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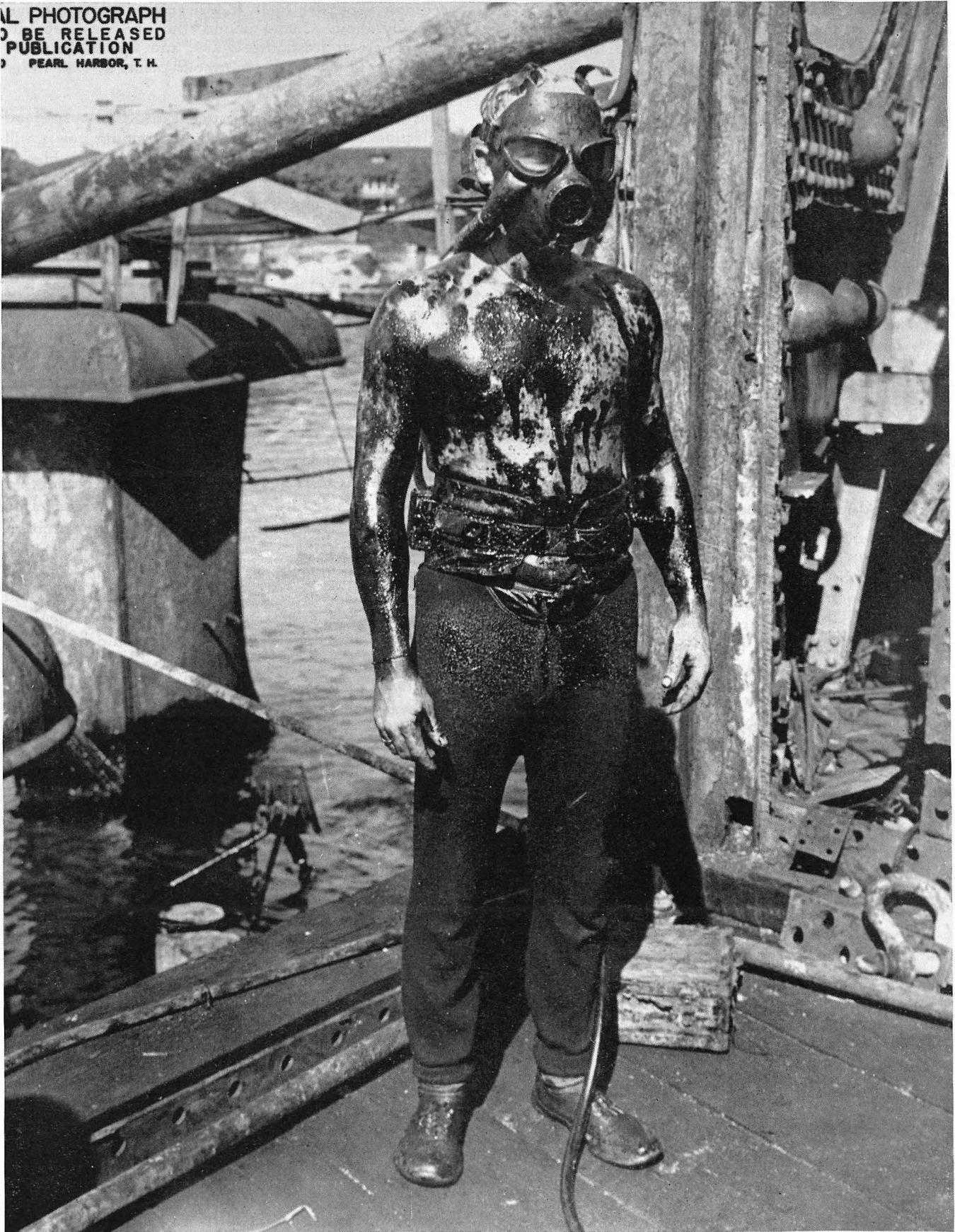


Fig. 1 A closeup of the diving dress worn for work in unwatered compartments, which were sometimes under air pressure, and in shallow water diving (less than 35 ft) where simple, relatively non-hazardous work was required.

SALVAGE OF THE *OKLAHOMA* at Pearl Harbor

By LEE P. MORRIS

BEFORE launching into a report of the salvage of the battleship *OKLAHOMA*, it is desirable to give some review of the events leading up to December 7, 1941. Subsequent information indicates the facility with which the Japanese attacking force accomplished its moves.

The Pearl Harbor attack was planned originally by the Japanese as the initial step of their Pacific campaign. Admiral Isoroku, then Commander-in-Chief, Combined Fleet, supposedly originated the plan early in 1941. The task force assigned to strike Pearl Harbor rendezvoused, starting November 14, 1941, at Hitokappu Bay in the northern Kurile Islands. The force finally assembled consisted of 2 battleships, 6 carriers, 3 cruisers, approximately 20 destroyers, 5 submarines, including midgets which were carried by mother submarines, and a normal complement of auxiliaries. On November 25 the Com-

mander-in-Chief, Combined Fleet, issued the order for the assembled force to proceed to a predetermined location for refueling. The force departed at 6 a.m., November 26, Japan time, and set an indirect northern course for the next rendezvous, 200 miles north of Oahu. On December 6, when the force was still 800 miles north of Oahu, it received the long awaited code message, "Climb Mount Niitaka," to proceed with the attack. Thus far the force had gone undetected. Luck stayed with it, and on December 7, at 6 a.m., the Japanese began launching their airplanes. The last of the striking force of 361 airplanes departed about an hour later. The United States Navy was to suffer its worst defeat in history.

When the Japanese attacked, 86 vessels, including 8 battleships, 7 cruisers, 28 destroyers and 5 submarines, plus the usual complement of small craft, were

