USS FRANK KNOX (DDR-742) STRANDING SALVAGE

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FOREWORD

The salving of FRANK KNOX will be remembered as a significant event in the annals of Ship Salvage for at least two reasons:

First--and no doubt, foremost--the successful completion of this very difficult job can only be attributed to the great skill and greater tenacity of the salvors on the scene. The weather they suffered through was fierce, and lesser men would have found the job "no cure" at any of several junctures. These salvors came back to work after each of three typhoons had disrupted them. They employed just about every "standard salvage technique"--pulling tackle, pumping, dewatering by air, jettisoning, ballasting, trenching and explosive reaction. The only major salvage technique not used to any extent was the application of external lift forces, and even this was prepared for use as a last resort. But even greater skill was required to effectively develop and use a completely new salvage technique--that of Foam-in-Salvage. All this was done on the most inhospitable reef imaginable, in the remoteness of the South China Sea. Logistic support was ever a problem.

The other significant factor in the salving of FRANK KNOX is, of course, the milestone use of a cast-in-place foam for the application of internal buoyancy. This new technique, called Foam-in-Salvage, did not in itself salvage the destroyer. What it did, however, was save her, for had she been pulled free with her forward two engineering spaces flooded and her seriously weakened hull sagging, the hull girder would have broken in two. The bow would surely have sunk. And since FRANK KNOX is a DDR--a Radar Picket, her great value was forward, in the CIC. She was at the time a newly converted ship, and the value of her electronic suit--undamaged by the stranding--was well over $15 million.

This report has been prepared by people who actually performed the salvage job: Commander J. Huntly Boyd, USN, who ran the job and deserves the bulk of the credit for this "cure" salvage operation; and Mr. Alex Rynecki, who as a Lieutenant, USNR, had learned the Ship Salvage trade in a SERVPAC ARS, and as a civilian contract employee supervised the Foam-in-Salvage operations on FRANK KNOX. This report, issued by the Supervisor of Salvage, U. S. Navy, is primarily intended as a case study, and for use in the U. S. Navy Diving and Salvage School. It is also issued to all Salvage Ships and Activities for possible use as a guide in future major salvage operations. This report is written candidly. Problems and blind alleys are frankly described, as are the advantages and disadvantages of Foam-in-Salvage at the time of the FRANK KNOX operation in 1965. Between then and the publication of this report, many of these problems, and especially the several disadvantages of foam, have been solved or corrected. But that is another story, and will better be studied in the new Ship Salvage Manual and the Foam-in-Salvage Manual.

W. F. Searle Jr.

W. F. SEARLE, JR., CAPTAIN, USN
Supervisor of Salvage, U. S. Navy

25 October 1968

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1. INTRODUCTION

The salvage operation involving the USS FRANK KNOX (DDR 742) at Pratas Reef was long, difficult, and complicated, as the result of three major and uncontrollable factors:

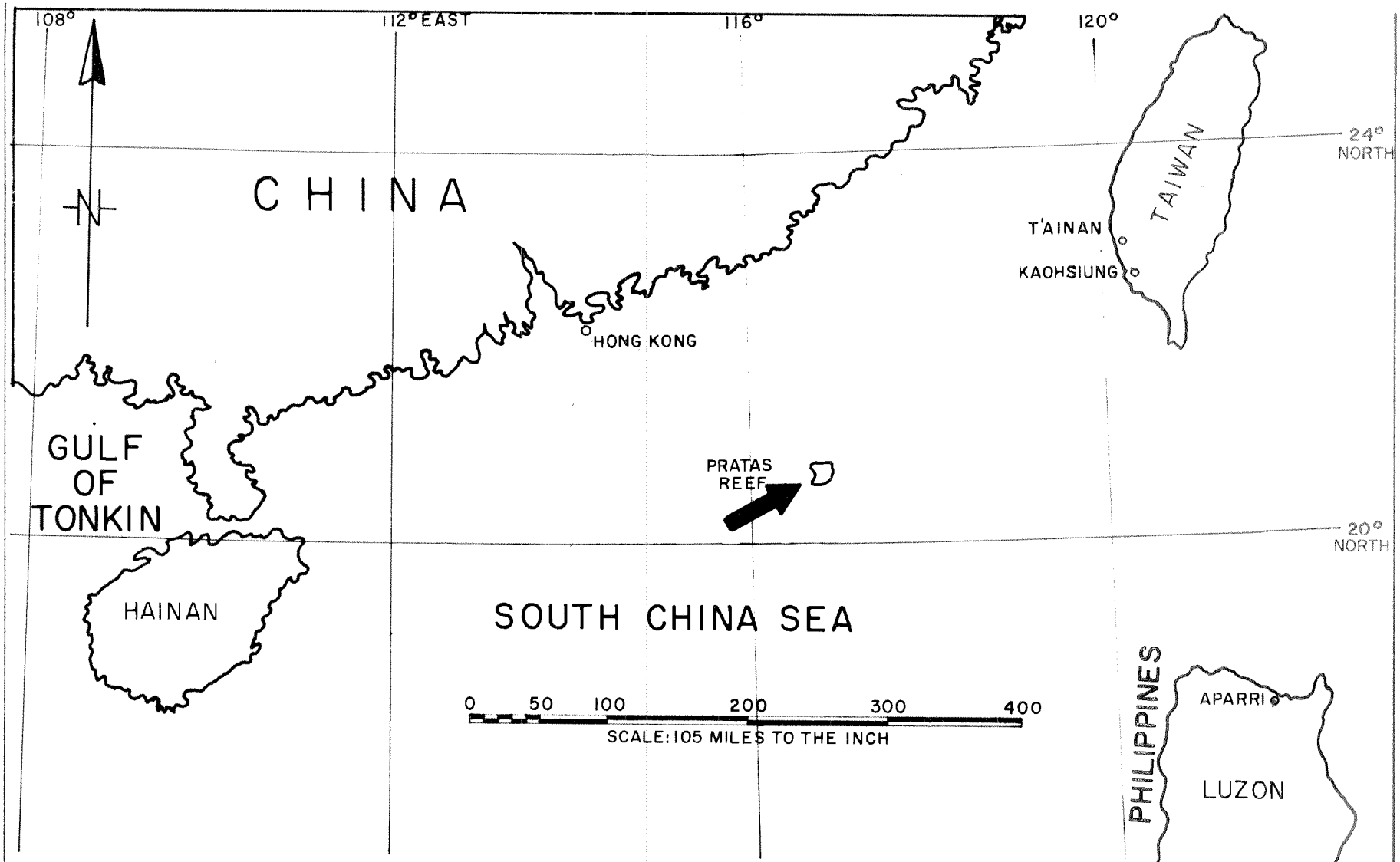
1. The nature of the hydrographic features of the reef.
2. The remoteness of the area.
3. The vagaries of the weather.

The successful, intact refloating of this destroyer was the result of five weeks of long, hard work by a determined group of men, and the help of other ships.

As is always the case in a large-scale operation, a great amount of logistic support was required. Industrial support was provided by USS PRAIRIE (AD 15). Additional diving support was provided by USS GREENLET (ASR 10). Helicopter support was provided by USS MIDWAY (CVA 41), USS IWO JIMA (LPH 2), and USS MARS (AFS 1). Underway replenishment was provided by several different oilers and an AKS. Boat support was provided by USS TALLADEGA (APA 208) and USS POINT DEFIANCE (LSD 31). Four different Type Commands were represented in this salvage operation. A great amount of logistic backup was provided by the several commands at Subic Bay R.P., the nearest U.S. Naval Base. Technical support and direction was provided by COMSERVPAC and the office of the Supervisor of Salvage in the Bureau of Ships. The response to specific needs, by higher commands and all concerned, was outstanding.

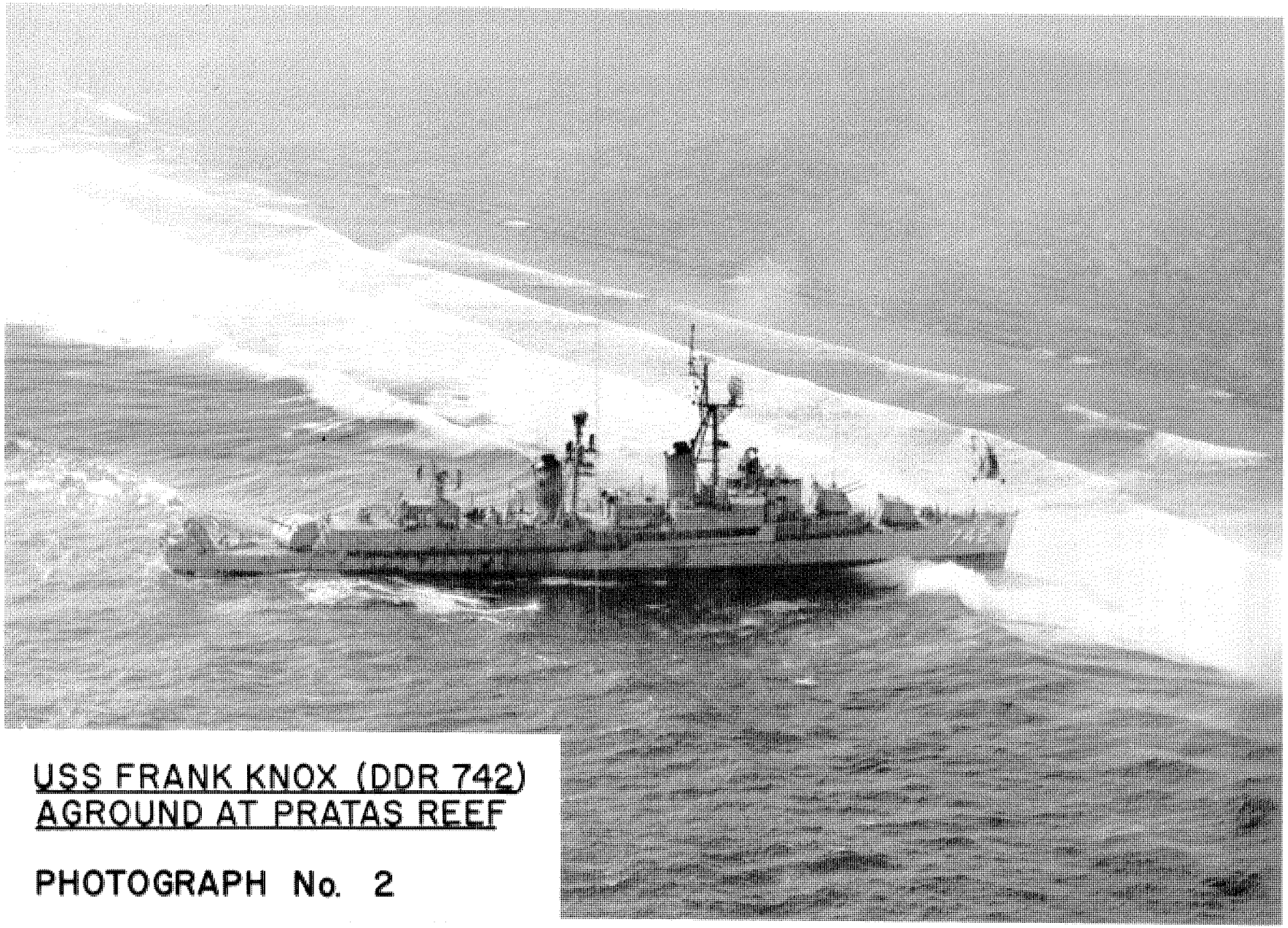
With respect to the procedures used: selective coral blasting, beach gear, and dewatering (using cast-in-place foam), each played its own important part. It is doubtful that any two of these techniques could have led to intact refloating without the third; the use of foam, however, was certainly the key. If this new technique had not been available, dewatering of the flooded spaces would have been a long-time project, and successful completion of the operation, very likely, would not have been possible because of the exposed nature of Pratas Reef and the frequency of typhoons.

Following a successful salvage, USS FRANK KNOX underwent major shipyard repairs in Yokosuka, Japan. On completion of the repairs, the ship was returned to serve on the line with the fleet.



LOCATION OF USS FRANK KNOX (DDR 742) GROUNDING

FIGURE A



USS FRANK KNOX (DDR 742)
AGROUND AT PRATAS REEF

PHOTOGRAPH No. 2

2. FIRST PHASE, 18-20 July

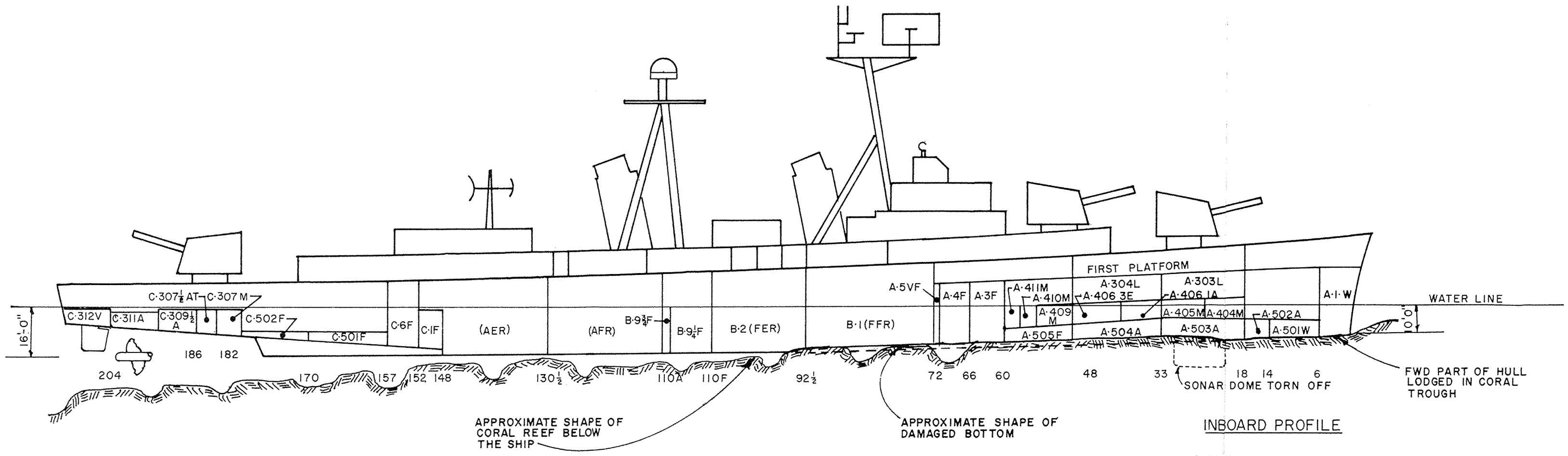
At 0235, 18 July 1965, while steaming at 16 knots, USS FRANK KNOX grounded on Pratas Reef in the South China Sea at position 20°-36'N, 116°-49.3'E. The ship immediately attempted to back-off, using engines, without success. Assistance was requested by 0300, and the ship was ballasted forward. Winds were light with sea state zero. Pratas Reef is a roughly circular atoll, about 12.5 miles in diameter with a small island on its western side. It is located 180 miles SE of Hong Kong, 425 miles north of Subic Bay, R.P., and 240 miles SW of Kaohsiung, Taiwan. FRANK KNOX is a Radar Picket destroyer of the long-hull DD-692 class with the following particulars:

LOA	390 ft. 6 in.
LBP	383 ft.
WIDTH	41 ft. 2-1/4 in.
DISPLACEMENT (Full Load)	3460
DRAFT (Full Load)	14 ft. 7 in.
YEAR BUILT	1945

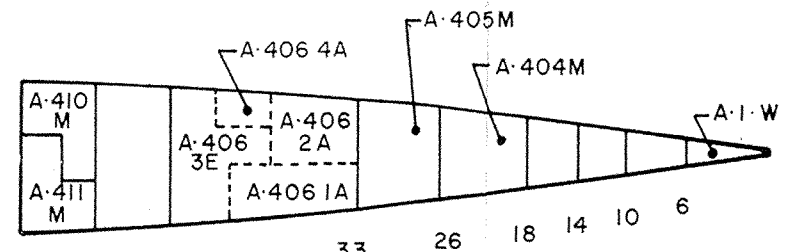
NOTE: All times are local unless otherwise noted. All bearings are true from north, unless noted as relative.

During the early morning of 18 July, a team of Chinese Navy UDT divers arrived from nearby Pratas Island and offered their services. These divers reported that the ship was aground from frame 20 to frame 130 on a slightly sloping coral bottom. All propeller blades were chipped and one blade on each propeller was bent. The sonar dome was sheared off, and the compartment above, A-503-A, was flooded. (See Figure B, page 5, for an inboard profile of the destroyer.) The access hatch to A-503-A initially leaked somewhat, but this was corrected by shoring. There was also some flexing of numbers 1 and 2 longitudinals in the forward fireroom and forward engineroom, with several intercostal stiffeners bent and two small leaks in the forward engineroom. Minor leaks were developing in the air casing of boiler numbers 1 and 2. There was no additional known damage, and the crew had not suffered injuries. The ship's heading varied from 030° to 045°, staying generally perpendicular to the reef and finally settling on a bearing of 046°. The reef was essentially awash with small rocks being exposed at low tide. The ship had taken a 6-degree starboard list and soundings ranged from 12 feet at the bow to 20 feet at frame 150.

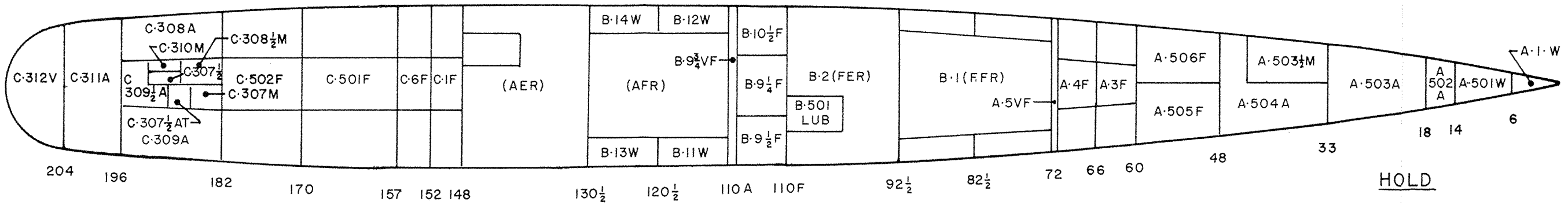
At about 0400 on 18 July, Commander Service Group THREE/CTF 73, as the logistic agent for Commander SEVENTH Fleet, commenced ordering salvage forces to the scene.



INBOARD PROFILE



THIRD PLATFORM



HOLD

USS FRANK KNOX (DDR 742)

SCALE: NONE

FIGURE B

By good fortune, USS GRAPPLE (ARS 7), USS MUNSEE (ATF 107) and USS COCOPA (ATF 100), were within one day's steaming of the grounding site, and were immediately ordered to the scene. The picture was complicated somewhat by the fact that GRAPPLE had three U.S. Army barges in tow, and COCOPA was escorting a YO from Subic Bay to Sasebo, Japan. COCOPA vectored her charge toward Taiwan from her position about 75 miles south of the island, and the YO arrived safely at Kaohsiung that evening. GRAPPLE proceeded to the scene with her tows. All three ships arrived on the scene by 0300, 19 July, at which time GRAPPLE's tows were transferred to COCOPA, thus leaving one ARS and one ATF free for salvage work.

The CSG 3/CTF 73 Salvage Officer, LCDR J.H.Boyd, Jr., USN, was also dispatched to the scene. Transportation was primarily by aircraft; it was intended that the amphibian would land at Pratas Reef if arrival was prior to onset of darkness. However, it was about 2100 by the time the plane arrived, so it continued on to Hong Kong where the USS JOSEPH STRAUSS (DDG 16) was standing by to provide transportation if needed. JOSEPH STRAUSS departed Hong Kong at midnight and delivered the Salvage Officer to the scene about 0700, 19 July, at which time LCDR Boyd took charge of the salvage operation on board FRANK KNOX. (LCDR Boyd acted as principal salvage officer throughout the operation.) After a quick survey of the situation, STRAUSS and USS SOUTHERLAND (DD 743), which had been standing by, were released to proceed as directed.

NOTE: Figure B, page 5, presents the FRANK KNOX compartmentation plan. The condition presented here shows the ship in her grounded state on the reef shortly before the successful salvage. FRANK KNOX's situation changed during the early phases of salvage and continued to vary until the freeing of the ship. This plate will be a useful reference to the reader in following the several phases of the salvage operation.

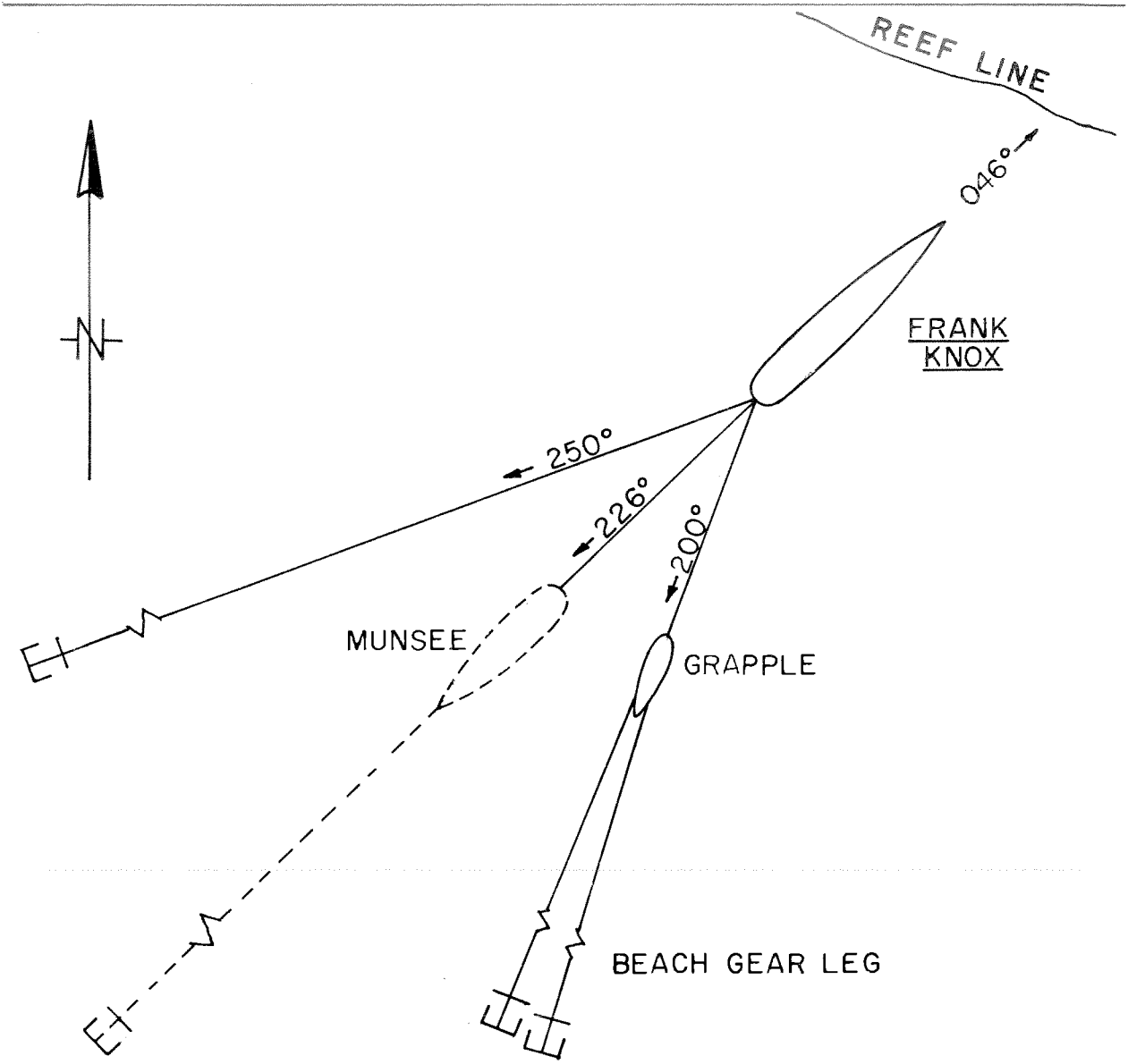
The ship was found to be solidly aground with no detectable movement in the smooth seas. An inspection by GRAPPLE's divers confirmed the findings of the Chinese divers and further revealed that the bottom was composed of hard, generally smooth coral with occasional small, sharpsided crevices running perpendicular to the reef. There were no bottom obstructions to preclude an extraction course directly astern. The initial evaluation of the situation was that one set of beach gear must be rigged from the destroyer to provide protection from broaching; GRAPPLE would then lay two sets of beach gear for heaving from her own deck. Although GRAPPLE already had two sets of beach gear rigged for laying in the

usual USN fashion, one set had to be rerigged for laying from the FRANK KNOX, and a third set would have to be rigged for laying toward the stranded ship. With the high tide expected around 1100, it was obvious that the beach gear work could not be completed in time for a useful pull on 19 July; any effort to do so would have diluted efforts pointing toward the 1125 high tide on 20 July. The initial pulling plan, then, was for three sets of beach gear, FRANK KNOX pulling on one set, and GRAPPLE pulling on two sets. MUNSEE would also be used for pulling with one set of beach gear or with engines only, depending on the time available.

FRANK KNOX was not exactly perpendicular to the reef. (See Figure C, page 8.) It was decided to lay the single set of beach gear off the ship's port quarter so as to allow the maximum maneuvering room for the salvage ships. This location would be ideal for westerly seas and would give some protection from broaching in the event of easterly seas. The necessary falls, blocks, stoppers, etc., were transferred to the destroyer and were rigged by men from MUNSEE who were familiar with beach gear. GRAPPLE laid the ground leg for this set of beach gear at 1500 and the gear was quickly set up by leading the hauling part of the falls to the anchor windlass capstan of the destroyer.

Meanwhile, a rough weight study was made and it was apparent that the ship must be lightened forward. One of the Army barges was brought alongside the destroyer's starboard quarter by boats, and off-loading of all ammunition forward commenced in the early afternoon.

