DISMANTLING OF A SHIP WHILE FLOATING NEXT TO A PIER

by

Edward B. Greenspan

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Submitted to the Department of Ocean Engineering on June 11, 1984, in partial fulfillment of the requirements of the degrees of Bachelor of Science in Ocean Engieering and Master of Science in Naval Architecture and Marine Engineering.

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Abstract

The technological feasibility of scrapping a ship while it remains in the water at dockside was investigated. This method of scrapping a ship would provide a lower cost alternative to drydocking a ship before it is dismantled.

The plan entails washing and gas freeing all tanks to ensure safe working conditions throughout the dismantling procedure, and then removing material from the aft end of the ship forward. At every stage of the dismantling, hydrostatics and structural integrity of the ship were examined to ensure a safe and successful scrapping operation. This sequence of removing material moves the center of gravity of the ship forward, causing the aft part of the keel of the ship to lift out of the water, permitting it to be cut and removed. This allows for the entire ship to be dismantled without the use of a drydock.

A 900-foot bulk oil carrier was used as a typical ship for testing the plan. The ship was theoretically completely disassembled according to the procedure. It met all safety requirements throughout the dismantling.

Additional guidelines and suggestions for other types of ships and environmental conditions are included.

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Chapter One

Introduction

When the demand for a ship's services does not provide enough income to cover its expenses, it oftentimes becomes economically advantageous to dismantle the ship and sell the material as scrap. Currently, there are several methods used to dismantle ships. One procedure is to drydock the ship and then dismantle it. This, however, has become more expensive with the ever-increasing cost of drydocking. There has been interest in trying to develop alternative, less expensive methods for dismantling a ship. These methods include beaching the ship prior to dismantling and completely dismantling a ship while it is still floating. The purpose of this thesis was to examine the technical requirements and develop a plan to completely dismantle and scrap a ship while it is floating.

1.1 Plan overview

One method of dismantling a ship while it is floating is to start removing sections of the ship from the aft end. This decreases the overall draft of the ship and, more importantly, raises the stern. When enough weight is removed, the stern is raised out of the water, enabling the keel to be cut. This procedure continues moving forward until finally there is only a small section of the bow left in the water. This small section is removed by hoists, possibly with the help of a larger crane, to the dismantling dock and then moved to the processing area where it can be further cut and prepared for sale.

The aft end of the ship was chosen to be removed first to ease the removal of the machinery, which is normally located near the stern. It also permits the removal of the superstructure of most ships at the beginning of the process, reducing the total weight and moving the center of gravity forward.

At every stage of the dismantling, hydrostatics, GM, and the structural and flooding integrity of the ship need to be examined.

The first step of the plan before actual dismantling occurs is the emptying and washing of all tanks including the removal of hazardous gases. This is needed to create a safe working environment throughout the ship.

The next step is the removal of all outfitting from the ship. Much of the outfitting is capable of being sold, reconditioned, and reused with minimal rebuilding; therefore, careful handling is necessary.

The third step is the removal of the superstructure, allowing the access into the machinery space. After the removal of the machinery, most of the hull, bulkheads, and deck is removed starting with the aft portion of the ship and working forward.

1.2 Ship and Equipment

The 900-foot bulk oil carrier "Voyager" was used as a typical ship for testing the plan. The Voyager's design generally conforms to that of a typical mono-hull bulk cargo carrying displacement ship with a high block coefficient.

The Voyager is a single screw, steam propelled bulk oil carrier with a bulbous bow and one complete deck with forecastle. The deckhouse and machinery are located aft. It is 950 feet long overall with a maximum beam of 147.5 feet. Its molded depth is 63.5 feet, with an average lightship draft of 8.8 feet. To provide maximum efficiency as an oil carrier, it was designed with a block coefficient of 0.800. A table of the ship's characteristics are shown in Table 1-1. Profile and body plans are shown in Figures 1-1 and 1-2.

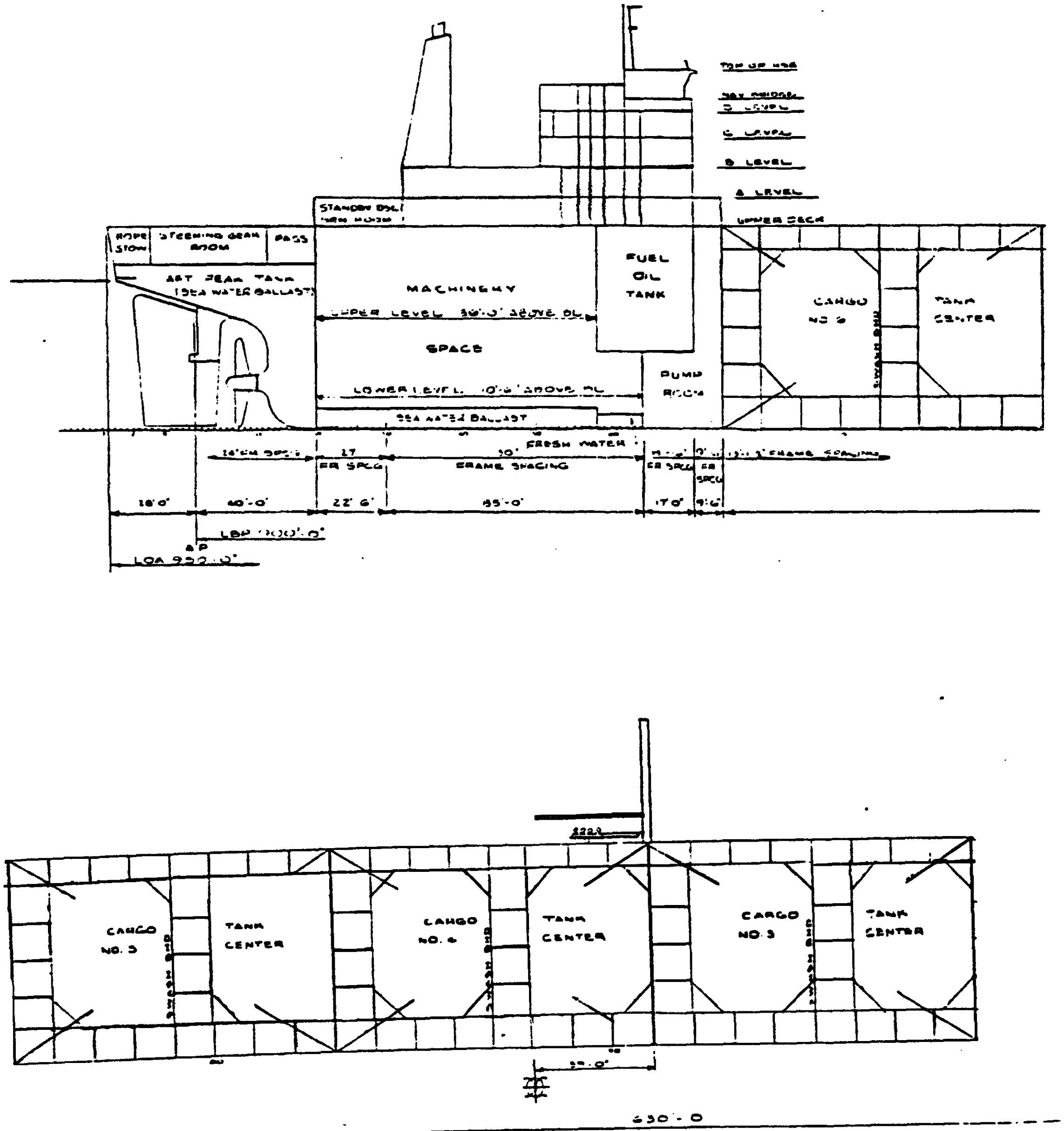
The dismantling of a floating ship should be performed at a dock which is easily accessible to either trucks or railway. The dock should be constructed to provide maximum area adjacent to the ship. Large hoists, similar to those used in ship cargo handling, are needed to remove most of the pieces from the ship to waiting trucks. The trucks then take the material to a processing area, on or near the dock, where the pieces are cut up further for easy sale and transportation. Two hoists are required to remove the machinery due to its weight. Except for the machinery, which is more valuable for resale in larger pieces, easy maneuverability and transportation determine the limiting size of the pieces removed.

1.3 Location Requirement

A calm water location is required to enable the easy dismantling of a ship in the water. The absence of waves reduces the probability of water coming over the sides of the ship, and decreases the longitudinal bending moment and

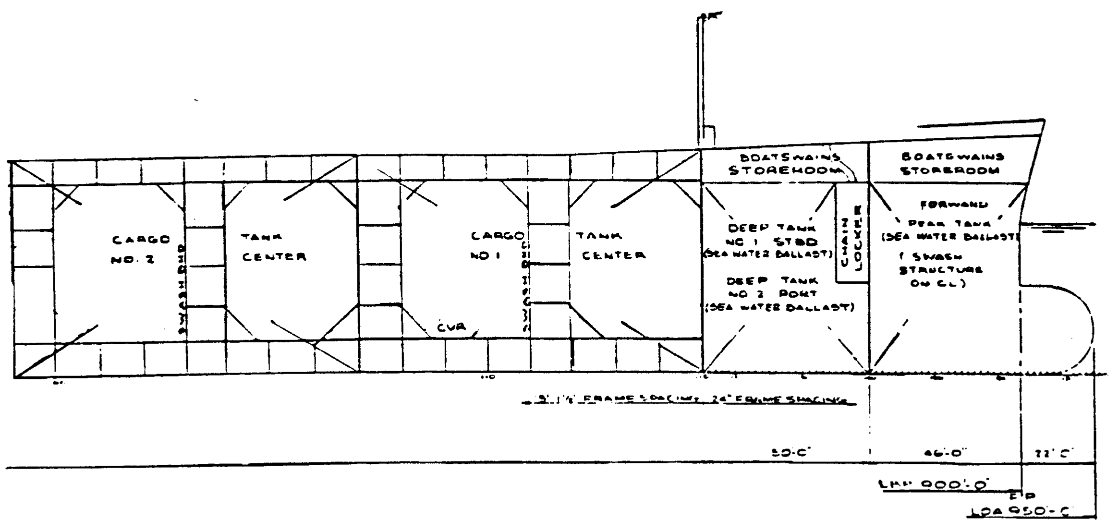
Table 1-1: Main characteristics of the oil carrier "Voyager"

Length overall, ft.	950.0
Length between perpendiculars, ft.	900.0
Beam, maximum molded, ft.	147.5
Depth to strength deck at side, minimum, ft.	63.5
Displacement at design draft, long tons	147,400.0
Type of main propulsion machinery	steam turbine
Block coefficient	0.800
Midship coefficient	0.996
Displacement, lightship, long tons	22,200.0
Draft, lightship mean, ft.	8.8
forward perp., ft.	4.2
aft perp., ft.	13.4
Longitudinal center of gravity, lightship	471.1



INBOARD PROFILE

Figure 1-1: Profile drawing of the Voyager (2 pages).


CARGO
NO. 2
TANK
CENTER
CARGO
NO 1
TANK
CENTER
BOATSWAINS
STOREROOM
BOATSWAINS
STOREROOM
DEEP TANK
NO 1 STBD
(SEA WATER BALLAST)
DEEP TANK
NO 2 PORT
(SEA WATER BALLAST)
CHAIN
LOCKER
FORWARD
PEAK TANK
(SEA WATER BALLAST)
SWASH
STRUCTURE
ON CL)
CVR
46'-0"
F P

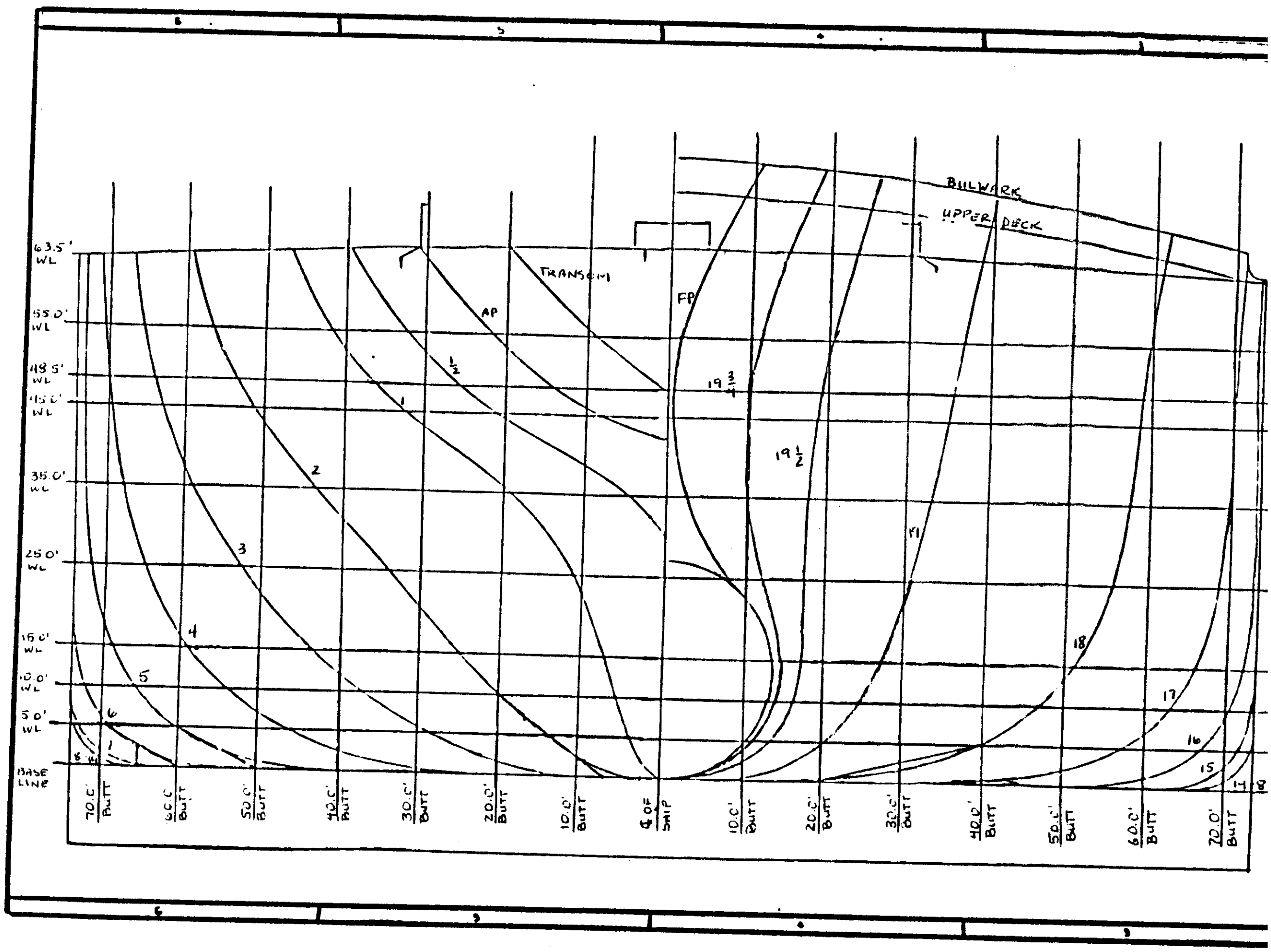


Figure 1-2: Faired body plan of the Voyager.

torsional load applied to the ship. In the calculations, only static loads are considered.

