the roof of turret III at an angle of about 20 degrees from the vertical and from starboard. The actual release of the bomb was not observed. The first indication was a trail of smoke in the general direction of the bomber which observers at first thought to be a falling plane.

19. The bomb made only a "whooshing" noise as it hit. Considerable debris from the balsa life rafts stowed on top of turret III was thrown high into the air. A heavy jolt was felt and personnel at the 20mm guns on the main deck near turret III and on bridges were knocked

down. A tremendous turbulence developed in the water abreast turret III to port, and clouds of smoke and vapor issued up from this turbulence. Smoke poured out of turret III in great rolls and combined with that coming out of the water, completely blanketing the forward half of the vessel. Photos 1 through 4 bear eloquent witness to these phenomena.

20. The bomb pierced the 2-inch roof plate of the turret 3 feet from the front edge and about 8 inches to the left of the centerline, leaving a jagged hole about 21-1/2 inches in diameter (Photo 6). It struck the rammer and breech block hydraulic motor and pump, demolishing them. Passing between the left and center slides, it broke off the left half of the slide, struck the roller path at a point 45 degrees to port from the centerline of the ship and was thus deflected almost straight downward inside the barbette. It passed through the electric deck (3/8-inch medium steel), the shell deck (1-inch STS), the first platform (2-inch STS) and detonated in the 6-inch lower handling room about 2 feet above the second platform at frame 48, some 5 or 6 feet to port of the centerline. A total thickness of about 5 inches of STS and of about 2 inches of medium steel was penetrated prior to detonation, and travel from point of impact was 36 or 37 feet.

21. The immediate consequences of the detonation were severe, and comprised the following:

(a) All electrical power was lost except that from the after emergency diesel generator. General lighting failed but the automatic relay controlled emergency battle lanterns furnished illumination.

(b) All telephone communications on the primary circuits went out, including ship control, gunnery, ship's service and I.C. circuits.

(c) The general announcing system circuit went out.

(d) The engine order telegraph and annunciator system circuits from the pilot house to main engine control went out.

(e) Steering control from the pilot house to after steering was lost.

(f) Both gyros were rendered inoperable.

(g) A serious fire was burning in turret III.

(h) The ship took an immediate list to port which increased to 8 degrees in 3 minutes. The draft before the explosion was about 22 feet 3 inches forward and 24 feet aft. When the ship had settled the draft was about 34 feet forward and 21 feet aft.

(i) Several small fires, caused by burning debris from the top of turret III, were scattered about the main deck.

(j) There was very little pressure on the fire main.

(k) Steam pressure to the main engines was falling rapidly. Smoke filled No. 1 fireroom, the fuel oil supply to boilers in Nos. 3 and 4 firerooms was failing, and feed water supply to the boilers in No. 2 fireroom was diminishing.

22. Repair parties went into action immediately. The small deck fires were quickly stamped out. The after emergency diesel fire pump (in compartment D-307-3-E) was started in approximately one minute, and within 4 minutes, 80 pounds pressure was available at some plugs adjacent to turret III. Hoses were rapidly hooked up and streams were directed into the turret through the hole in the roof plate and through the muzzles of the guns. The pump room, compartment A-502-AE on the second platform and in which was located the forward emergency diesel fire pump, could not be manned at General Quarters because the access hatch on the first platform at frame 20, port, could not be opened from below. (The pump room had been converted from a storeroom, not manned at General Quarters, and the hatch cover was fitted only with dogs on the top. A scuttle had been authorized but lack of availability had prevented installation.) It was the practice for the crew of the pump to stand by on the second deck. This pump, however, was in operation within 3 minutes, although a break in the fire main in the ruptured area prevented delivery of full pressure to the plugs forward of turret III. Considerable difficulty was experienced in isolating the break in the lower branch of the forward loop. The break, of course, was aft of the diesel pump. The cut-out valve at frame 35 in 6-inch magazine A-512-M was jammed open and operation of the remote control rod from the second deck failed to close the valve. It was necessary to descend again into the smoke-filled second deck spaces and operate the remote control wheel for the cut-out valve in A-504-M (the lower handling room for turret I). Within 8 minutes, the pump was delivering water at working (80 pounds) pressure to second and main deck fire plugs forward of turret III. Pressure from this pump, combined with that from the after pump and reinforced within a few minutes by steam pumps in the engineering spaces, assured pressure and capacity adequate to operate seven 2-1/2-inch nozzles. All were directed into turret III, and in 15 minutes the fire was under control. It was extinguished in about 2 hours, although considerable smoke continued to pour out of the turret. As a precaution, a few streams were played into the turret until the middle of the afternoon. Although not reported, it is apparent from the record that the cut-out valve at frame 61 in the forward fireroom, which controls the supply of water to the lower portion of the forward loop, was closed by the engineering force, thus isolating the break in the main. It was found later that the lower branch of the forward loop was demolished between frames 40 and 55. Thus the break was isolated both forward and aft in a very short time, and the upper branch of the forward loop served the plugs which were utilized in extinguishing the fire. In addition to using hoses connected to the fire main, five portable gasoline handy billies were brought to turret III and placed in operation immediately. Fog applicators were used with these pumps and the Commanding Officer reported that both the pumps and fog nozzles were highly satisfactory.

23. At 1008, about 24 minutes after the detonation of the bomb, a secondary explosion occurred in the gun room of turret III. It was severe enough to knock down several men who were spraying water through the rear door and through the hole on top of the turret. At this time, vent ducts around the base of turret II were cut open and water directed into them. The electrically-operated magazine sprinkling valves could not be operated because of the loss of power.

24. The three forward turrets and the second deck between bulkheads 18 and 59 were filled immediately after the hit with a heavy smoke. Reference (a) reported that the smoke was toxic, containing nitrous oxide fumes and some carbon monoxide. The smoke on the second deck was cleared in about an hour by opening main deck hatches and cutting down the canvas light locks around the ladders. The ventilation set supplying the wardroom (A-213-L) was found to be operable and assisted in clearing this and adjacent compartments. All of the men in the gun rooms of turrets II and III, were removed within 30 minutes, but only five from turret II could be revived. The majority of personnel in the upper spaces of turret I escaped. Members of repair parties and others entered turrets with type "A" rescue breathing apparatus, but these proved difficult to use because the lung deflated as the wearers bent over or crawled, or attempted to handle casualties. It was necessary to remove the breathers when working in the restricted areas of the gun rooms. The rescue breathers, however, were apparently satisfactory for work on the second deck. All of the rescue breathers were equipped with the specified rubber cap over the relief valve, but this did not prevent deflation of the lung when used in cramped spaces.

