UNCLASSIFIED

AD NUMBER
AD367467

CLASSIFICATION CHANGES	
TO:	unclassified
FROM:	confidential

LIMITATION CHANGES

TO:

Approved for public release, distribution unlimited

FROM:

Distribution: USGO: others to Director, Defense Atomic Support Agency, Washington, D. C. 20301.

AUTHORITY

DSWA ltr., 18 Apr 1997; DSWA ltr., 18 Apr 1997

THIS PAGE IS UNCLASSIFIED

XRD 109 (14) XRD-109

CONFIDENTIAL
Security Information

(9) BUREAU OF SHIPS [redacted] (1)

TECHNICAL INSPECTION REP[redacted]T.

CONFIDENTIAL
Security Information

Classification (Cancelled) (Changed to ________ DATED 18 APRIL 1949
By Authority of JOINT CHIEFS OF STAFF JCS 1795/36
By John H. Doyette Date 23 SEP 1953

367467

(6) OPERATION CROSSROADS.

U.S.S. SKIPJACK (SS 184).

TEST BAKER.

(8)

VOLUME 1 [redacted]

U. S. GOVERNMENT AGENCIES MAY OBTAIN COPIES OF THIS REPORT DIRECTLY FROM DDC. OTHER QUALIFIED DDC USERS SHALL REQUEST THROUGH

Director
Defense Atomic Support Agency
Washington, D. C. 20301

(11) 1947,
(12) 141p.

CONFIDENTIAL
Security Information

OPERATION CROSSROADS

[redacted]

DIRECTOR OF SHIP MATERIA[redacted]

JOINT TASK FORCE ONE

GROUP-3
Downgraded at 3 year intervals; Not automatically declassified. 1 JAN 1965

DDC RECEIVED DEC 2 1965 TISIA E

[redacted] CONFIDENTIAL

REG. NO. 58

7123

CONFIDENTIAL

BUREAU OF SHIPS GROUP

TECHNICAL INSPECTION REPORT

U. S. GOVERNMENT AGENCIES MAY OBTAIN COPIES OF THIS REPORT DIRECTLY FROM DDC. OTHER QUALIFIED DDC USERS SHALL REQUEST THROUGH

Director
Defense Atomic Support Agency
Washington, D. C. 20301

"This document contains information affecting the National Defense of the United States within the meaning of the Espionage Laws, Title 18, U. S. C., Section 793 and 794. Its transmission or the revelation of its contents in any manner to an unauthorzied person is prohibited by law."

SUBMITTED:

C. L. Gaasterland,
Commander, U.S.N.

APPROVED:

F. X. Forest,
Captain, U.S.N.

SECRET

USS SKIPJACK (SS184)

Page 1 of 141 Pages

GROUP-3 1 JAN 1965
Downgraded at [illegible] intervals;
Not automatically declassified.

CONFIDENTIAL

TABLE OF CONTENTS

PAGE NO.

VOLUME I

Ship Characteristics Sheet - - - - - - - - - - - - - - 3

Midship Section - - - - - - - - - - - - - - - - - 4

Overall Summary of Damage - - - - - - - - - - - - 5

Hull Technical Inspection Report (Section I) - - - - 10

Machinery Technical Inspection Report (Section II) - 91

Electrical Technical Inspection Report (Section III) - 118

VOLUME II

Photographic Section - - - - - - - - - - - - - - - 2

U.S.S. SKIPJACK (SS184)

SHIP CHARACTERISTICS

Building Yard: Electric Boat Company

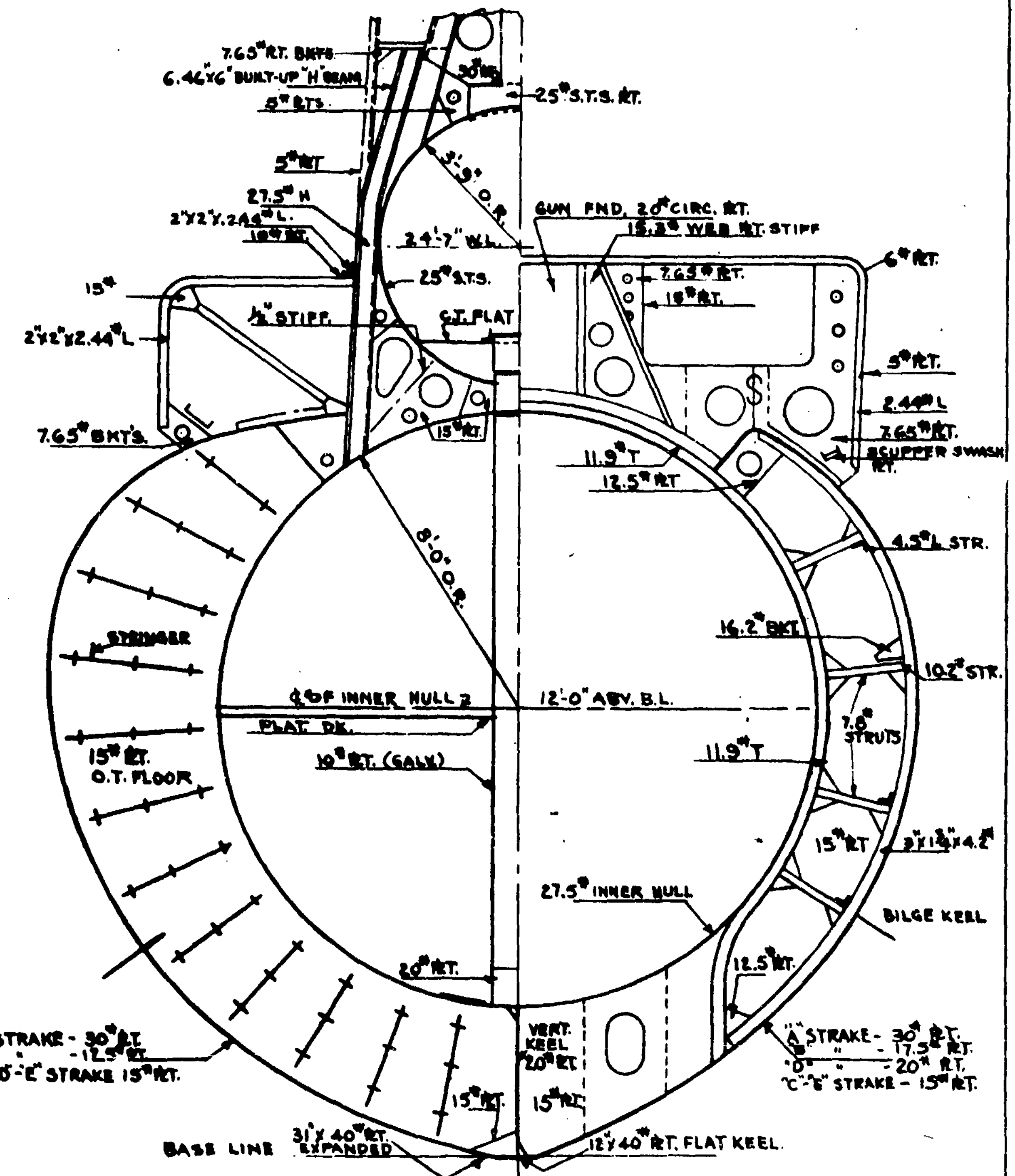
Commissioned: 30 June 1938.

HULL

Light Hull Construction.
Length Overall: 308 feet.
Length (between perpendiculars): 300 feet 0 inches.
Beam (extreme): 26 feet 1 7/8 inches.
Beam (molded 25 feet 7 inches.
Height (lowest point of keel to top of periscope supports): 43 feet 5 1/2 inches.
Drafts (at time of test): Submerged.
Standard Displacement: 1435 tons.
Displacement (at time of test): 2229 tons.

MAIN PROPULSION PLANT

Main Engines: Four General Motors, 16 cylinder, Type 16-278A.
Auxiliary Engine: General Motors, 8 cylinder, Type 8-241.
Main Motors and Generators: Elliott.
Main Storage Battery: Gould.
Main Controls: Cutler-Hammer.
Reduction Gears: Farrell-Birmingham.
Composite Drive.



FRAME 71
LOOKING FORWARD

FRAME 49
LOOKING FORWARD

TEST B

TECHNICAL INSPECTION REPORT

OVERALL SUMMARY

I. Target Condition After Test.

(a) Drafts after test; list; general areas of flooding, sources.

The SKIPJACK was submerged for test B in 30 fathoms of water to a keel d pth of approximately 85 feet. The relative bearing to the bomb was about 270°, and the range about 800 yards. After test B the ship was found on the bottom with all compartments flooded. The major sources of flooding were a 20" x 1" rupture of the shell plating at frame 30 and the torpedo tubes. Compartments other than the torpedo rooms flooded slowly via damaged or partially opened fittings and by progressive flooding through leaks in the main bulkheads.

(b) Structural damage.

The circular hull plating is generally dimpled (up to a maximum depth of 2 1/2 inches), but predominantly on the port side. Distortion of the circular hull frames had just started. The major damage was confined to the single hull sections at either end of the ship where severe frame distortions (up to 8 1/2 inches) and one rupture of the shell plating were found. Dimpling of the single hull plating between frames is severe on the port side and moderate on the starboard side. The performance of structural welding was exceptionally good. Only three minor failures were found.

(c) Other damage.

Nearly all equipment within the ship was incapacitated by flooding, shock or hull distortion. The superstructure and main deck were moderately damaged. The torpedo tubes were all put out of action by distortions of the barrels and failure of the fittings. Gaskets were blown out of nearly all of the main ballast tank emergency vent valves and bulkhead ventilation flappers, and the vent risers and flood valves were severely damaged.

All machinery and equipment was inoperable except for hand power steering when the ship was surfaced, due mainly to salt water damage and misalignment of foundations incident to structural deformations. Main and auxiliary machinery received small direct primary damage as a result of the bomb, this damage being limited to isolated cases of broken or cracked castings.

Practically all electrical equipment was rendered inoperable due to flooding of all compartments. Considerable corrosion due to electrolysis occurred, particularly on exposed copper parts. Even if flooding could have been controlled, the electrical damage due to shock was severe enough to render the propulsion system inoperable, and seriously impair ship control and fire control. However, sufficient temporary repairs probably could have been effected by the ships crew to permit emergency operation of major electric equipment except where hull and machinery damage would have prevented operation.

All electronic equipment was flooded. The QC-JK, QB and NM sound heads had ruptured diaphragms.

II. Forces Evidenced and Effects Noted.

(a) Heat.

There was no evidence of heat.

(b) Fires and explosions.

Secondary electrical fires resulted from flooding of the vessel with salt water. These were confined to the shore connection junction boxes in the pump room. There is no evidence of an explosion.

(c) Shock.

There is plentiful evidence that the vessel was subjected to severe shock. Several castings cracked in areas where the hull distortion was negligible. Numerous items of electrical and other equipment were thrown out of their housings, and foundation bolts were generally loose, stretched, bent or broken.

(d) Pressure.

The distortions of the pressure hull are convincing evidence of extreme pressures. The "Coordinator's Report on Air Blast and Water Shock, tests A and B" of 27 September 1946 indicates the pressures wave attained a value of approximately 1150 p.s.i.

(e) Effects apparently peculiar to the atom bomb.

In confined spaces, such as the vent risers from the ballast tanks, there is evidence that (1) the pressure within the space was built up to a higher value than the ambient pressure or (2) the ambient pressure wave passed on, leaving a relatively high pressure within the space for a short time longer. For example, the vent risers, which were open at one end, split along their seams, apparently as a result of excessive internal pressure. This phenomenon was common during the air burst of test A, and appears to have a counterpart under water.

Radioactivity was more pronounced in this vessel than in the other submerged submarines. This phenomena is under study in the San Francisco area.

III. Results of Test on Target.

(a) Effect on propulsion and ship control.

Nearly all such items were placed out of commission by flooding, shock and hull distortion. Had the ship been manned, ships force may have been able to effect temporary repairs to permit limited emergency operation.

(b) Effect on gunnery and fire control.

Gunnery and fire control equipment was generally damaged by flooding, shock and hull distortion. Major damage was caused by flooding.

(c) Effect on watertight integrity and stability.

The watertight integrity was completely destroyed although there was only one major breach in the hull. Small leaks accounted for the flooding of all compartments except the forward torpedo room.

With all compartments flooded the center of gravity moves up approximately 0.7 feet which reduces the initial stability approximately 70% from the normal submerged condition.

(d) Effect on personnel and habitability.

Habitability completely destroyed. The effect on personnel is difficult to evaluate since no personnel were aboard; however, it is estimated that all personnel in the forward torpedo room would have been lost from flooding since that was the only compartment in which the pressure hull was ruptured. It is further estimated that had personnel in other compartments survived the effects of shock and the immediate possible effects of radioactivity, they could have prevented the complete flooding of the ship and possibly brought her to the surface.

(e) Total effect on fighting efficiency.

Assuming the ship had not sunk, due to the efforts of an alert crew, the fighting efficiency would nevertheless be negligible. She could not submerge, it is doubtful if the screws would turn over, and no torpedo tubes were operative.

IV. General Summary of Observers' Impressions and Conclusions.

It is apparent that the SKIPJACK was subjected to a pressure wave of great severity. It is believed that reflections caused local peaks of even higher pressure. The circular hull is more resistant to such an attack than the non-circular hull. The non-circular parts of the ships were damaged to such an extent that a complete collapse must have been imminent. Despite these severe distortions, the structural welding was almost 100% intact and only the forward torpedo room would have flooded had there been no failure of fittings.

From damage to the SKIPJACK and also to the APOGON, it is concluded that the lethal range of an underwater explosion of an atom bomb of the type used in test B is in the order of 950 yards.

V. Preliminary Recommendations.

It is considered that the SKIPJACK should be retained for further detailed study at such times as new designs of features found in this ship are being prepared. Ideally, the ship should be placed on dry land in the vicinity of the leading submarine design agency.

While detailed recommendations are contained in the following sections of this report, the following general suggestions are considered to be of major importance.

(1) The single hull type of construction should be eliminated or greatly strengthened. Instead of the strongest, it is the weakest part of the structure against such an attack. Investigations of the measure of protection provided by the outer shell, of the effect of the proximity of rigid and relatively flexible structure and a review of the physical properties of the various steels and welds available for hull construction should be undertaken in the light of what has been learned regarding atomic bomb underwater explosions.

(2) The distribution of the damage to the pressure hull of the SKIPJACK lends support to the suggestion, made in the Bureau of Ships Technical Inspection Report on the USS SKATE for test A, namely to extend the side tanks up over the top of the hull. It now appears that such a structure would not only improve the resistance to damage from an atomic air explosion and protect personnel from neutron radiation, but would also even out the peaks in the underwater pressure wave.

(3) The standard of fittings affecting watertight integrity must be improved, particularly access hatches and valves, and particularly with regard to gaskets.

(4) The method of mounting equipment to bulkheads and on foundations should be improved so as to minimize shock failures of securing bolts, welded joints and supports.

TECHNICAL INSPECTION REPORT

SECTION I - HULL

GENERAL SUMMARY OF HULL DAMAGE

I. Target Condition After Test.

(a) Drafts after test; list; general areas of flooding, sources.

The SKIPJACK was submerged for test B in 30 fathoms of water to a keel depth of approximately 85 feet. The relative bearing to the bomb was about 270°, and the range about 800 yards. After test B the ship was found on the bottom with all compartments flooded. The major sources of flooding was a 20'' x 1'' rupture of the shell plating at frame 30 and the torpedo tubes. Compartments other than the torpedo rooms flooded slowly via damaged or partially opened fittings and by progressive flooding through leaks in the main bulkheads.

(b) Structural damage.

The circular hull plating is generally dimpled (up to a maximum depth of 2 1/2 inches), but predominantly on the port side. Distortion of the circular hull frames had just started. The major damage was confined to the single hull sections at either end of the ship where severe frame distortions (up to 8 1/2 inches) and one rupture of the shell plating were found. Dimpling of the single hull plating between frames is severe on the port side and moderate on the starboard side. The performance of structural welding was exceptionally good. Only three minor failures were found.

(c) Other damage.

Nearly all equipment within the ship was incapacitated by flooding, shock or hull distortion. The superstructure and main deck were moderately damaged. The torpedo tubes were all put out of action by distortions of the barrels and failure of the fittings. Gaskets were blown out of nearly all the main ballast tank emergency vent valves and bulkhead ventilation flappers, and the vent risers and flood valves were severely damaged.

II. Forces Evidenced and Effects Noted.

(a) Heat.

There is no evidence of heat.

(b) Fires and explosions.

One or two electrical short-circuits resulted in local fires or heat damage. There is no evidence of an explosion.

(c) Shock.

There is plentiful evidence that the vessel was subjected to severe shock. Several castings cracked in areas where the hull distortion was negligible. Numerous items of electrical and other equipment were thrown out of their housings, and foundation bolts were generally loose, stretched, bent or broken.

(d) Pressure.

The distortions of the pressure hull are convincing evidence of extreme pressures. The "Coordinator's Report on Air Blast and Water Shock, tests A and B" of 27 September indicates the pressures wave attained a value of approximately 1150 p.s.i.

(e) Effect apparently peculiar to the atom bomb.

In confined spaces, such as the vent risers from the ballast tanks, there is evidence that (1) the pressure within the space was built up to a higher value than the ambient pressure or (2) the ambient pressure wave passed on, leaving a relatively high pressure within the space for a short time longer. For example, the vent risers, which were open at one end, split among their seams, apparently as a result of excessive internal pressure. This phenomenon was common during the air burst of test A, and appears to have a counterpart under water.

III. Effects of Damage.

(a) Effect on machinery, electrical and ship control.

Nearly all such items were placed out of commission by flooding, shock and hull distortion. No detailed observations were made.

(b) Effect on gunnery and fire control.

Gunnery and fire control equipment was generally damaged by flooding, shock and hull distortion. No detailed observations were made.

(c) Effect on watertight integrity and stability.

The watertight integrity was completely destroyed although there was only one major breach in the hull. Small leaks accounted for the flooding of all compartments except the forward torpedo room.

With all compartments flooded the center of gravity moves up approximately 0.7 feet which reduces the initial stability approximately 70% from the normal submerged condition.

(d) Effect on personnel and habitability.

It is estimated that all flooding except that of the forward torpedo room could have been controlled. Assuming prompt action on the part of the crew, and no interference from an enemy on the surface, the SKIPJACK might have been blown to the surface where the hole in the forward torpedo room would have been above the water line. In this event, the casualties should not have been greater than 15%, disregarding radiological effects. After restoring equipment to its normal location, the ship, had it not sunk, would have been habitable for emergency condition. However, the equipment would have required extensive repairs before the ship could be considered habitable in the usual sense.

(e) Effect on fighting efficiency.

Assuming the ship had not sunk, due to the efforts of an alert crew, the fighting efficiency would nevertheless be negligible. She could not submerge, it is doubtful if the screws would turn over, and no torpedo tubes were operative.

IV. General Summary of Observers' Impressions and Conclusions.

It is apparent that the SKIPJACK was subjected to a pressure wave of great severity. It is believed that reflections caused local peaks of even higher pressure. The circular hull is more resistant to such an attack than the non-circular hull. The non-circular parts of the ships were damaged to such an extent that a complete collapse must have been imminent. Despite these severe distortions, the structural welding was almost 100% intact and only the forward torpedo room would have flooded if there had been no failure of fittings.

V. Preliminary Recommendations.

It is considered that the SKIPJACK should be retained for further detailed study at such times as new esigns of features found in this ship are being prepared. Ideally, the ship should be placed on dry land in the vicinity of the leading submarine design agency.

While detailed recommendations are contained in the following sections of this report, the following general suggestions are considered to be of major importance.

(1) The single hull type of construction should be eliminated or greatly strengthened. Instead of the strongest, it is the weakest part of the structure against such an attack. Investigations of the measure of protection provided by the outer shell, of the effect of the proximity of rigid and relatively flexible structure and a review of the physical properties of the various steels and welds available for hull construction should be undertaken in the light of what has been learned regarding atomic bomb underwater explosions.

(2) The distribution of the damage to the pressure hull of the SKIPJACK lends support to the suggestion, made in the Bureau of Ships Technical Inspection Report on the USS SKATE for test A, namely to extend the side tanks up over the top of the hull. It now appears that such a structure would not only improve the resistance to damage from an atomic air explosion and protect personnel from neutron radiation, but would also even out the peaks in the under water pressure wave.

(3) The standard of fittings affecting watertight integrity must be improved, particularly access hatches and valves, and particularly with regard to gaskets.

DETAILED DESCRIPTION OF HULL DAMAGE

A. General Description of Hull Damage.

(a) Overall condition of vessel.

The ship was sunk and all compartments were eventually flooded. The general damage is severe. The fighting efficiency was reduced to almost zero and it is probable that even with a crew on board, she would have been lost.

(b) General areas of hull damage.

The pressure hull and outside tank structure was generally dented and distorted from bow to stern. There was more damage on the port than on the starboard side. The most severe distortions were located in the single hull non-circular structure at both ends of the ship. Frame 176 had the greatest permanent deflection, amounting to 8 1/2 inches in from the molded line. The one break in the pressure hull plating was located at frame 30, on top of the torpedo room.

(c) Principle areas of flooding with sources.

All compartments were flooded. The forward torpedo room flooded via the break in the plating at frame 30. The remaining compartments flooded slowly via the various fittings which are listed in Item L below.

(d) Residual strength, buoyancy and effect of general condition of hull on operability.

Although the hull resisted collapse underwater pressure at 30 fathoms, for all practical purposes the hull is unfit for diving and the ship has no residual strength. All buoyancy and operability were destroyed.

B. Superstructure and Weather decks.

(a) Description of damage and causes.

All topside structure on this ship was well corroded prior to the test. In addition, considerable unavoidable damage was done during salvage, particularly to the deck and fittings. Consequently, in many cases it is difficult to identify the cause of damage. Such damage as can definitely be attributed to the bomb is discussed herein. It is more or less evenly distributed throughout the length and on both sides of the topside structure. The damage appears to be the result of an overall pressure on the outboard surfaces tending to crush the structure in toward the hull. The deck and sideplating is moderately but generally distorted with local areas of more serious damage as described below. The displacements of this general distortion are of the order of magnitude of one to three inches, sufficient to make some of the salvage fittings inaccessible and to cause buckling and failure of some of the superstructure and deck supporting brackets. A large number of fittings, such as stanchions and cleats have been torn loose or badly bent, but in no case is this type of damage definitely traceable to the bomb and detailed descriptions are therefore omitted.

1. In the region forward of the conning tower fairwater there is one localized area of relatively severe damage. The 3" x 3" angle forming the deck stringer at frame 30 failed completely through a butt weld near the deck edge, thus permitting fracture of four wooden deck strakes between frames 29 and 31. Photograph on page 2 of Volume II shows this damage, which is particularly significant because it is directly above an area of intensified damage to the hull plating and the structure between the hull and the deck. Photograph on page 3 of Volume II shows the buckled angle and channels which form the deck supports at frames 30 and 31, port. Numerous weld failures occurred at the foot of these supports, particularly the channel at frame 29. This photograph also shows the collapse of the pressure proof stowage tub at frame 30, the dishing of the pressure hull plating between frames 30 and 31 and the underwater weld which repaired the rupture in the shell plate at the after edge of frame 30. Judging from the concentration and degree of damage it appears that the pressure was somewhat intensified in this area. The reason for

such intensification is not apparent. Similar buckling and welding failures in the deck supporting beams, but less severe, occurred throughout the superstructure, particularly in way of the forward torpedo room. Photograph on page 4 of Volume II shows a typical buckled bracket frame, the one shown being at frame 34, port. It is possible that the compression failures of deck supports were accentuated by momentary elongation of the vertical axis of the hull in way of the forward torpedo room.

The superstructure bulkhead at frame 10 is slightly wrinkled and distorted while that at frame 28 is bulged forward and has a few small tears in welds as a result of compression loading. The bulkhead at frame 60 is torn loose at the bottom weld from the centerline to its outer port edge. The port half of the bulkhead is bulged and displaced forward about six inches. This damage is also believed to be due to compression loading, and is shown in photograph on page 5 of Volume II.

2. The conning tower fairwater is lightly wrinkled and distorted in way of the light plating at the after end. The heavier S.T.S. bridge protection plate does not appear to have been distorted or damaged.

3. In the superstructure aft of the conning tower fairwater the only area of severe damage is between frame 173 and 179. Photograph on page 6 of Volume II shows the collapsed deck. Although there is no evidence to support such a theory, a heavy piece of structure blown through the air from another ship, or perhaps a large piece of coral, could have caused the damage. However, it appears more likely that sudden water pressure caused the collapse of the deck which in this area was somewhat weak due to the presence of an access hatch.

(b) Evidence of fire.

None.

(c) Estimate of relative effectiveness against pressure.

Such damage as occurred was general. There is no basis for differentiating between plating of different thicknesses, shapes, covering or angles of attack. The 20 pound S.T.S. around the bridge is not damaged.

(d) Constructive criticism.

There is no doubt but that the metal parts of the superstructure and main deck of the SKIPJACK were too weak to withstand the attack successfully. While none of the damage in this region would have vitally affected the peace-time operation of the ship, the loose structure would have unquestionably made the ship too noisy for submerged action in wartime. It is believed that even in the uncorroded condition the structure is sufficiently light to be susceptible to this type of damage. The problem appears to be subject to the same solution as suggested in the report of test A damage to the USS SKATE: (1) reduce the extent of topside structure to the absolute minimum and (2) increase the weight of the plating and the strength of the supports, particularly at the welds. The wooden deck strakes which, on the SKIPJACK, extend the entire length of the deck, withstood the attack satisfactorily except where the members supporting them failed.

C. Turrets, Guns and Directors.

(a) Guns.

There were no guns mounted for the test. The five inch foundations fore and aft are in good condition with no visible damage. The deck to which the forward 20 mm gun mount is bolted is distorted, giving the mount a downward inclination at the after end. The foundation for the after 20 mm gun is slightly distorted. However, it is believed that 20 mm guns could be fired from both foundations without appreciable difficulty.

(b) Target bearing transmitter foundations.

There were no target bearing transmitters mounted for the test. The two foundations appear to be undamaged.

(c) Periscopes and radar masts.

Only the after periscope was installed for the test This was serial 1248, designation 92KA 40/1.9. When it was pulled (21 November), the lower section jammed in the bearings and a three ton pull was required to remove the periscope. The periscope tube was checked and found to be out of line only 0.015 inch. The nitrogen had leaked out and considerable water had entered the periscope. The optical surfaces were ruined, apparently by the action of salt water. The head prism was shattered and the power shift and stadimeter mechanism were inoperative, probably as a result of corrosion.

An internal pressure test of the periscope disclosed no significant leaks up to 130 p.s.i.. A very small leak was found in the focusing stuffing box but it is not believed to have been the source of flooding.

The periscope was covered with rust preventative compound, boxed and lashed to the deck of the SKIPJACK.

After pulling the periscope the two top bearings show evidence of hard rubbing on the starboard side. Other than this, the periscope shears and foundations show no indications of damage.

As a check on mast straightness and bearing alignment, the SJ mast was rotated and the SD mast hoisted by improvised means. There was no indication of damage to the masts, bearings or supports.

(d) Constructive criticism.

None.

D. Torpedo Tubes and Appurtenances.

(a) Tubes.

1. All torpedo tubes were seriously damaged by the blast. None retained any effective watertight integrity. The muzzle doors and poppet emergency stop valves were open by varying amounts up to one turn. Nearly all breech and muzzle door gaskets (smooth type, seating on a bead) were damaged, and all after roller drain lines for 'B' roller were broken off in the threads of the

copper nipples as a result of the upward deflection of the hull under the after tubes.

Photographs on pages 7 to 14 of Volume II show the breech doors and their damaged gaskets. Some had been forced partly out of the grooves and all were cut or torn. The muzzle door gaskets were in almost identical condition.

After replacing door gaskets on tubes 1, 3, 5, 6, 7, and 8 and plugging the roller drains on tubes 5, 6, 7 and 8, a 5 p.s.i. internal air test was applied for 10 minutes with the following results.

Tube No.	1	2	3	4	5	6	7	8
Drop in oz.	0	16	0	16	0	0	0	24

Both tube nests were boresighted and found to be cocked slightly to port. The angle of the forward nest with the original centerline of the forward torpedo room is 0° - 5', and that of the after torpedo room is 0° - 6'. There is no evidence of bulkhead distortion around the torpedo tube supporting rings.

Due to the severe hull deformation beneath the after tubes, the support pedestal for tubes 7 and 8 was pushed up with sufficient force to dent these two tubes. See photographs on pages 15 and 16. An attempt was made to pass a bore gage 21.080 inches in diameter through the remaining tubes but there was a distortion in each tube near the muzzle. The distances from the muzzle at which the gage jammed were:

Tube No.	1	2	3	4	5	6
Inches.	18	42	7	4	18	72

For micrometer readings of the torpedo tube barrels see Bureau of Ordnance Technical Report.

The interlock mechanisms on all tubes are operable but the drain valves on all tubes except number 4 are inoperable by reason of excessive corrosion or misalignment of the shafts and levers.

Muzzle door clearance measurements on all tubes were satisfactory. The shutters had been welded in place prior to Operation Crossroads and had to be cut away in order to examine the tubes.

2. All torpedo tubes were out of action as a result of the bomb damage listed above.

(b) Cradles and loading gear.

The torpedo stowage facilities in both forward and after rooms were badly damaged by shock and hull distortion.

The cradle supports moved inboard with the hull so that the portable crossrails had to be shortened from 1 to 4 inches in order to be used for unloading the torpedos. As a result of this inward displacement and the distortion of the tank tops for main ballast tanks numbers one and three, the portion of the cradle supports which form the rails were misplaced by the following amounts (inches):

Tube No.	Fwd. Track	Middle Track	After Track
1	1 1/4 Low	1/2 low	1/2 low
2	1 1/8 low	5/16 low	Badly bent
3	1/16 low	3/4 high	1 1/16 high
4	1/16 high	5/8 high	1 5/16 high
5	3/4 low	1/16 low	21/32 low
6	3/8 low	5/8 low	3/4 low
7	1/32 low	7/32 low	3/16 low
8	7/16 low	9/32 low	1/2 low

All cradles locking bars were bent or broken and nearly all cradles were slightly twisted or distorted from the shock. Two cradles securing straps were parted in the forward torpedo room.

The torpedoes were secured in the cradles with only one securing strap each. No straps were broken, but the battery compartment of one torpedo in a starboard cradle of each room was dented by the strap. Other damage to torpedoes and war heads is discussed in [illegible]reau of Ordnance Technical Report.

The after topside torpedo loading skid was thrown overboard by the blast.

(c) Air flasks and war heads.

The forward torpedo impulse flasks are secured to the superstructure in a vertical position and the after flasks lay horizontally on the outside of the pressure hull under the superstructure. All flasks impulse firing piping, hull and emergency stop valves are intact but the valves are stiff. The flask for tubes number 4 and 5 were left charged to 300 p.s.i. for the test with the hull and emergency stops open. Examination at Mare Island showed the two flasks to be completely discharged but there was no way of determining whether the firing valves had lifted.

A hydrostatic test of the impulse flasks disclosed a small leak at the hull gasket of tubes 1, 2, 3, 4 and 7. Tube No. 5 had a slight leak through the gasket for the hull valve bonnet and tubes No. 6 and 8 showed no drop.

The after impulse flasks were severely jolted and there are gaps of approximately 1 inch between the flasks and their securing straps. Photograph on page 17 of Volume II shows how the flanged portions of the straps opened and the connecting bolts bent. This same type of failure was found on the securing straps for the air flasks in the ballast tanks.

(d) Constructive criticism.

1. The securing straps for the impulse flasks are designed so as to throw a bending movement on the bolts when load is applied. Nearly every strap of this design throughout the ship showed the same type of failure as indicated in photograph on page 17 of Volume II. A more effective strap would result if the design were such that the load is applied in line with the axis of the bolt or other fastening.

2. In those designs of submarines where the torpedo room flat does not form the pressure boundary of an outside tank, it is proposed that the torpedo stowage be supported principally from

the flat rather than the hull, since the distortion (elastic or plastic) of the hull can normally be expected to be much greater than that of the flat. The upper portion of the stowage could be braced to the hull through a shock absorbing fitting, perhaps with a portable rigid spacer for exact alignment during loading. It might be desirable to shock mount the entire stowage as was done by the Germans on the type XXI submarine.

3. The torpedo cradles on both SKIPJACK and SKATE were thoroughly jammed by bent broken cradles locking bars. It is suggested that these bars be strengthened or that new design, less susceptible to damage from shock, be adopted. Stronger strapping arrangements are also indicated.

4. Unfortunately, the rubber gaskets on the SKIPJACK are not of the latest design. The damage to the torpedo tube door gaskets (as well as those in other parts of the ship) confirms the decision to abandon the dove tail shape. Even the 'T' shaped gaskets that have a flat surface seating against a lip of small radius were, in general, torn by pressure. It is suggested that the behavior of the present 'lip' type gaskets under similiar conditions of severe loading be investigated further, and that a more effective gasket be installed in the breech doors of torpedo or other types of tubes.

5. The need for abandoning threaded nipples, which has been previously recognized, is emphasized by the SKIPJACK damage to the roller drains.

E. Weather Deck.

Combined with Item B.