The dismantling dock should be situated in a port deep enough to prevent groundings at every stage of the dismantling procedure. If the bow of the ship becomes grounded, a forward change in the center of gravity of the ship will not result in the stern raising out of the water; the grounding will prevent a change in the trim angle of the ship. During the first stages of dismantling, the center of gravity of the ship moves forward, and the draft at the bow of the ship becomes much larger than the stern's lightship draft. This continues until after much of the ship's weight has been removed and part of the keel has been cut. For this reason, the terminal should have a depth three times the lightship draft of the ship.

1.4 Ship Anchoring System during Dismantling

Although the Voyager is equipped with a complete anchoring system, it is necessary to supplement this system with additional mooring cables during the scrapping process. The Voyager is equipped with heavy anchoring system capable of anchoring the ship in water much deeper than will be present at the terminal. The anchor chains connect to the ship on the deck of the bow. This section of the ship is not removed until stage 10 of the removal. Using the existing anchoring system, provides minimum motion of the front of the ship throughout most of the dismantling procedure. To supplement the existing anchoring system, an additional mooring cable should connect the aft end of the ship with the dock. The cable should be connected to the ship just forward of the machinery space. This section will not be removed until stage four of the removal. As dismantling progresses, the mooring cables will have to be relocated. During stage four of the removal the aft mooring cable should be relocated and attached near the base of the ship just forward of the machinery space. This will moor the ship through stage seven of the procedure. After stage seven of the dismantling, the ship will be adequately moored with the front anchoring system. When the front anchoring system is removed during stage 10 of the procedure, mooring cables will have to be relocated closer to the baseline.

Chapter Two

Tank Cleaning and Gas Freeing

Before any dismantling of a crude oil tanker can be undertaken, the ship has to be made safe for hot work. This should be done by first washing and then gas freeing all cargo and fuel tanks. The International Chamber of Shipping and the Oil Companies International Marine Forum have established recommended practices to ensure safety in operations requiring hot work in crude oil cargo tanks.

Oftentimes crude oil tankers directly connect their fixed position washing equipment to the cargo pumping system, enabling them to use crude oil instead of water as the washing medium. This is an effective means of stripping the crude oil from the bottom of all cargo tanks and redissolving oil sediments adhering to the tank surfaces. It is recommended to use crude oil washing when possible during the discharge of the cargo on the ship's final voyage.[1] Water washing will still be necessary in order to adequately clean the tanks for hot work.

In order to have combustion in a cargo tank, both a combustible mixture

[1] *Crude Oil Washing Systems*, Inter-Governmental Maritime Consultive Organization, London, 1980, pp 8-12.

and an ignition source must be present[2]. To prevent the existence of both of these conditions occurring simultaneously, certain safety precautions must be taken. The following is a procedure for cleaning and gas freeing cargo tanks and other enclosed spaces after the discharge of petroleum carried in a non gas-free tank.

2.1 Preparation

Before and during tank cleaning and gas freeing operations, all normal precautions to be taken on board a tanker should be observed. All personnel on the ship and on support crafts alongside the tanker should be aware that tank washing and gas freeing are about to begin. Hoses that are to be used in conjunction with portable tank cleaning machines should be tested with a low voltage ohm meter for electrical continuity. All gas measuring instruments should be tested and calibrated before washing begins.[3]

2.2 Cargo Tank Washing and Cleaning

Crude oil cargo tank water washing consists of continuous high pressure spraying and draining of water. The ship's washing machine can be either permanently mounted or portable. Most of today's tankers are equipped with automatic deck mounted or fixed bottom washing machines. The machines are pre-programmed to spray water at a certain pressure over a specified arc. This

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[2] "Interim Report, Tanker Accident Study Group", Nov. 1970, The American Petroleum Institute, Washington, D.C.

[3] *International Safety Guide for Oil Tankers and Terminal*, International Chamber of Shipping and the Oil Companies International Marine Forum, Witherby and Co., Ltd., London, 1979, pg.45.

washes down the sides, top, and bottom of the tank and removes any buildup of residue on the surface. Another part of the washing system are drain hoses, which are connected to pumps to prevent buildup of liquid during the washing process, which might inhibit effective washing.

2.3 Choice of a Washing Environment

While tank washing can be accomplished in any of four atmospheres. When proper equipment is available an atmosphere below the lower flammable limit (LFL), atmosphere B, is highly recommended. This atmosphere will enable tank washing and gas freeing to be accomplished in the least amount of time and can follow a standard process. Since the tanks have to be cleaned to a degree suitable for hot working, washing in an uncontrolled atmosphere, atmosphere A, will not clean the tanks to meet the necessary requirements since heated water is not permitted for safety reasons. If atmosphere A is the only alternative (due to lack of equipment) then a hot wash would be necessary after the tanks are made gas free after the initial cold wash. Atmospheres which have low levels of oxygen or hydrocarbon contents above the upper upper flammable limit (UFL), atmospheres C and D, require that the gas content be raised, either inert gas or hydrocarbon gas, for the washing before gas freeing. In addition, a "too rich atmosphere" in very large tanks can not be guaranteed under normal operating conditions[4]. For this reason, using Atmosphere B would save time by starting the gas freeing process from the beginning and

[4]William O. Wiley, "Tank Cleaning", International Tanker Safety Conference, Oct. 1971, paper # 5, Brighton, England pg. 22.

never having to add an unwanted gas to the cargo tanks. Appendix A contains detailed descriptions of all washing atmospheres and necessary precautions in each.

2.4 Gas Freeing

In a gas freeing operation, air is pumped into the tank, forcing it to mix with the existing gases in the tank. This mixes together any layers of flammable gases that may be present. The resultant mixture is expelled to the outside atmosphere. As more air is pumped into the tank, the concentration of hydrocarbons existing in the tanks decrease. A complete list of the required safety measures are shown in Appendix B.

2.5 Attaining a Too Lean Atmosphere

There are currently many different ways to attain an atmosphere that is well below the lower flammable limit. All these methods can be basically grouped into one of the following three areas:

* The forced ventilation of tanks.
* The movement of ballast (yo-yo), with or without forced ventilation or bottom flushing of cargo tanks.
* The use of ballast surface skimming, with or without forced ventilation of the tanks.

2.5.1 Forced Ventilation

Forced ventilation is the simplest method of reducing the hydrocarbon gas content. It involves blowing air into or extracting gas from the tank, or a combination of both. It is performed prior to washing, reducing the hydrocarbon content to a safe level, and during washing, keeping the atmosphere safe, and continuing during the tank gas freeing process. The air can be introduced through cargo lines, openings in the deck, or specially designed and installed distribution system; or any combination of these methods.

With a straight forced ventilation system, air is pumped into the tanks causing mixing between the hydrocarbon gas and the air. Since the tanks are not air tight, this mixture is able to leave the tanks while more air is pumped in, causing further mixing and a lower overall hydrocarbon gas percentage. This is continued until a safe gas content is reached.

A subtype of forced ventilation is the displacement method. This system takes advantage of the fact that hydrocarbon gas is heavier than air and thus will settle to the bottom of the tanks. A suction hose, set up a the bottom of the tank, sucks out the hydrocarbon gas as fresh air enters from the top. This method is quicker than the straight forced air ventilation, since the air and hydrocarbon gases do not mix, and mainly hydrocarbon gas is sucked out.

2.5.2 Movement of Ballast

The movement of ballast from one tank to another and the expulsion of the ballast to holding tanks act as preliminary washing. Ballast water is pumped into the tanks, where it is permitted to sit before getting pumped out, stripping the tanks clean. This procedure is repeated several times, reducing the hydrocarbon content, before machine washing begins.

This procedure is very controllable, and tests can be performed to measure the gas content at almost any time during the operation. The pumping in of ballast provides a positive displacement of gas within the tank and removes free oil, which may cause hydrocarbon gas regeneration when machine washing begins. Unfortunately, this process is very time consuming and involves a considerable amount of water to be handled.

2.5.3 Ballast Surface Skimming

The use of skimming in cargo tanks removes oil residue, floating on the surface. This prevents gas generation during subsequent machine washing. One device used for this process is a stainless steel and plastic skimmer. It is lowered into the tank in an upside-down collapsed position. It is then expanded by means similar to an umbrella and righted and lowered the rest of the way into the tank until it reaches the level of the tank ballast. The buoy floats on the water surface, extracting the top layer of oil by an external suction through the suction gap. The oil flows up through the chord and out the top of the tank (Figure 2-1).

When this method is combined with forced ventilation, it has proven very effective. In tests, it has reduced the hydrocarbon gas content to below 20% LFL within four hours, tests were performed in large cargo tanks. In subsequent machine washings, the hydrocarbon gas content never rose above 25% LFL,

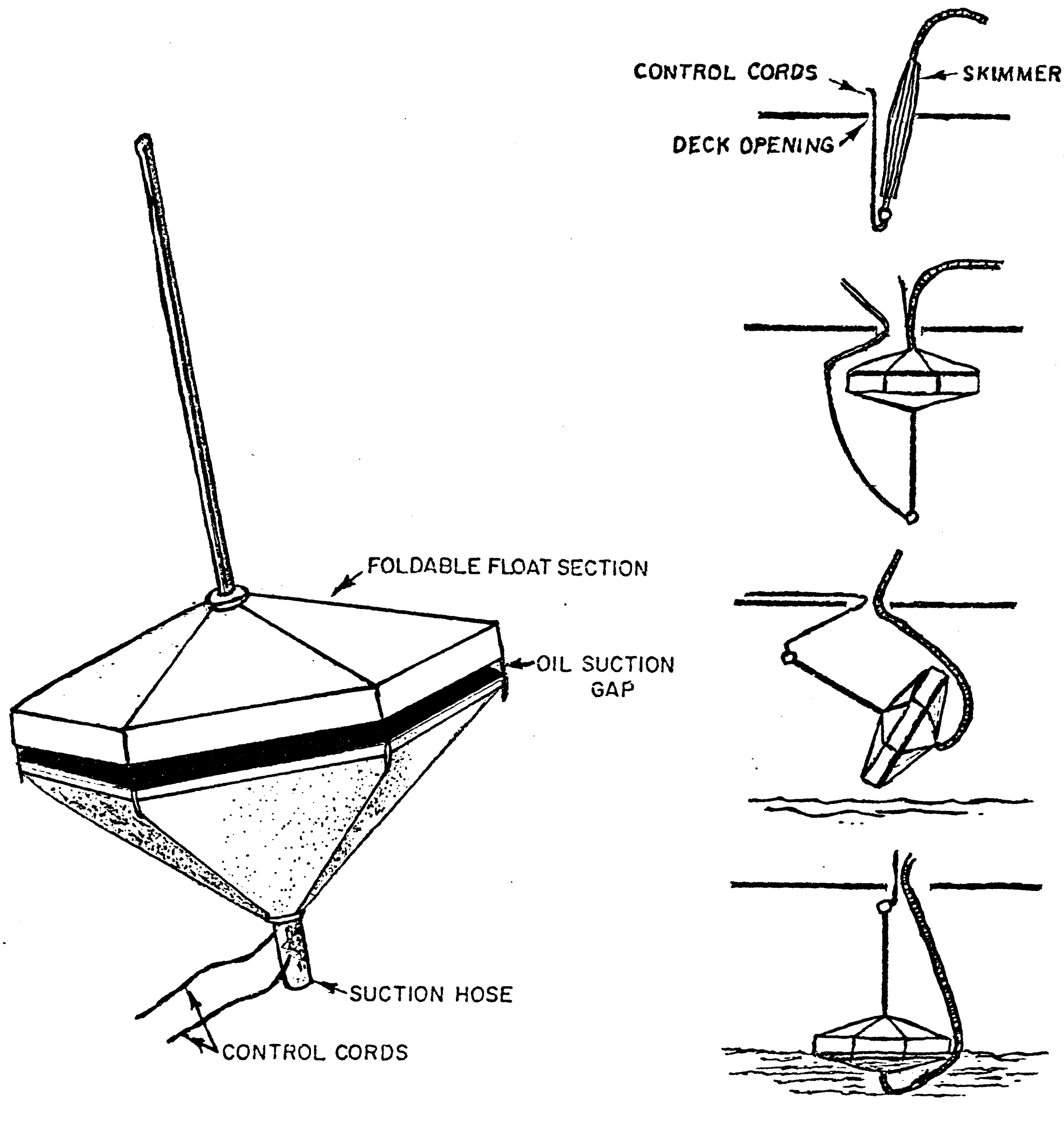

Figure 2-1:Lowering of skimmer into tank

which is still a safe level for tank washing[5]. For this reason, a quick and lasting, yet simple, gas freeing process, a combination of oil skimming and forced air ventilation, is recommended to reduce the hydrocarbon gas content down to a safe level for washing.

2.6 Preparation for Hot Work

Gas freeing should continue during and after the tank washing process. After the washing has been completed, forced air ventilation should continue until the tanks obtain oxygen and flammable material concentrations safe for hot work. The tanks are considered safe when the oxygen content of the atmosphere is at least 19.5 % by volume and the flammable material concentration is below 10 % of the lower flammable limit. When this condition is obtained, holes should be cut in the side of all of the tanks, approximately three feet square. This increases the rate of gas freeing in the tanks. The forced air ventilation should continue until all tanks are safe for entry and hot work without a breathing apparatus. This condition occurs when the hydrocarbon gas content throughout the compartment is less than one percent of the lower flammable limit. After this has been reached, the forced air ventilation can be discontinued, since the holes in the sides of the ship will maintain a safe hydrocarbon level. When this procedure is employed, the working conditions on the ship will prevent potential fires and explosions and keep the atmosphere safe for the workmen.

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[5] *Ibid*, pp.23-28

Chapter Three

Hydrostatics

At every stage of dismantling, the ship should be checked for static stability. All ships are designed to insure the static stability at all times when the ship is in the water. This generally means that the ship has been statically evaluated for all weights between initial launching, lightship condition without some of the outfitting, and maximum operating condition. During the scrapping process, the ship exists in many conditions, various weights and trim angles, that have not been tested during the design process. For this reason, the ship should be periodically checked for static stability.

A ship is transversely statically stable if it has a positive transverse "GM". GM is defined in the following equation:

$$GM = BM - KG + KB$$

where $BM = I_{transverse}$ / volume of water the ship displaces

$I_{transverse}$ = transverse moment of inertia $= \iint y^2 dydx$

KG = distance between the ship's keel and center of gravity

KB = distance between the ship's keel and center of buoyancy

3.1 Stability for Ships with High Block Coefficients

The Voyager has a high block coefficient, as almost all bulk oil carriers do, thus has a high lightship value of GM and high static stability. The high block coefficient is a result of oil carriers having very wide beams even at small distances from the keel. When this large beam value is cubed, it creates a large moment of inertia while displacing very little water, resulting in a high BM. This high value of BM results in the transverse GM, at lightship for the Voyager being 165.5 feet, representing a very stable ship.