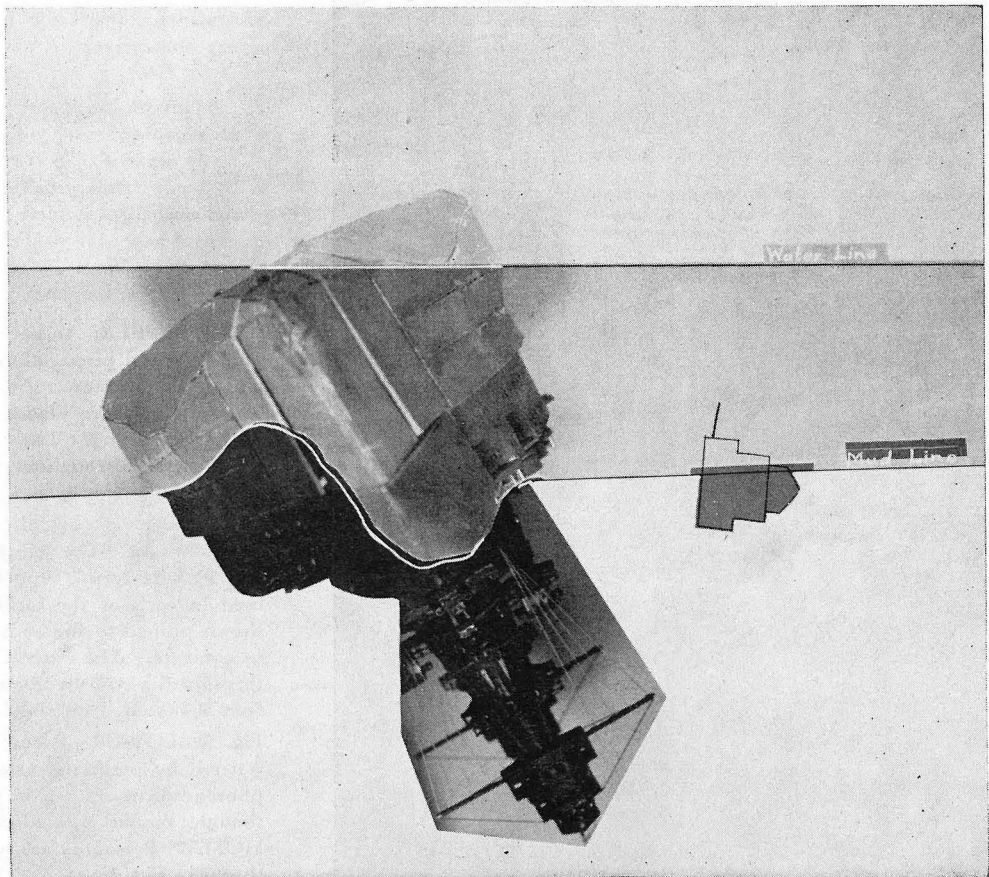
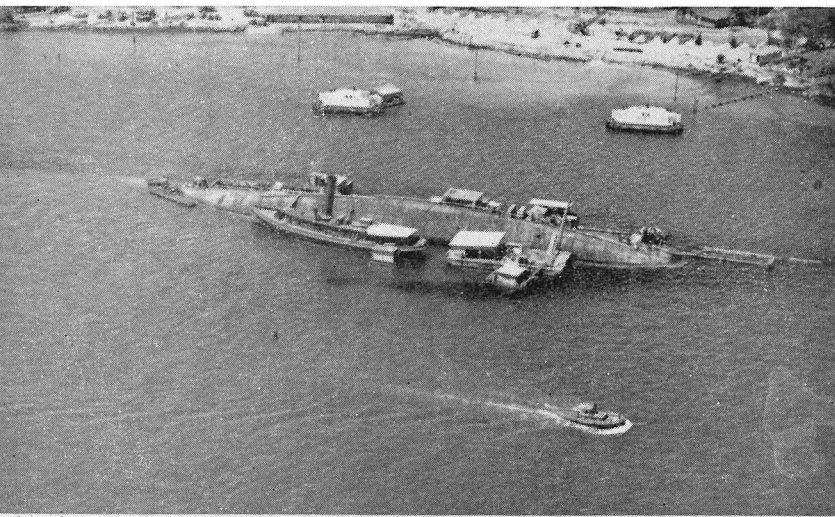


Fig. 2 Cardboard model of the *OKLAHOMA* placed to show the position of the ship before righting. The S-shaped mud line was caused by a mud bank formed when the forward section of the ship became embedded in soft mud before it capsized.



based in the harbor. It is of interest that, contrary to public opinion, the Japanese task force learned December 6 from its espionage service that no aircraft carriers were moored at Pearl Harbor. This absence of carriers was a piece of luck for which we were later exceedingly thankful. When the onslaught subsided, nearly every ship bore scars. One of the worst damaged, the *Oklahoma*, was salvaged by one of the most complex operations in history.

The *Oklahoma* was, at the time of the attack, located outboard of the battleship *Maryland*, which was moored alongside Ford Island. She was struck on the port side by four or five torpedoes, which caused the ship to capsize quickly to port and come to rest on the bottom at an angle of $151^{\circ} 30'$ from upright. Only the starboard bilge showed above water. See Fig. 3. With the ship in this position, about 30 men were rescued through holes cut in the bottom during the 24-hour period following the attack.

RIGHTING OPERATIONS

Two steps were required in the salvage operations on the *Oklahoma*. Before the second step of refloating

Fig. 3 UPPER: An aerial view, showing the various facilities used in initial preparations for salvage, including diver's floats and air compressors. Accessible fuel oil, the starboard propeller, and the three blades of the port propeller were removed prior to righting. The tug shown was used as a tender and headquarters throughout most of the operation.

Fig. 4 CENTER: Winches and righting tackles, looking north showing central control station, and midship and after position stations. The block assemblies are reeved with 1 in. 6 x 19 wire rope. Approximately 9500 ft of 1 in. rope was used in each of the tackle assemblies. The inner blocks are shown pinned to the ends of steel beams which were anchored in concrete. The outer blocks are each to be attached to two three-in. 6 x 37 wire rope lines which will be extended to "A" frames mounted on the bottom of the ship.

Fig. 5 LOWER: Recovering equipment from a turret, unwatered by pumping, after removal of guns and slides. This photograph was taken in the #2 turret of the *ARIZONA*, although similar operations were performed on the *OKLAHOMA*. Personnel are wearing the shallow-water diving dress shown in Fig. 1.

could commence, righting had to be carried out. The Oklahoma capsized in a position parallel to the shore. Righting operations involved the use of 21 five hp DC motor-driven winches, each of which, through two 17-part tackles, applied an approximately horizontal force transverse to the ship. To effect large turning moments, pendants extending from the outer blocks were secured to the tips of 21 40-ft-high "A" frames mounted on the above-water portion of the starboard bilge. See Figs. 8 and 10. The frames transmitted the pull exerted by the winches through compression members to thrust brackets mounted along the centerline or port docking keel of the bottom (Fig. 9), and wire rope back stays transmitted the pull to the starboard blister, which had previously been reinforced to prevent buckling of its transverse members (Fig. 18). Figs. 4 and 7 give an idea of the winches and righting tackle on shore. Preparatory to righting, the following steps were taken to assist the operation:

1. Oil in accessible fuel oil tanks was removed. Also some machinery in the above-

water portion inside the ship, the starboard propeller, and three blades of the port propeller were removed.