F. Exterior Hull Above and Below Waterline.

(a) Condition and causes of damage to:

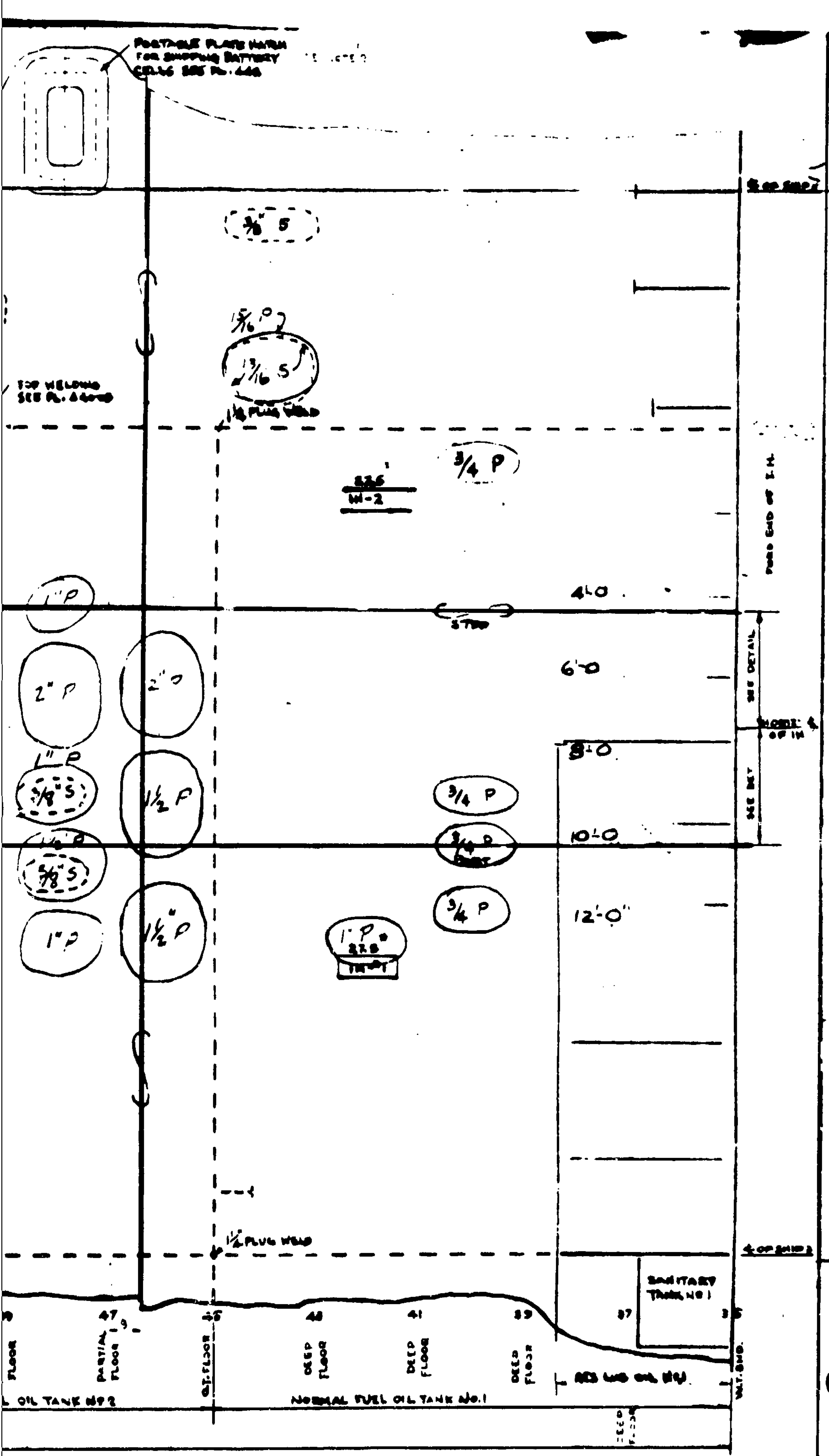
1. Circular hull plating and framing.

The drawing on page 24 is an inner shell expansion plan, marked to show the shape, location and depth of the dimples on the port and starboard sides of the circular hull. The solid lines indicate dimples on the port side and the dotted lines indicate dimples on the starboard side. The depth (in inches) of each dimple, measured with reference to the two adjacent frames, is marked in or near each dimple. The numerous dimples less than 1/4" deep were not recorded.

The port side of the inner hull shows more damage than the starboard side, and the depth of the dimples in the plating is generally greatest in the region at or below the longitudinal axis of the circular hull. The maximum depth of any dimple is 2 1/2" and the maximum length is 30 inches, the distance between frames. The most frequently observed pattern of dimples is an approximate horizontal line. Examples of these dimples are shown in the photographs on pages 18, 19 and 20 of Volume II.

Considering the longitudinal distribution of damage to the inner hull plating, the dimpling is principally concentrated between frames 45 to 71, port and frames 133 to 145, port. Frames 45 to 71 are in way of normal fuel oil tank number 2 and fuel ballast tanks 4 and 6. Frames 133 to 145 are in way of the expansion tank and normal fuel oil tank number 11. The middle section and the two extreme ends of the circular hull sufferred much less than the regions mentioned above.

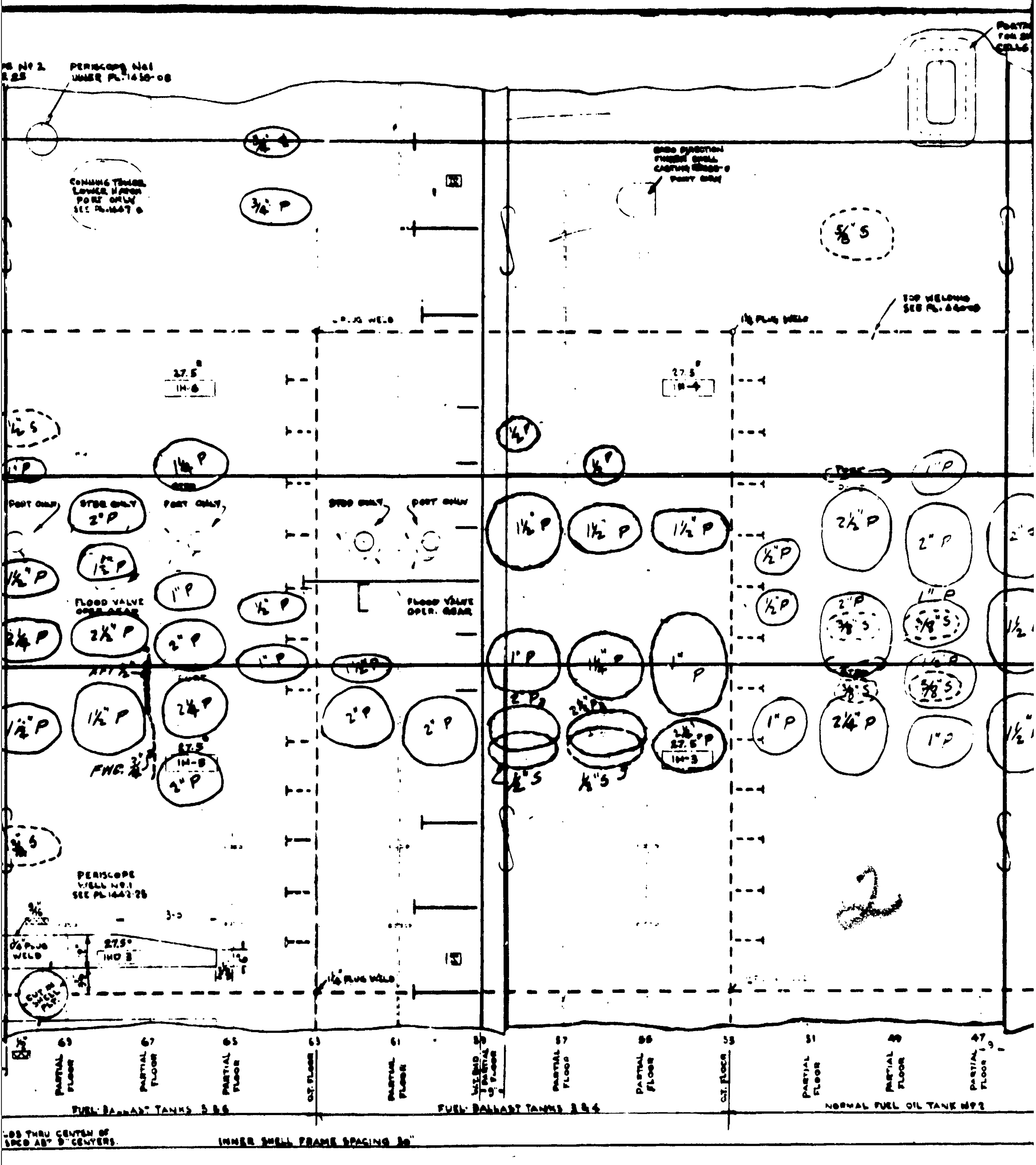
Incipient frame deformation occurred throughout the more severely dimpled areas of the inner hull. In all instances where frame distortion is in evidence, the web of the 'T'frame has pulled toward the center of a deeply dimpled area, pulling the face plate of the frame out of line. Examples of the above type of frame failure are as follows: At frame 67, port side, this distortion is 3/4" in a forward direction and 1/2" in an aft direction within a vertical distance of about 30". Frame 139 has pulled forward approximately 1/2" in way of a 2" dimple in the inner hull between frame 137 and 139. Frame 141 has pulled aft 1/4" in way of a 2 1/2" dimple in the inner hull between frames 141 and 143. At frame 143 the distortion is 3/8" forward in way of a 2 1/2" dimple in the inner hull between frames 141 and 143, and just above this it is pulled 1/2" aft in way of a 2 1/2" dimple between frames 143 and 145.



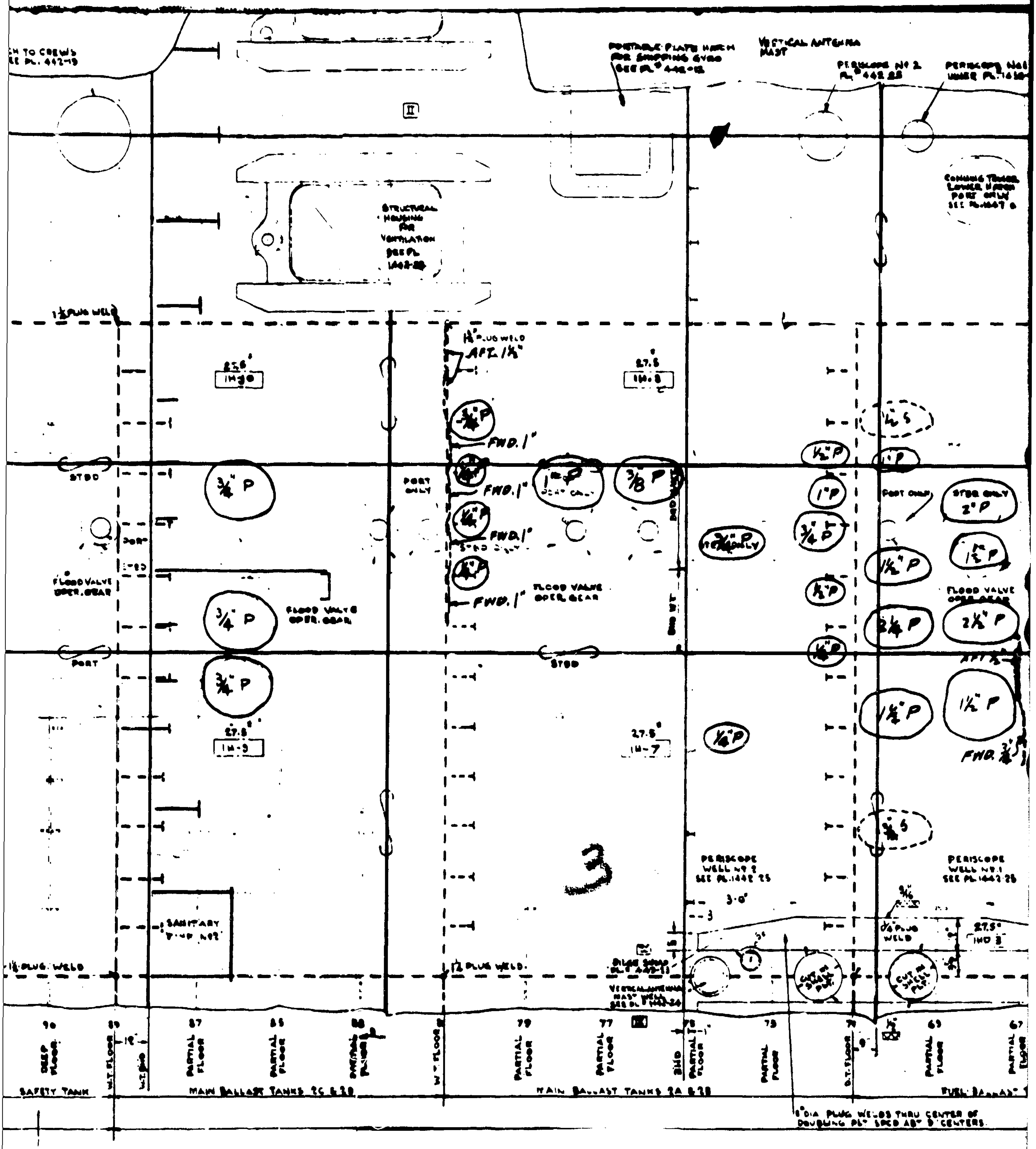
DIMPLES IN CIRCULAR HULL PLATING

(MARKED ON INNER PLATING)

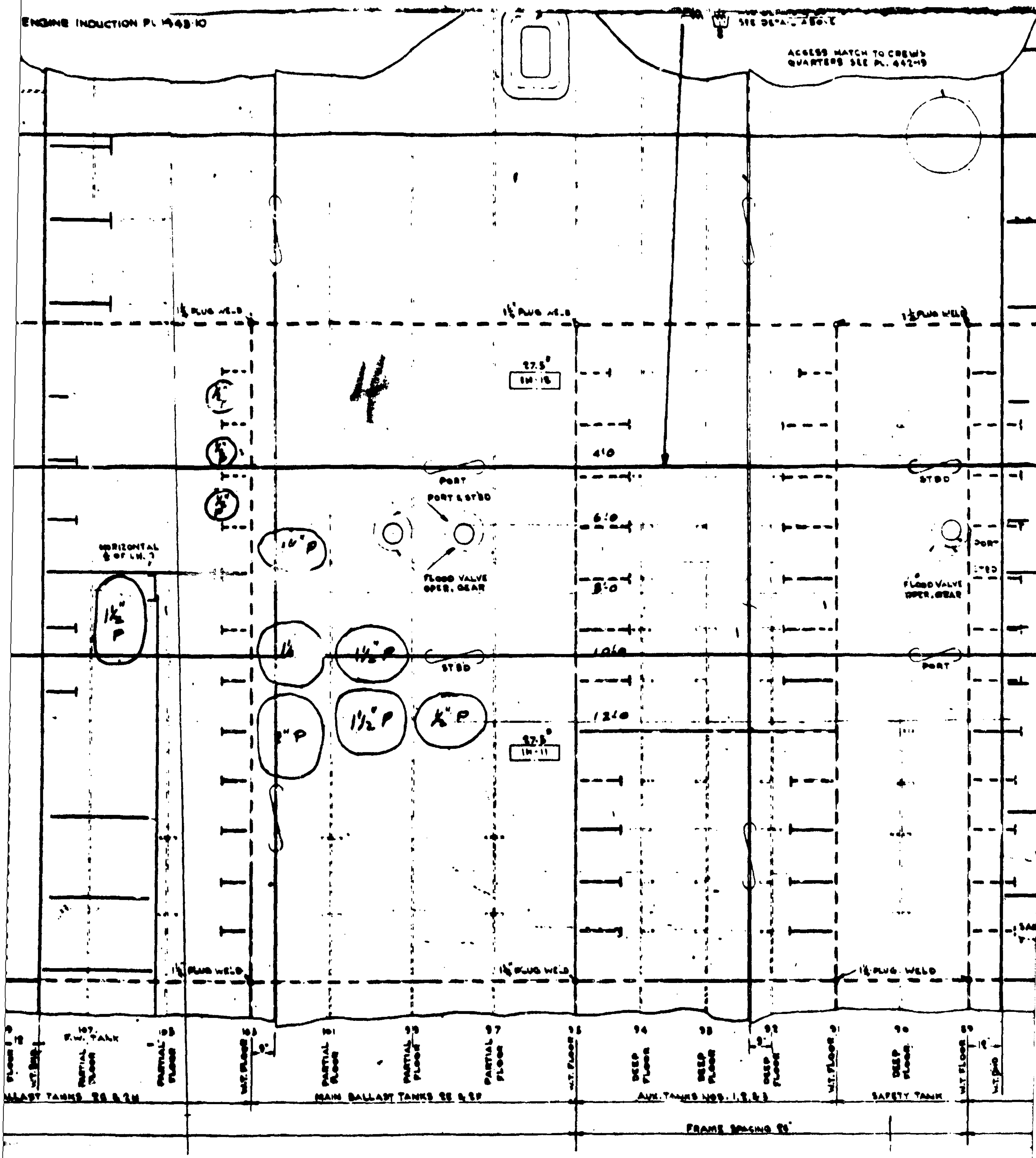
SECRET U.S.S. SKIPJACK(SS184)



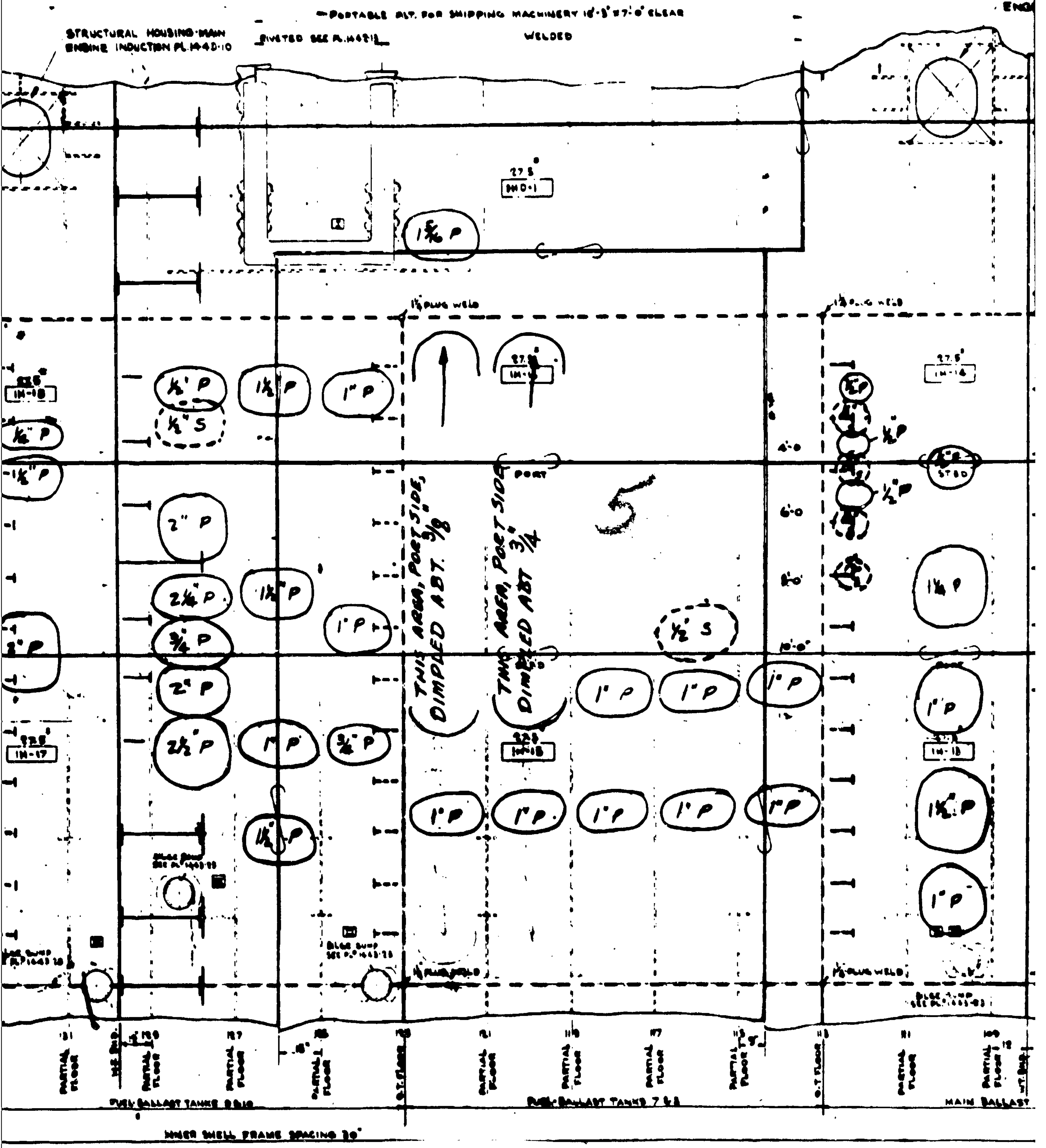
CONNING TOWER LOWER HATCH PORT ONLY
PORT ONLY
STBD ONLY
FLOOD VALVE OPER. GEAR
PERISCOPE WELL No.1
FUEL BALLAST TANKS 5 & 6
FUEL BALLAST TANKS 3 & 4
NORMAL FUEL OIL TANK No 2
INNER SHELL FRAME SPACING 30"
69
67
65
63
61
59
57
55
53
51
49
47
PARTIAL FLOOR
O.T. FLOOR

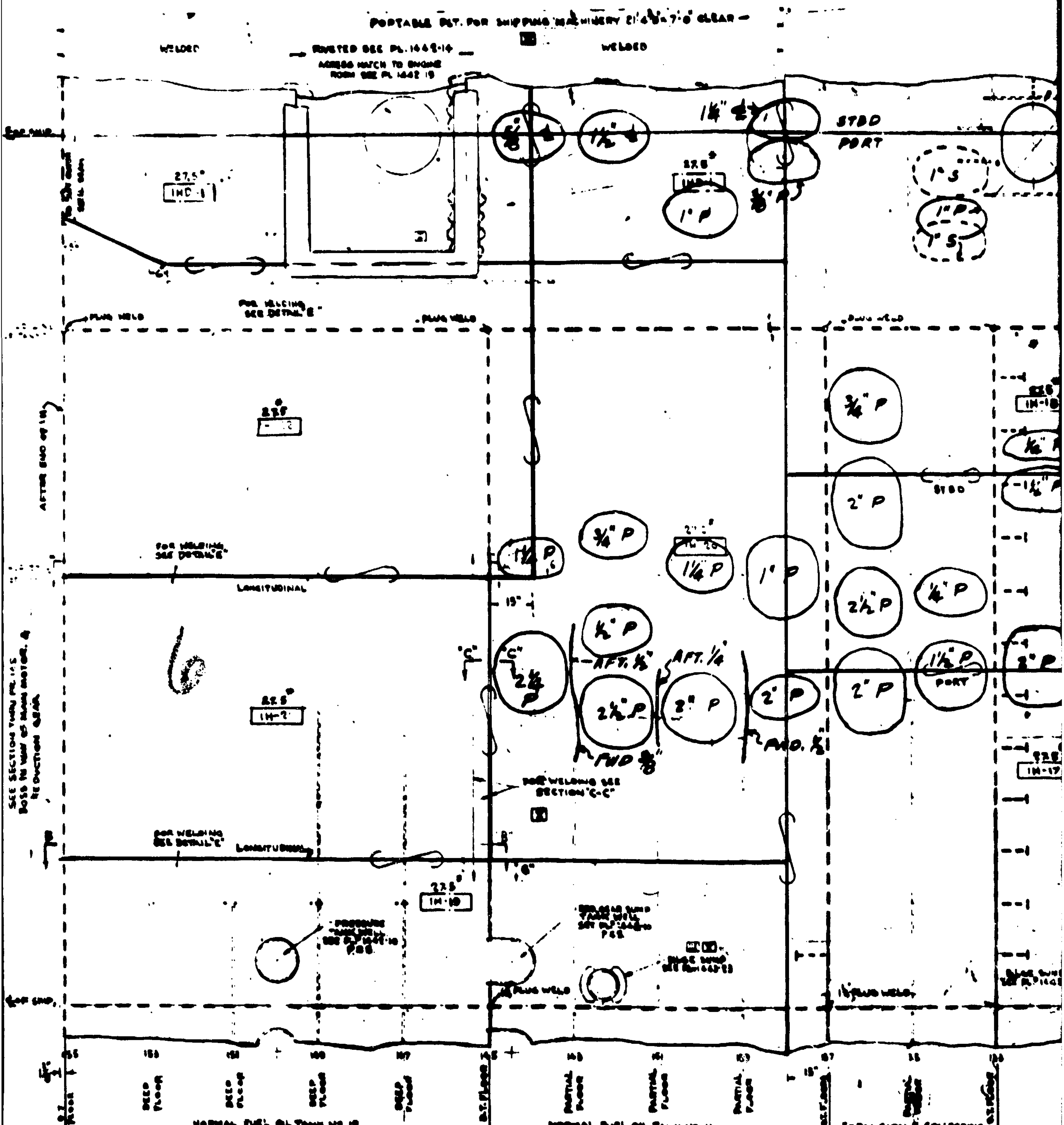


STRUCTURAL HOUSING FOR VENTILATION SEE PL. 1442-28
VERTICAL ANTENNA MAST
PERISCOPE Nº 2 PL. 442 25
CONNING TOWER LOWER HATCH PORT ONLY
1½" PLUG WELD
AFT. 1½"
FWD. 1"
3/4" P
1" P
3/8" P
1½" P
2¼" P
2" P
PORT ONLY
STBD ONLY
STBD
PORT
FLOOD VALVE OPER. GEAR
27.5° 1H-8
27.5° 1H-7
27.5° 1H-9
PERISCOPE WELL Nº 2 SEE PL. 1442 25
PERISCOPE WELL Nº 1 SEE PL. 1442 25
SANITARY TANK Nº 2
1½" PLUG WELD
FWD. 3/4"
3
90
89
87
85
83
81
79
77
75
73
71
69
67
DEEP FLOOR
W.T. FLOOR
PARTIAL FLOOR
SAFETY TANK
MAIN BALLAST TANKS 2C & 2D
MAIN BALLAST TANKS 2A & 2B
FUEL BALLAST
1" DIA PLUG WELDS THRU CENTER OF DOUBLING PL. SPCD AB' 9" CENTERS.



ENGINE INDUCTION
ACCESS HATCH TO CREWS QUARTERS
1½" PLUG WELD
4
PORT
PORT & STBD
STBD
FLOOD VALVE OPER. GEAR
HORIZONTAL
1½" P
F.W. TANK
PARTIAL FLOOR
DEEP FLOOR
W.T. FLOOR
MAIN BALLAST TANKS
AUX. TANKS NOS. 1, 2 & 3
SAFETY TANK
FRAME SPACING


PORTABLE PLT. FOR SHIPPING MACHINERY
STRUCTURAL HOUSING MAIN ENGINE INDUCTION
WELDED
THIS AREA, PORT SIDE, DIMPLED ABT. 3/8"
THIS AREA, PORT SIDE DIMPLED ABT 3/4"
5
PARTIAL FLOOR
O.T. FLOOR
FUEL BALLAST TANKS 9 & 10
FUEL BALLAST TANKS 7 & 8
MAIN BALLAST
INNER SHELL FRAME SPACING 30"



PORTABLE PLT. FOR SHIPPING MACHINERY 21'-6" x 7'-0" CLEAR
WELDED
RIVETED SEE PL. 1442-14
WELDED
ACCESS HATCH TO ENGINE ROOM SEE PL 1442-19
STBD
PORT
1¼"
1½"
1" P
1" S
1" P
1" S
27.5°
IHD-1
FOR WELDING SEE DETAIL "E"
PLUG WELD
AFTER END OF
¾" P
2" P
STBD
1½"
FOR WELDING SEE DETAIL "E"
LONGITUDINAL
1½ P
¾" P
1¼ P
1" P
2½ P
¼" P
15"
½" P
"C"
2½ P
AFT. ½"
AFT. ¼
2½" P
2" P
2" P
FWD ⅜
FWD. ⅜
2" P
1½ P
PORT
2" P
27.5°
IH-2
FOR WELDING SEE SECTION "C-C"
FOR WELDING SEE DETAIL "E"
LONGITUDINAL
27.5°
IH-19
PLUG WELD
PLUG WELD
DEEP FLOOR
DEEP FLOOR
DEEP FLOOR
DEEP FLOOR
PARTIAL FLOOR
PARTIAL FLOOR
PARTIAL FLOOR
NORMAL FUEL OIL TANK NO 12
NORMAL FUEL OIL TANK NO 11
EXPANSION & COLLECTING TANKS

2. Non-circular pressure hull plating and framing.

The damage to the plating in way of the non-circular pressure hull has been recorded on the photographs which appear on pages 21 to 65 of Volume II and on the sketch on page 13 of Volume I. Pages 21 to 30 are general views of the damaged areas of the single hull starting at the port bow and moving aft, around the stern and back to the starboard bow. Pages 31 to 65 are close-ups of the dimpled areas starting at the port bow and repeating the circuit of the ship. In the photographs it will be noted that a line was painted around the perimeter of each dimple. An approximately straight vertical and horizintal line through the depression was added to bring out the depth and shape. The vertical extent, horizontal extent and maximum depth (in inches) was painted within the perimeter of each dimple. The depths shown were measured from the two adjacent frames regardless of frame deformation and therefore do not represent the total displacement from the molded line. To obtain total displacement the pertinent frame deformations must be combined with the depth of the dimple.

The distortions of the Non-circular pressure hull forward of frame 35 and aft of frame 155, were of much greater magnitude than those of the circular hull. This is true of both plating and framing.

There was one break in the pressure hull plating. This occured on the top of the forward torpedo room at frame 30, about 4 feet to port of the centerline. The fracture, which is 20 inches long, was in the immediate vicinity of the frame weld at the after edge of frame 30. It was repaired by a divers weld while the ship was on the bottom. The photographs on pages 66 and 67 of Volume II show the fracture, after the repair welding was done, from the exterior and interior, respectively. In the photograph on page 66 the extent of the fracture is marked roughly by the two white marks. A section of the hull containing the fracture was cut out and sand blasted and sent to the Bureau of Standards for metallurgical tests. In order to reduce the radioactivity, it was necessary to blast intensively with steel grit in the region of the fracture. This removed the divers repair weld almost completely. The photographs on pages 68 and 69 of Volume II show the fracture from above and below after blasting. There is very little if any, of the parent metal missing. In part the break appears to have been facilitated by insufficient penetration of the weld metal, but the fracture, at its outboard end, extends into the plate and away from the weld. As can be seen in the photograph on page 69 of Volume II there is an intermediate T-bar at frame 30 3/4 for the purpose of strengthening the hull in way of the cut out for the forward torpedo loading hatch. The dimple between the T-bars at frames 30 and frame 30 3/4 is 2 1/2 inches deep. A view of this and adjacent dimples appears on pages 70 and 71 of Volume II, and in the sketch on page 27 of this Volume.

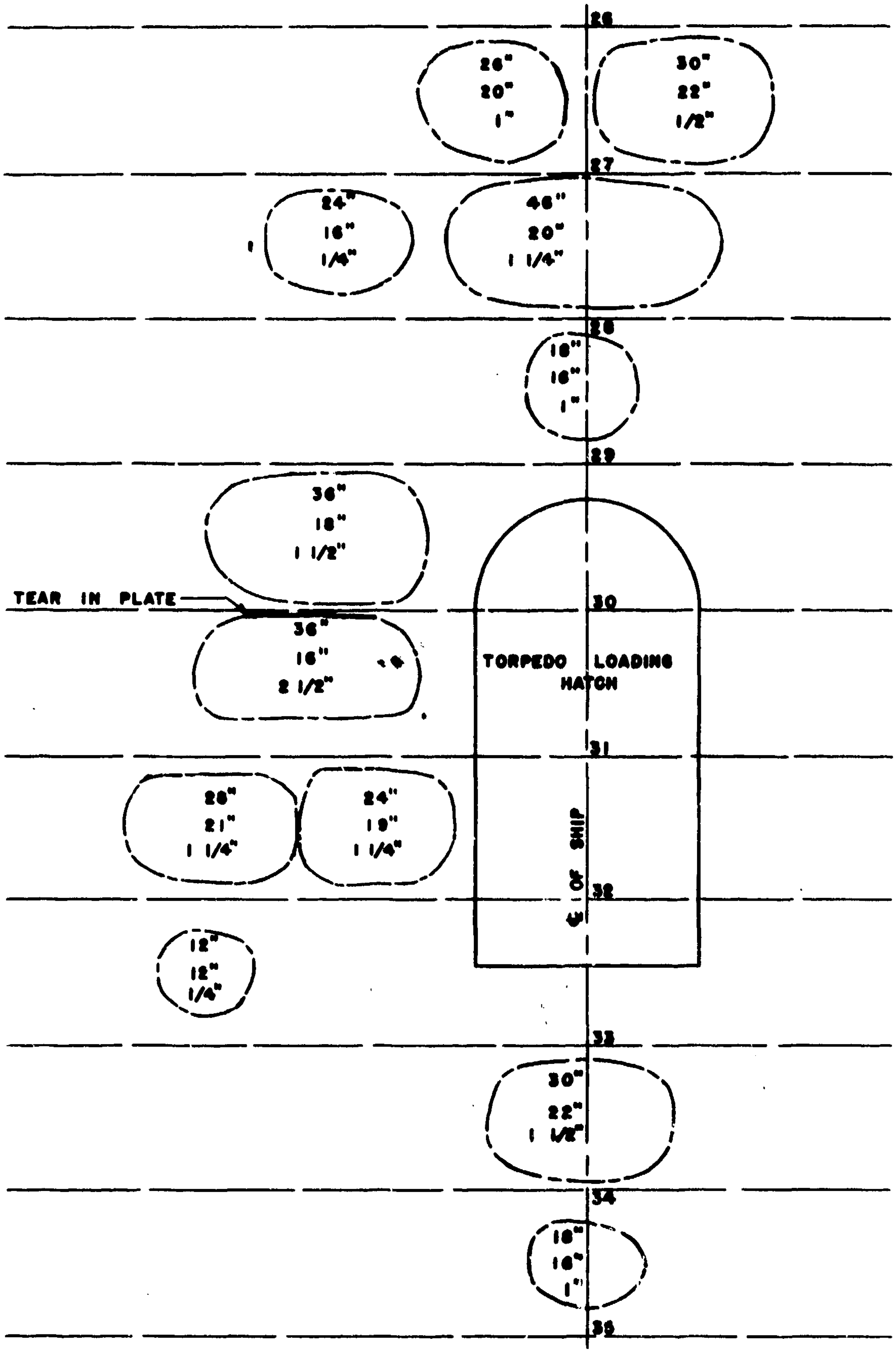
Although the fracture described above is the only complete failure of plating, there is severe distortion throughout the non-circular hull.

The forward trim tank plating has been dimpled on each side, from the flat keel up about 4 feet, between frames 21 and 22. At the 13 foot waterline, between frames 13 and 16, on the port side, there are three dimples 1 1/2 inches deep. See page 31 of Volume II. The corresponding dimples on the starboard side, which appear on page 65 of Volume II, are 1 1/8 to 1 3/8 inches deep.

The entire area between frames 155 and 162 on the port side is severely damaged, the maximum depth of dimples being 3 inches. In Volume II, pages 22 and 23 show overall views of this area and pages 37, 38 and 39 show the close-up views. Between the same frames on the starboard side the distortion was much less severe, and occured principally near the keel. Pages 28, 58 and 59 of Volume II show the starboard side.

In way of the after torpedo room and after trim tank the plating damage is general and severe on the port side (see pages 24 and 25 of Volume II). On the starboard side the damage is much less severe except near the keel (see pages 26 and 27 of Volume II). The heaviest damage occured between frames 174 and 184, adjacent to the keel on both sides. Here the plating indentations reached 3 inches in depth on the starboard side and 2 inches on the port side. Pages 44, 46, 47, 49, 50, 52, 53, 54 and 55 of Volume II show the details in these areas.