During the first one third of the dismantling, the transverse GM of the Voyager rises. This is due to the beam being almost equivalent to the maximum breath of the ship even at very low waterlines (Figure 3-1). As a result, the moment of inertia remains practically constant as the total volume of displaced water decreases. This leads to a much higher metacentric height and a larger BM. GM grows even further due to the lowering of the center of gravity (KG), caused by the removal of most of the weight from the top half of the ship. This decreases much more than the center of buoyancy (KB), which starts out very low at the beginning of the scrapping operation. This increased GM keeps the ship in a very stable static condition.

Even in the latter portion of the dismantling, the transverse GM remains high due to the large beam and small volume displacement. Eventually, the longitudinal GM becomes the critical criteria in determining the static stability of the ship. This occurs when the length of the ship becomes smaller than the breadth of the ship. The longitudinal moment of inertia is then calculated in BM, BM, $\iint x^2 dxdy$. When this finally takes place in the project, the volume of displaced water is sufficiently small to keep BM sufficiently large to ensure that GM is positive, and thus the ship remains statically stable.

3.2 Stability for Ships with Low Block Coefficients

For faster ships which tend to have a much lower block coefficient, great care has to be taken to insure that the partially dismantled ship remains statically stable. A low block coefficient indicates that the beam of the ship is significantly reduced, from maximum breadth, at lower waterlines. This means that as material is removed from the ship and the draft decreases, the beam at the waterline will decrease considerably. Since the beam is taken to the third power in calculating the transverse moment of inertia of the ship, and thus BM and GM, a small decrease in beam represents a large decrease in the static roll stability (Figure 3-2).

To prevent ships with lower block coefficients from becoming transversely unstable, special care must be taken to insure that the beam at the waterline does not decrease too quickly.

If calculations show that the ship may become statically unstable when weight is removed from the aft portion of the ship, it may be beneficial to remove material from the front of the ship. This will decrease the overall draft of the ship but increase the draft at the stern. This will increase the ship's stability, since the transverse moment of inertia will increase. After the ship becomes more stable, it may be possible to remove weight from the aft end of the ship. At

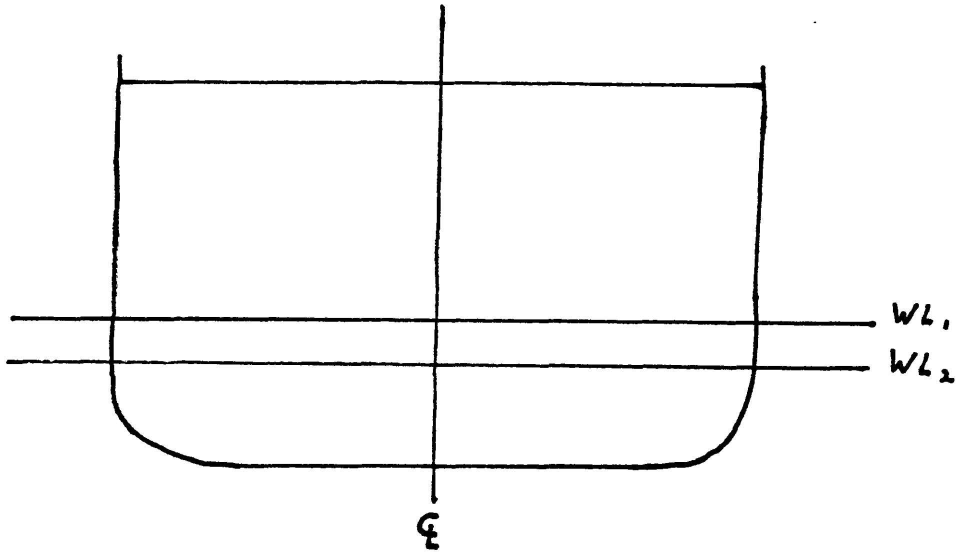

Figure 3-1:In a ship with a high block coefficient, a decrease in draft will not change the breadth or the transverse moment of inertia.

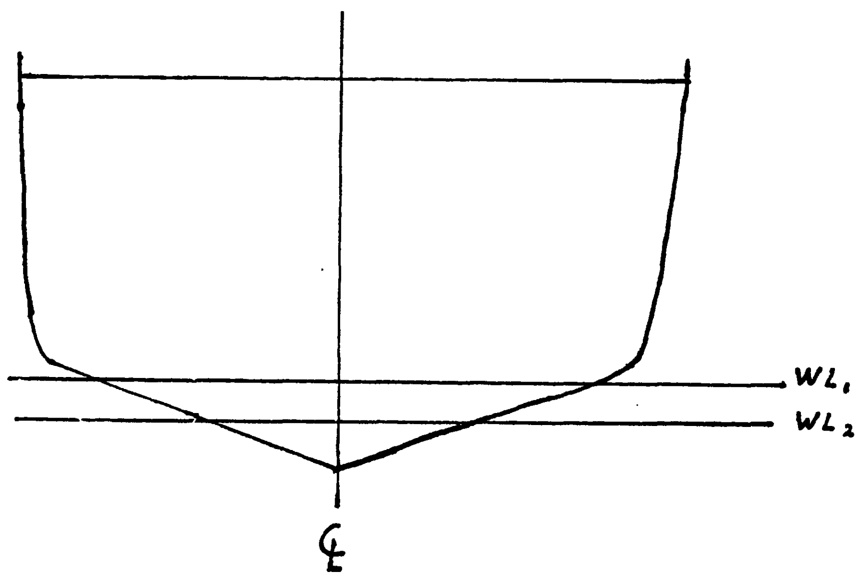

Figure 3-2:In a ship with a low block coefficient, a small decrease in draft represents a significant decrease in the breadth and the transverse moment of inertia.

this point, the ship will displace less water and have a lower center of gravity, so a decrease in the transverse moment of inertia may not make the ship unstable.

Removing weight from the front of a ship with a low block coefficient, does not adversely affect the entire scrapping project. Ship's with low block coefficients are designed with a much higher center of gravity than high block coefficient ships. This allows a larger percentage of the ship's weight to be removed before it is necessary to start removing the transom or keel of the ship.

Chapter Four

Longitudinal and Torsional Strength

Ocean-going ships are designed and constructed to be capable of withstanding the stress produced by the ship's static weight and the dynamic action of passing waves. These stresses are calculated by determining the bending moments applied to the ship. When part of a ship's structure is removed its overall longitudinal strength is reduced. When the deck or other structural member has been removed, the ship will no longer act as a continuous member and will contain stress concentrations in the area where material has been removed. To reduce the external load applied to the ship the dismantling should be performed in calm water, absent of any waves causing additional bending moments.

In the static condition, absent of all waves, the stress acting on the ship is caused by the difference in the bending moment due to the ship's weight and buoyancy force. On most ships, the maximum bending moment, and thus maximum stress, occurs in the vicinity of amidships. In order to determine the maximum stress level in the ship, stress calculations were performed at several locations around amidships continually throughout the dismantling. The stress calculations were always performed where there was a maximum amount of structural "damage" in order to determine the maximum stress present in the ship. This maximum stress was always kept well below the critical stress level for the steel.

Simple beam theory, along with stress concentration factors, was used to determine the maximum stress levels. In the beginning of the project, weight per unit length values were determined, from the ship's preliminary design weight control status report (Appendix C), for every piece of material throughout the length of the ship. In many cases, these values were only approximate, due to the lack of specific weight information provided in the preliminary design report. In several cases, assumptions had to be made regarding a constant amount of framing in and around all the crude oil tanks based on the total weight and longitudinal center of gravity of a specific framing category listed in the weight control status report, for example web frames.

4.1 Stress Calculation Without Stress Concentrations

The weight information enabled a weight curve to be calculated. It also enables the bending moment due to a ship's weight to be calculated easily by multiplying each weight, on one side of a predetermined location by its respective lever arm. This was performed for the Voyager at amidship and at stations seven, eight and nine, 135, 90 and 45 feet aft of amidship (station 10), respectively. These bending moments could be easily modified throughout the procedure by simply subtracting the moment of the piece removed, i.e., the weight of the piece multiplied by the distance aft of the appropriate station, in order to determine the total weight bending moment acting on a specific location at every step of the procedure.

The bending moment due to the buoyancy force was also continually calculated throughout the operation. The body plan was used to calculate the transverse section area at every station, along the length of the boat. This enabled a complete diagram of Bonjean curves to be drawn. The Bonjean curves were used for two main tasks during the project. The first was to determine the waterline and angle of trim of the ship throughout the dismantling. After material was removed from the ship, the total weight of remaining ship was calculated along with the overall longitudinal center of gravity:

$$Weight_{remaining} = Weight_{previous} - Weight_{removed}$$
$$LCG_{remaining} = (Moment_{previous} - Moment_{removed})/Weight_{remaining}$$

Since Archimedes' law states that a body partially immersed in a fluid has to have a buoyancy force equal to and normal to the weight of the body, the Bonjean curves are used to find what draft, both forward and aft, will create a force equal and opposite in direction to the weight force. This buoyancy force can be found by drawing a straight line between a forward perpendicular draft and an aft perpendicular draft on the Bonjean curves and performing a numerical integration of the transverse sectional areas, indicated by the waterline at every station. The integration over the length of the ship gives the volume of the displaced water. The longitudinal center of gravity can be determined by multiplying each sectional area by a lever arm corresponding to the distance from the forward perpendicular to the station considered and dividing by the total sectional transverse areas of the stations (Table 4-1). The forward and aft drafts can be varied until the buoyancy force calculated is equal

Table 4-1: Calculation of the displacement and longitudinal center of gravity of the ship. After stage 4 of dismantling.

Draft: F.P. = 7.7' A.P. = 2.0'

Station	Area	Multiplier	f(∇)	Lever	f(LCB)
AP	0	0.25	0	20	0
1/2	0	0.5	0	19.5	0
1	20	0.75	15	19	285
2	40	1	40	18	720
3	100	1	100	17	1700
4	240	1	240	16	3840
5	345	1	345	15	5175
6	480	1	480	14	6720
7	570	1	570	13	7410
8	620	1	620	12	7440
9	660	1	660	11	7260
10	700	1	700	10	7000
11	730	1	730	9	6570
12	780	1	780	8	6240
13	815	1	815	7	5705
14	870	1	870	6	5220
15	870	1	870	5	4350
16	850	1	850	4	3400
17	700	1	700	3	2100
18	490	1	490	2	980
19	260	0.75	195	1	195
19.5	170	0.5	85	0.5	42.5
FP	140	0.25	35	0	0

$\Sigma f(\nabla) = 10190.$

$\Sigma (LCB) = 82352.5$

$\nabla = s\Sigma f(\nabla) = 458550 \text{ ft.}^3$

$\Delta = \rho g \quad = 13183.3$ long tons

$LCB = s\Sigma f(LCB) / \Sigma f(\nabla) = 363.7$ ft. aft of F.P.

and opposite the weight of the ship.

The second use of the Bonjean curves in this project was to calculate the bending moment due to buoyancy at and around amidship. This is done by using the same sectional areas off the Bonjean curves as were used in calculating the proper draft but using a lever arm equal to the distance from the middle of the station to amidship or the appropriate station, where the moment calculation is being performed. Only stations aft of the point where the moment is to be calculated were used, The sum of the numerically integrated moments is equal to the total bending moment at calculated station. The bending moment used in the stress calculations is the absolute value of the difference between the weight bending moment at the specific station, seven, eight, nine or ten, and the buoyancy bending moment taken about the same location.

The equation of the maximum stress, without a stress concentration factor in the ship is:

$$\sigma = Mc/I \text{ or } M/SM$$

where M = net bending moment, previously discussed

c = distance from the neutral axis to the extreme member

I = moment of inertia of section

SM = longitudinal section modulus

In calculating SM, the following general rules were applied: below the strength deck, all continuous longitudinal members were included; above the strength deck, the gunwale angle bar and the extension of the sheer strake were included.[6]. A sample section modulus calculation for the Voyager is shown in Table 4-2. It uses beam moment of inertia formulas including the parallel axis formula.

4.2 Stress Concentration

The stress, σ, calculated in the previous section would represent the maximum stress under static loading conditions if the ship was made of constant section or a gradual change in contour without discontinuities. When cutting takes place, especially when the side shell is cut, there is a modification of the simple stress distribution so that localized high stress areas occur. This localization of high stress is known as stress concentration, measured by the stress concentration factor, k_T.

To avoid a stress concentration approaching infinity, and almost certain fracture, which can be present at sharp corners (Figure 4-1), a more gradual change in contour is necessary.

4.3 Shoulder Fillets

For a ship with a high block coefficient, a large portion of the above waterline material, at the aft end of the ship, has to be removed early. For this reason, cutting the side shell to leave rounded shoulder fillets is the best solution and should be used for all steel removal. Shoulder fillet stress

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[6] *Principles of Naval Architecture*, The Society of Naval Architects and Marine Engineers, New York, N.Y.,1967, p.182.

Table 4-2: Section modulus calculations. After stage 4 of dismantling. Midship section has 15' depth.