No accurate pre-grounding drafts were available since the ship had been out of port for almost one month. In addition, tides at Pratas Reef were not accurately known. By working backward from the full-load condition, the weight of the ship was determined, and comparing these displacement drafts to the actual drafts at the observed local high tide at about 1100, on 19 July, it was realized that further lightening was necessary. The fuel state was such that all fuel could be transferred from forward to midships and after tanks. It was decided to pump the midships tanks (155 tons) into the barge, and to dump the potable and reserve feed water from the forward fireroom tanks. This led to a computed ground reaction of 210 tons during the observed high tide of 19 July. Tide information had been requested, and by late that day, tide data was received which showed that the 1125 high tide on 20 July was 0.2 feet lower than the tide on 19 July. Ground reaction was computed at 280 tons for the pulling effort. (Tides were diurnal, i.e., only one tide per day, during this period. See Appendix 7.3. for Tide Tables.)



SCALE: NONE

INITIAL PULLING PLAN SCHEDULED FOR HIGH TIDE ON 20 JULY

FIGURE C

With an expected ground reaction of 280 tons, and an estimated coefficient of friction of 0.6, the required pull to refloat the stranded ship was in the neighborhood of 168 tons. The three sets of beach gear could provide up to 50 tons pull each; if MUNSEE could be used, she could generate 30 tons pull with engines alone or 80 tons from engines plus one set of beach gear. FRANK KNOX's own engines and propellers were of questionable efficiency, but it was estimated that her engines could generate a pull of between 50 and 100 tons. In any event, the plan provided for sufficient pulling power, even without MUNSEE. (See Figure C, page 8, for the beach gear layout plan.)

Typhoon Gilda had been a worry during this first day, but it was later reported to have dissipated as it passed over northern Luzon.

USS MAHOPAC (ATA 196) arrived at 1800 on 19 July, and took the two barges from COCOPA leaving both ATF's free to assist.

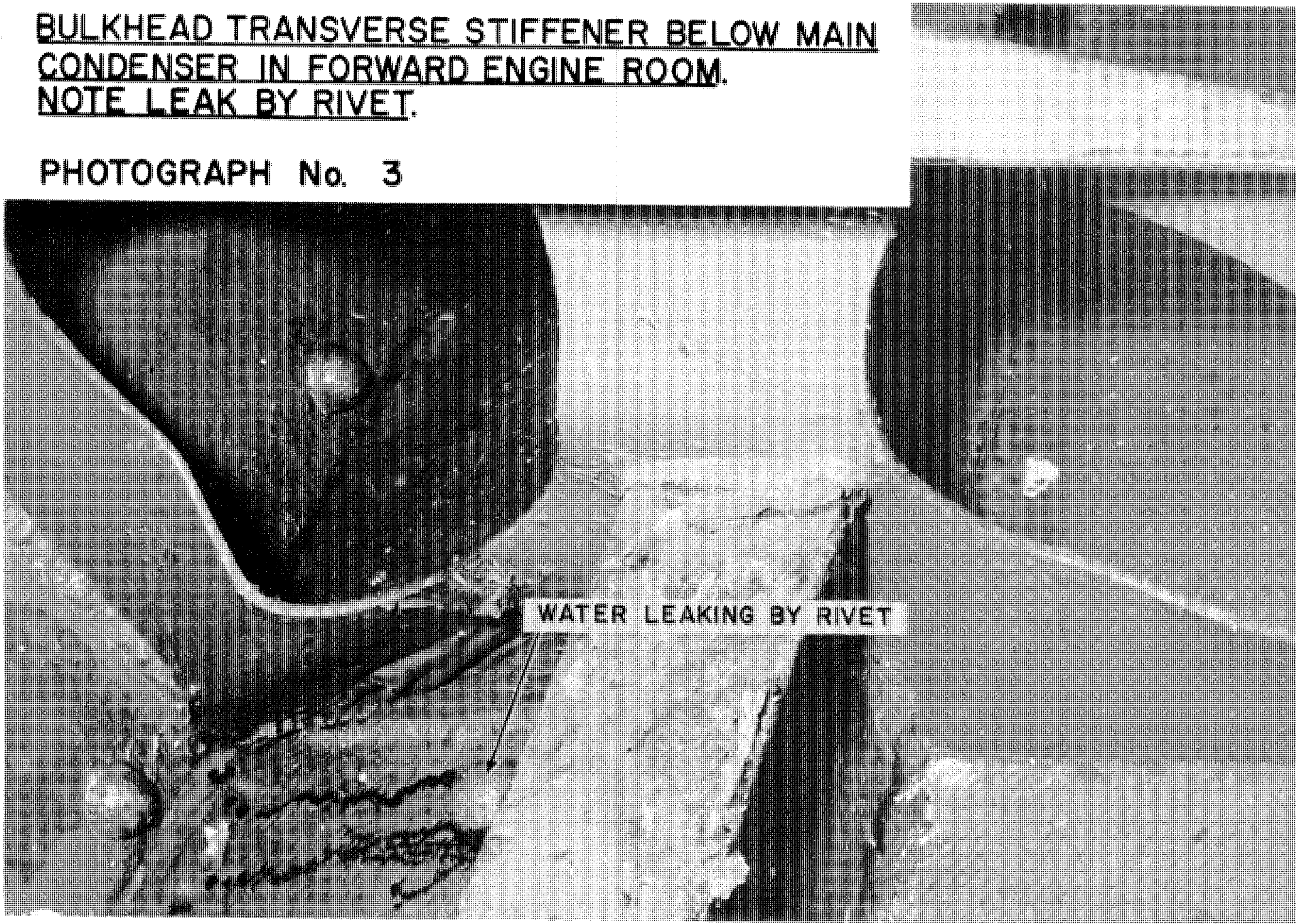
GRAPPLE laid one set of beach gear for herself at 1616 and stood off to rig the second set which was dropped at 2100. While dropping this set, the plate shackle connecting the 2 1/4-inch chain to the first length of 1 5/8-inch wire fouled on the ship's side, and the momentum of the falling anchor and chain caused a pin in the shackle to shear off. The anchor and chain were lost, since the anchor crown buoy did not watch; probably due to the combination of current and deep water involved. GRAPPLE then picked up the 1 5/8-inch wire of the first set for fear of losing it, and rode to this set during the night, using a heavy nylon line to stop off the beach gear wire. Meanwhile, a new anchor chain was rigged to the remainder of the second set.

There was a strong current of 5 to 6 knots running parallel to the reef. This current shifted during the evening and the nylon holding the first set of beach gear parted. This set was unrecoverable, since the recovery buoy again did not watch. There being insufficient time to rig and lay still another set of beach gear for use during the day's 1125 high tide, GRAPPLE laid the one set then rigged at 0922, and after much difficulty with the lateral currents, managed to pass the tow hawser that was shackled to a shot of chain which had been passed around the base ring of mount 53.

With the tide already falling, there was not time to pass MUNSEE's tow hawser. Heaving commenced at 1241. GRAPPLE pulled with the one set of beach gear plus engines, FRANK KNOX backed on her engines and a medium heavy strain was obtained on the beach gear rigged to the destroyer. By the time heaving was secured at 1540, the grounded ship had moved aft

BULKHEAD TRANSVERSE STIFFENER BELOW MAIN CONDENSER IN FORWARD ENGINE ROOM. NOTE LEAK BY RIVET.

PHOTOGRAPH No. 3



about 12 feet. It was intended to have one ATF lay a second set of beach gear to GRAPPLE the following morning, and to use the other ATF, possibly with one set of beach gear, for the 1207 high tide on 21 July. These plans were being formulated when the weather broke. Gilda had regenerated after crossing Luzon.

During the day, winds had been from the west with much rain, and there was a 1-2 foot swell. Shortly after securing the pulling effort, the wind shifted to the southeast and began building rapidly as did the swells. By 1600, the winds, swell and surf, broad on the starboard side, caused the ship to roll and work heavily; heading began to shift to the right, that is, toward a broached position. Reballasting of the destroyer's forward tanks commenced immediately. GRAPPLE commenced heaving again to prevent broaching and FRANK KNOX backed on engines. It appeared that GRAPPLE's Eells anchor was no longer holding, so engines were used at full power with occasional heaving on beach gear. This effort managed to hold the ship's heading, but the destroyer continued to sustain a terrific beating. The bottom in the forward fireroom and forward engineroom worked badly and smaller structural members began to take a permanent set; rivets began to leak. (See Photograph 3 page 10.)

Meanwhile, the Army barge with the ammunition and oil aboard, rode heavily against the starboard side. (It had been intended to take the barge from the side after refloating when there was ample water depth for an ATF to come alongside.) Many shells, hedge hogs and powder cases broke loose and fell over the side. Mooring lines parted and there was danger that the barge could foul GRAPPLE's tow wire if it broke away. COCOPA managed to pass a line to the barge under very hazardous conditions to personnel; the barge was then towed from FRANK KNOX's side at 2000.

Winds continued to build to 30 knots from 130°T with swells of 10 to 12 feet from 170°T. Swells were breaking over the fantail while surf was breaking over the forecastle, making each area untenable. Leakage in the forward fireroom and forward engineroom remained under control for a while, using the main drain system and the number 1 main circulating pump on bilge suction. Number 4 boiler was providing steam to both auxiliary plants. Machinery foundations and piping worked heavily until 2140, when the number 1 main circulating pump turbine exhaust line parted. Attempts to pump from the after spaces were fruitless because of parted and/or leaking bilge piping systems. P250 and P500 pumps were rigged, but the water in the forward engineering spaces slowly rose. They were finally abandoned, flooding to the waterline by about midnight.

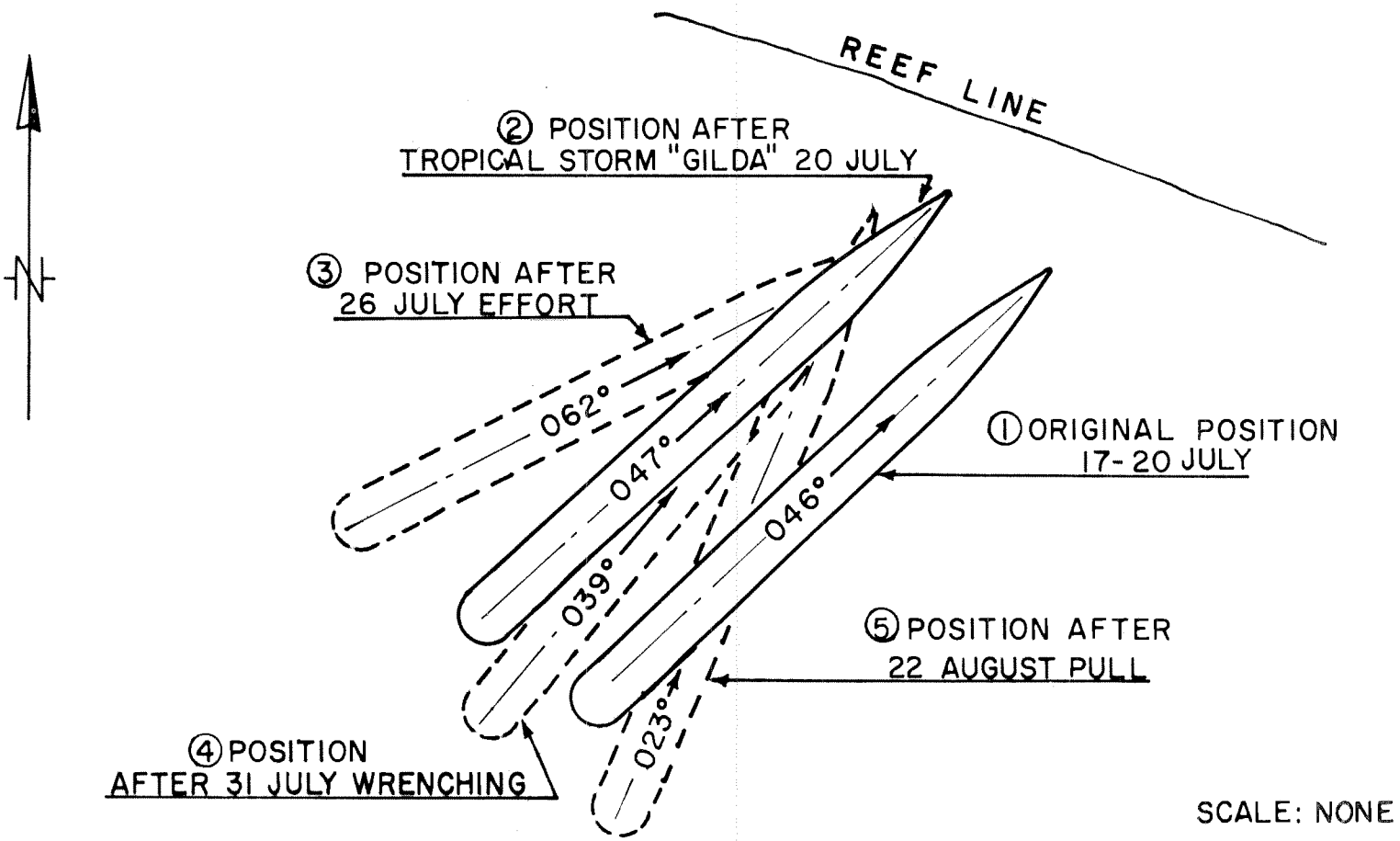


FIGURE D

VARIOUS POSITIONS OF THE STRANDED FRANK KNOX

Number 3 boiler developed leaks during the pounding and was unusable. Twice during the evening, number 4 boiler was thought to have ruptured, and was secured. Each time, however, fires were relighted and power was maintained.

GRAPPLE's beach gear anchor continued to drag until the ARS was dangerously close to the reef. By 2300, FRANK KNOX's heading had stabilized at 047° and GRAPPLE had been set down to a position off the port quarter. The ARS was actually pulling in a direction tending to increase the ship's heading. The destroyer was estimated to have moved laterally on the reef about 75 feet and had apparently entrenched itself in the coral. Finally, it was mandatory that GRAPPLE clear the area. This was accomplished at 2310 by slipping the beach gear and letting the tow wire run off its drum, since the destroyer's fantail was untenable and it was impossible to cut the tow wire loose from FRANK KNOX.

Although the destroyer continued to work very heavily, the heading remained constant, and no lateral or fore and aft movement was detected. The winds abated to about 25 knots, and the majority of the swells were about four feet high with an occasional swell of about 12 feet, as Gilda passed to the south. (See Figure D, page 12, for various positions of the destroyer.)

During the early evening, while the ship was suffering its greatest buffeting, and with boat operations impossible, there were serious doubts that the ship or its crew would survive. At this report, Commander SEVENTH Fleet, thinking it likely that FRANK KNOX would have to be abandoned, ordered USS MIDWAY (CVA 41) and an amphibious task group with USS IWO JIMA (LPH 2) to proceed to the scene, since each ship had several helicopters. By midnight, however, it was apparent that the worst of the storm had passed and FRANK KNOX would survive to see another day. MIDWAY arrived at 0700, 21 July, and immediately commenced removing 155 nonessential personnel by helicopter. The carrier task group commander RADM Marshall W. White, USN, assumed duties as on-scene commander.

At this time, CTF 73 was ordered to proceed to the scene to take charge. RADM J. W. Williams, Jr., USN, arrived on board MIDWAY from Japan at 1500, 21 July, and assumed on-scene command. MIDWAY was retained to provide a landing platform for receipt of additional personnel and equipment expected, and to provide helicopter service until arrival of IWO JIMA on late 22 July.

Thus ended the first phase of the FRANK KNOX salvage operation which saw the complexion of the task change from a relatively simple refloating problem to a major salvage operation in the short period of about eight hours.

3. SECOND PHASE, 21-25 July

A summary of the condition of FRANK KNOX on 21 July was as follows:

1. Based on the last inspection prior to abandoning the forward engineering spaces, some structural damage had been sustained by the bottom six feet either side of the keel; many intercostal transverse stiffeners were deformed. Minor leaks existed in bulkheads 72 and 92-1/2 at the bottom on the centerline. There was minor deformation of the vertical keel web in two locations. The sum total of this damage was not considered to preclude safe tow/escort after refloating.

2. Based on the rate at which they flooded, the leaks in the forward fireroom and forward engineroom were estimated to be approximately 500 GPM in each space. Minor leaks existed in the after fireroom which were easily controlled by the installed bilge pumps and a six-inch submersible pump. A-503-A was flooded. There were no other known leaks.

3. Only number 4 boiler was operable and was steaming under a badly salted condition. Boiler water was being treated heavily and large-scale boiler blows were being used. (It is assumed that the system had salted through damaged condensate lines in the forward engineroom while steaming the forward turbo generator, cross-connected the previous evening.) Number 2 ship service turbo generator was on the line and number 2 evaporator (4000 GPD) was in operation. The forward emergency diesel generator was providing vital power to the forward areas of the ship. Casualty power was being rigged to provide power for additional vital services forward.

4. Wind and seas shifted astern of FRANK KNOX, but continued to be too rough for boating or external diving operations. Additionally, the seas prevented the taking of accurate draft readings and quantitative ground reaction calculations.

The basic salvage plan at this point was to rig additional pulling force and to dewater the forward engineering spaces. Two ARS's were to be positioned at relative bearings of 150° and 210°, leaving room for an ATF dead astern. Each ship would pull on two sets of beach gear. Favorable tides commenced on 24 July (2.6 ft.), and worked up to a maximum of 4.0 feet on 29 and 30 July. USS CONSERVER (ARS 39), USS SIOUX (ATF 75) and USS GREENLET (ASR 10) were ordered to the scene. Since ample AC power was available and leakage was assumed to be within their capacity, six-inch submersible pumps seemed to be the answer to the dewatering problem. Two pumps were available on the scene aboard GRAPPLE, two were expected shortly aboard CONSERVER, and as back-up, three pumps were

requested from the Emergency Ship Salvage Material (ESSM) Pool, Subic Bay, R.P. The three pumps from Subic were flown to MIDWAY by COD aircraft and transferred to FRANK KNOX by helicopter on 21 July.

The following additional personnel proceeded to the scene to advise and assist as needed:

CAPT W.L. Marshall, USN	CO, SRF GUAM
CAPT W.A. Walker III, USN	COMSERVRON FIVE
LCDR C.K. Naylor, USN	CO, EODU ONE

They arrived on 22 July.

One six-inch submersible pump was rigged into each engineering space; the pumps in the after two spaces were to handle additional flooding if it should occur.

On 21 July, COCOPA and MUNSEE each laid one set of beach gear off FRANK KNOX's starboard quarter for use by GRAPPLE. On the early morning of 22 July, the ARS attempted to enter a moor, but could only locate one of the recovery buoys. It was considered too dangerous to enter the moor with only one set of beach gear in view of past experience with the strong lateral currents. GRAPPLE, therefore, rigged one set of beach gear and subsequently a second set when the second recovery buoy ceased to watch. GRAPPLE laid the two new sets of beach gear and entered the moor off FRANK KNOX's starboard quarter on 24 July. The connection between the ships was made using a seven-inch nylon hawser, since GRAPPLE's tow wire was still to be recovered from the bottom where it had been left when GRAPPLE made her emergency breakout on 20 July. Recovery of the two-inch tow wire was accomplished, and GRAPPLE was firmly moored by the evening of 24 July. Meanwhile, CONSERVER arrived, early, the 24th with two sets of beach gear rigged for laying, which was done that morning. CONSERVER also completed her moor off the destroyer's port quarter by the evening of 24 July.

The following ships arrived during these busy days:

USS PRAIRIE (AD 15)	22 July
USS IWO JIMA (LPH 2)	22 July
USS POINT DEFIANCE (LSD 31)	22 July
USS TALLADEGA (APA 208)	22 July
USS SIOUX (ATF 75)	23 July

MIDWAY was detached on 22 July after arrival of IWO JIMA with her helicopters; MAHOPAC was detached with the Army barge containing the ammunition and oil from FRANK KNOX on 23 July. POINT DEFIANCE (part of the amphibious task group) was also detached on 23 July.

The heavy boiler blow requirements left FRANK KNOX in a critical status concerning feed water. In addition, it was not known how long number 4 boiler could be continuously steamed. PRAIRIE boiler repair personnel proceeded to the destroyer upon arrival, and succeeded in making repairs to number 3 boiler and in getting a satisfactory hydrostatic test. Since this boiler had many air casing leaks, it was reserved for emergency use only. PRAIRIE also fabricated several large tanks of about a 150-gallon capacity each, that were utilized to carry feedwater to FRANK KNOX by helicopter. However inefficient this was, it solved the feedwater problem.

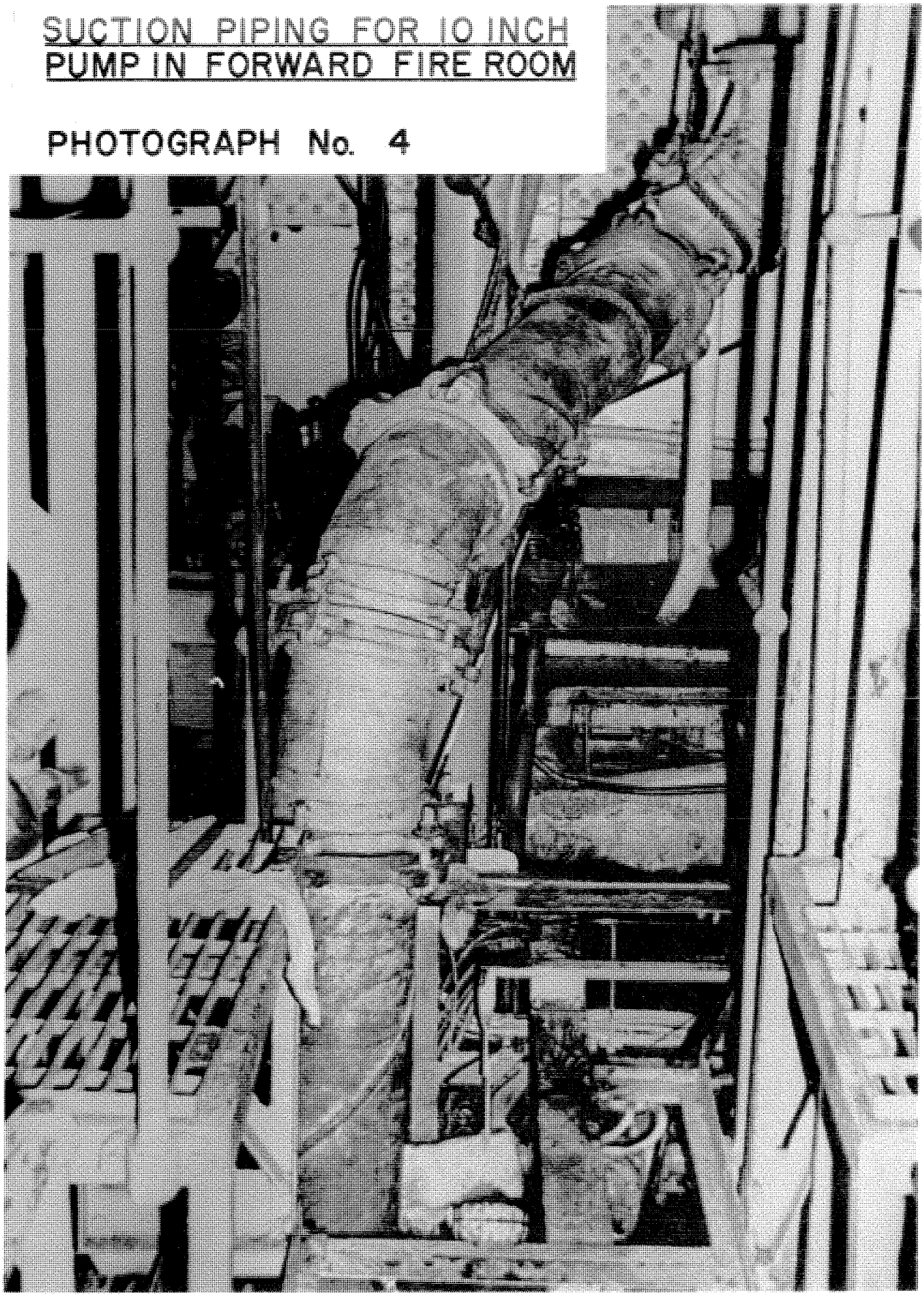
The sea conditions continued to be marginal. It was apparent that the 1500-pound capacity IWO JIMA helicopters had many limitations. Accordingly, USS MARS (AFS 1) with her two 4000-pound capacity UH 46 helicopters was ordered to the scene on 23 July. MARS arrived early 25 July.

FRANK KNOX continued to work heavily in her bed of coral, particularly during low tide. A-504-A was discovered to be flooded on 22 July, and the working of the bottom was transmitted to the reefer machinery deck above this space by stanchions, piping, battens, etc. As is typical of all destroyers, the reefer machinery deck of FRANK KNOX was in poor condition, and it developed many small leaks which were extremely difficult to patch because of the deteriorated condition of the deck and the awkward location of many of the leaks, i.e., adjacent to bulkheads, piping spools and stanchions. After making the best possible patches, leakage was contained with a P-500 pump which eventually failed. Finally, a six-inch submersible pump was installed in the reefer machinery space. This pump easily contained the leakage. The fuel tanks A-505-F and A-506-F, which were ballasted, were found to be leaking when the decks of the magazines above these tanks began to leak. Access to A-410-M and A-411-M was difficult and these spaces had to be abandoned for fear of progressive flooding above the second platform prior to successfully closing the leaks. The leaks in the deck of A-409-M were again difficult to close, and as in the case of the reefer machinery space, a six-inch submersible pump was eventually installed in this compartment.

The foregoing problems led to questions concerning the forward fuel oil service tanks, A-3-F and A-4-F. On 23 July, FRANK KNOX personnel lined up the transfer manifold in the forward fireroom and a suction was taken using the after bilge and ballast pump. After a short while, several feet of water had been transferred to an after tank while the level in the forward service tanks was unchanged. Since there was a possibility that the transfer line was damaged in either of the flooded forward engineering spaces, this test was not inclusive.