Frame damage to the non-circular pressure hull was general but especially severe around frames 20 - 22 starboard.



DIMPLES IN NON-CIRCULAR HULL IN WAY OF FORWARD TORPEDO LOADING HATCH

30 - 32 port, 156 - 158 port and 176 - 184 on both sides of the keel. The existing molded lines of the distorted frames in the most severely damage areas were determined and compared with the original molded lines. The results are plotted on pages 30 to 56 of this Volume.

To digress momentarily, the method of measurement may be of interest for future similiar work. From the table of offsets the molded lines were laid down full scale on the mold loft floor. Wooden templates or molds were then constructed (in two parts), extending from the top to the bottom centerline of the hull. By placing the mold on the ships frame, lining up the top and bottom centerlines exactly and scribing from the shell at the frame, an outline of the frame (extended outboard 6 inches) was obtained. This process is shown on pages 72 and 73 of Volume II. When frame distortions were abrupt, scribing was supplemented by scale measurements along intermediate water lines and buttocks. The template was then returned to the mold loft where a new table of offsets were prepared.

This method of measurement has the advantages of being fast and independent of the list of the ship or the motion of a floating drydock. It has the disadvantages of requiring staging and essentially complete clearing of all structure in way of the frame to be measured. As the topside structure was of no further value and staging was required for other reasons, the disadvantages were not serious on the SKIPJACK.

Photographs were taken of the more seriously distorted frames. In Volume II, page 74 shows frame 21, starboard which was bent in a distance of 5 inches at this point. There is a bulge in the web of the frame between the two pipe hangers. Page 75 of Volume II shows the distortion of frame 31, port, which was pushed in a distance of 4 inches at this point. The toe of frame 31 was held fixed by the lower torpedo stowage crossrail, which resulted in the sharp discontinuity shown on page 76 of Volume II. Note the buckled web. No welding failures were discovered.

Frame 32, port, was pulled out of line by dents in the plating above and below the longitudinal thrust brackets. The distorted flange is shown on page 77 of Volume II.

Page ?8 of Volume II shows the lower section of frame 158, port, which was the most severely deformed T-frame in the ship. The maximum inward distortion of this frame is 7 3/4 inches and the face flange is pushed out of line about 2 1/2 inches.

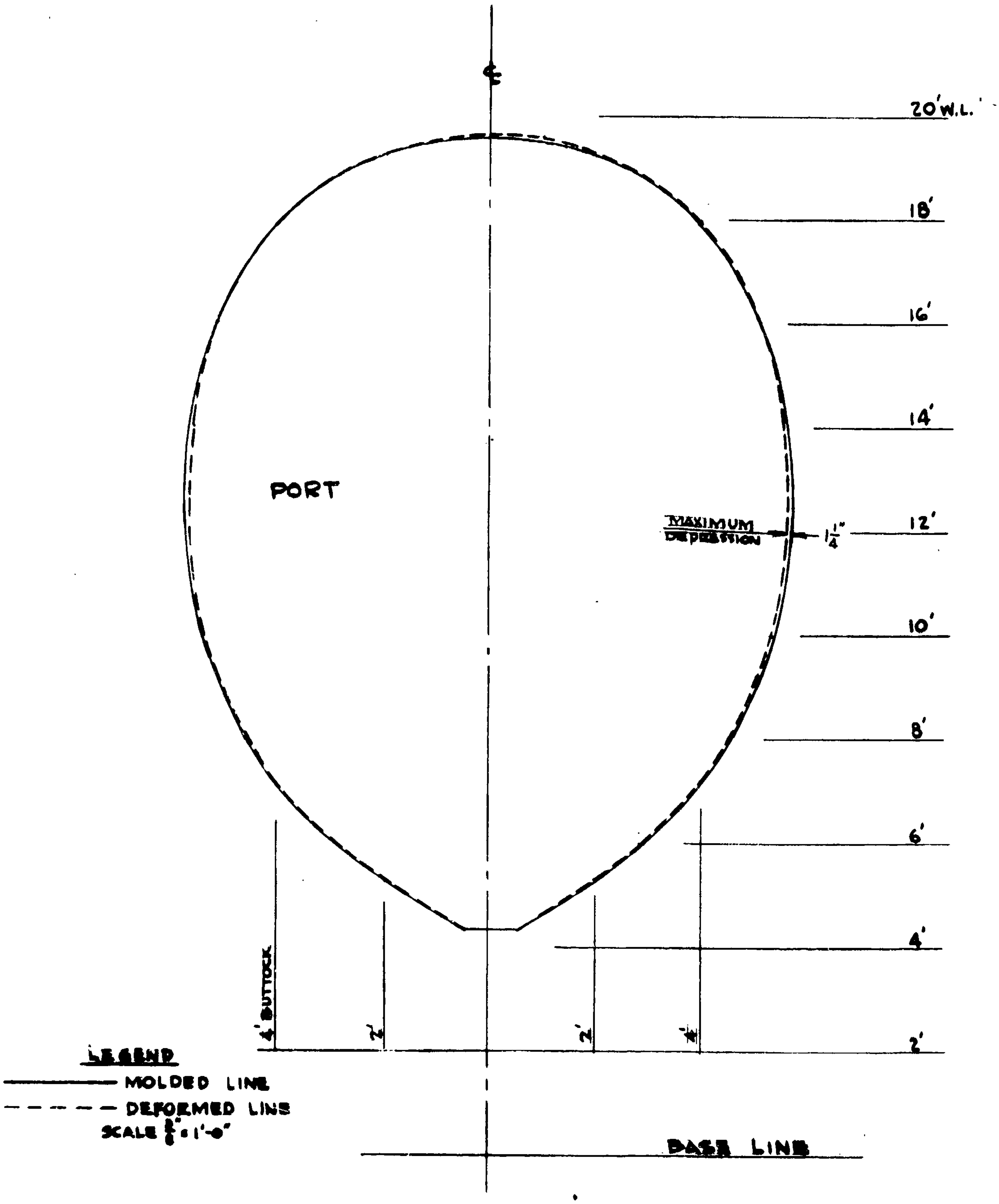
In the after torpedo room bilge, at frames 176 - 179, just above the keel, the floor frames on each side have collapsed. The pressure plating moved inward and upward about 8 inches and the relatively unstiffened floors were unable to resist the deformation. Pages 79 and 80 of Volume II show typical examples of the collapsed floors in way of the lightening holes. The same remarks apply to frames 181 - 184 in the after trim tank.

In the SKIPJACK, the tank tops of main ballast tanks 1 and 3 form part of the pressure boundaries of the two torpedo rooms. As such, they were subject to the full pressure forces, but the distortions were not severe. The tank top of number 1 main ballast tank was bulged up from 1/4 to 3/4 inch between the bulkhead stiffeners of bulkhead 35. Farther forward, in way of frames 26 - 32, the panels of the tank top are bulged up about 3/4 to inch. Between frames 24 and 25, adjacent to the starboard hull plating, there is a bulge of about 3/4 inch which accounts for the welding failure described below under 'welding'. As noted above in Item D, the stowage tracks for torpedo tubes 3 and 4 varied from 1/16 inch low forward, to 1 5/16 inches high aft, which indicates a corresponding movement of the tank top frames on which the tracks rest.

In the after torpedo room, the number 3 main ballast tank top, between frame 162 and 163, is bulged up 1/4 to 1/2 inch between the stiffeners of bulkhead 162 (the top of sanitary tank No. 3 is not bulged). The remainder of the tank top is generally bulged between the deck stiffeners, about 1/2 inch maximum. As noted in Item D above, the stowage tracks for torpedo tubes 7 and 8 are all low, relative to the tubes. Since the tank frames could hardly have dropped, it is assumed that the readings are low because the bulkheads carrying the torpedo tubes have moved up.

3. Bow framing.

The bow framing and plating shows no damage which can be attributed to the atom bomb.

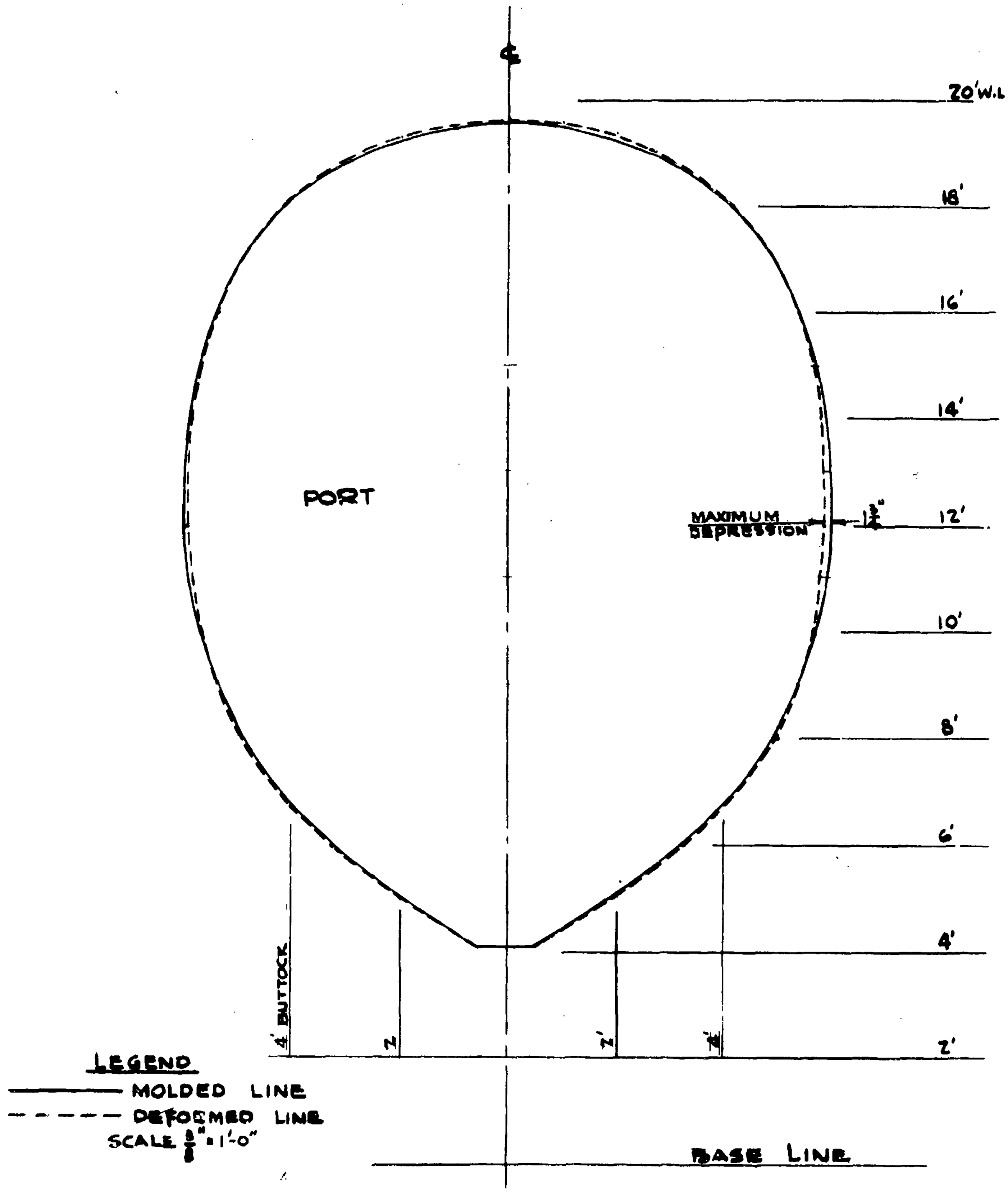


FRAME # 19

SECRET

PAGE 30 OF 141 U.S.S. SKIPJACK (SS 184)

7123

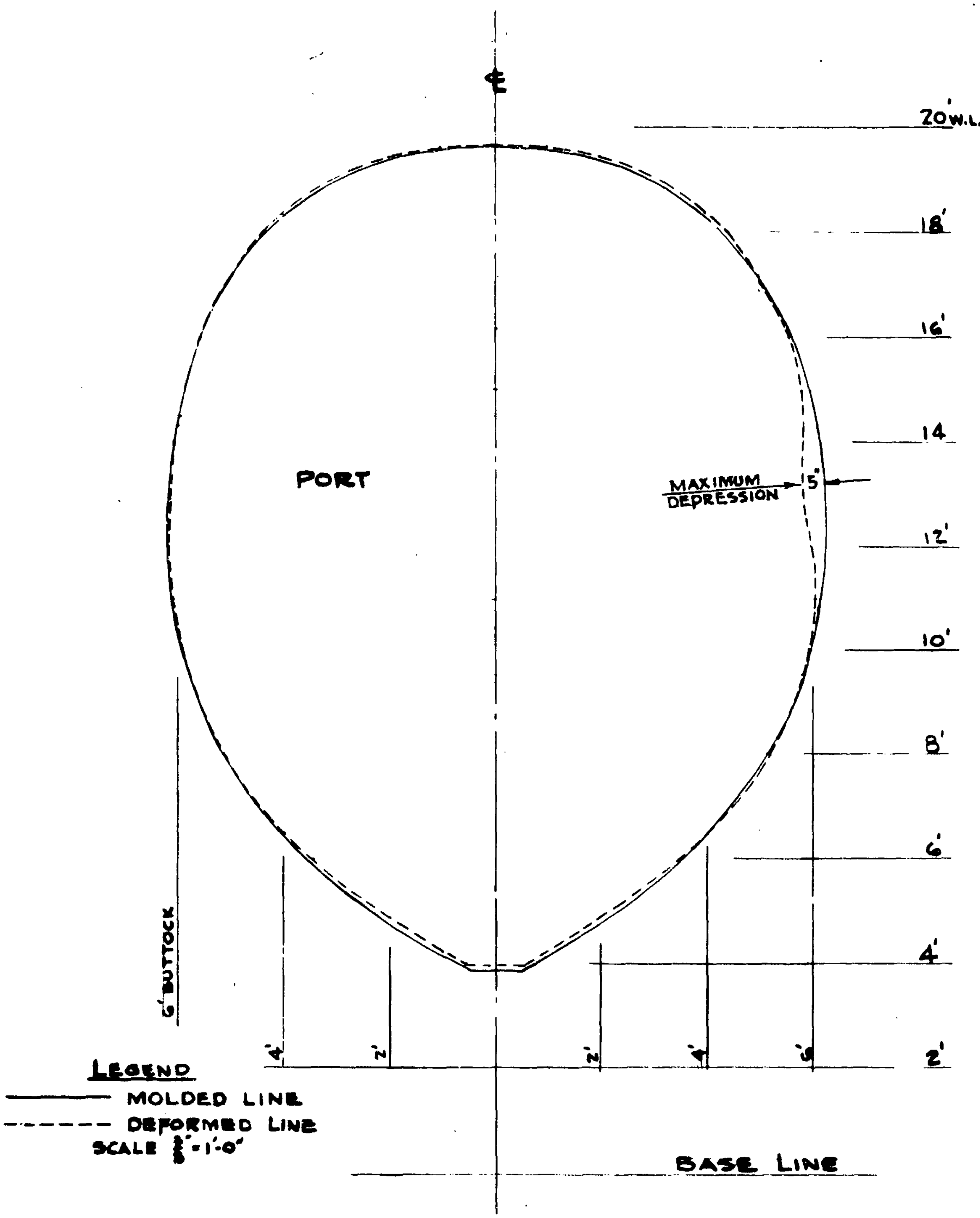


FRAME # 20

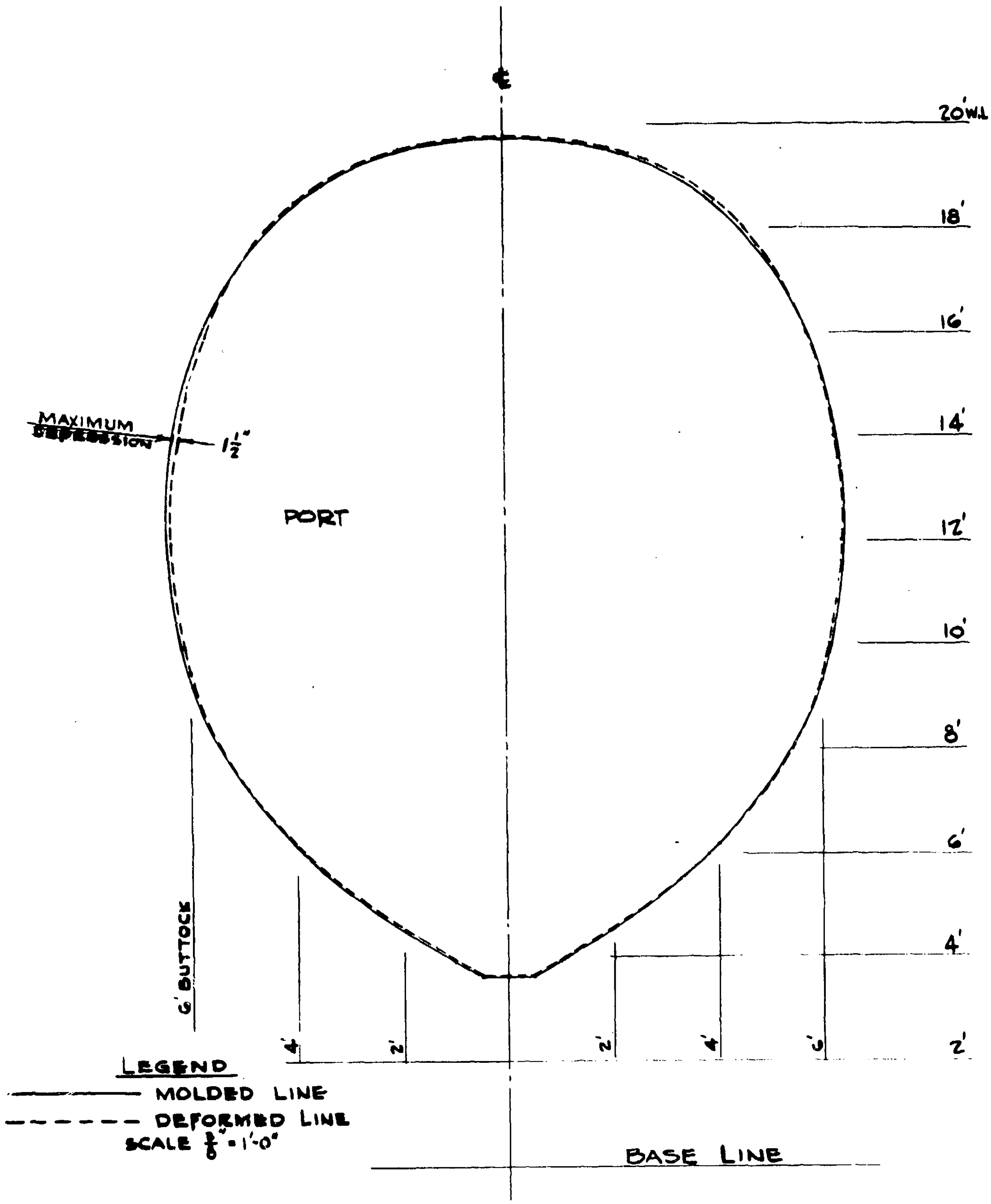
SECRET

PAGE 31 OF 141 U.S.S. SKIPJACK (S.S 184)

7123


℄
20' W.L.
18'
16'
14
12'
10'
8'
6'
4'
2'
PORT
MAXIMUM DEPRESSION 5"
6' BUTTOCK
4'
2'
2'
4'
6'
LEGEND
MOLDED LINE
DEFORMED LINE
SCALE 3/8"=1'-0"
BASE LINE

FRAME #21

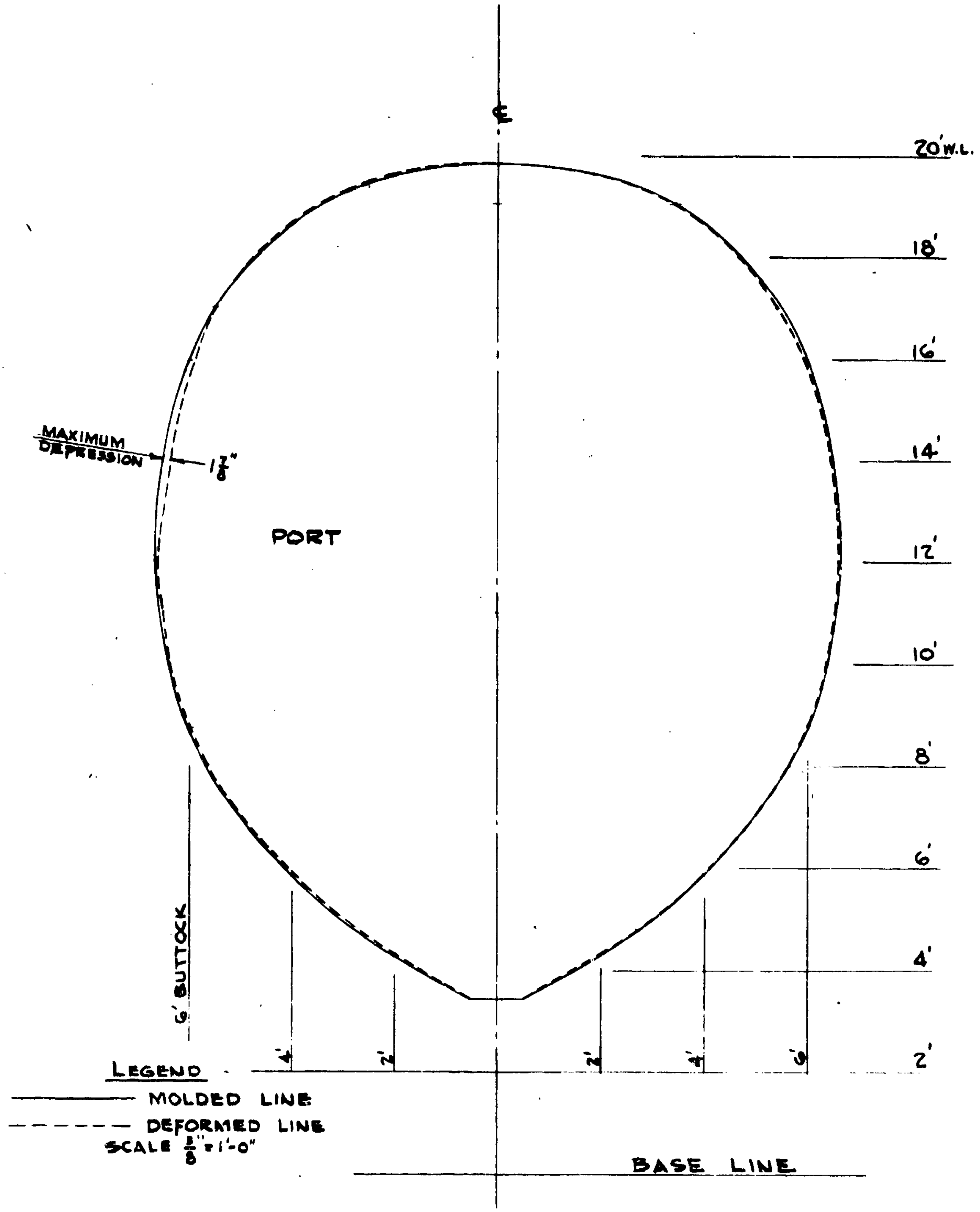


FRAME #22

SECRET

PAGE 33 OF 141 U.S.S. SKIPJACK (S.S. 184)

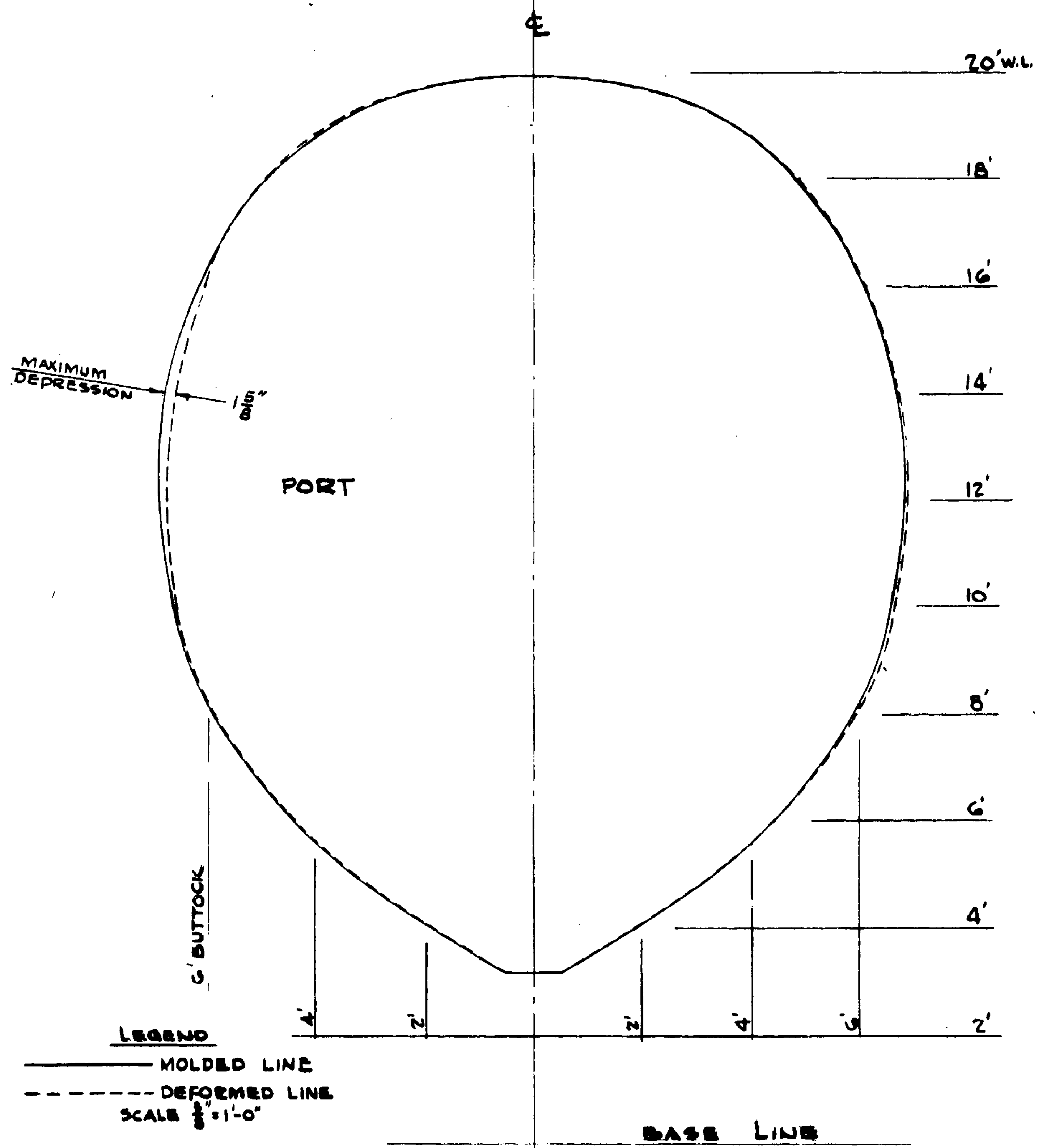
7123



FRAME #23

SECRET

7123

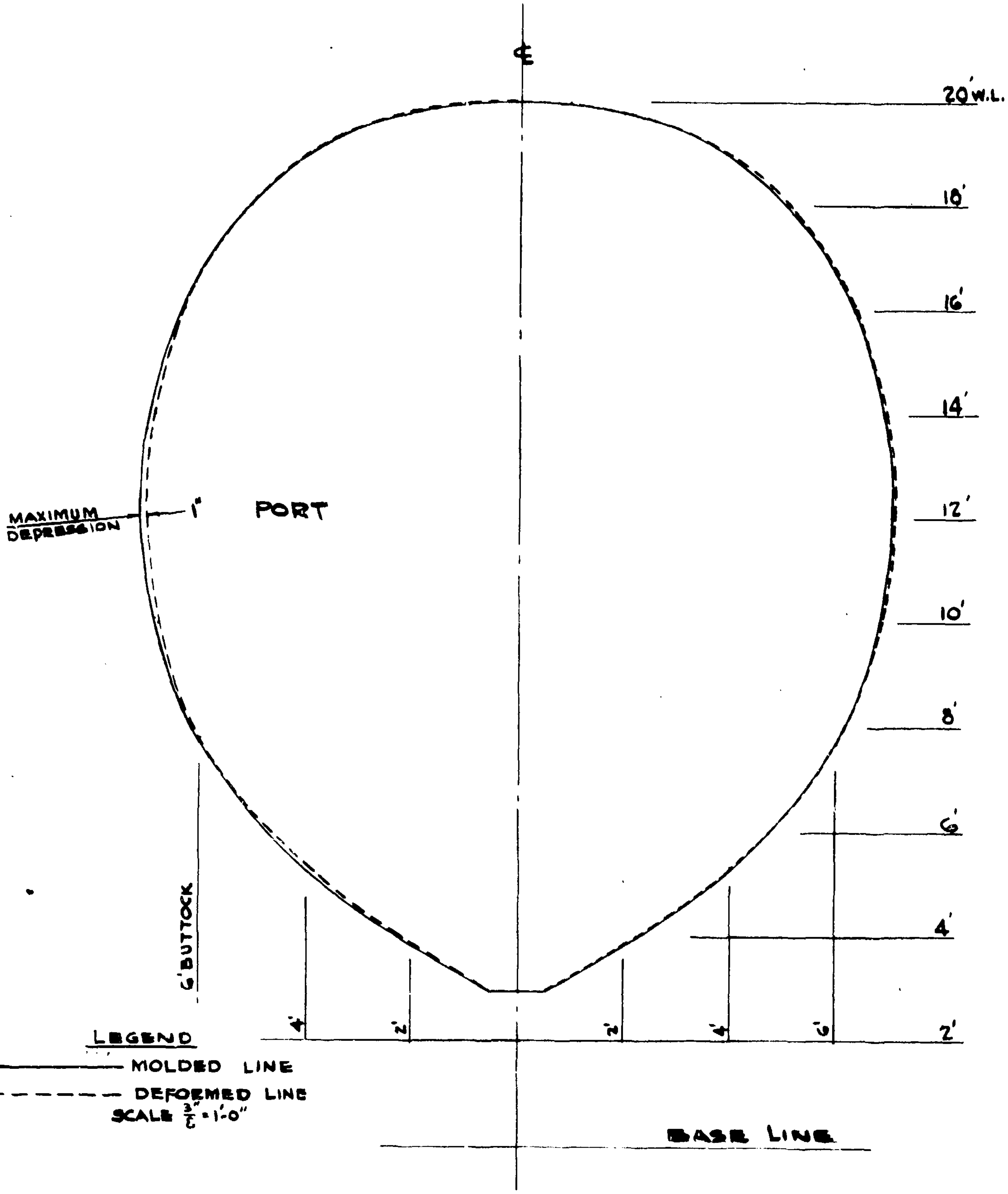


FRAME # 24

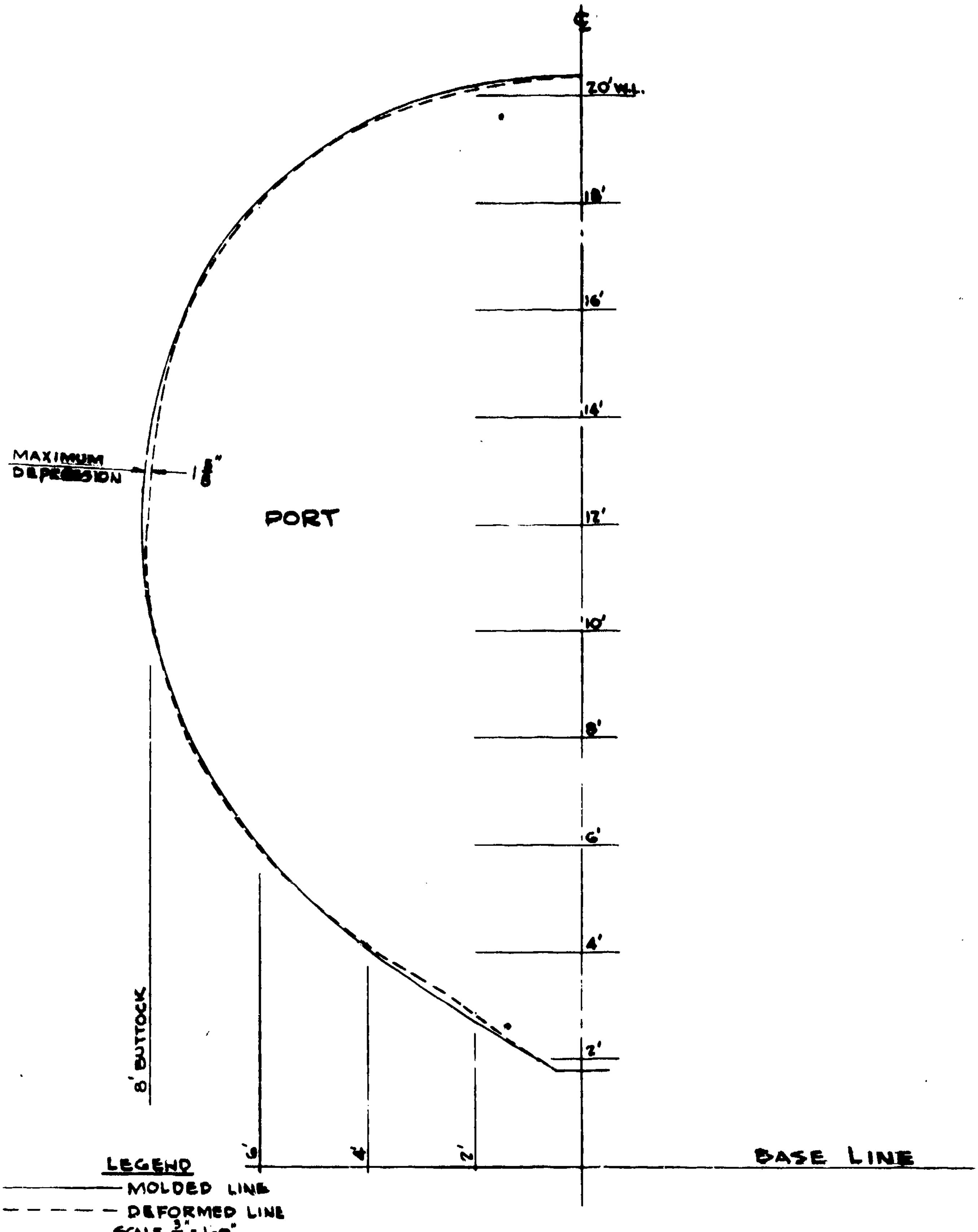
SECRET

PAGE 35 OF 141 U.S.S SKIPJACK (SS-184)