	Scantling	a	dn	adn	adn^2	h	i_o
above 12.5'							
side shell	30 x 1	30	1.25	37.5	46.88	2.5	15.63
side inside	60 x 1	60	1.25	75.0	93.75	2.5	31.25
center	30 x .687	18.75	1.25	23.4	29.29	2.5	10.73
total top		108.75	3.75	135.9	169.92		57.61
below 12.5'							
side shell	78 x 1	78	3.25	254	823	6.5	275
bilge keel	102 x 1.37	140.2	9.5	1332	12658		1000
bottom shell	769 x 1.37	1057	12.5	13212	165156		
flat keel	44 x 1.44	63.25	12.5	791	9882		
side inside	120 x 1	120	2.5	300	750	5.0	250
bottom inside	430 x 1.25	538	5.0	2690	13450		
center	150 x 0.69	103	6.25	644	4025	12.5	1342
bottom very in.	324 x 1.25	405	6.25	2531	15820		
slant brace	120 x 1.25	150	2.5	375	950	5.0	312.5
girders	1296 x 0.5	648	9.0	5832	52488	6.0	1946
total bottom		3302.5		27961	276002		5126

$A = \Sigma a = 3411.25 \text{ in.}^2$

$In = \Sigma adn^2 + \Sigma i_o = 281355.5 \text{ ft.}^2\text{in.}^2$

$adn_{top} - adn_{bottom} = -27825.0 \text{ ft.}^2\text{in.}^2$

$dg = -27825.0/A = -8.18 \text{ ft.}^2$

$A \times dg^2 = 226964.9 \text{ ft.}^2\text{in.}^2$

$I/2 = In - adg^2 = 54390.65 \text{ ft.}^2\text{in.}^2$

$I = 108781.3 \text{ ft.}^2\text{in.}^2$

$c = \text{assumed neutral axis} + |dg| = 20.66 \text{ ft.}$

$SM = I/c = 5265.3 \text{ ft.in.}^2$

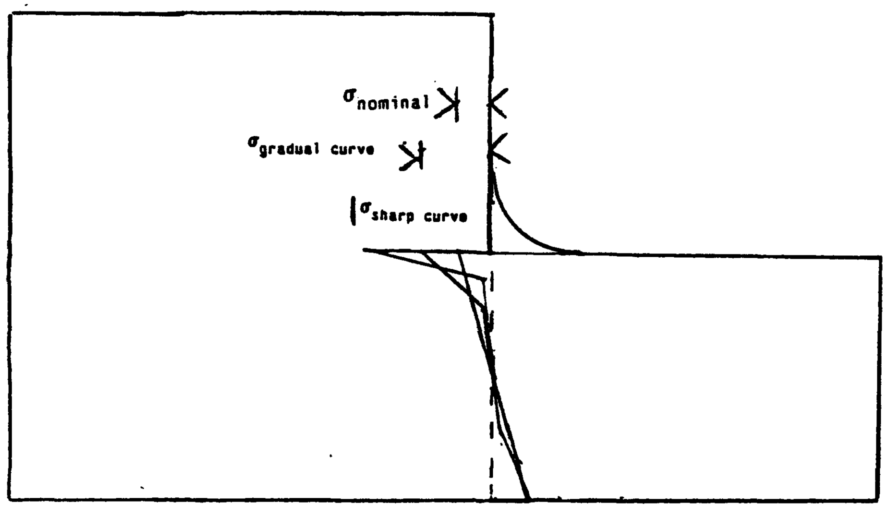

Figure 4-1:Stress concentration approaching infinity and a more gradual curve to reduce the concentration.

concentration factors can be easily be kept under three, and a careful removal can keep the factor around two. With the shoulder fillets, it is important to retain a continuous curvature when the size of the plating is reduced. Any discontinuities in the curvature can create very high stress intensities which could complete structural failure.

There are two main designs for shoulder fillets which provide small stress intensities in bending adequate for this project. The first (Figure 4-2) uses a circle to determine the curvature of the shoulder. The larger the ratio of the circular radius, r, to the depth of the smaller section of the beam, d, the lower the stress intensity. The stress intensity also depends on the ratio of D/d. Using this shoulder fillet, the Voyager could contain a gradual contour change from a depth of 60 feet to a depth of 15 feet while undergoing stress intensities of only twice the nominal stress calculated for a continuous ship. This would require the radius of curvature to be approximately two and a half feet[7].

The other design for a shoulder fillet uses an elliptical fillet (Figure 4-3). In this design the stress intensities are dependent on the ratios D/d, b/a,and b/d. For a gradual contour change from a depth of 60 feet to a depth of 15 feet, with b/a equal to two and b/d ratio of 0.5, photoelastic tests reveal stress intensities of under 1.5.

Both of these shoulder fillets allow a large amount of the ships structure to be removed without increasing the maximum stress beyond the critical stress of the structure. The elliptical fillet is especially useful because the stress intensity decreases as the b/a ratio increases from two to four[8]. This allows for as easier straight vertical cut to be made for most of the removal before the elliptical corner is required.

In using the shoulder with the elliptical fillet, large pieces of the side shell could be removed. These large pieces can then be cut up into more easily controllable pieces at the processing area before being loaded onto trucks for

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[7] M.M. Leven and J.B. Hartman, "Factors for Stress Concentration for Flat Bars with Enlarged Sections", Proc. SESA, Vol. 19, No. 1 (1951), p.51.

[8] D.C. Berkey, "Reducing Stress Concentration with Elliptical Fillets", Proc. SESA, Vol. 1, No. 2 (1944), p.56.

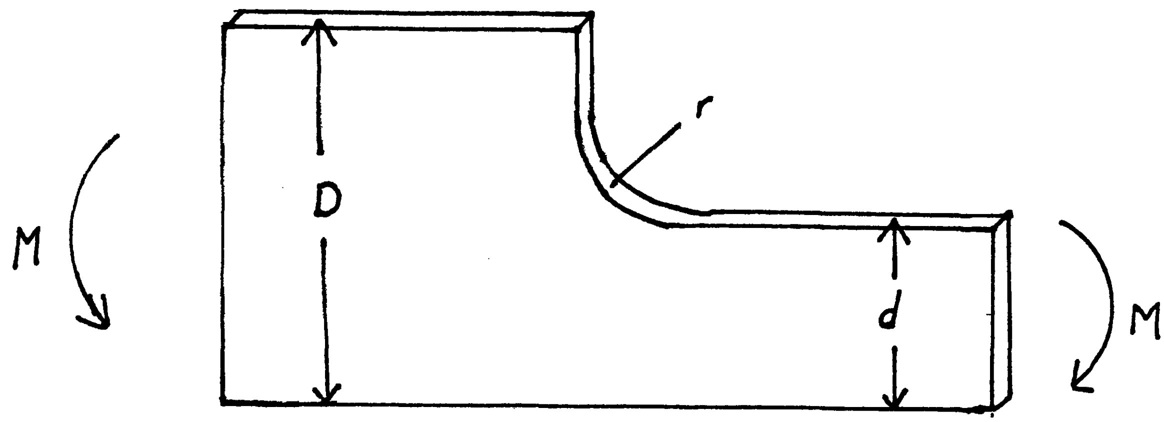


Figure 4-2: Shoulder fillet with a circular curvature.

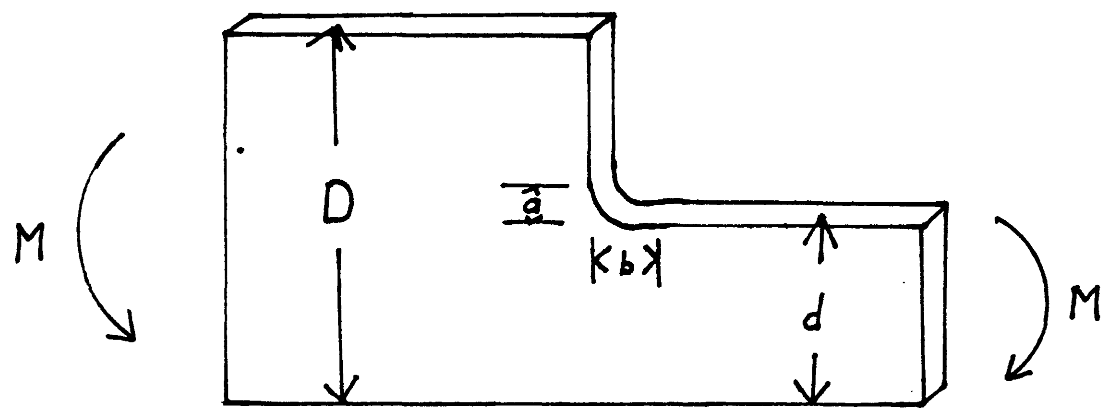


Figure 4-3: Shoulder fillet with elliptical curvature.

long distance hauling. This will save time by allowing the workers to use many more straight cuts, instead of requiring the proper curvature to be cut as every small piece is removed.

By using a conservative stress concentration factor, two for most stages of the ship's dismantling, it is easy to determine the maximum stress at amidship (Table 4-3) and other stations. By performing periodic stress calculations, at and around amidship, it is possible to insure that the ship has enough longitudinal strength. Periodic calculations also allow trends to be observed, such as increasing net bending moments, which may cause structural problems as the project continues. These trends can be corrected by removing more weight either forward or aft of amidship in order to increase or decrease the net static bending force and reduce the longitudinal stresses.

4.4 Safety Factor

All of the stress calculations made in the preceding sections assumed that the steel was in excellent condition and that the quality of workmanship in the dismantling procedure was very high. Since ships are generally scrapped after being in service for several years, their steel has usually begun to corrode. This corrosion will increase the stress in the structure by decreasing its cross-sectional area, thus moment of inertia, and by causing local stress concentrations around localized pitting.

The added stress concentrations calculated for the shoulder fillet are based on continuous curves near the point of large contour changes and the

Table 4-3: Calculation of maximum stress. After stage 4 removal.

Buoyancy moment at amidship.
Draft F.P. = 7.7'
Draft A.P. = 2.0'

Stations	Force (lbs.)	Lever (ft.)	Moment (ft.lbs.)
A.P. - 1	21,735	420	9,128,700
1 - 2	79,695	382.5	30,483,338
2 - 3	202,860	337.5	68,465,250
3 - 4	492,660	292.5	1.4410305×10^8
4 - 5	847,665	247.5	2.0979709×10^8
5 - 6	1,195,425	202.5	2.4207356×10^8
6 - 7	1,521,450	157.5	2.3962838×10^8
7 - 8	1,724,310	112.5	1.9398488×10^8
8 - 9	1,854,720	67.5	1.2519360×10^8
9 - 10	1,970,640	22.5	4.43394×10^7

Σ buoyancy moments = 1.371966×10^9 ft.lbs.

Weight moment = 1.2775437×10^9 ft.lbs.

ΔM = buoyancy moment - weight moment = 2.96529×10^7 ft.lbs.

SM = I/c = 5,265.3 ft.in.^{2}

$\sigma = \Delta M/SM$ = 5631.75 psi.

stress concentration = K_T = 2

factor of safety = 3

σ_{total} = 33,790 psi.

curves being of predetermined shapes. In order to allow the dismantling to occur at a reasonable rate, it is necessary to make allowances for imperfections in the markings of the cut and the cutting of the metal.

To accommodate both of these conditions, a safety factor of three was used in all longitudinal stress calculations. This factor of safety was multiplied by the calculated stress throughout the dismantling procedure to ensure that the possibility of material strength failure was negligible.

4.5 Torsional Strength

The torsional failure limit of the ship is never approached during the dismantling process. Throughout most of the procedure, a high percentage of the torsional strength of the ship is left intact. During the beginning of the dismantling, the outfitting, superstructure, and machinery are removed. This does not affect the torsional strength of the ship. Even in later portions of the dismantling, parts of the deck are left intact, maintaining much of the intact torsional strength.

After the portions of the deck are removed, the torsional load from external sources applied to the ship is minimal. The dismantling dock is located in a sheltered area which contains only waves with short wavelengths. These waves will not apply a torsional load to the ship.

In addition, the procedure for dismantling the ship prevents the torsional load due to internal ship torsional forces from becoming large. The ship is to be dismantled symmetrically around its centerline. This method allows for the maximum amount of weight to be removed from each longitudinal section as the dismantling moves forward. By symmetrically removing weight from the port and starboard sides of the ship, the weight forces are the same around the centerline of the ship, so there is no internal torsional load due to weight distribution.

Chapter Five

Dismantling Procedure

5.1 Removal of the Outfitting

At the same time as the ship is undergoing tank washing and gas freeing operations, the initial stages of dismantling should begin. The first steps in dismantling do not require any cutting in the vicinity of the gas-filled tanks, and are therefore safe to perform before the gas freeing has been completed.

The first step is the removal of all easily removable outfitting. Much of this equipment is bolted in place, either to the deck or the inside structure. Some of the outfitting remains in excellent condition throughout the life of the ship and is valuable in the resale market. Due to this resale value, care should be taken in removing valuable equipment.

The placement of the ground hoists at intervals of 100 feet along the length of the dock expedites this stage of dismantling since the machinery and outfitting are numerous and distributed throughout the length of the ship. Simultaneous removal of the outfitting can occur at many points along the length of the ship. When this equipment is removed, it should be trucked to the processing yard where it can be sorted. Since the furniture, navigational aids and other outfitting would be sold to many specialized vendors, who are interested in refurbishing selected items, the material should be sorted to suit the specific buyers.

After all the deck machinery, navigation equipment and other easily removable equipment has been removed and loaded onto trucks, the removal of pumping systems can begin. These systems can not be removed until after the cargo and fuel tanks have been freed of all flammable gas, according to the standards discussed earlier, since their use in the tank washing and gas freeing process is essential. After the pumping systems are removed from the ship to the processing yard, all bronze parts should be removed. Since bronze has a high resale value it should be separated from the rest of the outfitting and sold.

Along with all the pumping systems, any outfitting requiring cutting should be removed at this time. Some equipment, for example, some of the galley equipment, may be difficult to remove at this point in the operation. If this equipment is in the aft portion of the ship, its removal should wait until after the deck covering the compartment has been removed. If the equipment is in the forward section of the ship all necessary efforts should be taken, including cutting the equipment if absolutely necessary, to remove the equipment. Some of the equipment, for example the anchor chain, will have to be cut into several pieces to reduce the weight of each section being removed to remain within the maximum weight capabilities of the hoists and trucks used in the handling and transportation of the material.

When this stage of the removal is completed, almost all of the material under the "outfit" heading of the weight control status report of the Preliminary

Design Report will have been removed. The exceptions to this include material that can not be easily separated from other portions of the ship, for example paint, and the material in the aft portion of the ship that will be taken off after the deck covering the equipment's compartment is removed, as mentioned above.

5.2 Removal of the Superstructure and Machinery

After all of the easily removable outfitting has been taken off the ship and sorted in the processing area, the structural dismantling of the ship should begin. Since the propulsion system contains heavy equipment which does not contribute to the ship's structural strength, the machinery should be removed as early in the procedure as practicality permits. Since in most merchants ships the machinery rooms are located in the aft section of the ship below the superstructure, it is desirable to remove the superstructure and machinery as the first major dismantling step; this will decrease the draft of the ship and move the longitudinal center of gravity forward.

The superstructure should be removed by cutting approximately eight foot square sections from the top of the structure, allowing for curved corners to decrease the stress concentrations. This process should continue down the side of the superstructure, including the floors of every level. The entire superstructure down to the main deck should be removed.

In order to facilitate easy access into the machinery compartment and easy removal of the equipment, the entire main deck directly above the machinery space should be removed in approximately eight foot square sections. In addition, a small portion of the side of the ship should be removed, approximately the top eight feet over the center 30 feet of the machinery space. This side removal allows for easy access into the machinery compartment. The complete transom and deck above the transom should be left intact to insure the torsional strength of the ship. This stage of the removal is shown in Figure 5-1.

5.2.1 Removal of a Steam Turbine System

There are two main types of propulsion systems used on merchant ships: steam turbine and diesel. Most components of the steam turbine system are light enough to easily remove them without cutting or disassembling. The exceptions to this are the reduction gears and some of the piping and shafting. Due to the heavy weight, the reduction gears will have to be disassembled into several pieces before removal. The piping, shafting, and stern tubing should be cut up to reduce both the weight and size of the components to allow for easy removal. Both the shafting and stern tubing should be secured to the hull of the ship at its point of exit. This portion of the shafting and stern tubing should remain in place until later in the scrapping procedure, as much of them within the hull should be removed at this time. Other systems, for example, the feed and condensate system, will have to be disassembled into individual or a cluster of small components before their weight and size will permit removal with the dock hoists.

