DOCKMASTER TRAINING MANUAL
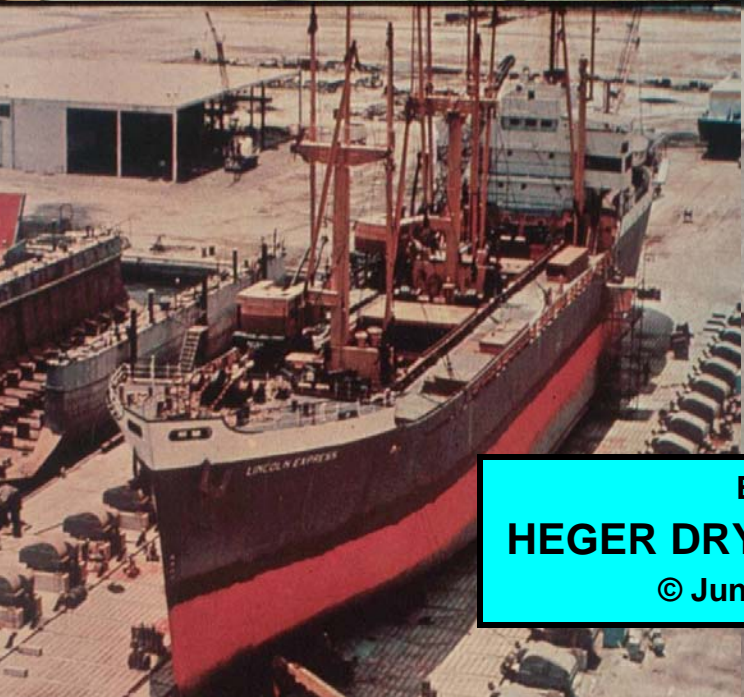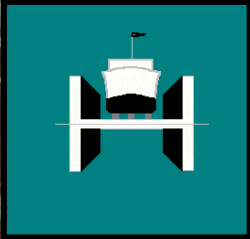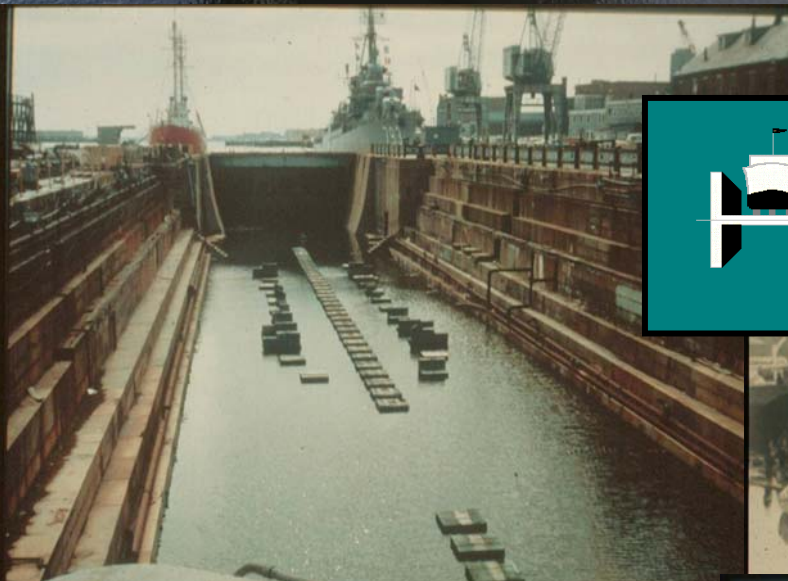
TABLE OF CONTENTS

LECTURE NOTES

TABLE OF CONTENTS

TABLE OF CONTENTS

1.0 - TYPES OF DRY DOCK

DRY DOCK TYPES

Dockmasters are not structural or marine engineers and are not expected to design dry docks. They must, however, operate their dock in such a manner as to not exceed the operational limits of the dry dock that have been set by the designer. A basic understanding of how a dock is designed and built provides insight into how and why the dock's operational limitations have been derived. This knowledge can assist the dockmaster when he is assessing situations that do not meet standard operating procedures.

There are several basic types of dry docks:

- ➢ Basin or Graving docks
- ➢ Floating Dry Docks
- ➢ Marine Railways
- ➢ Vertical Lifts
- ➢ Marine Travel Lifts

1.1 – BASIN DRY DOCKS

Basin or graving docks are large, fixed basins built into the ground at water's edge, separated from the water by a dock gate.

Basin docks are capable of docking all sizes of vessels, with capacities of over 200,000 tons.

Its basic structure consists of a floor, sidewalls, head (front) wall and a dock gate. Alters (steps) may be incorporated into the side walls for structural stability.
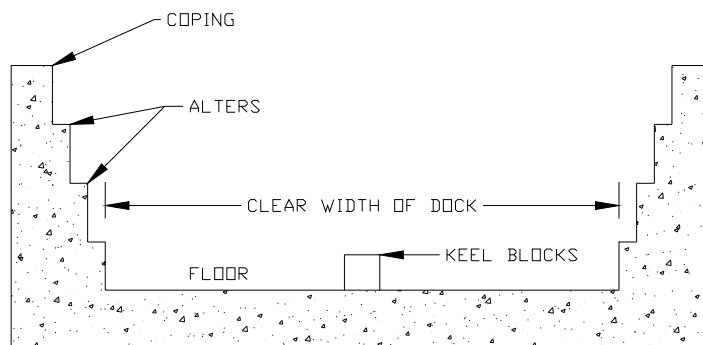
CROSS SECTION THROUGH BASIN DOCK BODY