25. A man was sent down the forward A.A. director control tube to the scuttle at the first platform above central station. The scuttle was found to be closed, but some water was leaking into the lower end of the tube. There were no signs of life in central station below.

26. Initially, the third deck flooded to a depth of about 18 inches between bulkheads 39 and 61. As the ship slowed, the water increased in depth and reached 4 feet when the ship stopped. It was found later that about 15 feet of the port A strake was hanging down and aft, hinged at about frame 43, and this apparently created a slight suction through the hole in the bottom when the ship was underway and thus tended to reduce the water level inside the hull. The third deck flooded through the hatches at frames 52 and 55, which were blown off, and those at frames 41 and 45 (port) which were blown open. All the doors in bulkheads 45 and 49 were either blown off or warped so badly that they leaked. In addition, many ventilation ducts passing through this area from spaces below were split open by blast and permitted some flooding. The water on the third deck was covered by a thick layer of fuel oil.

27. In the afternoon, two tugs with portable salvage equipment came alongside and rigged two large pumps on the main deck. Considerable time elapsed before the pumps were placed in operation, because of the unwieldiness of the steel pipes used for the pump suctions. Efforts to lower the water level on the third deck with these and portable submersible pumps were unsuccessful on account of the

large openings in the deck through which water entered. The pumps were successful, however, in removing most of the surface fuel oil. Late in the afternoon the tugs departed, leaving the pumps aboard for emergency use. The pumps were so large, however, that the Commanding Officer did not believe they would have been of much value inasmuch as they could not be moved to the second deck. Fortunately, they were not needed on the voyage to Malta.

28. A short time after the hit, it was found that four men were trapped in Radio III (A-425-C, first platform, starboard, frames 56-61). A natural exhaust duct at frame 57 leading to this space was cut above the second deck and a compressed air hose led into the duct in an effort to draw air down the duct to the compartment. This was not successful. Communication was established by using audio channels from the main radio. After the fan room (A-214-3E, second deck, centerline, frames 55-59) was cleared of smoke, the supply ventilation system to Radio III was placed in operation and the air supply established. The transmitter control circuit was found to be intact, and by connecting this cable to the emergency power system the trapped men were furnished with electric power for the operation of an electric light and one fan. A hose could not be forced down the exhaust duct because of bends and angles in the duct. Late in the afternoon, however, the trapped men tied some toilet tissue to a thread and started it up the exhaust duct, and the draft carried it to the second deck. A two-way pull line was established and water and food provided. Upon arrival at Malta a square cofferdam, built during the voyage, was placed on the third deck over Radio III, and Yard workmen drilled and chipped through the deck (3/4-inch STS). The men were released about 60 hours after being trapped and were in excellent condition.

29. Shoring was restricted to the lower portion of the forward bulkhead (No. 61) of the forward fireroom in the port and starboard airlocks.

30. In paragraph 21, the casualties which occurred in the machinery spaces were listed. The efforts of the engineering personnel were as intense as those of the repair parties,and gave successful results in an incredibly short time.

31. At the time of the hit, the generators were in a split-plant setup. No. 1 turbo-generator, in the forward engine room, was supplying power to all circuits forward of frame 96, and No. 3 turbo-generator in the after engine room was supplying power to all circuits aft of frame 96, except that one of these generators energized port turret circuits and the other energized starboard turret circuits. Nos. 2 and 4 turbo-generators, in the forward and after engine rooms respectively, were not in use. Both the port and starboard power cables to the forward turrets were energized to the selector switches in the turrets, as is standard practice, although it was not reported which of the two generators was actually supplying power to the forward turrets.

32. Immediately following the hit, all electric power except that from the after diesel generator was lost, as both No. 1 and No. 3

turbo-generators tripped out. The after emergency diesel generator (100 KW capacity, located in the hold just aft of the after engine room) started automatically and continued to supply power to the following: steering motors, after emergency lighting circuits, and the auxiliary I.C. switchboard (in D-604-E, in the hold aft of the after diesel generator room). The forward emergency diesel generator and its switchboard, in A-532-E on the second platform, port, were demolished. The holding circuit from the forward main generator switchboard to the forward diesel starting relay was short-circuited, causing No. 1 main generator to trip out. This circuit later was found to be unprotected and attempts to put No. 1 main generator back on the line failed as the generator circuit breaker continued to rip out. Short-circuited main power leads to the forward turrets caused No. 3 turbo-generator to trip out. The initial surge from the short circuits went through the turret feeder breakers and tripped the generator circuit breakers almost simultaneously with the feeder breakers. No circuit breakers were locked in.

33. An attempt was made immediately to put No. 1 main generator back on the line. As noted in paragraph 32, however, the unprotected short-circuited holding circuit to the diesel relay prevented this. At the same time, attempts were made to close the bus tie circuit breakers between the two main switchboards, but because of the same short-circuited holding circuit on the forward main board, No. 3 generator circuit breaker tripped out. In the meantime, No. 4 turbo-generator had been started. The bus tie between the two main distribution boards was then tripped, and No. 4 main generator was paralleled with No. 3. After this was done, an attempt was made to supply the forward main distribution board from the after main distribution board, but the short on the forward main board caused the bus tie circuit breaker to again trip out. Next, No. 1 main generator was shifted to atmospheric exhaust (probably because of loss of vacuum) and cut in again on its switchboard, but the generator circuit breaker again tripped out.

34. At this point, all circuits on the forward main distribution board were pulled, and No. 1 generator was again put back on its board. The generator carried the load on the board for about 30 seconds, but the diesel relay starting circuit again overheated, shorted out at the board and started a fire. The forward engine room, with no power to the ventilation blowers, filled with smoke from the fire. The fire was immediately extinguished with CO_2 extinguishers. Casualty power cables were then run from the after main switchboard to the power panel supplying the blowers in the forward engine room, and the blowers were started, clearing the engine room. When this was completed, the trouble-making circuit was cleared and the bus tie to the after main board closed. The after generators then took the load. The forward board was then re-oriented and power was restored to normal as far forward as frame 65. A few upper circuits forward of this point were also found to be intact and were energized.

35. Although the measures described above seem involved and tedious, actually they were performed rapidly. At 0952, only 8 minutes after the hit, Nos. 3 and 4 turbo-generators were furnishing power to the after half of the vessel and by 1000, only 16 minutes after the hit,

power was available to the entire vessel except in the zone of damaged circuits.

36. Nos. 1 and 2 main generators were eventually ready for operation, although their use was unnecessary. As will be described later, during the first few minutes after the hit, steam supply was inadequate to run more than two main generators under load.