7123


℄
20' W.L.
18'
16'
14'
12'
10'
8'
6'
4'
2'
MAXIMUM DEPRESSION
1"
PORT
6' BUTTOCK
4'
2'
2'
4'
6'
LEGEND
MOLDED LINE
DEFORMED LINE
SCALE 3/8" = 1'-0"
BASE LINE

FRAME #25

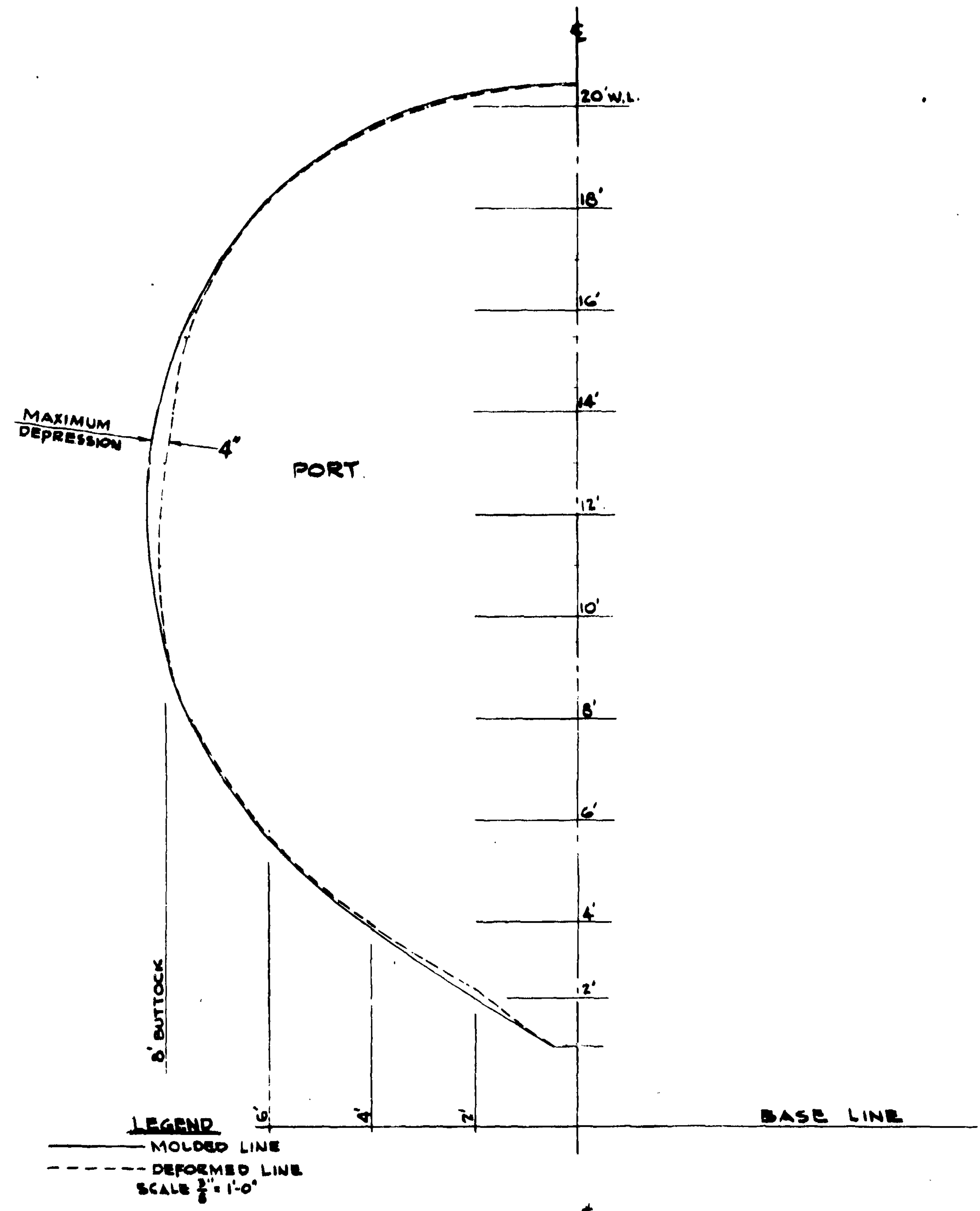


SECRET

FRAME #30

PAGE 37 OF 141 U.S.S. SKIPJACK (S.S. 184)

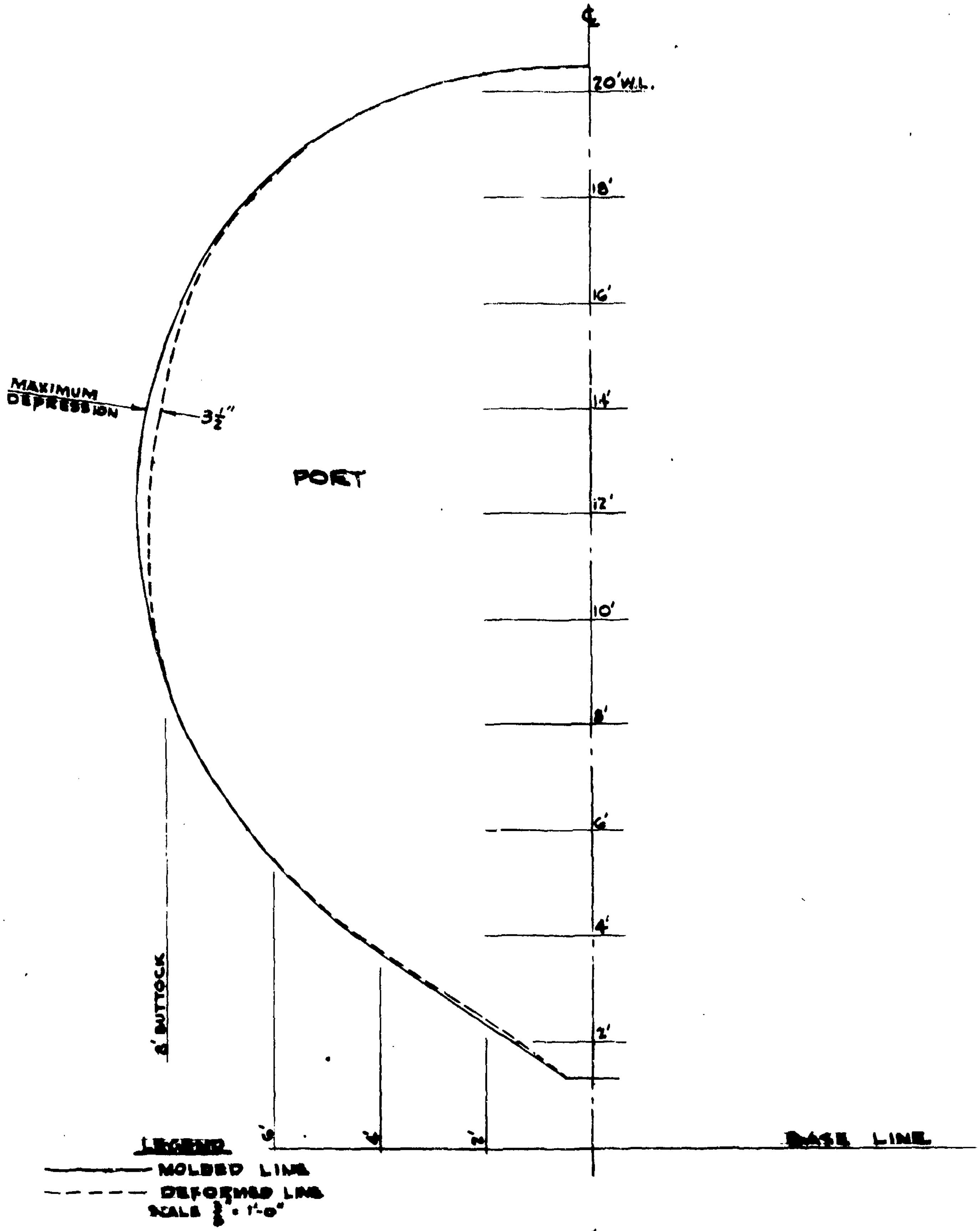
7123



FRAME #31

SECRET

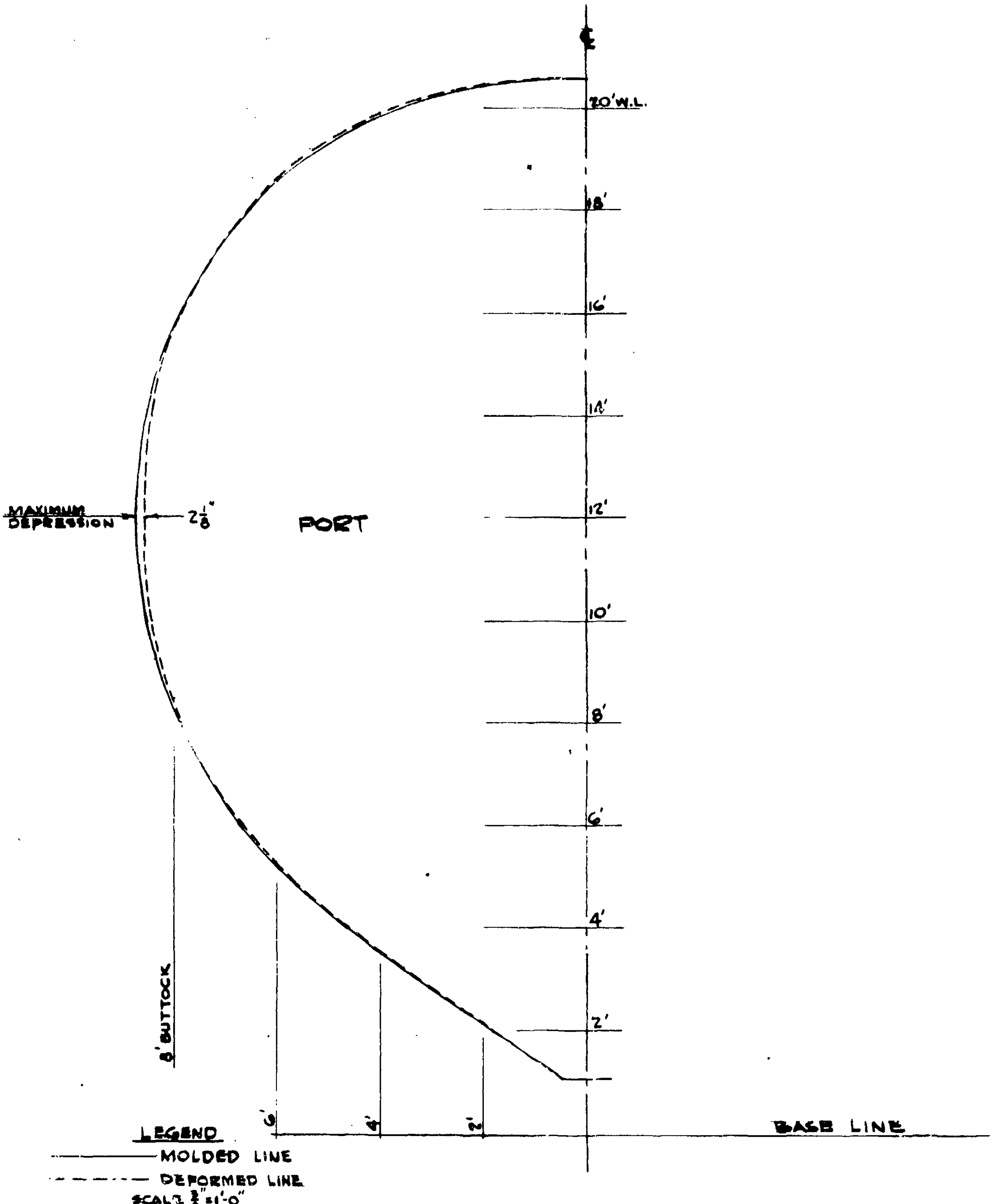
7123



SECRET

FRAME # 32
PAGE 39 OF 141 U.S.S. SKIPJACK (S.S 184)

7123

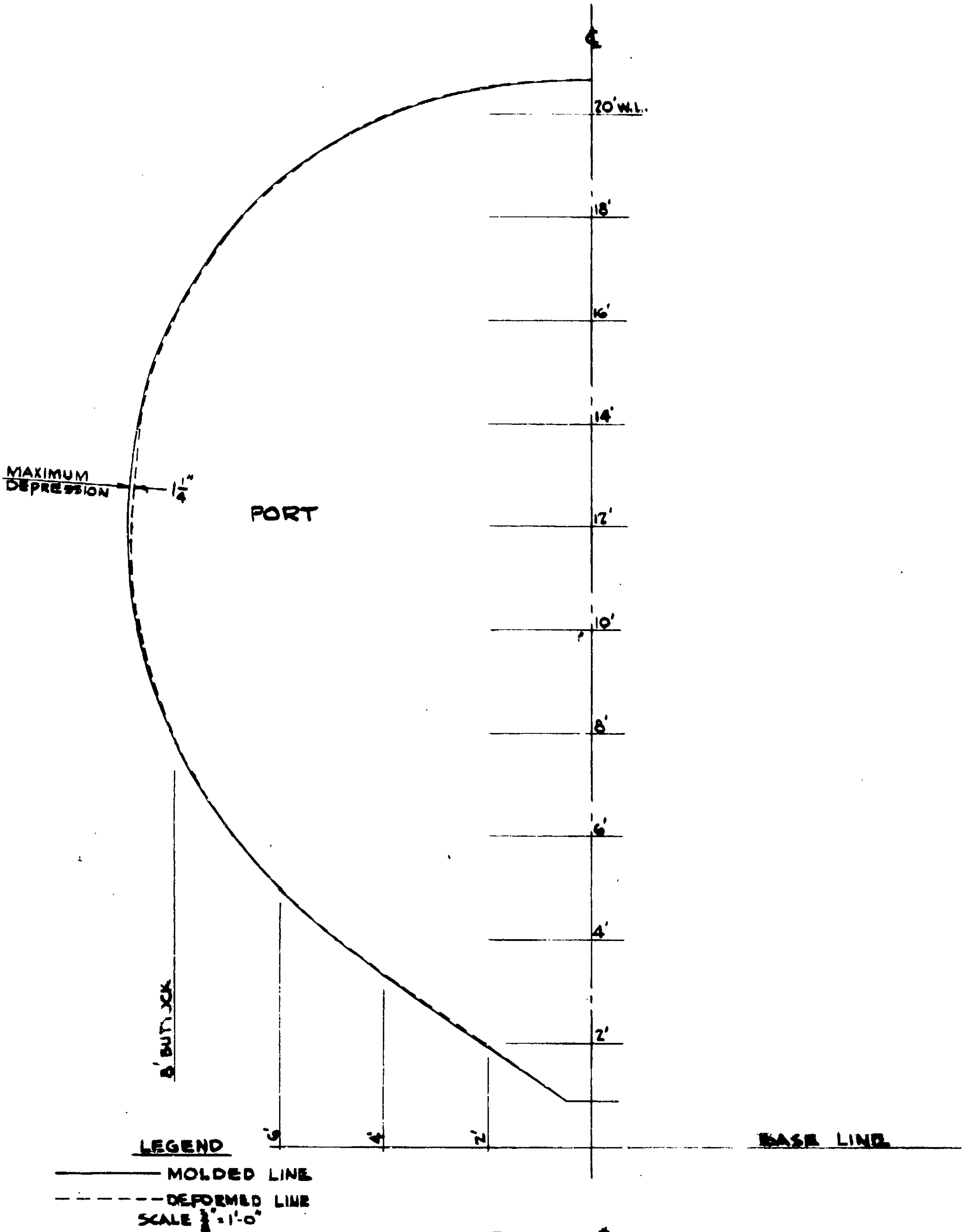


FRAME # 33

SECRET

PAGE 40 OF 141 U.S.S SKIPJACK (S.S 184)

7123

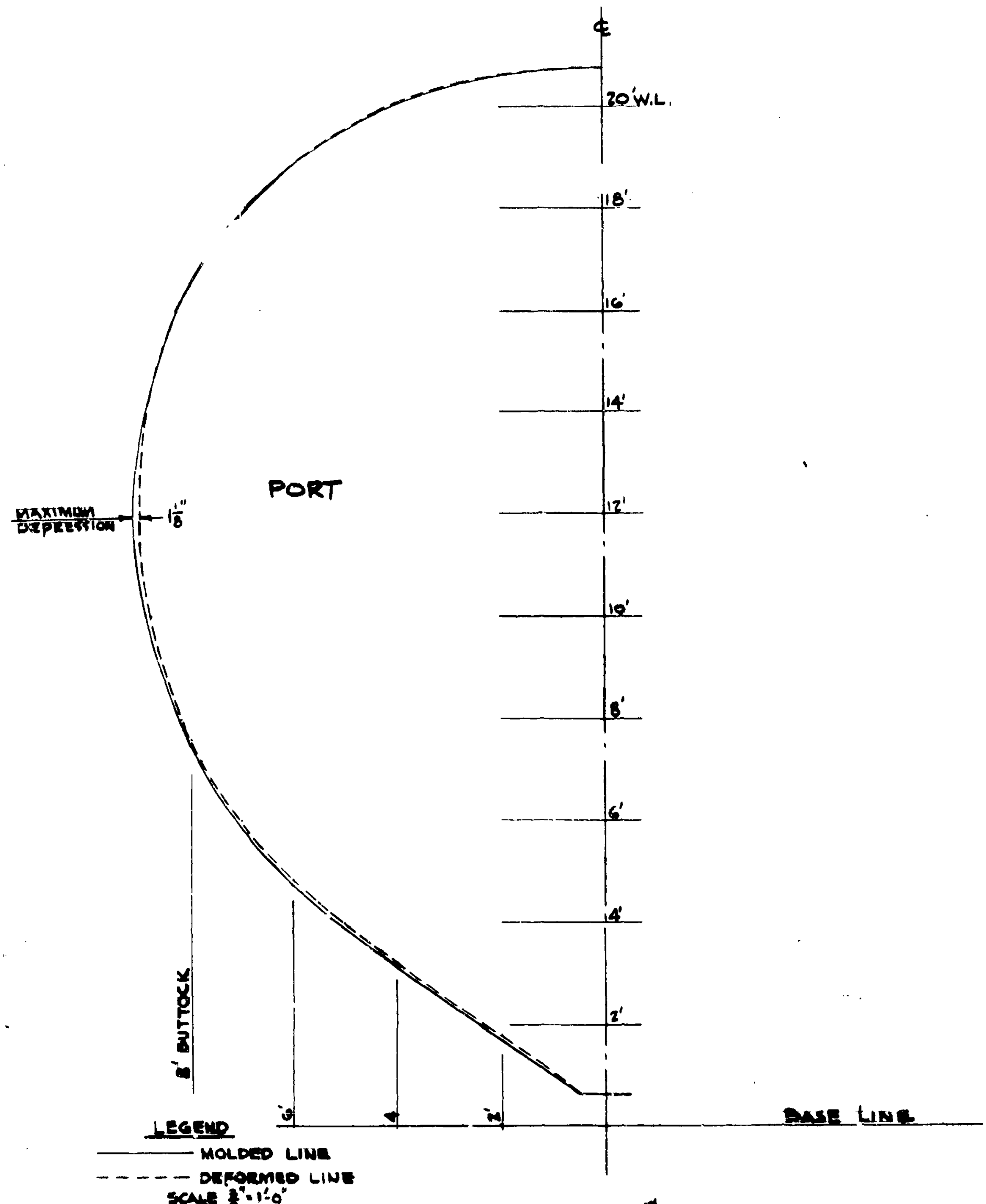


FRAME # 34

SECRET

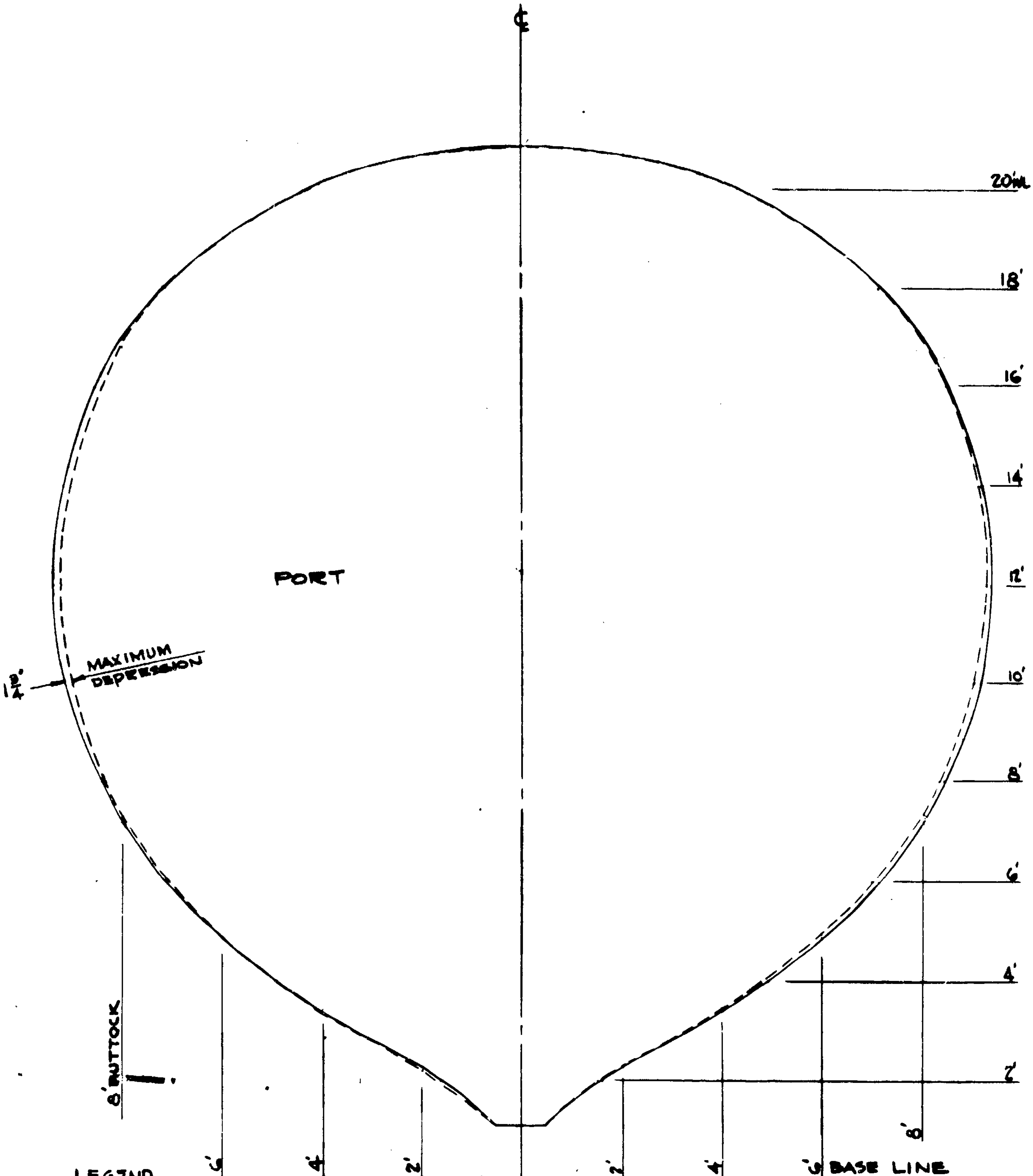
PAGE 41 OF 141 U.S.S SKIPJACK (S.S 184)

7123



SECRET

FRAME #35

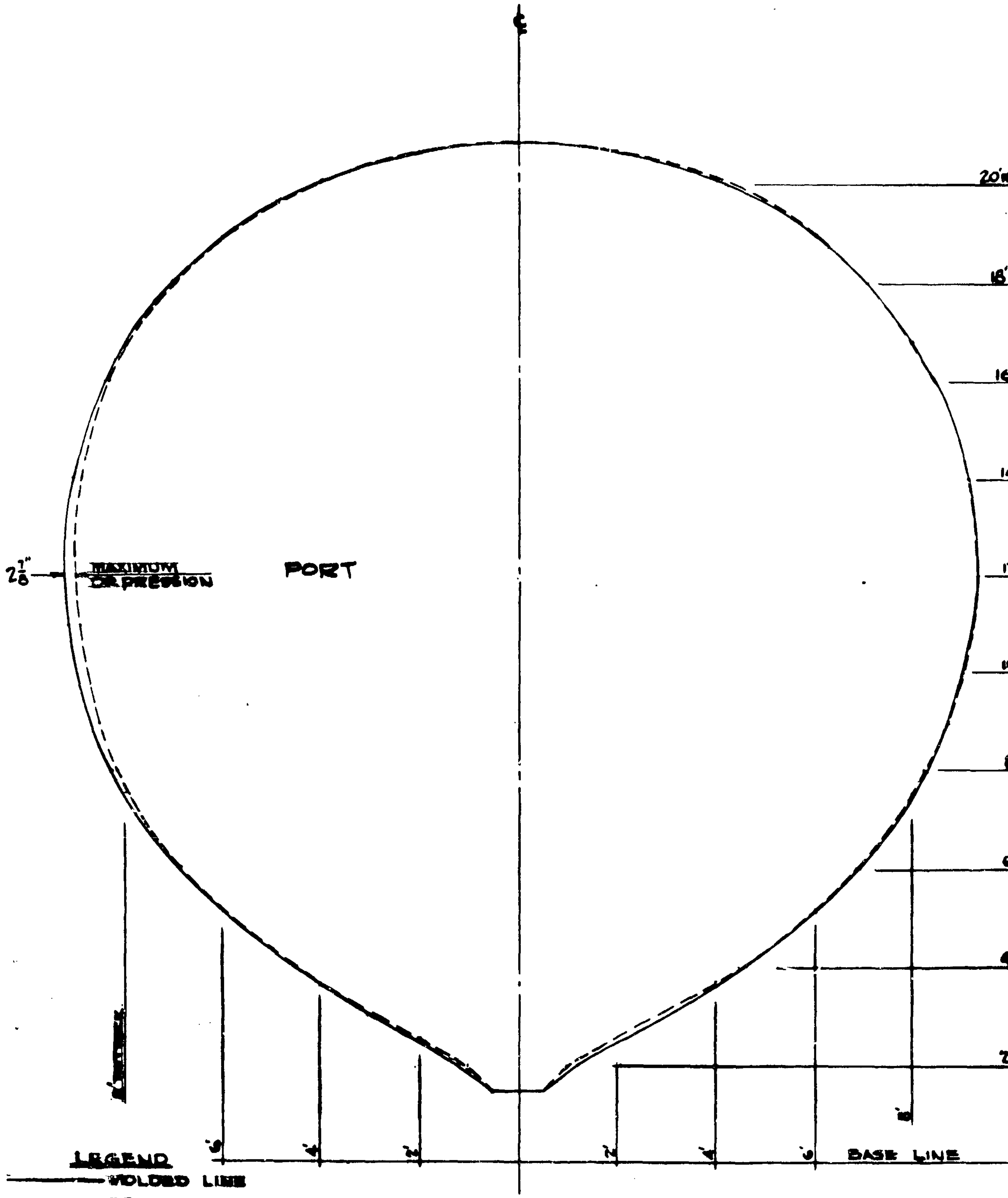


SECRET

FRAME #155

PAGE 43 OF 141 U.S.S. SKIPJACK (S.S 184)

7123



LEGEND

——— MOLDED LINE

- - - DEFORMED LINE

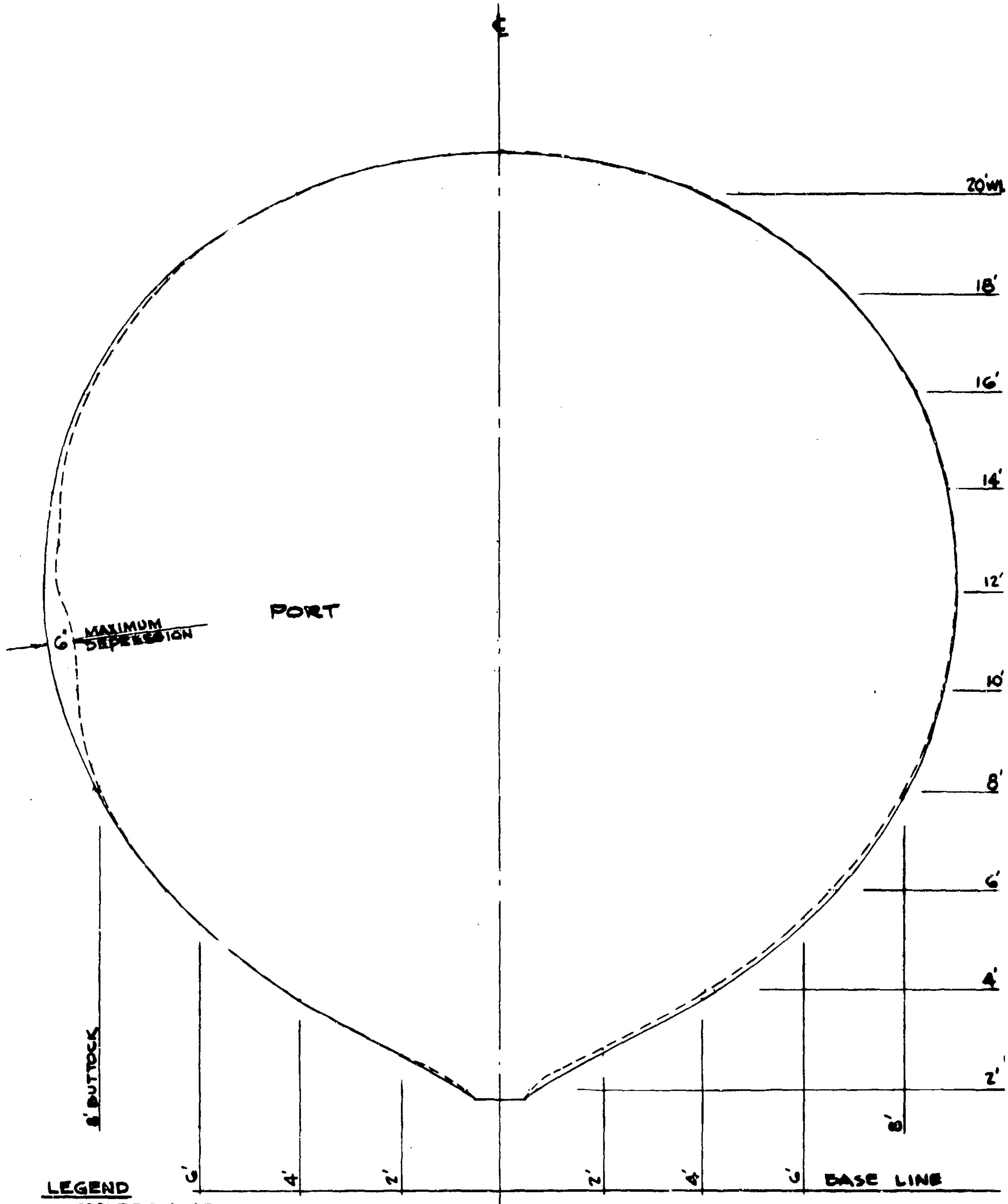
SCALE

SECRET

FRAME #156

PAGE 44 OF 141 U.S.S. SKIPJACK (S.S 184)

7123



LEGEND

——— MOLDED LINE

– – – – – DEFORMED LINE

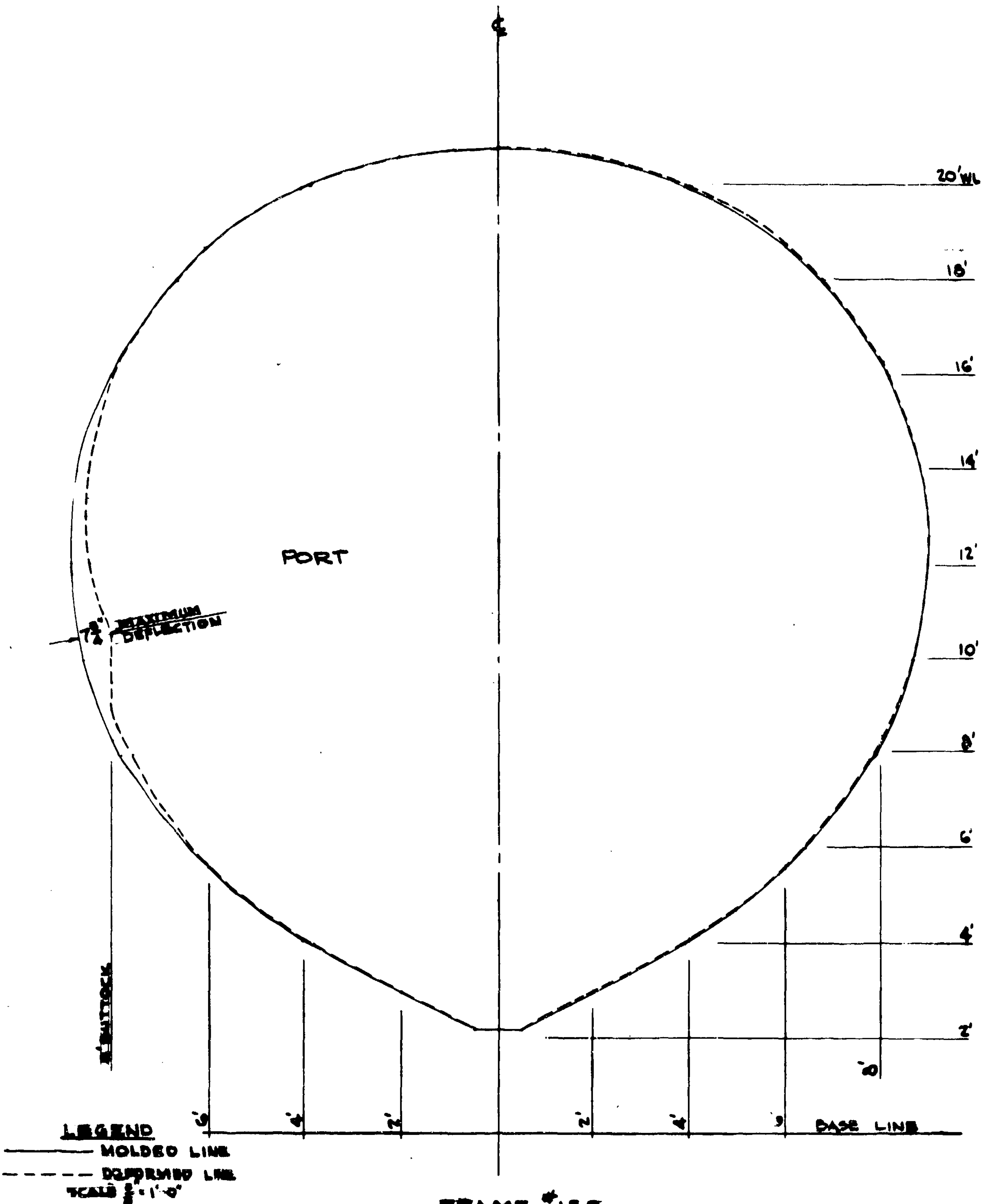
SCALE $\frac{3}{8}$" = 1'-0"