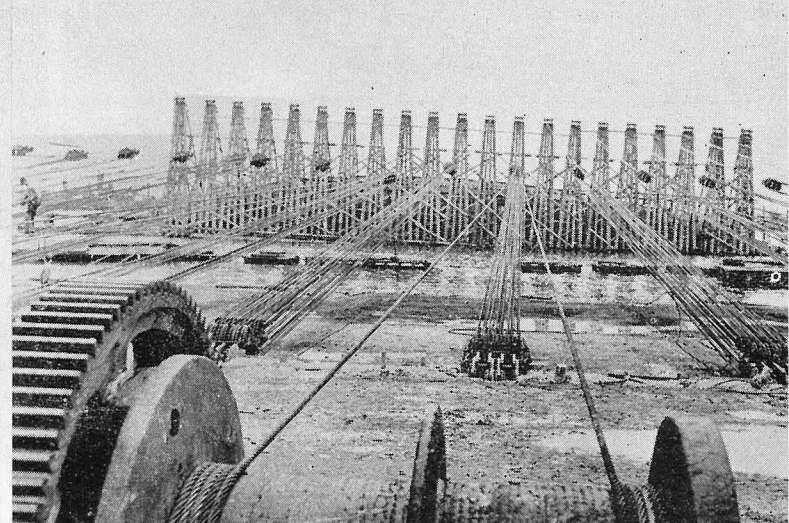
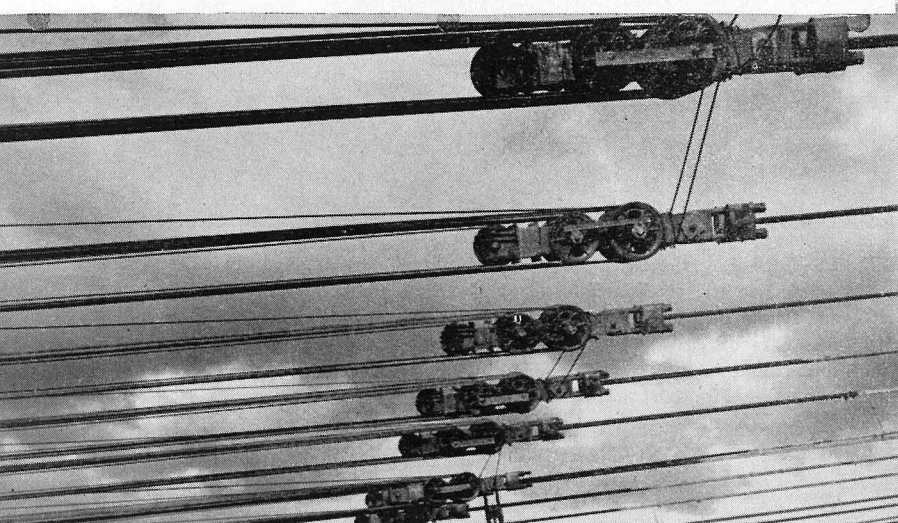
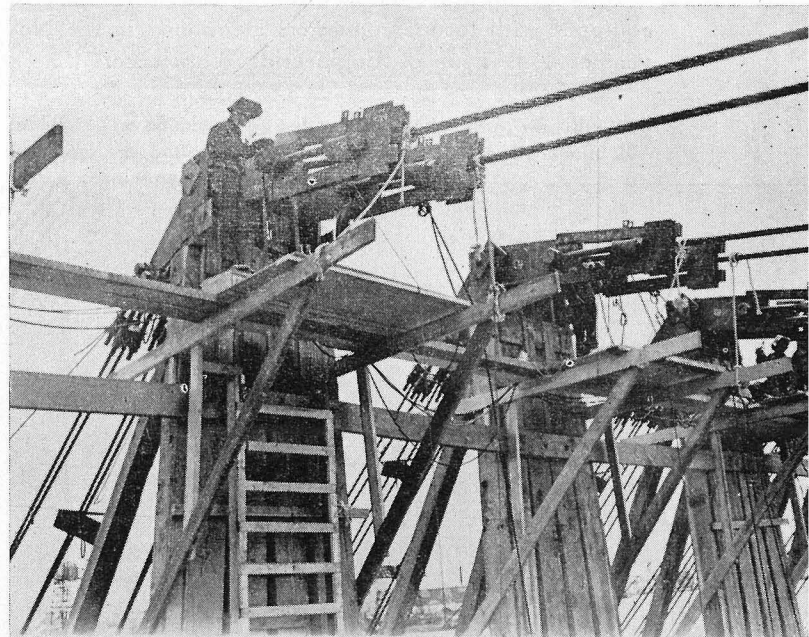
2. Air pressure was applied inside the hull to lighten the vessel and aid in righting. To prevent a complete and rapid loss of air in the event of a serious leak during righting, the air was compressed in seven separate sections which were rendered watertight by opening and closing hatches and doors inside the hull as required. This work was accomplished by divers. Fig. 12 is an air lock for access to and from a watertight section. Final sealing of each section was done by men wearing shallow-water diving masks.

3. Because mud in the path of the rolling ship was particularly prevalent inshore of the forward end, 4500 cubic yards of coral were deposited in the way of the bow to provide a better bed.

Fig. 6 LOWER LEFT: Outer or moving blocks composed of eight 28 in. diameter sheaves, eight 24 in. diameter sheaves, and one 20 in. diameter sheave. The small sheave served to equalize the tension on each pair of load lines extending from an individual winch. All tackle was especially designed for the job.

Fig. 7 UPPER RIGHT: "A" frame head fittings, fabricated from heavy steel plate. Of welded construction, these were bolted to steel plate extensions on the "A" frames and pinned to allow rotation in a lateral plane.

Fig. 8 LOWER RIGHT: View from Ford Island of the OKLAHOMA in 140° position. The three photographs in this group were all taken in March 1943. In this phase of salvage operations, righting was frequently interrupted to re-rig the tackles or because of rigging failures. Reasons for re-rigging included: Avoidance of too many layers of wire rope on winch drums; shifting tackle from "A" frames to the ship's structure. Failures occurred in the structure of "A" frame head fittings and in wire rope slings used to transmit the pull to various hull structures after "A" frames were removed.