37. Once the main power supply was assured, electricians busied themselves in making emergency repairs. Emergency telephone circuits between the pilot house, main engine control and after steering station were rigged and in operation by 1200. The forward gyro was disconnected from the after gyro switchboard (the flooding of central station and the I.C. room had completely disrupted telephone, general announcing and forward I.C. service). The after gyro was then restored to service. An emergency lead was run from the secondary conning station to the pilot house for one gyro repeater. Four sound-powered telephone circuits were cleared of shorts and placed in operation by isolating them from damaged circuits at cut-out boxes. Casualty power supply was run from the forward distribution board to a forward power panel on the second deck to supply submersible pump outlets. Jumpers were installed between lighting panels forward to provide lights forward of and above the damaged area. The next day, emergency cables were run to provide steering selsyn control from the after steering station to the pilot house and others to provide rudder angle indication to the pilot house. Emergency power was also provided to the anchor windlass in case the regular cable suffered a short circuit.

38. All power cables beginning or ending in flooded areas were removed from the after distribution switchboard. Degaussing coils were disconnected at their respective connection boxes. On 14 September a small fire occurred at the forward main switchboard. It was caused by water leaking through cables from the forward diesel generator room. Time apparently had not been available to completely strip this board of all cables leading to the damaged area, but after this casualty stripping was completed as soon as possible. Typical cables which permitted water to pass more than 160 feet are shown in photo 37.

39. Prior to the hit, the steam plant was operating on a split basis with boilers 1, 2 and 8 furnishing steam to the port turbines and boilers 3, 4 and 7 supplying steam to the starboard turbines. The feed system was also separated, with No. 1 main feed pump supplying boilers 2, 4 and 8 and No. 2 main feed pump supplying boilers 1, 3 and 7. Boilers 5 and 6 were on 15 minutes' notice. Nos. 1 and 2 electric fire and flushing pumps were supplying the fire main. The machinery arrangement on vessels of this class is such that a more complete segregation is impractical.

40. At 0935, boilers 5 and 6 had been lighted off, and at the time of the hit steam pressure had been raised to 125 pounds. Immediately after the hit electrical power and lighting went out as has been described. The automatic emergency battle lanterns functioned, however,

and these, along with flashlights, furnished illumination in the machinery spaces until electrical power was restored.

41. The electric fuel oil pumps in Nos. 3 and 4 firerooms stopped and fires went out under boilers 5, 6, 7 and 8. Nos. 1 and 2 electric fire and flushing pumps (one located in each engine room), Nos. 1 and 2 electric cruising condensate pumps, and gland leak-off exhausters on all engines also stopped. Within two minutes of the hit, No. 1 fireroom was filled with heavy smoke which was drawn in by the fireroom blowers. The smoke was toxic, and fires had to be secured and the fireroom abandoned.

42. In No. 2 fireroom, the feed water supply was failing, and boilers 3 and 4 had to be secured because of low water. The personnel on watch in Nos. 3 and 4 firerooms had started the steam-driven fuel oil pumps when the electric fuel oil pumps had stopped, and fires under boilers 5, 6, 7 and 8 were relighted within 3 minutes of the hit. Steam pressure had dropped, however, on main and auxiliary steam lines, and throttles for all engines were closed to conserve steam until boilers in Nos. 3 and 4 firerooms could furnish sufficient steam to serve the main engines as well as the generators (it will be recalled that at least two main turbo-generators were furnished with an uninterrupted steam supply). Six minutes after the hit, boilers 5 and 6 were cut in on the main and auxiliary steam lines and steam was restored to the engine rooms. The cross connection in the main steam line in No. 3 fireroom and that in the feed system in No. 4 fireroom were then opened. At this time, 0950, the steam turbines for the fire and flushing pumps in the engine rooms were started and 80 pounds pressure was available to the fire main.

43. As noted in paragraph 35 electric power was restored to the after engine room at 0952, only 8 minutes after the hit, and at 0954 this engine room reported ready to answer bells. At 1000 electric power was available to the forward engine room and it reported ready to answer bells.

44. At 1000,boilers 3 and 4 were relighted. Although the reason for failure of the feed water supply to No. 2 fireroom was not reported, it probably was caused by low pressure on the main feed system as the result of falling steam pressure to the main feed pumps in the forward engine room. When full steam pressure was regained, the feed water supply difficulties disappeared.

45. When uninterrupted steam supply, electric power and fire main pressure had all been assured, the engineering force turned to the problem of removing the 8-degree port list. At 1005, the shifting of fuel oil was commenced. About 17,000 gallons were transferred from port to starboard 'B' tanks (abreast the firerooms). No ballast was taken aboard. About 30,000 gallons of fresh water were pumped out of four forward peak and potable water tanks. These measures, completed in about 1-1/2 hours, brought the vessel to the upright and raised the bow about one foot.

46. The air attack ended at about 1040, and SAVANNAH anchored at 1108. As noted previously, two salvage tugs came alongside. Work of transferring casualties started at 1200. Another air attack developed shortly after this, but did not interrupt work. The pumps from the salvage tugs were in operation by 1300, but were unsuccessful.

47. During the afternoon the extent of damage and flooding was determined and the situation assessed. At 1600 a diver went over the side and inspected the bottom. He found the large hole in the bottom and the open seam below the armor belt shown on plate I and in photos 7 and 8. The initial list was caused by off-center flooding in compartments A-538-T, A-518-T and A-514-T on the second platform, A-606-M in the hold and A-434-A on the first platform. 800 gallons of aviation gasoline were transferred during the afternoon. With the situation under control, departure for Malta was made at 1800 to the accompaniment of a large and bitter air battle overhead at high altitudes.

48. The harbor at Valetta, Malta, was reached at 1900 the next day, 12 September. The passage was uneventful and was made for the most part at 18 knots. Although drafts forward of 35 feet -8 inches and aft of 21 feet were reported in reference (a), it is apparent from photo 5 that draft forward was about 33 feet. This latter figure also checks with the depth of water on the third deck reported to have been about 4 feet. Frequent inspections were made in and around the damaged areas.

49. At Malta, considerable work was necessary to reduce the trim by the bow to permit safe docking. Anchors, chain cable and all other forward movable gear were removed. All storerooms aft of frame 126 were emptied of stores and supplies and then flooded. The guns and roof plates of turrets I and II were removed. A-316-L, on the third deck, was made tight by closing the hatch at frame 60 to the evaporator room below, and was pumped out. The doors in bulkhead 45, above the third deck, were blanked off and A-312-L was unwatered. A-602-F was emptied. Projectiles were removed from turrets I and II. Divers cut away the wreckage projecting below the bottom. Finally, SAVANNAH was placed in dock during the afternoon of 19 September with drafts of 29 feet -4 inches forward and 25 feet -2 inches aft. Damage to the pumping plant at Malta from previous bombings made unwatering of the dock a slow process. The slow unwatering of the dock permitted the flooded storerooms to be unwatered simultaneously with the dock, thus removing any danger of excessive loads on the dry dock blocks. At 0730 on 20 September the dock was dry, and clearing away of wreckage and removal of the dead were commenced.

