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U. S. S. ERIE (PG50)

TORPEDOING AND LOSS

WILLEMSTAD, CURACAO, N. W. I.

12, NOV. - 5, DEC., 1942

The Commander-in-Chief, United States Fleet and Chief of Naval Operations directs that this report be shown only to those persons to whom the report would be of value in the performance of their duties.

Steps shall be taken accordingly to insure that the report will be seen by those persons responsible for design, construction and repair of naval vessels, as well as for their operation, but by no others.

25, September, 1943

Bureau of Ships
Navy Department

WAR DAMAGE REPORT No. 31

U.S.S. ERIE (PG50)

Torpedoing and Loss

Willemstad, Curacao, N.W.I.

Class	Gunboat	**Length (O.A.)**	328′ -6″
Launched	29 Jan., 1936	**Beam (W.L.)**	41′ -3″
Displacement (Standard)	2000 tons	**Draft (estimated prior to damage)Mean**	14′ -2″

References:

(a) C.O. ERIE conf. ltr. PG50/A16-3/L11-1, Serial 051 of 9 Dec., 1942 (Action Report).
(b) C.O. ERIE conf. ltr. PG50/L11-1, Serial 052 of 11 Dec., 1942 (Loss Report).
(c) Ind. Manager, 15th Naval District, conf., Serial 088023(1) of 8 Dec., 1942 (Report of Material Inspection).
(d) Supt. Mechanical Division, Dept. of Operation and Maintenance, Canal Zone, conf. memo of 8 Dec., 1942 (Report on Torpedo and Fire Damage – Capsizing).

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F O R E W O R D

The eventual loss by capsizing of ERIE is a clear case of the inevitable result of negative stability characteristics. The series of events which caused this condition to develop has been established within narrow limits. The circumstances which led to the capsizing were not unusual by any means, and are liable to recur with almost any type of vessel which incurs battle damage causing extensive flooding. The problem of insuring positive stability characteristics in such situations thus becomes of universal and continuing interest. These considerations have impelled the Bureau to give this report a wide distribution.

SECTION I - SUMMARY
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1. ERIE was torpedoed on the afternoon of 12 November, 1942, while a unit of a convoy escort. At the time, the convoy was some four miles south of Willemstad, Curacao, N.W.I.

2. The torpedo struck on the starboard quarter blowing a large hole in the hull and ripping the main deck from side to side. The torpedo explosion was followed within a few seconds by another explosion of considerable violence in the same general vicinity. Fuel oil tanks, a diesel oil tank and the aviation gasoline compartment were all ruptured and caused flooding of the second deck aft with oil and gasoline in addition to water. Fire broke out almost immediately and quickly spread throughout the damaged area and up through the after deck house. A heavy starboard list developed. The port shaft and steering gear remained operable.

3. ERIE was beached on the coast of Curacao two miles from Willemstad some 50 minutes after being torpedoed. This was done to prevent foundering. Within two minutes of beaching flaming oil and gasoline, pouring from the rupture, had almost completely surrounded the vessel. Outside assistance was unobtainable and ERIE was abandoned.

4. The fire above the second deck almost burned itself out in two days. During this interval two 325-pound depth bombs and two lOO-pound G.P. bombs in the ready stowage on the airplane deck exploded doing an enormous amount of topside damage. Salvage and fire fighting parties arrived. Fires were extinguished and salvage operations commenced. On 28 November ERIE was removed to Willemstad harbor and moored to special buoys.

5. Between 1 and 4 December thorough inspections led to the decision that ERIE was worth repairing and returning to service. Action was started to remove the port list and part of the trim then existing. Two port tanks were pumped dry and the anchors and chain were replaced on 4 December.

6. During the early morning of 5 December ERIE slowly came upright and listed to starboard coming to rest at an angle of 10° against a salvage barge on the starboard beam. D-1-W, 43 tons capacity, was found to be flooded at this point. The two port tanks pumped dry during the day before were counterflooded. A few minutes after this operation ERIE again slowly came upright and, passing through the vertical, capsized to port and sank.

7. ERIE then was judged not worth the cost of salvage and repairs and has since been stricken from the register. The hulk remains in Willemstad harbor pending the availability of time and labor to remove it.

8. In the loss of ERIE we find again some of the same lessons learned in the naval actions of the Pacific. Unessential inflammable material and inadequate fire fighting facilities prevented controlling the fire. Aviation gasoline vapors undoubtedly caused the second explosion which started the fire and then materially assisted in its rapid and violent spread.

9. As a result of ERIE's loss, CHARLESTON will have her fire fighting facilities radically augmented at the next availability. The advisability of carrying a plane on the CHARLESTON with the twin dangers of aviation gasoline and aircraft bombs, has been questioned and is now being studied with the aim of eliminating the plane.

10. Capsizing of the ERIE was the result of negative GM and negative dynamical stability. After thorough analysis the Bureau concluded that the unexplained, but nonetheless definite, flooding of starboard reserve feed tank, D-1-W, during the night of 4-5 December was the most important of a series of events which caused the negative stability condition to develop.

11. Although the references are unusually complete, no mention is made in them of calculations or formal estimates of stability for any of the several operations. Thus, it would appear that none were made. If this were so, the fact that ERIE's stability was so low subsequent to removal from the beach could not well have been thoroughly appreciated. The failure to improve stability during the interval in Willemstad harbor and the subsequent errors on 4 and 5 December of removing low liquids, adding high weights and counterflooding are understandable in this light.

SECTION II –NARRATIVE
(Plates I and 11 - All Photos)

12. The references are unusually complete with respect to both material condition of ERIE and events as they occurred. Photographs were supplied by the Naval Air Station, Coco Zolo, Canal Zone and the fire fighting party from Norfolk. Plates were prepared by the Bureau based on sketches and data forwarded by the Commanding Officer.

13. On 12 November, 1942, ERIE was a unit of an escort for a convoy traversing the waters off the coast of Curacao, N.W.I., not far from Willemstad. The Cqmmanding Officer of ERIE was also the escort Commander and ERIE was directly ahead of the vessels being convoyed but still well within the anti-submarine screen. The submarine which torpedoed ERIE apparently penetrated the screen without detection.