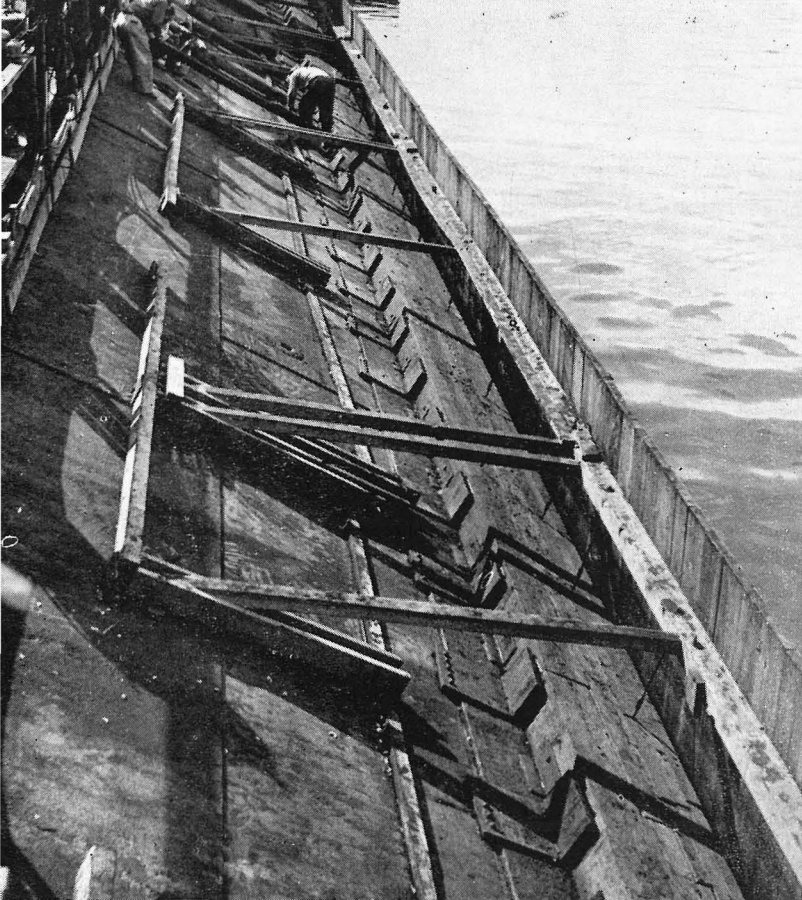


Fig. 9 Thrust brackets welded to the bottom along the centerline. Each bracket absorbed the force transmitted by individual compression members, of which there were four for each "A" frame. The cofferdam on the right holds water back during high tide.

It is of interest that several of the winches were equipped with torque converters mentioned in the November 1945 issue of *Engineering & Science*. These

winches exert maximum pull at zero speed. In 100 days the vessel was rolled over to a final port angle of $2^{\circ} 10'$. See Fig. 16. The total actual pulling time was 73 hours, an average of a little more than 2° per hour. During the 100-day period, most of the time not spent in actual pulling was spent in removing by water jets the mud bank built up inboard as the vessel rolled toward the shore, in inspecting damage as the topside portions of the vessel were exposed, and in rerigging the pulling tackle to the ship's structure. The "A" frames were removed after the vessel had rolled to a 68° position. See Fig. 13. Most of the facilities used to right the Okla-

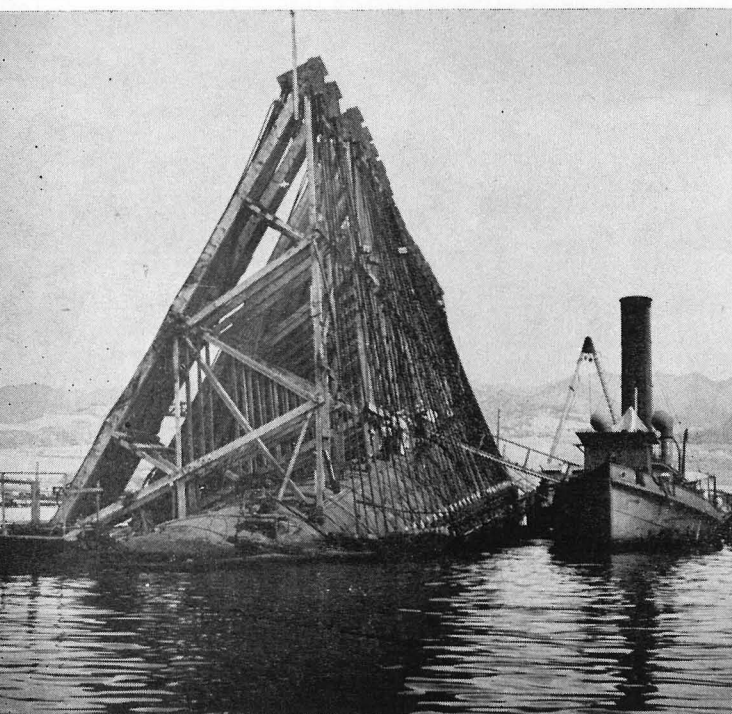


Fig. 10 "A" frames mounted on the ship's bottom. After the OKLAHOMA was rotated to a 68° position from the vertical, the frames were removed and the direct pull was assumed by the back stays. This photograph was taken in February 1943.

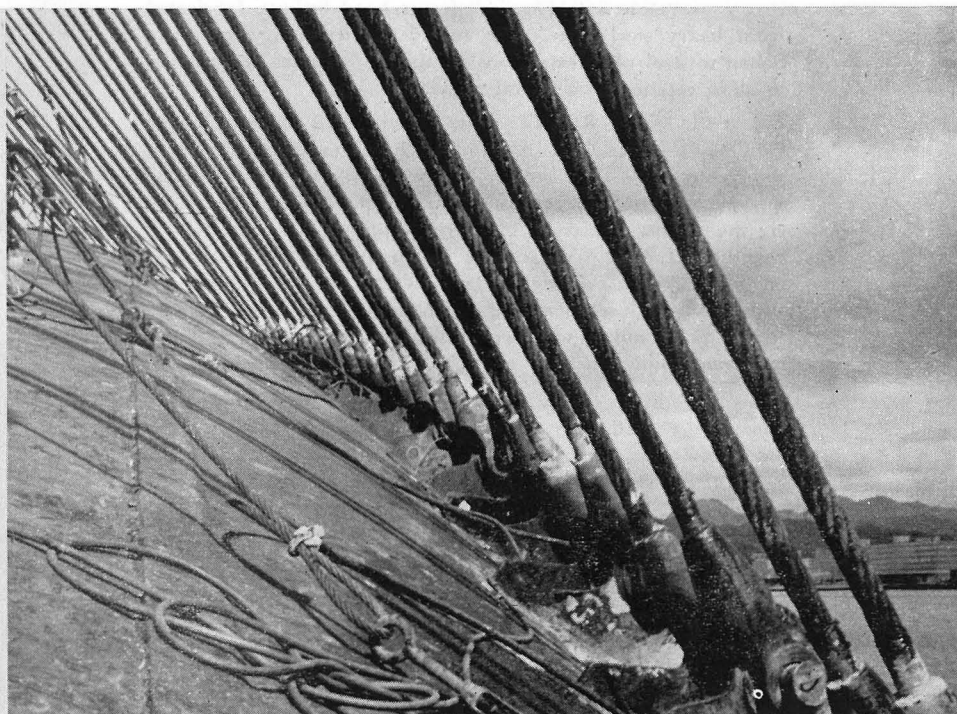


Fig. 11 Back stay detail. The back stay attachments consisted of pads welded to the starboard blister. The attachments were spaced at every frame of the hull to correspond to the individual compression members of each "A" frame. There were two back stays for each individual compression member. This photograph was taken a month after Fig. 10.

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Fig. 12 Airlock for access to and from one section of the main air bubble. The bubble, designed to lighten the ship, was divided into seven sections which extended from stem to stern. It was effective from the bottom to the second deck, originally about 25 ft below the water level. Each air lock while being used was manned by a crew supervised by an officer diver.

homa were later moved to the other side of Ford Island, where they were reused to right the *Utah*.