50. Photos 11 through 29 show the details of the damage to the interior of the ship. The overall picture of the situation is best obtained from an inspection of plate I. All compartment boundaries on the second platform within 20 feet of the point of detonation were obliterated. A hole, about 30 feet in diameter, was blown in the second platform proper. The port A and B strakes of the bottom shell were blown open for a length of about 28 feet. The seam in the shell plating

just below the port armor belt was ripped open between frames 41 and 52, a distance of about 45 feet (Photo 7). The riveted scarf in the 2-inch STS first platform plating in way of bulkhead 49 was ruptured, and the deck blown up almost to the third deck, with the riveted seams at the inboard edge of both port and starboard stringer plates separating between frames 49 and 55 (Photos 13, 18 and 19). The countersunk rivet points pulled through the holes in all of these joints. The third deck, protected from the blast by the 2-inch STS first platform, was deflected upward only slightly in the vicinity of barbette III. The entire assembly, including the barbette, of turret III was lifted about 4 inches.

51. By reference to plate I, it will be noted that all doors in transverse bulkheads between the second and first platforms from and including bulkhead 29 to bulkhead 56 were either demolished by blast, blown completely out of the frames, or blown open. Bulkheads 55-1/2, 56, 29 and 35 were otherwise practically undamaged and were made tight at Malta by blanking with plates welded to the frames. The doors in certain longitudinal bulkheads also failed. In those bulkheads which were otherwise substantially undamaged, the doors failed by crumpling in the middle with little or no damage to the dogs. In some cases the hinge pins sheared. The doors were of the lightweight CRS, dogged type and had successfully withstood a pressure equivalent to that of the test head level (in this case the second deck) during the building period. It was the failure of these doors which permitted fumes and flooding to spread through magazines A-507-M, A-504-M and A-503-M and up through turret I, resulting in the heavy casualties to personnel in these spaces.

52. The behavior of the ammunition in turret III, in its powder magazines and in adjacent 5-inch magazines is of interest. Reference (a) contains a very complete report which was based on a careful inspection, followed by complete recording of the facts, of the contents of the affected magazines and turret spaces. The following is a condensation of that portion of reference (a) dealing with the subject.

53. Magazines A-522 (5-inch handling room), A-523 (6-inch powder), A-527 (5-inch cartridges), A-620 (40mm), and the after half of A-516 (5-inch cartridges), A-515 (6-inch powder) and A-517 (5-inch cartridges) were completely demolished and the ammunition was only a tangled mass of debris, intermingled with other wreckage. Inspection revealed the following in these spaces:

(a) About 100 rounds of 5-inch/25 powder (illuminating cartridges and AA common) in A-527-M had burned. The expellant* charge in about the same number of illuminating cartridges had burned and expelled the stars, which in turn were partially burned.

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* The charge in the base of the projectile which expels the parachute flare.

(b) 5-inch ammunition in the remaining 5-inch magazines had not ignited. Cartridge tanks of all this ammunition were tightly shrunk upon the cartridge and in many instances the powder case was collapsed. Photo 33 shows the general condition of such ammunition. Although there was evidence of fragment attack through the inboard longitudinal bulkhead of 5-inch magazine A-516-M, no 5-inch projectiles had detonated. There was no definite indication that any 5-inch projectiles had been struck by fragments.

(c) About six of the 6-inch powder charges in A-515-M showed evidence of having burned. The deck of this space was covered by unburned powder grains to a depth of 5 inches. The 6-inch charges in the forward half of this space were thrown about in disorder. The tanks were badly deformed and had shrunk tightly upon the powder cases.

(d) The 40mm ammunition boxes in A-620-M were badly crushed and it was estimated that about 400 rounds (of a total of 4000) had burned. About 50 projectiles had detonated.

54. In other forward 6-inch magazines, the powder charges were largely still in their racks, except in A-507-M where they were thrown about. The tanks were shrunk on the cases and, of course, had been submerged. Photo 34 shows typical recovered 6-inch charges.

55. As noted in paragraph 23, about 24 minutes after the detonation of the bomb there was a secondary explosion in the gun room of turret III. Later inspection revealed that the powder cases at the top of each of the three powder hoists had ignited almost immediately after the hit, having been penetrated by small fragments (apparently structural). The fire was intense, although the evidence of it was confined to the after end of the gun room and adjacent to the booth. Personnel in the after end were more severely burned than those forward. High capacity projectiles in the left rack (30 inches below the turret roof along the side armor) were scattered about the gun room and the rack was blown away. A bulge about 4 inches deep, 20 inches long and 12 inches high was found in the 1-1/2-inch turret side plate in way of the rack. Two of the projectiles were found in a condition which indicated that low-order detonations had occurred. One of these is shown in photo 31. Another projectile, photo 32, was found split open by impact, apparently when it fell off the rack, with the filler unburned. Finally, the intensity of the explosion can be gauged by the fact that personnel on the turret roof and one man on the deck playing a hose in the rear hatch were knocked over by it.

56. There were more than 200 fatalities. The majority of these were located in the three turrets and their magazine spaces. The next biggest groups were trapped in the Plotting Room, Central Station and I.C. room. There also were several blast and asphyxiation fatalities on the second and third decks. These were caused by blast and fumes traveling up ventilation ducts. The natural exhaust ducts from the magazines terminate in second deck spaces and are not fitted with closures at the upper end. The lower ends of the ducts in the maga-

zines (with their closures) were blown off. Other ducts were split open by blast in spaces on the first platform and third deck and permitted fumes to spread as well as some flooding. Flame traveling up ventilation ducts caused some deaths from flash burns. Personnel killed from this cause were incompletely clothed. Personnel in turret spaces above the waterline were killed by fire and blast in turret III and some by asphyxiation in turrets I and II. Fumes passed up the powder and projectile hoists, in addition to the turret ventilation systems.

57. Opening the right tail hatch cover in the high turret (No. II) enabled five men to escape. However, the cover was not latched upright, although a toggle pin was provided for the purpose, with the result that the cover fell on the sixth man as he was coming through and other men piled on top of the cover pinning him. The weight of men on top of the cover effectually retarded rescue efforts until too late. The left hatch cover was latched open, but men were overcome before the armored hatch could be undogged*. Thus, all but five men in the gun room were asphyxiated although all were removed within 30 minutes.