SUCTION PIPING FOR 10 INCH PUMP IN FORWARD FIRE ROOM

PHOTOGRAPH No. 4



The tank top covers of A-3-F and A-4-F were removed, and eductors were dropped directly into the tanks for a test. (The tank tops were several feet above the external waterline.) It was soon apparent that both of these tanks were holed. Soundings of A-507-F, A-508-F, A-509-F and A-510-F showed water standing in their sounding tubes to the waterline. The sluice valves of these tanks were open, however, and since the tank tops were below the high tide waterline, the condition of these tanks could not be easily determined. The same conditions applied to the midships fuel tanks. Tanks and spaces known, or suspected to be open to the sea, were rigged for blowing with air. PRAIRIE manufactured blow manifolds with appropriate valves, gages and fittings, while the following tanks and spaces were rigged for blowing by blanking overflows and air escapes:

A-503-A	A-507-F	A-3-F	B-9-1/4-F
A-504-A	A-508-F	A-4-F	B-9-1/2-F
A-505-F	A-509-F	A-5-VF	B-9-3/4-F
A-506-F	A-510-F		B-10-1/2-F

Hopes for easily dewatering the forward engineroom and fireroom ended on 22 July, when test pumping with the six-inch electric pumps revealed large leaks; the water level in each space could only be lowered about six inches. Plans were immediately made to use 10-inch gasoline driven salvage pumps in these spaces. The pumps weighed 2700 pounds and were, therefore, far beyond the capacity of IWO JIMA helicopters. Boating conditions were still impossible, so nothing could be immediately done about the large pumps. However, 10-inch foot valves and suction piping were transferred by helicopter, so that the time-consuming rigging of the pump suctions did proceed with one suction being placed down the port side access to each forward space. (See Photograph 4, page 17.)

Diving external to the ship was still impossible, but the arrival of PRAIRIE brought divers who were familiar with the inside of a destroyer's engineering spaces. Diving inside the forward engineroom and fireroom commenced late 23 July and continued throughout the night. The divers found the bottom flexing up to one foot, relative to heavy machinery and lower level deck plates, making conditions hazardous to divers who were wearing shallow water diving gear. However, the divers closed every valve they could find and discovered a large number of popped rivets. They could not find any large holes, but many areas remained unexamined. One pair of valves found open was the cooling water valves to the main engine lube oil cooler, which allowed a large amount of water to enter since the discharge line was found to be parted. The divers attempted to plug the missing rivet holes with small hardwood plugs, but this was unsuccessful because the plugs would back right out as the bottom worked. Finally, seaming wedges were driven

between the longitudinals and the bottom in way of the rivet holes.

The flooded engineering spaces were inspected again late 24 July. Additional areas, not previously reached, were inspected and no large holes were located, but all the wedges that were driven the night before had worked themselves out. The wedges were reinstalled, and nails were driven through the rivet holes into the wedges. Surprisingly, this ploy was successful. The divers could not find any damage done to the keel during their inspections.

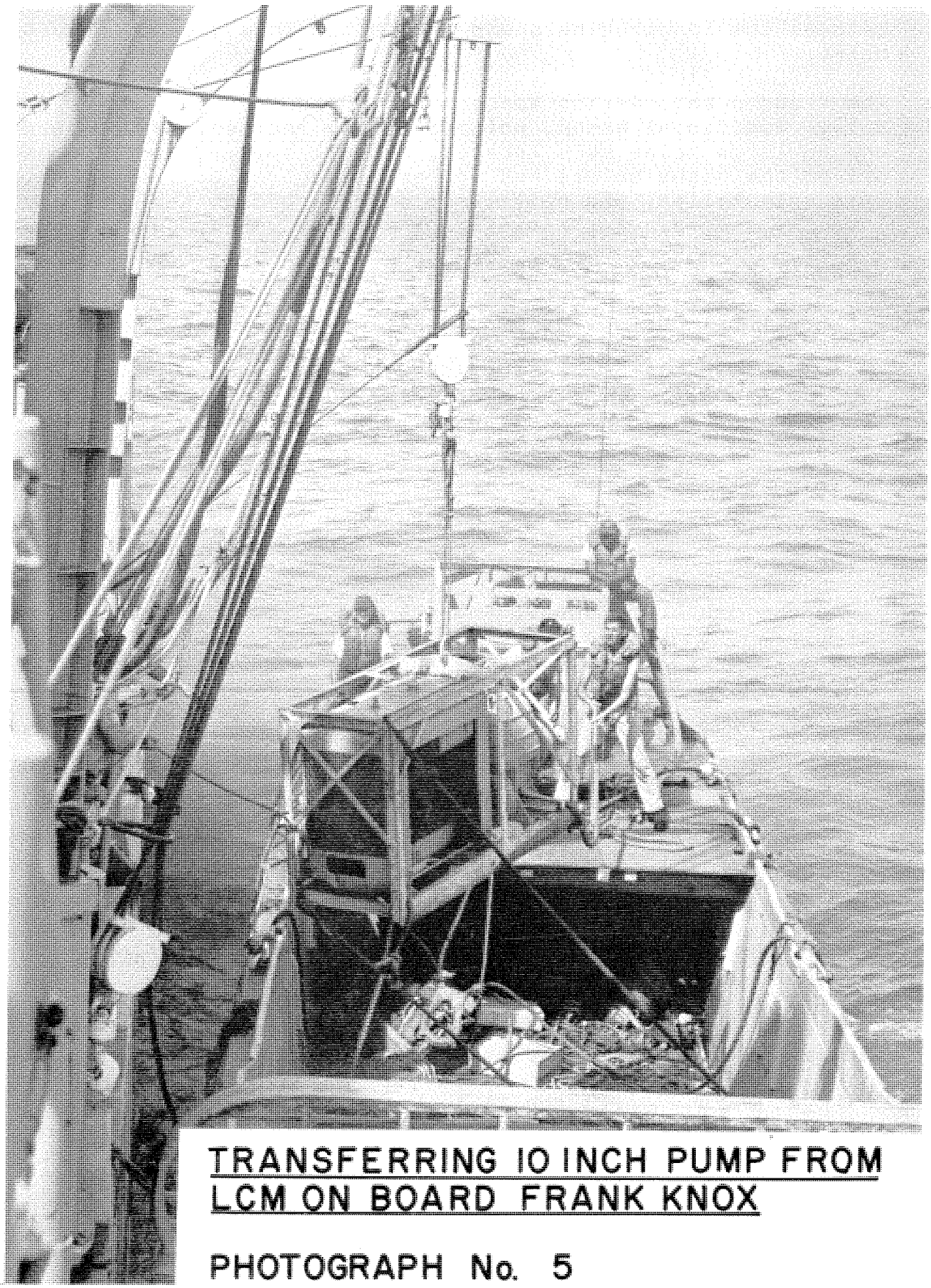
TALLEDEGA's important assets were two LCM-6's. It was too rough on the 22nd, even to launch these boats; they were successfully launched on the 23rd, and one boat made a trial landing along the port side of FRANK KNOX in an attempt to transfer heavier equipment to the stranded ship. However, conditions were too hazardous and all efforts were delayed another day. Conditions were marginally satisfactory on 24 July, and as the result of outstanding seamanship by the boat crews, two 10-inch pumps and three 105 CFM air compressors were successfully transferred to FRANK KNOX, using the destroyer's boat falls for lifting the equipment aboard (see Photograph 5, page 20). One pump was quickly rigged for each flooded engineering space, and the compressors were piped up for blowing tanks and flooded compartments. The LCM's were also invaluable in running messengers and seven-inch nylon lines between the ARS and the stranded ship.

25 July, high tide: 3.05 feet at 0451. Commenced heaving at 0345 on 25 July. Seas had fallen rapidly until they were almost calm. Blowing of tanks got a late start and results were largely indeterminable. Many 10-inch pump problems were experienced, but they did succeed in lowering the water level in the forward fireroom by three feet, and in the forward engineroom by one foot. The ship gave one shudder, but no movement was detected, and the effort was concluded at 0500. GRAPPLE's two sets of beach gear held well, as did the single set to FRANK KNOX. However, CONSERVER's two sets dragged somewhat during the pulling effort.

Looking towards an 0.2 foot higher tide on the 26th, the following work was accomplished on 25 July:

1. Transferred two 10-inch pumps from CONSERVER by MARS helicopter. These pumps were rigged in the starboard side accesses to the flooded engineering spaces.

2. Improved the tank/compartment blowing system and procedures.



TRANSFERRING 10 INCH PUMP FROM LCM ON BOARD FRANK KNOX

PHOTOGRAPH No. 5

3. Continued with patching efforts in the flooded engineering spaces, both internally and externally, now that weather conditions permitted external diving operations.

4. It was intended to lay two sets of beach gear for COCOPA to pull in from a position directly astern of FRANK KNOX between GRAPPLE and CONSERVER. In order to speed the rigging of the gear, SIOUX rigged one set and COCOPA the other; SIOUX laid her set by mid-afternoon, but it was dropped too far out; COCOPA laid her set by late afternoon and was connected up by early evening. SIOUX rigged and laid another set of beach gear that evening for COCOPA.

Typhoon Harriet now became a problem and was predicted to pass close aboard within 24 hours. CTF 73 received orders from higher authority that if the effort on 26 July was unsuccessful, all personnel were to be removed from FRANK KNOX and all ships were to sortie on typhoon evasion. This, of course, would result in the after fireroom flooding completely and would make subsequent salvage efforts even more difficult, if not impossible. Anticipating evacuation, all excess personnel were removed from the destroyer that evening along with classified documents, records, publications and other data.

MUNSEE, with the remaining Army barge in tow, was detached for typhoon evasion on the afternoon of 25 July.

26 July, high tide: 3.34 feet at 0541. 25 knots of wind from 260°; seas eight feet from 210°. Commenced heaving at 0400, 26 July. The predicted ground reaction, assuming the forward fireroom and forward engineroom were pumped down five feet and two feet respectively, was 500 tons, and would require a pull of about 300 tons. The maximum axial component of the beach gear pull was estimated at 260 tons; the pull of the remaining port engine was expected to add 30-40 tons pull. This total pull was certainly not overwhelming, but it was all that was available considering the time constraints and was really pointed toward the 4.0-foot tides of 29 and 30 July, when the ground reaction would be some 210 tons less. CONSERVER and COCOPA commenced heaving first, since their beach gear holding power was questionable. These ships started to develop a heavy strain and GRAPPLE commenced heaving at about 0500. At 0508, GRAPPLE's tow wire parted aft of her fantail, probably due to chafing when recovering the wire from the bottom. The ARS slipped her beach gear and stood out of the area. At 0545 FRANK KNOX, with the port engine backing, started to move aft a foot or two at a time until 0737, when the dog on COCOPA's towing engine failed, allowing the ATF's tow wire to run free. (It turned out that COCOPA had not used a Carpenter stopper or figure-eights around the "H" bitts to secure the tow wire, but was heaving "from the dog.")

CONSERVER continued heaving and FRANK KNOX backed-up until about 0750, when the effort was terminated because the heading of the stranded ship was increasing. With CONSERVER off the port quarter, and the single set of beach gear to FRANK KNOX also off the port quarter, the destroyer's heading increased from 047° to 062°, or toward a broaching position. The ship seemed to be following a constant depth contour along the reef when the effort was terminated. Total movement for the day was about 30 feet. During the effort, the pumps were only successful in lowering the waterline in the forward fireroom and forward engineroom by 23 and 14 inches respectively, despite the additional pumps.

Just prior to this refloating effort, CTF 73 had received permission to remain with the striken ship depending on local conditions, since the storm appeared to be veering.

The wind was from the south at 30 knots and seas were building, eventually reaching 10-foot swells. However, the barometer had stopped falling and was holding steady. The decision was to remain with the ship as long as the weather did not deteriorate. All the ships except CONSERVER, IWO JIMA, and MARS proceeded south on typhoon evasion; CONSERVER was still moored to FRANK KNOX, and the helicopters on IWO JIMA and MARS were needed to evacuate personnel from the destroyer. By 0700 winds were westerly at 30 knots and steady, and after holding steady for about four hours, the barometer began to rise. The crew and salvors held on while the ship did some rough riding, but not nearly as bad as during typhoon Gilda.

4. THIRD PHASE, 26 July - 2 August

Tides continued to rise until 30 July, and good tides still remained on 31 July, 1 and 2 August (see Appendix 7.3. Tide Table). The new position of the ship left the bottom of the after fireroom hard aground at low tide, with the resulting working causing much concern. Furthermore, the quickest and easiest path to deeper water was to wrench the stern to starboard. It was generally intended to place the two ARS's off the starboard quarter and to use double anchor sets of beach gear to obtain better holding power.

Availability of beach gear was a problem, however. Upon the return of all units early 27 July (with the exception of MUNSEE who was detached with her tow), GRAPPLE commenced beach gear recovery operations. Only one of the recovery buoys was watching, but two more were located just below the surface by using the helicopters for spotting. Two anchors could not be broken out from the bottom. GRAPPLE was successful in recovering only one set. This set, plus gear still available aboard CONSERVER, permitted GRAPPLE to rig two tandem anchor sets. It was intended that the ARS would use the COCOPA tow wire, which had been left on the bottom, to replace her own parted wire. In the meantime, CONSERVER remained in her moor to provide emergency restraint to the FRANK KNOX.

All beach gear (five sets) had been requested from the Subic Bay ESSM Pool, and these were expected to arrive on 28 July. It was planned to use these sets to augment CONSERVER's gear, so that each ship would have a tandem anchor for each set. Enough gear would then be leftover to rig two sets to an ATF.

Pumping in the forward fireroom and forward engineroom had not progressed as expected. It was decided to fabricate large collision mats which could be hogged under these spaces in many areas, at high tide, utilizing the several natural trenches that ran under the ship for passing the lines.

In addition, it was decided to attempt to partially dewater the engineroom by using air. PRAIRIE personnel removed ventilation ducts and installed blanks. A 210 CFM compressor (6700 lbs) from CONSERVER was broken-down into two liftable parts and transferred to FRANK KNOX by LCM and boat falls. The first blow was made on 28 July, but only 1/4 psi could be maintained in the space. After two days of plugging leaks, patching holes, and repacking leaking stuffing tubes, the maximum obtainable air pressure in the engineroom was still only 1/4 psi. Blowing attempts were, therefore, terminated, and efforts at patching the space for pumping continued.

NOTE: The danger in completely dewatering the engineroom with air existed and was fully appreciated.

> This was due to the fact that the pressure everywhere would be equal to the hydrostatic head of the water driven from inside the space. It was doubtful that the upper bulkheads, or perhaps even the main deck along the centerline, where plating is light, would take this high head. The intention was only to attempt to blow down to a reasonable level, and anything greater than 14 inches would have been better than the pumping effort of 26 July.

The salvors were in doubt as to the structural strength of the hull after 24 July. BUSHIPS reported that if the ship should break in half, the break would likely occur at about frame 85 in way of number 2 boiler uptake. Since bulkhead 92-1/2 was known to be leaking, and BHD 110 (forward) could fail, BHD 110 aft was shored to act as a holding bulkhead for the after-half of the ship which was expected to remain afloat and stable.

By 28 July, another typhoon, Ivy, became a threat and was expected to be in the area on 30 July. Preparations proceeded with a renewed urgency.

On 28 July, GRAPPLE laid her two tandem anchor sets of beach gear and entered her moor using her shortened tow wire. With GRAPPLE providing emergency restraint, CONSERVER could then be released to pick up her own beach gear which was rerigged with tandem anchors on each set using two of the anchors that had arrived from Subic Bay earlier that day. One new set of beach gear, each, was also transferred to SIOUX and COCOPA.

CONSERVER laid her two tandem anchor sets of beach gear the afternoon of 29 July on a relative bearing of 130° from FRANK KNOX. GRAPPLE, meanwhile, managed to recover the bitter end of COCOPA's tow wire just in time for another setback. The lateral current was running from the west at about 5 knots at the time, and GRAPPLE's anchors began to drag. The ARS was set rapidly toward the reef to the east and had to be released. Fortunately, GRAPPLE was able to hold on to her beach gear and managed to hold a reasonable position using her engines. Meanwhile, CONSERVER had taken her two beach gear legs on deck, but she could not pass her tow hawser under these current conditions which left both ARS's in a precarious position, each swinging to two sets of beach gear in a strong lateral current and with no connections to the stranded ship.

Some good news was received: typhoon Ivy had changed course and was no longer a threat.

SIOUX laid her one set of beach gear (single anchor) late that afternoon on a relative bearing of 150° from FRANK KNOX.

It was intended to have COCOPA lay her set of beach gear to SIOUX, but the current conditions and little available time did not permit this.

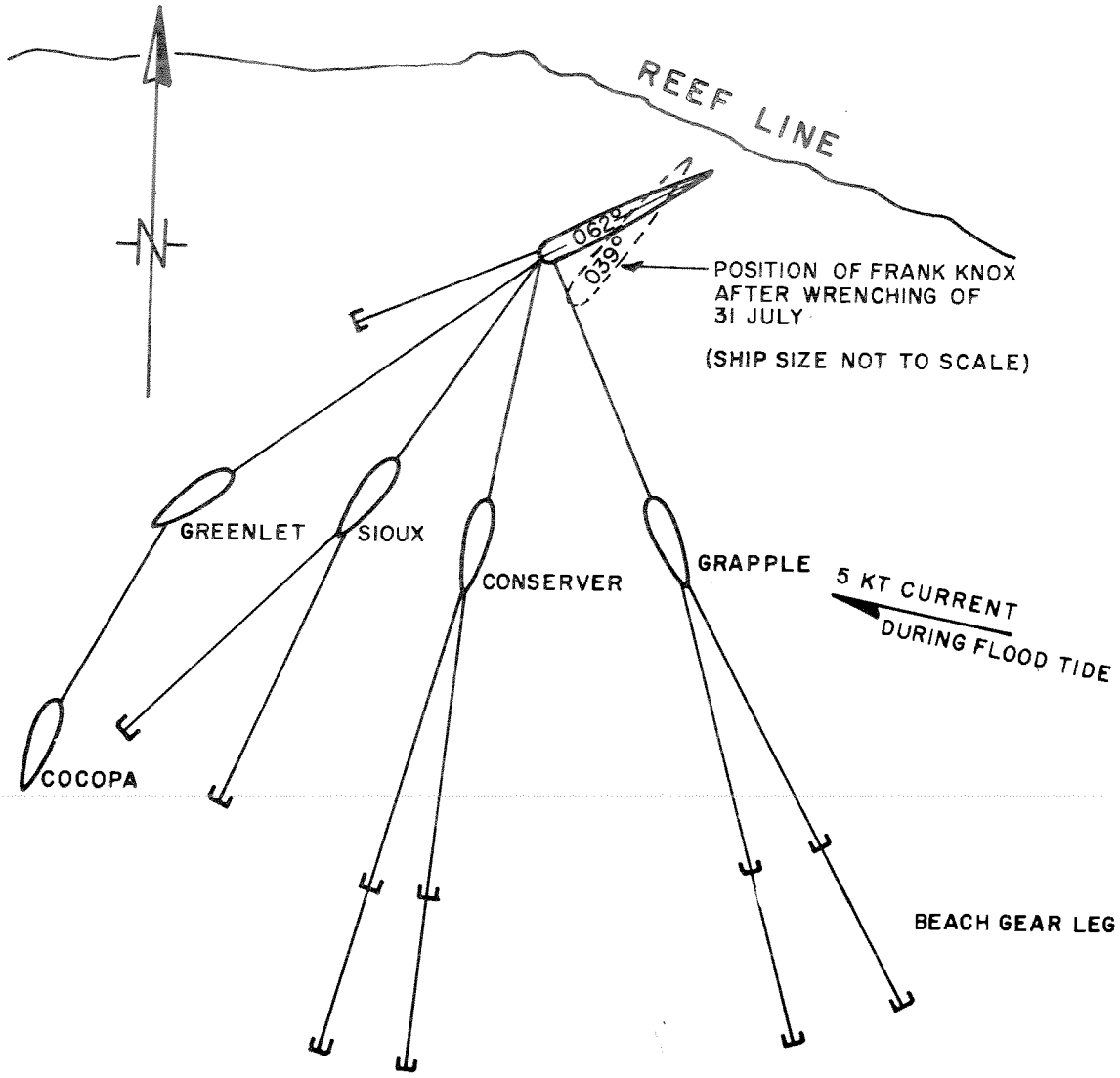
That night, as the current slackened, SIOUX's tow wire was passed to FRANK KNOX and secured, then CONSERVER's, and finally GRAPPLE's. This was an all-night task which was finally completed about 0800, 30 July.

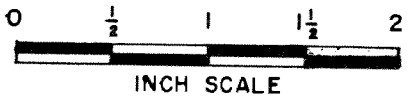
30 July, high tide: 4.0 feet at 0911. Seas slight. All tanks were blown, but the pumps only succeeded in lowering the water level in the forward engineering spaces four inches. Commenced heaving at 0830, but never achieved a good strain, as most anchors had not yet set. The effort was secured at about 1000 with no observable movement. (Subsequent divers's inspections showed that the ship had moved three feet aft.)

That afternoon was spent tuning pumps and beach gear fittings, and installing three of the seven large collision mats, which PRAIRIE had completed, under the engineering spaces. Divers were also able to wedge-up several cracks and splits under the engineering spaces, and were able to drive hardwood plugs in many of the empty rivet holes. COCOPA laid her single anchor set of beach gear to SIOUX. 30 July was also the day when the availability of a new salvage technique, cast-in-place foam, was first discussed. It was decided to be worth a try as backup in case the current high tides passed without success, especially in view of the obvious problems of pumping the engineering spaces, and the probable worsening condition of the bottom. Forty tons of the material, good for about 800 tons of buoyancy, were ordered by BUSHIPS along with technical assistance and the necessary support equipment required for its use.

On 30 July, divers reported that the top flange of the vertical keel had parted at frame 91, and that the web had also probably parted. This was of grave concern, but it was decided to proceed with the next day's effort since seas were relatively calm and additional collision mats were available for positioning after refloating, permitting substantial dewatering of the forward engineroom and fireroom.

31 July, high tide: 3.8 feet at 1002. Wind 12 knots; three-foot swells. GREENLET moved into position directly astern of FRANK KNOX and had passed her tow wire by 0800. COCOPA held GREENLET's bow in the usual strong lateral current. Heaving commenced at 0800 and continued until 1200. GREENLET heaved with engines only. All other beach gear anchors took a good strain but appeared to drag home slowly. CONSERVER's anchors were the worst offenders. GRAPPLE, CONSERVER, and SIOUX each used engines to supplement beach gear when anchors were not holding. (See Figure E, page 26 and Photograph 6, page 27 for relative position of ships and beach gear.)





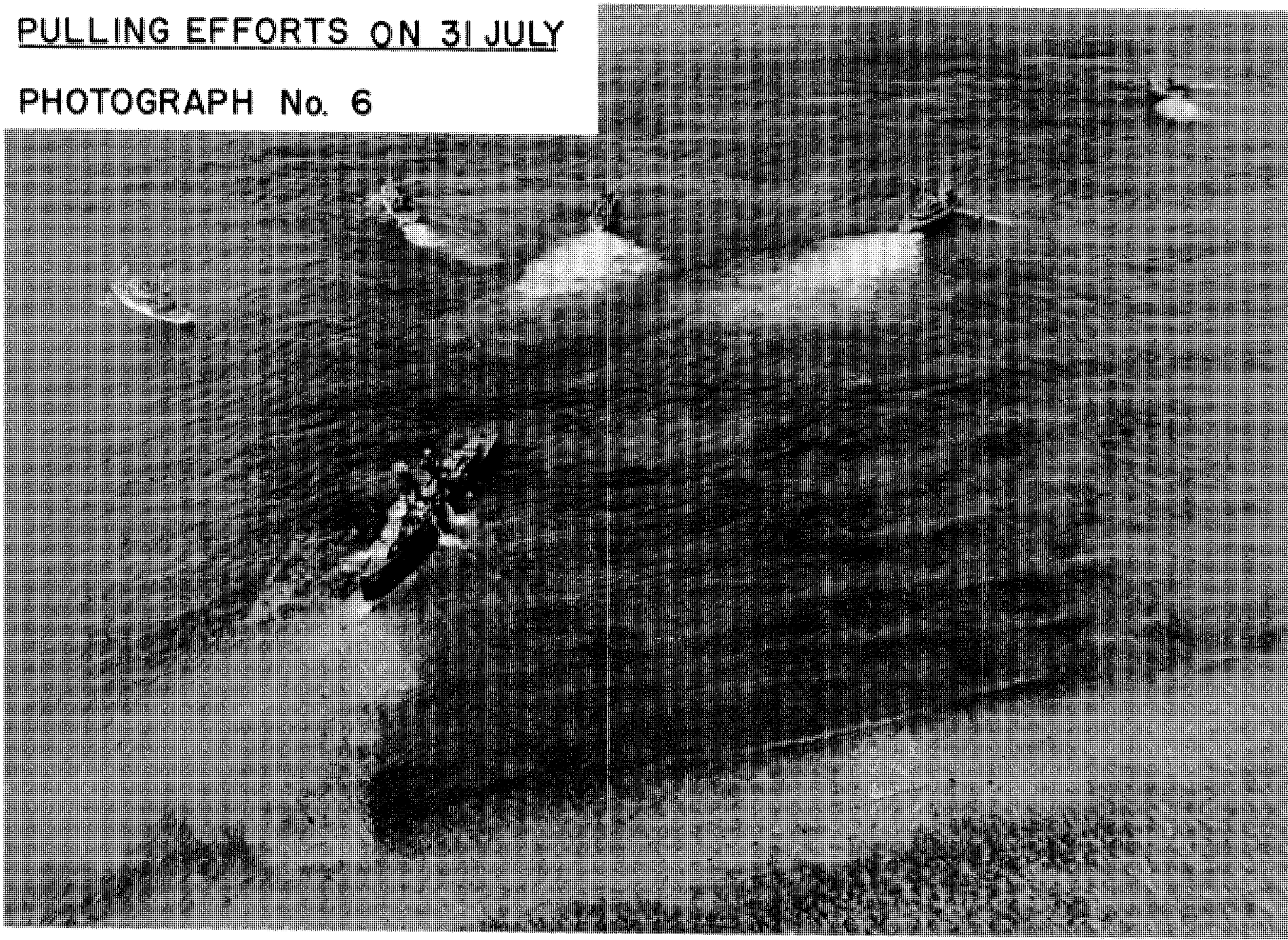
SCALE:
1. 1 INCH = 210 YARDS
2. SHIPS NOT TO SCALE

ARRANGEMENT OF SHIPS AND BEACH GEAR 30 JULY-2 AUGUST

FIGURE E

PULLING EFFORTS ON 31 JULY

PHOTOGRAPH No. 6



NOTE: In Photograph 6, page 27, note the general view of pulling effort on 31 July 1965. Shown clockwise from FRANK KNOX are USS GRAPPLE (ARS 7), USS CONSERVER (ARS 39), USS SIOUX (ATF 75), (each with two sets of beach gear), and USS GREENLET (ASR 10); GREENLET pulling with engines only. USS COCOPA (ATF 107) (shown at upper right) assisting GREENLET in holding her position in a 5-knot lateral current. (Note wash on port side of the two ARS produced by the current.) CONSERVER and SIOUX used main engines to supplement the pull on their beach gear anchors which were not holding well. This effort was successful in rotating the stern of FRANK KNOX into deeper water, which left the ship in a much better position. The original grounded position of the stricken ship can be seen about 75 feet to starboard of its present position. The ship had bounced laterally along the reef the night of 20 July during tropical storm "Gilda." It was at this time that the majority of the serious damage to FRANK KNOX occurred. The white area forward of FRANK KNOX is a deposit of fine coral sand which was ground by the action of the destroyer's hull pounding and working against the bottom.