FIGURE 1.1
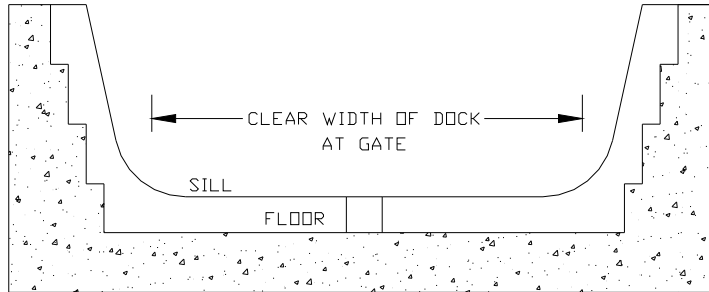
CROSS SECTION THROUGH BASIN DOCK AT GATE

FIGURE 1.2
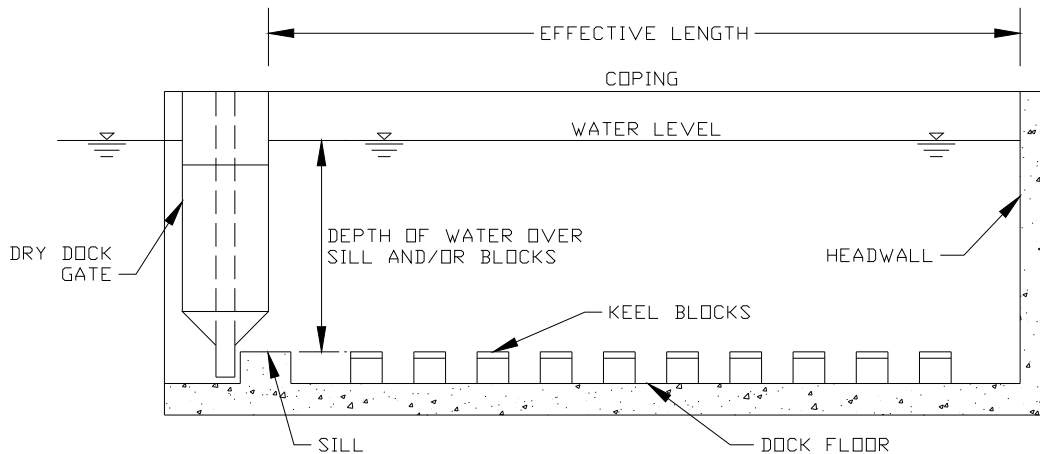
LONGITUDINAL SECTION THROUGH BASIN DOCK BODY

FIGURE 1.3

<u>Advantages of a basin dock</u>:

➢ Long life expectancy of the basic structure.

➢ Low maintenance costs. (Dock floor and walls can be built of granite or concrete which last a very long time with little maintenance)

➢ There is no limit to the size of the basin dock.

➢ There is no need to worry about ship/dock stability, pumping plans or longitudinal deflection of the dock while docking ships. (Ship stability and block loading must still be addressed, however)

> ➤ The basin can be equipped with an intermediate gate that allows flooding of the aft half of the dock while the forward half remains dry.

Disadvantages of a basin dock:

> ➤ High initial construction cost.

> ➤ The basin is a fixed structure, which cannot be moved. Makes it harder to re-sell thus harder to get financing.

> ➤ Routing of men and material is difficult since floor is below grade.

> ➤ Ventilation and lighting are not good because one has to work "in a hole".

> ➤ It is very difficult to enlarge a basin dock.

> ➤ Transfer is not possible from a basin dock.

> ➤ Usually slower to operate (Power is inversely proportional to size).

Types of Basin Docks

A basin dock is a large structure cut into the ground that usually has a natural water table. Unless that water can be prevented from reaching the structure, hydraulic pressure will build up tending to "float" the dock out of the ground.
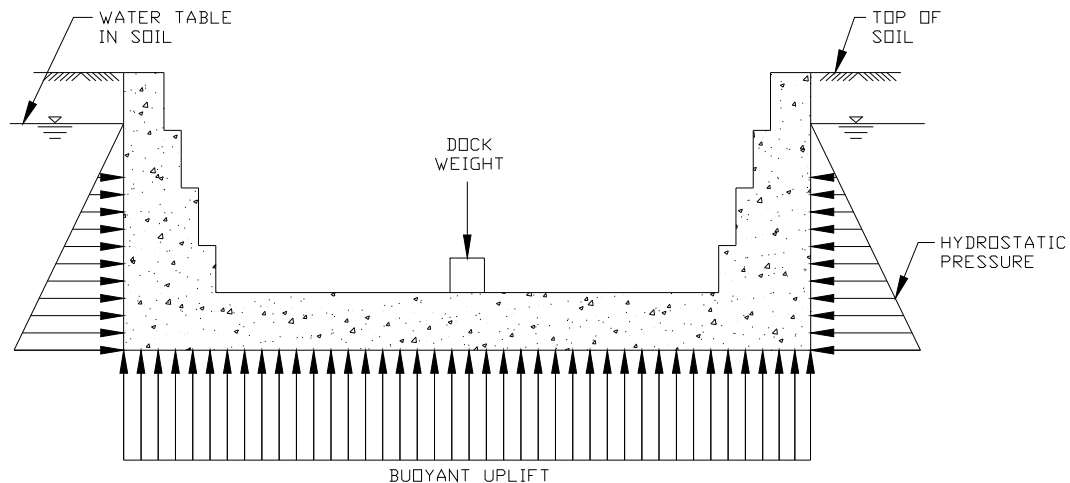
HYDROSTATIC FORCES ON A BASIN DOCK

FIGURE 1.4

The method of overcoming the hydraulic pressure (by eliminating it or resisting it) determines how the dock is classified. The design of the basin dry dock depends on the hydraulic pressure surrounding the structure. The pressure that develops is a function of its type of construction: full hydrostatic, fully relieved or partially relieved.

There are 3 basic types of basin docks:

1)   Full Hydrostatic Dock - A full hydrostatic dock uses its weight or an anchorage system to resist the full hydrostatic head at the maximum water table.

2)   Fully Relieved Dock - A fully relieved dock uses a drainage system around the entire dock to drain away the water before it can build hydrostatic pressure on the walls and floor.

3)   Partially Relieved Dock - A partially relieved dock uses a drainage system under the dock floor to eliminate the hydrostatic pressure on the floor only. The walls resist the full hydrostatic head.

Full Hydrostatic Dock

No material, not even rock, can be considered impervious in the sense that it will prevent the build up of hydraulic pressure on the structure.

MASS GRAVITY FULL HYDROSTATIC DOCK

FIGURE 1.5

ANCHORED FULL HYDROSTATIC DOCK
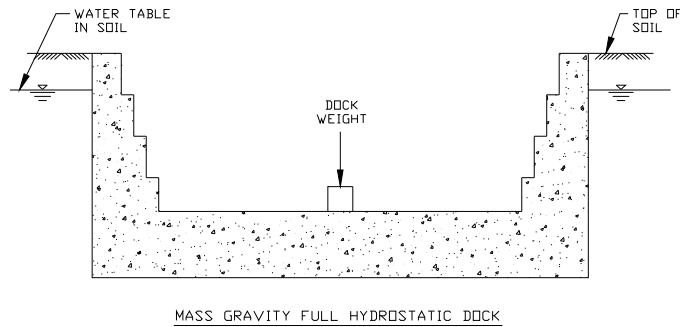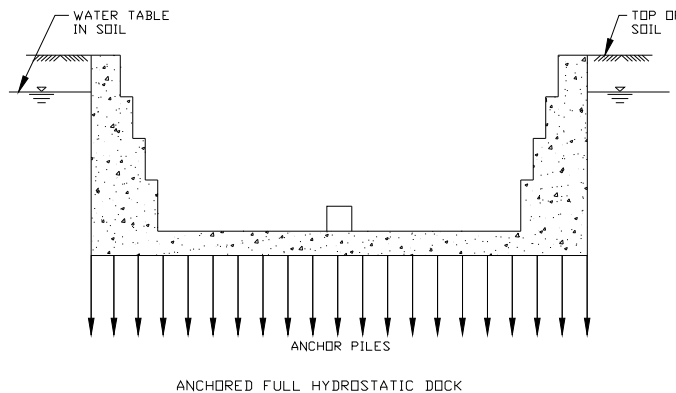
FIGURE 1.6

Even the smallest amount of leakage will eventually build up to the maximum pressure over time if it is not drained away.