58. Structural repairs made at Malta were of a temporary nature, but entirely satisfactory for the trip back to the United States. Deep frames were installed at frames 42, 45, 49 and 52; the keel was replaced in the damaged area; the longitudinals in the damaged area were replaced by deep girders; support was provided for turret III; and temporary plates were installed and faired into the shell. Photos 9 and 10 show the shell after completion of repairs. The most interesting job was that of making tight the 2-inch STS first platform. Possessing neither the facilities nor the time required to remove, reroll and reinstall such heavy plates, the deck was made tight in place by welding light plates and shapes, cut to fit the irregularities, into the gaps between the raised portion and adjacent structures. A portion of this installation is shown in photo 18.

59. The ship's force assisted and actually performed much of the work. SAVANNAH's crew also assisted in the operation of the yard power plant and gave assistance to the crews of two U.S. destroyers which were present at the same time at Malta for battle damage repairs.

60. SAVANNAH's electricians established power supply to the 5-inch directors and established gun train, gun elevation order and fuze setting from the directors to the 5-inch battery. Thus, the following conditions of the armament prevailed for the passage home:

(a) Director control of the 5-inch battery in indicating only with starboard guns controlled by the forward director and port guns by the after director.

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* The two armored hatches in the rear of the overhang of high turrets open downward. Hatch covers for these are provided inside the turrets to prevent stumbling over the dogs and possible inadvertent undogging of the armored hatch. The hatch covers open inward.

(b) Turrets IV and V in director control from the after main battery director.

(c) 20mm and 40mm batteries were normal except that fifty percent of the mark 14 gun sights were left in the area as battle spares for other vessels.

61. SAVANNAH was undocked on 5 December with temporary repairs complete (see Photos 9 and 10). After brief post-repair tests, she departed on 7 December and proceeded to Bizerte, Tunisia, where the aviation unit was re-embarked. A stop was made at Mers-el-Kebir, Algeria, to pick up passengers on 10 December A storm blew up in the afternoon and tug service was inadequate to move her (wind force was 7). On the morning of 11 December she made her departure and stopping only once, at Bermuda on 20-21 December for fuel, she arrived at Philadelphia, on 23 December.

62. At Navy Yard, Philadelphia, SAVANNAH is receiving what amounts to a substantial modernization and complete overhaul. The principal alterations are the replacement of the 5-inch/25 AA guns with 5-inch/38 double purpose guns in twin mounts, the installation of blisters, certain rearrangements of interior spaces to provide necessary control spaces to accommodate the new battery, and improved subdivision.

SECTION IV - DISCUSSION

A. Type of Bomb

63. The bomb which struck SAVANNAH undoubtedly was of the radio-controlled type employed by the Germans and one which is commonly referred to as the "FX" or "Fritz X". This bomb is of the armor-piercing type with a total weight of 1400 kilograms (3080 pounds) and contains a bursting charge of 270 kilograms (594 pounds) of an explosive similar to Amatol.

64. The altitude of release was obtained by one of SAVANNAH's A.A. directors which tracked the attacking plane at an altitude of 18,700 feet almost at the instant of release. With a bomb of such large size, this altitude is more than sufficient to effect penetration of any practicable thickness of armored deck.

B. Structural Damage and Flooding

65. The point of detonation was deep within the ship not more than 6 feet from the centerline. A 594-pound charge detonating in such a central location is certain to cause extensive structural damage and large-scale rupture of the underwater hull in ships of cruiser size or smaller. Comparison of the structural damage in this case with that caused by torpedoes with warhead charges of approximately

equivalent size detonating against cruiser hulls* indicates that SAVANNAH's damage was somewhat more extensive than would have been caused by such a torpedo striking the side at about the same fore and aft location (frame 48). This can be attributed to the central location of the detonation, the effects of which were almost entirely confined within the hull. In a side contact detonation, a portion of the explosive energy is expended in moving large quantities of water. This phenomenon is manifested by the column of water usually thrown up at the side by a torpedo detonation. Photos 1 through 4 show that the plume in SAVANNAH's case was comprised largely of gas, smoke and vapor.

66. Flooding in this case also was somewhat more extensive than that which normally would result from a side torpedo hit in approximately the same fore and aft location. Flooding was almost complete from bulkhead 23 to bulkhead 61, a length of 152 feet. Flooding following a contact detonation of 660 pounds of TNT at mid-depth at frame 48, for example, would be expected to be confined between bulkheads 39 and 61, a length of only 88 feet. That flooding was so extensive on SAVANNAH is attributable to two factors: first, severe blast effect which was of such magnitude that all bulkheads between frames 38 and 58 were wrecked; and second, the presence of watertight doors which were blown out of bulkheads otherwise undamaged. The subject of doors in main transverse watertight bulkheads will be discussed more fully in the following sub-section.

67. The 2-inch STS first platform effectively limited the vertical extent of blast damage. Although the riveted scarf connections joining deck plates failed, as described in paragraph 50, the third deck was not ruptured and received only a moderate permanent set. The efficacy of comparatively heavy thicknesses of STS in limiting blast and fragment damage was recognized long before the war, particularly with respect to vertical bulkheads, and has been demonstrated many times since the start of the war. STS deck plates of moderate thicknesses in newer vessels are joined by welding, which improves both the tightness and the efficiency of the connections.

C. Limitation of Damage Following Torpedo Attack or Bomb and Projectile Detonations Inside the Hull

68. It has been noted in the narrative, paragraph 51, and indicated on plate I that failure of watertight doors in bulkheads between the first and second platforms in the forward magazine spaces greatly increased the extent of blast damage, the spread of toxic gases and flooding. Specifically, the failure of the doors in bulkheads

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* For examples, see Buships War Damage Report No. 36 which describes torpedo damage to CHESTER and MINNEAPOLIS.

35, 29, 55-1/2 and 56, which were otherwise substantially intact, greatly extended the damage and was responsible for many fatalities. Reference (a) criticized the installation of doors in transverse bulkheads and recommended further subdivision of the magazines.

69. These doors were initially provided to facilitate the transfer of ammunition between the turrets and to permit horizontal access between second platform spaces. The principle of vertical access to spaces between transverse bulkheads has been universally recognized for many years and has long been applied to machinery space bulkheads. This case, however, served to emphasize the desirability of carrying transverse bulkheads intact to the second deck (in cruisers). The principle was first extended to include all main transverse bulkheads in cruiser designs, beginning with the CL106 class, contract plans for which were completed in September, 1942. This principle also has been extended to other types, insofar as practicable.