14. At 1733 ERIE was struck by a torpedo from a submerged submarine. The torpedo struck and exploded on the starboard quarter about frame 126 (abreast the after 6" gun) and about five feet below the waterline. The hull below the waterline was ruptured for a length of about 45 feet. The break extended vertically from five feet above the keel, on the starboard side, up to the main deck and across the main deck almost to the port side. The platform and second decks were both ruptured in way of the torpedo explosion. The after 6" gun foundations were demolished and the mount fell vertically several feet. On the second deck all bulkheads between bulkheads 107 and 141 were torn and ripped. The watertight door in bulkhead 107 was distorted and could not be closed. Fuel oil tanks, the diesel oil tank and the gasoline compartment, all in way of the explosion, were largely demolished and oil and gasoline were spread throughout the second deck coincident with the flooding of the area between bulkheads 99 and 141.

15. A few seconds after the torpedo explosion there was a second explosion of considerable intensity in the same general area. It seems probable that this explosion resulted from the ignition of gasoline vapor formed after the destruction of the two aviation gasoline tanks. The latter contained more than 800 gallons of gasoline. The fire, fed by oil and gasoline, spread rapidly throughout the second deck and up through the after superstructure.

16. The starboard propeller shaft was broken, but the port shaft and engine continued to function normally. Steering control was momentarily lost due to the cutting out of a main generator when the circuit breaker tripped because of shock. The auxiliary diesel generator automatically cut in. Later the circuit breaker was reset and the main generator resumed the load. Other than this, shock effects were minor.

17. After the initial list to port, caused by the shock of the explosion, ERIE began listing gradually to starboard and settling by the stern. The vessel was held on a course across wind for a few minutes in an attempt to prevent the spread of the fire both forward to the 6" ready service rooms and aft to the depth charges. As list and trim increased, however, sinking appeared imminent and the Commanding Officer hastily picked a point on the coast of Curacao some two miles northwest of Willemstad and headed for it.

18. Although all available fire fighting equipment was immediately brought into use, the facilities were hopelessly inadequate and the fire was never controlled. The fire main had been severed in way of the explosions and, inasmuch as only one cut-out valve (at frame 98) for the after main was provided, it was necessary to cut out the entire section aft of frame 98 to isolate the break. Two 1-1/2-inch hose lines were led aft from the forward main but pressure was too low to maintain effective streams or to use fog nozzles. As the fire continued to spread, concern was felt for the forward magazines and orders were given to sprinkle them. Actually, they were not sprinkled because of a misunderstanding, but it was realized quickly that if they were sprinkled even less pressure would be available at the fire inasmuch as the sprinkling system operated from the fire main and pumping capacity was not even adequate for fighting the fire.

19. Within 12 minutes of the torpedo explosion ready service powder charges in the ready service room for the after 6" gun had been roasted sufficiently to begin exploding. These went off singly. In about twenty minutes projectiles started detonating with low order bursts. There was no mass explosion. Anxiety for the ready service ammunition for No. 3 gun caused the powder to be removed from the ready service room, but not jettisoned because of the shallowness of the water. It was placed on deck forward of the fire. An attempt to jettison the plane was unsuccessful as the fire spread so rapidly that personnel were driven from the vicinity or the kingpost. In addition, the backstays for the kingpost were burned in two. Boats, except the motor boat in the skids, were launched and the wounded put ashore. The fire never reached the depth charges. Four or these had been jarred overboard by shock of the torpedo explosion. One of these was a ready charge with a depth setting for 100 feet. The other three were on the safety setting. At least one of the four exploded in the water. This was presumably the ready charge.

20. During the events related above, ERIE was slowly but steadily running for the beach. One local tug came out to assist in fighting the fire but stranded. At 1823, fifty minutes after being torpedoed, ERIE grounded gently but firmly. Prior to beaching, list had increased to 15° and the starboard quarter of the main deck was underwater forward to frame 104. Upon beaching, the starboard list was removed and a slight list to port assumed, following the contour of the bottom.

21. When forward motion of the vessel ceased, blazing oil and gasoline poured from the broken tanks and spread forward on the surface of the water, pushed by the wind. All of the hull but a small portion of the bow was encircled. Within two minutes after grounding almost the entire superstructure was afire. Exploding ammunition, excessive paint and inflammable material of all types throughout the topsides caused a raging inferno. The ship was abandoned at 1826, three minutes after grounding.

22. After ERIE was abandoned, the fire raged uncontrolled and apparently had largely burned out by 14 November, when a fire fighting party with a tug from a local petroleum company boarded the vessel. This party extinguished the fires above the second deck. Fires still burned below the second deck.

23. Some time during the two-day interval, the two aircraft depth bombs and the two l00-pound G.P. bombs exploded. These were in the ready service stowage located approximately at frame 72 on the airplane deck slightly to starboard of the stack. The stack was knocked down and badly damaged; large holes were blown in the airplane and main decks; the second deck, of 50 lb. S.T.S. plating, was deflected slightly downward and the starboard leg of the mast demolished. The forward bridge structures also received extensive fragment damage.

24. On 15 November a second fire righting party arrived from Norfolk and, in two days, extinguished the fires below the second deck.

25. The machinery spaces were practically undamaged and a large amount of ordnance gear was in relatively good condition. These factors apparently led to the decision that the ERIE was worth salvaging and re-

pairing. On 19 November, salvage operations commenced under the direction of Merritt, Chapman and Scott. The topsides were stripped, debris was removed from the second deck, stores were removed from the platform decks and several tanks were emptied. These steps resulted in the removal of weight estimated by the Bureau (from lists furnished by the Commanding Officer) to total about 375 tons.

26. ERIE was refloated by hauling off on 28 November and towed to Willemstad harbor where she was moored. As noted previously, ERIE had a 15° starboard list and the starboard quarter of the main deck was underwater when she was beached. When refloated, her list was 8-1/2° to port and she was drawing 24 feet aft and 8-1/2 feet forward. The stern section aft of the damage drooped an estimated 24 inches at the after perpendicular. Prior to refloating, a Spanish windlass of heavy wire cables had been rigged across the break on the starboard side. During the entire period on the beach the stern section had remained buoyant.