FRAME #157

PAGE 45 OF 141 U.S.S. SKIPJACK (S.S 184)

7123

SECRET

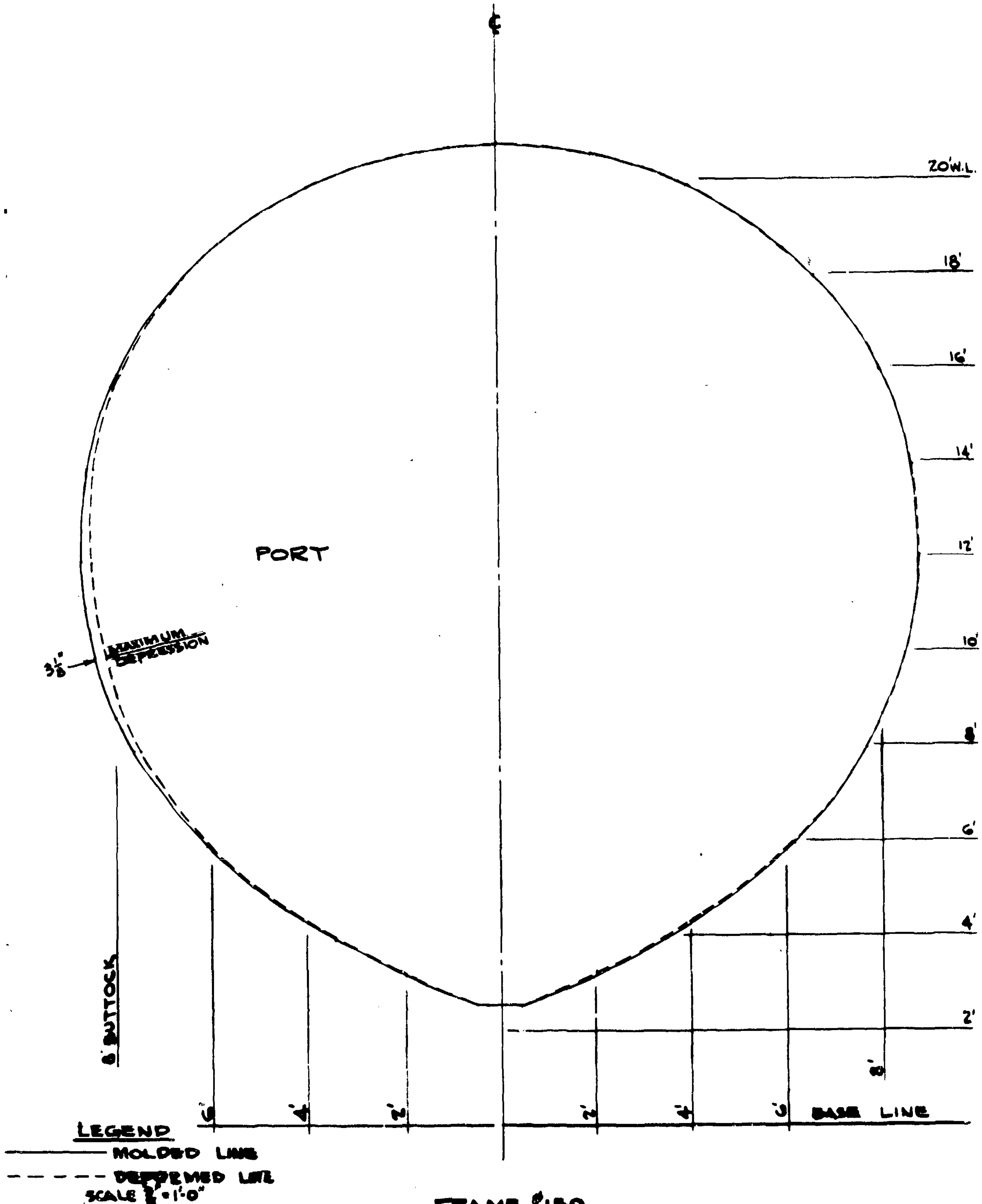


SECRET

FRAME #155

PAGE 46 OF 141 U.S.S SKIPJACK (S.S 184)

7123

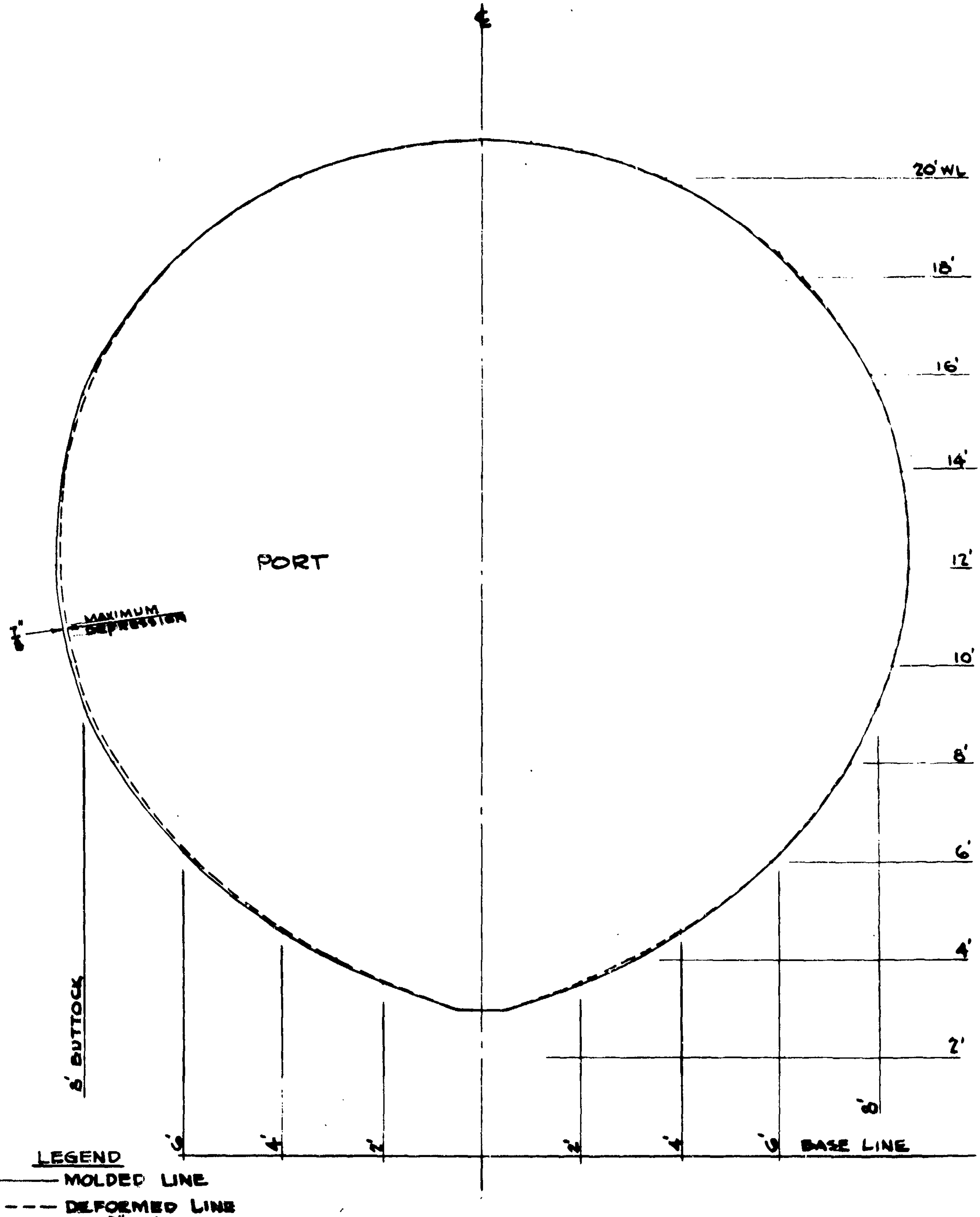


SECRET

FRAME #159

PAGE 47 OF 141 U.S.S. SKIPJACK (S.S 184)

7123



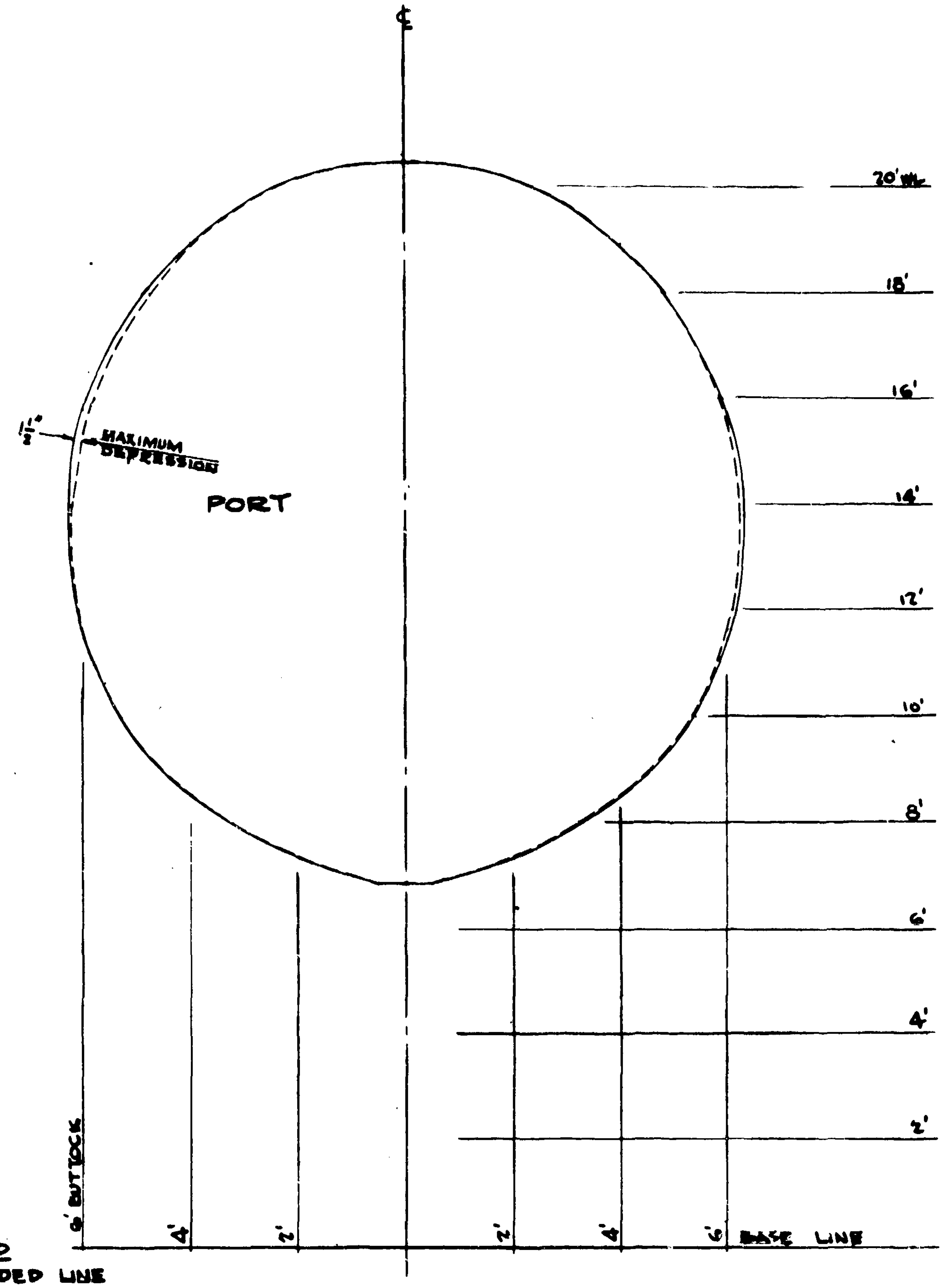
LEGEND
——— MOLDED LINE
- - - - DEFORMED LINE
SCALE 1/8" = 1'-0"

SECRET

FRAME # 160

PAGE 48 OF 141 U.S.S SKIPJACK (S.S 184)

7123



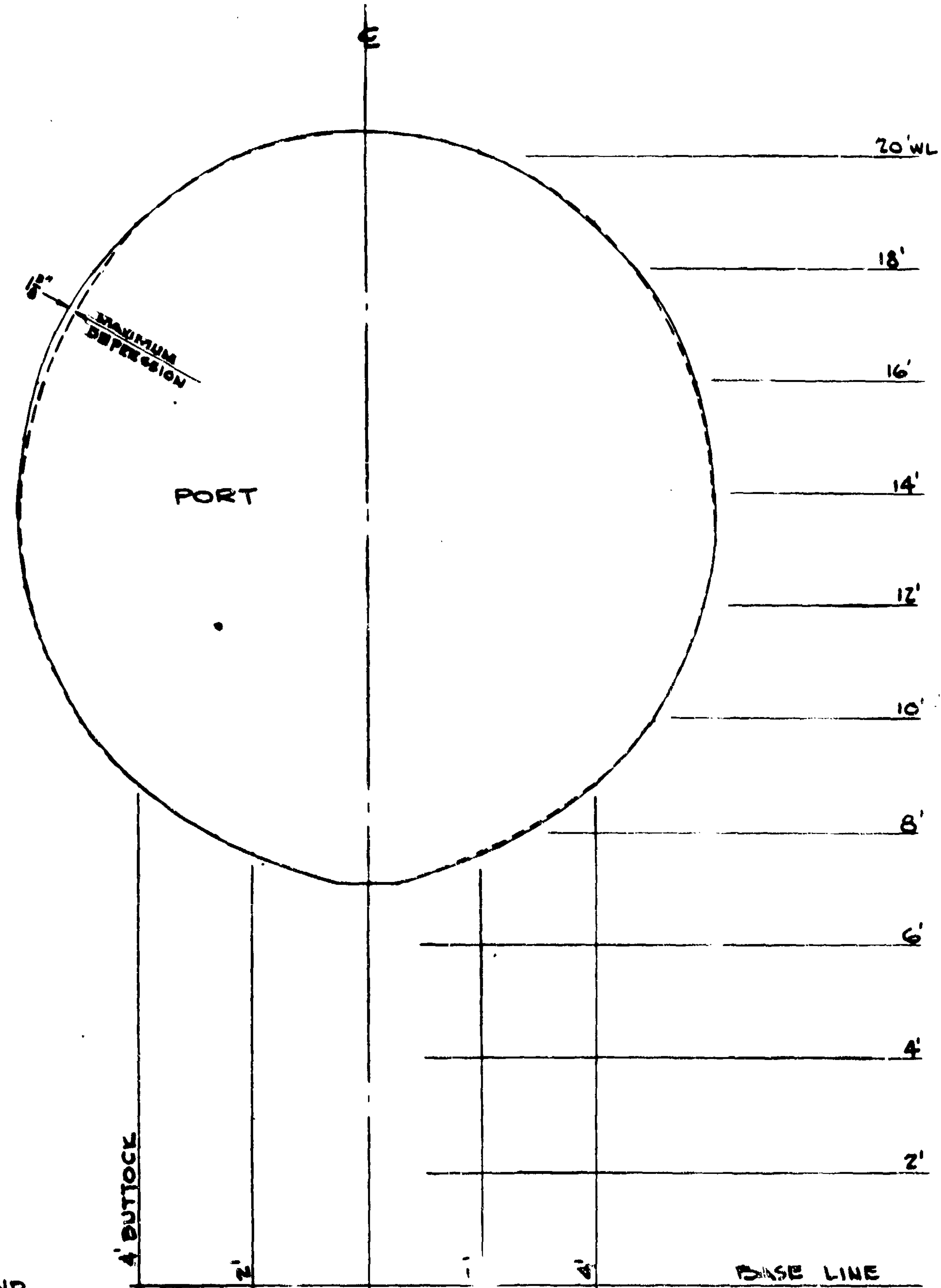
LEGEND
—— MOLDED LINE
- - - DEFORMED LINE
SCALE ⅜"=1'-0"

SECRET

FRAME #178

PAGE 49 OF 141 U.S.S SKIPJACK (S.S 184)

7123



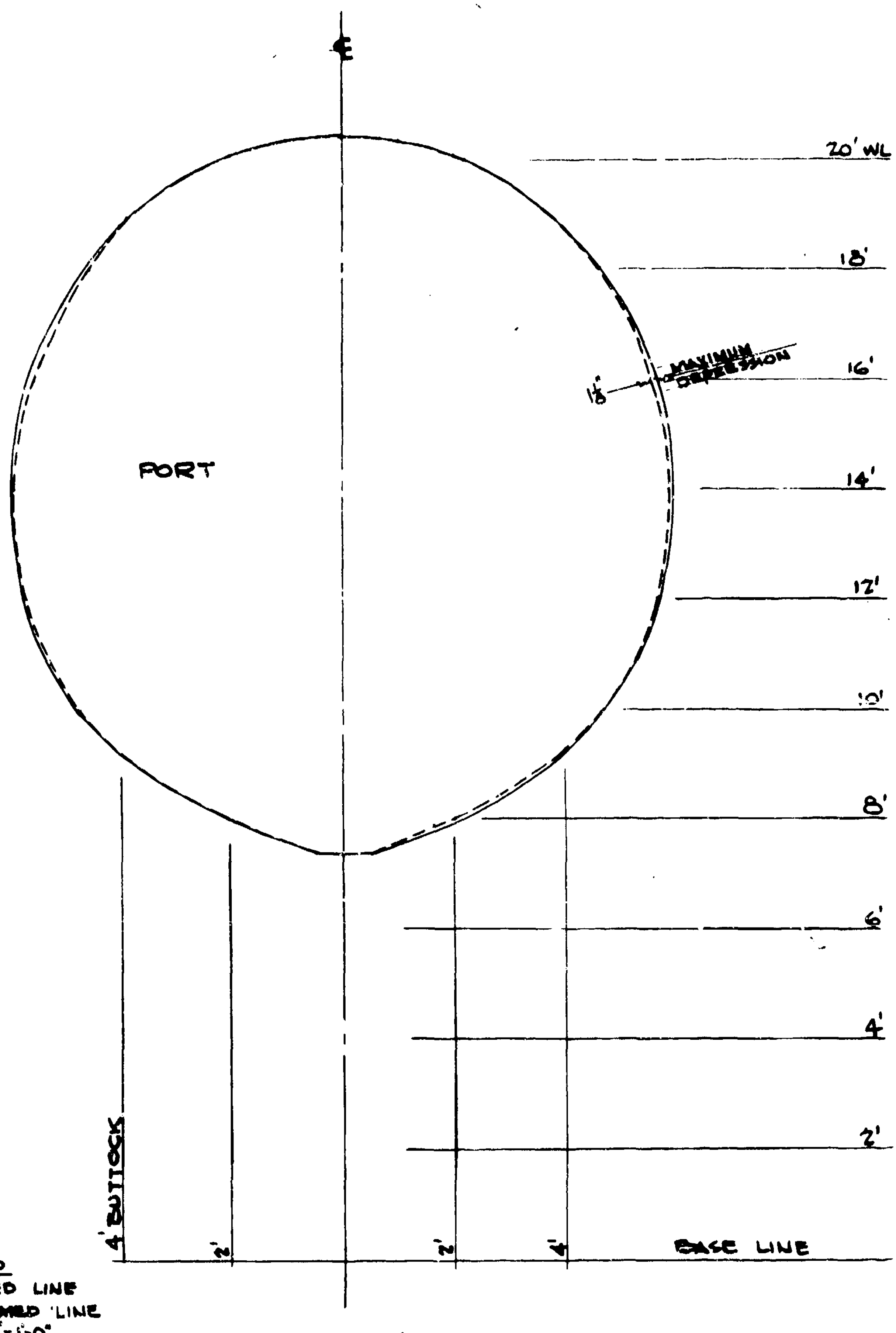
LEGEND
—————— MOLDED LINE
- - - - - - DEFORMED LINE
SCALE $\frac{3}{8}$" = 1'-0"

SECRET

FRAME # 174

PAGE 50 OF 141 U.S.S. SKIPJACK (S.S 184)

7123



LEGEND

——— MOLDED LINE

– – – DEFORMED LINE

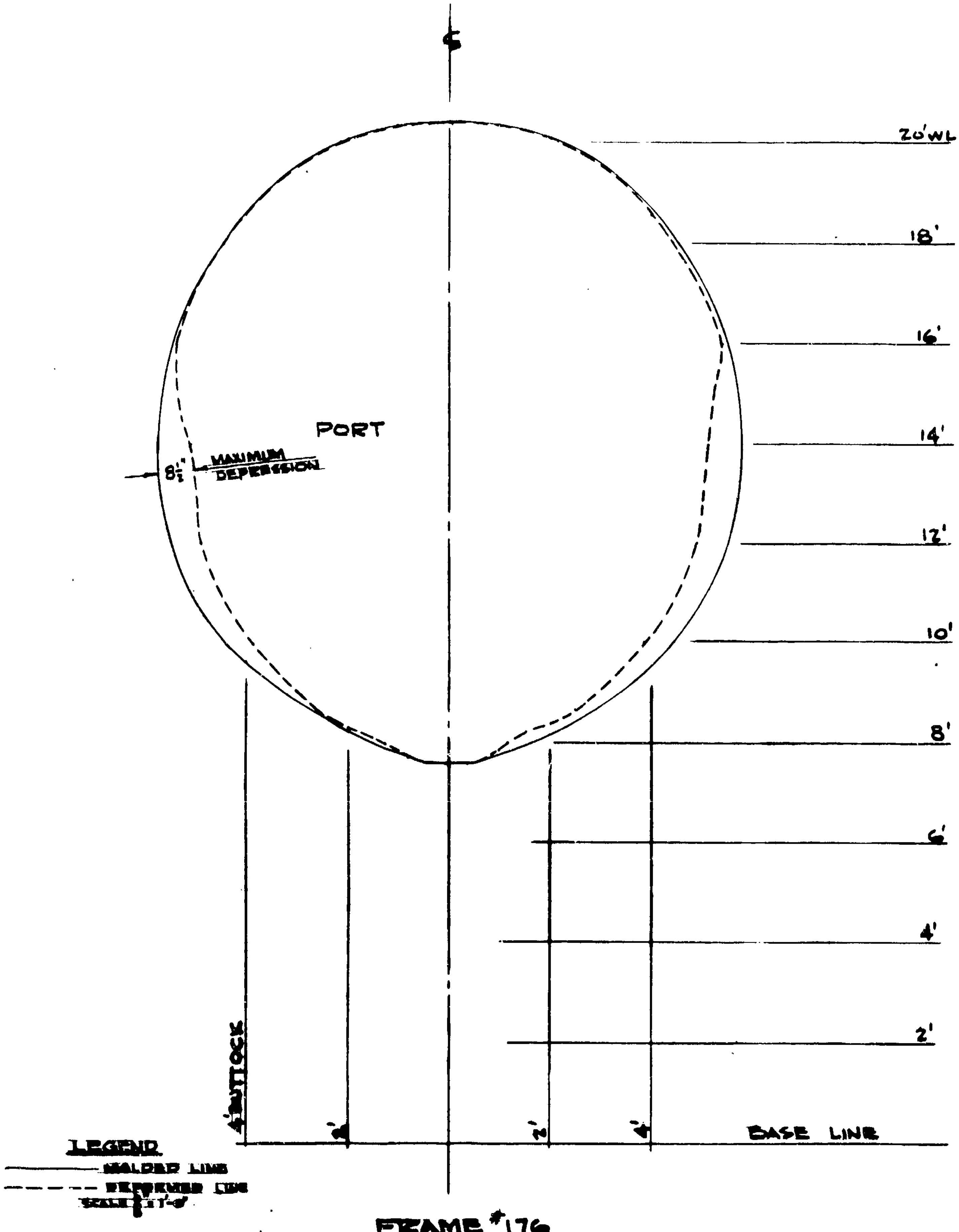
SCALE 3/8" = 1'-0"

FRAME #175

PAGE 51 OF 141 U.S.S SKIPJACK (S.S. 184)

SECRET

7123

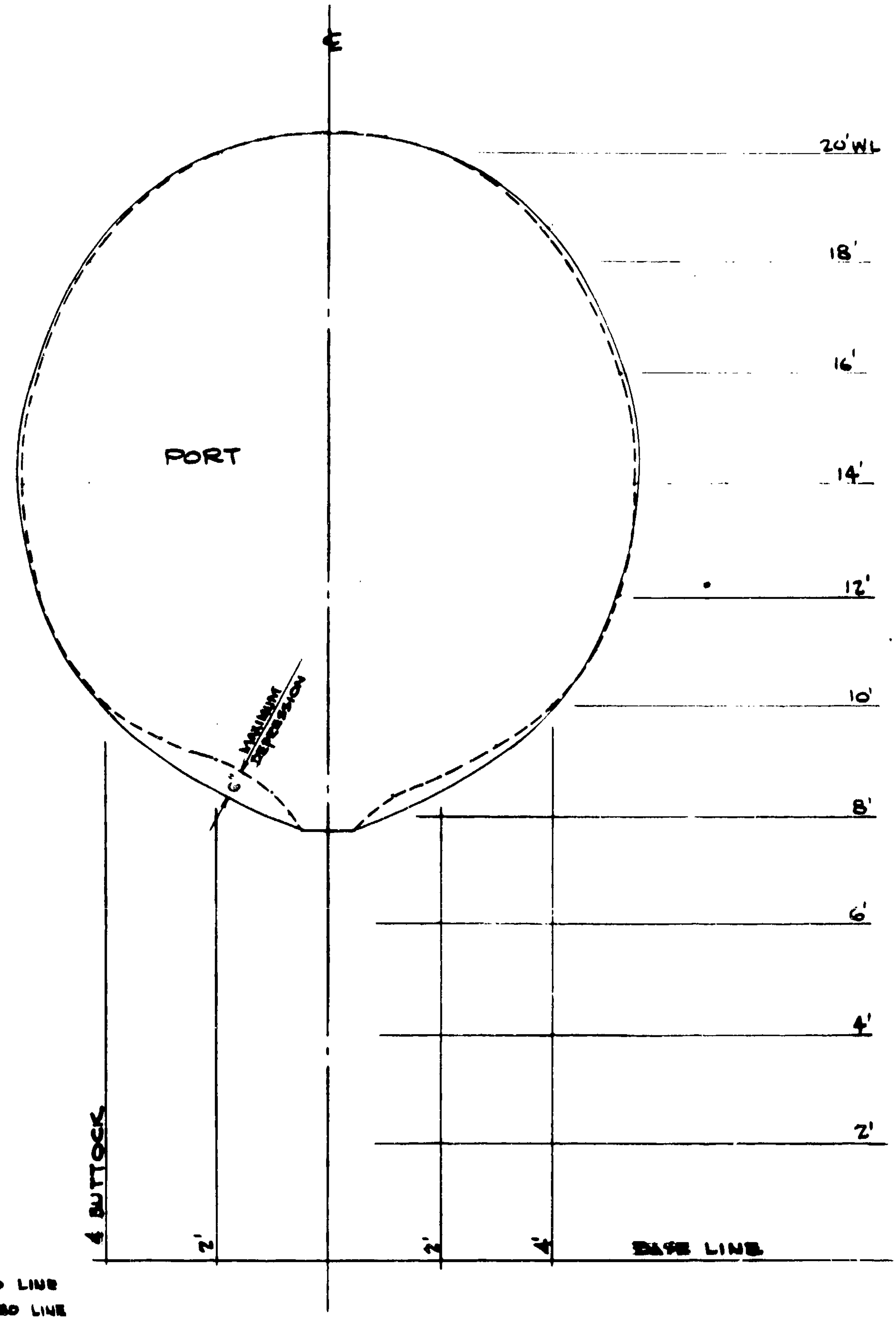


FRAME #176

PAGE 52 OF 141 U.S.S SKIPJACK (S.S 184)

7123

SECRET



LEGEND

——— MOLDED LINE

- - - - DEFORMED LINE

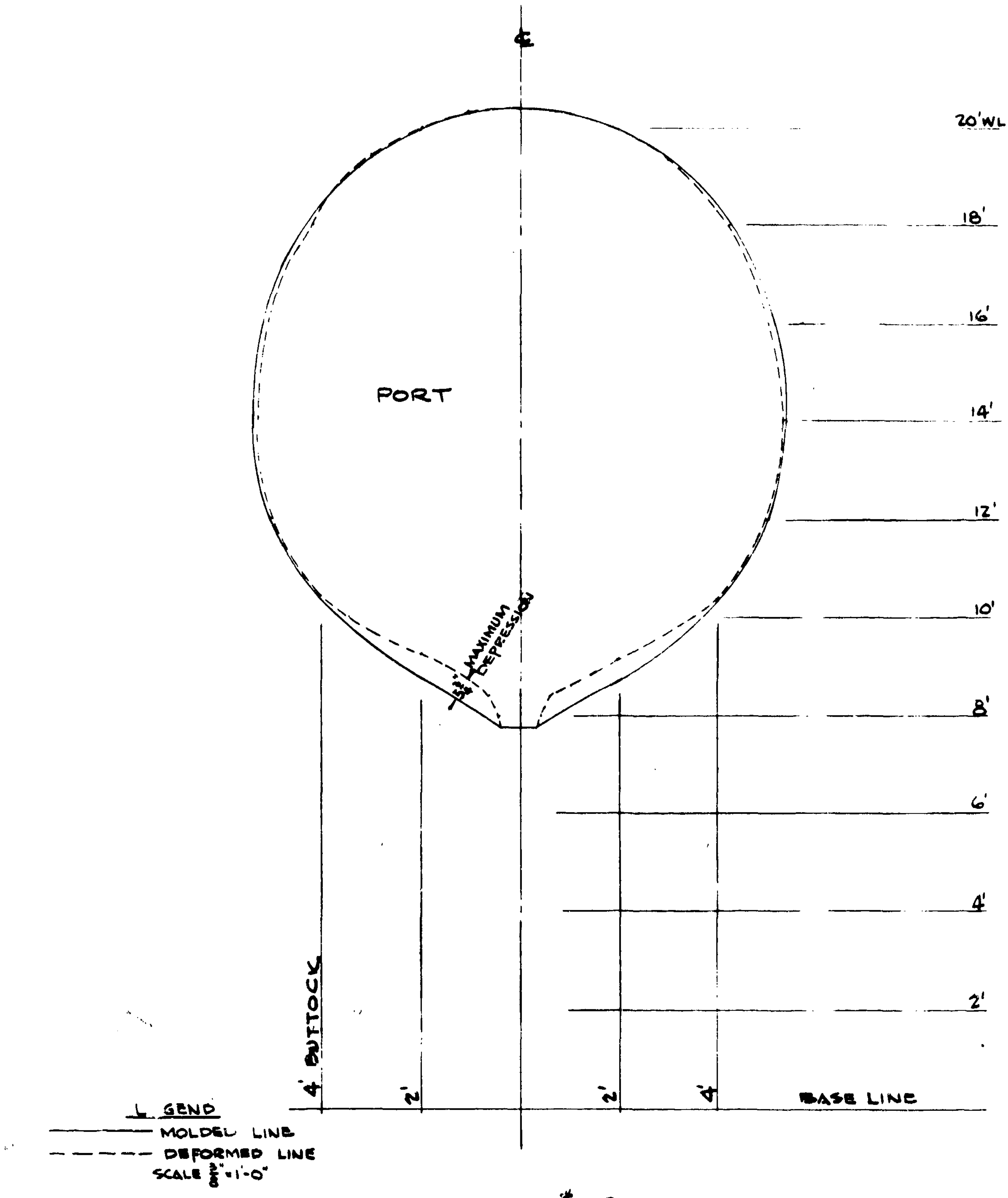
SCALE 3/8" = 1'-0"

FRAME #177

PAGE 53 OF 141 U.S.S. SKIPJACK (S.S 184)

7123

SECRET

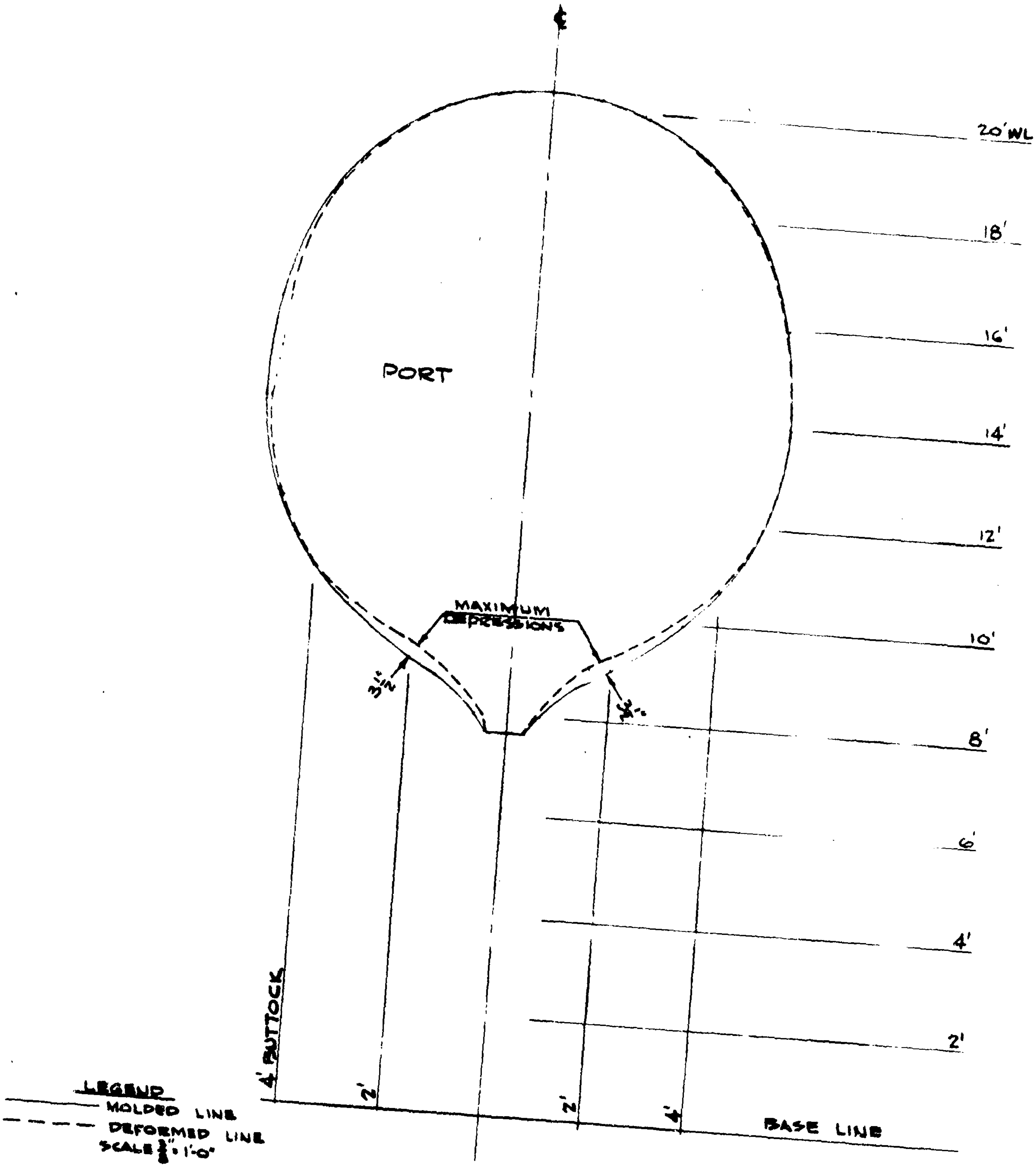


SECRET

FRAME # 178

PAGE 54 OF 141 U.S.S SKIPJACK (S S 184)

,7123

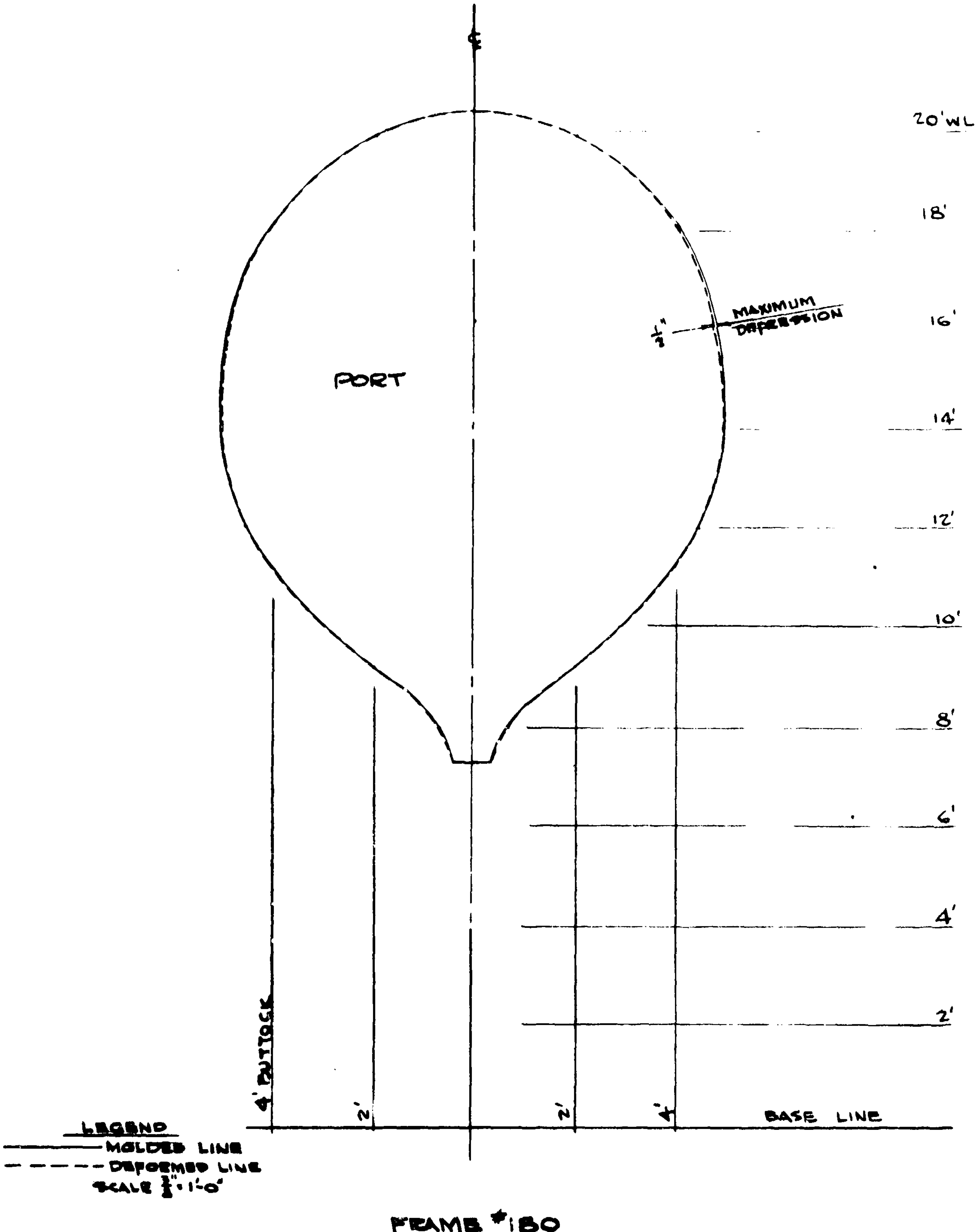


SECRET

FRAME #179

PAGE 55 OF 141 U.S.S. SKIPJACK (S.S.184)

7123



FRAME #180

SECRET

7123

4. Stern framing.

The stern framing shows no damage which can be attributed to the atom bomb.