70. In SAVANNAH and sister vessels, additional transverse bulkheads at frames 32 and 116 will be installed between first and second platforms, thus dividing both A-507-M and D-507-M. The door in bulkhead 39 is to be blanked off. The spaces between frames 49 and 61 are being rearranged in order to provide adequate plotting and I.C. facilities for the new 5-inch/38 battery and doors in transverse bulkheads will be largely eliminated. The blanking off of doors and the installation of additional bulkheads, similar to the action taken in the case of SAVANNAH, has been authorized where applicable for other cruisers.

71. In many ships, as on SAVANNAH, it has not been possible to eliminate all such doors in the lower portions of transverse bulkheads because unacceptable restrictions on the ammunition supply would be created. The doors which failed on SAVANNAH were of lightweight CRS. Such doors have been satisfactory insofar as tightness under test head water pressures is concerned, but in this case proved to be weaker when subjected to blast than the bulkheads in which installed. Lightweight doors have not been installed in spaces below the weather deck for some years, but the older vessels still have them. Doors in the newer vessels are of medium steel which so far have performed somewhat better under blast than CRS doors. Nonetheless, a comprehensive test program has been inaugurated with the objective of developing a type of door which will offer the same degree of resistance to blast as the bulkhead in which it is installed.

72. The Commanding Officer, in reference (a), also criticized the arrangement of armor, making the point noted in paragraph 13 that armored decks of moderate thickness cannot defeat large A.P. bombs. It was suggested that the weight employed in horizontal armor might be better utilized for vertical STS bulkheads, which would tend to localize damage. He stated, in support of this argument, that it was problematical whether 2 inches of horizontal armor (the thickness of the armored deck on SAVANNAH) would defeat any but minor caliber shells. Armored decks in the older cruisers were installed primarily to provide protection for the vitals against projectiles fired from guns of the same caliber (6-inch in SAVANNAH's case) at the most likely

battle ranges. This principle has long been recognized as offering a reasonable compromise between the conflicting requirements of weight and protection. Actually, the 2-inch armored deck on SAVANNAH provides excellent protection against 6-inch projectiles at ranges below 19,600 yards and against 500-pound S.A.P. bombs when dropped from below 5,000 feet in horizontal bombing. In new cruiser designs, the thickness of the armored deck has been somewhat increased above the standard required to defeat projectiles at probable battle ranges in order to provide greater protection against bombs.

73. The desirability of localizing damage from bomb or projectile detonations within the hull, however, is unquestionable, as noted in paragraph 13. War experience* and tests have demonstrated that STS of moderate thicknesses will offer appreciable resistance to blast and fragments, as in the case of SAVANNAH's 2-inch STS first platform which shielded the spaces above from blast and fragments resulting from the detonation below. In addition, transverse STS bulkheads will reduce the fore-and-aft extent of damage and flooding following side torpedo hits. In view of the real value of the protection against projectiles and moderate-sized bombs afforded by horizontal armor, it is unwise to omit it in ships such as cruisers. Horizontal armor has been required by the "Characteristics" approved by the Department for all modern cruisers. Unfortunately, weight limitations preclude large-scale installation of STS bulkheads in addition to armored decks on moderate-sized ships. In certain larger ships of recent design 1/2-inch and 3/4-inch STS bulkheads have been provided. For example, the CA139 class, now in the design stage, will have seven 3/4-inch STS transverse bulkheads.

D. Ammunition Behavior

74. Paragraphs 52 through 55 have described the behavior of the ammunition in turret III, its 6-inch powder magazines and in adjacent 5-inch magazines. That no magazine explosion occurred is significant and of more than passing interest. In some respects this case is similar to that of BOISE** in which an 8-inch projectile detonated in a 6-inch powder magazine.

75. In general, magazine explosions may be caused in three ways:

(a) A propellant-powder fire which results in an explosion of the propellant-powder magazines. Ignition of powder may be caused by hot fragments, flash from a detonation, or high temperatures outside the magazine proper. High density of loading of the magazine, high temperature in the magazine and some pressure within the magazine

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* The cases of YORKTOWN (War Damage Report No. 23) and MARBLEHEAD (War Damage Report No. 34) are of interest in this connection.

** War Damage Report No. 24.

are all important factors. Inasmuch as an appreciable interval of time is required to build up temperature and pressure sufficient to cause the powder to explode, a magazine explosion is not likely to occur if the sprinkling system is operated promptly, or if the magazine floods rapidly from the sea through damage to the underwater shell thus extinguishing the fire, or if large fragment holes in the peripheries or other openings (doors, ventilation ducts and passing scuttles) are present in the bounding bulkheads or decks.

(b) The roasting effect of high temperatures applied for an appreciable interval to projectiles or bombs loaded with high explosive. In general, a detonation of one or two projectiles or bombs may occur first. If the projectiles or bombs be thin-walled, fragments produced by the initial detonation striking adjacent projectiles or bombs may result in a mass detonation of the other projectiles or bombs in the bin or adjacent stowages if they be racked close together. It is emphasized that an appreciable period of high temperature ordinarily is required to cause the initial detonation, but that the mass detonation will occur almost simultaneously with the initial detonation.

(c) High velocity fragments striking thin-walled projectiles or bombs loaded with high explosive, resulting in a mass detonation of the magazine contents. This is, in effect, but a variation of (b) with the difference that the fragments are from sources external to the magazines. A bomb or projectile detonation in the magazine or a torpedo detonation in way of the magazine, if it be unprotected by a liquid layer or armor, may result in high velocity fragments striking the magazine contents.

76. ARIZONA was destroyed by an explosion of the forward 16-inch powder magazines, initiated as described in (a) above. Evidence indicates that an A.P. bomb, with comparatively small bursting charge, penetrated to and detonated in the forward powder magazines. A few moments later a violent explosion occurred in the vicinity of these magazines. The forward magazines of SHAW*, containing 5-inch/38 ammunition, exploded with great violence following events such as described in (b) above. In the case of SHAW, burning fuel oil from ruptured tanks (the ship was in drydock at the time) surrounded the forward magazines. After some moments the forward magazines exploded. All evidence pointed to a mass detonation of 5-inch/38 projectiles, which are comparatively thin-walled. The aircraft bomb magazine of NEW ORLEANS** detonated under circumstances such as described in (c) above. Thin-walled aircraft bombs were stowed adjacent to the hull and were not protected against fragments from underwater explosions, either by a liquid layer or armor. A torpedo detonated against the hull in way of the bomb magazine and this was followed by a mass detonation of aircraft bombs. As a result, NEW ORLEANS' bow structure was completely severed between turrets I and II.

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* Buships War Damage Report No. 7.
** Buships War Damage Report No. 38.