Therefore, without a drainage system, one or more of the following must resist the full buoyancy of the dry dock at the highest water table elevation:

The weight of the structure (a dock that uses primarily its own weight to resist the uplift is called a "Mass Gravity Dock")

The weight of the soil below the dock engaged by hold down devices (anchors, piles etc.)

The weight of the soil resting on the ledge formed by the projections of the floor beyond the sidewalls

Friction created by the soil on the sidewalls.

Fully Relieved Dock

A fully relieved basin dock requires a drainage system to remove water from around the dock as it seeps through the soil. This prevents pressure from building up on the walls and the floor slab.

The reduced pressure on the walls and floor allows a lighter structure to be built, resulting in savings on initial construction costs. The initial cost savings will be offset somewhat by the continued cost of operating and maintaining the relieving system pumps throughout the life of the dock.

FULLY RELIVED BASIN DOCK
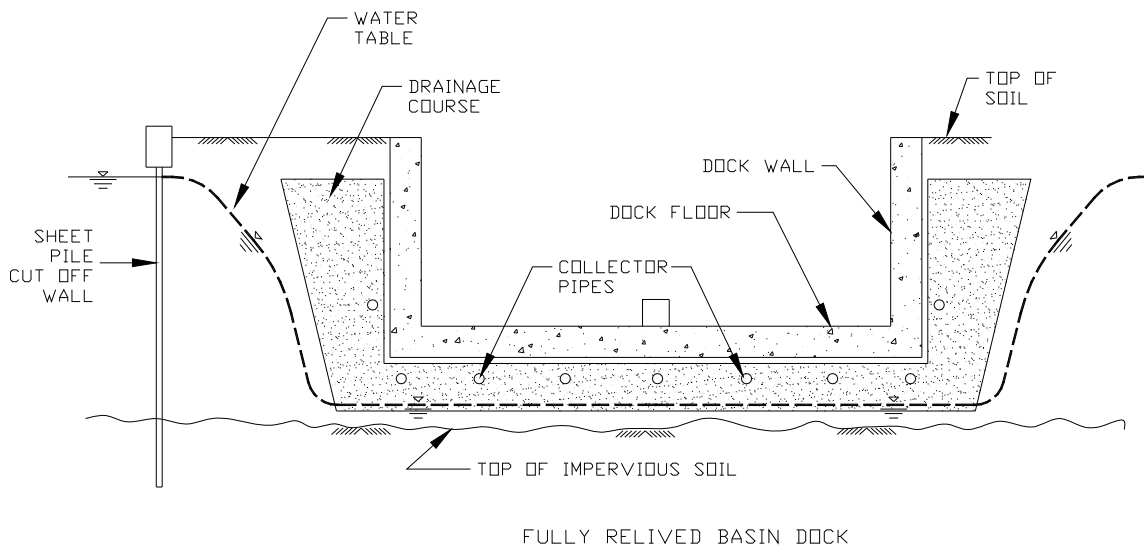
FIGURE 1.7

The cost of operating the relieving system pumps is a direct function of the rate of seepage of ground water to the dock. The higher the rate of seepage, the more water that must be pumped out and greater the operating costs.

Therefore, it is attempted to keep seepage to a minimum by:

➤ Using naturally impervious soil barrier around the dock.

➤ Driving a sheet pile cutoff wall around the entire dock. The wall should be driven to a depth that reaches an impervious layer of soil below the dock and be kept at a distance away from the dock wall to allow the hydraulic pressure to drop gradually.

To remove the water that seeps in under and around the dock, drainage courses are provided under the floor and at the walls.

For greater amounts of seepage the drainage courses are supplemented by a pipe system, which carries the water into the dry dock pumping chamber for disposal.

Even rock has seepage, therefore even docks built with concrete linings on rock should have weep holes to relieve pressure.

Partially Relieved Dock

A partially relieved dock provides relief of hydrostatic pressure under the dock floor only. The walls are designed for full head.

A cutoff wall is usually driven at the edge of the floor slab to reduce seepage. As in the fully relieved dock, a drainage course is provided under the floor slab for collecting any water that does seep in.
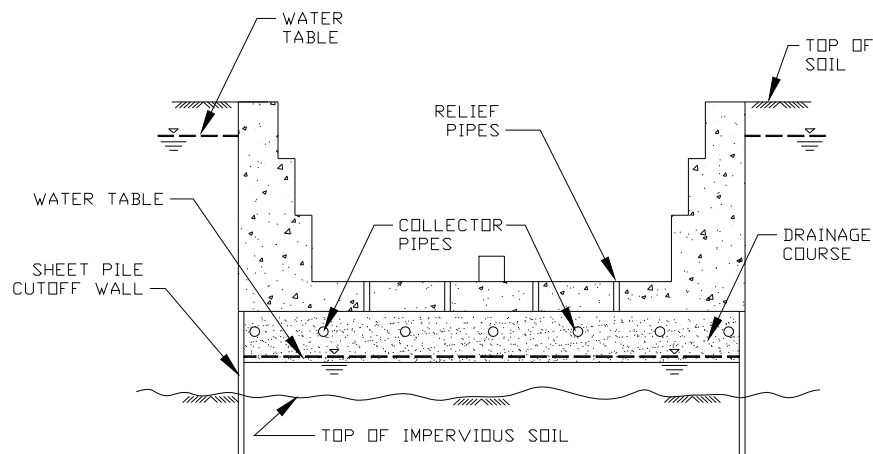
PARTIALLY RELIVED BASIN DOCK

FIGURE 1.8

Pipes may be used to collect the water and carry it to the pumping chamber if larger volumes are expected. Some docks allow the water to seep through holes in the slab (relief pipes) and collect in troughs, which run to the pumping chamber.

For all types of basin docks, piles may be used to support the dock and vessel weights if the allowable pressure on the soil is not adequate. In this case, keel and side blocks must be placed over the piles.

These piles can also be used in tension as anchor piles to resist hydrostatic uplift if required.

Entrance Closures

All basin docks must, of course, have an entrance closure that keeps water out of the dock once the ship is in and retracts out of the way for docking and undocking operations.

The basic requirements of the entrance closure are:

- ➢ Ease & speed of installation and removal

- ➢ Water-tightness

- ➢ Low maintenance

- ➢ Feasibility of traffic movement across top

- ➢ Cost

There are many types of closure gates, each with their own advantages, disadvantages and design considerations.

Mitre Gates

Consists of a pair of gate leaves hinged at the dock walls. The gates swing open horizontally. Sides and bottom fit against seats in the dry dock walls and floor when closed.

<u>**Advantages:**</u>

- ➢ Fast operating

<u>**Disadvantages:**</u>

- ➢ Creates heavy loads on floors

- ➢ Operating mechanism is costly & requires costly maintenance.