5. Welding.

The performance of the structural welding on the SKIPJACK is considered to have been excellent. Despite the severe deformations described above, there are only two known failures of structural welds. Both failures occurred in the forward starboard corner of main ballast tank number 1 where the main frame face plate (which is inserted into the floor of the tank, directly below the toe of the frame above the tank top) is secured to the under side of the tank top. These failures, at frames 24 and 25 respectively, are shown on pages 81 and 82 of Volume II.

6. Structural castings.

No failures of structural castings.

(d) Constructive criticism

The performance of the circular pressure hull can hardly be criticized. Considering the pressure to which the ship was subjected, the fact that it is constructed of 'light', medium steel and the proof furnished by the damage to the ends of the ship that the duration of the pressure was long enough to cause heavy distortion, it is considered that the circular pressure hull plating, framing and welding exhibited exceptional resistance.

On the other hand, the performance of the non-circular hull leaves much to be desired. Presumably the strongest portion of the ship, the frames permitted such excessive distortion as to break, bind or unmount sufficient vital equipment to incapacitate the ship and a plating rupture permitted the forward torpedo room to flood sufficiently rapidly so that there is doubt if the ship could have been saved with a crew on board.

Two courses suggest themselves: (1) eliminate as much as possible of the present non-circular type of construction, and (2) strengthen the remainder.

In regard to the first course, the following theory was advanced by Mr. Charles Trilling of San Francisco Naval Shipyard, formerly of the David Taylor Model Basin. Mr. Trilling was asked to assist in the damage analysis.

"The bulges in the circular pressure hull were often slightly staggered longitudinally and in general appeared to be more the result of tangential stresses induced by a fairly uniform pressure than due to any more or less concentrated loading normal to the shell. Also the frames were all virtually intact. In the non-circular single pressure hull, in addition to numerous bulges, there was a complete cave in - inward bulges of the shell along the same longitudinal line, accompanied by corresponding depressions in the frames which were badly distorted in the depressed region. Here failure seems to be more the direct result of a transverse 'push-in' by the pressure. Apparently, then, the single pressure hull was subjected to sharp peaks of pressure rather than the more uniform pressure taken by the circular pressure hull. The liquid layer outside the circular pressure hull, plus the protection of the outer hull evidently had the salutary effect of breaking down high pressure concentrations and transmitting a more uniform pressure load to the inner hull. The superstructure had somewhat a similar effect in the keystone region, but naturally did not offer as much protection as the outer hull, so failure was more marked in this region."

"- - - It is believed that the entire single pressure hull, both at the bow and at the stern, was more vulnerable to concentrated pressure loads, i.e. high pressure peaks, than the double hull. As mentioned before, the liquid layer and structure surrounding the circular inner pressure hull evidently offered some measure of protection by levelling off high pressure peaks. Moreover the circular hull is somewhat more elastic than the rather rigid non-circular hull."

"- - - It is possible that the mechanical difficulties of extending the double hull over the entire length of the pressure resisting part of the ship can be overcome and still preserve a satisfactory ship form. If so this is believed to be an excellent construction. It accomplishes the dual improvement of making the ends of the ship more elastic and better able to resist shock loads, and also eliminating the present discontinuity where the double hull and the single hull are joined.

Certainly Mr. Trilling's suggestion is reasonable from a theoretical point of view. The investigations in connection with surface ship torpedo defense may be relevant to the question of whether the outer shell affords protection. At any rate the subject appears to be worthy of further investigation from a submarine viewpoint.

Granted that a construction involving a double hull for the entire, or nearly the entire length of the pressure body has disadvantages (especially in view of the trand toward slim sterns for high underwater speed), it could be done if the advantages proved to be adequate.

The second course, to strengthen the single hull structure, appears to be mandatory if the firs course is not adopted. The damage to the SKIPJACK (confirmed by what is known regarding the APOGON) shows that the non-circular hull is the weakest part of the ship against such an attack.

To strengthen the frames Mr. Trilling also suggests that ar 'I' or 'H' section might be substituted for the present 'T'. This would at least provide more frame stability, and the scantlings could be increased to gain strength.

Likewise the plating strength must be increased by improved physical qualities or greater thickness. In this connection the relatively 'brittle' nature of the fracture in the high tensile steel shell plate of the APOGON must not be overlooked.

Finally, there are some indications that 'hard spots' had an adverse effect on the structure of the single hull. In nearly all cas the most severe deformations appeared adjacent to a relatively stiff structure. On the port side the most severely distorted frames in the forward torpedo room, 30 to 34 are surrounded by the bulkhead at frame 35, the heavily strengthened boundary for main ballast tank number 1 and the reinforced area around the torpedo loading hatch. Also the tear in the shell at frame 30 lies in this same area and affected frame space is 18 inches instead of the normal 24 inches. Moving aft, the severe deformation at frames 156 - 160, port, lies between the bulkhead at frame 162 and the heavily reinforced junction between single and double hulls at frame 155. Also the severely distorted structure at frame 175 - 179 is bounded by the W.R.T. tank, the bulkhead at frame 180 and the stiff stern post-keel combination.

The area at frame 19 - 22 starboard does not have any apparent adjacent 'hard spots' except for the W.R.T. tank. The other examples quoted above may be mere coincidence. However, it seems logical that where a structure having regions of unequal flexibility is required to abosrb a given amount of energy, the most flexible regions must take a disproportionate share of the energy which means excessive displacement and strain. At least, the damage on the SKIPJACK requires that transitions from heavy to light structure be viewed with suspicion and avoided as much as possible until they can be proved to be harmless.

G. Compartments.

Unless otherwise stated all damage discussed under this item is believed to have been caused by shock, high water pressure or both. All compartments were air tested before test B and found tight at 15 p.s.i..

(a) Shell, framing and bulkheads.

The damage to the shell and framing is discussed under Item F. None of the bulkheads appear to have any structural damage except that the end bulkheads of the conning tower are dished in slightly more than normal at their centers and that part of bulkhead 35 which forms the after boundary of No. 1 main ballast tank has dents about 1/4 inch deep between stiffeners. Photographs on pages 83 and 84 of Volume II show the interior of the forward and after conning tower bulkhead respectively.

(b) Joiner bulkheads, decks and floor plates.

The shock and deformation of the hull, particularly in the torpedo rooms, caused moderate distortion of the joiner work and floor plates. Locker doors and drawers were thrown open and the contents scattered. On some, the locks were jammed. Many of the floor plates were thrown out of position and hatches to the battery tanks, meat and cool rooms and magazines were either jammed of misaligned in their hinges. There is general moderate damage to all joiner work and light decks throughout the ship.

(c) Access closures.

In general the bulkhead doors are undamaged and except for the control room doors, are tight under air test. The gaskets on the control room doors have a fairly deep permanent indentation from the seat, but no other damage.

The door to the forward escape trunk, an oval, four dog design is dished in at the center about one inch as shown in the photograph on page 85 of Volume II. This distortion forced the lugs which support the dogs into the metal of the door frame so that the door cannot be moved. The door leaks badly under the gasket during air test.

During salvage operations all exterior circular hatch covers (except the conning tower hatch) were tightened by the divers. While the reports are confused, it appears that one to three turns were required to tighten each hatch while the ship was on the bottom. Upon air testing the compartments, the following hatches were found to leak badly. An examination disclosed the defects listed.

Hatch Cover For	Damage
(1) Forward Escape Trunk, Upper	Seat .004'' low on port side and .002'' low on starboard side. Cover .040'' high on port side and .006'' high on the starboard side.
(2) Forward Torpedo Loading	Seat .068'' low on port side and .020'' low on starboard side. The cover is .040'' high on the port side and .006'' high on the starboard and after sides.
(3) Conning Tower, Upper	Seat .043'' low on port side and .020'' low on starboard side. The starboard dog on the cover is cracked and the hinges are slightly misaligned.

(4) After Torpedo Loading

The seat is .044" low on the port side and .042" low on the starboard. The cover is .040" high on the port side and .026" higl on the starboard. The starboard dog, which is a bronze casting or forging, failed in tension and bending in way of the hinge pin. See photograph on page 86 of Volume II.

The lower oval hatch covers for the conning tower and forward escape trunk leak under air test applied from above. Although measurements were not taken, it is assumed there is some distortion of the seat or cover as visual examination shows no other damage.

In salvaging the ship it was necessary to remove the lower hatch blanks before their efficacy could be determined. The only definite information known is that the lower hatch blank in the after torpedo room was found about two inches slack. The reason for the looseness cannot be determined as the hatch blank was mislaid during salvage.

In analyzing damage to watertight access closures it must be remembered that the air pressures used in the compartments during the salvage operation were sometimes 30 to 40 p.s.i. higher than sea pressure, and the differential may have exceeded these figures for a short time as the ship came to the surface.

(d) Hull fittings and Equipment.

All items in this category are discussed elsewhere.

(e) Foundations, shock mounts, sound mounts and holding down bolts.

Small foundations in way of hull distortions were generally bent or broken by the shock and/or distortion. For example, the photograph on page 87 of Volume II shows the position in which the bow plane rigging controller and the forward impulse manifold were found. These items were mounted at frames 21 - 22, starboard, and the bolts and foundations were torn loose by the shock transmitted through the hull. The broken, after bracket for the impulse manifold may be seen on page 88 of Volume II and the forward bracket, with all four bolts broken, appears in the picture on page 89 of Volume II. On page 90 of Volume II there is a typical example of the failure of small foundation brackets in way of hull distortion. The strain was held by the piping while the hull collapsed the brackets.

One of the most universal types of failure was that of the straps holding down air flasks. Nearly every air flask in the ship moved an inch or more relative to its foundation, as a result of bending of the straps and bolts. Typical examples of the failure are shown on pages 91 and 92 of Volume II. In both of these cases the connecting air piping was ruptured. A similar situation with regard to impulse flasks is discussed in Item D above.

Except for number 2 main motor, which is adjacent to the port hull in way of a dimpled area, the larger foundations were not seriously distorted. The distortion of the number 2 main motor foundation caused the fracture of several bolts and general misalignment.

In general such equipment as was properly sound or shock isolated, appeared to be undamaged. On the other hand there were numerous instances of casting failures due to shock where solid mounting was employed. For example, pages 93 and 94 of Volume II show fractures in the after inboard cast iron feet of nos. 1 and 2 turboblowers. The liners are steel. Pages 95 and 96 of Volume II show fractures of the aluminum castings which form the housings for the bow and stern plane hand tilting gear boxes in the control room. The liners are wood.

In the only two instances noted where sound isolating mountings failed, the installation was improper. Page 97 of Volume II shows a collapsed rubber doughnut under the ship's service air compressor. The cause of failure is not known except that the compartment was full of oily water. However, the other side of the compressor was rigidly bolted to the foundation.

On page 98 there is a picture of an unusual type of sound isolation mount. The rubber is enclosed in steel and there was insufficient clearance between the top of the steel casing and the foundation plate. As a result, under shock loading, a piece was broken out of the foundation plate. The mount could never have been effective as installed, and it illustrates the hazard of installing sound or shock mounts without adequate information.

To obtain data on holding down bolts and nuts, 85 major foundations were examined. Of these 54 had one or more loose or broken bolts or nuts. Of the 54, about 70% had no type of locking device, and the remaining 30% were locked with various devices, principally fiber inserted nuts.

It would be incorrect to base any rigid conclusions on the above analysis as the bolts and nuts were not checked for tightness prior to the explosion. Also, the figures quoted are for the numbers of foundations without regard to the number of bolts in each.

A more rigid analysis was made of the behavior of the fiber inserted nuts installed on the holding down bolts of the main engines and main motors and of the studs with castellated nuts and cotter pins installed on the reduction gears. The fiber inserted nuts were installed at Mare Island during re-engineering of the SKIPJACK, but could not be identified as to manufacturer. A sample has been delivered to Code 5815 of the Bureau of Ships. The results of the examination were:

Equipt.		No. of nuts Examined	No. of nuts found loose	% Loose
Main engine no.	1	34	6	18
	2	34	4	12
	3	29	10	34
	4	31	6	19
Main motor no.	1	8	6	75
	2	10	8	80
	3	7	6	86
	4	7	6	86
Total fiber inserted Nuts		160	52	32

Reduction gear, stbd.	20	5*	25
port	21	14*	67
Total castellated nuts	41	19	46%

* These figures are the number of loose studs. No nuts were loose. One bolt in the port reduction gear was broken.

Eight bolts, including the one broken one from the port reduction gear and two bent bolts from the no. 2 main motor were analysed in the Industrial Laboratory at Mare Island. Nothing unusual was noted except that the bolt which broke was the only one not undercut at the base of the threads. That this omission is significant is strongly suggested by the results of recent investigations by the Germans in connection with increasing the resistance of bolts to shock loading. These investigations are reported in a report by the U. S. Naval Technical Mission in Europe. The laboratory report on the broken bolt has been delivered to Code 5815 of the Bureau of Ships.

With regard to the condition of the portion of the battery tanks which serve as a foundation for the cells, a complete examination could not be made as there was only time to pull five cells. In way of these cells the steps were in good condition. An examination of the strongbacks and tie rods disclosed no damage.

(f) Evidence of fire.

There is no evidence of fire except for one or two local short circuits in electrical cables.

(g) Damage to watertight integrity.

After blanking all ventilation valves in the bulkheads, the results of a 15 p.s.i. 10 minute compartment test at Mare Island were as follows. The tests were applied to uncover breaks in the watertight integrity of the compartments.

Forward Torpedo Room.

A maximum of 8 p.s.i. running head could be built up with 80 p.s.i. yard pressure. All torpedo tube muzzle doors, the torpedo loading hatch, the escape trunk upper hatch and the escape trunk door leak rapidly.

Forward Battery Compartment.

There was a one oz. drop with some leakage through the bulkhead ventilation blanks.

Control Room, Crew's Galley and Conning Tower.

A maximum of 12 p.s.i. running head was built up with 80 p.s.i. yard pressure. Both bulkhead doors and the conning tower hatch leaked. Air escaped into the forward trim tank. Air escaped through the fresh water and sanitary lines running aft to the crew's head.

Conning Tower.

Only 2 p.s.i. running head could be built up due to leaks through the upper and lower hatches and the conning tower bilge drain. The union joints on the control room stop valve in the bilge drain line were so loose that the valve fell off when it was touched.

After Battery Compartment.

There was a 7 oz. drop in ten minutes. Some of the leakage was through bulkhead cable stuffing boxes, the fresh water lines to the control room and the crew's basin drain lines.

Forward Engine Room.

There was a 16 oz. drop in 10 minutes. Leaks were found in the blanks installed on the bulkhead ventilation valves, the drain line, the studs for the main engine exhaust valve riser and the intercompartment salvage air valves.

After Engine Room.

There was a 6 oz. drop chiefly through the main engine and main motor sea suction lines.

After Torpedo Room.

There was a 15 p.s.i. drop through the torpedo tubes, the loading hatch and the escape hatch.

During the salvage, and immediately thereafter, it was necessary to perform certain operations which obscured, or partially obscured, the evidence concerning the sources of compartment flooding. For example, blowing and venting the compartments may have been the primary cause of damage to the bulkhead ventilation flapper valves. Likewise, the first men to board the ship opened and closed valves while trying to keep her afloat. An attempt was made later to reconstruct their actions, but such a reconstruction cannot be expected to be complete. Therefore the following tabulation of the breaches in the watertight integrity of each compartment is surely not complete or exactly accurate. Compiled from compartment air tests piping tests and examinations at Mare Island and from notes taken during the salvage, it gives the known or strongly suspected breaches in the watertight integrity of each compartment. The material failures are described in more detail elsewhere in this report.

Forward Torpedo Room.

1. Torpedo tubes - all outer doors were open one half to one turn of the hand operating gear. The poppet emergency stop valve for number one tube was open 3/4 of a turn and water is known to have entered the compartment slowly via the poppet drain. Also the breech door gaskets of all tubes were damaged and probably leaked slowly under a high pressure differential. See pages 7, 8, 9 and 10 of Volume II.

2. The operating rod for the forward marker buoy had broken off and come out of its gland. Water had free access here until the divers welded a plug in the hole.

3. The major source of leakage from the sea was unquestionably the tear in the shell plating at frame 30. This tear, which was welded while the SKIPJACK was on the bottom, is shown on pages 66, 67, 68 and 69 of Volume II.

4. After the compartment pressure was partially equalized with the sea pressure, the two circular hatches probably permitted the entrance of considerable water.

5. The four vents for the nos. 1 and 2 normal fuel oil tanks were found open.

6. The sea valve for the pitometer log was found open.

7. The escape trunk flood valve was found 1/8 turn open.

8. The stop valve in the fresh water supply to the forward torpedo room was found open.

Items 6 and 8 and possibly 5 above are believed to be due to errors in rigging the ship rather than damage from the bomb.

Forward Battery Compartment.

1. This compartment has no breaches in the pressure hull.

2. The bulkhead flappers in bulkhead 59 leak freely as all gaskets are blown out.

3. The watertight door in bulkhead 59 leaks when 15 p.s.i. air pressure is applied in the control room.

4. The stop valve for the pantry sink drain was apparently left open by mistake during test B.

Conning Tower.

1. The upper and lower hatches leak badly under a 15 p.s.i. air test.

2. The union joints in the conning tower drain line are so loose that the stop valve in the control room fell off when an attempt was made to close it.

Control Room and Galley Compartment.

1. The inboard vent for normal fuel oil tank no. 4 was partially opened by the blast.

2. The air leak to the forward trim tank (during compartment air tests) indicates the valves in the trim line or the 200# blow line had been jarred open by the blast.

3. During the compartment air test air escaped freely from the basin drains and a fresh water spigot in the crew's wash room at the after end of the after battery compartment. Valves loosened by the shock may have contributed to this leakage.

4. Most of the plug cocks and some of the hull stop valves in the 10 lb. blow line leaked under external air test of the 10 lb. lines.

5. The gaskets in the bulkhead ventilation valves in bulkheads 59 and 89 were blown out or damaged, probably by air or water pressure after the ship sunk.

6. The conning tower drain line leaked at the union joints.

7. The air leaks through the bulkhead doors were probably caused by subsequent air or water pressure, rather than by the bomb.

8. One induction drain was apparently left open by the crew.

9. The overboard discharge valve to no. 2 sanitary tank was jarred open and the plumbing drain from the galley to the sanitary tank was found open during the compartment air test.

After Battery Compartment.

1. The overboard discharge valve for the forward crew's head was jarred about half open.

2. The port inboard vent to the safety tank was partially opened by the bomb.

3. The watertight access hatch was observed to be leaking air while the ship was on the bottom and was tightened by the divers. It may have backed off under the action of the bomb.

4. The bulkhead door between the control room and the after battery compartment leaked during the air test of the control room. This is attributed to the permanent indentation of the gasket by air or water pressure after the explosion.

5. The bulkhead ventilation valves in bulkheads 89 and 108 were blown out or damaged, probably by air or water pressure after the ship sunk.

Forward Engine Room.

1. The sea suction valves and stop valves for the no. 1 and 2 main engine circulating water were partially open.

2. The drain from the forward engine main induction pipe was 3 1/2 turns open. This was probably an error in rigging the ship for the B test.

3. The gaskets for bulkhead ventilation flappers in bulkheads 108 and 130 were blown out or damaged by air or water pressure after the bomb explosion.

4. A grease fitting for no. 2H flood valve operating gear was broken off at the shell. Page 99 of Volume II shows the hole plugged with a wooden plug.

After Engine Room.

1. A section of the gasket between the bolting down flange of no. 2 main motor sea suction valve and the hull liner was blown out by the blast, and the holding down bolts were loosened. Page 100 of Volume II shows the valve leaking under a 90 p.s.i. external pressure.

2. The sea suction and stop valves for nos. 3 and 4 main engines were slightly open by the blast, permitting leakage into the compartment through interior breaks in the circulating watersystem.

3. The stern tube packings were leaking when the ship was surfaced having been loosened by the blast.

4. The hull flange for the main motor circulating water discharge valve was loosened sufficiently by the blast to leak very slowly.

After Torpedo Room.

1. Torpedo tubes - all muzzles doors and poppet emergency stop valves were partially open. The torpedo tube muzzle and breech door gaskets were torn. See pages 11, 12, 13, and 14 of Volume II.

2. The after loading hatch cover and the after escape hatch cover were loosened by the blast. The former had a broken dog (see page 86 of Volume II) and both had warped seats and covers.

(h) Reduction in watertight subdivision, habitability, utility and personal casualties.

It is considered that when the ship was reboarded there was no bulkhead which was strictly watertight. All compartments had been flooded and their habitability and utility therby destroyed completely. However, evidence indicates that, with the probable exception of the tear in the forward torpedo room shell plating, all flooding and leaks could have been controlled. Had the ship been manned and surfaced promptly she could probably have been kept from sinking. In this event personnel casualties would have been confined to injuries from concussion and flying debris.

(i) Constructive criticism.

The destruction of the gasket for the no. 2 main motor sea suction valve is not too serious but is a common casualty.

The development or adoption of a metal reinforced gasket for such applications appears to have merit.

Past practice has been to install locking devices on bolts and nuts outside the pressure hull and in inaccessible or extremely important locations. Since the "loosening effect" of ordinary depth charging has generally been local, this practice has been adequate. It is apparent, however, that one atomic bomb can loosen bolts and nuts throughout the ship. Consideration should be given to increasing the extent of locking device applications and to investigating the effectiveness of various types of locking devices, particularly fiber inserted nuts.

The progam of developing valves which will not "back off" should be actively pursued.

Shock mounting principles should be extended to protect more of the important material with cast housings or other brittle or moderately delicate parts. A considerable proportion of the severely damaged equipment on this ship was secured to the shell plating. According to German investigations the accellerations in the shell plating are roughly twice those on the inboard flange of the single hull frames. At least three electric motors, the two turbo blowers, the two diving plane control gear boxes at the diving station and the refrigerating compressor had fractured castings. Of these, two of the motors were mounted on phenolic doughnuts, and the gear boxes were mounted on wood liners. The remaining items were mounted solidly to steel. It is not believed that the phenolic or wood was intended as shock protection but it is worthwhile noting in passing that neither proved satisfactory in the cases mentioned. The important point is that the application of proper shock mounts can and should be broadened to include other equipment, even if flexible couplings are thereby required.

Recommendations regarding particular items of equipment are included in other sections of the report.

The access door to the forward escape trunk should be eliminated if practicable. If not, the circular design appears to be better.

The matter of adopting for important applications a design of bolt better able to withstand impact (perhaps along the lines of the German design mentioned above) deserves study.

Straps for air flasks (and similar items) should be redesigned so that the bolts are not subjected to bending and the straps cannot open up at the flanged portions.

While the breaks in the dogs of the watertight hatch covers on this ship and on the APOGON may have been due to excessive internal air pressure, the weak point of the linkage has been definately established by these tests. Strengthening the dogs appears to be in order.

Recommendations concerning other details will be found in various relevant sections of this report.

H. Armor Decks.

None fitted.

I. Combined with Item G.

J. Underwater Hull.

(a) Condition and causes of damage to the undereater hull and fittings.

The condition and causes of damage to the pressure hull plating and framing, the bow plating and framing and the stern plating and framing is described in Item F.

There is no apparent damage to any of the structural castings, struts, rudders, diving planes or keel except for the bent stem bar and wrinkled bilge keels. The damage to the stem bar was done while the SKIPJACK was being towed and the bilge keel damage appears to have been caused by the pressure of the bottom or by salvage operations.

By applying 500 p.s.i. hydraulic pressure to the rams the rudder could be moved through its full swing to port and starboard which indicates there is no severe misalignment of the rudder bearings, post, cross head or rams.

The extensive permanent distortion of the hull in way of the stern plane tilting ram prevented any motion of the stern planes. The shaft carrying the planes appears to be undistorted.

The bow planes could not be rigged out even after cutting the shaft between the topside bevel gear and the pinion gear. All units of the bow plane rigging system are jammed, probably as a result of hull distortion and corrosion.

(b) Effect of damage on buoyancy, operability, maneuverability and resistance.

Prior to salvage the vessel had no applicable buoyancy. Operability and maneuverability are non-existent. There is no reason to believe that the resistance to propulsion has been significantly increased.

(c) Constructive criticism.

None.

K. Tanks.

(a) Condition and causes of structural damage to exterior and interior tanks.

In order to facilitate salvage, either the main or emergency vent valve was closed for test B on all main ballast tanksand all fuel ballast tanks that were rigged as main ballast tanks. Fuel ballast tanks 7,8,9 and 10 were rigged for oil. In order to avoid air pockets in the vent risers, the emergency vent valves were closed and the main vents opened on all ballast tanks containing salt water except nos. 1 and 3. Since nos. 1 and 3 main ballast tanks do not have emergency vent valves, it was necessary to close their main vent valves and install a 1/4 inch petcock in the high point of the main vent valve housing. The petcock was left open.

Safety tank was rigged as a ballast tank. All ballast tank flood valves, except those for fuel ballast tanks 9 and 10, were left open for test B.

The structural damage caused by the bomb to exterior tanks was, as might be expected, confined chiefly to pressure tanks.

The damage to the trim and W.R.T. tanks is discussed under Item "F" above.

On pages 101 and 102 of volume II are pictures of the port side of the auxiliary tanks. The starboard side was almost identical. The plating between each frame was pushed in, in some cases up to 2 inches, but the framing was not significantly damaged. The negative tank suffered similar denting as shown on page 103 of volume II. Page 104 shows a section of the intermediate bottom frame in the negative tank. The curvature has been reversed and sheer wrinkles have formed in the web of each end.

As the safety tank was open at the flood valve, no structural damage resulted from the bomb. However, in returning the ship to the United States the tugs battered the ship's sides considerably, particularly to starboard. On the starboard side of the safety tank there is a moderately deep dent at the 15 foot W.L., believed to have been so caused. Pages 105, 106 and 107 of volume II show the consequent buckling of the two end bulkheads and the intermediate floor in way of this dent.

In way of the non-pressure, exterior tanks there were numerous dents. Some are known to have resulted from salvage or towing operations, or from resting on the bottom. Others may have been caused by the bomb. Photographs on pages 108 and 109 of volume II show typical examples of such dents. Referring to the dents shown immediately below the bilge keel, it is difficult to imagine any source other than the bomb as the bilge keel is still intact.

The dents shown on pages 110 and 111 in way of main ballast tanks 2C and 2D appear to have resulted from an air bubble in these tanks at the time of the explosion. The tanks span frames 81 to 89, and the dents are 8 inches deep.

The bulkheads in the ballast tanks were generally bulged between stiffeners. Sometimes the bulges between successive stiffeners were in opposite directions. It is believed that these bulges were caused by the salvage air put into the tanks, and that the reversal of the bulges may be accounted for by the staggered and sometimes reversed sequence of blowing the tanks. The stiffeners on the tank bulkheads are moderately to severely distorted in way of the dents in the outer shell. Page 112 of volume II shows a typical example of such distortion. More serious damage resulted at the tank bulkheads at frames 81 and 113 where apparently an overall pressure had been applied to the tank exterior. These stiffeners were not buckled, but the inner shell, at the toe of the stiffener, was dimpled. The present practice of inserting a doubler plate under the foot of these stiffeners should prevent such damage to the inner hull.

The damage to the tank tops of main ballast tanks Nos. 1 and 3 is described in Item "F". A note worthy phenomenon occurred in way of the flood valves of both of these tanks and is shown, for main ballast tank No. 3, on pages 113 and 114 of volume II. With remarkable symmetry, the plating between the forward and after flood valves of both tanks, on both sides, was dented in from 1 1/2 to 2 inches. Page 115 of volume II shows an example of the resultant frame distortion. Considering the symmetry of the damage, the bomb blast seems to be the only likely source.

No significant primary damage to interior tanks was observed and there were no breaks in the plating of exterior or interior tanks.

(b) Leakage.

All tanks were air tested to 15 p.s.i. After blanking nearly all of the emergency vent valves and the flood valves, the tests were reasonably satisfactory with the following exceptions:

1. Sanitary tank No. 1.

The boiler tight manhole gasket was torn on the forward edge. The cause is not known. The inboard vent was partially open.

2. Sanitary tank No. 2.

The overboard discharge valve and the galley drain line leak.

3. Main ballast tank No. 3.

The welding between the port stern tube and the bulkhead bearing casting is cracked, permitting a small leakage from the tank into the stern tube.

(c) Main Vent Valves.

As stated above, all main vent valves, except those for main ballast tanks 1 and 3 and fuel ballast tanks 7, 8, 9 and 10 were open at the time of the explosion. During salvage, the linkage of nearly all main vent valves was disconnected or cut at the spring and the flappers gagged by the divers. This was necessary as the emergency vent valves would not hold salvage air.

The valve on main ballast tank No. 1 was found to be partially open after the explosion and subsequent examination of the operating gear at Mare Island showed it to be also 1/4 open. The operating shaft is jammed by corrosion or misalignment. Divers found the main vent valve for main ballast tank No. 3 also partially open. At the point of 3/4 travel (toward "open"), the operating shaft through the hull is bent. It is assumed that the pressure wave acting on the flapper and the shaft itself, moved the operating gear until the shaft bent. Other than corrosion, no additional damage to any main vent valve was found.

(d) Flood valves and flood valve linkage.

As stated above, all flood valves, except those for fuel ballast tanks 7, 8, 9 and 10 were open for the test. No flood valve for any fuel ballast tank was damaged. On the other hand, one or more valves or linkage in every main ballast tank except two was damaged. The reason for such discrimination has not been discovered. A tabulation of the flood valve damage in the main ballast tanks follows:

Tank.	Damage.
Main ballast #1.	The seats of all four doors were badly twisted by the deformation of the hull plating described above. One starboard reach rod was bent and the forward port operating rod passing through the tank top was bent.
Main ballast #2A.	None.
Main ballast #2B.	On the after valve the operating rod which passes through the hull was bent up about 1 inch. See page 116 of volume II. All air flask had been jarred out of position sufficiently to interfere with the lower bell crank of the forward flood valve. See page 117 of volume II.
Main ballast #2C.	On both valves the ball and socket joint at the back of the door had pulled apart as a result of fracture of the cast locking nut. The gaskets were blown out of both doors.
Main ballast #2D.	On both valves the ball and socket joint at the back of the door had pulled apart as a result of fracture of the cast locking nut. Both operating rods passing through the hull were bent up as in 2B.
Main ballast #2E.	None.
Main ballast #2F.	On the after door, one nut in the foundation of the upper bell crank was split. On the forward door the operating rod that passes through the hull was bent up about 2 inches as in tank 2B.