REFLOATING OPERATIONS

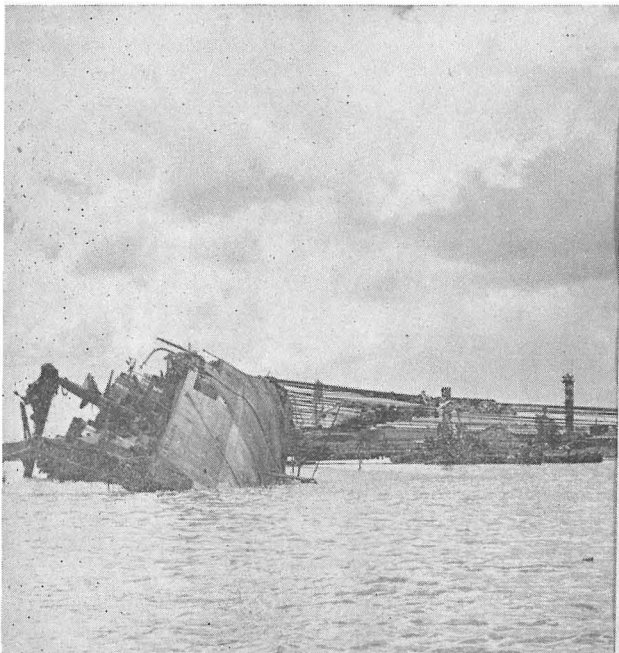
Refloating operations were commenced by installing four independent patches, the largest of which consisted of five sections and was 130 ft long by 57 ft high. This patch, one section of which is shown in Fig. 20, was of wood construction heavily reinforced by external steel trusses. The external structure served to reinforce the patch, which consisted of 4-in. thick siding sealed with packing materials. The sections were secured to the sides by means of hook bolts installed in holes burned by divers through the damaged shell of the ship. The patches were sealed by means of concrete poured into forms along the bottom and up both ends.

A fence type cofferdam was also installed around the main deck aft. Refloating was accomplished with the aid of numerous electric- and Diesel-driven deep-well and portable submersible pumps. See Fig. 21. In order to have sufficient pumps to keep the vessel afloat during the trip from the berth to drydock, some of the electric pumps were driven by Diesel generators. The rest of the power requirements during refloating were sup-

plied from shore. Views of the vessel in drydock before and after removal of the patches are shown in Figs. 23 and 24.

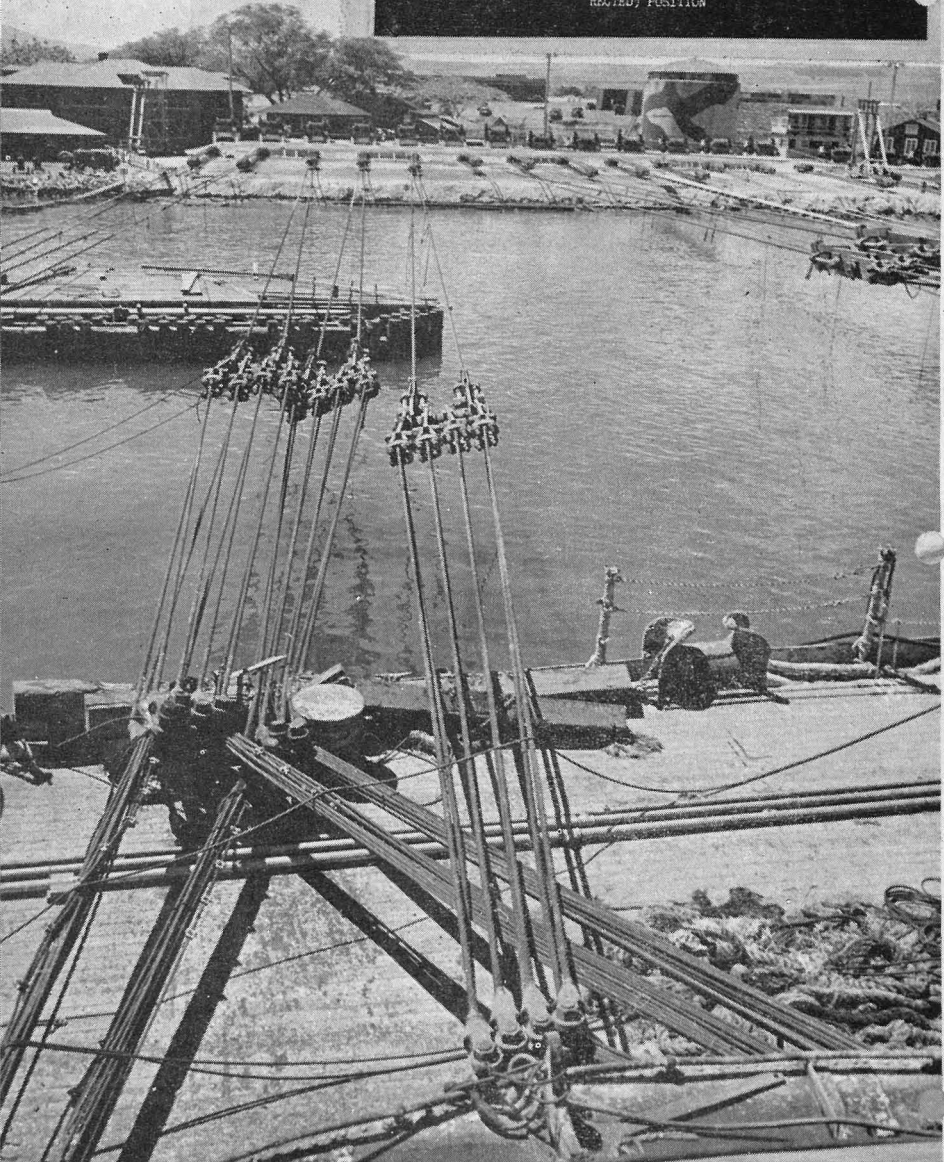
DIVING OPERATIONS

No article on ship salvage is complete without mentioning the hazardous work performed by divers. At Pearl Harbor their numerous tasks included interior and exterior inspections, closing and opening doors and hatches, installing and sealing patches and cofferdams, and removing wreckage and salvable equipment. The Pearl Harbor divers are all the more to be respected when it is realized that they operated inside capsized vessels, wearing deep-sea diving dresses weighing 185 lbs, and working for many hours several hundred feet from access openings. All of this was done in total darkness, underwater lamps being of no use because of the excessively murky water. All in all, about 6000 individual dives were made, during salvage operations at Pearl Harbor, averaging approximately four hours per dive. In all of the salvage work undertaken at Pearl Harbor there was only one Navy casualty, and that was not on the *Oklahoma* operations. A diver on the *Utah* after working several hours, suddenly had an air supply