- ➢ Major repairs require removal of gate.

Flap gates

Consists of a rigid one-piece gate hinged at the bottom that swings downward and outward.

<u>**Advantages:**</u>

- ➢ Fast operating

Disadvantages:

- ➢ Creates heavy loads on walls

- ➢ Operating mechanism is costly & requires costly maintenance.

- ➢ Major repairs require removal of gate.

- ➢ Recesses must be built into walls to maintain clearances.

Sliding or Rolling Caissons

These are built up box sections with a sliding or rolling surface at the base. The gate slides or rolls into a notch built into the side of the dock.

CAISSON IN OPEN POSITION

Advantages:

- ➢ Fast operating

Disadvantages:

- ➢ Cleaning and maintenance of rollers or slide paths is difficult.

- ➢ Operating mechanism is expensive

- ➢ Major repairs require removal of gate

- ➢ Recesses must be built into walls.

Floating Caisson Gate

This is probably the most common type of basin closure gate. It is a watertight box girder with flooding and dewatering systems.

After flooding the dock, the caisson is deballasted to raise it up off the seat. It can then be towed out of the way.

To reseat the gate, the caisson is pulled back into position and flooded to lower it into its seat. Water pressure against the gate seals it tighter as the dock is dewatered.

Since the gate is a floating body, stability must be adequate during all phases of raising and lowering.

Advantages:

> ➤ Low cost

> ➤ Can be towed to other sites

> ➤ May be used in more than one dock.

> ➤ Reversible – the exposed side can be repaired in place.

Disadvantages:

> ➤ Slow operating

> ➤ Needs shore power to operate

> ➤ Set-in-Place Gates

FLOATING CAISSON GATE IN DRY DOCK

These are built in one or more pieces that are designed to be lifted in and out with a crane. They require no costly operating mechanism of their own but is time consuming to erect and need a large crane for installation and removal. Set-in-place gates are sometimes used as intermediate gates to divide a basin into multiple areas.

Basin Dry Dock Operation

Most basin docks flood entirely by gravity. A few docks have a super-flooding feature, which allows pumping the water inside the dock to a greater elevation than the outside water, although this greatly complicates the gate design.

There are 3 basic methods of flooding basin docks:

> ➤ Through culverts built into the walls and connected to floor openings spaced along the dock length.

> ➤ Through culverts passing transversely under the dock floor near the entrance and with openings leading up to the floor.

> ➤ Through pipes in the entrance closures (gates).

Some common features that are usually incorporated into the basin dock flooding systems are:

> ➤ Trash racks are placed over inlet openings to prevent the intake of solid matter. The racks should be removable for maintenance and replacement.

> ➤ Vertical slots should be provided between the trash racks and the sluice gates to accommodate stop logs to shut off water for sluice gate maintenance.

> ➤ Sluice gates (one for each intake tunnel) control the dock flooding.

Basin docks usually have 2 separate dewatering systems.

> ➤ The primary system, consisting of large high-capacity pumps, performs the main portion of the dock's deballasting.

> ➤ The secondary system, consisting of smaller pumps, collects the last few inches of water in the basin as well as rain water, flushing water and water from the under drain system.

Sand sumps (settling basins) should be located in accessible areas of the water collector channels. These allow abrasive materials such as sand, grit, etc., to settle out of the water before reaching the pump impellers.

In general, operation of a basin dock is easier than that of a floating dock.

The operator does not have to be concerned with dock deflections, ship/dock stability or differentially deballasting different ballast tanks under the vessel to provide proper lift as in a floating dock.

Ship stability, block loadings and loading of floor slab must be considered, however. Because trim of the keel block line can not be easily adjusted care must be taken to properly trim the vessel to reasonable match the keel block trim or large skeg or sue loads could develop. This could overload the blocks and affect the stability of the vessel as she lands.

On some types of pressure-relieved docks, care must be taken not to dewater the basin too quickly, since the water table in the surrounding soils must be allowed to drop as the basin level drops. This can greatly increase the time required for a docking or undocking evolution.

Prior to docking a vessel in a basin dock, the following minimum calculations should be performed:

> ➤ Stability of vessel afloat

- ➤ Stability of the vessel at landing on blocks

- ➤ Stability of the vessel at hauling of side blocks (if applicable)

- ➤ Block/slab loading calculations

- ➤ Hurricane/Earthquake overturning calcs

1.2 – FLOATING DRY DOCKS

Floating dry docks are structures with sufficient dimensions, strength, displacement and stability to lift a vessel from the water using buoyancy.

Floating docks range in lift capacities from a few hundred tons to over 100,000 tons. In general the most economical range for floating docks is about 1,000 to 100,000 tons.

Advantages of a floating dry dock are:

➢ It does not use valuable waterfront real estate.

➢ It can be built at the yard of low bidder and towed to the site; this keeps construction costs low by increasing competition.

➢ It can be sold on the world market, which keeps resale values high and makes it easier to get bank financing.

➢ Vessels can be transferred to and from shore relatively easily.

➢ Dock can be operated with a list or trim when docking vessels with a list or trim. This can reduce block loading and reduce or eliminate vessel stability problems when landing.

➢ Vessels longer than the dry dock can be docked by overhanging the bow and/or stern.

➢ The dock can be easily moved for dredging.

➢ Minimal landslide civil works are required which can result in easier permitting.

➢ The dock can be moved away from land to deeper water for docking and undocking operations. This can reduce or eliminate dredging and bulk-heading requirements.

➢ The dock can be lengthened relatively easily.

Disadvantages of a floating dry dock are:

➢ High maintenance is required on pumps, valves and steel structure.

➢ Routing of men and material is restricted to gangplank and/or crane service.

➢ Large tidal variations can complicate gangways, mooring etc.

Floating dry docks consist of 2 main parts – pontoon and wingwalls.
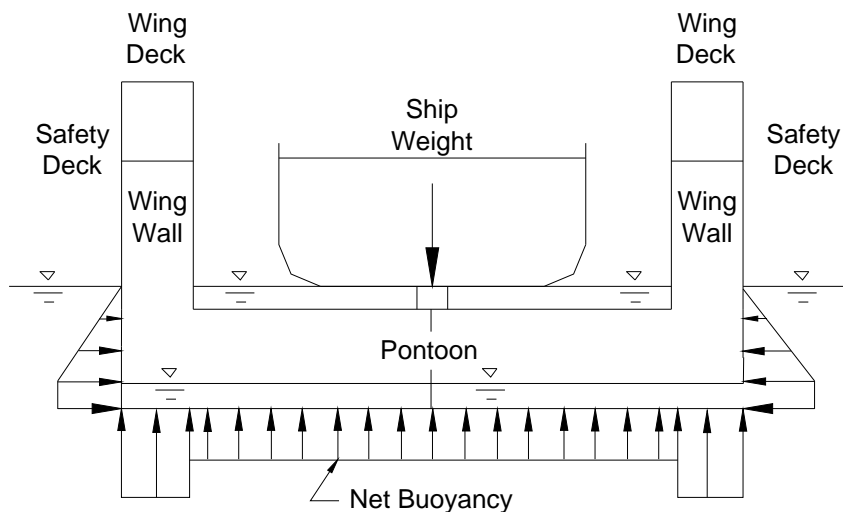
FLOATING DRY DOCK COMPONENTS

FIGURE 1.9

Pontoons are the main supporting body that must displace the weight of the vessel & dry dock in order to lift the vessel using buoyancy.