Main ballast #2G.

On the after valve the operating rod passing through the hull was bent as in 2B, and the lower end of the lower reach rod was broken off at the base of the forged eye. Pages 119 and 120 of volume II show the after door. Here the lower reach rod was broken in a similar manner as on the forward door. In addition the hinge arms were split open, the cover was bulged up in the center and the ball and socket joint was damaged as shown on page 118 of volume II. Note that the locking nut around the ball has cracked at several points and the shank of the ball was pulled out of the boss on the door, splitting the boss. This is typical of the damage to the ball and socket joints in other tanks, and it indicates that the center of the door tried to pull away from the ball joint.

Main ballast #2H.

On the after door the hinge arm is broken in a manner similar to that shown on page 119 of volume II.

Main ballast #3.

The seats of all four doors were twisted by the distortion of the adjacent plating and the hinge arms were cracked. In addition the gaskets of the two forward doors were blown out.

Safety tank.

None.

Negative tank.

This flood valve was closed for the test. As shown on pages 121 and 122, the high pressure acting on the T-shaped gasket distorted the retaining ring badly and broke off the heads of a large number of the holding down screws for the ring.

The frequently found damage to the flood valve operating shaft that passes through the hull stuffing box (bending up) may have resulted when strenious efforts to close the flood valves from inside were made after raising the ship. As the linkage and flood valves hinges were broken or otherwise jammed, the upper bell crack could have been held stationary while the connecting link forced the operating shaft to bend up. The mechanics involved in the damage to the doors and ball and socket joints is difficult to analyze. Most of the linkage seems to have been damaged by compression forces (trying to close the door), yet the ball and socket joints appear to have failed under a tensile load.

(e) Emergency vent valves.

As, stated above, all emergency vent valves were closed for the test except for main ballast tank 2A. The rubber gasket of all main ballast tanks having emergency vent valves were partially or completely blown out of their grooves. The emergency vent valves of fuel ballast tanks 6 and 7 were found in similiar conditions. A typical example of the condition of the partially blown gaskets appears on page 123 of Volume II. It would normally be expected that the pressure from the explosion would act on both sides of the valve simultaneously, However, to cause the damage, there must have been a pressure differential across the valve. The direction in which the gaskets were displaced indicates that the pressure was higher in the vent riser than in the tank.

Page 124 shows the emergency vent valve in main ballast tank 2E. The link between the quadrant and the disc has been buckled, apparently as a result of high pressure on top of the closed valve.

(f) Vent risers.

The following tabulation shows the condition of the vent risers and the thickness of the pipe actually installed. Electric Boat Co. Plan No. 1476-19 indicates all risers were manufactured of galvanized steel, 0.125 inches thick. Apparently some changes have been made since the vessel was built.

Tanks.	Thickness of pipe (inches).	Condition.
MBT 1	no riser	
FBT 3	.125	split
FBT 4	.131	split
FBT 5	.375	no damage
FBT 6	.295	split
MBT 2A	.125	ruptured
MBT 2B	.153	ruptured
MBT 2C	.131	no damage
MBT 2D	.131	ruptured
Safety, stbd.	.110	no damage
Safety, port.	.125	no damage
MBT 2E	.120	10 lb. blow leaks
MBT 2F	.117	ruptured
MBT 2G	.124	no damage
MBT 2H	.117	no damage
FBT 7	not measured	no damage
FBT 8	.133	split
FBT 9	.131	no damage
FBT 10	.113	no damage
MBT 3	no riser	

A typical ruptured vent riser is shown on page 125 of volume II. Most of the splits occurred along a welded seam. The nature of the damage indicates that the pressure wave inside the vent risers must have had a longer duration than that outside the pipe, or else there was a peak pressure built up inside the riser that was higher than the free field pressure.

(g) Constructive criticism.

The gaskets in the flood valves and emergency vent valves have a "dove-tail" cross-section. In general, they emphasize the desirability of a design more resistant to being blown out. From inspection of the negative tank flood valve it is apparent that the "T" gasket and retaining ring installed thereon is not a satisfactory design either. As previously recommended in this report, a thorough review of the behavior of different types of gaskets and retaining rings appears to be in order.

The ruptures of the vent risers point to the use of seamless pipe.

L. Flooding.

(a) Major flooded areas.

All compartments and most tanks were blown in order to bring the ship to the surface. Every compartment had been flooded to or near the overhead. While it is possible that the conning tower and forward battery compartment were dry before salvage operations were started, it is believed that these compartments as well as the others were flooded as a result of the test. The details of the damage mentioned below are discussed in Item "G" above and other sections of this report.

(b) Sources of flooding.

The forward torpedo room flooded fairly rapidly through the tear in the shell plating at frame 30. (See pages 66, 67,68, and 69 of Volume II). In addition number one torpedo tube leaked through the muzzle door and the partially opened poppet valve into the bilges. The operating rod of the forward marker buoy broke and was pushed out of its gland, leaving a small hole for the entry of water. The other three tubes may have leaked slowly.

The forward battery compartment is believed to have flooded slowly from the control room via the damaged bulkhead ventilation flappers, the leaky bulkhead door and through cable stuffing tubes. None of these items leaked during the compartment air test conducted prior to the explosion, but of course the pressure differential on the bottom was nearly five times as great as that used for the air test.

The conning tower is believed to have flooded slowly through the upper hatch and the periscope stuffing box. The upper hatch coaming is only slightly distorted, but the hatch cover locking mechanism has one cracked dog and was probably loosened by the blast sufficiently so that the gasket leaked when the pressure differential was reduced by the flooding of the control room.

The control room is believed to have flooded slowly through the inboard vents for No. 4 fuel ballast tank, the No. 2 sanitary tank (sea valve and galley drain), the 10 lb. blow lines and one main induction drain. Water had access between the control room and the conning tower via the conning tower drain line, and between the control room and the after battery compartment via the fresh water and drain lines. However, it is not definitely known which of these three compartments flooded first.

The after battery compartment flooded directly but slowly via the port inboard vent for the safety tank and possibly via the access hatch. It is believed that additional water came from the control room via the bulkhead ventilation flappers and the fresh water and sanitary drain lines, and also from the forward engine room via the bulkhead ventilation flappers.

The forward engine room probably flooded slowly via the drain to the main engine induction piping, the main engine circulating water system and the broken grease fitting at the flood valve operating gear for main ballast tank 2H. As the after engine room is believed to have flooded faster than the forward engine room, additional water probably entered the latter via the bulkhead ventilation valves in bulkhead 130.

The after engine room flooded via the sea suction valve for the number two main motor. (See page 100 of volume II.) Other sources of slow leakage were the stern tube glands, the main motor overboard discharge valve flange, the main engine sea suction valves and the loosened hatch cover.

The after torpedo room flooded through leaking torpedo tube muzzle doors and partially opened poppet valves. As the compartment pressure approached sea pressure, flooding was undoubtedly augmented by the partially undogged hatch covers, particularly the cover for the loading hatch.

A path of slow intercompartment flooding for all compartments existed in the drain line, where the bilge suction stop valves were almost universally partially open or leaking.

In all except the two end compartments, the damaged gaskets of the bulkhead ventilation valves probably permitted the flooding to become progressive.

(c) It is also believed that all compartments except the forward torpedo room flooded slowly enough so that an active crew could have controlled the leakage by emergency measures. Being at the top of the hull, the tear in the plating at frame 30 would have been very difficult, if not impossible, to handle while submerged.

(d) Recommendations are included in the parts of the report that deal with the particular items that failed.

M. Ventilation.

(a) Condition and causes of damage to the hull and engine induction piping and the compartment ventilation.

Both hull and main engine induction valves were gagged from topside in preparation for the test. Experience with the SEA RAVEN and the DENTUDA in Test B substantiates the statement that these valves cannot be closed tightly by this method. During salvage both valves had to be jacked closed by the divers, but even with jacks both valves leaked when a 15 p.s.i. air test was applied at Mare Island. The fairing around the main induction valve seat was crushed by the pressure. It is shown on page 126 of volume II, after the conning tower fairwater had been cut away. Careful examination of both valves revealed no significant damage other than a slight tearing of the main engine induction valve gasket. (See photograph on page 127 of volume II.)

The remainder of the engine and hull induction systems were tight under air test after the drain valve for the forward engine room induction piping and the control room drain were closed.

The inboard compartment's ventilation piping was not significantly damaged except that all gaskets at the flange had been pushed out by pressure or swelling of the oil-soaked rubber. Page 128 of volume II shows a typical example of such a gasket. The major damage was confined to the bulkhead ventilation valves which are of an obsolete design. On this ship the bulkhead valves are double, but the operators operate the flappers on their side of the bulkhead only. The near flappers open away from an observer facing the bulkhead. The gaskets are rectangular in cross section and fit into a rectangular groove, hence they are easily blown out. When examined at Mare Island, the valves were closed and locked, but in the following material condition.

Bulkhead.	Valve locations.	Damage.
35	all four flappers	None. It is concluded that these gaskets remained undamaged because of their smaller diameter.
59	all four flappers	All gaskets blown out.
88	forward starboard	Gasket blown out.
88	forward center	Slight cutting of gasket.
88	forward port (battery ventilation)	Slight cutting of gasket.
88	after starboard	Gasket blown out.
88	after center	Gasket blown out.
88	after port	Slight cutting of gasket.
108	forward port	Gasket blown out.
108	forward stbd.	Gasket shredded. (See photograph on page 129 of volume II.
108	after port	Gasket cut.
108	after stbd.	Gasket in shreds.

130	forward stbd.	Gasket cut on edge toward center of disc and torn at top. (See photograph on page 130 of volume II.)
130	forward port	Gasket blown out of groove, small cut on edge toward center of disc.
130	after stbd.	Gasket shredded around outside perimeter.
130	after port	No apparent damage.
162	all four flappers	Tight and intact. Same remarks as for Bhd. 35.

One valve at bulkhead 88 and one at bulkhead 130 were removed and examined carefully. There was no damage other than to the gasket.

(b) Evidence that ventilation system carried heat, blast or water into any compartment.

All ventilation lines inboard were flooded with the compartments. It is believed, but not proved, that all except the end compartments were in communication with adjacent spaces via the bulkhead ventilation valves.

(c) Constructive criticism.

The SKIPJACK design of bulkhead ventilation valves is faulty on two counts: (1) The near flapper should seat with pressure and (2) the gasket design should be such that it cannot be blown out of the groove, even after soaking in oil. The present design meets the first objection but may not meet the second.

N. Ship Control and Fire Control.

(a) Damage to control stations due to failure of compartments.

Structural failure is not a factor of the damage to the bridge, conning tower or control room. All control stations were rendered useless by failure of vital equipment under shock or hull distortion. The flooding of the conning tower and control room via access closures and fittings completed the task of inactivating all equipment.

(b) Constructive criticism.

None.

O. Fire Control.

Except for flooding there is no damage relevant to hull material.

P. Ammunition Stowage.

(a) Condition, operability and causes of damage.

Except for excessive corrosion of the covers, all ready service lockers are in good condition. None are known to have flooded, and none are deformed or displaced.

The magazines were flooded with water and fuel oil that seeped down from the crew's mess, but otherwise undamaged.

(b) Constructive criticism.

None.

Q. Ammunition Handling.

(a) Condition, operability and causes of damage.

The damage to the torpedo stowage and loading cradles was discussed above in Item "D".

There is no ammunition passing scuttle or other material concerned with ammunition handling.

(b) Constructive criticism.

None.

R. Strength.

(a) Details of damage.

1. In way of the circular hull, the geometry of the pressure hull plating is generally destroyed by dimples. The distortion is especially severe along the port side and while the frames have not begun to "lay over", it is apparent that the strength of the circular hull is reduced. As far as strength is concerned, the conning tower plating and framing is intact and undamaged.

The plating of the single hull is not intended to contribute to the strength of the pressure body in the same proportion as the circular hull plating. However, there is already one tear in the single hull plating (at frame 30) and there are numerous locations where the deformation is so severe that complete fracture must be imminent.

2. The circular hull framing appears to be undamaged but several frames in way of the single hull have collapsed. They appear to retain virtually no value as strength members. The fact that the ship remained at a depth of 170 feet without general collapse of the single hull is considered to be exceptionably remarkable

3. No significant deformation of or damage to the compartment bulkheads was noted.

4. Only three mincr failures of structural welding were found.

5. On the port side, immediately adjacent to the junction of the single and double hulls, the deformation of the single hull both forward and aft was especially severe (Frames 30 - 34 forward and 155 - 160 aft). Whether the severe damage in these two areas is due to local peaks of pressure, to the proximity of the adjacent, heavily strengthened discontinuities, cr to the fact that average diameter of the single hull in these localities is the greatest, is not known. Certainly the matter deserves to be investigated further.

Along the same line, it is considered possibly significant that between frames 155 and 160, the most severe deformation of the hull plating occured between the heavy longitudinal brackets designed to transmit the end thrust between the single and double hulls.

The tear in the shell at the after edge of frame 30 also occured in the neighborhood of a "hard spot", for there is an intermediate frame 18 inches aft of frame 30 designed to reinforce the loading hatch. When available, the determination of the physical properties of the steel adjacent to the break should throw some light on the problem. (The section containing the break was cut out and sent to the Bureau of Standards.)

(b) Constructive criticism.

See pages 57 - 60 of volume I.

S. Miscellaneous.

No comments.

T. Coverings.

No primary damage was noted. This comment includes the hexagonal white tiling in the galley, wash rooms, heads and showers. This tiling was discontinued in submarines because of its reputed susceptibility to shock damage.

U. Welding and Rivetting.

(a) General summary of welding performance.

In view of the excessive deformation of the single hull frames and plating, the performance of the structural welding is considered exceptional. Only three minor cracks, as previously noted, were observed. In general the non-structural arc welding was badly corroded and showed numerous failures.

A significant number of failures in silver brazed joints were disclosed. These are reported in the machinery section of this report.

(b) General summary of riveting performance.

No significant damage was observed. The riveting on this ship is confined to minor non-structural plating.

(c) Constructive criticism.

In view of the severe distortions of the welds on this ship and the knowledge that almost all structural welding contains some porosity or other defects, a radiographic survey of the welding in certain critical areas might prove fruitful.

The recommendations concerning brazing that appear on page 45 of the Bureau of Ships Technical Report of the U.S.S. SKATE damage for Test A are reinforced and emphasized by the observations on the SKIPJACK.

TECHNICAL INSPECTION REPORT

SECTION II - MACHINERY

GENERAL SUMMARY OF MACHINERY DAMAGE

I. Target Condition After Test.

(a) Drafts after test; list; general areas of flooding, sources.

The SKIPJACK was found on the bottom with all compartments flooded when attempts were made to surface her by normal planned measures after Test B. Her surfacing was turned over to the salvage unit and was accomplished some six weeks after the test. She was towed to Mare Island via Pearl Harbor after emergency repairs to make her watertight and seaworthy had been accomplished. Inspection for this report was made at and assisted by Mare Island Naval Shipyard.

Areas and sources of flooding are covered in the Hull section.

(b) Structural damage.

Covered in Hull section.

(c) Other damage: machinery, ship control.

All machinery and equipment was inoperable except for hand power steering when the ship was surfaced, due mainly to salt water damage and misalignment of foundations incident to structural deformations. Main and auxiliary machinery received small direct primary damage as a result of the bomb, this damage being limited to isolated cases of broken or cracked castings.

II. Forces Evidenced and Effects Noted.

(a) Heat.

None.

(b) Fires and explosions.

None.

(c) Shock.

The vessel was subjected to a very definite shock wave. Shock was the cause of most primary damage to machinery. The apparent direction of shock was not evident since shock damage was not localized. Shock damage limited its effect for the most part to machinery and equipment not shock mounted and of out-of-date design and material, although there were some instances of shock damage to piping at silver-soldered joints and at bolted flanges.

(d) Pressure.

The ship suffered its major structural damage as a result of pressure. Structural damage is covered in detail in the Hull section. Much of the machinery damage resulted from hull deformations due to pressure.

(e) Any effects apparently peculiar to the atom bomb.

The only effect apparently peculiar to the atom bomb was radioactivity retained by the ship.

III. Effects of Damage.

(a) Effect on machinery, electrical and ship control.

Machinery, electrical and ship control, with the exception of hand power steering, equipment was completely inoperable.

(b) Effect on gunnery and fire control.

Gunnery and fire control equipment completely destroyed.

(c) Effect on watertight integrity and stability.

Completely destroyed.

(d) Effect on personnel and habitability.

Habitability completely destroyed. The effect on personnel is difficult to evaluate since no personnel were aboard; however, it is estimated that all personnel in the forward torpedo room would have been lost from flooding since that was the only compartment in which the pressure hull was ruptured. It is further estimated that had personnel in other compartments survived the effects of shock and the immediate possible effects of radioactivity, they could have prevented the complete flooding of the ship and possibly brought her to the surface.

(e) Total effect on fighting efficiency.

Completely destroyed.

IV. General Summary of Observers' Impressions and Conclusions.

The ship as inspected was a complete and total loss; however, as noted in III (d) above, had she been manned it is possible that she may have been saved.

V. Any Preliminary General or Specific Recommendations of the Inspecting Group.

Much of the machinery installation in this ship was out-moded and all in poor condition due to age and time out of overhaul.

The only specific recommendation which can be made is to reduce the number of pressure hull fittings and strengthen the irreducible minimum.

The machinery installation appears to be able to withstand an attack of this nature with less resulting damage than the structural hull.

DETAILED DESCRIPTION OF MACHINERY DAMAGE

A. General Description of Machinery Damage.

(a) Overall condition.

In general no machinery was operable when she was surfaced due partially to primary shock damage and mainly to salt water flooding.

(b) Area of major damage.

Primary damage was not localized and consisted primarily of shock damage to foundations. Secondary damage from flooding was general throughout the ship. Various machinery items were misaligned and damaged due to structural deformation.

(c) Primary cause of damage in each area of major damage.

The primary cause of damage to machinery was shock and misalignment due to structural deformation by pressure.

(d) Effect of target test on overall operation of machinery plant.

The effect of the test was to make the machinery plant completely inoperable due primarily to secondary damage from salt water flooding.

B. Boilers.

Not applicable.

C. Blowers.

Not applicable.

D. Fuel Oil Equipment.

(a) Heaters.

Undamaged by bomb. Inoperable due to flooding.

(b) Strainers.

Undamaged.

(c) Manifolds.

Undamaged.

(d) Fittings (Thermometers, gages).

In general distant reading thermometers, gages and other fittings were undamaged where shock mounted. All were ruined by salt water and oil flooding.

(e) Flexible fueling hose.

Stowed in superstructure. Undamaged.

E. Boiler Feedwater Equipment.

Not applicable.

F. Main Propulsion Machinery.

(a) Main and auxiliary engines.

1. Foundations.

All main and auxiliary engine foundations were undamaged. Several holding down bolts in each foundation were loose. These were probably loose before the test. Representative bolts were pulled, examined and checked by metallurgical laboratory of Mare Island Shipyard. Report by the shipyard recommended that all bolts not displaying outward indications of failure, such as bending, be magnafluxed and if found free from cracks that they could be continued in service. None of the bolts examined by the laboratory exhibited cracks upon being magnafluxed. See photograph on page 131 of Volume II for picture of foundation bolts in general.

2. Casings and cylinders.

Undamaged. Engines, if flooded, were not apparently damaged thereby as determined by visual inspection.

3. Bearings, crankshafts, pistons, etc.

Undamaged.

4. Couplings.

Undamaged.

5. Fuel inspection system.

Undamaged.

6. Superchargers.

Undamaged except for small crack in blower casing of number four main engine. This crack could not be seen and was discovered by water seeping out.

7. Governors.

Undamaged.

8. Inboard and outboard exhaust valves.

Undamaged, except for No. 4 outboard exhaust valve which had a cracked casting. See photographs in Volume II pages 132 and 133.

9. Mufflers and exhaust piping.

Number one muffler undamaged.

Number two muffler entering pipe collapsed and pulled off flange by pressure. See photograph in Volume II on pages 134 and 135.

Number three muffler forward end dished by pressure and tail pipe corroded away.

Number four muffler dished at end by pressure. See photograph on page 136 of Volume II. Auxiliary engine muffler was collapsed by pressure at center weld. See photograph in Volume II on pages 137 and 138. Mufflers were old, corroded and in poor condition before test.

10. Cooling system.

Undamaged, except for #2 main engine. Fresh water line to header has silver solder leaks at reducing Tee (See photograph on page 139 of Volume II) and a leak in silver soldered joint where pipe enters elbow outboard of check valve. See photograph on page 140 of Volume II.

11. Miscellaneous.

Gauges in general, where shock mounted, were undamaged except from salt water and oil flooding and electrolysis by which practically all were ruined. For photographs of typical gauge boards see pages 141 and 142 of Volume II.

G. Reduction Gears.

(a) Foundations and casings.

Undamaged. See comment under Item F (a) 1 which also applies here.

(b) Gears and shafting.

Undamaged though slightly misaligned on port side by structural deformations.

(c) Bearings.

Undamaged.

(d) Couplings (flexible and solid).

Undamaged.

(e) Fittings (oil sights, thermometers, etc.)

Undamaged except for distant reading thermometers and gauges ruined by flooding.

(f) Turning gears.

Undamaged by direct causes. Inoperable due to corrosion incident to flooding.

H. Shafting and Bearings.

(a) Shafting.

Undamaged.

(b) Bearings and bearing foundations.

Bearings undamaged. Port steady bearing displaced slightly by structural deformation.

(c) Alignment.

Port shaft was misaligned by structural deformation causing slight movement inboard and up of steady bearing forward of coupling. When coupling was unbolted, the stub shaft went outboard 15/32" and dropped 3/32".

(d) Hull packing gland.

Undamaged.

(e) Thrust bearings.

Undamaged.

(f) Strut bearings.

Undamaged.

I. Lubrication System.

(a) Coolers.

Coolers undamaged. Number 4 main engine lub oil cooler was displaced by hull deformation to the extent that the lub oil discharge pipe to the engine was twisted and deformed; however no leakage was caused. See photograph in Volume II on page 143.

(b) Filters and strainers.

Undamaged except that edge type strainer for number 4 main engine was displaced by hull deformation. No leaks were caused. Wiper shaft was bent. See photograph in Volume II on page 90.

(c) Purifiers.

Undamaged except for cracked motor end bell on one purifier. Inoperable due to secondary damage from salt water flooding.

(d) Tanks.

Undamaged. Tested.

(e) Fittings (gages, etc.)-

Gages and distant reading thermometers ruined by salt water and oil flooding.

J. Condensers and Air Ejectors.

Not applicable.

K. Pumps.

All pump motors were grounded out and inoperable from flooding hence no pumps could be operated. Visual inspection and examination of all pumps disclosed no direct damage as a result of test.

L. Auxiliary Generators.

Discussed under Item F.

M. Propellers.

(a) Blades.

Undamaged.

(b) Caps, nuts, etc.

Undamaged.

N. Distilling Plant.

(a) Distillers.

Apparently undamaged. Not operated.

(b) Compressors.

Apparently undamaged. Not operated. Motors inoperable due to flooding.

(c) Miscellaneous valves, fittings, gages, attached piping, etc.

Undamaged except from salt water flooding.

O. Refrigerating and Air Conditioning Plants.

(a) Compressors.

Apparently undamaged from visual inspection and turning over by hand. Not operated.

(b) Motors.

Inoperable due to salt water flooding.

(c) Condensers.

Apparently undamaged from visual inspection. Not tested.

(d) Foundations.

The after inboard leg of the refrigerating compressor was broken by shock. Material is cast iron as determined by analysis. Others not damaged.

(e) Refrigerant piping and cooling coil.

Undamaged.

(f) Insulation and lagging.

Undamaged by bomb. Ruined by flooding.

(g) Miscellaneous valves, switches, controls, fittings, etc.

All electrical wiring, switches and control panels ruined by flooding, undamaged by bomb. Same for gauges and distant reading thermometers.

P. Winches, Windlasses and Capstans.

(a) Foundations and bed plates.

Forward and after winches and anchor windlass foundations misaligned by structural deformation.

(b) Brakes and brake lining.

Undamaged.

(c) Gearing.

Misaligned by structural deformation.

(d) Drums, bearings, shafting.

Drums undamaged; bearings and shafting both forward and aft misaligned by structural deformations.

(e) Hydraulic systems.

Not applicable.

(f) Fittings, valves, etc.

Undamaged.

Q. Steering and Diving.

(a) Steering rams and cylinders.

Undamaged. Tested by putting hard over against stops on both sides in hand operation. Exposed portion of rams very corroded.

(b) Hydraulic systems, including pumps, piping, etc.

Undamaged.

(c) Bow plane rigging mechanism.

Foundation for bull gears in superstructure displaced by structural damage causing binding and preventing operation. Motor inoperative due to flooding.

(d) Bow plane tilting mechanism.

Inoperative. Screw gear casing cracked by structural deformation or shock. See photograph in Volume II on page 144.

(e) Stern plane tilting mechanism.

Inoperative. Tilting gear case at frame 175 was displaced 2 3/16" upward by hull deformation thereby misaligning and freezing the mechanism. Motor is of a watertight design and it is worthy of note that it did not flood.

(f) Foundations.

Both bow and stern plane foundations were displaced by structural deformation causing misalignment. Steering foundations apparently undamaged.

(g) Miscellaneous.

Hand operation gear boxes in control room for both bow and stern planes had foundation feet broken off by shock. See photographs in Volume II on pages 96 and 95. Material of gear box castings was aluminum.

The horizontal shaft between 90° gear boxes in control room connecting conning tower and control room steering stands was bent, probably by hull deflection, causing very stiff operation of conning tower steering wheel.

R. Elevators - Ammunition Hoists, etc.

Not applicable.

S. Ventilation (Machinery).

(a) Battery ventilation blowers.

Undamaged by bomb. Damaged by salt water flooding and electrolysis. Motors ruined by salt water.

(b) Battery air flow meters.

Both were knocked loose from foundations by shock but otherwise undamaged by bomb. Damaged by salt water flooding and electrolysis.

(c) Hull supply and exhaust blowers.

Undamaged by bomb. Damaged by salt water flooding and electrolysis. Motors ruined by flooding.

(d) Engine air and ventilation induction hull valves and mechanisms.

Undamaged. Mechanisms corroded and stiff from flooding.

(e) Bulkhead flappers.

Mechanisms undamaged though corroded and stiff from flooding. Leaked due to gaskets blowing out probably during salvage operations. Gaskets damaged and deteriorated by oil flooding. Typical ones are shown in photographs on pages 130 and 129 of Volume II.

(f) Foundations and mountings.

Undamaged.

(g) Fans and motors.

Fans undamaged except by salt water. Motors ruined by salt water flooding.

T. Compressed Air Plant.

(a) High pressure air compressors.

Undamaged as determined by visual inspection by bomb except for framing pieces securing upper part of motors to H.P. cylinder blocks; on the starboard unit this member was cracked and on the port unit broken. See photographs in Volume II on pages 145 and 146. Motors ruined by flooding. Compressors possibly damaged by salt water, not tested.

(b) Low pressure blowers.

Undamaged by bomb except for inboard foot on each blower broken off by shock. Damaged incident to salt water flooding. Motors inoperative due to flooding; hence, blowers not tested. See photographs in Volume II on pages 94 and 93.

(c) Foundations.

Undamaged except for some air flask foundations deformed by structural damage and shock mount of 200 lb. ships service air compressor ruined. See photograph on page 97 of Volume II.

(d) Coolers.

Undamaged.

(e) Air banks.

Air bottles undamaged. One of the four air banks leaked due to damaged piping, covered in Item V. All banks except #4 were found bled down.

(f) Torpedo tube impulse flasks.

Flasks undamaged. Slightly displaced by structural deformation.

(g) Miscellaneous gages, attached piping, etc.

Gages in general were undamaged by the bomb. They were damaged by salt water and oil flooding. Piping covered in Item V.

U. Diesels.

Not applicable - see Item F.

V. Piping Systems.

(a) High pressure (3000 p.s.i.) air piping.

1. The high pressure air system was tested and found in a satisfactory operating condition except as follows:

(a) The adaptor in the air flask line for a bottle in main ballast tank 2B of number 2 air bank broke off at the flask head. (See photograph on page 147 of Volume II).

(b) The piping connection to the accumulator flask in the pump room was also broken off at the flask (see photograph on page 148 of Volume II.).

(c) Forward torpedo room gages are inoperative due to corrosion as a result of flooding.

(d) The hull valve of the bow buoyancy tank, the root valve in the starting supply line for the auxiliary engine and the aft group blow valve in the control room are in a leaky condition.

2. Damage to the ruptured lines and leakage through valves appear to have been caused by shock. However, the valves were not disassembled to accertain this.

3. The undamaged sections of the system were tested at 3000 p.s.i. for approximately one hour.

(b) Main ballast blow (600 p.s.i.) air piping.

1. This system is intact and in an operating condition except as follows:

(a) The regulator for main ballast tanks number one, two (port group), number two (starboard group) and fuel oil ballast tanks numbers three to ten inclusive, leak enough to cause a pressure drop. The cause of leakage has not been determined since the regulators have not been disassembled, however, considering the large amount of leakage found through other valves, this could be attributed to shock. Operationof the system was not affected by the condition of the regulators.

2. The system was tested at a pressure of 600 p.s.i. which could not be maintained due to the condition of the regulators.

(c) Service (200 p.s.i.) air piping.

1. This system is intact and in an operating condition except for a slow leak at the forward bulkhead of the crews space which would not have impaired operation. When tested this leak

resulted in a pressure drop of 30 p.s.i. in 10 minutes in the piping in the area of the leak. The remainder of the system was tested to 200 p.s.i. for an hour.

(d) Main ballast tank blow (10 p.s.i.) air piping.

1. Damage to the piping of this system outside of the hull as a result of the test could not be accurately determined since a major part of it was damaged as a result of salvage operation. The undamaged sections were found intact up to the hull stop valve. The piping within the hull was found undamaged and intact except for leakage of the plug cock for #5 fuel oil ballast tank. Leakage through this valve would not have impared operation and probably existed before the test. The system was subjected to a test of 100 p.s.i. for a duration of 10 minutes.

(e) Torpedo impulse air.

1. This system is intact except as follows:

(a) The gaskets on the inboard side of the hull liners of number 1, 2, 3, 4, 5 and 7 torpedo tube impulse lines were found in a leaky condition which can be attributed to stretching of the flange bolts due to shock and hull distortion. This damage would have made it impossible to operate the above torpedo tubes had the compartment been dry.

(b) The forward impulse tank drain line was ruptured by shock.

(c) All the valves of the forward impulse air lines leak except for the manifold. The hull valves to bottles also leak.

(d) The forward torpedo tube impulse manifold foundation bolts were sheared off as a result of shock. See photograph on page 88 of Volume II.

2. The above valves were not examined and it is possible that valve leakage existed before the test. All torpedo tubes

except as noted above could be operated as far as the impulse piping is concerned.

(f) Engine air starting piping.

1. This system is undamaged and in an operating condition.

(g) Engine shut down air piping.

1. This system is undamaged and in an operating condition.

(h) Salvage air piping.

1. There was no inspection or test made of this system. However, salvage operation forces reported that due to shifting of top side structure some of the connections were inaccessible and the two valve operating rods were found sheared off. The piping was reported intact and was used to blow tanks.

(i) Main ballast tank vent piping.

1. This system is covered in the hull report.

(j) Hull and battery ventilation piping.

1. This system is covered in the hull report.

(k) Trimming system piping.

1. This system is intact and in an operating condition except as follows:

(a) The trim pipe in #6 fuel ballast tank was crushed due to hull damage. A blank flange was installed after removal of the damaged section and the piping inside the hull tested. Except for leakage through the valve and the threads on the shell fitting ring flange the line was found to be intact.

(b) The trim pump suction line outside of the pressure hull came apart at the flange. Distortion of the hull appears to have stripped the flange bolt threads.

(c) A leak was found at the hull flange of the trim line deck hose connection.

(l) Drain system piping.

1. This system is intact and in an operating condition except as follows:

(a) Bulkhead flange bolts sheared off on the after side of the forward torpedo room bulkhead as a result of hull damage. This damage would have made it impossible to take drainage suction forward of the Officers Quarters.

(b) Various valves were found to be in a leaky condition in the forward torpedo room, control room and forward machinery compartment. It is believed that this damage was due to shock.

(c) The con[illegible]d union joints of the conning tower drain line were loosened up and partially pulled apart by shock. The joints were not damaged and could have been made tight if necessary.

2. This system was given a 100 p.s.i. hydrostatic test.

(m) Magazine flooding.

1. This system is intact and in an operating condition.

(n) Plumbing piping.

1. This system is intact and in an operating condition except as follows:

(a) Slow leaks were found in the Officers Water Closet sea valves. It is believed that leakage is due to shock. Leakage into this space would not have occurred since the inboard valves are tight.

(b) The wash water line for filling the engine cooling system was ruptured at the after bulkhead of the forward machinery compartment. This would not have effected engine operation.

(o) Fuel oil piping.

1. This system is intact and in an operating condition except as follows:

(a) A flange in the fuel oil filling and transfer main pulled apart at the after bulkhead of the crews galley, The brass bolts of this flange failed in shear which can be attributed directly to shock since there was no hull damage in this area. See photograph on page 149 of Volume II.

(b) Leakage occured at the bonnets of both hull filling line valves and at the sight glass in the line to the collecting tank. This damage appears to have been caused by shock.

(p) Fuel oil compensating piping.

1. This system is intact except as follows:

(a) Pipe hanger broke loose from the structure and the sight glass in the line to the expansion tank broke in the after engine room.

(b) The compensating water main valve screwed bonnet was pulled away from the valve due to shock, This damage would have made operation of the compensating main impossible. The above damage was due to shock.

(q) Lubricating oil piping.

1. This system is intact and in an operating condition except as follows:

(a) One bolt and nut are missing from the flange in the discharge from #2 main engine and from the discharge flange of the strainer. However, this did not cause leakage of the flange.

(b) Slight leakage was found in the bonnets of #1 engine strainer and cooler relief valves.

(c) The brackets for the metal edge strainer at frame 157 1/2 port was badly bent. See photograph on page 90 of Volume II.

(d) The discharge line from #4 cooler was badly twisted due to movement of the cooler which resulted from distortion of the hull structure (see photograph on page 143 of Volume II).