77. Turning now to the BOISE, the evidence indicated clearly that a fire was ignited by hot fragments in the 6-inch powder stowage. It was also clear that the inrush of water through the projectile entry hole (well below the armor belt and the waterline) extinguished the fire before the temperatures and pressures necessary to cause an explosion of the remaining powder were created. Other factors which tended to prevent a powder explosion were large fragment holes in the after bulkhead of the magazine, open passing scuttles (BOISE was in action at the time), a ruptured ventilation duct and the fact that a substantial quantity of the powder normally carried in the magazine had been expended. Thus, BOISE escaped a powder magazine explosion of the type described in paragraph 75(a).

78. In the case of SAVANNAH, it is clear that some powder in 6-inch magazine A-515-M was ignited and that a considerable number of both propellant and star-shell expellant charges for 5-inch/25 ammunition in A-527-M had burned prior to the almost immediate inrush of water through the large ruptures of the side and bottom. This case was thus somewhat similar to that of BOISE with the significant exception that flooding was undoubtedly much more rapid.

79. As noted in paragraph 53(b), personnel of SAVANNAH failed to find evidence that any of the 5-inch/25 projectiles had detonated, although a specific search for such indications was made. Representatives from this Bureau carefully confirmed this point in conversations with the ship's officers. The only direct evidence of fragment attack in and adjacent to the 5-inch magazines consisted of a few small holes in the wreckage of the after part of the inboard longitudinal bulkhead bounding A-516-M. It is definite that a mass detonation of 5-inch projectiles did not occur and it seems probable that none was struck by fragments.

80. The explosion in the gun room of turret III, described in paragraph 55, which occurred 24 minutes after the bomb struck the roof and very nearly the same interval after the start of the fire in the gun room, was undoubtedly the detonation of the two 6-inch H.C. projectiles found later to be split open with the filler consumed. One of these is shown in photo 31. It will be noted that the appearance of this projectile is such as to definitely indicate a low-order detonation. Such behavior following prolonged exposure to high temperatures is consistent with that noted in other war experience* involving projectiles loaded with high explosives. Further, the ignition of the 6-inch powder cases at the top of the hoists in the gun room of turret III, also described in paragraph 55, was undoubtedly the result of attack by structural fragments on the cases. This, too, is consistent with other war experience** and also with the results of tests conducted by the Bureau of Ordnance.

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* Interesting examples will be found in the cases of ERIE (War Damage Report No. 31) and PENSACOLA (War Damage Report No. 35).

** The case of STERETT (War Damage Report No. 33) is particularly convincing proof.

E. Engineering Notes

81. SAVANNAH was the first cruiser in which complete shorting out of a main switchboard has occurred as the result of battle damage. This casualty brought to light two defects in the electrical plant. As described in paragraph 32, shorting out of the forward main board occurred because of the unprotected circuit to the diesel starting relay. This circuit has since been modified to eliminate this defect. Shorting out of the main board also stopped the forward engine room ventilation blowers (see paragraph 34). In general, it is standard practice to provide duplicate leads to engine room blowers from each of the two main boards in order to provide power in case of casualty to one of the boards. Duplicate leads have now been installed on SAVANNAH and authorized for other vessels of the class.

82. It is noted that trouble was encountered with water leaking through electrical cables. Photo 37 is perhaps one of the best pictures to come to the Bureau's attention which shows how large cables will permit water to travel great distances via this means. To prevent such leakage is particularly difficult because of the large number of cables involved on any one ship. Present instructions for ships now under construction require that the ends of the cables be sealed. For the older ships, sealing of the cable ends has been authorized, but this will require a long period of time to accomplish. The action of SAVANNAH's crew in stripping the main boards of all cables which led to the flooded areas undoubtedly prevented many short-circuits and damage through flooding.

83. In paragraph 21 it was noted that both gyros were rendered inoperable. On SAVANNAH, as on other early cruisers, main power supply (both single and three-phase) to both gyros was from the forward I.C. switchboard. Thus, when the I.C. room and central station were flooded, power to the after gyro compass was not available until emergency circuits to the after gyro board were rigged. When this was done the after gyro was placed in operation and it fed the after auxiliary I.C. switchboard. On SAVANNAH, both single and three-phase power circuits are being modified to provide the forward gyro compass with power from the forward I.C. switchboard, and the after gyro compass with power from the after auxiliary I.C. switchboard. In addition, the auxiliary I.C. switchboard will be so arranged that it can receive power from either forward or aft. These modifications also have been authorized for all vessels of the CL40-43, 46-49 and the older CA classes.

84. In addition to the modifications described above, improvements in flexibility for providing Own Ship's Course input to the main and secondary battery switchboards have been made. In the original installation Own Ship's Course input was supplied to the two battery switchboards only from the forward gyro compass repeater panel. (Input from the after gyro compass, when it was in use, was effected through tie cables controlled on the forward gyro compass repeater panel.) As modified, an individual Own Ship's Course input will be

fed to both the main and the secondary battery fire control switchboards from the forward repeater panel, and, in addition, an alternate supply to both of the fire control switchboards is being provided directly from the after gyro repeater panel using either port or starboard cables. Selector switches have been provided for each of the main and secondary battery fire control switchboards so that Own Ship' Course input may be obtained directly from each source as follows:

(a) From the forward repeater panel.

(b) From the after repeater panel, port cables.

(c) From after repeater panel, starboard cables.

85. Alterations similar to the above have been authorized for the other vessels of the CL40-43 and 46-49 classes. The older heavy cruisers also will receive similar alterations when opportunity permits. These improvements are in accordance with the standards established for more modern cruisers beginning with the CL55 class.

86. Despite the unusual nature of the engineering difficulties, SAVANNAH's personnel handled them in a most expeditious and intelligent manner. Thorough familiarity with the plant, gained by intensive training and education of all engineering personnel, resulted in an outstanding performance under very trying conditions.

F. Damage Control Notes

87. Difficulties with rescue breathers, Type A, were described in paragraph 24. These were caused by collapse of the lung when working in restricted areas and in crawling through the small tail hatches of the turrets. Such difficulties are unavoidable even though the relief valves be equipped with rubber caps as specified by the Bureau. The probability of collapse of the lung has led to the development of a hose mask, or "air-line" mask as it is sometimes called. The most promising type at the present time appears to be the conversion of the face pieces of the standard ND Mark III or Mark IV service gas masks into hose masks. An experimental lot of equipment, which comprises air hose, air regulator, pressure gage, quick-acting connection, safety belt and life line, has been provided the forces afloat for trial. If they are found satisfactory, it is proposed to supplement the rescue breathing apparatus with hose masks which will be carried as permanent equipment in damage control repair lockers on the basis of two for each locker. Pending this, the Bureau has no objection to improvising hose masks from the face pieces of service gas masks. Instructions for accomplishing this were promulgated by the Bureau's letter, File S93-(6)(688), EN28/A2-11 of 22 April, 1944.