The pontoon must distribute the concentrated load of the ship along the dock's centerline to the uniform buoyant support of the water pressure by its transverse strength.

The wing walls provide stability when the pontoon is submerged and the longitudinal strength to distribute the irregular ship weight to the uniform buoyant support.

Stability can be critical in floating docks with small wing walls or having walls that do not extend the length of the dock.

Types of Floating Dry Docks

Floating dry docks can be broadly classified   into 3
main types:

"RENNIE" OR PONTOON DOCK

- ➢ Pontoon or "Rennie"

- ➢ Caisson, Box or One-piece

- ➢ Sectional

BOX OR ONE-PIECE DOCK
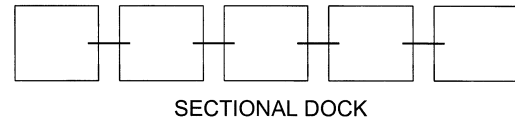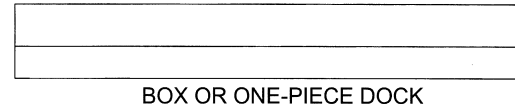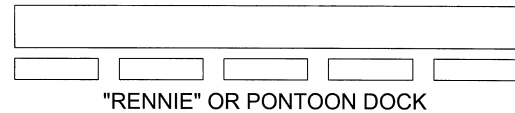
SECTIONAL DOCK

TYPES OF FLOATING DOCKS

Pontoon or "Rennie" Dock

FIGURE 1.10

The pontoon or "Rennie" type docks have continuous wing walls with sectional pontoons.

The pontoon sections usually can be self docked by detaching them from the wings, turning them 90 degrees and docking them on the remaining sections.

This type dock is generally weaker in the longitudinal direction than the one-piece dock since only the wingwalls are effective for longitudinal strength.

Ocean tow is usually not possible (unless the dock is cut into shorter sections) due to the lower longitudinal strength.

The structure of a "Rennie" type dock is generally heavier than the one-piece dock since double transverse bulkheads are needed at the gaps (end bulkheads for each pontoon section), and the wingwalls must be heavier to get the required longitudinal strength.

Caisson, Box or One-piece Dock

The caisson, box or one-piece type dock is built in one piece, with continuous wing walls and pontoon.

This type dock can be lighter and stronger than the other types since its full depth is effective in longitudinal bending.

The capability to ocean tow a one-piece dock is easier to achieve although not all one-piece docks can be ocean towed.

A one-piece dock cannot be self-docked. It's also harder to build it in sections and join afloat.

Sectional Dock

A floating dock, which has no structural continuity over its length, is a sectional dock.

Some sectional docks are joined with locking logs which loosely aligns the sections but cannot take much force or hinge pins, which can take shear (vertical force) but not moment (sections can rotate relative to one another).

Other sectional docks are joined with moment connections (pins or plates at the top and bottom of the wings) and act like a "Rennie" type dock. It is very important the condition of these pins to be monitored and inspected.

Additionally, ballasting and deballasting operations can be very critical on these types of docks due to bending and deflection.

Sectional docks are usually self-docking.

The U.S. Navy does not allow docking of their vessel in a sectional dock unless the sections have been attached with moment connectins forming a "Rennie" type dock.

FLOATING DOCK DESIGN

All floating docks must be designed to have adequate:

- ➢ Longitudinal strength

- ➢ Transverse strength

- ➢ Local strength

- ➢ Stability

Longitudinal strength

Theoretically, if a floating dock could be dewatered to provide buoyancy that was equal and opposite to the exact loading configuration of the vessel, then the dock would not need longitudinal strength.

In reality, however, the ship's weight is never uniform and the keel-bearing length of the vessel is seldom equal to the exact distance between watertight bulkheads in the dock. This means that the buoyancy can never be exactly equal to the weight directly above it and some buoyant lift is applied beyond the keel bearing length. This results in longitudinal bending stresses, which must be resisted by the longitudinal strength of the dock.

The magnitude of the longitudinal strength of the floating dock should be based on the size of the ship being docked.

Lloyd's Register of Shipping "Rules & Regulations for the Construction and Classification of Floating Docks" states that "The longitudinal strength is to be calculated for the condition when the ship of length "Ls" is supported on the keel blocks, the center of the ships length being over the mid-length of the dock and the … level of water ballast is constant over the length "Ld"

(dock length). The ship weight curve is to be taken as a rectangle with a superimposed parabola of half the area of the rectangle, the length of each being "Ls".

Ls = the length between perpendiculars of the shortest ship whose displacement is equal to the lifting capacity of the dock.

For normal cases, for docks below 40,000 tons lift capacity, Ls may be assumed to be 0.8 Ld."

Below is a diagram of the longitudinal loading condition required by Lloyd's.
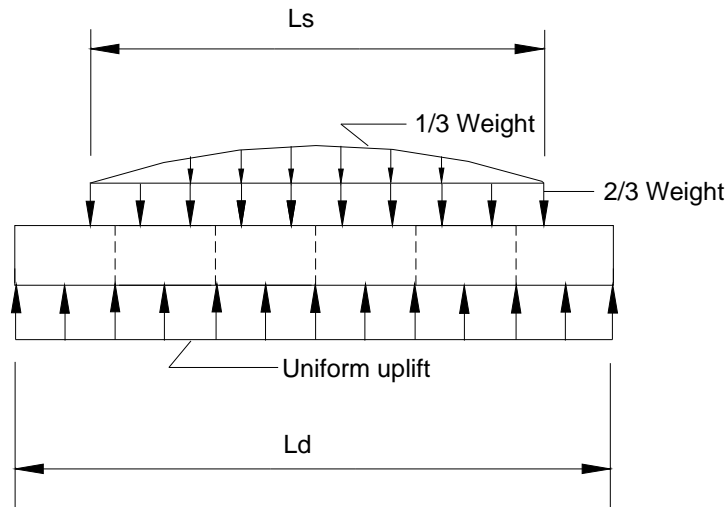
LLOYD'S RULE FOR LONGITUDINAL BENDING

FIGURE 1.11

For docks not certified by Lloyd's other less severe longitudinal bending cases can be investigated.

In general you only want to provide lift to the ship with the tanks that are under the keel blocks (longitudinally). Tanks that do not have loaded keel blocks over them should be de-ballasted to lift their own (dead) weight only. If you try to de-ballast unloaded tanks in front of, or aft of the loaded keel blocks you can easily overstress the dock longitudinally.