27. While on the beach, divers had inspected the damaged hull. The Commanding Officer, in reference (b), stated that, according to the diving report, the port shell plates showed some buckling in the weakened area but appeared generally sound and that the hull remained intact on the port side and five feet beyond the keel on the starboard side. The Superintendent of the Mechanical Division, Canal Zone Department of Operation and Maintenance, in reference (d), stated that at frame 124 the sheer strake had a crack and, from the diver's report, a buckle at about frame 124 extended to and around the keel and about five feet to starboard and further, that the diver stated that the keel was broken. The Superintendent believed it likely that both garboard strakes were also broken.

28. Between 1 and 4 December a material inspection of ERIE was made by representatives from the Canal Zone and the Fifteenth Naval District primarily for the purpose of determining the time and material required to rehabilitate the vessel. References (c) and (d) are reports of these inspections and each contains an opinion as to the cause of capsizing which happened subsequent to the inspections. A conference was held at which it was decided to place ERIE in a local dry dock for structural repairs sufficient to permit towing to a repair yard. Draft aft was to be reduced to 20 feet and list was to be removed by further removal of scrap and debris, pumping out the fuel remaining in port tanks A-4l8-F and A-40F, flooding forward compartments and placing counterweights on deck. Ammunition in the forward magazines and heavy stores in the forward hold storerooms were to be left aboard to provide stability. The ship appeared safe and in no danger from structural failures. No written report of this conference was made, other than that in reference (b) from which the above account was prepared. This conference apparently was held either 3 December or the morning of 4 December. In any event, the execution of the program outlined to permit docking was started on 4 December with the pumping of the two port tanks and the replacing aboard of the anchors and chain. From 28 November to 3 December operations apparently were confined to pumping out accumulations of rain water and seepage. The auxiliary diesel generator also had been placed in operation to furnish power for lights. Pumping of the two tanks was completed at 1930 on 4 December. Port list seems to have been about 5° at that time.

29. About 0300 on 5 December, some 7-1/2 hours after pumping had stopped, the guards aboard noted that ERIE had righted and was commencing to list to starboard. Motion was slow and jerky. Motion eventually stopped at 9 or 10 degrees with the hull resting against a fuel oil barge secured on the starboard side. A-418-F, of 20 tons capacity, was filled again. Water entered second deck spaces through the engineers' washroom starboard side frames 69 to 77, probably via the drains. A handy billy gained slightly on this water. The starboard reserve feed tank, D-1-W, of 43 tons capacity, which had been kept dry by pumping 300 to 400 gallons every two days, was found flooded. Counterflooding of A-4-F, capacity 45 tons, was then done. Approximately 12 minutes after A-4-F was full, ERIE started to come upright, moving slowly. When the upright was passed, the motion accelerated as the hull rolled port. Motion did not cease until ERIE had rolled through an angle of 120° from the vertical. Only a small portion of the forward keel and starboard shell remained above water.

30. No change in the position of the stern section relative to the forward section was noted during the interval of 28 November to 4 December inclusive, although the stern section had been observed to be working slightly. After the hull had assumed its starboard list on the morning of 5 December, it was observed that the stern section was not in its previous position relative to the forward section. The deck line of the stern section was observed to be more nearly in alignment with the deck line of the forward section. At this point it was also observed that the Spanish windlass hung slack. As the vessel passed the upright position, when listing to port, it was observed that the stern section, still buoyant, was such as to indicate that a pronounced change of trim by the stern of the forward section had occurred. The stern section evidently remained attached to the remainder of the hull inasmuch as it too capsized.

31. ERIE was declared not worth salvaging and has been stricken from the register. The hulk still remains in Willemstad harbor pending time and availability of labor to remove it without interfering with ship movements in the harbor.

SECTION III - DISCUSSION

A. Damage from Torpedo Explosion

32. It 1s known that both German and Italian submarines ordinarily use torpedoes which have a warhead charge of about 660 pounds.* The shallow depth, estimated as five feet, at which the torpedo struck the hull probably accounts for the fact that underwater damage was somewhat less than would normally be expected to result from a 660 pound explosive charge. Topside damage was comparatively more extensive than would occur from a deeper running torpedo.

* Prior to 1942 the warhead charge invariably used was TNT. In 1942, warheads with material of more explosive power than TNT made their appearance. Judging from the damage, this charge could hardly have been more potent than TNT.

B. Fires and Explosions (Plate I - Photos 1-3 and 6-9 inclusive)

33. The second explosion apparently resulted from the ignition of gasoline vapors formed by the rupture of the two 750-gallon tanks. One of these was full and the other contained approximately 80 gallons. Ignition of the vapor could have been caused by a spark from any one of a number of sources including hot fragments and shorts in energized circuits.

34. The rupture of fuel oil, diesel oil and gasoline tanks by the torpedo explosion resulted in the spread of inflammable liquids by flooding throughout the second deck between bulkheads 99 and 141. The explosion of gasoline vapors in way of the torpedo damage ignited the oil and gasoline in second deck compartments and the entire area was aflame in a very short time.

35. At this point the inadequacy of ERIE's fire fighting facilities became apparent. ERIE was equipped with four pumps. Two of these were electric centrifugal flushing pumps rated at lOO G.P.M. each at 50 pounds pressure. These were on the fire main at the time ERIE was hit. The other two were the fire and bilge pumps. These were reciprocating steam pumps rated at 120 G.P.M. each at 100 pounds pressure. One of the fire and bilge pumps was immediately cut in on the fire main and the other was cut in a few minutes later. Pressure on the main immediately dropped to zero because the main had been broken in the vicinity of the torpedo damage. Only one cut-out valve, located at frame 98 in the auxiliary engine room, was available for isolating the break. Some three or four minutes were required to close it. When this was done only two main deck plugs, one at frame 90 and the other at frame 65, could be used. All pumps, however, were in the intact portion of the system. Hoses (1-l/2"} were led aft from these but the maximum pressure available was 40 pounds. Numerous reasons existed why the pressure was so low. Almost all salt water service on the ERIE came from the fire main, including refrigeration, flushing, magazine sprinkling, cooling water to the guns, cooling water to auxiliaries such as lubricating oil coolers, feed pumps, etc. The ship's force attempted to cut out all of these services but there were some, such as cooling water to the main feed pumps, which could not be secured and others were probably missed. In addition, attempts were made to counterflood forward and to sprinkle the forward magazines from the fire main. Finally, the shock of the explosions might have caused leaks unnoticed at the time.