FRANK KNOX's port engine was backed at maximum available RPM (112 was achieved since about two feet of each blade tip was missing). As usual, the beach gear anchor to FRANK KNOX's set held well until the 1 5/8-inch wire parted where it had chafed against a closed chock at the deck edge. Blowing of tanks was effective, but the pumps still made only 14 inches in the forward fireroom and seven inches in the forward engineroom.

The well coordinated effort with an estimated maximum strain on each of three tow wires, plus GREENLET's and COCOPA's engines, resulted in wrenching the ship around from a heading of 062° to 039° and moved the ship about six feet astern. This effort was successful in getting the stern to deeper water and the bottom of the after fireroom off the coral during all tides. At high tide, all of the forward engineroom and most of the forward fireroom were clear of the bottom. The grounded area appeared to be centered at about frame 45. (See Photograph 7, page 29. Arrow indicates approximate position of frame 45.)

The COMNAVPHIL Salvage Officer, CWO W.D. Thomas, USN, and two enlisted men arrived from SRF Subic the morning of 31 July. These men were to be of great assistance to the Salvage Officer as the task became too complex for one man to manage every detail.

AERIAL VIEW FOLLOWING WRENCHING AND SEAWARD MOVEMENT ON 31 JULY

PHOTOGRAPH No. 7

(LCDR Naylor, having arrived on 22 July, had since been assisting the Salvage Officer in many areas, particularly with respect to the diving work.)

IWO JIMA and TALLADEGA were detached at 1400 on 30 July. TALLADEGA's two LCM remained with PRAIRIE.

With hopes of being ready for a maximum pull on 1 August, COCOPA was provided one of the sets of beach gear received from Subic Bay. This set was laid to replace the port set on CONSERVER, which had dragged to a position such that the first anchor was only about 600 feet from the ARS. Sufficient wire was added to this shortened set and the bitter end was passed to FRANK KNOX where a set of falls was being rigged on the starboard side. The plate shackle at the end of the first 600-foot length of wire on FRANK KNOX's port quarter set of beach gear, which had failed, was known to be only about 100 feet from FRANK KNOX. Divers located this shackle, removed the failed wire from the plate shackle, and inserted a new wire in its place. This resulted in two sets of beach gear being aboard FRANK KNOX, which would be alternately hauled on by the anchor windlass capstan.

With excellent external diving conditions prevailing, divers continued their attempts to position the large collision mats and "water plug" concrete was tried on the ship. Divers had no success inside the ship with the water plug, since the water would flow in and out of the holes with the swell action, and the water plug would be washed away before it could set up. In an attempt to close or reduce the leakage through bulkhead 72, bags of water plug were piled against that bulkhead. Although this concrete did stay in place, it could not be fitted very well because of piping interferences. Divers made what appeared to be good progress external to the flooded engineering spaces.

NOTE: In Photograph 7, page 29, note an aerial view of FRANK KNOX following the successful wrenching of the stern to starboard and moderate movement to seaward on 31 July. The original grounded position was at the upper right; the position prior to wrenching was off the port side. The scar on the coral to port of mount 53 was caused by the propellers when the ship bounced along the reef during the storm of 20 July. The connections for the tow wires are madeup on the fantail. Clockwise, the wires are GRAPPLE's, CONSERVER's and SIOUX's (each with a 2 1/4-inch chain bridle passed around the base ring of mount 53), GREENLET's (with a two-inch wire bridle around mount 53), and the beach gear wire for the set being heaved on by the destroyer.

Discharges from the four 10-inch salvage pumps attempting to dewater the forward engine and firerooms are also visible.

A very large portion of the ship's bottom forward of frame 55 was aground and most of it was inaccessible to divers's inspections. What could be seen showed heavy damage with large areas being torn open. There was a good possibility that the ship was impaled in one or more locations.

It was soon apparent that the many projects proceeding would not permit a full-scale effort on 1 August. It was decided to wait for 2 August, with the expectation that the additional efforts would be more complete and would offset the 0.4-foot lower tide.

In order to lift the bow and decrease ground reaction, the following voids, storerooms and tanks were ballasted: C-311-V, C-312-V, C-9-F, C-10-F, C-11-F, C-12-F, C-301-A, and all spaces between frames 182 and 196 below the first platform.

2 August, high tide: 3.0 feet at 1140. Seas calm, wind slight. Pulled from 1000 to 1300 with two sets of beach gear each from GRAPPLE, CONSERVER, and SIOUX. Two sets plus port engine in use on FRANK KNOX. GREENLET was again used to the west of SIOUX and COCOPA was used to hold GREENLET's head and to provide a portion of the tandem pull. Blew the usual bubble on flooded tanks and spaces, but could only pump the forward fireroom nine inches down and forward engineroom 14 inches down. Both sets of beach gear on CONSERVER dragged. CONSERVER did get a heavy strain by using full power on her engines to compensate for the dragging anchors. (It must be pointed out that even though anchors were dragging, they still took a considerable strain.) GRAPPLE's port set held well; her starboard set dragged. GRAPPLE also used engines but not to full power. One SIOUX set dragged badly, the other held occasionally. SIOUX also used maximum engine power. Both sets to FRANK KNOX held a heavy strain.

The grounded ship moved only four feet during the effort. A recapitulation of the weight statement, allowing for actual conditions in the flooded engineroom and fireroom, showed that the ship was 600 tons aground for the effort. With an estimated 400-ton effective pull astern, it was felt that the ship should have been refloated unless it was impaled.

5. FOURTH PHASE, 3-24 August

Tides after 2 August continued to fall (see Tide Table in Appendix 7.3.). The next 3.0 foot tide would be on 8 August; 12 August had a 3.4 foot tide from whence they fell again. The next good tides started with a 3.0 foot tide on 22 August with tides increasing until 26 and 27 August, with 3.8 foot tides. The plan was to work toward the mid-month tides with the most optimistic estimate for another effort being 11 August. This new plan basically involved rerigging all beach gear to FRANK KNOX and selected dewatering flooded spaces with foam.

Response was rapid on the task of providing foam; preparation of materials was immediately commenced; shipment was made within 72 hours. The material was air-shipped to Subic Bay, arriving on 3 August, and loaded in POINT DEFIANCE along with the following additional gear:

- an LCU with a 10-ton crawler crane embarked
- two beach gear winches
- four 10-inch pumps
- 600 feet of large "I" beams
- two 600 CFM blowers
- one 315 CFM construction-type air compressor

plus all necessary fittings, accessories, and associate equipment. One representative of Merrit Chapman and Scott, the prime contractor, and two representatives of Murphy Pacific, the sub-contractor for the foam operation, arrived on the scene by amphibian aircraft on 3 August. The remaining three Murphy Pacific personnel remained behind in Subic Bay to supervise the loading of the gear and material in POINT DEFIANCE.

The condition of FRANK KNOX at this time was as follows:

1. All bottom compartments were essentially open to the sea forward of frame 110A except A-1-W, A-501-W and A-502-A. Although questionable, but because their tank tops were below the waterline, A-507-F, A-509-F and B-9 1/2-F were dewatered by blowing the sluice valves connected to their respective center tanks and open to assure an exit for the water.

2. Number 4 boiler was steaming and the after turbo-generator was on the line. The forward emergency diesel was providing power forward. Feedwater consumption was high, but the helicopter lift and, subsequently, transfer by boat in good weather, kept ahead of consumption.

3. Noon and evening meals were being provided by PRAIRIE and MARS by helicopter or boat.

4. The ship's bottom was deformed from frame 130 forward, with major damage extending forward of frame 97. The keel forward of frame 18 was intact. The bottom from frame 25 to 60 was suspected of being flattened or pushed in, but this area was not visible. The area around the sonar dome, frames 24-30 was wide open with the remains of the dome being pushed up into A-503-A through the hole. It was thought that dome remains, some of which were also extending outward about three feet to starboard,would be a problem, but eventual impalement as the ship was pulled astern remained a possibility.

5. The ship was running low of fuel. This was partially alleviated by GRAPPLE pumping several thousand gallons of diesel fuel to FRANK KNOX through firehose prior to leaving her moor on 3 August. To conserve fuel, the boiler was secured at this point and relighted only for pulling operations. This action also reduced the number of personnel that had to remain on board. The forward and after emergency diesel generators provided the necessary power.

6. Two sets of beach gear were rigged to FRANK KNOX; GRAPPLE, CONSERVER, and SIOUX each had two sets out with their tow wires to the stranded destroyer.

7. Salvage personnel and the FRANK KNOX caretaker crew were on board; working parties from PRAIRIE and other ships augmented the crew as necessary.

5.1. RERIGGING OF BEACH GEAR

It was decided to rig the majority of beach gear to the stranded ship, based on the following rationale:

1. Tandem anchor sets rigged to the salvage ships repeatedly dragged after being once set. This was, of course, partially due to the nature of the hard coral bottom, but was also due to the continued working of the pulling ships that pitched badly during the often rough weather, and were forced from side-to-side by the lateral current which, at times, reached an estimated 8 knots. These factors created a wrenching action that would tend to break the anchors loose from whatever bottom obstruction they had found.

2. The pulling ships themselves were being hazarded and could embarrass the adjacent ships at any time if their anchors dragged. Twice it had been necessary to release GRAPPLE under emergency conditions. There was no guarantee that, once in a good moor, a pulling ship would still be available in the same moor four or five days hence.

3. Pulling from FRANK KNOX would eliminate the continued wrenching and jerking action on the Eells anchors. The anchors would be in shallower water, since approximately 1000 feet of tow wire would be eliminated between the anchors and the destroyer.

4. The long-time reliability of the original beach gear anchor laid to FRANK KNOX and the recent good experience with the previously dragging tandem anchor set, which had been passed from CONSERVER to FRANK KNOX, tended to confirm the above reasoning.

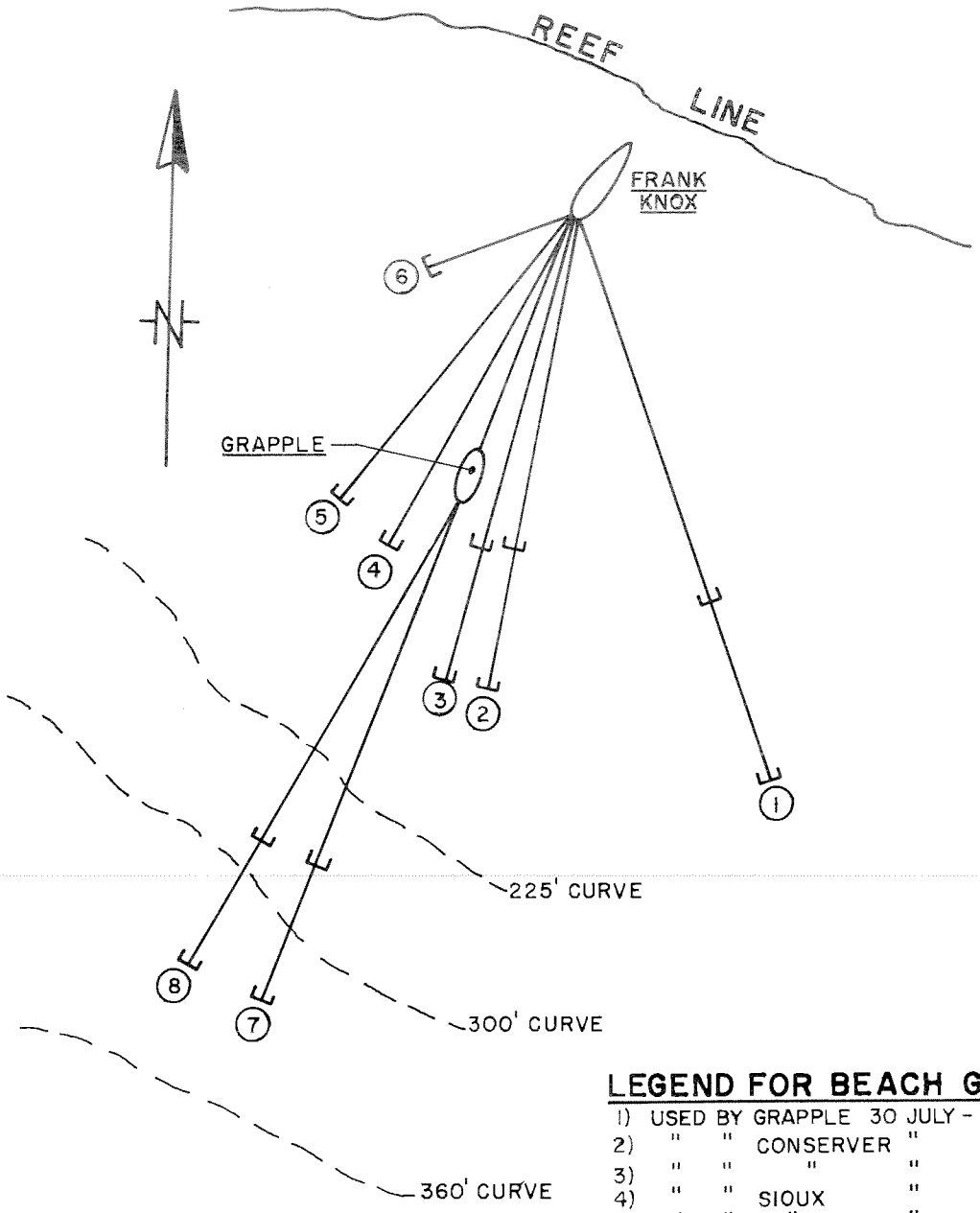
5. Rigging the beach gear to FRANK KNOX ensured availability of good holding power should a storm require the smaller ships to clear the area. In addition, gear laid to FRANK KNOX could be tightened at anytime and be ready for all eventualities.

With two beach gear winches on the way, and one on board each ARS, six sets of beach gear were decided on as the number that could be handled aboard the destroyer. The principal bottleneck was deck space for the beach gear falls.

On 3 August, SIOUX lengthened and passed the bitter ends on her two sets of gear to FRANK KNOX. When this was completed, SIOUX tripped out of her beach gear, but fouled her screw in a crown wire to one of the sets of CONSERVER's gear.

WELDING PLATES WITH PADEYES AT FRAME 112 STBD FOR HOLDING STANDING BEACH GEAR BLOCKS

PHOTOGRAPH No. 8



LEGEND FOR BEACH GEAR SOURCE

1) USED BY GRAPPLE 30 JULY - 2 AUG
2) " " CONSERVER " "
3) " " " " "
4) " " SIOUX " "
5) " " " " "
6) ORIGINAL SET LAYED ON 19 JULY
7) 2400' SET TO GRAPPLE
8) 2400' SET TO GRAPPLE
(THIS SET FAILED AND WAS REPLACED BY ANOTHER LONG, SINGLE ANCHOR SET ON 12 AUG)

NOTES:

A. SCALE: NONE
B. GRAPPLE NOT USED ON 11 AUGUST

ARRANGEMENT OF BEACH GEAR
11-24 AUGUST

FIGURE F

With the seas again becoming rough, the wire was cutoff with explosives, but two days of efforts by divers failed to clear the screw. Finally, SIOUX was towed to Kaohsiung by COCOPA on 6 August, since neither ship was of any further direct use to the operation; one without propulsion, and the other without a tow wire.

CONSERVER lengthened and passed her second tandem anchor set to FRANK KNOX and tripped out on 4 August. GRAPPLE passed her better tandem anchor set (starboard), and also tripped out on 4 August, after providing 20,000 gallons of diesel fuel to FRANK KNOX by firehose. This action resulted in six sets of beach gear aboard the destroyer. PRAIRIE fabricated two large heavy plates, each with two padeyes for standing blocks, which were welded to the main deck, port and starboard, at frame 112 (see Photograph 8, page 35). The LCU that had arrived with POINT DEFIANCE late 4 August, made it alongside FRANK KNOX on 5 August, and the two beach gear winches were lifted to the boat deck, frame 110F. One winch was positioned on each side at the after extremity of the boat deck outboard extension, so that they could pull in a direct line with the falls on the main deck. Space was cramped, and sea conditions did not permit boating, even for the LCU, on 6 August, so it was decided to use only two winches.

NOTE: In Photograph 8, page 35, note welders from USS PRAIRIE (AD 15) welding a heavy plate with two padeyes for the standing beach gear blocks at frame 112, starboard side, on FRANK KNOX. These men also welded two heavy "T" stiffeners along each side (port and starboard, frame 72 to 130) to strengthen the hull. An LCU with a crane embarked is alongside to starboard. This craft, with its crane, proved very valuable from its arrival on 4 August until the salvage operation was completed on 24 August.

It was also decided not to attempt to pull on beach gear with the winch gypsies because of their poor control (they will not stop unless the engine stops), and the danger of getting riding turns on the gypsy. Instead, one set of falls was used to heave on two sets of 1 5/8-inch wires by shifting the moving block and stopper from wire-to-wire. The third set on each side was heaved on by the anchor windlass capstan. This scheme worked satisfactorily and by 7 August all six sets of beach gear were tight on relative bearings of 122, 151, 156, 171, 181, and 211 degrees (see Figure F, page 36).

5.2. USE OF FOAM

It was soon realized that the amount of foam material initially ordered was insufficient to completely foam both the forward engineroom and fireroom; the above waterline airspace, in addition to the volume of flooded space in both compartments, presented a total volume too great to be filled with the foam material available on board. If a method to hold the foam down from the present waterline could be developed, the flood water would be displaced with the amount of foam materials available; there would be no need to foam the air void above the waterline. Furthermore, there appeared to be a good chance of patching the engineroom, with its lesser amount of damage, tight enough to permit substantial dewatering by pumping. It was decided to foam strategic forward tanks first, as a trial, and then proceed to the fireroom. After foaming the fireroom, the remaining foam, if any, would be expended in flooded compartments forward which had been only partially dewatered by air.

The seas began to pick up starting on 3 August. The LCU, having arrived late on the 4th, managed to get alongside on 5 August. While alongside, the LCU transferred two beach gear winches, 150 bottles of nitrogen for the foaming operation, "I" beams for the stiffening of the starboard stringer plate, shoring material, and other much needed supplies. The remainder of the foam materials and equipment was in two LCM-8's which found it too rough to get alongside. It was too rough even for the LCU to come alongside the next day.

As long as the nitrogen was aboard, the foam could be mixed and placed in the pressure tanks aboard POINT DEFIANCE, with the tanks being lifted by helicopter to FRANK KNOX. The first space foamed on 6 August was A-504-A, since it was hoped that the foam would slow or stop the leakage into the reefer area; this leakage had been steadily increasing, but was still within the capacity of the six-inch submersible pump installed in that space.

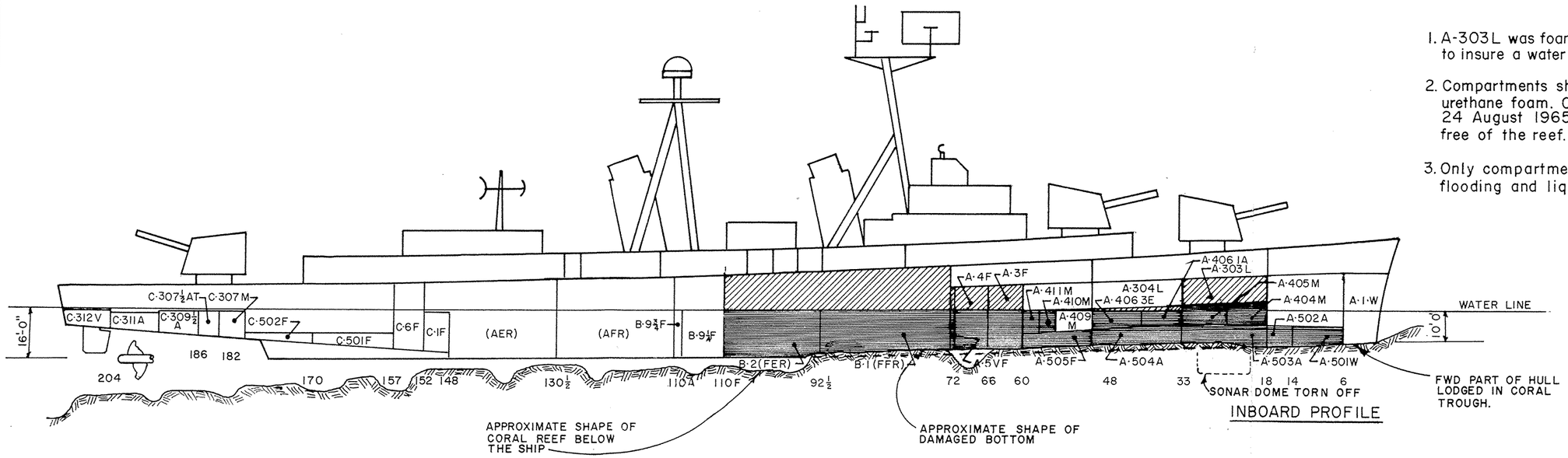
NOTE: In Figure G, page 39, note all spaces that were eventually foamed.

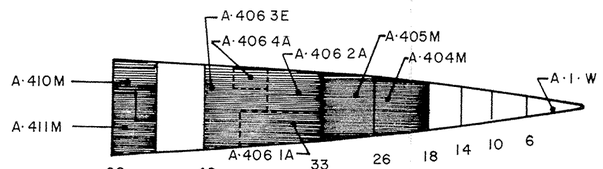
Divers had attempted to gain access to the flooded magazines, A-410-M and A-411-M with the intention of installing a mattress patch over the cracks in the deck to hold foam within the tanks below. This again failed, so these two magazines were also foamed followed by A-505-F and A-506-F below the magazines. This work also completed on 6 August, and the leakage into A-409-M and the reefer machinery room was greatly reduced.

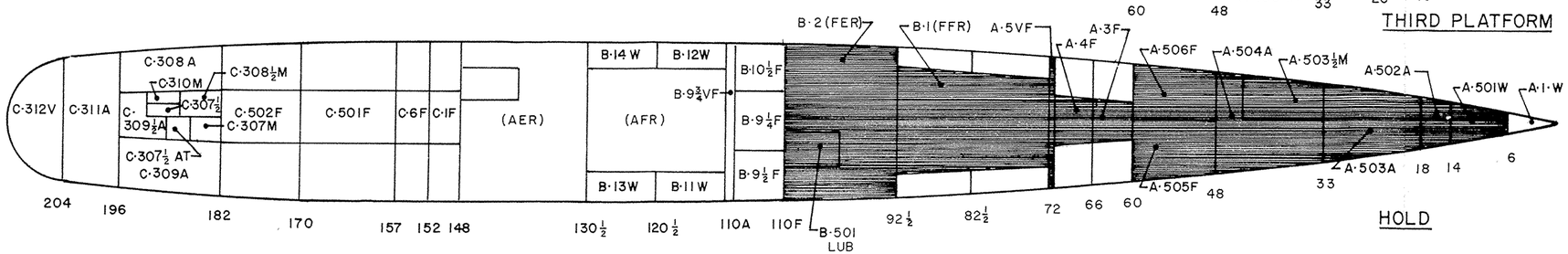
The general procedure used was to drill 1 1/8-inch holes in the deck into which the foam gun barrel was inserted. Foam accumulated from the top downward. The point at which foaming a space was completeted was somewhat indeterminate, but a fair gauge was the amount of foam expended.

NOTES

1. A-303L was foamed as a damage control measure to insure a water seal from A-405M & A-404M.
2. Compartments shown shaded were filled with urethane foam. Condition shown was as of 24 August 1965 prior to time ship was pulled free of the reef.
3. Only compartments and details relative to flooding and liquid loading are shown.







LEGEND:

- Foam used for water displacement.
- Foam cast in air. Used to brace under water foam.

CAST-IN-PLACE FOAM IN USS FRANK KNOX (DDR 742)

SCALE: NONE

FIGURE G

In shallow spaces like these, a probe was finally used to determine whether the foam extended to the bottom. This only tested the area under the hole, but the method was considered to be satisfactory.

In order to conserve foam, consideration was given to possible methods of containing the foam in the fireroom at the waterline. After considering several alternatives the following scheme appeared to have the best chance for success: a blanket of foam about two feet thick would be laid on top of the water; within a few minutes the foam would harden and would easily support men walking on it. A 3/4-inch plywood cover would then be laid over the foam and appropriately shored to the overhead. Foaming below the blanket could then proceed, thus saving some 10 tons (25%) of the foam. The false deck and its supporting system was designed based on a loading of 1000 pounds per square foot (corresponding to a 16-foot head). The system of strongbacks, wales, and shores required, turned out to be very extensive and quite elaborate; for instance, some sixty 6 x 6 shores to the overhead would be needed.