For a rule of thumb:

If you limit the lift in any ballast compartment to the vessel load applied over that compartment, the dock should resist the bending induced.

Problems can arise if you try to dewater an unloaded or partially loaded compartment to its full extent.

The following examples illustrate how the lift in a partially loaded tank should be limited to the load on the tank to limit longitudinal bending.
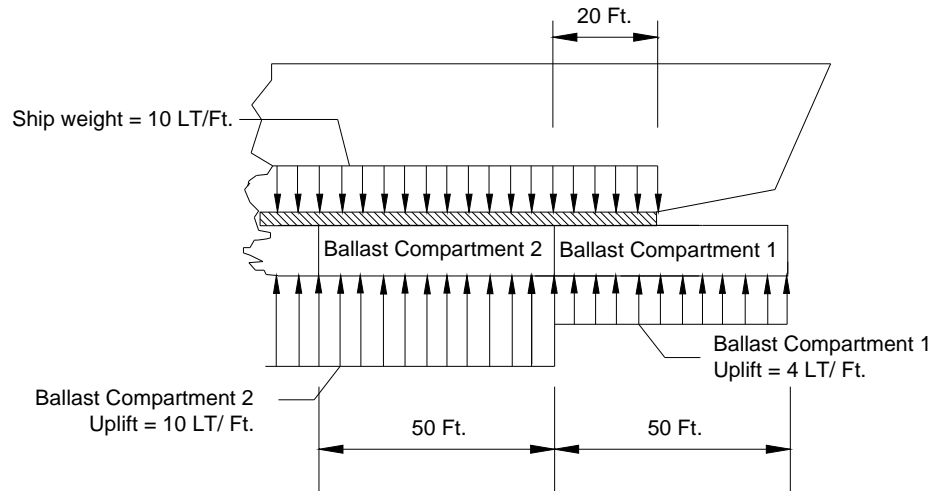
EXAMPLE 1

20 Ft.

Ship weight = 10 LT/Ft.

Ballast Compartment 2 | Ballast Compartment 1

Ballast Compartment 1
Uplift = 4 LT/ Ft.

Ballast Compartment 2
Uplift = 10 LT/ Ft.

50 Ft.

50 Ft.

Load on Comp. 2 =
10 LT/ Ft. x 50 Ft. = 500 LT
Uplift on Comp. 2 =
500 LT / 50 Ft. = 10 LT/Ft.

Load on Comp. 1 =
10 LT/ Ft. x 20 Ft. = 200 LT
Uplift on Comp. 1 =
200 LT / 50 Ft. = 4 LT/Ft.

EXAMPLE 2
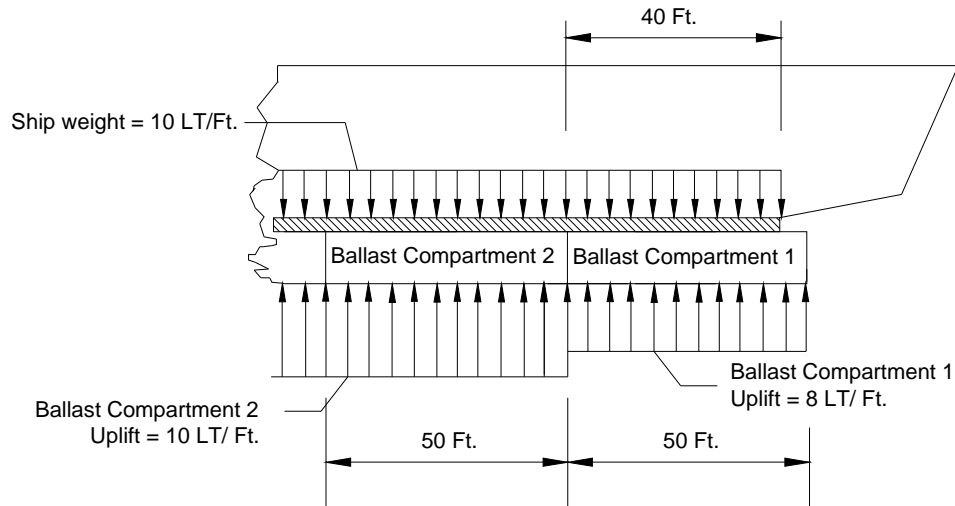
40 Ft.

Ship weight = 10 LT/Ft.

Ballast Compartment 2 | Ballast Compartment 1

Ballast Compartment 1
Uplift = 8 LT/ Ft.

Ballast Compartment 2
Uplift = 10 LT/ Ft.

50 Ft.

50 Ft.

Load on Comp. 2 =
10 LT/ Ft. x 50 Ft. = 500 LT
Uplift on Comp. 2 =
500 LT / 50 Ft. = 10 LT/Ft.

Load on Comp. 1 =
10 LT/ Ft. x 40 Ft. = 400 LT
Uplift on Comp. 1 =
400 LT / 50 Ft. = 8 LT/Ft.

The above examples demonstrate a rule of thumb only. Some docks may be designed to deballast partially loaded tanks in excess of this rule but the effects on bending must be known before attempting this.

When determining allowable stresses induced by longitudinal bending, it is extremely important to investigate critical buckling stresses for all plate panels that are in compression. Low critical buckling stresses can severely limit the allowable longitudinal bending moment for a dock.

Monitoring longitudinal deflection is essential for longer docks. The magnitude of the stress induced by longitudinal bending is in direct relation to the longitudinal deflection of the dock. Thus if you know the dock's deflection you can correlate that to a stress in the structure. The dock's designer should have calculated the deflection that will produce the maximum allowable stress in the dock. The maximum allowable operating deflection is usually a percentage of this.

When operating the dock longitudinal deflection should be monitored continuously. As hog or sag develops in the dock the rate of ballasting or de-ballasting should be adjusted to bring the hog or sag out. For example, if a sag is developing when flooding the dock, the rate of flooding in the ballast tanks in the middle of the dock should be slowed down or the rate of flooding in the end tanks speeded up. If a sag is developing when pumping the dock, the rate of pumping in the ballast tanks in the middle of the dock should be increased or the rate of pumping in the end tanks slowed down. The response to a hog would be just the opposite.

By limiting longitudinal deflections at all times to values lower than the maximum set by the designer, you will never overstress the dock due to longitudinal bending.

For docks that will be towed in open water, a separate analysis of stresses induced by waves must be conducted.

Transverse Strength

The transverse strength of the dry dock is provided by the transverse bulkheads (watertight and non-watertight) and/or transverse trusses in the pontoon.

The pontoon structure must distribute the concentrated load of the ship along the dock's centerline to the buoyant support of the water over its entire width by its transverse strength.

At least 4 separate loading conditions should be investigated when analyzing transverse strength:

- ➢ Maximum positive bending

- ➢ 50% Keel, 50% Side block loading

- ➢ Partial load, Maximum head condition

- ➢ Reverse bending

Maximum Transverse Bending

The maximum positive transverse bending moment occurs at the point when the exterior water is at the top of the keel blocks. At this time, there is 100% of the vessel weight on the dock while the pontoon and the submerged section of the wing provide lift.