36. Whatever the causes, the amount of water and pressure available was hopelessly insufficient to bring such an extensive fire under control. The fire spread rapidly, progressing up through the after deck house and forward on the main and second decks.

37. It will be noted from paragraph 35 that ERIE's total pumping capacity for fire fighting was only 440 G.P.M. with all other services secured and that only 240 G.P.M. was available at l00 pounds pressure. Comparing this with the DD445 class of destroyers, for example, which have pumping plants of 900 G.P.M. capacity at l00 pounds pressure, it is obvious that ERIE's pumping capacity was much too low. There also were, as has been indicated, too few plugs and main cut-out valves. As one result of ERIE's loss, two additional fire pumps of 400 G.P.M. each, two additional fire plugs and four additional cut-out valves will be installed on CHARLESTON, ERIE's sister ship, at next availability.

38. The fire, spreading up and forward, soon reached the vicinity of the ready service room for No. 4 6" gun. Twelve minutes after the torpedo explosion the 6" powder charges started exploding. Ten minutes later the projectiles began detonating. The heat from the fire literally roasted the ammunition. The powder charges in No. 3 ready service room were removed and placed on deck before the fire reached the stowage. After ERIE was reboarded, projectile fragment holes were found in the vicinity of all the 6" ready rooms as noted on Plate I and shown on Photos 6, 7 and 9. There was no evidence of mass explosions or detonations. This behavior of projectiles and powder charges is consistent with other battle experience and tests made by the Bureau of Ordnance.

39. The detonation of the four aircraft bombs after ERIE was abandoned, noted in paragraph 23, gave the effect of a mass detonation judging from the amount of damage caused. Here there was a comparatively large concentration of high explosive which could be expected to do severe damage when ignited.

40. The effects of the disastrous fire can scarcely be over-exaggerated. It is doubtful if any reasonable amount of fire fighting equipment could have controlled the conflagration, initially spread as it was over a large area by gasoline and oil. The fire very effectually prevented any damage control measures other than beaching the vessel. Damage from the fire was much more extensive and would have been more costly and time-consuming to repair than that caused by the torpedo.

41. Complete information concerning the formation and dissemination of gasoline vapor throughout the after compartments in the vicinity of the gasoline tanks is lacking. ERIE was in a condition of complete closure in the immediate vicinity of the gasoline tank compartment when the torpedo struck. Nonetheless, the case of ERIE serves to highlight the fact that vessels, when operating in areas where underwater attack is possible and with appreciable quantities of gasoline stored in tanks in locations exposed to underwater attack, should have all spaces in the vicinity of the tanks in a state of closure, as complete as is possible, in order to prevent the spread of gasoline vapor, in the event of damage, into undamaged areas. Although the fire was very extensive in ERIE in spite of the closures, there will be cases of somewhat less severe damage where the closures will establish effective boundaries against the spread of gasoline vapors or fires. This procedure is particularly important for the following classes of vessels: aircraft carrier escorts (CVE), aircraft carriers (small)(CVL), motor torpedo boat tenders (AGP), cruisers (CA and CL), and the various classes of seaplane tenders (AV, AVD and AVP).

42. The Commanding Officer, in reference (a), extensively described and discussed the fire. He noted that linoleum-covered decks were badly warped, bulkheads were buckled, aluminum lockers and their contents consumed and wooden decks burned. Evidence of the intense heat generated is apparent in photos 1-3, 8 and 9. He particularly emphasized the hazard of paint on both interior and exterior surfaces. This is one of the few cases which have come to the attention of the Bureau where it is clearly evident that large quantities of paint were actually consumed by fire. Ordinarily paint is charred and blistered. Photo 8 is also the first positive evidence received that a wooden deck has been consumed by. fire. Wooden decks frequently are charred, however. From all the evidence and the references, the fire which gutted ERIE appears to have been an unusually intense general conflagration to which practically everything aboard contributed.

43. The program of removal of inflammable material and paint had not been completed primarily because of continued operations which did not provide either the time or personnel required for execution. It is doubtful, however, if any removals, short of creating an absolutely bare vessel both inside and out, would have had an appreciable effect in retarding the fire.

44. ERIE was comparatively small and lightly armored. On such vessels it is impossible adequately to protect the gasoline stowage from the effects of underwater explosions. Another serious hazard was presented by aircraft bombs. The effects of detonation of even a few bombs carried on board can be expected to jeopardize the survival of smaller vessels because of the comparatively large amount of high explosive stowed in concentrated form. These considerations, clearly demonstrated by the history of the ERIE, impelled the Bureau to question the necessity of carrying a plane aboard the CHARLESTON. The matter is now before the forces afloat for decision.

45. The Commanding Officer, in reference (a), also thoroughly discussed the question of uniform in the tropics for officers and crew. He had encouraged the practice of exercise in abbreviated costume in order that his men not only would be physically fit but also would develop sun-tanned bodies with resistance to sun burn in case of being adrift. Fortunately, the daily exercise period had been concluded and only one officer in abbreviated clothing at the time of the explosion was exposed to flash. He was severely burned. One enlisted man was changing his outer shirt at a point on the second deck some 45 feet from the impact. The part of his body protected by his undershirt was unhurt, but his arms, neck and face were quite severely burned by flash. As a result, the Commanding Officer concluded that sun bathing should not be permitted at sea, that men should be fully clothed at all times, even during exercise, and that concentrations of men, except at battle stations, should be avoided. He believed that clothing should be complete but as light as possible and that even when sleeping the minimum protection or a sheet over the body is required. These conclusions all appear to be reasonable for smaller vessels in submarine infested waters.