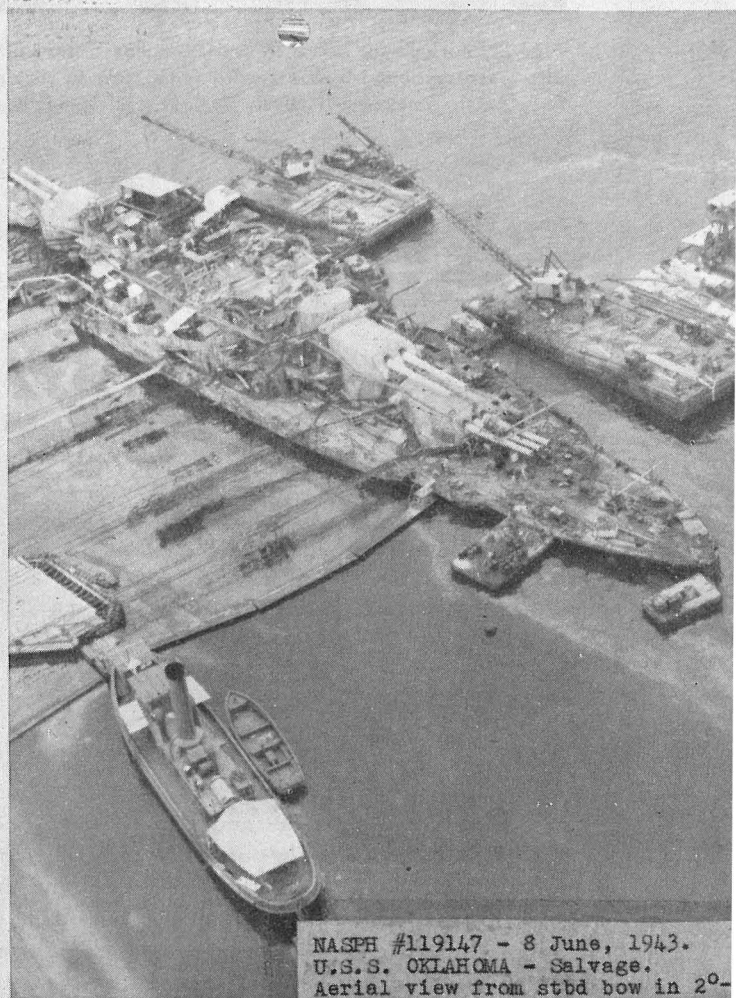


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USS OKLAHOMA - SALVAGE 6 MAY, 1943 2621-43
VIEW TOWARD FORD ISLAND FROM TOP OF TURRET #2, WITH SHIP IN 10° (CORRECTED) POSITION

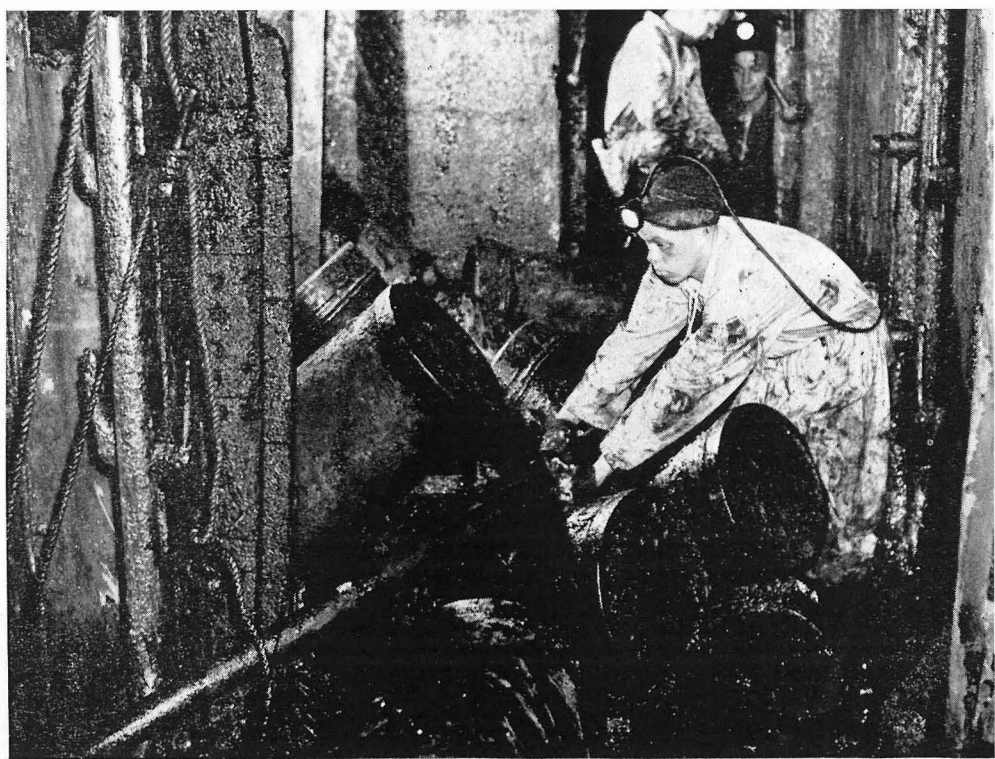


ASBP(V-J-1) #2172
U.S.S. OKLAHOMA -



NASPH #119147 - 8 June, 1943.
U.S.S. OKLAHOMA - Salvage.
Aerial view from stbd bow in 20°

Fig. 17 Adjusting a discharge hose from a submersible pump in 14 in. magazine spaces during refloating operations. None of the 14 in. ammunition was removed because of the dangers and difficulties in handling.



failure and lost consciousness from lack of oxygen. He died by drowning, water entering through the helmet exhaust check valve after he fell to a prone position. Many men trained at Pearl Harbor developed into seasoned divers and proved invaluable in subsequent Navy

salvage operations throughout the world.

CONCLUSION

Today little evidence remains at Pearl Harbor of the salvage work which required two years to accomplish.

Fig. 13 UPPER LEFT: The OKLAHOMA late in March 1943. Seen from astern with ship in about 68° position.

Fig. 14 UPPER RIGHT: Looking aft at about the same period as Fig. 13. The ship had been rolled 39° in 19 hours the day previously, the longest roll made at one time. Compressors in the foreground were used to assist in maintaining the air bubble mentioned in Fig. 12.

Fig. 15—LOWER LEFT: Detail of righting tackles. Nos. 3, 4 and 5 tackles in the foreground are connected through wire rope slings to No. 2 turret structure. The special shackle fittings were formerly used to secure the backstays to the attachment pads on the starboard blister. The fittings in the middle of the picture were formerly part of the "A" frame head fittings. Although it may appear differently, the deck bitts shown did not serve as righting tackle attachments. In the background, the outer or moving blocks are nearing the stationary blocks. Positions were "corrected" regularly at shore observation stations by means of transit and distance measuring wires.

Fig. 16 LOWER RIGHT: June 1943. This is the final position to which the vessel was pulled by righting tackles. At this position the total pull required to hold the ship was nearly 8500 tons. The two large barges are each carrying cranes and miscellaneous salvage material. Outboard of the forward barge is a smaller barge loaded mainly with deepwell pump pipe, and outboard of the small barge is a floating derrick. The small floats are mainly divers' floats or are carrying compressors. The salvage tender is moored to the forward key.