5.2.2 Removal of a Diesel Propulsion System

For merchant ships containing diesel propulsion systems, substantial disassembly must occur. This is due to the very heavy weight of the diesel engine. Since ship diesel engines can oftentimes be reused with a minimal amount of reconditioning, careful dismantling should be used. The diesel engine manufacturer's assembling instructions, which are used to assemble the large diesel engines at the shipyards after the manufacturers have shipped the partially assembled engines from the manufacturing plant, should be used in reverse order to disassemble the engine for removal from the ship.

The other complimentary systems used in the propulsion and ship service systems should be removed in the same manner as with the steam turbine system; again piping, shafting and stern tubing will need to be cut. The exceptions to this are the reduction gears and the feed and condensate systems. Almost all diesel engines do not require reduction gears. The only feed and condensate system on diesel engine ships will be for auxiliary equipment and will be small and light enough for easy removal without dismantling.

5.3 Ship Structure and Shell Removal

After the superstructure and machinery have been taken off, the remaining ship structure and plating should be cut and removed. At this stage of the dismantling, the Voyager had an even keel draft of 6.95 feet.

The plan for dismantling the rest of the ship can be seen in Figures

5-2 thru 5-11. All figures represent a centerline symmetrical removal of material. This plan is designed to keep a large amount of the ship's torsional strength throughout many of the stages of dismantling. This is accomplished by leaving of the sideshell, supporting framing, and main deck intact throughout the length of the ship during the first few stages of removal.

The order in which material is removed from the ship is designed to minimize the stress intensities on the ship's structure. To accomplish this, the plan attempts to minimize the difference between the weight and buoyancy moments acting at various points along the ship's length. In addition, small changes in the ship's depth were made at several locations in order to minimize the stress concentration factor and stress intensity at any single point. An example of this is shown in the fifth stage of dismantling (5-5).

This plan insures that the Voyager will remain hydrostatically stable, in both the transverse and longitudinal directions, throughout the entire dismantling procedure.

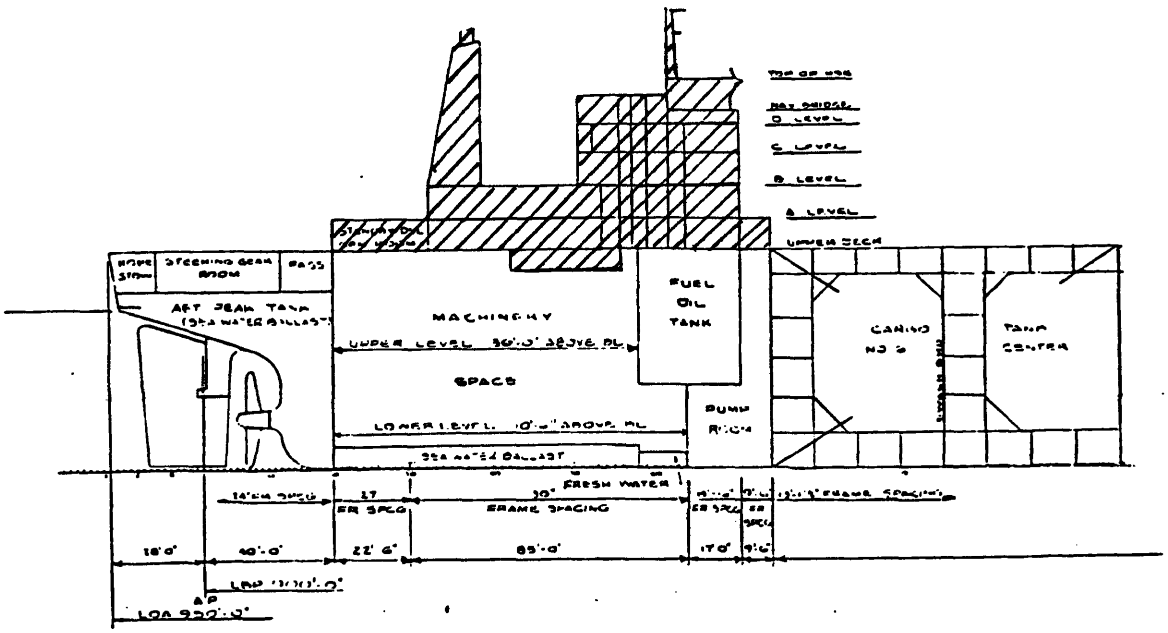


Figure 5-1: Stage 1 removal. Superstructure and machinery are removed. Shaded area represents the section of the ship to be removed during this stage of dismantling. GM = 179 ft., σ = 2050 psi.

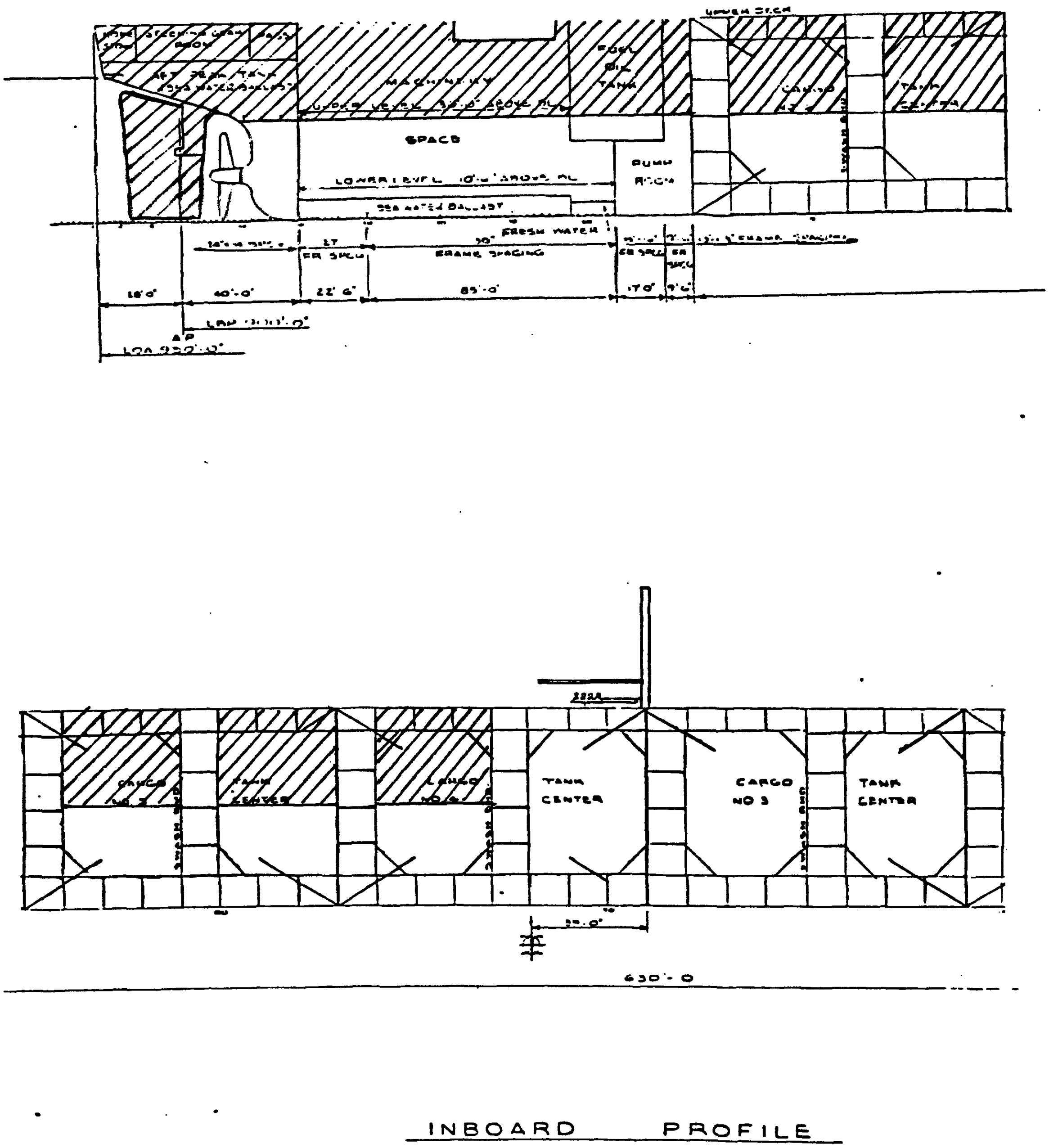


Figure 5-2: Stage 2 removal. Removal of main hull plating and structure begins. Column left to retain torsional strength. GM = 197 ft., σ = 7730 psi.

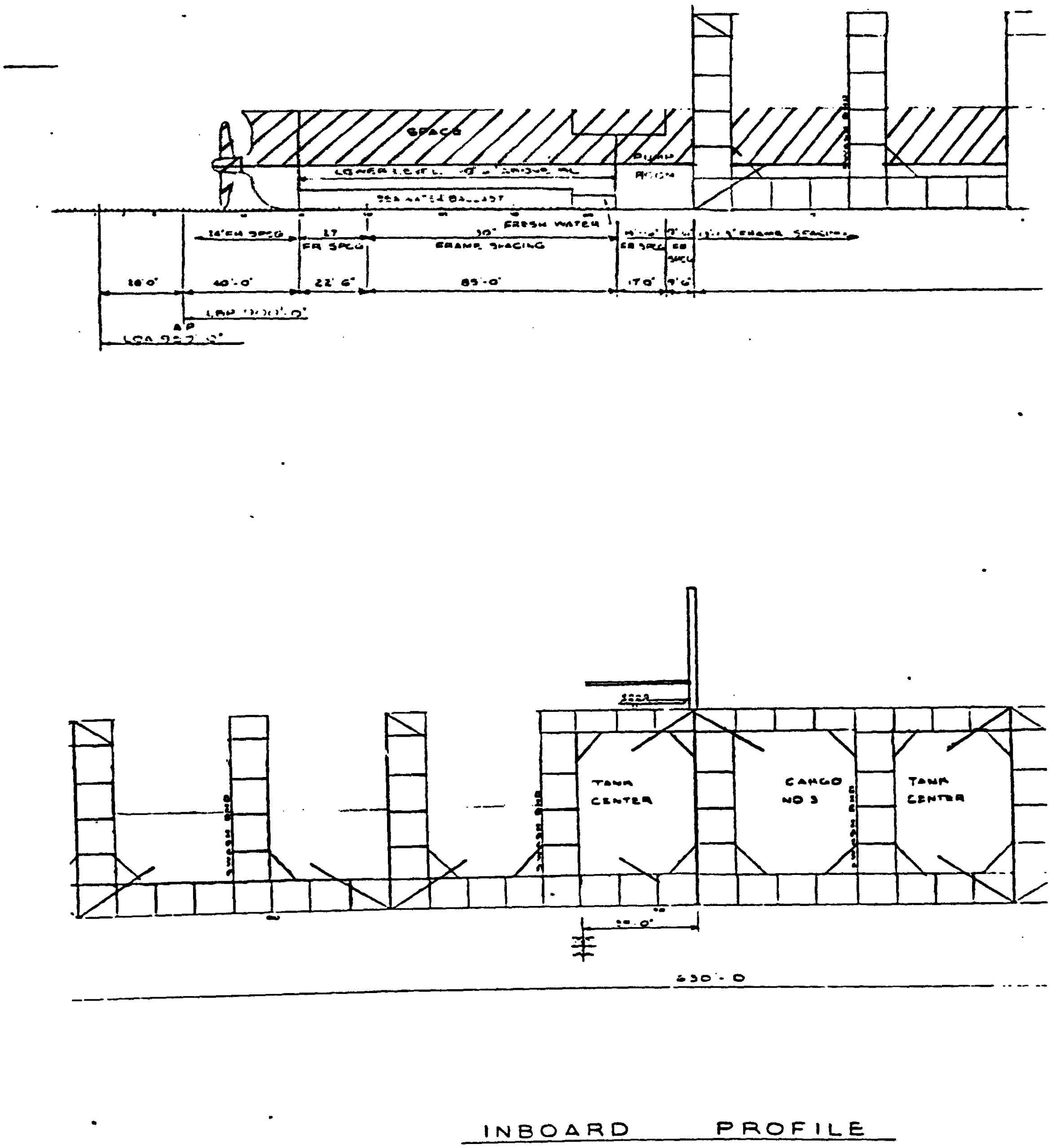
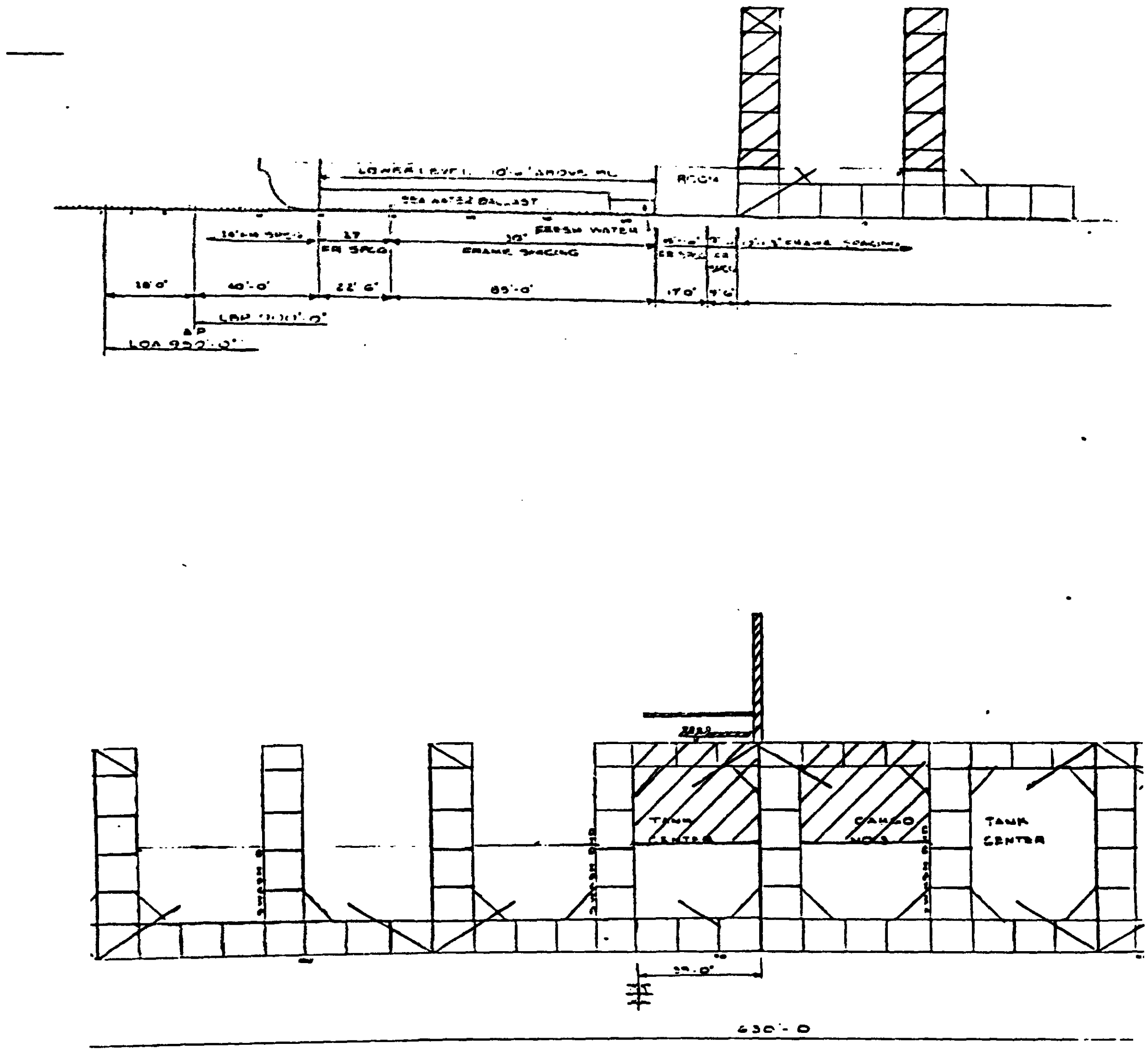


Figure 5-3: Stage 3 removal. Aft end removal continues. GM = 203 ft., σ = 9250 psi.