C. Analysis of Stability (Plates II and III)

46. All of the events reported in the references which effected stability are listed in chronological sequence below:

(a) 12 November. ERIE was torpedoed. Flooding was as indicated on Plate II. Stability was seriously reduced by the destruction of approximately 25% of the total waterplane area by flooding between bulkheads 99 and l4l. Off-center flooding occurred in the starboard shaft alley. Prior to beaching, the list was 15° starboard and ERIE was down by the stern, with water over the starboard quarter of the main deck.

(b) 12-28 November. The port shaft alley flooded because of grounding. Approximately 375 tons of weight were removed. A total of some 20 tons of liquid remained in forward port tanks A-4l8-F and A-4-F. Starboard reserve feed tank D-l-W was emptied but had leakage at the rate of some 400 gallons per two-day period. Anchors and chain were removed.

(c) 28 November. ERIE was removed from the beach to Willemstad harbor. List was 8-1/2° port with a draft forward of 8-1/2 feet and aft of 24 feet.

(d) 28 November - 3 December. Apparently nothing much was done except to remove accumulated rain water and seepage by pumping.

(e) 4 December. Operations were started to prepare ERIE for drydocking. A-418-F and A-4-F were pumped dry. Anchors and chain were replaced aboard with the chain on the forecastle. List at nightfall was about 5° port.

(f) 5 December. About 0300 ERIE was found to have righted and was beginning to list to starboard. The roll continued to starboard until the hull rested against the oil barge secured alongside. D-1-W, 43 tons capacity, was found full. Water was found to be running in on the second deck from the engineers' washroom and from there into C-201-L. This flooding extended at least to the centerline trunk in C-201-L as water was reported running down the hatch to the engine room. Attempts were made to control this flooding with a portable pump and some slight gain was reported. A-418-F and A-4-F were filled to overflowing to remove the list. A few minutes after the latter operation was completed, ERIE started to come upright, then passed the vertical and with increasing acceleration capsized to port. As ERIE passed the vertical it was noted that the hull forward of the break had changed trim by the stern some 36 inches and that the stern section aft of the break was still buoyant.

47. ERIE's draft before damage was not reported but it is known that the vessel had been fueled and provisioned to capacity one week before, giving a mean draft then of 14'-7" with a displacement of 2830 tons. This would indicate a displacement of about 2730 tons with a mean draft slightly in excess of 14 feet at the time of torpedoing allowing 100 tons for consumption of fuel and stores at the known rates. This corresponds quite closely to Condition VI of the inclining experiment data. The curve of statical stability, uncorrected for free surface, for this condition (Curve A) is given on Plate III. GM was about 3 feet, uncorrected for free surface. Insofar as stability characteristics were concerned, ERIE thus was not only in a satisfactory condition but also in one which offered the maximum resistance to underwater damage. The exact distribution of liquids prior to damage was not reported. Probably the after tanks had been used. Free surface correction could not have been greater than three inches and is omitted for these reasons.

48. The torpedo explosion destroyed approximately 25% of the waterplane area. From the inclining experiment, prior to damage, the metacentric radius* was about 11.1 feet. A quick estimate, and one which could be made on the spot, assuming that BM * varies linearly with the length of intact waterplane, gives a reduction of about 2.8 feet in BM * and indicates a similar loss in GM. This hasty estimate indicates that GM was about 0.2 feet prior to beaching. The Bureau, by more elaborate and precise calculations, found that GM, uncorrected

* The vertical distance between the center of buoyancy, B, and the transverse metacentre, M.

for the free surface in the forward tanks, was actually just about zero. The statical stability curve for this condition, Curve B, is also given on Plate III. The maximum righting moment, it will be noted, is only 675 tons-feet, or approximately 14% of that in the intact condition, while the range of stability has decreased from 70 to 43 degrees. Flooding of the starboard shaft alley (the only known unsymmetrical flooding) gave an upsetting moment of approximately 330 tons-feet which, from the curve of statical stability, indicates a list of 15°. This was the list reported by the Commanding Officer and constitutes a very good check on the calculations. The residual dynamical stability after the 15° list was assumed is shown on Curve B by the cross hatched area. It will be noted that approximately two thirds of the dynamical stability when upright had been utilized in assuming the 15° list.

49. It will be noted that the statical stability curves of Plate III are plotted in terms of list versus righting moment in tons-feet rather than in the customary manner of list versus righting arm in feet. This was done to give the picture more clearly in terms of moment. The curves also include the effect of the positive stability of the stern section. The total area under each of the curves is dynamical stability of the work in foot-tons required to capsize the vessel. After damage the dynamical stability required to cause capsizing was reduced from 3567 foot-tons to 283 foot-tons or to 8% of the intact value. Little else is needed to indicate that ERIE was in a precarious condition when beached.

50. Salvage operations while ERIE was on the beach resulted in the removal of about 375 tons of weight. This weight was by no means all from topside, although all possible topside weights were removed. Actually, about 200 tons of liquid were included in the 375 tons removed. The lowering of the center of gravity, and consequent increase in GM, therefore could be expected to be comparatively small for the amount of weight involved. This proved to be the case and the center of gravity was lowered only about 0.4 feet and GM was increased to only 0.7 feet. The statical stability curve for this condition, Curve C, was calculated and is plotted on Plate III. It is evident that the effect of removal of the weight is not felt appreciably in the smaller angles, i.e., below 15°. The greatest effect was to increase the maximum righting moment to about 1900 tons-feet and to extend the range of stability almost to the intact value. Dynamical stability required for capsizing was increased to about 1124 foot-tons, some 32% of the intact value. It is apparent that when ERIE was refloated, stability, although much better than when beached, left the vessel in a very precarious condition.

51. The port list of about 8-1/2°, when ERIE was refloated, could have been caused by unsymmetrical distribution of the weights remaining aboard. For example, the 20 tons of liquid left in A-4-F and A-18-F and the flooding of the port shaft alley would be sufficient to cause such a list if the vessel otherwise was balanced.

52. The effects of removing the 20 tons of liquid from A-418-F and A-4-F plus the addition of the anchors and chain on 4 December were first, a decrease of 25% in GM (from 0.7 feet to 0.5 feet) and second, a decrease in port list from 8-1/2° to 5°.