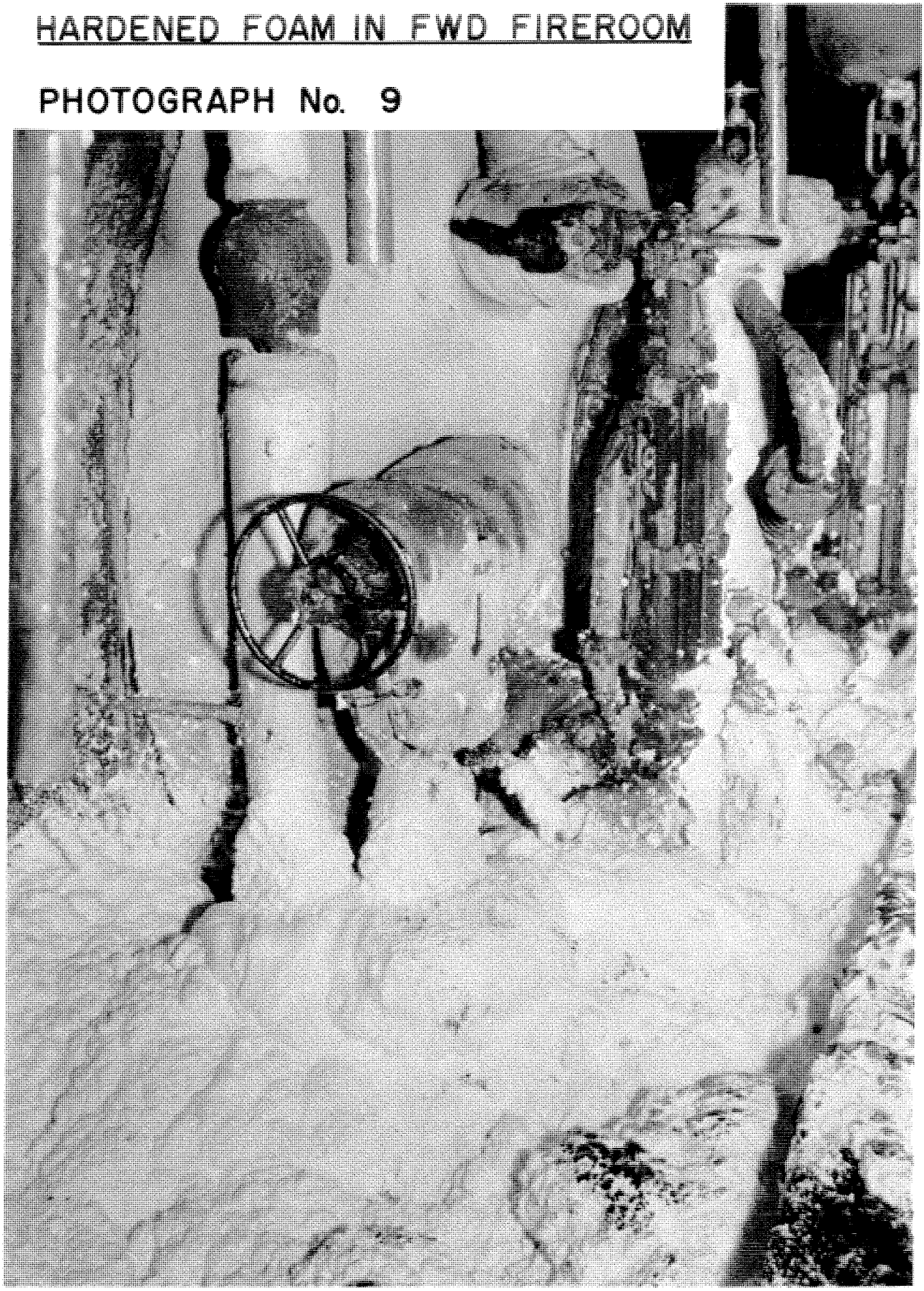
The foam does have some shear strength (reported to be 28 psi), so it was not necessary that every square inch of the foam blanket be covered with plywood. The foam blanket would flow into all nooks and crannies and would provide its own seal when set up. Nevertheless, in order to simplify the laying of the false deck, a working party entered the fireroom, and using hand tools, removed every possible interference that could be removed from the upper level to three feet above that level. (At high tide, the water level was about one foot above the upper level deck plates.) Items removed were handrails, vent ducts, steaming lockers, smoke periscopes, gauge lines, pipe hangers, tool boxes, etc.

The LCU succeeded in getting alongside FRANK KNOX again on 8 August and transferred foam material and gear to the destroyer where the complete charging and mixing operation was set up.

The foam blanket was laid on the water surface of the forward fireroom on the morning of 9 August. Inspection of the blanket revealed a rough, lumpy surface with several holidays where the foam was only a few inches thick. Most importantly, the foam rose and fell with the tide rather than locking itself into the many obstructions present, as had been expected. While the holidays could have been filled, and the high areas cutoff with saws or hatchets, the free floating characteristic meant that shoring would be extremely difficult, and obtaining an equalized load among shores impractical. The false deck idea was abandoned, and foaming of the entire fireroom proceeded immediately.

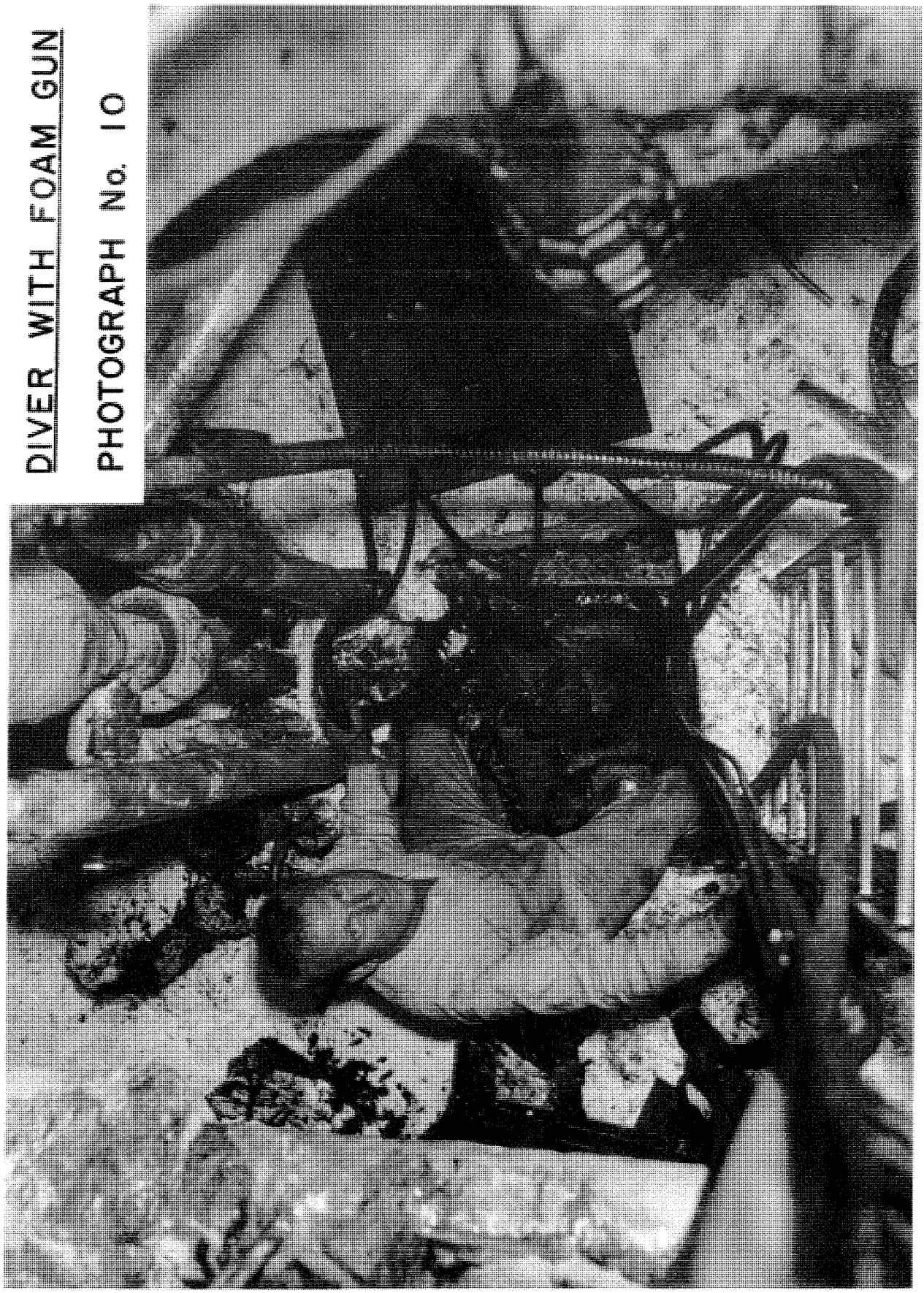
HARDENED FOAM IN FWD FIREROOM

PHOTOGRAPH No. 9



DIVER WITH FOAM GUN

PHOTOGRAPH No. 10



NOTE: In Photograph 9, page 41, note the view from starboard in forward fireroom aboard FRANK KNOX showing hardened foam built up around steam drum of number 2 boiler. Note handrails and hangers that had been cutoff to reduce obstructions to laying a plywood deck over the foam. This decking scheme was later abandoned.

An important consideration in abandoning the foam blanket scheme was the risk involved. If the false deck should carry away after refloating, the amount of water in the space would increase greatly as would the hull girder stresses. It was considered that the insurance factor of foaming the air space justified the additional use of foam.

While the air space of the fireroom was being foamed, divers foamed the firesides and air casings of the boilers. A cofferdam was installed extending down to about three feet from the lower level deck plates. After completion of the air space and the boilers, this cofferdam permitted divers to foam under the waterline to about the six-foot waterline, after which, the foaming continued from outside the bottom through holes in the shell. (See Photograph 10, page 42.) Foaming the fireroom proceeded on a 24-hour basis, using GREENLET divers, and was essentially completed on 11 August.

NOTE: In Photograph 10, page 42, note a diver descending into the flooded space of forward fireroom, FRANK KNOX, with a foam gun, to foam the large areas inside the boilers. The diver's tender shown here will don an airline mask prior to commencing foaming because of the fumes generated during actual operations which tend to irritate the lungs and cause spasmodic coughing.

5.3. STIFFENING OF THE HULL

The observed conditions of the ship's structure were reported regularly. As early as 24 July, BUSHIPS reported that there was a strong possibility the ship might break in half after extraction, in view of the weakened bottom and the possibility of a large amount of weight in the forward engineering spaces. It was estimated that the ship would probably part at frame 90, and that the forward section would be unstable and end-up floating like a cork with its bow up. The after-half would be stable and would float with drafts of 20 feet at frame 110A and 12 to 13 feet aft. The after-half would probably remain intact as long as bulkheads 110 forward and 110 aft remained sound. It was recommended that bulkhead 110 aft be shored; this had been done on 27 July. There was, however, a strong likelihood that bulkhead 110-F would fail where the starboard shaft went through; particularly if the reduction gear and turbine on this shaft were not supported adequately after the hull broke.

The Bureau's estimates were based on the assumption that the vertical keel and six feet of bottom plating on either side of the keel near frame 90 were ineffective. The best information available on the scene, however, was that the keel was sound, and the plating in question would be about 90% effective in tension. In addition, it was originally assumed that the flooded engineering spaces would be essentially dewatered. The Bureau also recommended that the sheer and stringer strakes be stiffened to provide additional hull stiffening. This was not immediately done because of the lack of material and a generally optimistic estimate of the ship's condition. These estimates were supported by observations of the action of the ship's hull in heavy stern seas. The observed hull flexing was as follows: a maximum of about a six-inch vertical flexure over a 110-foot span between frames 85 and 140, and the expansion joint at frame 95-1/2 on the 01 level worked forward and aft about 1/4-inch. These observed movements did not appear to be excessive for a destroyer.

On 31 July, however, divers reported that the top flange of the vertical keel had failed at frame 91-1/4, and that the web had probably also failed. In addition, a slight dishing of the sheer strakes was noted at frame 107, port and starboard. It was not certain whether this was new deformation. Definite plans to stiffen the hull were made at this time, and the required material was requested from Subic Bay for delivery by POINT DEFIANCE.

Divers subsequently found that they had been in error in reporting that the keel had failed at frame 91-1/4. The failure was actually in one of the adjacent longitudinals.

While the keel was still apparently intact, plans for stiffening the hull girder proceeded. These plans called for a stiffening between frames 72 and 130, with a 12-inch beam being welded to the stringer strake between the deck edge and the first deck longitudinal and a 10-inch beam between the first and second deck longitudinals. The purpose was to reduce the unsupported panel span of the deck plating, the principal strength member, to ensure that the stringer strake did not fail by buckling. Any additional strength from the beams would be minor. It was also intended to add beams to the sheer strake, time permitting.

Six welding machines from the ARS's and ATF's were lifted, by helicopter, aboard FRANK KNOX on 5 and 6 August. While the LCU was alongside on 5 August, enough steel for the two starboard side deck stiffeners was off-loaded. (It was too rough for the LCU to make the port side at the time, but the amount of steel was ample to keep all available welders busy. The port side stiffeners were to have been off-loaded the following day, weather permitting.)

The seas continued to get rougher, from the east; welding of the stiffeners on the starboard side was precluded by the waves, which regularly deposited salt water in the areas concerned. Since it was impossible to bring the LCU alongside FRANK KNOX, the beams were manhandled to the port side where the deck was generally dry and welding of the stiffeners by PRAIRIE personnel proceeded on 6 August, and continued on a 24-hour basis. The LCU was again able to come alongside on 8 August, at which time the required additional steel was placed aboard.

During the early process of foaming, it had been discovered that the foam which was produced in air would burn. Foaming strategic areas of the forward fireroom was, therefore, delayed while welders concentrated on the frame 72 to 92-1/2 portions of all four deck stiffeners, so there would not be any foam in contact with the underside of the deck and, also, so that access for fire-watch purposes was maintained.

Many difficulties were experienced in the stiffener welding program: welding machines developed many problems; it was necessary to make "Tee" (T) beams by cutting off one flange of the wide flange beams in order to obtain a satisfactory fit; and there were many obstructions, i.e., 10-inch pumps, davits, and mooring bitts. The welding of the Tee beams on deck was finally completed on 10 August. Welding of stiffeners on the sheer strake was still not possible because of rough sea conditions. It was finally decided not to add these stiffeners even if weather eventually permitted, because interference with boating would result, and because of the possibility of foam in the engineering spaces being a fire hazard.

Foaming of these spaces could not be delayed with the tenuous hope that seas would abate long enough to permit welding of the sheer strake stiffeners. The overall strategy of the hull stiffening was to do everything that could be done, time and weather permitting, but not to delay an extraction effort when otherwise ready, just to complete additional stiffening work. It was decided that the risks of suffering additional, and perhaps mortal damage by remaining on the reef during the most active typhoon season, outweighed the risks that the ship might breakup after extraction. After extraction, of course, it was intended to do everything possible to reduce heavy hogging or sagging loads by ballasting or deballasting.

5.4. ATTEMPTS TO DEWATER THE FORWARD ENGINEROOM

When it was realized that there was insufficient foam available in the first batch ordered to completely fill both of the forward engineering spaces, the decision to foam the fireroom first was made, based on the following:

1. Dewatering the fireroom would have a more favorable effect on reducing the ground reaction forward.

2. Containment of foam, if feasable, would be much easier in the fireroom because the boilers effectively divided the compartment into several small areas, whereas the engine-room presented one large area.

3. There was an excellent possibility that the engine-room could be successfully dewatered using pumps. Divers's inspections had revealed that the actual holes in the engine-room bottom were not too extensive and were generally accessible to divers.

The prinicpal problem in dewatering the forward engineroom was its forward bulkhead (92-1/2), which was extensively crushed and presented an extremely difficult patching problem. It was not expected that foaming of the fireroom would have much, if any, effect on leakage through this bulkhead. Access to the bulkhead damage from the engineroom side was precluded by many piping and structural interferences. It was decided to apply patches to the bulkhead from the fireroom side.

Bulkhead 92-1/2 had cracks, tears and holes up to 2 feet x 2 feet between and around the vertical keel and the first two longitudinals on each side. The damage was most irregular, and complicated by unfairness of the surface, caused by the buckling and crushing of the panels. There was also very little access on this side, but divers managed to wedge cracks and tears and to fit plates against the larger leaks.

While pumps maintained a continuous suction in the engineroom, oakum, rags and mattress stuffing were packed around the plates. It was impossible to firmly fix the patches in place because of interferences, which made it necessary to rely on maintenance of a constant head in the engineroom to ensure that the patches remained in place. After patching the bulkhead as well as possible, pumps were able to lower the water level in the engineroom by 30 inches. It was expected that continued work on the bottom would further reduce leakage, and that at least half of the water (about 200 tons) could be pumped from the engineroom.

All progress was lost on 9 August. One 10-inch pump was down for repairs when the second 10-inch pump burst into flames. It turned out that the soldered gas line pulled out of the fuel tank allowing gasoline to fall on the exhaust manifold. The resulting fire burned fiercely for about 15 minutes until it was finally extinguished by fire-fighting foam. The pump was ruined, and the differential head that had been holding the engineroom patches in place was lost. Although the pump was replaced by another machine, it was then impossible to gain access to the fireroom side of bulkhead 92-1/2 because the foaming of that space had long since been commenced. Much diving effort was expended on the patches from the engineroom side of the bulkhead, but no significant progress was made. It was then decided to foam the entire forward engineroom using additional foam which had been requested on 4 August and was, by then, on the way.

5.5. CORAL BLASTING

Large-scale use of explosives to excavate a channel in the coral bottom at Pratas Reef was not required; the general bottom contour sloped seaward in the area of interest. After the successful wrenching action of 31 July, the ship was everywhere free of the bottom aft of the forward engineroom, without any obstructions present to cause interference when the ship could be pulled to seaward. On 1 August, use of Mark-8 hose charges (25-foot flexible line charge containing 50 pounds of explosives) was suggested in order to provide a jarring action, which might knock loose impalements, and/or for digging a trench into which the ship could be wrenched. The trenching was thought by some to be practical for laying successive hose charges in the previous crater, resulting in a trench of ever-increasing size. This procedure was not considered to be practicable by the on-scene personnel, because the coral was extremely hard and was not expected to be susceptable to the blasting by hose charges without tamping. Use of powder points (holes drilled into the coral with pneumatic jack hammers, and packed with plastic explosives) was thought to be much more effective in the type of bottom involved. This procedure was also originally rejected because it required a larger, reliable air source than was available; it was dependent on good diving conditions, and would be a long-time project which would dilute other necessary efforts.

On 9 August, the sea conditions abated for the first time in several days allowing a good diver's inspection. It was found that the bow of the ship had entrenched itself in the coral to a depth of about five feet below the surrounding area. This finely shaped portion of the hull had retained its shape forward of frame 18, but the bottom was badly crushed aft from about frame 20 to 60. Most of this area was not visible except at the sonar dome, where it could be seen that there would be an interference of about four feet between the coral and the intact keel forward of frame 18. There was, however, one of the previously described natural trenches in the coral that ran from the sonar dome area aft. The trench was about six feet to starboard of the keel at the shallow end and ran straight to sea at an angle of about 20 degrees from the ship's heading. The trench had vertical sides two to three feet deep, and was about four feet wide; it offered a ready-made channel capable of reducing the interference caused by the intact forward portion of the ship's keel. If the ship could be wrenched further over as it was pulled aft, and the trench extended forward to join with the existing trench formed by the bow, the extraction of the ship would be greatly facilitated. The intervening "dam" was about 10 feet long. A close check of the wrenching possibility showed that the coral bottom sloped gently up to a crest of six to twelve inches above the general bottom contour at the edge of the trench.

It was decided to lay a Mark-8 hose charge in the trench against its side wall closest to the ship. At the forward end, the charge curved outboard around the forward end of the trench in a hook shape. It was hoped that the wall of the trench would be disrupted enough to permit the placing of subsequent charges until the slight crest was knocked down and the dam at the head of the trench was "unplugged." The hose was nowhere closer to the hull than three feet, a distance which was reported to be more than sufficient to preclude hull damage. Nevertheless, all hands were cleared from the forward half of the ship when the charge was set off on 9 August.

The resulting explosion caused a disheartening amount of damage in the frame 18-33 area. The starboard side shell plating and longitudinals were pushed in about three feet from the original shape with damage extending up to about the 15-foot waterline (see Photograph 11, page 58). A large jagged hole about 12 feet long was opened up to about the four-foot waterline; the third platform was pushed up about three feet on the starboard side causing complete flooding of the previously dry magazines A-404-M and A-405-M; the second platform deck had numerous splits and holes in it, leaving A-303-L open to the sea; even the first platform was damaged where the five-inch dredger hoist was pushed up through the deck. In addition, the leakage through the third platform into the reefer area, which had previously been reduced to a trickle by the foaming of A-504-A, commenced again. The lost buoyancy was partially regained by the eventual foaming of A-303-L, A-404-M, A-405-M and the entire reefer area including the reefer boxes. However, foaming of the two magazines was only partially successful because of the action of the waves through the large opening in the hull, and much of the foam (apparently of poor quality) was washed out during subsequent heavy seas.

The operation was not an entire failure, however. It was found that the hose charge did a good job of shattering the coral forming the trench wall. The forward end of the trench was also lengthened extensively, but did not completely extend to the intact keel at frame 18; a powder point was drilled using a rock drill (jack hammer) and packed with 4-1/2 pounds of C-3 plastic explosive. The resulting shot effectively extended the forward end of the trench. While coral rubble prevented exact measurements, it appeared that the resistance caused by the intact keel section (forward of frame 18) had been substantially reduced by the shot.

The damage caused by the Mark-8 charge proscribed further use of that type explosive close to the ship. It was decided to continue with powder points. There were several additional coral trenches adjacent to the ship; these were deeper than the first trench (up to five feet), and extended well under the ship at the usual angle of about 20 degrees with the keel.

Two trenches passed under the deck edge at about frames 55 and 85. It was decided to drill powder points horizontal into the walls of these trenches with the intent of further reducing actual high points and areas which might develop into problems as the ship was further wrenched and pulled astern.

On 10 and 11 August, seven powder points were drilled in the two trenches of interest. These powder points were everywhere separated from the shell plating by at least three feet. However, they were directly under the hull, generally in the area of the "C" strake, starboard side and spread from frames 50 to 80. The first charge of one-half pound C-3 was set off as a trial and was found to produce only a sharp jar on the hull; the charge successfully shattered the coral. The remaining powder points were packed with 1/4 to 1/3 pound charges and set off with excellent results. It was decided to continue with the program of coral blasting; however, since drilling the powder points was a very slow process because of the inadequate air supply then available, the program proceeded by placing small charges in indentations on the coral. Charges were often set in the craters made by previous charges. The general procedure was to place about six different charges all rigged for shooting. They were then set off one-at-a-time from aboard the destroyer. On a good day, as many as 25 charges were set off.

As the blasting progressed, several locations were uncovered where the hull was impaled by damaged shell plating digging into the coral. All locations found were cleared.

On 12 August, during a pull effort, a Mark-8 hose charge was set off 30 feet to port between frames 18 and 33 at high tide. No results or damage were noted. This action was repeated again on 13 August, except with a reduced stand-off distance of 15 feet; again, no results, but some minor dishing of shell plating panels was noted. No further use of the Mark-8 hose was made.

NOTE: As a matter of interest, the above two hose charges were simply laid on the coral bottom and had so little effect on the coral that divers had difficulty in locating the original positions of the charges after they had been fired.

In conjunction with primary salvage evolutions, the selective blasting program continued until 24 August. In addition to the three Mark-8 hoses and 4-1/2 pounds of powder point, previously described, 142 small charges of one-half pound or less were fired. This program is evaluated as having been very successful in removing impalements.

5.6. ADDITIONAL PREPARATIONS

Lightening of the ship commenced on 2 August, and except for several interruptions when boating was impossible, continued until the ship was refloated. Approximately 184 tons of gear, provisions and equipment were removed; this included ammunition, hedgehog mounts, torpedo tubes, electronic equipment, spare parts, barrels from mounts 51 and 52, stores and provisions, and many other pieces of equipage that were readily removable.

Once the six sets of beach gear were ready for pulling from aboard FRANK KNOX, the general strategy was to attempt to extract the destroyer when the foaming was essentially complete and tides were favorable, or when heavy seas were available to assist, whichever came first. The coral blasting program was to continue until the ship was afloat.

5.7. EXTRACTION EFFORTS 11-13 August

On 8 August, the Bureau of Ships provided data concerning the optimum scope of wire and chain for using beach gear in very deep water. Where the water depth was 50 fathoms, the desired ground leg included 1800 feet of wire and four shots of 2 1/4-inch chain. There was not sufficient chain available, so it was decided to make-up two sets for GRAPPLE, each of the following composition: Eells anchor, two shots of chain, 600 feet of wire, another Eells anchor, and 1800 feet of wire. The inboard anchor was not intended for holding power but to add catenary to the system. Six hundred feet of wire was used outboard of the inner anchor to facilitate recovery.

On 10 August, GRAPPLE laid the first of the two long sets of beach gear. The recovery wire on the inboard end, however, became fouled in her screw and by the time the wire was cleared, it was too late to lay the second set prior to high tide on 11 August.

By 10 August, the majority of the foam that was received in the first batch ordered had been expended; the foaming of the forward fireroom was complete down to about the three-foot waterline, and further progress was slow, since all foaming had to be through the bottom from the outside using any holes that could be located. Additional holes were drilled through the bottom to facilitate foaming, but the amount of foam that could be applied from any given hole was rather small, as the immediate area of the foaming tended to fill up quickly due to structure, piping, and foundations.
It was decided to go ahead with a pull on 11 August, without GRAPPLE.