INBOARD PROFILE

Figure 5-4: Stage 4 removal. Due to limited amount of material exposed to wind forces in the aft portion of the ship the columns are removed. Material removed around amidship to decrease the difference between the weight and buoyancy moments. GM = 208 ft., σ = 11263 psi.

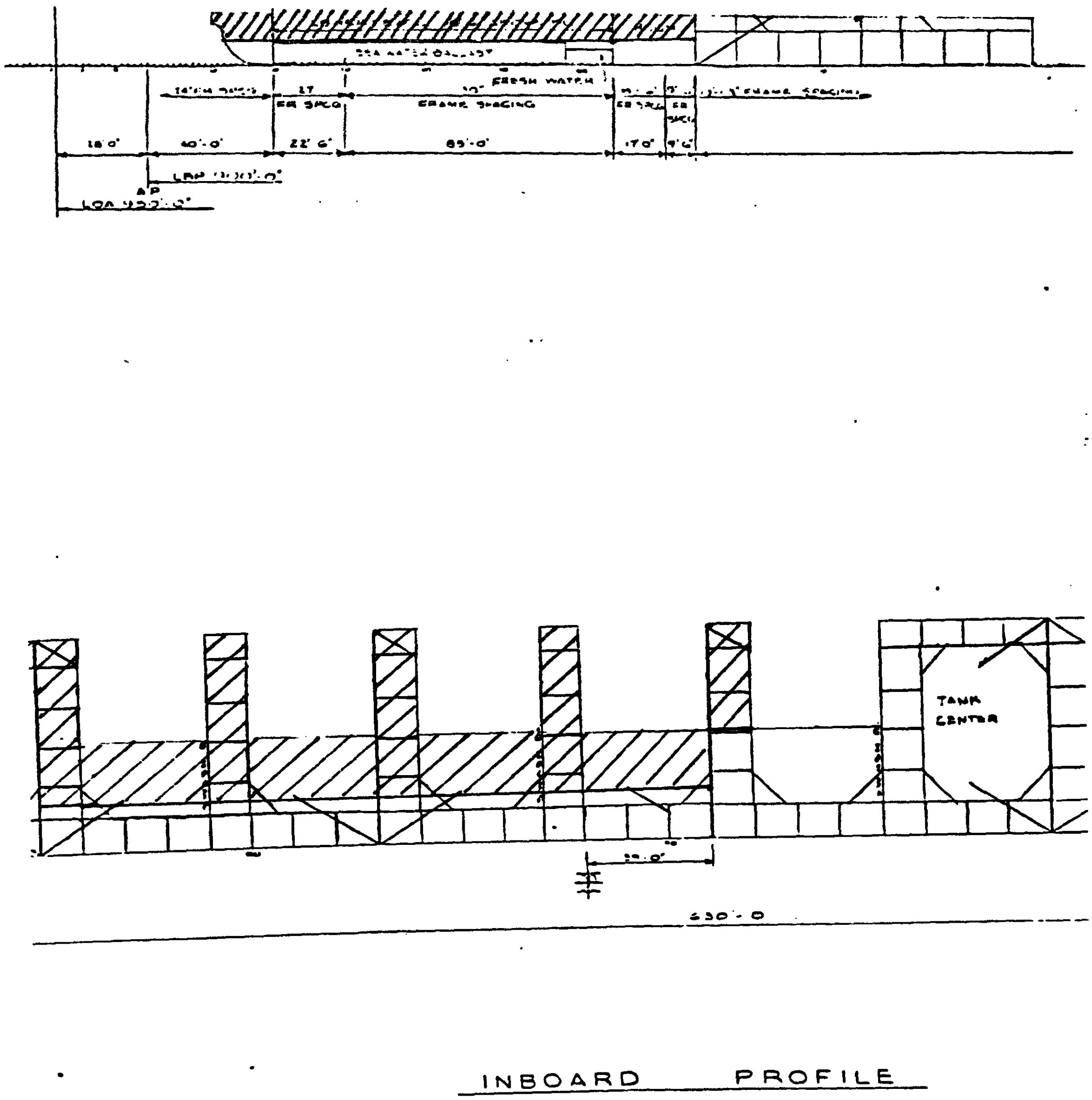
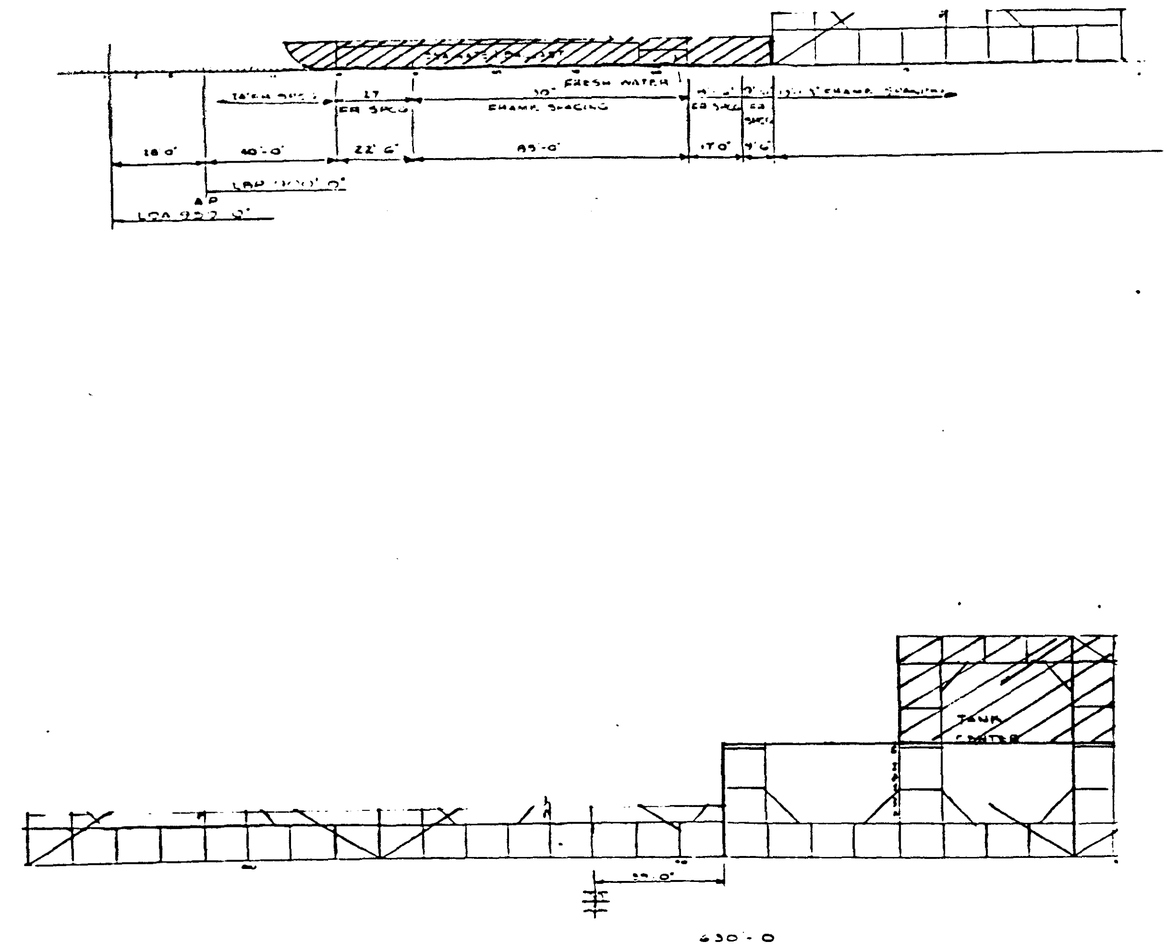
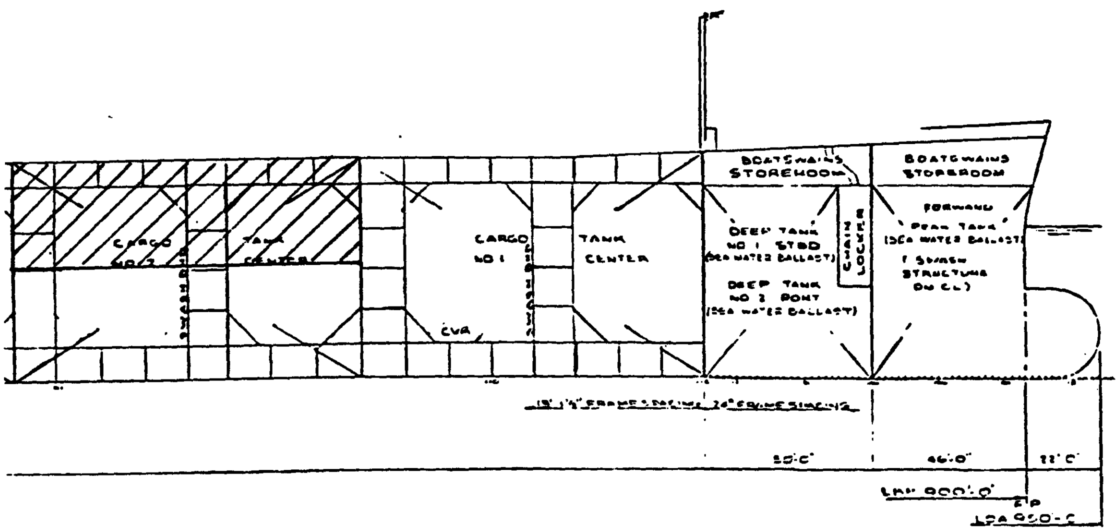


Figure 5-5: Stage 5 removal. Stress concentrations decreased by using step changes in the ship's depth. GM = 192 ft., σ = 10540 psi.



INBOARD PROFILE

Figure 5-6: Stage 6 removal. Stern's keel is out of the water and removed. GM = 162 ft., σ = 9200 psi. (2 pages)


CARGO
TANK
CARGO
NO 1
TANK
CENTER
BOATSWAINS
STOREROOM
DEEP TANK
NO 1 STBD
DEEP TANK
CHAIN
LOCKER
FORWARD
STRUCTURE

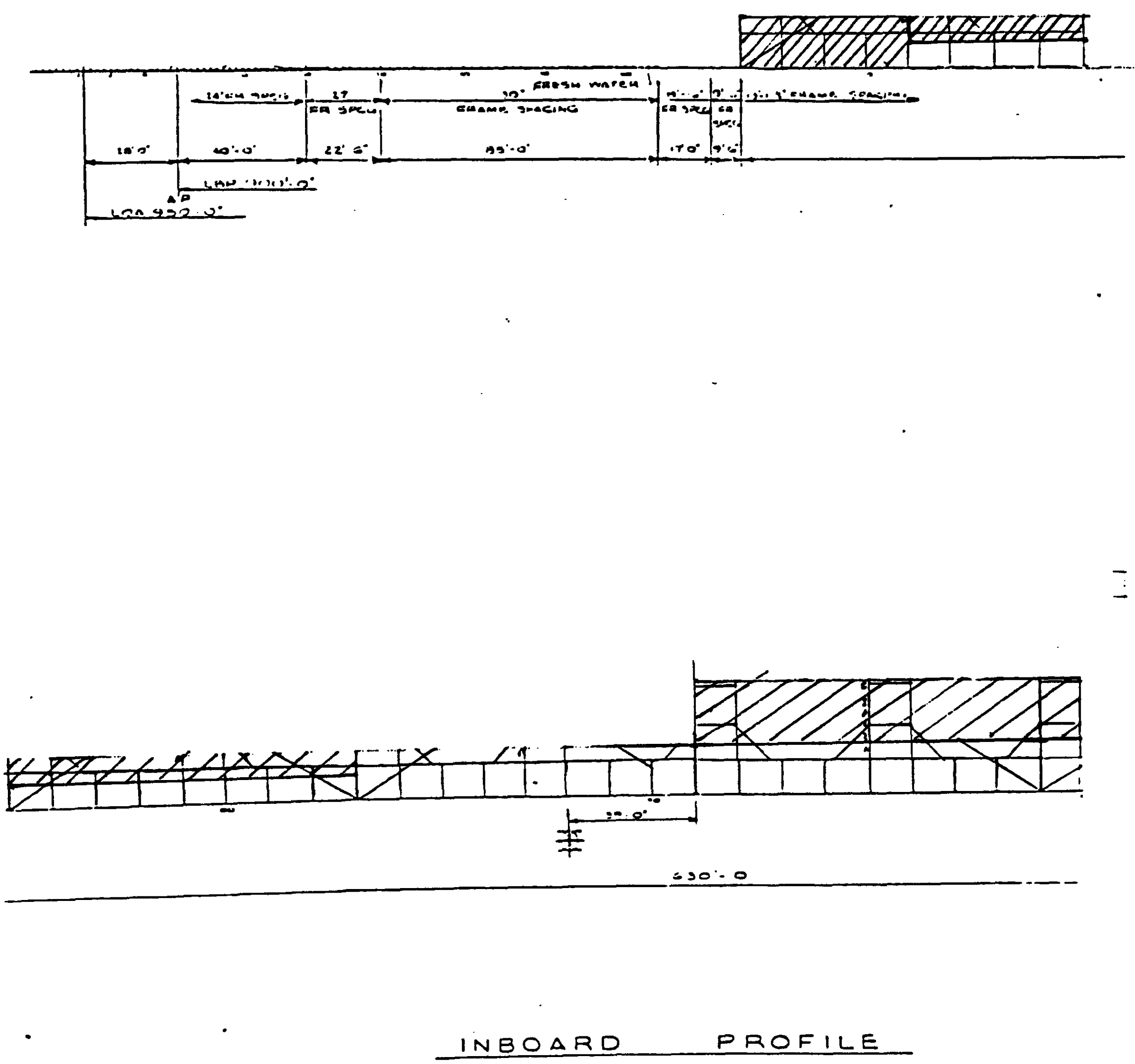
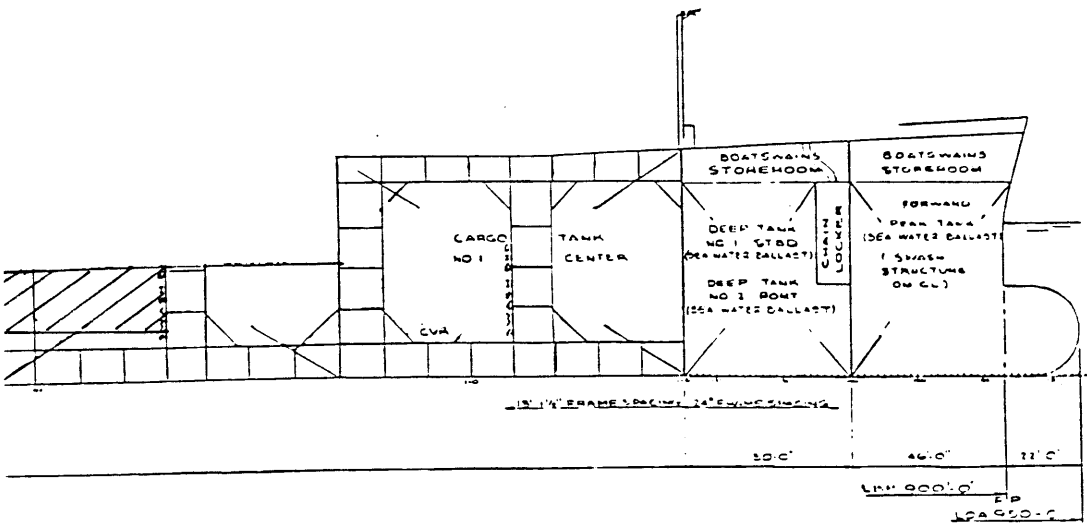