The submerged section of the wing provides additional buoyancy farther away from the dock centerline, which increases the bending moment. For this case 100% of the ship's weight is assumed to act on the keel blocks at the transverse centerline.

100% Ship Wt.

Net Buoyancy

NET LOADING

Maximum Moment

MOMENT DIAGRAM
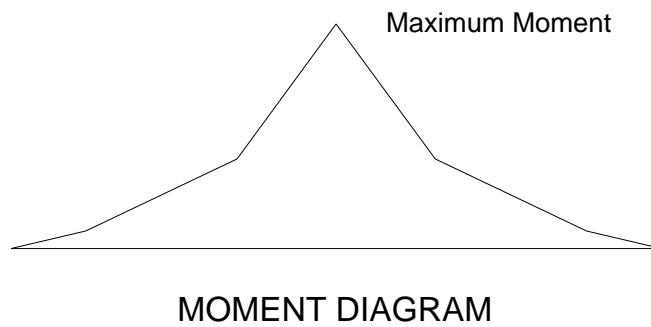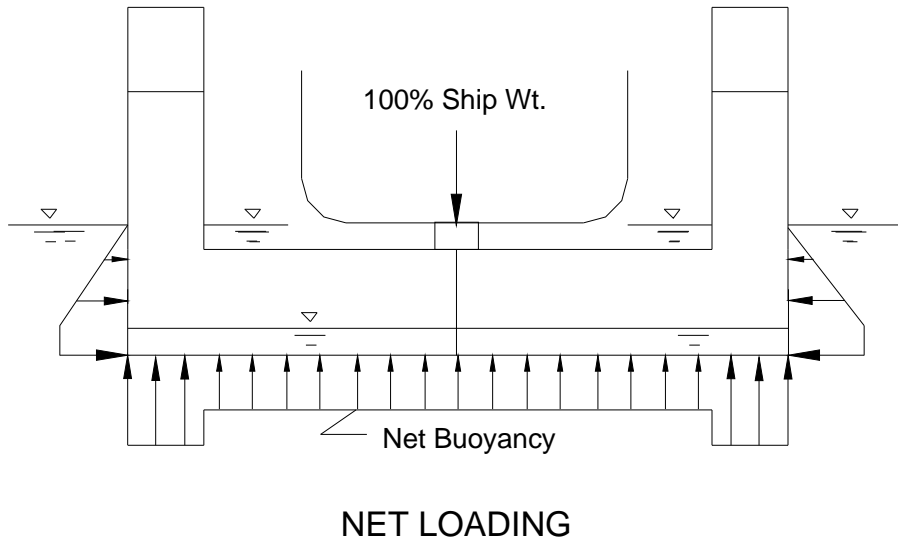
MAXIMUM TRANSVERSE BENDING CONDITION

FIGURE 1.12

50% Keel, 50% Side Block Loading

The case in which 50% of the vessel load is on the keel blocks and 25% is on each row of side blocks should also be investigated.

Also, other combinations of keel and side block loading should be analyzed if the ships to be docked might impose unusually large side block loadings.

Although the transverse bending at centerline for this case is less than that for the previous case, the moments along the outer portions of the bulkheads may be greater.

NET LOADING
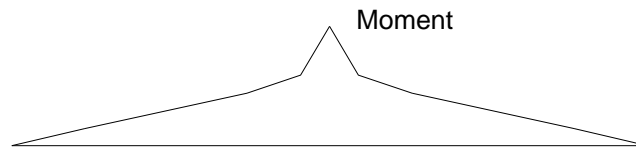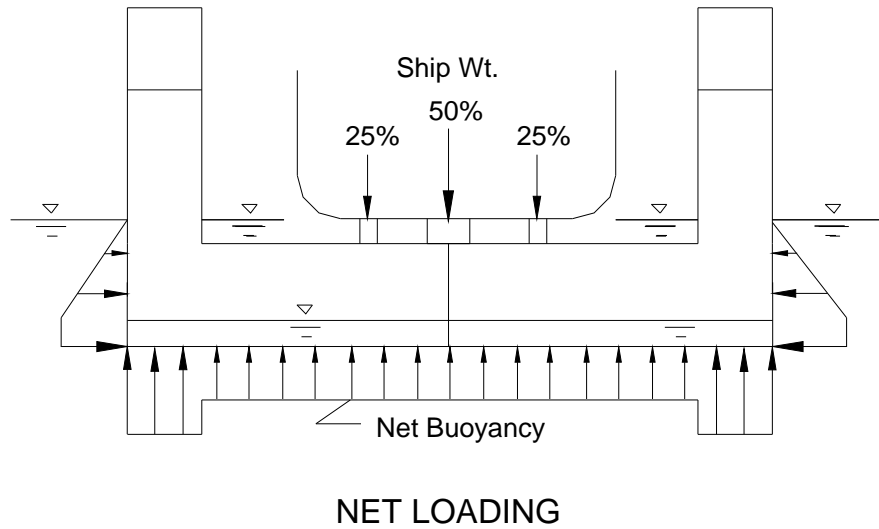
MOMENT DIAGRAM

50% KEEL, 50% SIDE BLOCK LOAD
BENDING CONDITION

FIGURE 1.13

Partial Load, Maximum Head Condition

The partial load, maximum head condition is the point at which the maximum hydrostatic head occurs on the shell of the dry dock.

Although the load at the centerline is only a portion of the total vessel load and the bending moment is not as great as in the first case, the bending stresses, when combined with the local stresses caused by hydrostatic head pressure may control.

The partial load, maximum head condition occurs when the internal water level has reached the base of the wings.