These changes in weight also resulted in a decrease in the port upsetting moment (calculated from the weights involved) of about 200 tons-feet. This checks quite closely with the increment of righting moment between angles of 5° and 8-1/2° indicated on the curve of statical stability to be 175 tons-feet and is an indication of the accuracy of Curve C. It is apparent that neither the pumping or the adding of topside weight was wise at this stage of operations although when concluded, stability remained positive. They clearly indicate, however, a fundamental lack of appreciation of ERIE's low stability condition.

53. Turning now to the causes of capsizing, reference (d) advanced structural failure of the port shell connection between the buoyant stern section and the forward section as the basic cause of capsizing. It was considered that an upsetting moment was applied by the buoyant stern to the port side, causing a virtual rise in the center of gravity and a reduction in GM, and that this caused the starboard list; and further, that the counterflooding measures then employed, plus the free surface existing, next caused the list to port and capsizing. Reference (c) gives substantially the same opinion.

54. Although the Bureau agrees that the counterflooding and the free surface were probably the causes of the final list to port and capsizing, the theory that structural failure of the connection between the two parts caused the initial starboard list does not fit with certain facts reported in the references. These, briefly summarized, are:

(a) A structural fault at frame 124 extended around the girth from and including the port sheer strake to the hole in the starboard shell. (Reference (d)).
(b) The stern section drooped some 24 inches at the after perpendicular. (Reference (b), reference (d) and photos 1 and 2).
(c) The intact portion of the vessel forward of the damage had changed trim some three feet by the stern but the stern section did not change trim. This was first noted after the vessel had listed to starboard. (Reference (b)).
(d) The stern section had been buoyant since the damage had been incurred. (References (b) and (d)).
(e) The stern section had been noted to be working slightly with relation to the rest of the vessel while at anchor in Willemstad. (References (b) and (d)).
(f) The Spanish windlass was completely slack after the starboard list had been assumed. (Reference (b)).

55. It thus appeared probable that the stern was in a condition of equilibrium with respect to weight and buoyancy. For the portion aft of bulkhead 135 - calculations verified this - the weight totaled about 150 tons and the buoyancy to the indicated waterline was about the same. Although the stern section undoubtedly was not in a condition of complete transverse or longitudinal balance all the evidence indicated that listing and trimming moments were of small magnitude. These considerations, coupled with the flexibility of the hinge connection formed by the remaining intact structure, made it seem improbable that the stern section could have exerted any sudden

appreciable vertical force tending to overturn the forward section. Rather, if any force was exerted by the stern, it would have tended to hold the forward section upright, inasmuch as the stern had positive stability. Structural failure of the hinge connection resulting in an upward force at the hinge connection thus did not appear to be the cause of the initial starboard list.

56. In reference (b) the Commanding Officer stressed the fact that D-1-W flooded during the night, apparently from failure of the after watertight boundary. The tank was adjacent to the damaged zone and was known to have some leaks. Possibly the after bulkhead failed. Whatever the reason, the tank was found flooded immediately after the vessel listed to starboard and it had been empty the evening before.

57. The effect of the flooding of D-1-W was easily calculated. The starboard upsetting moment was found to be 667 tons-feet. From the curve of statical stability for this condition, Curve C, such a moment would cause a total list of about 18°. ERIE had a 5° port list so a 13° starboard list could be expected. Actually, a list of about 10° developed with further listing stopped by the barge. This list did not develop abruptly, indicating that D-1-W flooded slowly. Flooding of D-1-W imposed an after trimming moment of some 5200 tons-feet. As the moment to change trim one inch for the forward section was calculated to be only 153 tons-feet, this would cause a change of trim of about 34 inches which is reasonably close to the three feet estimated by the Commanding officer. Flooding of D-1-W had one other effect – a beneficial one - in that it caused GM to increase slightly. The increase would, of course, cause a minor reduction in the 18° estimated total list.

58. The flooding of the second deck, noted in paragraph 46(f), had a disastrous effect on this GM. The free surface effect caused a reduction calculated to be about 1.6 feet causing the GM to become about a negative 0.9 feet; It is obvious that ERIE would have capsized to starboard had not the barge prevented. In addition, counterflooding of A-4-F and A-418-F had also started and provided an ever-increasing port moment.

59. The fourth statical stability curve shown on Plate II, Curve D, is for the condition with D-1-W flooded, D-4-F and D-418-F empty and free surface to the centerline of C-201-L. It is thus a close approximation of ERIE's stability immediately prior to counterflooding and capsizing. It can be seen that neither positive initial or dynamical stability existed. The only possible immediate action which could have saved the vessel was the rapid removal of the free surface in C-201-L, followed by the cautious adding of low ballast, either on or to starboard of the centerline, taking advantage of the support given by the barge in preventing capsizing to starboard. Counterflooding of the two port tanks introduced an upsetting moment to port of some 915 tons-feet. GM, however, increased to a negative 0.6 feet due to the low position of the tanks. The large moment made capsizing to port inevitable. The curve of negative statical stability explains the ever increasing acceleration of the rolling motion to port, once the vertical was passed, described by one observer thus: "she eased into the water with air whistling through her ports, hatches and open spaces, debris floating around her. She swung like a pendulum until her keel was above water."

60. Summarizing the events which occurred during 4 December and the early morning or 5 December, we find that stability was low and was further reduced by emptying the two tanks and adding the anchors and chain. Next D-1-W flooded and caused the starboard list with the rolling motion being stopped by the barge. In this position the starboard side of the second deck was well underwater, and flooding through the engineers' washroom into C-201-L created such a large amount or free surface that all positive stability was destroyed. Capsizing to starboard probably would have occurred had it not been for the support given by the barge and the beginning of counterflooding of the two port tanks. When the latter were filled, capsizing to port followed.

61. As noted in paragraph 28, stability apparently was mentioned at the conference described by the Commanding Officer in reference (b). Reference (d), in presenting the opinion as to the cause or capsizing related in paragraph 51, contains the statement "Neither this inspection party nor anybody talked to prior to December 4 noted or felt that there was any question regarding the stability of the U.S.S. ERIE at anchor in the harbor of Willemstad." These are the most positive references to stability contained in the reports forwarded to the Bureau. It thus appears that no formal estimates or calculations for ERIE's stability were made at any time during the various phases or operations. Possibly it was felt that the 375 tons of weight removed while the vessel was on the beach insured ample stability and precluded the necessity of formal stability calculations. In this connection it is pointed out that even this estimate of weight was prepared by the Bureau using lists of items furnished by the Commanding Officer and that there is no record of such a fundamental celculation being performed previously.