Figure 5-7: Stage 7 removal. More of the keel is removed. Removal continues using step changes in height. GM = 126 ft., σ = 10445 psi. (2 pages)


BOATSWAINS STOREROOM
BOATSWAINS STOREROOM
CARGO
NO 1
TANK
CENTER
DEEP TANK
NO 1 STBD
(SEA WATER BALLAST)
DEEP TANK
NO 2 PORT
(SEA WATER BALLAST)
CHAIN LOCKER
FORWARD
PEAK TANK
(SEA WATER BALLAST)
(SWASH
STRUCTURE
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CVK
46'-0"
FP

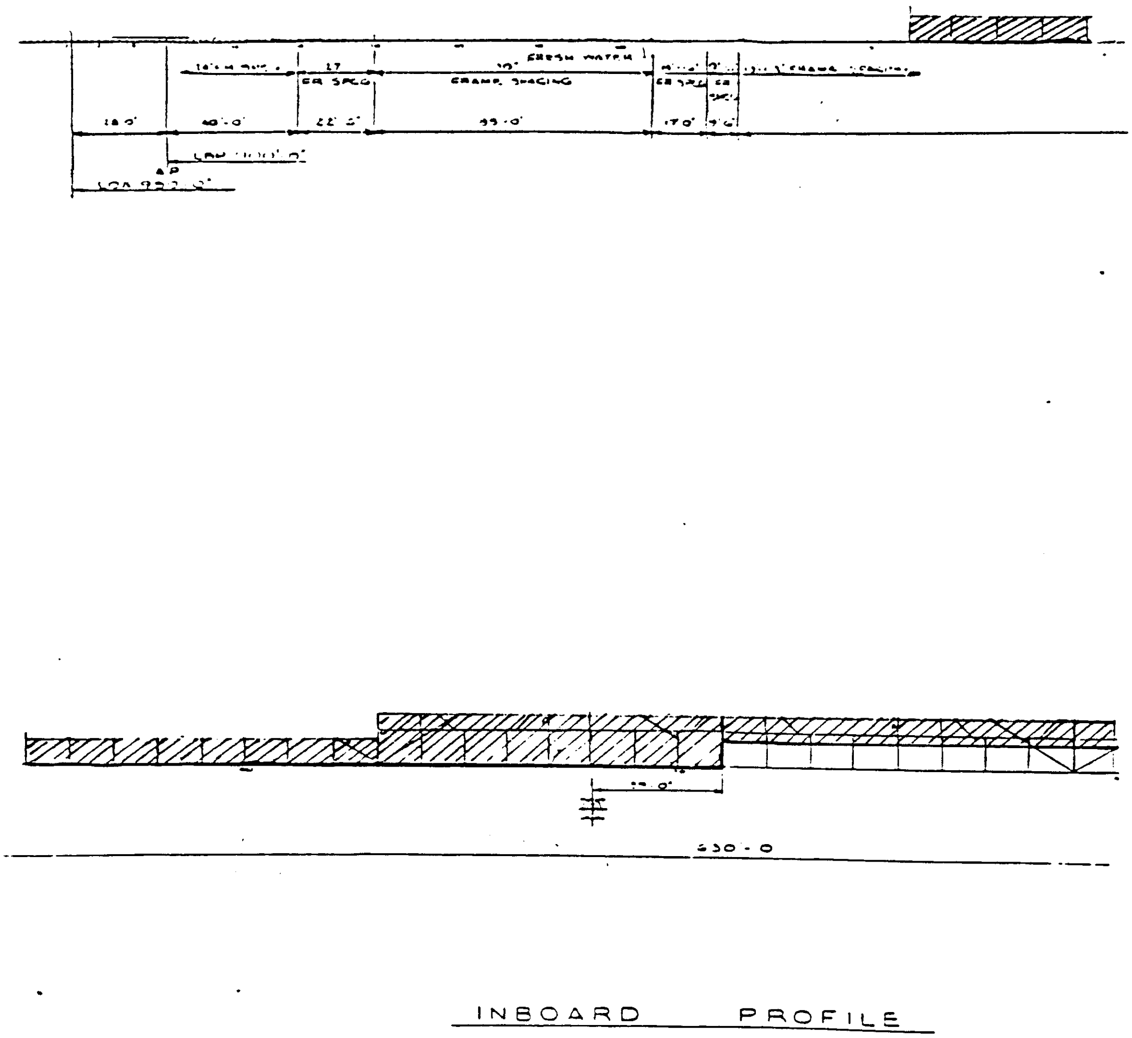
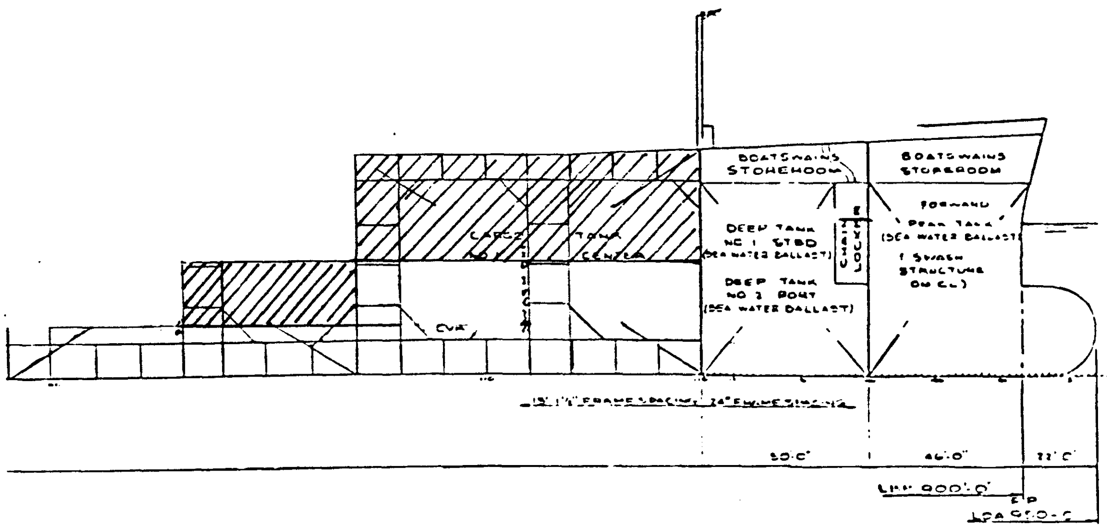


Figure 5-8:Stage 8 removal. GM = 59 ft., σ = 10320 psi. (2 pages)


BOATSWAINS STOREROOM
DEEP TANK NO 1 STBD (SEA WATER BALLAST)
DEEP TANK NO 2 PORT (SEA WATER BALLAST)
CHAIN LOCKER
FORWARD PEAK TANK (SEA WATER BALLAST)
SWASH STRUCTURE ON CL)
CARGO
TANK
CENTER
46'-0"
FP

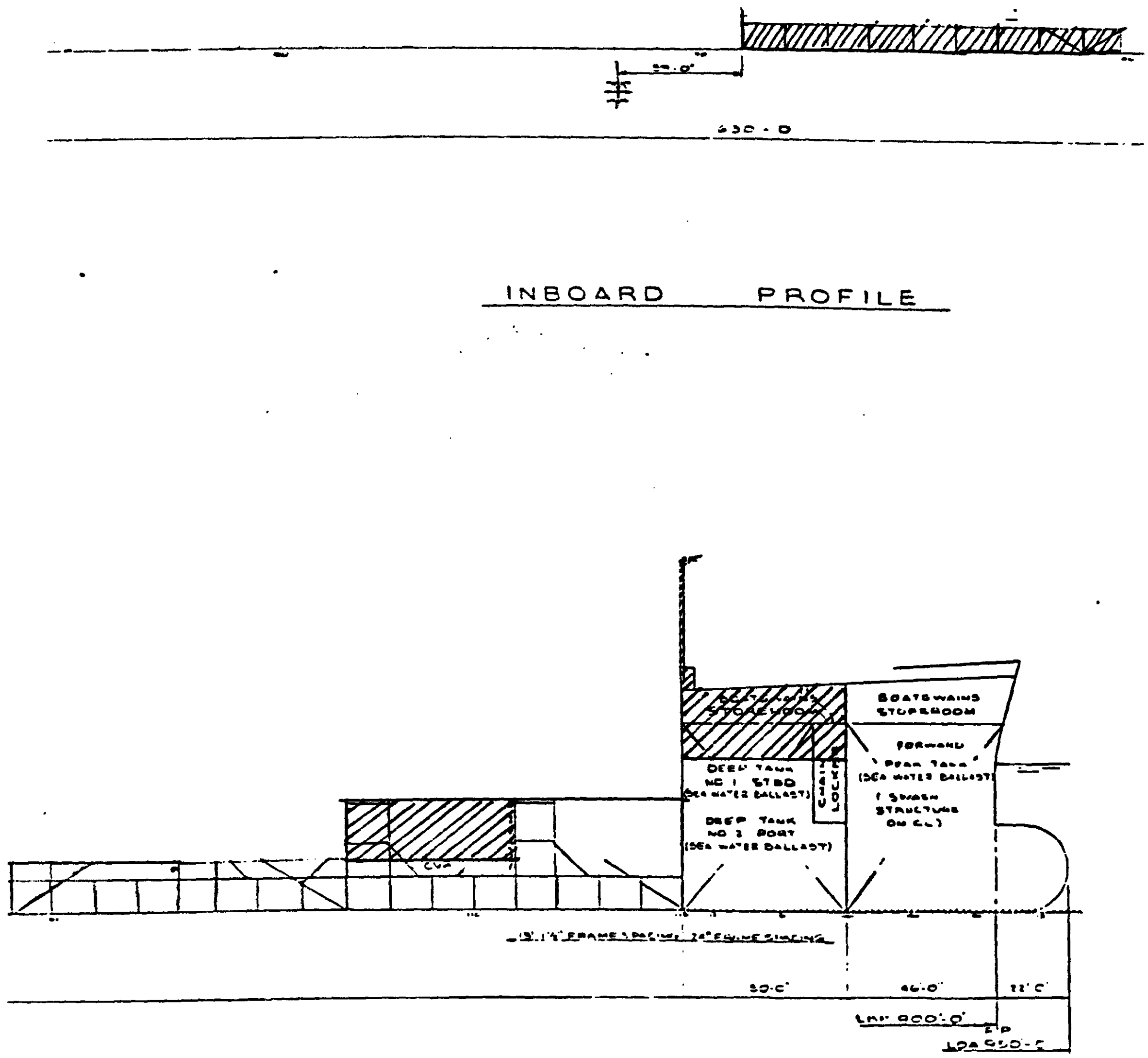


Figure 5-9: Stage 9 removal. GM = 37 ft., σ = 8850 psi.

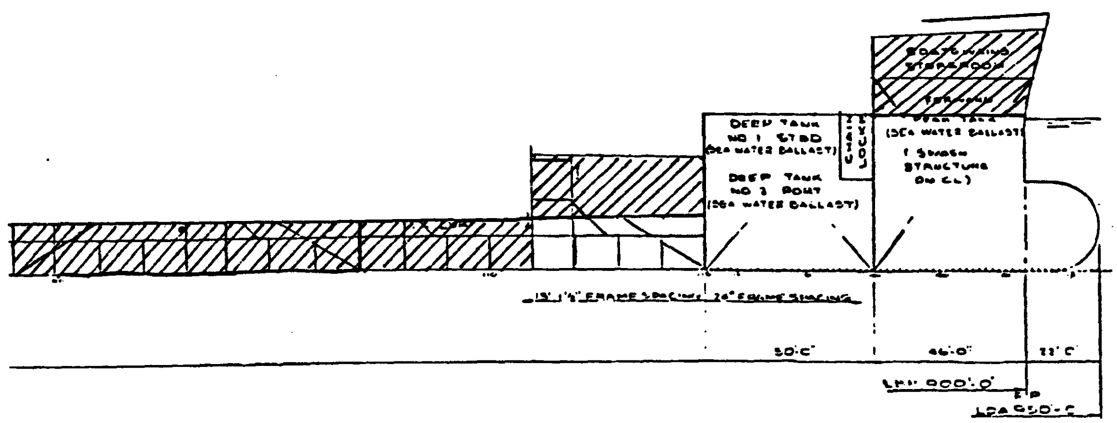


Figure 5-10:Stage 10 removal. GM = 15.5 ft., σ = 6940 psi.

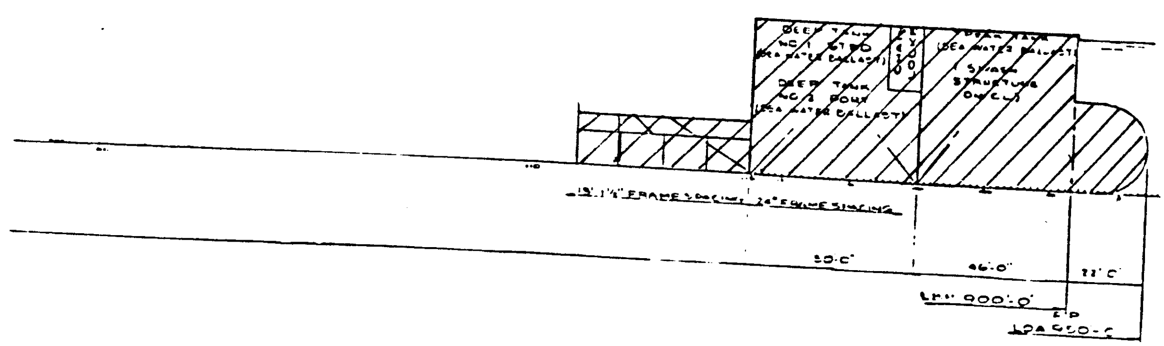


Figure 5-11: Last stage of removal. Last portions of ship are removed from the water.