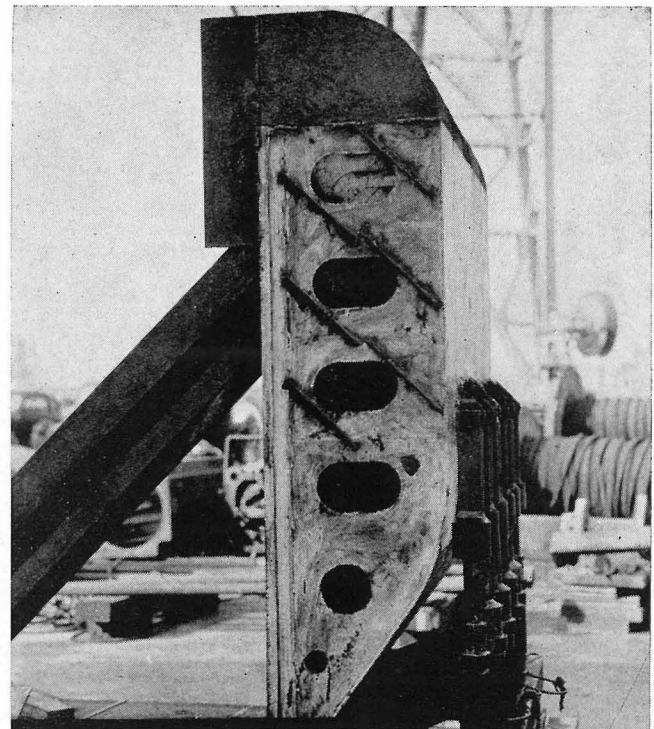
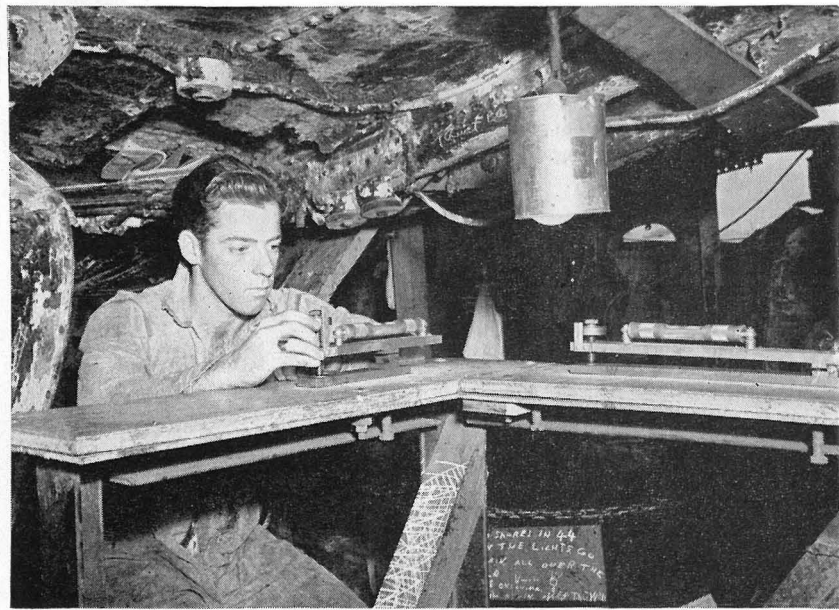


Fig. 18 One-fifth scale blister model. To determine the stresses to be induced in the starboard blister from the backstay connections, a model was designed to simulate the conditions. Hydraulic jacks were used to represent forces applied by the back stays. Premature buckling of the transverse members in the blister indicated diagonal stiffening would be required. This model has been reinforced by welding bars onto the transverse members and withstood the test. The OKLAHOMA starboard blister was similarly reinforced.

Fig. 19 RIGHT: Clinometer and trim indicator used to determine list and trim respectively during refloating operations. These instruments were set up on the center line, approximately amidships. The clinometer indicated the list to the nearest minute, and the trim indicator was sensitive to the point where it served as a check on draft readings at bow and stern. These instruments, along with other references, were observed at regular intervals.



The Oklahoma, after being drydocked December 28, 1943, was later purchased by the Moore Drydock Co.

of Oakland, California, for scrapping. On May 17, 1947, while under tow, the Oklahoma sank 540 miles out of Pearl Harbor with no one on board. Two other heavy casualties remain at Pearl Harbor. The battleship Utah is righted but has not been refloated, and the sunken hull of the battleship Arizona remains in an upright position.

ACKNOWLEDGMENT

The author is particularly grateful to Captain F. H. Whitaker, USN, who kindly furnished prints of the pictures ap-

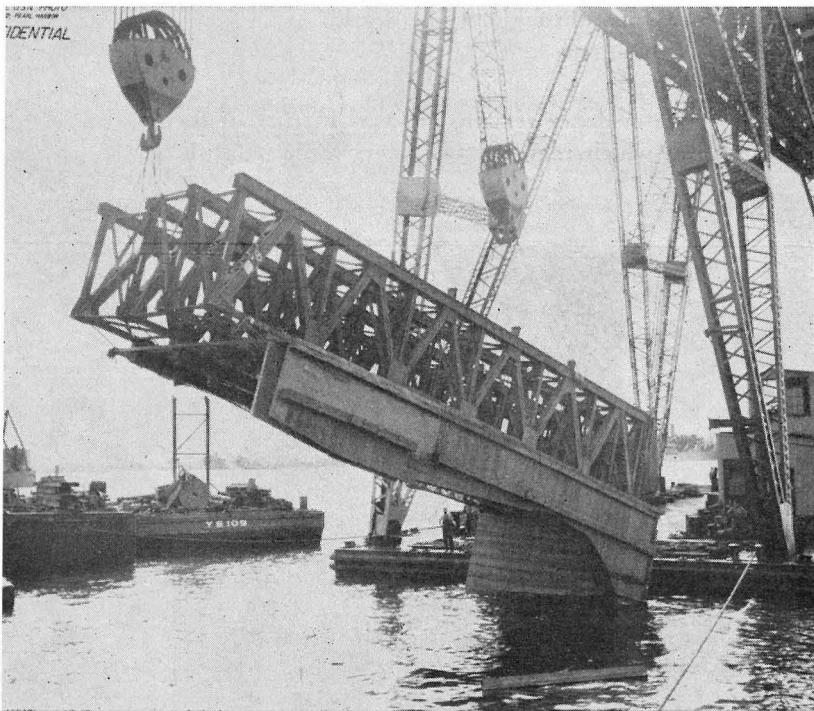


Fig. 20 UPPER: Forward section of the main five-section cofferdam patch. Preparatory to taking the measurements required for the design of the patches, considerable wreckage had to be removed from the port side by divers. Measurements were made by means of vertical and horizontal battens.