88. Paragraph 22 describes the measures which were taken to restore fire main pressure to the upper branch of the forward loop. The arrangement of the affected portions of SAVANNAH's fire main is shown on plate I. It will be noted that the forward loop is a vertical

loop with the lower branch below the armored deck (first platform) and the upper branch above the second deck. This layout of the fire main was more than vindicated by SAVANNAH's experience in which adequate service directly above the zone of damage was obtained in a very short time after the casualty occurred. Cruisers now under construction or in the design stage will have fire mains featuring similar vertical loops or a single upper main running almost the entire length of the ship above the second deck in conjunction with horizontal loops below the armored deck.

89. SAVANNAH's repair parties achieved excellent results despite the fact that damage control headquarters was wiped out and all personnel on duty there, including the damage control officer, were killed. In analyzing this case, only one minor criticism can be made of the damage control organization. It was noted in paragraph 22 that after the casualty, hoses were led out and connected to fire plugs. Although this was done very promptly, time would have been saved had the hoses been connected to the fire plugs prior to damage. The revised Damage Control Instructions, 1944, (FTP170-B), now being printed, require that hoses be connected to fire plugs at all times.

G. Miscellaneous Comments

90. In paragraph 56 it was described how ventilation ducts permitted blast, flame and noxious gases to spread to upper levels. This caused some personnel casualties on the second and third decks. Plate I shows in simplified form how some of the affected ducts were arranged. The majority of the ducts involved were natural exhausts from individual magazines and terminated in the second deck spaces. Such natural exhausts are fitted with a watertight closure valve at the lower end and are of watertight construction to above the second deck. Closures are not fitted at the upper ends of exhaust ducts except where the duct terminates in the weather. Reference (a) recommended that closures be installed at the upper ends to prevent the spread of blast and flame. The upper ends of natural exhaust ducts terminating inside the ship are not provided with watertight closures because they are unnecessary insofar as watertightness is concerned, and would constitute another operating complication for repair parties in closing up the ship for action. After examination of other war experience*, and considering the effects of blast, it has been concluded that closures at the upper ends would be ineffective unless they were made exorbitantly heavy. Proof of this may be seen in photo 35 where the watertight closure at the end of the mechanical supply duct to A-533-C was blown off by blast coming up the duct. If the cover were heavy enough to withstand blast, the duct itself would probably rupture under blast pressure.

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* BOISE (Buships War Damage Report No. 24) experienced very similar difficulties with supply and exhaust ventilation ducts.

91. Difficulties with the tail hatch covers in the high turret (No. II) were noted in paragraph 57. Covers are provided for the armored hatches in high turrets in order to prevent personnel from walking on the dogs when the armored hatch is closed. The Commanding Officer recommended that the hatch covers in the high turrets be removed pending the development of a satisfactory cover. The Bureau and the Navy Yard, Philadelphia, have very nearly completed the development of a spring-loaded hatch cover with an automatic latching device which shows every promise of being satisfactory.

92. As on other vessels which have received damage from explosions in interior spaces, the few men found dead from flash burns were incompletely clothed (see paragraph 56). The Commanding Officer emphasized this point in reference (a). In hot climates, particularly, special attention apparently is necessary to insure that below-decks personnel are properly dressed.

93. Reference was made in paragraph 27 to steel pipes which were installed on the suction side of the pumps supplied by the salvage tugs. The time required to place the pumps in operation led the Commanding Officer to recommend that rubber suction hose be supplied to salvage ships. He also recommended that smaller salvage pumps be furnished which would provide some portability. Actually, rubber suction hose, as well as steel pipe, is supplied to vessels carrying portabl salvage gear. In this case, the decision to use steel pipe, rather than rubber hose, for the pump sections was based on estimates which indicated that the pumping job, to be successful, involved the removal of a very large quantity of water. Under such circumstances it would have been necessary, for efficiency, to have a rigid pump suction which would provide air-tight connections between the pipe and the pump and between sections of the pipe, because of the large suction head involved The pumps were of large size because it was estimated that a large capacity would be required if pumping were to be successful. It was not intended that they should be moved by the ship's force after installation on the main deck.

94. Reference (a) also commented on the location of the damage control station and recommended that it be located in the superstructure. This recommendation was based on the probability of communication failures and also on the desirability of the Damage Control Officer's having ready access to the scene of damage. It was also recommended that the Assistant Damage Control Officer be stationed in a part of the ship remote from the Damage Control Officer. The location of the damage control station has received considerable attention since the outbreak of the war, both by the Bureau and by the forces afloat. It is the consensus that the damage control station should be centrally located in the best protected portion of the vessel. Although SAVANNAH's damage control station was wiped out, it was nonetheless centrally located behind the side armor and below the armored deck. There is no other location aboard cruisers so well protected as this. Secondary damage control stations with the necessary equipment are now being provided in locations as far removed as is practicable from the main damage control station. In this connection, the Damage Control Instructions, 1944 (FTP170-B), require that the damage control

organization provide for the Assistant Damage Control Officer to take charge in the event of casualty to the Damage Control Officer. Interior communications, when all telephone circuits have failed, are primarily a matter of providing and training messengers. FTP170-B specifically requires that trained messengers be made available for interior communications in the event of a general power failure.

95. The Commanding Officer made several other recommendations, most of which involved replacement of the 5-inch/25 single guns with 5-inch/38 D.P. twin mounts. This is being done in conjunction with the installation of blisters. The latter will give improved stability and buoyancy characteristics sufficient to permit the additional high weight involved in the new battery. The decision to install blisters was also based partly on the desirability of improving longitudinal strength so as to provide an additional margin in the event of a torpedo attack. The considerations underlying the installation of blisters are more fully discussed in the report of the loss of HELENA*. The primary factor governing the decision in this instance, however, was that SAVANNAH required a long availability for repairs, so that little additional time out of service would be necessary for the major alterations.

H. Conclusion

96. SAVANNAH is one of the earliest of the so-called modern cruisers, having been designed in 1933, and her survival testifies to the ruggedness of her hull. Although damage was both unusual and severe, this case is of great importance in demonstrating that one hit with a German radio-controlled bomb of the largest size yet known is not necessarily fatal to a cruiser. An almost perfectly functioning damage control organization was perhaps the outstanding feature from the operational point of view.

97. This case contained many lessons worthy of attention, from both the technical and the practical points of view. That so much of value can be derived is due, in large part, to the completeness and the general excellence of the Commanding Officer's report.

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* Buships War Damage Report No. 43 (now under preparation).