Chapter Six

Summary and Conclusion

After washing and gas freeing all tanks, it is technologically feasible to completely dismantle a ship while it is in the water alongside a dock. By removing material from the aft end of the ship and working forward, the longitudinal center of gravity of the ship shifts forward, raising the keel out of the water, permitting its removal. This procedure continues until all of the ship has been removed from the water.

The scrapping operation can be successfully performed if the dismantling plan retains some of torsional strength during the beginning of the operation and minimizes the stress intensities in the ship's structure throughout the dismantling. The torsional strength can be retained by leaving some portions of the side shell, structure, and main deck during the first parts of the operation. In addition, the torsional loads applied to the ship should be minimized by performing the operation in calm water and in a location with little wind. Also, the material should be removed symmetrically around the centerline of the ship. The stress intensity in the ship's structure should be minimized by attempting to equate the weight and buoyancy moments throughout the ship. In addition, stress concentration factors should be made as small as possible by using curved shoulder fillets where the ship's depth contour changes drastically when material is cut away. Also, step changes in contours will result in several smaller stress concentration factors, and thus stress intensities, to be present in different locations along the length of the ship.

Furthermore, the ship's body plan should be studied before the specific dismantling plan is formulated to insure that the ship will remain hydrostatically stable throughout the dismantling operation. Modifications to the general dismantling plan, presented here, may have to be made for lower block coefficient ships to ensure their static stability. In some cases, it may be beneficial to first remove some material from the front of the ship. This will increase the transverse moment of inertia and the ship's stability. After the stability has increased, weight can be removed from the stern in order to lift the keel out of the water and completely dismantle the ship.

Due to size and weight constraints of the equipment used in the dismantling procedure, modifications to the plan may have to be made for individual ships. This includes the removal of machinery from the engine compartment. Steam turbine propulsion systems have lighter components than the diesel propulsion systems and, for the most part, can be taken out intact. The main diesel engine will have to be partially disassembled, much in the same way as it is assembled at a shipyard after transportation from the manufacturer. With either system, some of the components will have to be cut in order to be removed from the ship.

After all material is removed from the ship, it will have to be trucked to an adjoining processing yard where it can be sorted and processed for further transportation.

Every type of ship will have to be analyzed to ensure that they will have adequate strength and stability throughout the dismantling procedure. Once this analysis has been performed and any necessary modifications to the general dismantling plan have been made, there is very little extra time required to scrap a ship in the water compared to using a drydock. Since dock space and an adjacent processing yard are much cheaper than drydocking facilities, scrapping a ship in water seems to be a viable economic and technological alternative to drydocking, especially when a large number of one type of ship are to be scrapped.

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Appendix A

Regulations Concerning Tank Washing

A.1 Tank Washing Atmospheres

Tank washing may be carried out in any of the following atmospheres depending of the equipment on the ship. Atmosphere B is recommended in order to save time before dismantling can occur.

* Atmosphere A - an atmosphere which is not controlled and which can thus be above, below, or within the flammable range.

* Atmosphere B - an atmosphere made incapable of burning by the deliberate reduction of the hydrocarbon content to below the lower flammable limit (LFL). The combustible gas indicator should not exceed 50% LFL.

* Atmosphere C - an atmosphere made incapable of burning by the introduction of inert gas and the resultant reduction of the overall oxygen content. The oxygen content of the tank atmosphere should not exceed 8% by volume.

* Atmosphere D - an atmosphere made incapable of burning by deliberately maintaining the hydrocarbon content of the tank above the upper flammable limit (UFL). A hydrocarbon content of at least 15% by volume should be attained before starting washing and maintained throughout washing.

A.2 Washing in an Uncontrolled Atmosphere (A)

Under Atmosphere A conditions, precautions must be undertaken to avoid ignition sources and all the following precautions should be observed:

* Washing machines in use at any one time should be restricted in any one compartment to not more than 4 machines each having a flow rate not exceeding 35 cubic meters/hour, or not more than 3

machines each having a flow rate of between 35 and 60 cubic meters/hour. Washing machines having a flow rate greater than 60 cubic meters/hour should not be used in Atmosphere **A**.

* All hose connections should be made up before washing machines are introduced into the tank and should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then tightened again before the machine is removed.

* Recirculated water should not be employed for tank washing and chemical additives should not be used.

* Wash water may be heated provided the temperature does not exceed 140°F.

* The tank should be kept drained during washing. Washing should be stopped to clear any unusual build up of wash water.

* Sounding and the introduction of other equipment should be done through a sounding pipe that is properly grounded.

A.3 Washing in a Too Lean Atmosphere (B)

The following precaution are recommended:

* If the tank has a vent system which is common to other tanks, the tank should be isolated from the other tanks or all tanks should be prepared for and washed simultaneously.

* The tank bottom should be flushed with water and stripped and the piping system, including cargo pumps, cross overs and discharge lines, should also be flushed with water.

* Before washing, the tank should be ventilated to reduce the gas concentration of the atmosphere to 10% or less of the lower flammable limit. Gas tests should be made at various levels to take into consideration possible gas pockets or layers of flammable gas. Mechanical ventilation and gas testing should continue throughout washing.

* Washing should be discontinued if the gas concentration rises to 50% LFL; washing may be resumed when continued ventilation has

reduced the gas concentration to 20% LFL.

* If portable washing machines are used, all hose connections should be made before the washing machine is introduced into the tank and should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then tightened again before the machine is removed.

* The tank should be kept drained during washing; washing should be stopped to clear any unusual build up of wash water.

* Sounding and the introduction of other equipment should be done through a properly grounded sounding pipe.

* Chemical additives may be used.

* Wash water may be heated above 140°F, but care must be taken to see that the gas concentration does not rise above 50%LFL.

A.4 Washing in an Inert Atmosphere (C)

* Before starting tank washing, the tank atmosphere should be checked to ensure that the oxygen content does not exceed 8% by volume throughout the tank. During the whole washing operation a positive pressure should be maintained on the system. Any inert gas supplied to maintain this positive pressure should be maintained.

* If the oxygen content rises above 8% by volume in any cargo tank, or a negative pressure develops in a tank, the washing should be stopped and the tank purged with inert gas until the oxygen level is 8% or less throughout.

* No other restrictions needed for atmospheres A or B need to be followed if the tank is inerted.

A.5 Washing in an Over Rich Atmosphere (D)

* The procedure for washing in an over rich atmosphere depends greatly on the properties of the particular cargo or medium for achieving this condition, and on the ship layout. Reference should be made to the special instructions issued by the owner.

* None of the operating restrictions for washing in Atmospheres A or B need to observed if the atmosphere is maintained at too rich a level to burn. Procedures have to be followed to ensure that air does not enter the tank.

* It should be confirmed by measurements that the hydrocarbon content of the tank atmosphere is at least 15% by volume throughout the washing operations.

A.6 Other Regulation Applicable to All Washing Atmospheres

* It is essential that slop handling procedures are adjusted so that a free fall of water of slop in the receiving tank does not occur at any time. The liquid level should always be such that the discharge inlets in the slop tanks are covered to a depth of at least one meter.

* The spraying of water into a tank containing a substantial quantity of a static accumulator oil could result in static generation at the liquid surface. Tank which contain a static accumulator oil should always be pumped out before they are washed with water, unless the tank is in an inert condition.

* Due to the hazard of static electricity, steam should not be introduced into any tank where a flammable atmosphere may exist.

Appendix B

Required Safety Measures for Gas Freeing

B.1 General

* The covers of tank openings should be kept closed until actual ventilation of the individual tank commences.

* Any tank openings inside an enclosed or partially enclosed space should not be opened until the pressure has been relieved to an area outside that space.

* The piping system including cargo pumps, crossovers and the discharge lines should be flushed through with water and the tank stripped. Valves other than those used for ventilation should then be closed and secured.

* If the vent system is common to other tanks, the tank should be isolated or all tanks should be ventilated simultaneously.

* Heating coils, if fitted, should be cleared with water.

* After ventilation the tank atmosphere should be tested at the bottom and at several depths through several tank openings using an approved combustible gas indicator. Ventilation should be suspended while these tests are being conducted.

B.2 Gas Freeing of Inert Tanks

* After flushing and washing, the tanks should be purged with inert gas to reduce the hydrocarbon content to 2% by volume or less so that during subsequent gas freeing no portion of the tank atmosphere is brought within the flammable range. The hydrocarbon content may be measured with an appropriate meter designed to measure the percentage of hydrocarbon gas in an oxygen deficient atmosphere. The usual combustible gas indicator is not suitable for this purpose.

* When portable fans or fixed fans connected to the cargo piping system are used to introduce air into the tank, the inert gas inlet into the tank should be blanked or valved off. If the inert gas system fan is employed operating on fresh air, the line back to the inert gas source should be valved or blanked off.

* The tank should then be gas freed.

* Gas freeing should continue until tests with an oxygen meter show a steady reading of 21% by volume and tests with a combustible gas indicator show less then 1% LFL.

* Positive fresh air ventilation should always be maintained.

* All tanks should be simultaneously made free of gas.

B.3 Gas Free for Entry and Hot Work Without Breathing Apparatus

* In order to be gas free for entry without breathing apparatus after the carriage of cargo, a tank should be ventilated until tests confirm that the hydrocarbon gas content throughout the compartment is less than 1% LFL.

* A full range of gas tests are required before entry into a cargo tank. These include tests to check the oxygen content, the presence of Benzene, hydrogen sulphide and other toxic gases.

* There also can not be any sludge on loose scale which, if disturbed or heated, could give off petroleum gas.[9]

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[9] *Ibid*,pp 48-49.

Appendix C

Preliminary Design Weight Status Report

Item description	Weight, tons	Longitud. moment, ft.tons
Stern casting	135.440	120,658
Flat keel	155.881	67,322
Shell plating	4,207.204	1,844,344
Bulwarks and breakwater	7.085	5,112
Center vertical keel	171.384	73,757
Transc. frmg. in inbttm	62.616	49,701
Longl.frmg. in inbttm	32.709	25,850
Transv. frmg. outside ib.	107.597	20,684
Longl. frmg. outside ib.	1,555.250	594,918
Framing in peaks	407.136	167,697
Transom framing	10.211	9,466
Web frames	2,968.050	1,257,552
Upper deck	3,755.075	1,694,589
Main trans. bulkhds	1,787.027	731,725
Transv. wt. and ot. bhds.	120.502	92,312
Longl. wt. and ot. bhds.	1,683.948	726,086
Structural nwt. bhds.	473.351	193,882
Non structural bhds	37.517	9,079
Structural trunks	11.000	8,525
Hatch coamings	7.331	3,013
Pillars	26.000	21,190
Innerbottom Plating	54.448	43,017
Platform decks	109.263	50,661
Miscellaneous flats	68.299	57,171
Main engines foundations	71.000	56,800
Boiler foundations	22.000	18,040
Aux. mach. founda.	32.000	25,440
Misc. foundations	30.000	16,366
A level	112.395	87,364
B level	68.237	52,637
C level	52.570	39,883
D level	36.817	27,698
E level	38.532	28,937
Navigation bridge level	18.108	13,591

Stack enclosure	16.000	13,040
Welding	183.000	87,840
Mill tolerance	274.000	131,520
Steel total	18,908.983	8,467,467
Mast and kingpost	14.213	7,877
Rooms	4.149	1,796
Hatch covers and beams	15.179	9,690
Sheet metal work	4.189	2,531
Hull fittings casting	76.518	28,077
Rails and stanchions	11.295	6,367
Ladders	16144	7738
Misc hull fitting	10.232	3891
Ratproofing	0.484	326
Hinged wt doors	1.582	1091
Manholes and Scuttles	3.595	2565
Airports and windows	1.599	1190
Hatches and ports	2.031	840
Nwt sti doors	2.804	2116
Misc carpenter work	0.734	533
Misc deck covering	8.125	6192
Inter. joiner work	53.735	40734
Furniture liv. spa.	13.558	10304
Accomodat. ladder	0.486	223
Insulation in quart.	13.316	10055
Fire Insulation	1.839	1390
Anchor chain	212.544	16141
Boat handling	18.651	13879
Rigging & Block	0.493	213
Canvas	0.657	399
Deck Outfit	1.533	856
Paint	155.143	74469
Galley equip	3.983	3062
Util and office sp.	7.821	5871
Stewards outfit	2.227	1671
Fire detect. sys.	26.944	16017
Heat sys.	2.897	2219
Natural vent	14.020	9807
Mech vent.	13.929	10586
Refrig sys	3.772	2812
Plumbing fix	24.009	18610
Deck Scuppers	12.397	8581
Bilge & bal. sys.	90.736	47644

Cargo oil sys.	280.671	164127
Fire mains	30.056	18296
Sanitary & fw sys.	5.762	4588
Fuel oil tran sys.	9.579	7207
Vents sounding	18.229	7261
Valve oper. gear	18.229	7581
Deck machinery	93.839	35202
Steer gear & rudder	83.192	75326
Commun. sys.	9.279	7170
Elect. sys.	79.076	61504
Outfit total	1467.023	766625
Main propul.	53.413	41777
Turbine drain	5.085	4103
Main reduc. gears	113.839	90844
Main condenser	50.893	39747
Main air ejector	1.167	932
Main circ. sys.	28.811	22400
Feed heaters	11.244	9074
Feed & conden. sys.	29.403	23064
Make up feed sys.	1.634	1323
Contaminated sys.	2.813	2261
S.w. evap. sys.	6.300	4903
Shafting	74.613	63261
Bearing &stern tube	32.128	26624
Propellers	46.875	41438
Shafting parts	2.138	1778
Prop. & sharft spare	3.377	2786
Lube oil sys.	24.887	20141
Misc. tanks	4.007	2611
Serv. Compress. air	5.782	4239
Start. air sys.	1.526	1284
Boilers	221696	182234
Boiler draft sys.	10.848	8812
Auto. comb. control	2.777	2252
Stacks & uptakes	4.768	3919
Fuel oil serv. sys.	8.538	6767
Main steam piping	26.509	21366
Aux. steam piping	26.481	21344
Exhaust pipinf	37.371	30204
Steam drain sys.	7.955	6412
Whistles	0.767	620
Access floor plts	65.128	49009

Work shop	4.905	3794
Lift & handling gear	2.108	1301
Machy. space vent.	18.973	15444
Machy. space fix.	0.617	497
Spare parts	14.995	12563
Instr. & gauges	3.121	2527
Liq. in machy.	134.002	104860
Machinery total	1091.454	878515