(e) All valves in the after machinery compartment transfer line are in leaky condition.

(f) Three flange bolts are missing in the starboard reduction gear lubricating oil cooler sea valves. There is evidence of slow leakage through the valve but not the flanges.

(g) A drain plug was found loose in the bottom of the auxiliary engine lubricating oil cooler.

2. It appears that damage covered by Items 1 (a), (b), (c), (e), (f) and (g) were caused by shock.

3. The system was tested to 60 - 75 p.s.i. pressure with no visible oil leaks.

(r) Hydraulic system piping.

1. This system was found intact and in an operating condition except as follows:

(a) The coned union joint at the hydraulic accumulator flask pulled apart due to hull damage that displaced the flask.

(b) The manifold for main ballast tank #2D operating gear was found to be cracked.

(c) The hydraulic and steering system vent and replenishing line was ruptured at the forward bulkhead of the crews quarters.

(d) The hydraulic line for main ballast tank operating gear manifolds for #2A, 2C, 2E and 2G was burned through by a shorted cable. This damage would have made it impossible to operate the flood valves of the above tanks hydraulically.

2. The above damage except for paragraph 2 (d) appears to have been caused by shock.

(s) Engine cooling salt water system.

1. The various engine cooling water systems are intact and in an operating condition except as follows:

(a) A 3/8" nipple broke off at the soldered joint in the pump discharge of #4 main engine.

(b) A 1 1/2" branch broke off at the soldered joint on the 5 inch pump discharge of #3 main engine.

(c) Number one engine pump discharge valve flange developed a leak.

(d) The 1 1/2 inch recirculating line on the 5 inch pump discharge of number three engine broke off at the soldered joint.

(e) The pump discharge flange on #4 main engine was fractured.

(t) Engine cooling fresh water piping.

1. This system is intact and in an operating condition except as follows:

(a) Minor leakage occurred in silver soldered joints of the outboard check valve near the reducing tee of the fresh water header and through loose unions on number two engine.

(b) A leak also occurred in the sylphon valve bonnet joint of number one engine.

2. The system was tested to 80 p.s.i. pressure.

3. Leakage of valve bonnet and silver soldered joint can be attributed to shock.

(u) Main motor cooling salt water piping.

1. This system is intact and in an operating condition except as follows:

(a) A silver solder joint failed in the circulating water line to the reduction gear lubricating oil cooler (port side) of number four main motor. See photograph on page 150 of Volume II. Another silver soldered joint failed in the salt water discharge line from number four main motor lubricating oil cooler. See photograph on page 151 of Volume II.

(b) Two silver solder joints failed in number 3 main motor starboard side circulating water line to the reduction gear lubricating oil cooler. See photograph on page 152 of Volume II.

(c) The sea suction valve flange of number 2 main motor developed a leak at the pressure hull flange. See photographs on pages 153, 100 and 154 of Volume II. It appears that shock caused stretching of the flange bolts and allowed sea pressure to rupture the gasket.

2. The above silver solder joints failed in the joint and during examination pulled apart. Failure was due to shock and poor workmanship.

(v) Distiller feed piping.

1. This system is intact and in an operating condition except that the sea suction valve is in a leaky condition.

(w) Refrigeration circulating water piping.

1. An elbow, two screwed unions and a section of pipe in the pump piping to the refrigeration compressor were ruptured (see photograph on pages 155 and 156 of Volume II). This damage would have

put the refrigeration plant out of commission until repairs could have been made. It is believed that these repairs could have been made by ships force if material had been available.

(x) Air conditioning circulating water piping.

1. This system is intact and in an operating condition.

(y) Fr on piping and coils.

1. This system is intact and in an operating condition.

(z) Air compressor circulating water piping.

1. This system is intact and in an operating condition.

(aa) Potable fresh water piping.

1. This system is intact and in an operating condition.

(bb) Battery water piping.

1. This system is intact and in an operating condition.

(cc) Oxygen air piping.

1. This piping is intact except for a broken line at a bottle, port side, frame 171. See photograph on page 157 of Volume II.

NOTE: The valves reported in a leaky condition were not disassembled for examination to determine whether leakage can be attributed to improper design. Some of these valves may have been in this condition before the test. However, due to the large number in this condition and the finding of ruptured and leaking valve bonnets, it must be assumed that this condition was mainly due to shock. A more detailed examination of the valves should be made by the shipyard and a report of the finding submitted to the Bureau so that the exact cause of the large scale valve leakage can be estimated.

W. Hydraulic System.

(a) Main hydraulic pump.

Undamaged as determined by inspection. Not tested as motors inoperable due to flooding.

(b) Hydraulic accumulator.

Undamaged as determined by inspection. Not operated. Corroded by salt water.

(c) Main vent hydraulic operating mechanisms.

Undamaged as determined by inspection. Not operated nor tested. Mechanisms stiff and badly corroded.

(d) Ballast tank flood valve hydraulic operating mechanisms.

Undamaged as determined by inspection. Not operated nor tested. Mechanisms stiff and badly corroded.

(e) Engine air induction valve operating mechanism.

Same as (c) and (d) above.

(f) Ventilation induction valve operating mechanism.

Same as (c) and (d) above.

(g) Main engine exhaust valve operating mechanism.

Same as (c) and (d) above.

(h) Auxiliary engine exhaust valve operating mechanism.

Same as (c) and (d) above.

(i) Sound head lower/raise mechanism.

Mechanism for port sound head apparently undamaged from inspection. Inoperable due to distorted travelling spiders and shafts in sound wells from hull deformation.

On starboard sound head, hollow central shaft carried away at upper support. See photograph on page 158 of Volume II.

(j) Hydraulic hand pump for sound heads.

Undamaged as determined by inspection.

(k) Hydraulic periscope lower/raise mechanism.

Not applicable.

(l) Hydraulic SD/SV radar mast lower/raise mechanism.

Not applicable.

(m) Bow plane hydraulic tilting mechanism.

Not applicable.

(n) Stern plane hydraulic tilting mechanism.

Not applicable.

(o) Bow plane hydraulic rigging mechanism.

Not applicable.

X. Navigational Instruments.

(a) Underwater log.

Apparently undamaged except from salt water flooding as determined by visual inspection. See photograph on page 159 of Volume II.

(b) Magnetic compasses.

Tank type compasses undamaged except from salt water flooding.

Y. Periscopes.

Only one periscope was installed for the test; design designation 92KA40/1.9 serial number 1248. Other periscope hull flange blanked off for test.

(a) Optics, bearings, train, stadimeter, etc.

Head prism was shattered. Considerable salt water had entered the periscope. Optical surfaces were apparently ruined by action of salt water. Power shift and stadimeter mechanism inoperative. A check for straightness of tube showed a misalignment of only .015". Internal pressure test up to 130 lbs. disclosed only a very small leak in focusing shaft stuffing box.

(b) Mechanical hoist mechanism.

Undamaged except from action of salt water. Both periscope hoist motors are of waterproof design. It is worthy of note that neither periscope hoist motor flooded.

Z. Radar and Sonar.

(a) Mechanical hoisting mechanism.

Undamaged except for salt water flooding of hoist motor and corrosion of mechanism.

(b) Training mechanism.

Training mechanism of SJ radar and of sound heads was undamaged except by salt water flooding. Sound heads could not be trained due to distortion of travelling spiders and sound shafts in sound wells due to hull deformation.

AA. Miscellaneous.

1. Lathe.

Not damaged except as result of salt water flooding.

TECHNICAL INSPECTION REPORT

SECTION III - ELECTRICAL

GENERAL SUMMARY OF ELECTRICAL DAMAGE

I. Target Condition After Test.

(a) Drafts after test; list; general areas of flooding, sources.

Not observed.

(b) Structural damage.

Not observed.

(c) Damage.

Practically all electrical equipment was rendered inoperable due to flooding of all compartments. Considerable corrosion due to electrolysis occurred, particularly on exposed copper parts. Even if flooding could have been controlled, the electrical damage due to shock was severe enough to render the propulsion system inoperable, and seriously impair ship control and fire control. However, sufficient temporary repairs probably could have been effected by the ships crew to permit emergency operation of major electric equipment except where hull and machinery damage would have prevented operation.

II. Forces Evidenced and Effects Noted.

(a) Heat.

No evidence.

(b) Fires and explosions.

Severe arcing occurred in the shore connection boxes where flooded. The resulting damage was limited to the terminal boxes and cable terminals. This was a secondary effect on the bomb blast. There were no other fires and explosions.

(c) Shock.

Shock was the cause of appreciable electrical damage within the pressure hulls and of considerable electrical damage on topside. Shock damage within the pressure hulls was severe in the forward torpedo room, engine rooms, the battery wells and in the pump room. The direction of the shock impulses as evidenced by electrical damage appeared to be from the port side of the ship.

The effect of shock on electrical equipment was evidenced by failure of cast iron parts, hard rubber parts and insulating material; failure of welded joints; and destruction of pressure proof lighting fixtures and instruments on topside.

The types of electrical equipment most seriously affected by shock were the propulsion control equipment, propelling batteries and battery vent ducts, motors and controllers, fluorescent light tubes, switch and recepticle units, and pressure proof lighting fixtures, repeaters and reproducers.

(d) Pressure.

There was no evidence of direct electrical damage due to pressure. However, numerous watertight electrical instruments, pressure proof and watertight lighting fixtures within various compartments were damaged due to the pressure occurring when compartments were blown during salvaging operations. This damage was evidenced by gaskets around covers and windows being forced out of place, allowing water and oil to enter the equipment.

(e) Any effect apparently peculiar to the atom bomb.

None other than radioactivity.

III. Effects of Damage.

(a) Effect on propulsion and ship control.

Propulsion and ship control were completely inoperable due to flooding. If flooding had been controlled, the ships force may have been able to effect sufficient temporary repairs to damage caused by shock to permit emergency operation of the propulsion and ship control equipment.

(b) Effect on gunnery and fire control.

Completely inoperable due to flooding of all compartments. If flooding had been controlled, electrical damage due to shock probably would not have seriously impaired gunnery and fire control, but circuits dependent on the gyro compasses probably would have developed appreciable errors.

(c) Effect on watertight integrity and stability.

None from an electrical standpoint. The slight damage to the drainage pump motor controller due to shock probably could have been repaired by the ships crew.

(d) Effect on personnel and habitability.

From the standpoint of electrical damage caused by shock, personnel would have been compelled to operate some equipment by manual means and to effect temporary repairs.

(e) Total effect on fighting efficiency.

Fighting efficiency was completely lost due to flooding of all compartments. If flooding had been controlled, shock damage to the propelling batteries and propulsion control cubicle would have caused loss of fighting efficiency until temporary repairs could have been effected.

IV. General Summary of Observers' Impressions and Conclusions.

This ship was sufficiently close to the subsurface atom bomb to suffer considerable damage to electrical equipment due to shock.

However, most of the damaged electrical equipment was of obsolete design with regard to shock resistance. It is considered that modern electrical equipment meeting naval high impact shock requirements would have suffered relatively slight damage, with the exception of the propelling batteries, battery vent ducts and topside pressure proof lighting fixtures, repeaters and reproducers.

V. Any Preliminary General or Specific Recommendations of the Inspecting Group.

The methods of mounting electrical equipment to bulkheads and on foundations should be improved so as to minimize failures of securing bolts, welded joints and supports due to shock.

Propelling batteries and battery vent ducts should be improved in accordance with recommendations listed in the Technical Inspection Report for the USS SKATE, tests A and B.

The design of outboard pressure proof lighting fixtures and electrical instruments should be improved, if practicable, to increase resistance to shock.

DETAILED DESCRIPTION OF ELECTRICAL DAMAGE

A. General Description of Electrical Damage.

(a) Overall condition.

All electrical equipment was inoperable due to flooding of all compartments. Considerable corrosion due to electrolysis occurred, particularly on exposed copper parts. Appreciable shock damage also occurred to electrical equipment.

The pressure proof electrical instruments and lighting fixtures on topside were damaged beyond repair.

Within the interior of the ship even if flooding had been controlled, the shock damage to electrical equipment was severe enough to immobilize the vessel. However, the ship's crew could probably have effected sufficient temporary repairs to permit emergency operation of major equipment for a limited period.

(b) Areas of major damage.

Major electrical damage occurred in all compartments within the pressure hulls and on topside.

(c) Primary causes of damage in each area of major damage.

Flooding was the cause of major electrical damage in all compartments within the pressure hulls.

Shock was also a cause of major electrical damage in the forward torpedo room, the battery wells, the forward and after engine rooms, pump room and on topside.

(d) Effect of target test on overall operation of electric plant.

(1) Electrical propulsion.

Inoperable due to flooding of engine rooms. If flooding had been controlled, the ships crew may have been able to effect sufficient temporary repairs to damage caused by shock to permit emergency operation.

(2) Main storage batteries.

Inoperable due to flooding of the battery wells and shock damage. If flooding could have been controlled it is believed that the shock damage to battery vent ducts could have been repaired sufficiently to permit emergency use of the propelling batteries for a limited period.

(3) Auxiliary power.

Inoperable due to flooding of engine rooms and control room. If flooding could have been controlled, the ships crew may have been able to effect temporary repairs to damage caused by shock to permit emergency operation.

(4) Communications.

Inoperable due to flooding of all compartments. If flooding could have been controlled, communication systems within the pressure hulls would probably not have been too seriously impaired.

(5) Fire control circuits.

Inoperable due to flooding of all compartments. If flooding could have been controlled, fire control systems would probably have been operable, but circuits dependent on the gyro compasses probably would have developed appreciable errors.

(6) Lighting.

Inoperable due to flooding of all compartments. If flooding could have been controlled, the lighting systems probably would have been operable throughout the ship except on topside.

(7) Ventilation.

Inoperable due to flooding of all compartments. If flooding could have been controlled, the ventilation system would have been operable except as limited by hull and machinery shock damage.

(e) Types of equipment most affected.

Electrical equipment most susceptible to shock damage consisted of motors having cast iron parts, the propulsion control cubicle, the propelling batteries, fluorescent light tubes, switch and receptacle units, and topside pressure proof lighting fixtures, repeaters and reproducers.

B. Electric Propulsion Rotating Equipment.

In addition to damage caused by flooding of the machinery spaces, some shock damage as discovered by visual inspection occurred as noted below.

(a) Propulsion generators.

Two holding down bolts on the inboard side of No. 2 propulsion generator were loose. The bolts of No. 1 propulsion generator were tight. There was no other visual evidence of shock damage.

(b) Auxiliary generator.

The auxiliary generator in the after engine room was found half filled with oil when inspected. One holding down bolt on the starboard side and two on the port side were loose. Two bolts which were removed and examined were found to be undamaged. There was no other visual evidence of shock damage.

(c) Propulsion motors.

No. 1 motor: Three holding down bolts on the inboard side were loose.

No. 2 motor: The air cooler was knocked loose from its supports and dislodged inboard. One holding down [illegible] was broken and the remainder loosened on the inboard side. All the holding down bolts on the outboard side were loose and bent. Two holding down bolts for the forward bearing pedestal were fractured. The motor was raised three-eights inch off its foundation on the outboard side.

No. 3 motor: All the holding down bolts were loose.

No. 4 motor: All the holding down bolts were tight. An examination of two holding down bolts removed from each motor was made. The bolts from No. 2 motor were badly bent. The bolts from the remaining motors were not damaged.

There was no other visual evidence of shock damage to the propulsion motors.

Recommendations: The methods of securing the propulsion machines and propulsion motor coolers to their foundations should be investigated and compared with methods employed on more modern submarines to determine whether present methods are adequate or should be improved.

C. Electric Propulsion Control Equipment.

In addition to damage caused by the flooding of the after engine room, the propulsion control cubicle suffered considerable shock damage. Considerable corrosion due to electrolysis had also occurred within the cubicle. Cork displaced from the hull was scattered over the inside of the cubicle.

Specific shock damage to the control cubicle apparent from visual inspection was as follows:

(a) Frame and mountings.

The entire cubicle shifted to port one-eighth inch at the front end and one inch at the rear end. The top mountings at the front end were bent about one eighth inch. The bolts securing the cubicle to the top mountings were dislodged at the front end. This cubicle was not shock mounted. See photographs on pages 160 and 161 in Volume II.

(b) Contactors, switches and relays.

Eight arc shields on contactors in the front section and eight arc shields in the rear section of the cubicle were dislodged or loosened. See photographs on pages 162 and 163 in Volume II. No. 2 propulsion motor field compensating relay was knocked loose from its support.

(c) Mechanical operating mechanisms and interlocks.

All operating levers were knocked out of line. See photograph on page 164 in Volume II.

(d) Instruments.

The glass on one ammeter was broken, its pointer dislodged and the case dented. See photograph on page 164 in Volume II. This damage was probably caused by a missile. Several vital instruments were removed from the cubicle prior to the test.

(e) Busbars and connections.

Shunts and busbars were badly corroded. See photograph on page 165 in Volume II.

Other propulsion electrical instruments suffered shock damage as follows:

The glass on No. 1 propulsion engine resistance thermometer was broken.

The glass on No. 2 propulsion generator voltmeter, located on the engine gauge board, was broken.

The lower securing lugs broke off on the Brown continuous reading temperature indicator for the auxiliary engine.

Comments: The propulsion control cubicle c.. this vessel is of an obsolete design. Modern control cubicles have shock mountings and employ high-impact shock-resistant instruments and equipment extensively. A modern propulsion control cubicle would have suffered considerably less damage from shock.

D. Generators - Ships Service.

Not applicable.

E. Generators - Emergency.

Not applicable.

F. Switchboards, Distribution and Transfer Panels.

In addition to damage caused by flooding of the various compartments, appreciable shock damage occurred. The following specific shock damage to switchboards and panels was noted from visual inspection.

(a) Auxiliary power switchboard in after engine room.

The glass on one ammeter was broken. The transite panel supporting a three-pole circuit breaker was fractured. See photograph on page 166 in Volume II.

(b) Auxiliary power switchboard in control room.

The transite panel supporting the circuit breakers was fractured across the upper corners and the panel was dislodged. Considerable corrosion occurred to the main copper contacts in one line of the circuit breakers. See photograph on page 167 in Volume II.

(c) Lighting switchboard.

The glass on one voltmeter was broken.

(d) Power distribution panel in forward torpedo room.

The insulating board in the panel was fractured.

The welds securing the panel to mounting pads failed, causing the panel to be dislodged.

Comments: The transite panels used in switchboards and panels in this submarine proved susceptible to damage from shock. In modern vessels, more shock-resistant insulating materials are employed.

G. Wiring, Wiring Equipment and Wireways.

In addition to damage caused by flooding of the various compartments, moderate damage occurred to cables, wireways and wiring equipment, primarily due to shock. Specific damage as noted from visual inspection was as follows:

(a) Cables.

The cable terminals and about fourteen inches of one SHFA - 650 cable were completely melted away at the shore connection boxes in the pump room. The terminals in the shore connection boxes had been energized from the main storage batteries before the test through the cable cutting circuit and temporary connections, which had been made with the intention of energizing the vent motors after the test without closing the battery disconnect switches. These terminals apparently were short-circuited when the pump room flooded. See photographs on pages 168 and 169 in Volume II.

Cables outside the pressure hull securely fastened in place were not damaged. Several loose DCP cables and the cables to the bow anchor light, the bridge blinker key, a bridge gyro repeater, and to a bridge IMC reproducer were severed. However, some or all of these cables may have severed during salvageing operations.

(b) Wireway supports.

The wireways to No. 3 and No. 4 propulsion motors were loosened in the after engine room when several bolts or welds failed.

Straps and supports for cables outside the pressure hull were not damaged.

Hull stuffing tubes apparently were not damaged.

(c) Connection and junction boxes, receptacles and plugs.

The auxiliary power shore connection boxes were partially destroyed by the severe arcing which occurred when the terminals were short-circuited, as noted in paragraph (a) above. The insulating material within these boxes burned completely and the copper terminals and straps melted away. See photographs on pages 168 and 169 of Volume II. The shore connection switches were tied open for the test.

Switch and receptacle units throughout the ship had covers cracked or knocked off by shock. Most of these units had bakelite covers. Several receptacle units broke loose from their supports.

A forty-wire connection box in the after engine room for the IMB and 2MB systems was opened for inspection and found to be full of fuel oil, but not otherwise damaged.

A four-circuit non-watertight feeder box in the forward engine room suffered damage. Its cover was knocked off and the terminal block was broken loose from its supports.

About eighty percent of the connection boxes throughout the ship had their rubber gaskets forced out of place, apparently due to the excessive pressure occurring during salvaging.

Comments: Switch and receptacle units of bakelite construction proved susceptible to damage from shock. Present standard switch and receptacle units employ metallic boxes and covers and are less susceptible to shock damage than the obsolete units of bakelite construction.

H. Transformers.

Not applicable.

I. Submarine Propelling Batteries.

This submarine was equipped with Gould batteries, the original Exide batteries having been replaced. The batteries were fully charged prior to the test. In addition to damage due to flooding, appreciable shock damage occurred. Specific damage as noted from visual inspection was as follows.

Forward Battery.

(a) Jars.

None of the jars were removed for inspection. It is likely that a number of jars were cracked as this was found to be the case in the after battery well.

(b) Covers.

Practically all cell breather caps were dislodged. Deck plates were also dislodged. See photograph on page 170 in Volume II.

(c) Wedges and strongbacks.

There was no observable damage to wedges and tie-rods. Rubber sheathing was knocked loose from longitudinal channels.

(d) Busbars and cell connectors.

About half of the individual cell fuse boxes were dislodged from intercell connectors, when the supporting screws failed. Many intercell connectors were corroded by electrolysis.

(e) Acid spillage.

Not ascertainable due to flooding. Some cells were apparently dry and others contained oil as well as electrolyte.

(f) Ventilation ductwork.

Approximately one-third of the hard rubber vent ducts were loose or broken, including three sections of the main vent duct secured to the overhead. Pieces of vent ducts were scattered about. See photographs on pages 170, 171 and 172 in Volume II.

(g) Ionizer.

The ionizer was not damaged.

(h) Disconnect switches.

The battery disconnect switches were badly corroded by electrolysis. See photographs on pages 171 and 173 in Volume II. The disconnect switches were tied open for this test.

After Battery.

(a) Jars.

Five cells, Nos. 8, 9, 10, 33 and 34, were removed for inspection in the battery shop at the Naval Shipyard, Mare Island. All of the jars were cracked along the corners and bottom. Oil was found in all of these cells. See photographs on pages 174, 175 and 176 in Volume II.

(b) Covers.

Practically all cell breather caps were dislodged. Deck plates were also dislodged. See photograph on page 177 in Volume II.

(c) Wedges and strongbacks.

There was no observable damage to wedges and tie-rods. Rubber sheathing was knocked loose from longitudinal channels.

(d) Busbar and cell connectors.

More than half of the individual cell fuse boxes were dislodged from intercell connectors, when supporting screws failed. Many intercell connectors were badly corroded by electrolysis. See photograph on page 178 in Volume II.

(e) Acid spillage.

Not ascertainable due to flooding. Some cells were apparently dry and others contained oil as well as electrolyte.

(f) Ventilation ductwork.

Approximately one-fifth of the hard rubber vent ducts were broken. This damage occurred mainly to port outboard horizontal ducts and to the T - sections. See photographs on pages 177, 179, 180, 181 and 182 in Volume II.

(g) Ionizer.

The ionizer was not damaged.

(h) Disconnect switches.

The battery disconnect switches were badly corroded by electrolysis. See photographs on pages 179 and 180 in Volume II. The disconnect switches were tied open for this test.

Comments: Battery shock damage was apparently caused by shock impulses acting with maximum force on the port side. In contrast to the effects noted on the USS SKATE in test B, there was relatively little permanent displacement of battery cells and wedges and no damage to the tie-rods and channels on the USS SKIPJACK. In other respects, the shock damage to the propelling batteries was similar on the USS SKATE and USS SKIPJACK in test B.

Recommendations: Supplementing the recommendations for propelling batteries as listed under Item I in Part C of the Technical Inspection

Report for the USS SKATE, tests A and B, the following recommendation applies:

1. Individual cell fuse boxes should be secured more sturdily to prevent dislodgement by shock.

J. Portable Batteries.

No damage was observed, other than that caused by flooding of compartments.

K. Motors, Motor-Generator Sets and Motor Controllers.

In addition to damage caused by flooding, moderate shock damage occurred. Specific damage as noted from visual inspection was as follows:

(1) Bow plane rigging and capstan motor (forward torpedo room).

The holding down bolts were found to be loose. Several bolts which secure the end bell on the commutator end gave way, and the end bell, magnetic brake and armature shifted aft about one inch. The armature was forced against the brush rigging, bending and displacing the brush holders. See photographs on pages 183 and 184 in Volume II.

(2) Bow plane tilting motor (forward torpedo room).

The nuts for the holding down bolts were found to be loose. Lockwashers were provided.

(3) Air compressor motor (pump room).

The terminal box of one air compressor motor was damaged and a screened cover at the commutator end was displaced. See photograph on page 97 in Volume II.

(4) I.C. motor-generator sets (pump room).

The bolts securing the rubber vibration mounts were loose on No. 1 and No. 2 I.C. motor-generator sets.

(5) No. 2 air conditioning motor (pump room).

Holding down bolts were loose.

(6) No. 3 and No. 4 battery vent motors (crews quarters).

Two bolts securing the rubber vibration mounts were loose on each motor.

(7) No. 1 lubricating oil and fuel oil transfer pump motor (forward engine room).

The cast iron end bell on the commutator end fractured and a portion broke off. See photograph on page 185 in Volume II.

(8) No. lubricating oil purifier motor (forward engine room).

The cast iron end bell on the commutator end fractured and the brush rigging was damaged and displaced. See photograph on page 186 in Volume II.

(9) No. 2 still motor (forward engine room).

One holding down bolts was loose.

(10) No. 1 and No. 2 lighting motor generator.

The bolts securing the forward bearing pedestals were loose. The bolts securing the motor and generator frames were tight.

(11) Lubricating oil standby pump motor (after engine room).

The outer grease retainer on the commutator end bearing was missing and the inner retainer had dropped down. All the bolts securing the bearing to the frame were broken off.

(12) Stern plane tilting and after capstan motor (after torpedo room).

Several holding down bolts were loose. The interior of this motor appeared to be clean and dry despite the fact that the compartment had been completely flooded. This motor was of water tight construction.

(13) Steering pump motor (after torpedo room).

The interior of this motor appeared to be clean and dry despite the fact that the compartment had been completely flooded. This motor was of watertight construction.

(14) Compartment fans.

The majority of fans throughout the ship were knocked loose from their brackets or supports when securing bolts failed.

(b) Control equipment.

(1) Bow plane rigging and capstan motor controller (forward torpedo room).

This controller was dislodged when welds securing it failed. The matal case deformed and the door was knocked off. The transite panel fractured and shifted. The internal electrical equipment was not materially damaged but was covered with silt. See photographs on pages 87 and 89 in Volume II.

(2) No. 1 air conditioning motor controller (pump room).

Two bolts securing the insulating panel were stripped.

(3) Drainage pump motor controller (pump room).

No. 2 accelerating contractor was bent out of line and its armature knocked off.

(4) Booster blower vent motor controller (after engine room).

This controller was dislodged when the welds securing it to the hull failed.

Comments: Material failures to rotating and control equipment were due primarily to the use of cast iron and construction not in accordance with present naval high impact shock requirements. It is considered that equipment designed to meet naval high impact shock requirements would have suffered considerably less damage.

Recommendations: The methods of securing electrical rotating and control equipment should be improved to minimize damage due to failures of securing bolts, welds and supports.

L. Lighting Equipment.

A limited number of globes and bulbs were broken in lighting fixtures throughout the ship. In some instances the fixtures were displaced from their brackets.

About eighty percent of the pressure proof emergency lighting fixtures throughout the ship had rubber gaskets forced in, allowing water and oil to enter the fixtures. This apparently occurred due to the pressure when air was forced into the compartments during salvaging.

Tubes in fluorescent lighting fixtures throughout the ship were broken and some fixtures knocked loose.

The globes on all the pressure proof navigation lights were shattered. In most cases, the top plates of these lights were pushed down against the bottom plates, with the studs protruding.

The bow anchor light bracket was bent upward and aft about forty-five degrees from the horizontal. See photographs on pages 187 and 188 in Volume II.

The after anchor light was knocked loose from its mounting and crushed. See photograph on page 189 in Volume II.

The case for the pressure proof blinker light key on the bridge was dished in. See photograph on page 190 in Volume II.

Comments: The standard type ships lighting fixtures in this submarine were provided with rough service lamps. Plate type shock mountings were generally employed within the compartments. Considering the magnitude of the shock impulses as evidenced by the extent of hull and equipment damage, it is believed that these fixtures held up comparatively well.

Recommendations: The design of pressure proof outboard lighting fixtures and blinker light keys should be improved, if practicable, to increase resistance to forces tending to collapse or crush such equipment.

Fluorescent lighting fixtures should be designed to meet naval high impact shock requirements, or the use of such fixtures in submarines should be discontinued.

M. Searchlights.

Not installed during test.

N. Degaussing Equipment.

Not applicable.

O. Gyro Compass Equipment.

(a) Master gyro compass.

Visual inspection revealed no evidence of damage other than that caused by the flooding of the control room and consequent corrosion. Mercury spillage probably occurred. Delicate parts, such as gages and lamps within the compass, were not broken. This is an Arma, Mark VII, model O unit. See photograph on pages 191 and 192 in Volume II.

(b) Repeaters.

A gyro repeater in the conning tower suffered a broken glass. See photograph on page 193 in Volume II.

(c) DRT and DRAI.

The DRT in the conning tower was knocked open.

The DRA indicator in the control room suffered shock damage. Lugs securing the door of the enclosure gave way, causing the door to open. The rubber gasket around the door was dislocated. Internal equipment apparently was not damaged except due to corrosion caused by flooding of the compartment. See photograph on page 195 in Volume II.

(d) Auxiliary gyro compass.

Visual inspection revealed no damage other than that caused by flooding of the control room and by corrosion. Mercury spillage probably occurred. This is an Arma, Mark IX, model 2 unit. See photograph on page 196 in Volume II.

Recommendations: A sturdier method of mounting pressure proof gyro repeaters on their gimbals should be provided.

Sturdier lugs for securing the doors of DRA indicators should be provided.

Transparent windows of increased resistance to shock should be provided on gyro repeaters.

P. Sound Powered Telephones.

Practically all telephone handsets were dislodged from their hooks. Some handsets were broken, probably due to impact with hull structure when dislodged.

Comments: It is considered that the present improved methods of securing handsets would have prevented their dislodgement.

Q. Ships Service Telephones.

Not applicable.

R. Announcing Systems.

(a) Portable (PAM and PAB).

Not applicable.

(b) Amplifier and control racks.

Two rectifier tubes were broken in the 1MC amplifier and control rack located in the control room. Meter glasses were forced in by pressure, but were not broken. See photograph on page 197 in Volume II.

(c) Transmitting stations.

The volume indicator on the 1MC transmitter in the conning tower was broken. The cover on the 1MC and 7MC selector panel on the bridge was dished in. See photograph on page 198 in Volume II.

(d) Reproducers.

The 1MC reproducers on the bridge were badly damaged. On both units the covers were dished in. Two bolts were sheared off the unit on the forward bridge. See photographs on pages 198 and 199 in Volume II.

(e) Inter-communication units.

One tube was broken in the 7MC amplifier unit located in the control room.

Recommendations: Equipment for 1MC and 7MC systems should be designed and mounted to meet naval high impact shock requirements. Covers for pressure proof equipment should be designed to withstand increased pressures, where practicable.

S. Telegraphs.

The 1MB and 2MB telegraph indicators on the propulsion control cubicle were found to be full of fuel oil. Gaskets in the 1MB and 2MB telegraph indicators in the control room were forced in, apparently by the pressure during salvaging.

T. Indicating Systems.

The rudder angle indicator broke loose from its supports on the propulsion control cubicle.

The bow plane angle transmitter in the forward torpedo room broke loose from its supports when bolts failed.

Throughout the interior of the ship numerous indicators, rudder angle indicators and bow plane indicators, suffered damage apparently due to the pressure which occurred when compartments were blown during salvaging. This damage consisted of gaskets being forced in and water or oil entering the instruments. For typical damage, see the photograph on the bow plane indicator on page 200 in Volume II.

Recommendations: Mountings for transmitters and indicators should be increased in sturdiness in order to permit withstanding shock impulses of higher magnitude without failure.

U. I.C. and A.C.O. Switchboards.

The hinges securing the gyro switchboard to its foundation were bent. There was no other damage observed from visual inspection of the I.C. and gyro switchboards, other than that caused by flooding of the control room.

V. F.C. Switchboard.

No damage other than due to flooding of the control room was observed, from visual inspection.

W. Miscellaneous.

Specific damage to miscellaneous electrical equipment observed from visual inspection and due to causes other than flooding, was as follows:

(a) The hot plates in the electric range were dislodged.

(b) The battery individual cell voltmeter panels in the after engine room and control room were knocked loose from their supports when welds failed. The voltmeter on the panel in the control room also had the voltmeter connecting studs broken off and suspending from the connecting cables. See photographs on pages 166 and 167 in Volume II.

Defense Special Weapons Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

TRC 18 April 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush (Security)

SUBJECT: Declassification of Reports

The Defense Special Weapons Agency has declassified the following reports:

AD-366588	XRD-203-Section 12
AD-366589	XRD-200-Section 9
AD-366590	XRD-204-Section 13
AD-366591	XRD-183
AD-366586	XRD-201-Section 10
AD-367487	XRD-131-Volume 2
AD-367516	XRD-143
AD-367493	XRD-142
AD-801410L	XRD-138
AD-376831L	XRD-83
AD-366759	XRD-80
AD-376830L	XRD-79
AD-376828L	XRD-76
AD-367464	XRD-106
AD-801404L	XRD-105-Volume 1
AD-367459	XRD-100

TRC 18 April 1997

Subject: Declassification of Reports

AD-367491	XRD-134-Volume 2
AD-367479	XRD-123
AD-367478	XRD-122
AD-367481	XRD-125
AD-367500	XRD-159-Volume 2
AD-367499	XRD-160-Volume 3
AD-367498	XRD-161-Volume 4
AD-367512	XRD-147
AD-367511	XRD-148
AD-367465	XRD-107
AD-366733	XRD-43
AD-367477	XRD-121
AD-367476	XRD-120
AD-367467	XRD-109-Volume 1
AD-367475	XRD-119
AD-367474	XRD-118
AD-367473	XRD-117
AD-367472	XRD-116
AD-367471	XRD-115
AD-367466	XRD-108
AD-801405L	XRD-113
AD-367470	XRD-112
AD-367469	XRD-111

TRC 18 April 1997

Subject: Declassification of Reports

AD-801406L ✓ XRD-114.

In addition, all of the cited reports are now **approved for public release; distribution statement "A" now applies.**

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center