62. The inclining experiment data booklet was unquestionably lost in the fire. The period of time while the vessel was on the beach permitted procurement of one had it been requested, inasmuch as certain other data, notably a booklet of general plans and the damage control book, were procured from the United States. Had this been available it would have been physically possible to make reliable stability estimates.

63. If none were made, it is understandable why low liquids were removed and high weights were added on 4 December in preparation for drydocking. It is also understandable why more active measures to improve stability were not undertaken during the interval of 28 November to 4 December. Further, the final "coup de grace", the counterflooding of the two port tanks, probably would not have been administered so readily, if ERIE's stability condition had been known even approximately.

64. It is evident, of course, that ERIE had positive stability while moored in the harbor. It is just as evident, however, that the positive stability was inadequate and should have been improved or, at the least, not deliberately reduced in preparing the vessel for docking. Flooding of D-1-W probably was the result of failure of bulkhead 106 in some measure and could not have been prevented unless the bulkhead previously had been reinforced. Flooding of the second deck in C-201-L might have occurred via the soil pipe drains, as they were underwater when the vessel was heeled to starboard. These drains were probably open, if the washroom had been in use by the salvage personnel. Open drains are a common occurrence and have been responsible for much difficulty in other salvage cases.

65. Preparing a vessel with low stability for docking is one of the most complex of all problems and invariably requires a detailed stability analysis followed by carefully planned operations. It is impossible to establish a definite set of rules to be followed in such cases, as each is a problem in itself. RALEIGH, after being torpedoed and bombed at Pearl Harbor on 7 December, 1941, was successfully placed in dock, although GM was only a few inches, a port list existed and she was down by the bow about 12 feet when brought to the Navy Yard. In this case a very complete stability analysis was made and the program of correcting list and trim worked out in chronological detail prior to operations. Topside weight was removed and low tanks filled one at a time. Approximately two weeks, including the time for calculations, were required to complete all the preparations. The main point is that RALEIGH's stability condition was thoroughly analyzed prior to shifting any weights on board.

66. Almost every vessel of the U.S. Navy is furnished with a booklet entitled "Inclining Experiment Data". This contains the basic stability data for the vessel and much itemized information relative to the weight, moment and location of the equipment and liquids normally carried aboard. Such booklets are intended, among other reasons, to provide personnel on the spot with sufficient information in convenient form to facilitate the making of reasonably accurate estimates of stability in a limited time. FTP170-A, also issued to all ships in commission, contains an excellent discussion of damaged stability. It contains, among other things, a specific warning of the evils of counterflooding when low or negative stability exists. Thorough familiarity with both booklets is recommended for all personnel whose duties may include the responsibility of keeping a ship afloat and upright.

Photo 1: USS ERIE – Willemstad Harbor, 2 December, 1942 - starboard side. Salvage operations in progress. Note sag of stern.

Photo 2: USS ERIE – Willemstad Harbor, 2 December 1942 – port side.

Photo 3: USS ERIE – Willemstad Harbor, 2 December, 1942 – starboard quarter.

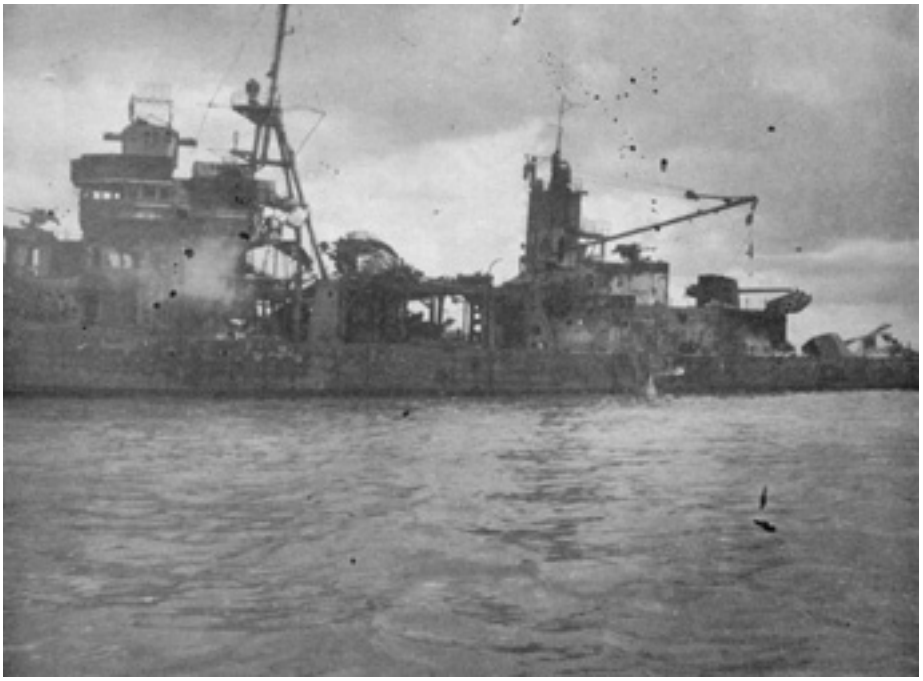

Photo 4: USS ERIE – Beached. About 18 November, 1942. Note remains of stack.

Photo 5: USS ERIE – Beached. Torpedo Damage, starboard quarter.