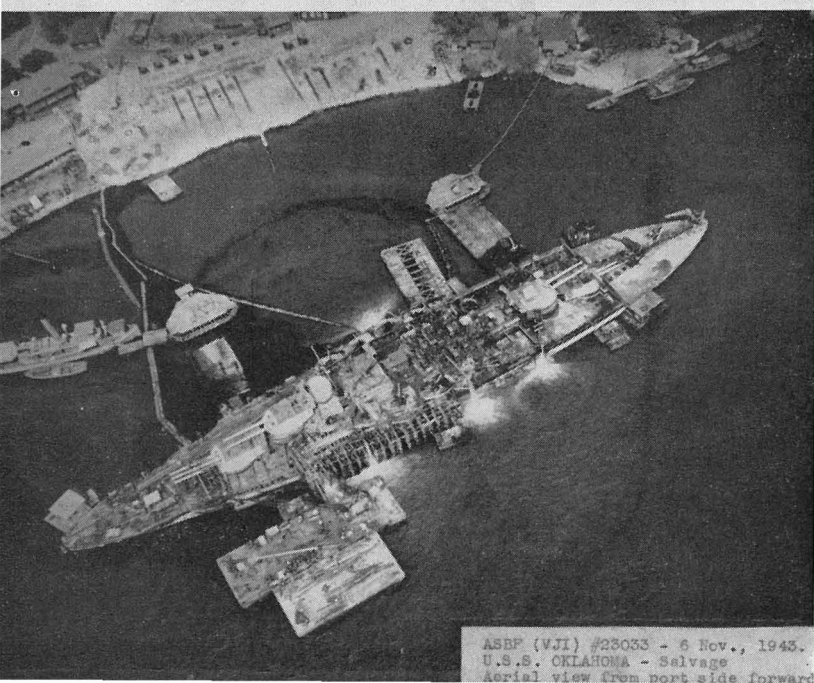
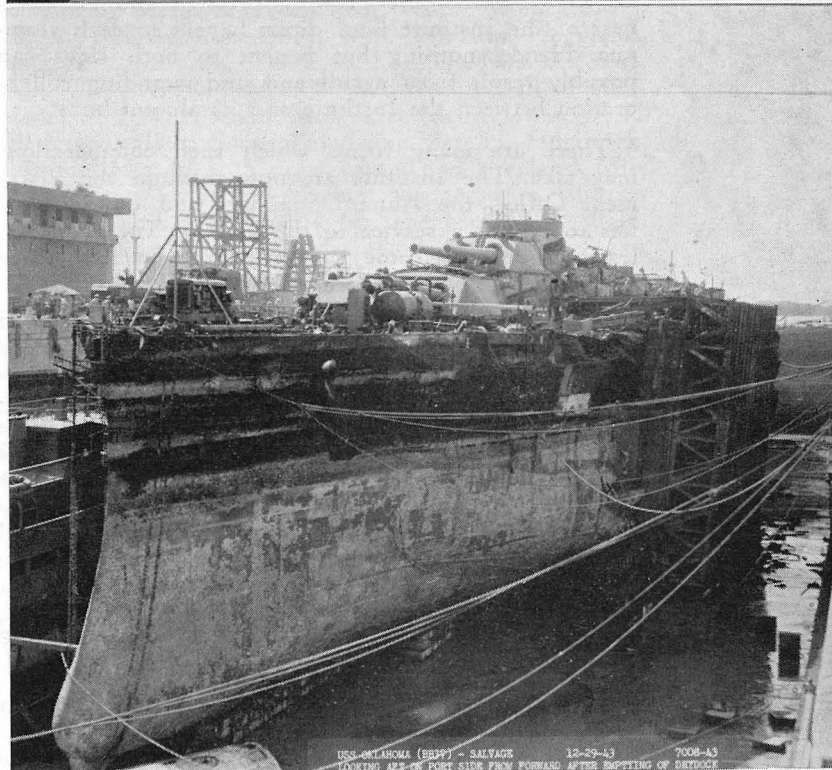
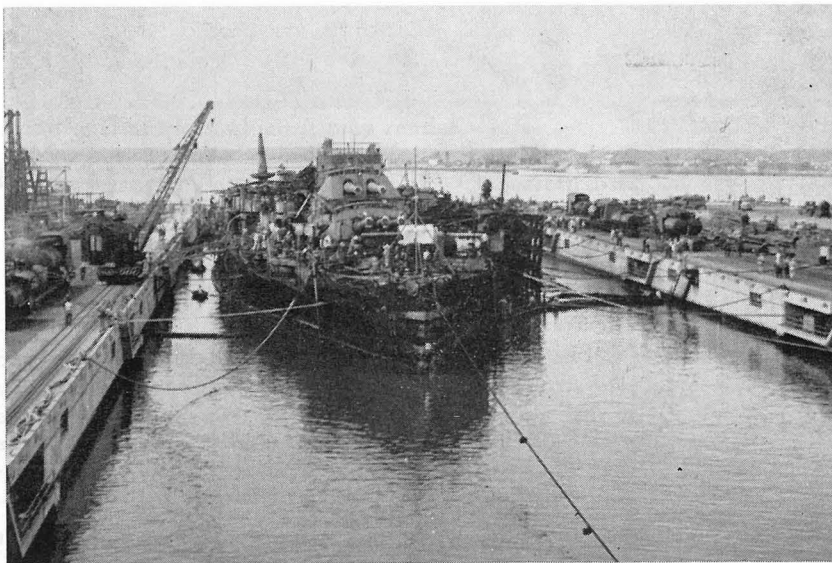


Fig. 21 LOWER: Aerial view from port side of the OKLAHOMA after refloating. The largest volume of water handled by deep well pumps used was at the start of refloating operations. Volume was then equivalent to that handled by approximately 16 10-in. pumps against a 50 ft head. Pumping was continuous. Nine righting tackles are still attached to the ship but were removed after this picture was taken. To restrict movement of the floated vessel, small barges were placed between the ship and quays and the vessel anchored. Guns were placed in a state of preservation, and fire, fresh water, and ventilation systems installed. Diving proceeded continuously during daylight hours.

ASBP (VJI) #23033 - 6 Nov., 1943.
U.S.S. OKLAHOMA - Salvage
Aerial view from port side forward

Fig. 22 UPPER RIGHT: View from ahead in drydock.
 Fig. 23 CENTER: A few hours later, December 29, 1943. Drydock blocks were set in accordance with the OKLAHOMA'S docking plan with some modification. In order that the patch projecting below the ship's bottom would clear the harbor bottom and drydock blocks, the vessel was given a 3° list to starboard. This was done by flooding the starboard blister and wing tanks and attaching pontoons to the main patch on the port side.



pearing in this article and most of the data regarding salvage of the OKLAHOMA. Captain Whitaker had full charge of the salvage of the OKLAHOMA.

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Fig. 24 Port side looking aft after removal of patches. These were removed by cutting the various supporting members. One of the important features in designing the patches was to insure against their premature collapse after the supporting forces of buoyancy and hydraulic pressure were removed when the ship was no longer water borne.