11 August, high tide: 3.3 feet at 0722. The sea was flat calm with about a one-foot swell. After pulling for about two hours through the crest of the tide, a small amount of movement was observed (which divers later verified to be six feet). The beach gear rigged to FRANK KNOX developed only a fair pull, only partially because of problems with blocks twisting on the falls. Another problem was thought to be that many of the beach gear legs that had been passed to FRANK KNOX from the ARS/ATF had not yet completely straightened out to their anchors. The destroyer's port engine was used during this effort. Pumps were also run in the forward engineroom, but no significant progress was made with the water level.

During the day, GRAPPLE laid her second elongated set of beach gear and was in her moor, ready to pull by nightfall. Blasting and foam operations continued. The arrangement of the beach gear falls aboard FRANK KNOX was improved for better handling. Divers patched additional holes that were found in the bottom of the forward engineroom.

12 August, high tide: 3.4 feet at 0803. Commenced heaving at 0741. All sets of beach gear to FRANK KNOX held well as did one set from GRAPPLE. GRAPPLE's starboard set parted early during the pull (the old-type cast steel shank of the inboard anchor parted), but GRAPPLE used engines to achieve close to a maximum total strain. Pumping succeeded in lowering the water level in the forward engineroom only 12 inches. The destroyer's port engine was again used. A Mark-8 hose charge that had been placed 30 feet off the port bow was set off at high tide during the maximum pull, and USS MARS made high speed runs offshore in an effort to produce waves in the calm sea. All to no avail! The ship made no appreciable sternway and the effort ceased at 0943, after the tide had fallen several inches.

The best estimates of the ship's weight and known flooding indicated that the ship should have had a zero ground reaction on 12 August. And in view of the previous day's progress with a smaller pull, less tide, less foam, and less pumping progress, the negative results of 12 August led to the obvious conclusion that the ship was now definitely impaled.

Following the pulling effort of 12 August, divers again carefully inspected the bottom, particularly in the area of the sonar dome. It still appeared that the wreckage of the dome would not cause much, if any, trouble, and no other specific areas of impalement could be located.

Extensive ballasting of the stern section of the ship had caused the ship's bottom to come in contact with the coral; several sections of the hull, now in contact with the coral, had previously been free of the bottom.

Much of the hull under B-1 and B-2 (FER and FFR) was visible to divers's inspections; it did not appear to be causing trouble. Computations led to the conclusion that the ballasting would reduce the ground reaction forward of the engineering spaces. Nevertheless, it was decided to deballast C-9-F, C-10-F, C-11-F, C-12-F, and C-301-A for the next day's effort. Divers continued topping-off of foamed spaces through holes in the hull, and foamed A-501-W and A-502-A which had begun to leak. CONSERVER rigged a long 2400 foot set of beach gear and laid it to GRAPPLE to replace the failed starboard set.

13 August, high tide: 3.3 feet at 0841. Pulled from 0700 to 1026 on 13 August with no significant results. All arrangements were essentially the same as the effort on 12 August except that GRAPPLE had two sets of beach gear, and a Mark-8 hose was set off 15 feet from the hull. The high tide on 14 August was only 0.1 foot less than on 13 August, but since the sea was still flat calm, no pull effort was made.

The question of reconciling the computed ground reaction with the observed conditions prevailed. Even though the ship may have been impaled, the computed ground reaction indicated that the ship should have been lively at high tide, even during the very low swells of about one-foot that were present. There were two possible explanations:

1. There was a large amount of hull crushing in the areas unaccessible to divers's inspections, thus decreasing the buoyancy.

2. The foam was not as efficient as originally thought, resulting in greater than estimated weight being in the ship.

A third possibility was that the hull was in a serious hogging condition, meaning that the displacement computed from the observed drafts forward and aft would be too high. To check this possibility, drafts were read at a low tide, when the maximum ballast had been aboard in the after portion of the ship. In this condition, there was only a five-inch hog in the hull. At all other times, the draft at midships was within two inches of the computed mean draft. Hogging of the hull was, therefore, not considered to be a serious contributing factor in the difference between computed and observed conditions.

5.8. FINAL PREPARATIONS

An additional 36 tons of raw material for foam formulation arrived by ship on 12 August. Foaming of the forward engine-room commenced on 13 August with the air spaces being foamed first. A small "vestibule" was left under each access, and a narrow tunnel was left between these two areas to provide access and ventilation. As in the forward fireroom, a wooden cofferdam was installed to allow access for the divers as the underwater areas were foamed from inside the space. Here again, this arrangement limited foaming, by divers, from the inside to about the seven-foot waterline. An additional purpose of the small access areas was to permit driving of holes down through the hardened foam, so that foam could be applied from above using long barrel extensions on the foam guns. This method worked quite well, but was far from perfect, as the holes would plug up when guns were changed. Providing new holes was a hard, time-consuming job because the tools would often run into machinery or deck plates before reaching the desired depth. By 18 August, foaming of the engineroom had to proceed from the outside, where divers drilled several holes through the shell for access. On 19 August, the swell and surge were too great to allow divers to drill holes, but 20 August was somewhat better and foaming of the engineroom was completed.

NOTE: A superior method of foaming a large space such as the engineroom would have been to pre-install several sets of pipe prior to foaming, with different pipes of each set extending to graduated distances from the bottom. Using this scheme, when the shorter pipes were plugged (the foam being below their bottom ends), the operation would turn to the next lower pipes and so on, until the foaming is completed.

On 14 and 15 August, swells measured about seven feet off the starboard quarter. The resulting action of the surf through the large hole in the hull at the sonar dome, and the damaged third platform deck in that area, caused most of the foam that had been placed in the magazines A-404-M and A-405-M to wash out. This foam had previously been keeping the holes in the deck of A-303-L tight, but these now began to leak badly. The irregular nature of these holes, and the strong gush of air and spray, made it impractical to patch this deck. It was decided to foam this compartment. First, it was necessary to make the first platform above, tight, where the dredger hoist had been pushed through the deck. The hoist was cutoff, the deck patched and A-303-L was foamed on 16 August.

Leakage continued into the reefer machinery space, A-406-3E, from below, but primarily through the doors from the reefer boxes. Leakage was estimated to be 600 to 700 GPM. (It was presumed that the decks of the reefers and/or their forward bulkhead (frame 33) were damaged by the Mark-8 hose charge of 9 August.) All efforts to stop this leakage by shoring and caulking the doors were of no avail.

The starboard reefer box, A-406-1E was foamed without good result. Under the conditions then present, it was expected that the leakage would increase when the ship was afloat because of the increased draft forward. A six-inch submersible pump was controlling this leakage; if this pump or its power supply should fail, not only would the entire reefer area flood, but also the compartment above. Compartment A-304-L would flood to the waterline; it was unlikely that the hose and pump could be pulled from the access and the hatch closed in time to prevent flooding. In addition, cracks were discovered in the bulkheads of the reefers, indicating that, even if made tight, these bulkheads could possibly carry away under increased hydrostatic head. It was, therefore, decided to foam this entire area as an insurance factor, since the additional weight and free surface of a flooded A-304-L could not be chanced.

On 19 August, the water was pumped down to the limit of the pump suction. The pump and hose were pulled out, and the hatch to the reefer machinery space was quickly closed and shored. The entire reefer machinery area was then foamed.

On 20 August, foaming of the forward engineroom was completed. Since there was enough foam material leftover, it was decided to foam the forward fuel oil service tanks (A-3-F, A-4-F) because it was known that about six feet of water remained in these tanks, even after the most successful dewatering with air. These tanks were successfully foamed on 20 August. Probing indicated that the foam had extended down to within three or four feet of the tank bottoms. The cofferdam A-5-VF was also foamed.

NOTE: See Figure G, page 39, for the extent of foamed spaces.

During this period, the coral blasting program continued as did the lightening of the ship through removal of stores, spares, and equipage. Salvage and foam equipment were removed as soon as these were no longer required.

The beach gear arrangements aboard FRANK KNOX were further improved by the placing of GRAPPLE's portable winch on the port side, main deck.

(CONSERVER's winch could not be used because it had been cannibalized for parts to keep the other winches running).

During this period, three storms threatened all efforts: typhoons Lucy and Mary, and tropical storm Nadine; Mary was an immediate threat. On 17 August, PRAIRIE and SIOUX were detached to proceed on a typhoon evasion course. Happily, Lucy and Nadine stayed out of the area; Mary veered, and these two ships returned to the scene late on 18 August.

5.9. FINAL EXTRACTION EFFORTS

There was a 3.0 foot tide at 0300 on 22 August, and the heights were to increase to 3.8 feet on the 26th and 27th. Everything appeared to be otherwise ready on 21 August, and the swells, which had been running five to seven feet for several days, were expected to fall. It was decided to make a pull during the three-foot tide, for fear of losing the advantage of a good swell on subsequent days.

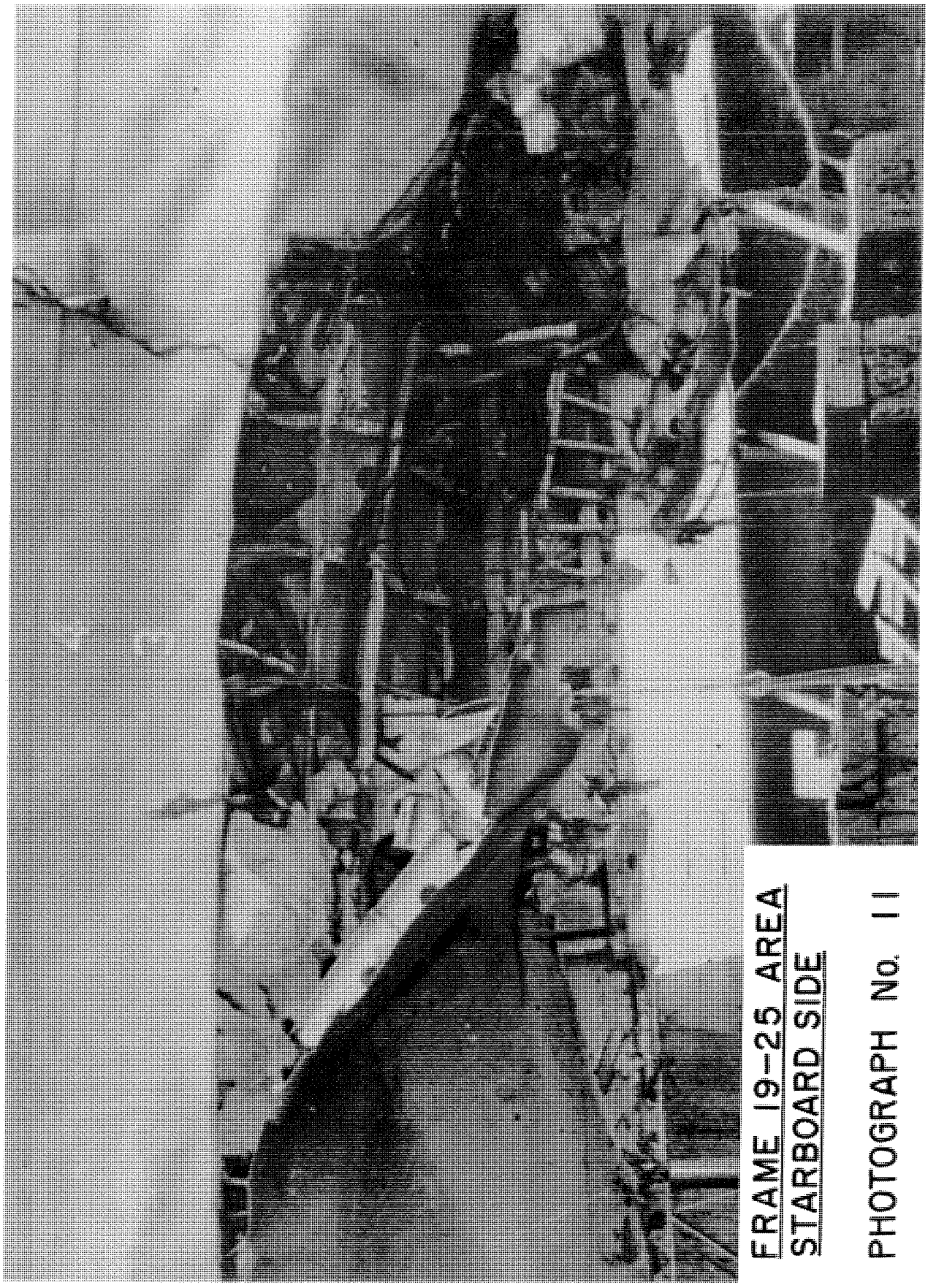
22 August, high tide: 3.0 feet at 0300. Tanks C-11-F and C-12-F, and voids C-311-V and C-312-V were ballasted. Commenced heaving at 2300 on 21 August with six sets of beach gear from FRANK KNOX and two sets from GRAPPLE. The destroyer's port engine was again used. Stopped heaving at 0450 after moving the ship eight feet aft and wrenching it around to a heading of 023°, or about 10° in the desired direction.

NOTE: In Photograph 11, page 58, note the view of the frame 19-25 area from the starboard side where the gap between structure and keel line (represented by keel blocks) can be seen. Shell plating on the far (port) side sheared off cleanly at the longitudinal from working on the reef. Wreckage of sonar, which was originally pushed up into this area, dropped free when the ship was refloated.

NOTE: In Photograph 12, page 60, note the view aft into A-503-A from starboard side of FRANK KNOX in drydock. All damage above the four-foot waterline was caused by the 50 lb. 25-foot long Mark-8 hose charge on 9 August. Damage below that location was caused by the coral bottom and by the remains of the sonar being pushed up into this compartment. The relatively intact area forward of frame 18 can be seen at the right. This is the area that acted as an anchor when the ship was dragged astern during the last days of the operation.

NOTE: Photographs 11 through 16 were taken in drydock after refloating FRANK KNOX. They are presented here as a pictorial view of some of the difficulties encountered.

A diver's inspection, shortly after daylight, indicated that the ship's position aft of the sonar dome was greatly improved. The entire area could be seen by divers for the first time; the bottom was in contact with coral in only a few locations, and these were not believed to be troublesome. The real problem was, again, the intact portion of the keel forward of frame 18.



FRAME 19-25 AREA
STARBOARD SIDE

PHOTOGRAPH No. 11

(See Figure G, page 39, and Photograph 12, page 60.) This area essentially formed a vertical hook and had come against the mound of hard coral which had previously been protruding into the large damaged area of the sonar dome. In moving aft, the keel had actually climbed this coral mound about 12 inches, and had to rise an additional 24 inches to reach the crest, where the height had previously been reduced by the blasting. The general conditions and observed rise of the bow gave much encouragement.

Preparations during the day included some additional coral blasting and the rigging of two "sealdbin" pontoons at frame 8. These pontoons are large rubber bladders that have a net buoyancy of nine tons each, and have a very low head requirement, about ten feet, so that they were useful on the relatively shallow destroyer's bow. The pontoons were previously requested from Subic Bay for on-scene evaluation, and had arrived on 16 August. However, the surf conditions at the bow prevented their installation until 22 August.

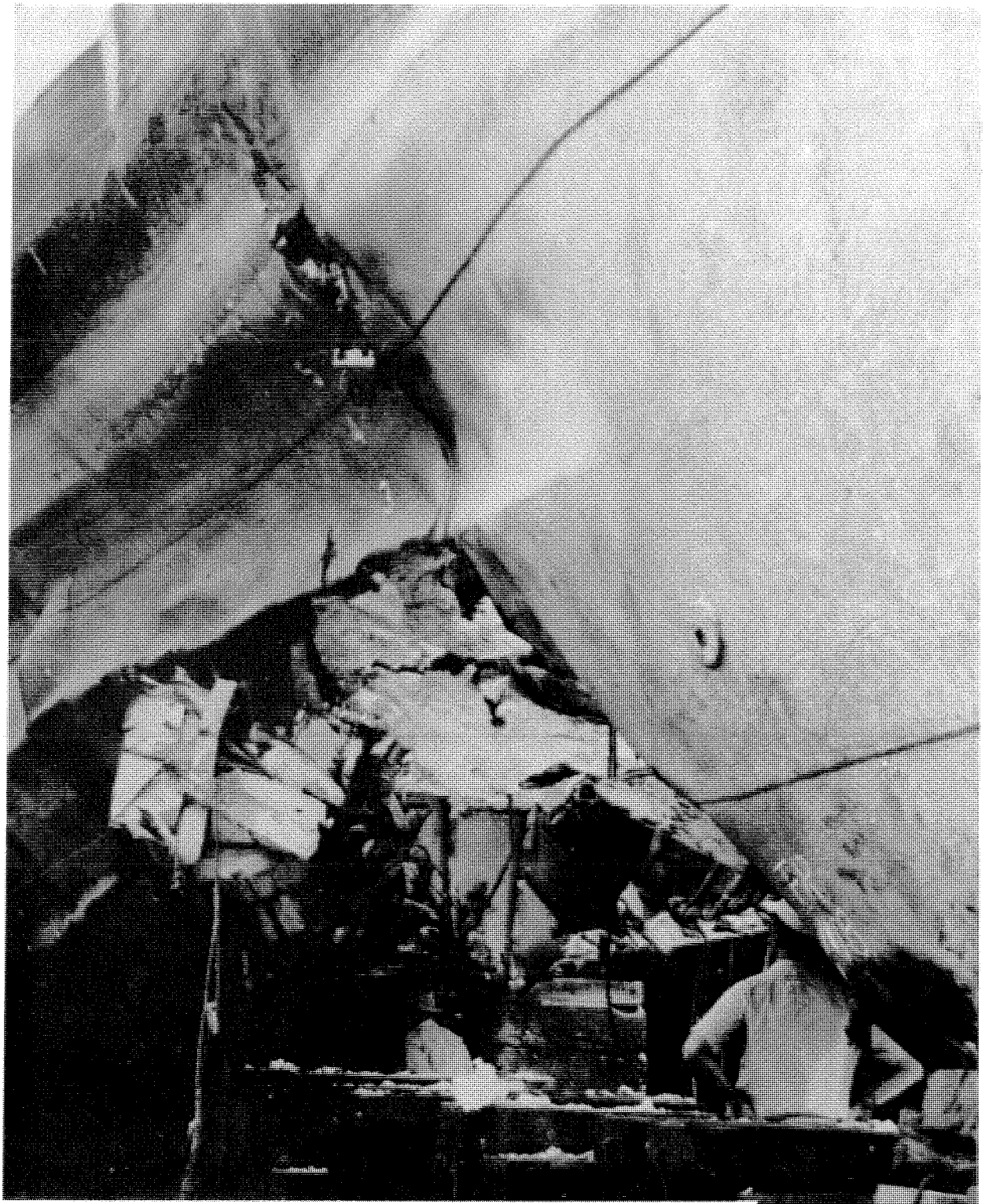
The ground reaction was now known to be well forward. C-9-F and C-10-F were ballasted to further reduce the ground reaction at frame 18.

With the sea conditions rapidly becoming calm, a destroyer was requested for the purpose of making waves. USS COGSWELL (DD 651) arrived after dark the evening of 22 August.

23 August, high tide: 3.3 feet at 0407. Commenced working up to maximum strain at 0220, being careful not to overstrain any set of beach gear prematurely. COGSWELL commenced making 27 knot speed runs parallel to the reef at 0230. It was found that the best results were obtained by steering a course towards GRAPPLE about 1200 yards off the beach, and turning sharply to seaward about 1000 yards prior to reaching the ARS.

Number 5 set of beach gear on FRANK KNOX did not hold well, and GRAPPLE's starboard set began to slip toward the end of the pull making it necessary for the ARS to supplement the pull of the beach gear with her engines, being careful not to overstrain her tow hawser. FRANK KNOX again used her port engine. Drafts were carefully taken at half-hour intervals. Some astern movement was detected and the drafts at the bow began to fall at 0300, an hour prior to the predicted high tide. Although it was dark, and the tide aboard that had long since been placed on the reef was not visible, previous daylight observations had given the salvors confidence in the predicted times and heights of tide. The lowering draft reading indicated that the bow had risen another nine inches. This effort was completed about 0530.

Subsequent divers's inspections indicated that the bow had indeed risen another 9 to 12 inches and the ship had moved aft about four feet.



LOOKING AFT ON STARBOARD SIDE INTO A-503-A

PHOTOGRAPH No. 12

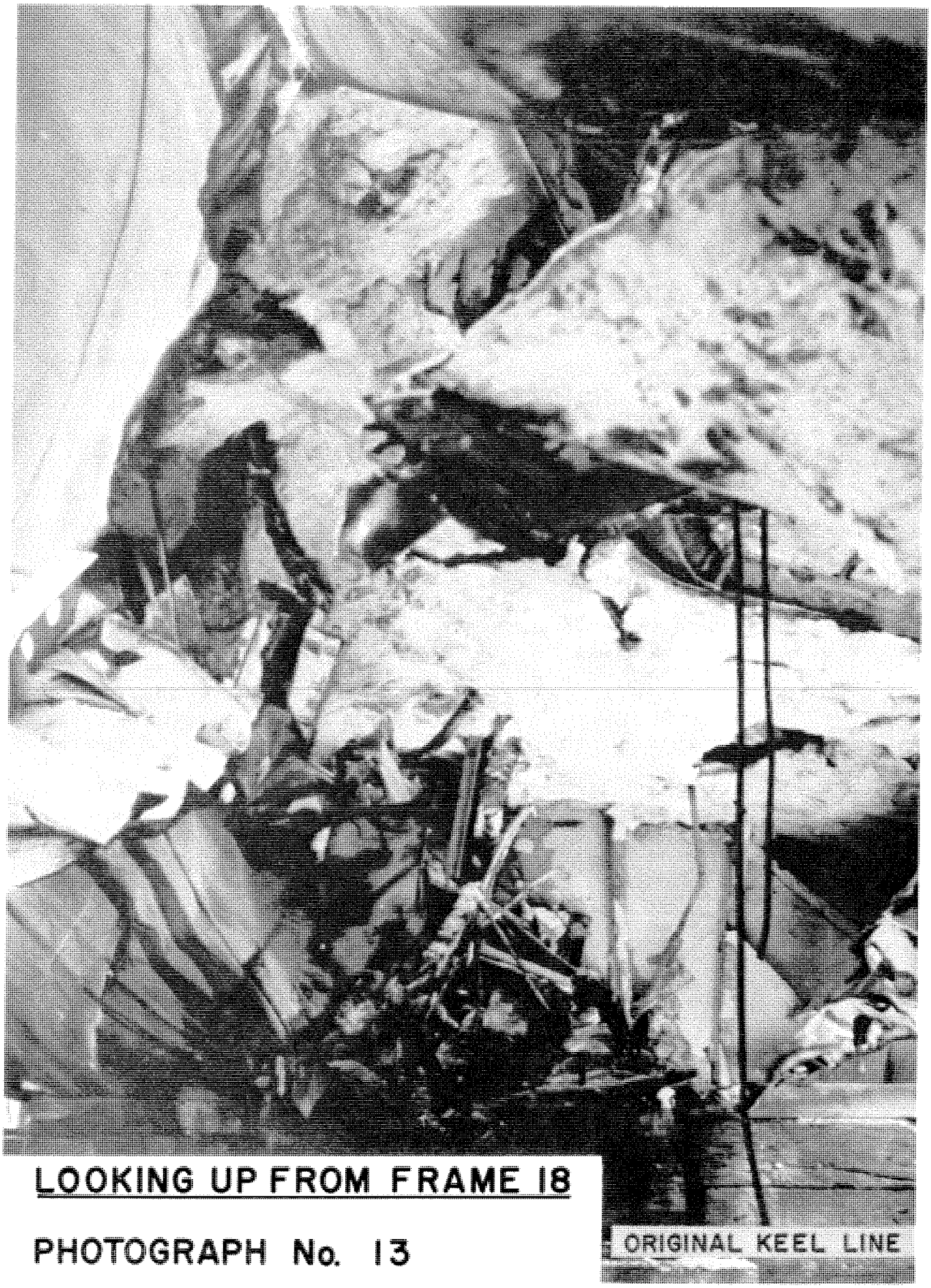
There appeared to be another rise of 12 to 15 inches required before the ship would no longer be impaled. Divers also found that the ship was now completely free of the bottom everywhere except at the immediate area of the sonar dome and the keel at frame 18. (The mound that the intact keel was required to climb over had a rising slope of about 1:3. The keel was, of course, not simply skidding up the incline, but was being pulled through the coral and rising at the same time.

NOTE: In Photograph 13, page 62, note the view from under FRANK KNOX looking aft from frame 18. Note the gap between centerline wreckage which included the vertical keel and the keel blocks. The white area on the overhead of A-503-A is foam, the remainder of what had been washed out by wave action. The third platform deck had previously been watertight, but after the blast of 9 August, compartments on the third and second platforms were open to the sea through damaged decks and eventually had to be foamed.

At this point, it appeared that some of the damaged structure in the area of the sonar dome would cause problems. About four feet of the keel and shell plating that was, originally, immediately aft of frame 18, was flattened, and sticking out 90 degrees from the centerline to port and was acting as a plow. While it was possible that this structure would continue to fold around as the ship was pulled astern, it was decided to cutoff the obstruction because diving conditions were ideal. Divers spent the afternoon of 23 August burning off all accessible obstructions in this area using oxy-arc burning gear.