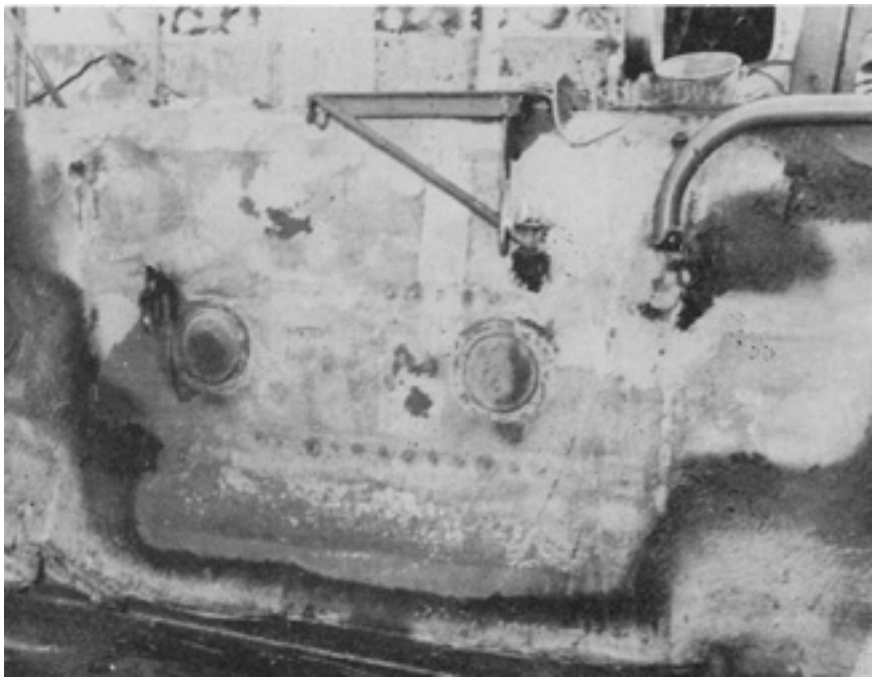

Photo 6: USS ERIE – Port shell, frames 110-115. Note 6″ projectile hole caused by projectile from No. 4 gun ready service room.

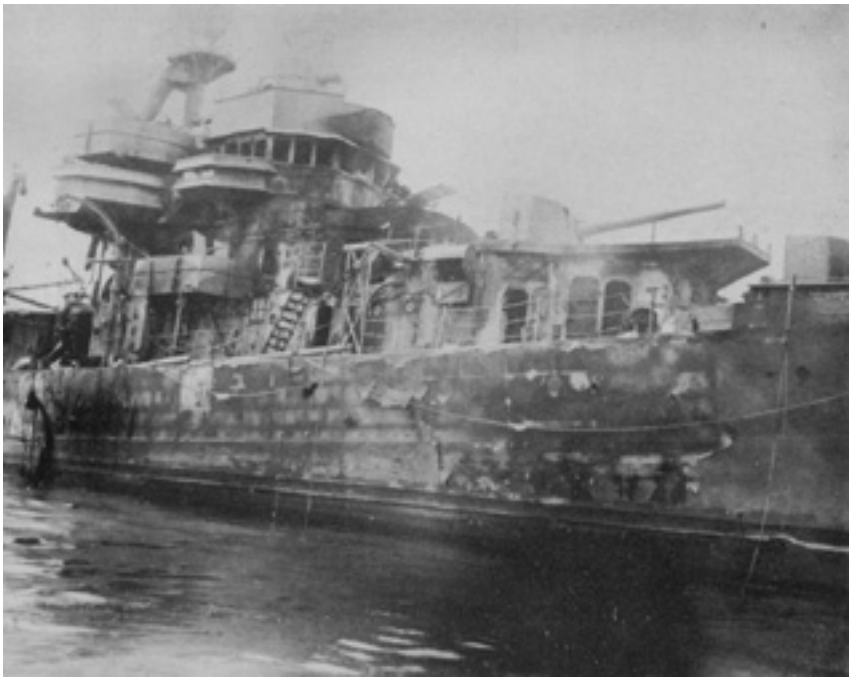

Photo 7: USS ERIE – Starboard shell, frame 15 looking aft. Note 6″ projectile holes caused by projectile from No. 1 gun ready service.

Photo 8: USS ERIE – Main deck abreast after deck house. Note that wood deck has burned.

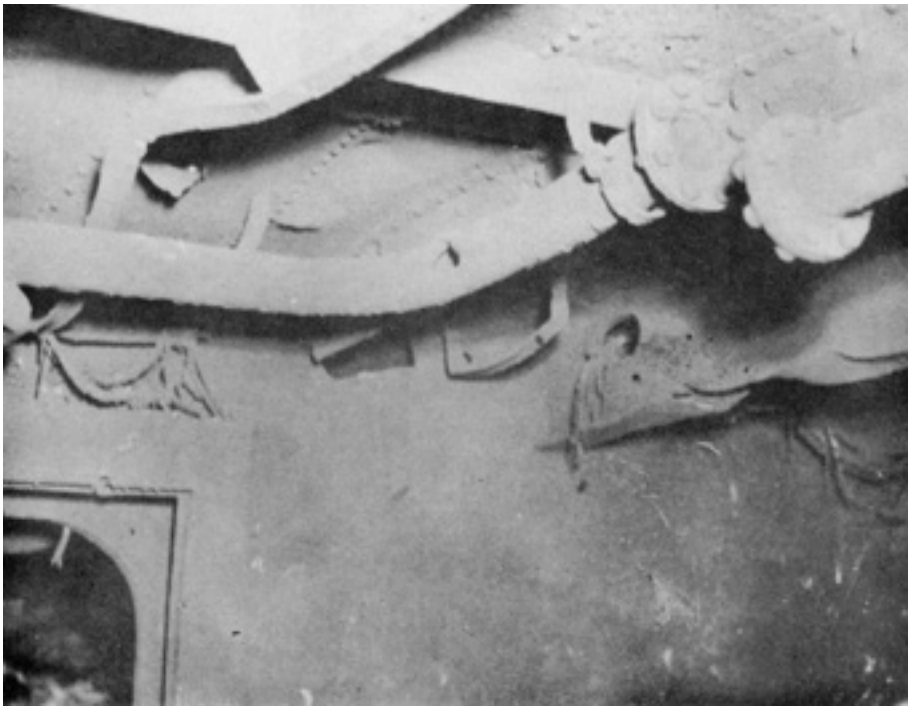

Photo 9: USS ERIE – Compartment D-202-1L looking forward to bulkhead 107. Note fragment hole in bulkhead and 4″ fire main. Note that composition valve body has melted away. The valve gate and stem were found on deck underneath.