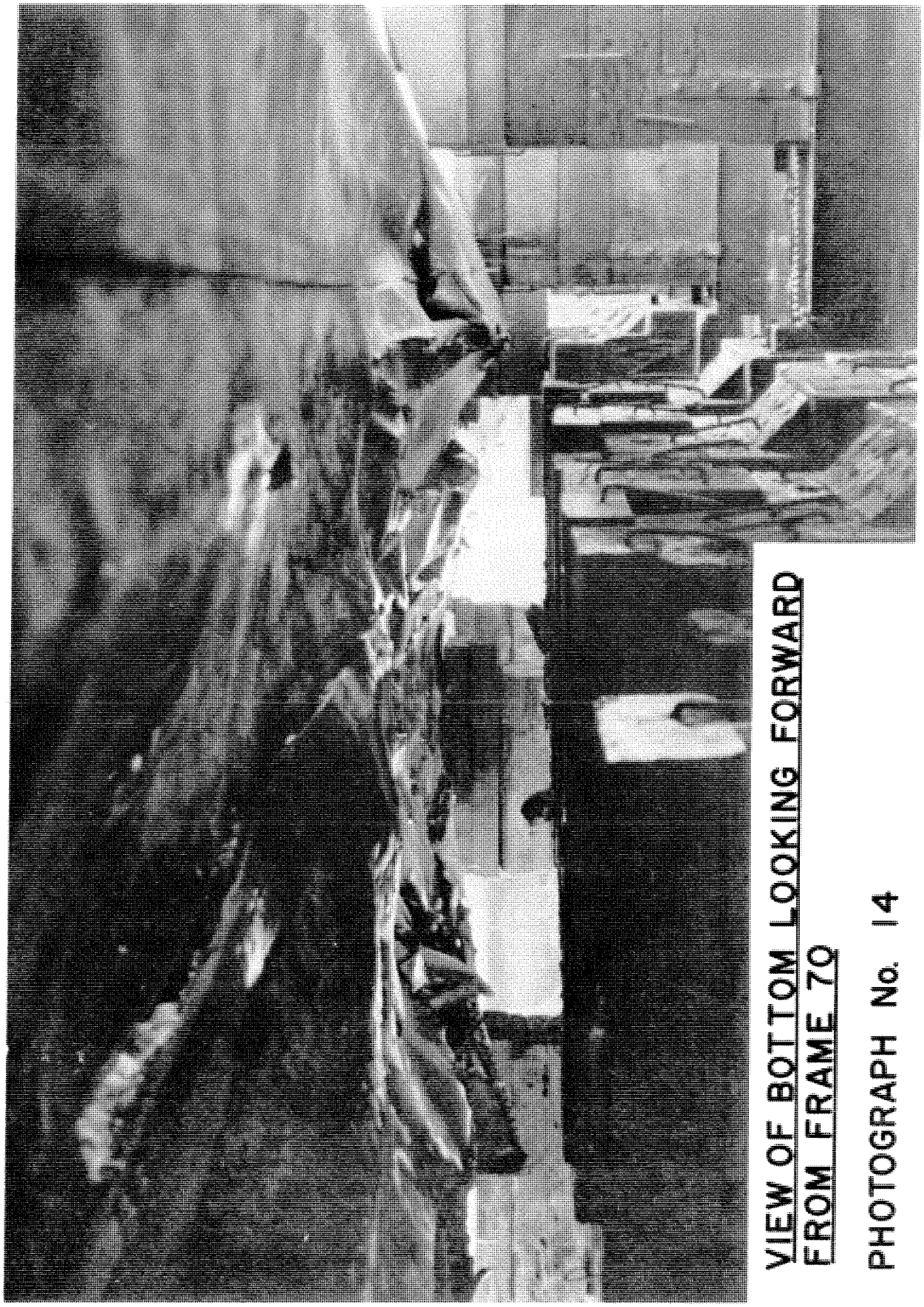
Since the remaining ground reaction was now firmly established to be concentrated in the frame 17-25 area, it was also decided to ballast all remaining dry compartments below the first platform aft of frame 157. C-301-A, C-305-M and C-306-M were ballasted that afternoon.

There was one Eells anchor left in Task Unit 73.4.1. and it was the old type with the cast steel shank. This anchor was in the forward hold of CONSERVER, and by borrowing a part here and wire there, enough gear was available to lay one more set of beach gear. This set was rigged and laid by CONSERVER, to the east of GRAPPLE, and CONSERVER had completed her moor by early evening. The usual lateral current of about 5 knots was running and had pushed CONSERVER far out of position. At 2310, as CONSERVER was pulling herself into position, the hauling stopper on the beach gear slipped; when it suddenly caught hold, the 5/8-inch falls parted. About a dozen men were knocked down, and five were evacuated for medical attention. (It later proved that no one was hurt seriously.)



LOOKING UP FROM FRAME 18

PHOTOGRAPH No. 13



VIEW OF BOTTOM LOOKING FORWARD FROM FRAME 70

PHOTOGRAPH No. 14

Even though the bitter end of the 1 5/8-inch wire hung up on the bow structure of the ship, CONSERVER was set down upon GRAPPLE before another set of falls could be rigged, and it was necessary for CONSERVER to trip out of her moor at about 2345.

24 August, high tide: 3.5 feet at 0515. Prior to lighting off, a routine inspection of number 4 boiler revealed several ruptured tubes, making the engineering plant of the destroyer useless. COGSWELL was ready with four boilers and 33 knots. Commenced heaving at 0230; COGSWELL started her high-speed runs at 0330. By 0400, the maximum forward draft was observed, and at 0420, the first slight sternward movement was felt when COGSWELL's waves reached FRANK KNOX. The 0430 forward draft was nine inches reduced, and by 0500, a total rise of the bow, of 14 inches, was indicated. Each time that waves from COGSWELL reached FRANK KNOX, the stranded ship moved several inches. Finally, at 0520, as COGSWELL's waves arrived, the stranded ship lunged about five feet aft. The beach gear quickly took up the slack and FRANK KNOX was refloated at 0530, with drafts of 15'6" forward, 15'5" aft. List was six degrees to starboard, and the seven-second period of roll indicated a GM of about six feet. This was extremely good.

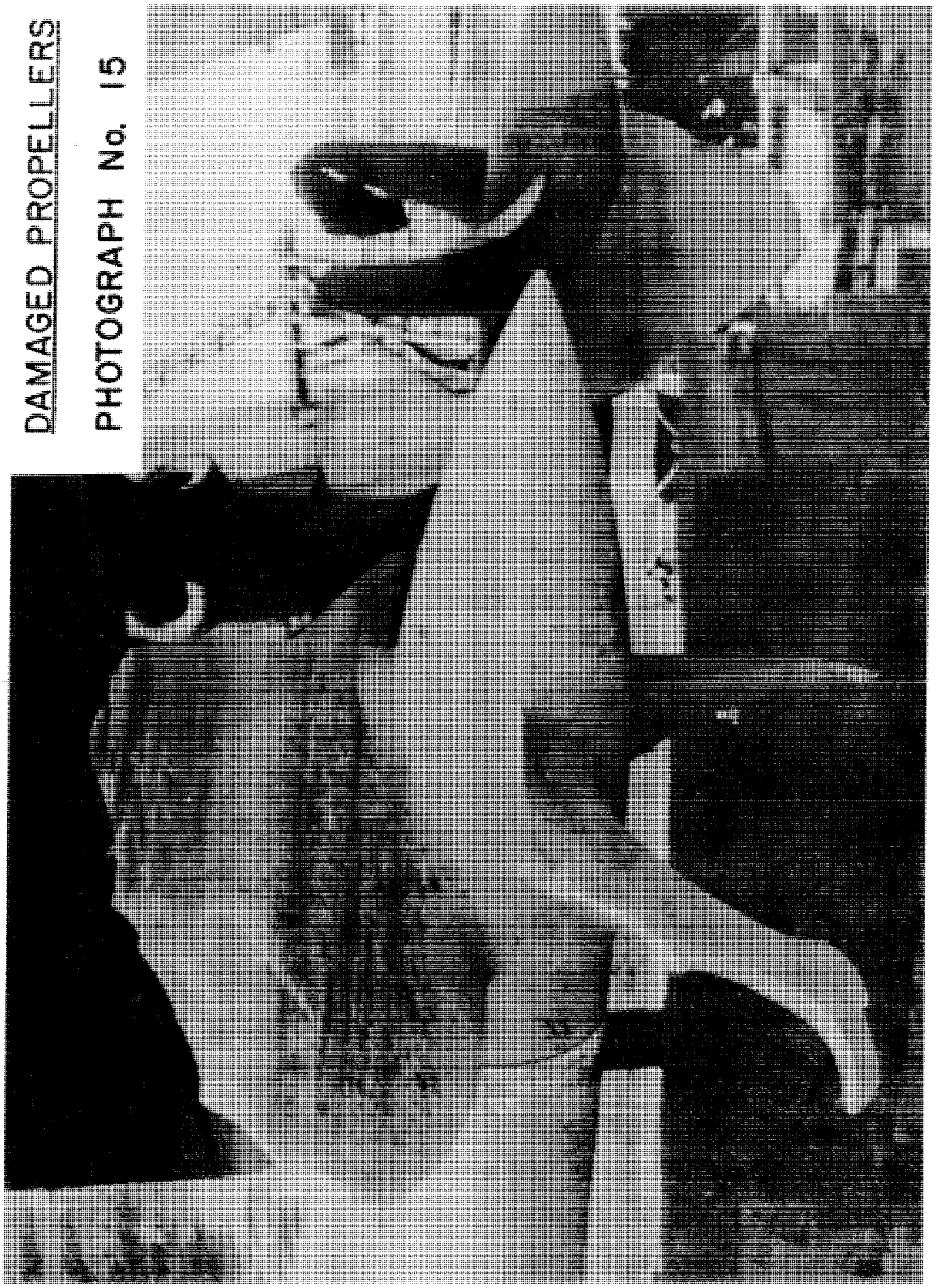
FRANK KNOX rode to her beach gear anchors as the beach gear was buoyed and cast off, one by one, in an orderly fashion. Finally, the last set was cast off; GRAPPLE slipped her own beach gear and towed FRANK KNOX several miles to sea, where the destroyer was completely cut loose so that CONSERVER could make up for the tow of FRANK KNOX, stern first, to Kaohsiung, Taiwan. (It had been decided to tow FRANK KNOX, stern first, in order to reduce dynamic pressures on bulkheads exposed to the sea through the large damaged area forward.) GRAPPLE and SIOUX stayed behind to recover beach gear.

When the tow of FRANK KNOX commenced at 1200, C-309-A was deballasted to reduce the list, and C-311-V and C-312-V were deballasted to raise the stern for better towing. Escorted by MARS and GREENLET, CONSERVER towed FRANK KNOX at 7 knots in mild seas. (The destroyer was a surprisingly good tow, stern first.) The tow arrived at Kaohsiung, early 26 August. FRANK KNOX was drydocked at the Fourth Chinese Naval Shipyard in Kaohsiung on 27 August. Thus ended a 40-day struggle to save a gallant ship, under weather conditions which were most fickle and perverse, from a literal graveyard of ships (over 20 wrecks are visible on Pratas Reef).

Temporary repairs were completed on 20 September. FRANK KNOX was towed to Yokosuka, Japan, by MUNSEE--escorted by GRAPPLE and USS POLLUX (AKS 4), for permanent repairs. With FRANK KNOX assisting, using her own port engine, the destroyer was delivered at Yokosuka on 27 September after a day's stopover at Sasebo, Japan, to wait out still another typhoon.

DAMAGED PROPELLERS

PHOTOGRAPH No. 15



PORT SIDE FORWARD OF SONAR DOME AREA

PHOTOGRAPH No. 16

NOTE: Photographs 14, 15 and 16 were taken in drydock; they exemplify some of the damage done to the ship.

In Photograph 14, page 63, note the damaged bottom plating of the destroyer. Patching of the bottom was very difficult; diligent efforts to stop the water from flooding proved unsuccessful because the damage was too extensive and too severe (as is evidenced in the photograph).

In Photograph 15, page 65, note FRANK KNOX's propellers after drydocking. Most of the damage shown here occurred during the night of 20 July when the ship bounced along the reef and engines were used to help prevent broaching.

In Photograph 16, page 66, note the port side of FRANK KNOX forward of the sonar dome area. The jagged metal on the right is part of the former shell plating in A-503-A that was bent forward as the ship was pulled aft. Foam inside A-502-A can be seen at center. Note the extreme crushing of the keel block due to the large concentrated weight forward of frame 18. The bottom was not well supported between frames 18 and 72.

6. SUMMARY

The successful intact salvage of FRANK KNOX was the result of long hard hours of work by a large number of personnel, and the ships that were on the scene. As is always the case with a large-scale salvage operation, a great amount of logistic support was required. The response and support by higher commands and the shore establishment was outstanding.

As to the procedures used: the selective coral blasting program, the use of beach gear, and the dewatering by foam, each played its own important part. It is doubtful that any two of these programs could have led to intact refloating without the third.

The use of foam, however, was certainly the key. Had this new technique not been available, dewatering of the flooded spaces would have been a long-time project involving a much more extensive use of air, and probably the use of concrete to close leaks in the engineroom and fireroom in order to dewater by pumping. These programs would have required the absence of typhoons,which make pre-floating abandonment necessary, and this was improbable.

After the ship was drydocked, an inspection of the bottom showed the keel and surrounding shell forward of frame 72 to be pushed up, giving a concave shape with a section much like a "W". The worst area was in way of A-3-F, frame 60-66, where the bottom was pushed up about four feet. All the bulkheads had failed in this area, and all forward fuel oil tanks were, in fact, open to each other and to the sea.

The moulded underwater section of the hull was reduced because of the dishing-in caused by the ship's pounding on the reef; this loss of underwater section accounts for much of the additional weight of FRANK KNOX not accounted for in calculation.

7. APPENDIX

7.1. COMMENTS ON THE USE OF FOAM-IN-SALVAGE

General

The Foam-in-Salvage technique was first used successfully in salvage work in late 1964 when Murphy Pacific Corporation, under contract to the U.S. Army Corps of Engineers, raised a lumber barge in Humboldt Bay, Eureka, California. The material was Polytron Urofroth foam. In this job, the foam created a 500 net ton lift, and raised the barge from 40 feet.

Foam technology is being advanced, under a BUSHIPS contract, to investigate the use of foam at deep depths.

In the salvage of FRANK KNOX, a Urofroth 502 mixture was used. This mixture consists of one-part resin and one-part catalyst. A positive displacement Alamite pump is used to transfer the catalyst and the resin from their shipping containers to separate cylinders. Freon 12 is then added to both catalyst and resin. Representative amounts of Freon 12 used in this operation were 55 pounds of Freon 12 per 500 pounds of catalyst, and 80 pounds of Freon 12 per 500 pounds of resin.

NOTE: In Photograph 17, page 70, note several "pairs" of foam mixing tanks aboard USS FRANK KNOX. At the foam filling station (not shown here), resin and Freon are pumped into one tank, while the other tank is filled with a catalyst and Freon in the proper proportions. The materials are then mixed by rolling the tanks. For the foaming operation, the filled tanks of a pair are connected to the gun by separate hoses where the materials are mixed together. The Freon forms small bubbles in the mixture which quickly expands and hardens in a matter of minutes. The materials are forced through the hose under pressure by an inert gas, nitrogen, in this case. Each pair contains about 1000 lbs. of material that will displace approximately 10 tons of water when mixed and expanded. It takes approximately one hour to expand one pair through one gun.

After adding the Freon 12, the catalyst and resin cylinders are rolled for about 30 minutes; this aids the absorption of the Freon 12 into the liquids. Upon completion of rolling, the material is ready for use.

FOAM MATERIAL TANKS ON 01 DECK, STBD SIDE

PHOTOGRAPH No. 17

The catalyst, resin, and a solvent of methylene chloride are pressurized with nitrogen and sent to the gun via separate hoses. Any inert gases can be used for pressurization, but nitrogen is most economical. At the gun, the catalyst and resin are passed through ball valves and proportioners into a baffled mixing chamber, where they are combined. The mixture then passes through the gun barrel, which is 3/4-inch diameter and anywhere from one to eight feet long.

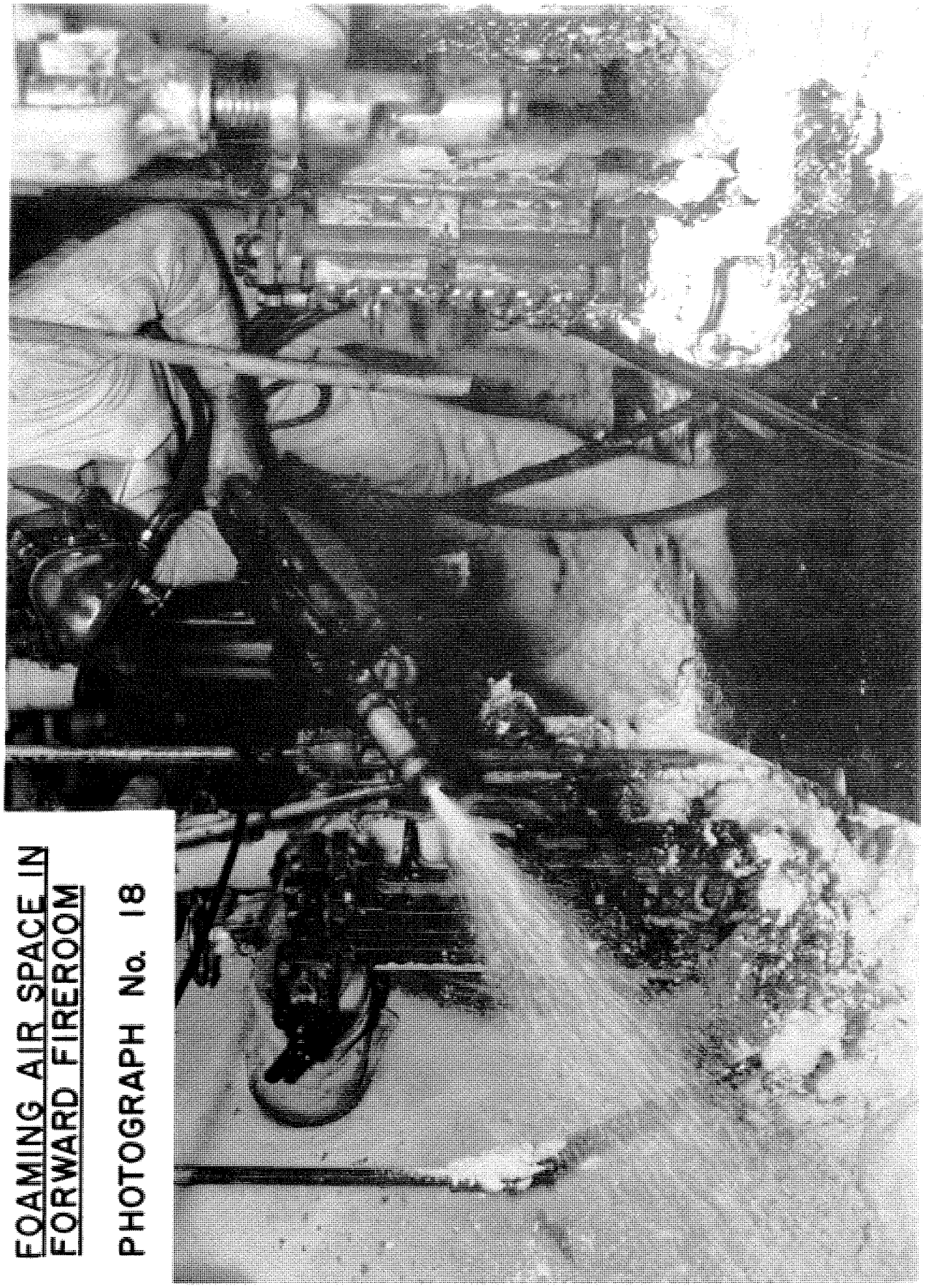
After completion of foaming, the gun must be flushed with solvent, otherwise, the mixture will solidify in the gun and its barrel and render them useless. This flushing had to be accomplished within about 10 seconds after completion of foaming.

Given just a few trained technicians who are required for formulating mixtures and general overall supervision, personnel, locally available, can provide the principal manpower for a foaming operation.

Techniques are not complicated, but certain basic limitations exist in the application of the foam. An important fact to note is that present foam formulations cannot be allowed to free-rise in water too far. If the foam rises too far from the gun mixing chamber, the bubbles in the foam will over-expand before the material hardens; the resulting composition will easily absorb large amounts of water and will lack sufficient strength to remain in place in presence of the smallest amount of water movement.

Another problem encountered in foam operations results from the fumes given off by the foam; several people working with the foam, topside, developed chemical bronchitis. (Divers using the foam did not acquire this condition.) It is imperative that adequate ventilation be afforded, or that a separate air supply be used by personnel involved in mixing or installing the foam. When the foam hardens, fumes are no longer given off.

NOTE: In Photograph 18, page 72, note a diver from USS GREENLET (ASR 10) building up a layer of foam in the upper level of the forward fireroom of FRANK KNOX. (It was necessary to foam above the waterline prior to proceeding with the underwater portions.) The diver is standing on plywood that had been laid on a layer of foam about two feet thick. Note the gun with two separate supply hoses carrying the resin and catalyst. The materials are mixed together in the small mixing chamber beyond the trigger. A barrel of appropriate length was added to the mixing chamber for foaming underwater.



FOAMING AIR SPACE IN FORWARD FIREROOM

PHOTOGRAPH No. 18

Although the sailors who were provided to work on the foam operation exercised care in the handling of equipment, many component failures occurred. Since these men are a representative sample of the personnel who will be involved in any future foaming operation, more rugged equipment is highly desirable.

The foam, as formulated in the FRANK KNOX salvage, is flammable except where it is immediately in contact with water. Water will saturate the foam to depths of from a few inches to several feet, depending on the local quality or consistancy of the foam. Saturated foam is not flammable; however, foam expanded in air or protected from water by several inches of foam will burn. Dry foam does not burn violently, but it gives off very toxic fumes and burns completely, leaving practically no ash.

When the flammability of the foam became known, the foaming of the air spaces in the forward fireroom of FRANK KNOX was delayed while hull stiffeners were being welded to the deck. This proved to be a wise precaution because a serious fire did occur later, when the ship was in drydock for temporary repairs. The fire was caused by sparks from a welder's torch when welding two remote reach-rod extensions on the main deck. (These fittings had been originally removed because they obstructed the placement of 10-inch salvage pumps.) The fire burned for about two hours before it was extinguished.

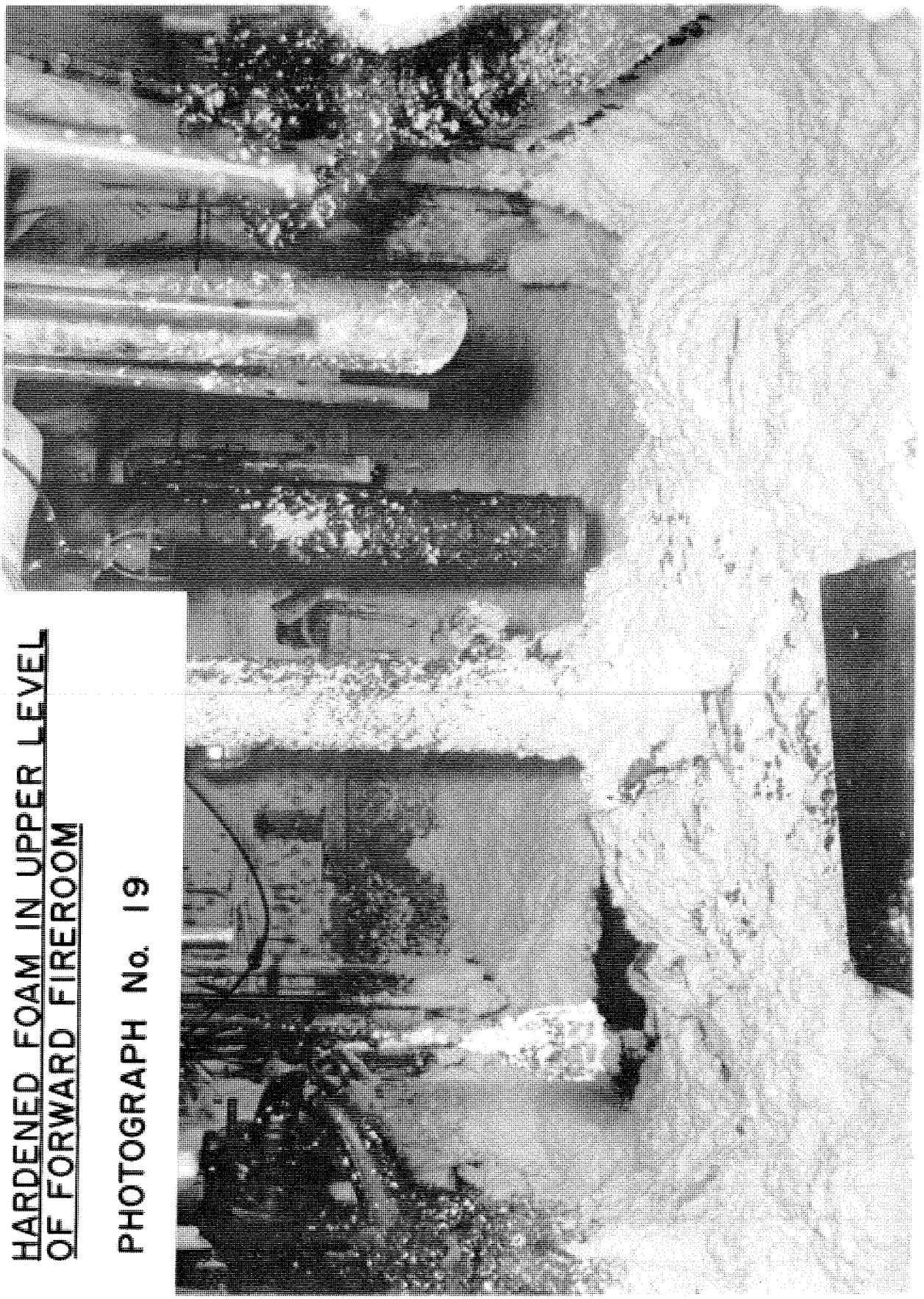
Use of Foam in FRANK KNOX

A total of 76 tons of foam raw material was sent to the scene. This is equivalent to 152 "sets" of foam. Of this, seven sets were lost or contaminated, 143 sets were used, and two were leftover. The following spaces were foamed:

A-3-F	A-406-2A	A-502-A
A-4-F	A-406-3E	A-504-A
A-5-VF	A-406-4A	A-505-F
A-303-L	A-410-M	A-506-F
A-404-M	A-411-M	B-1
A-405-M	A-501-W	B-2
A-406-1A	A-503-A	

NOTE: See Figure G, page 39, for location of foamed spaces.

It is difficult to evaluate the effectiveness of foam as used in FRANK KNOX. This was the first occasion where the technique was used in a complicated ship-shaped structure with relatively minute compartmentation, and where much equipment was within these compartments. Techniques were necessarily developed and improved as the project progressed.



HARDENED FOAM IN UPPER LEVEL OF FORWARD FIREROOM

PHOTOGRAPH No. 19

After the ship was refloated, the compartments that had been foamed would have contained 1243 tons of water. Allowing for the weight of the foam, and for the loss of underwater volume caused by the crushing of the hull, there must have been 530 tons of water still in these spaces. It was estimated that some 260 tons of water were present due to known (or assumed) voids at the bottom of compartments, or where foam had washed out, such as magazines A-404-M and A-405-M. This left 270 tons of water unaccounted for, which must have been absorbed in poor foam and in unknown voids within the foamed spaces.

Allowing for the weight of the foam, 641 tons of net buoyancy was obtained giving an overall efficiency of 51.5%. The efficiency goes up to 53.5% if the weight of foam (approximately 26 tons) unavoidably expended in air spaces is deducted. These spaces were the above-water portions of the forward engineroom and fireroom and A-303-L. (See Photograph 19, page 74.)

NOTE: Photograph 19, page 74, presents a view looking to port from between steam drums, upper level of FRANK KNOX's forward fireroom, showing hardened layer of foam about two feet thick. This material could be walked on within 15 minutes after application. In the hole shown at center left, the foam was only four to six inches thick and a diver almost fell through.

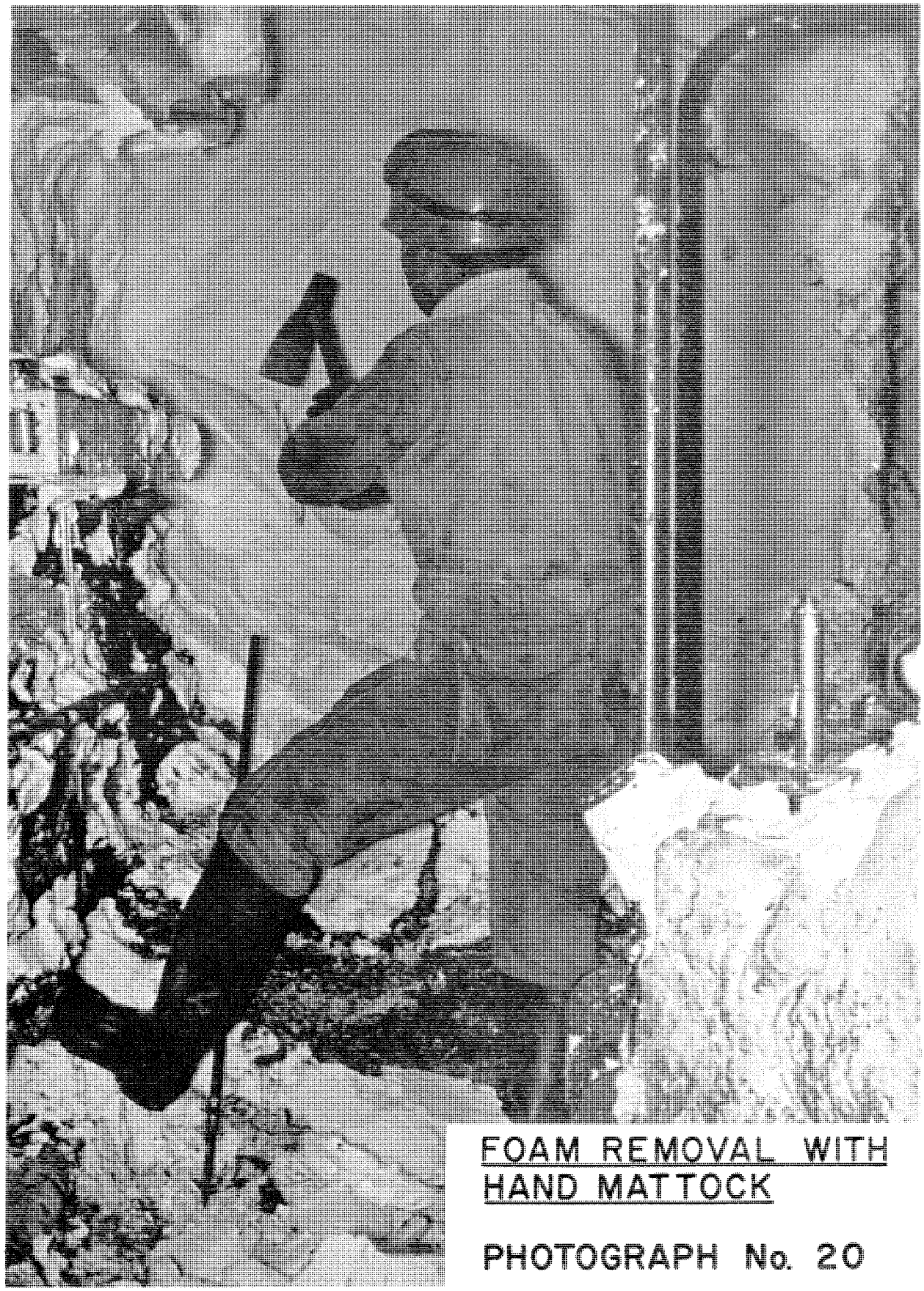
Of further interest is the net buoyancy obtained from a pound of foam. Overall, the figure is 10.5 pounds buoyancy per pound of foam. By deducting the foam expanded in air spaces, the figure rises to 16 pounds/pound.

There is no doubt that given the same or similar problem, next time, the same personnel will get much better results with foam because of lessons learned, and experience gained. There is no doubt that the use of foam was the key to the intact salvage of FRANK KNOX.

The drydock inspection (in those areas available to inspection) revealed that the extent of the foaming operation was about as expected. In some areas, foaming the space intended was more successful than expected, in other areas, less successful. The general conclusion is that with proper techniques, the largest portion of any given space or tank can be successfully foamed.

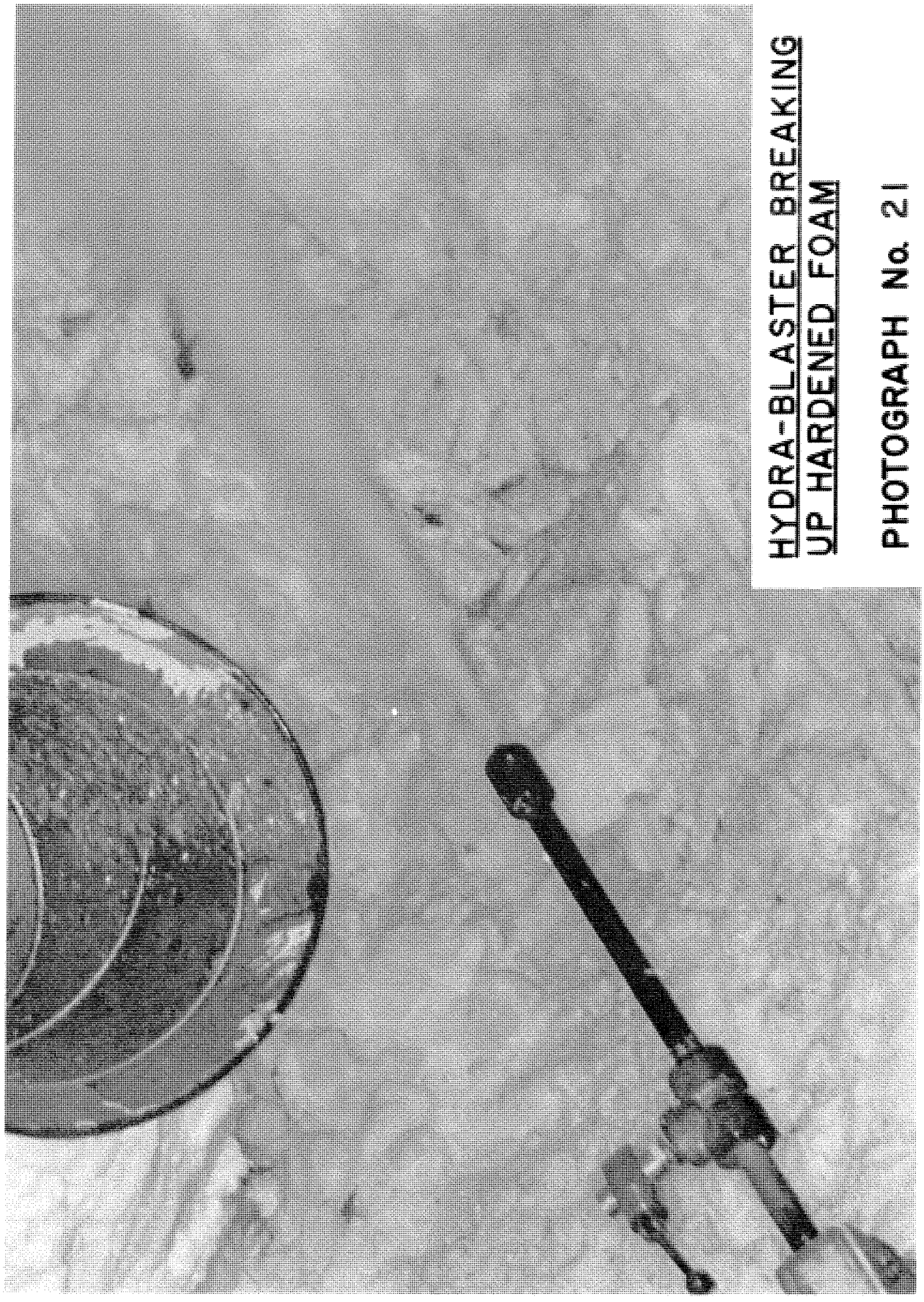
Subsequent foam removal

After the completion of emergency hull repairs at the Chinese Navy Yard in Koahsiung, Taiwan, the FRANK KNOX was towed to Yokusuka, Japan for overhaul. The first overall objective was foam removal.



FOAM REMOVAL WITH HAND MATTOCK

PHOTOGRAPH No. 20



HYDRA-BLASTER BREAKING UP HARDENED FOAM

PHOTOGRAPH No. 21

Following is a summary of the report prepared by the U.S. Navy Ship Repair Facility in Yokosuka concerning foam removal.

Removal of the foam was a two-phase operation:

1. The required breaking up of the foam mass.
2. The removal of the material from the ship.

Power and hand tools, low and high-pressure water systems, and small hand tools, such as paint scrapers and edgers were used to breakup the foam; hacksaws were successful, but slow. Dry foam (such as was located in the above waterline space of B-1 and B-2) had a density of 0.04, and was most difficult to remove. Where operationally possible, and where there was the least risk to the ship's equipment, lightweight hand mattocks were used. (In Photgraph 20, page 76, a worker uses a hand mattock to remove foam from the forward starboard corner of the forward engineroom, upper level.)

A high-pressure water blasting system was also utilized, but extra precaution was necessary to avoid danger, to the operator and assisting personnel, that might result from the high-pressure water jetting. The Hydra-Blaster was a Model WBG-263 unit, manufactured by the American Power Stage Company, and was operational in the 3000 to 5000 psi range (see Photograph 21, page 77). It was later estimated that the Hydra-Blaster was equivalent to the use of five men in removing foam mechanically.

No apparent damage was done to the ship or its equipment during this operation. Some of the foam near the bottom of the ship was wetter than the foam at the top and was easily removed with fire hose water jets of 60 psi (see Photograph 22, page 80).

During her stay in drydock, foam was removed from FRANK KNOX in small quantities over the main deck, and in large volume through the several access holes cut in the hull plating. It is estimated that 27,000 cubic feet of foam was removed from B-1 and B-2 (FFR and FER); 11,300 man-hours include cutting the access holes, the presence of safety inspectors, removal of some boiler outer-casing to facilitate removal of foam from inside the boiler, and basic manual labor. Approximately 25 working days were required to remove the foam from B-1 and B-2. Foam removal from the forward spaces (magazines, store-rooms, living quarters, tanks, etc), was somewhat cheaper and quicker because of considerably less interference.

Foaming did not cause any apparent damage to bulkheads, decks, or the ship's equipment, and there was no damage caused by any possible foam expansion. Dry foam (such as was placed in the above waterline spaces in B-1, B-2, and A-303-L), will burn when subjected to sufficient heat intensity (flashpoint 635°F).

Care must be exercised in keeping intense heat away from dry foam; foam placed directly in the water was somewhat wetter, and considerably less susceptible to fire. If foam material should be burned (as it might be for disposal purposes), there is a possibility of generating CO, CO_2, ammonia and amino; some of these gases are toxic and suitable air-breathing systems should be provided for personnel.

An interesting conclusion to the foaming operation in FRANK KNOX was that the foam in the machinery spaces served quite adequately to protect the equipment from being coated with an oil film, as is usual where a flooded space is pumped out. The foam sealed the machinery. It is significant that every single piece of machinery in FRANK KNOX's engine spaces was used again after the overhauling at SRF Yokosuka.

60 PSI FIRE HOSE WATER STREAM BREAKING UP WET FOAM

PHOTOGRAPH No. 22

Summary

In the past, the salvor has had only two effective means of eliminating water inside a wrecked ship, namely, pumping or blowing with compressed air. Use of foam provided a third means in which the water is displaced by a very light, non-soluble material. Based on experience in the FRANK KNOX, the following advantages accrued:

- A means has been provided of dewatering compartments which cannot otherwise be made tight for pumping or blowing without tremendous difficulty and a great deal of time. This was the situation on the FRANK KNOX.
- Materials for foam are air transportable.
- Foam can be installed from inside or outside a space.

Disadvantages

- Expensive, and requires several specially trained personnel.
- Once a space is foamed, use of any other technique is precluded.
- Toxic. Some difficulties were experienced with this on the FRANK KNOX, but this can be overcome with proper precautions.
- Foam must be contained; solid bulkheads are not essential; a wire matting or canvas will do for small gaps, but when completely open to the sea, it may be washed out by wave action as occurred in the damaged bow area of FRANK KNOX.
- As formulated on the FRANK KNOX, this foam was flammable.
- The use of foam in a complicated ship structure does not automatically guarantee 100% dewatering of the spaces without careful application procedures developed by experienced personnel.
- The problem of rapid removal of foam has not yet been solved.

Recommendations

- The foam should be used only after it is obvious that pumping or blowing is impractical, or much too time-consuming.
- The limitations and capabilities of foam as a patching material, either alone, or in conjunction with other materials, in a flooded space, should be fully explored.

HAND FOAM REMOVAL

PHOTOGRAPH No. 23

- An investigation should be made to see if foam can be made non-combustible. The foam used on the FRANK KNOX burned readily, except when in direct contact with water.
- Methods of rapid foam removal should be investigated.
- Procedures for foaming deep spaces entirely from above should be investigated.
- The foam equipment and apparatus should be redesigned or improved to be more rugged and reliable.

7.2. ADDITIONAL ASSETS NOT USED

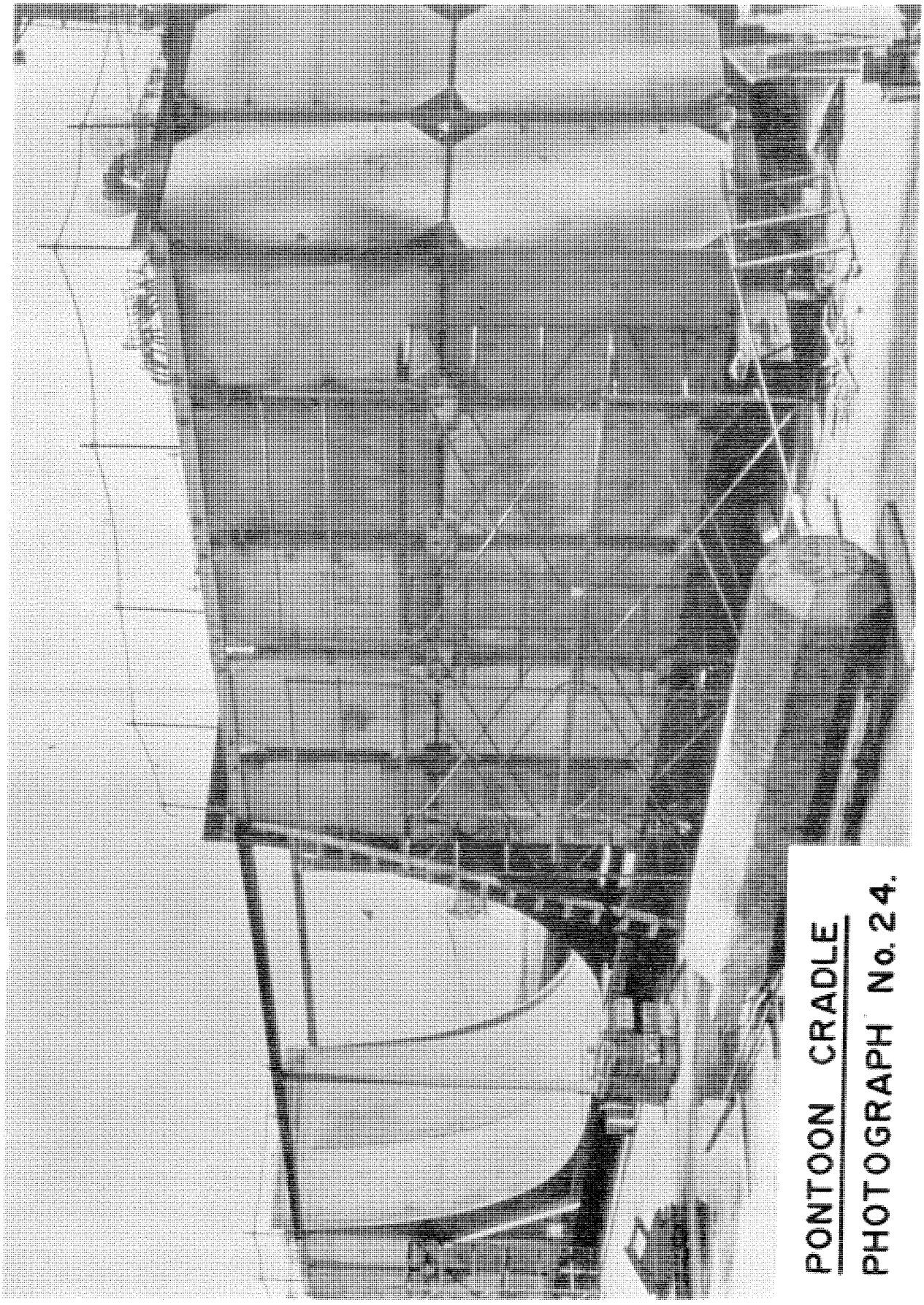
The following items were on the way to the scene of the salvage operation at the time FRANK KNOX was refloated:

1. Pontoon cradle. A large cradle fabricated from BUDOCKS pontoon cells was designed and built. This cradle was designed to be lifted to the scene in an LSD. It was to have been slid under the stern of FRANK KNOX to the mid-ships area where it would have provided 540 net tons of lift (see Photograph 24 page 85).

2. "Sealdtank" pontoons. These are large cylindrical rubber tanks used for storage of liquids. BUSHIPS leased 15 of these tanks in various lengths from 15 to 39 feet and 7 to 8 feet in diameter, and shipped them to the scene. The plan was to work these tanks under the ship as far forward as possible in the uninflated position. They would then be pressurized with water and would greatly reduce the coefficient of friction and the ground reaction, if they didn't actually lift the ship. The hull would then slide over the tanks relatively easy, and there was the possibility that the tanks would even roll as the ship was pulled to seaward by the beach gear.

3. "Sealdbin" pontoon. Two of these nine-ton pontoons were available at Subic Bay and were used mainly for evaluation. However, ten of these pontoons belonging to various CONUS Navy activities were on the way to the scene. They would have been used at the bow where their total of 108 tons buoyancy would have been most effective.

The use of each of the above mentioned procedures was largely dependent upon favorable sea conditions. Even after being positioned, heavy seas probably would have disrupted or destroyed these external lifting systems.



PONTOON CRADLE
PHOTOGRAPH No. 24.

7.3. TIDE TABLES

DATE	HIGH TIDE	WATER HEIGHT	LOW TIDE	WATER HEIGHT
20 July 1965	1125 hours	2.9 feet	2030 hours	0.0 feet
21	1207	2.6	2100	0.2
22	0258	1.8	0831	1.34
22	1350	1.8	2012	0.9
23	0327	2.3	1048	1.0
23	1546	1.3	2013	1.0
24	0405	2.6	1229	0.6
25	0451	3.05	1338	0.1
26	0541	3.34	1434	-0.3
27	0633	3.67	1525	-0.6
28	0726	3.94	1612	-0.7
29	0819	4.0	1657	-0.7
30	0911	4.0	1738	-0.5
31	1002	3.8	1816	-0.2
1 August	0053	1.1	0257	1.0
1	1052	3.4	1848	0.1
2	0103	1.3	0426	1.1
2	1141	3.0	1913	0.5
3	0126	1.7	0556	1.2
3	1232	2.4	1930	0.8
4	0157	1.9	0741	1.1
4	1329	1.8	1934	0.5
5	0234	2.3	0951	1.0
5	1455	1.3	1910	0.5
6	0317	2.5	1111	0.8
7	0406	2.7	1335	0.5
8	0458	3.0	1426	0.2
9	0549	3.1	1507	0.1
10	0637	3.2	1540	0.0
11	0722	3.3	1610	0.0
12	0803	3.4	1637	0.1
13	0841	3.3	1702	0.2
14	0918	3.2	1724	0.2
14	2347	1.3	NIL	NIL
15	0954	3.1	0210	2.3
15	2352	1.3	1744	0.4
16	1030	2.9	0315	1.2
16	NIL	NIL	1802	0.6
17	0004	1.6	0420	1.2
17	1109	2.6	1816	0.7
18	0022	1.8	0534	1.2
18	1154	2.3	0826	1.0
19	0048	2.1	0700	1.1
19	1250	1.8	1829	1.1

DATE	HIGH TIDE	WATER HEIGHT	LOW TIDE	WATER HEIGHT
20 August	0122 hours	2.3 feet	0848 hours	1.0 feet
20	1425	1.4	1813	1.2
21	0207	2.6	1048	0.7
22	0300	3.0	1222	0.2
23	0407	3.3	1328	0.1
24	0515	3.5	1420	0.3
25	0620	3.7	1506	0.4
26	0720	3.8	1546	0.3
27	0816	3.8	1623	-0.2
27	2241	1.2	NIL	NIL

7.4. PARTICIPATING UNITS AND PERSONNEL

On Scene Commander

RADM M.W. White, USN Commander Carrier Division SEVEN	21-22 July
RADM J.W. Williams, Jr., USN CTF 73/COMSERVGRU THREE	22 July - 26 August

Salvage Units

USS CONSERVER (ARS 39) (after 20 August)	LCDR D.T. Lamb, USN LCDR F.A. Hilder, USN
USS GRAPPLE (ARS 7)	LCDR D.E. Minnich, USN
USS SIOUX (ATF 75)	LT. W.C. Bender, USN
USS COCOPA (ATF 101)	LT. S. Steed, USN
USS MUNSEE (ATF 107)	LT. W.H. Fischer, USN
USS MAHOPAC (ATA 196)	LT. J.S. Jones, USN
USS GREENLET (ASR 10)	LCDR L.R. Clark, USN

Ships Providing Direct Support for Significant Periods

USS MIDWAY (CVA 41)	CAPT J.M. Obrien, USN
USS IWO JIMA (LPH 2)	CAPT D.A. Scott, USN
(Marine Medium Helo Sqdn 163 emb'd)	LTCOL H.G. Ewers, USMC
USS PRAIRIE (AD 15)	CAPT R.B. Pettit, USN
USS TALLADEGA (APA 208)	CAPT J.F. Davis, USN
USS POINT DEFIANCE (LSD 31)	CAPT W.W. Graham, USN
USS MARS (AFS 1)	CAPT R.C. Medley, USN
(Det 47, HELSUPPRON 1 embarked)	LCDR W.D. Dobbs, USN.
USS CARTER HALL (LSD 3)	CDR C.J. Casserky, USN
USS COGSWELL (DD 651)	CDR O.G. Baird, USN
LCU 1495	A.A. Wessel, BMC, USN

Personnel Assigned TAD or Otherwise Assisting at the Scene

TF 73/SERVGRU THREE

CAPT K.R. Dresser, USN	Maintenance Officer
LCDR J.H. Boyd, USN	Salvage Officer
LT. M.W. Freiberg, USN	OPS/COMM Officer

Miscellaneous Commands

CAPT W. A. Walker III, USN	COMSERVRON FIVE
CAPT W. L. Marshall, USN	CO, SRF GUAM
CDR E.B. Mitchell, USN	Fleet Salvage Officer
LCDR C.K. Naylor, USN	CO, EODU I

SRF SUBIC

CWO W.D. Thomas, USN	COMNAVPHIL Salvage Officer
R.M. McKenzie, SFC (DV), USN	SRF SUBIC
R.J. Smeller, BMC (DV), USN	SRF SUBIC
T.J. Bennett, HMC (DV), USN	SRF SUBIC

Provided by BUSHIPS for Training

LT L.C. Gies, USN
LT D.H. Hines, USN
LT W.N. Klorig, USN
LT H.A. Moore, USN
LT A.F. Pyatt, USN

Provided for Technical Assistance During Foam Operation

CAPT Nelson Hiller	Merritt Chapman and Scott Corp.
Mr. Alex Rynecki	Murphy-Pacific Marine Salvage Company
Mr. Dwain Aasved	Murphy-Pacific Marine Salvage Company
Mr. Wayne O. MacDonell	Murphy-Pacific Marine Salvage Company
Mr. Tom Laumann	Murphy-Pacific Marine Salvage Company
Mr. Dick Wilkins	Murphy-Pacific Marine Salvage Company