EXTERNAL WATERLINE AT KEEL TOUCHDOWN

SHIP WT = 0 LT

INTERNAL WATERLINE
BEFORE PUMPING

VESSEL JUST TOUCHING BLOCKS

ORIGINAL WATERLINE AT KEEL TOUCHDOWN

EXTERNAL WATERLINE AFTER PUMPING WING

RISE
OF
DOCK
AND
SHIP

SHIP WT = 0 LT

INTERNAL WATERLINE
AFTER PUMPING

PARTIAL LOAD AT MAXIMUM HEAD CONDITION
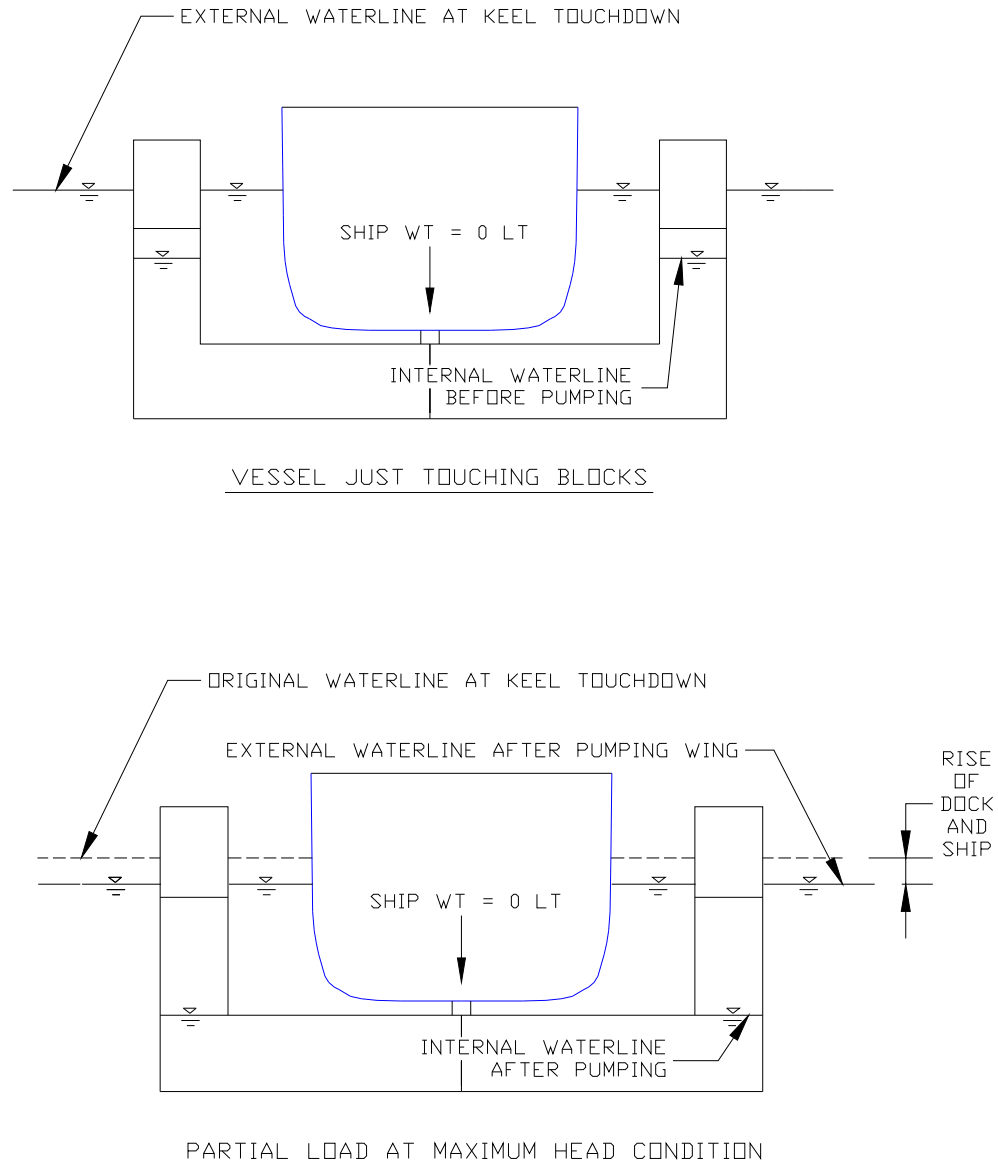
FIGURE 1.14

The magnitude of the hydrostatic head, which develops at this point, is a function of the vessel's draft and beam.

The deeper the draft and wider the beam of the vessel being docked, the higher the maximum hydrostatic head will be.

The volume of water that is pumped out of the wing walls (V1) after the vessel's keel contacts the keel blocks is equal to the volume that the vessel and dry dock wings rise out of the water

during that pumping (V2). With this volume known, along with the length and beam of the ship and dock wing walls, the rise of the ship and dock can be calculated.

The resulting depth of water over the pontoon deck is the maximum head on the dry dock for that particular vessel.

The displaced volume of the portion of ship that has been lifted out of the water (V2 Ship) is the weight of the vessel on the keel blocks for this condition.

MAXIMUM HEAD CONDITION
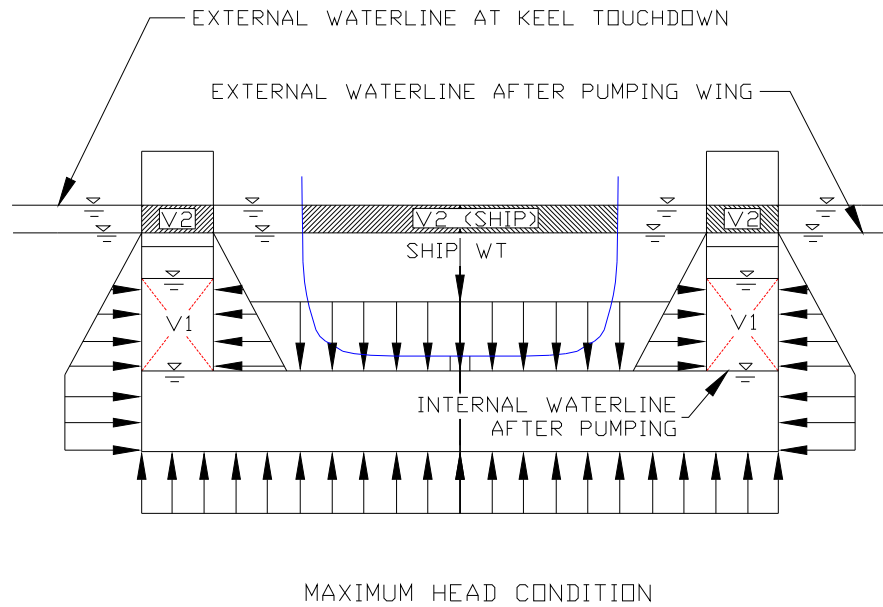
FIGURE 1.15

Reverse Bending

The final transverse bending condition that must be investigated is called reverse bending.

This condition occurs wherever there is a dewatered ballast compartment providing uplift in an area where there is no ship weight pushing down (such as an unloaded portion of a partially loaded compartment).

The pontoon is held down at the wings and buoyancy tends to bow it up – the reverse of a typical loading condition.

In this case, the pontoon bottom plate is in compression and must be investigated for plate buckling.

Ship Weight

Unloaded section
of pontoon

Pontoon
Uplift
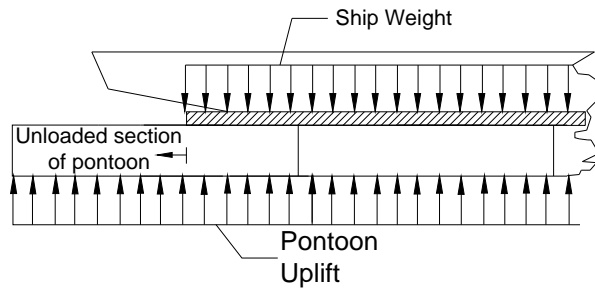
UNLOADED SECTION INDUCES
REVERSE BENDING

Wing Shear

Net Buoyancy
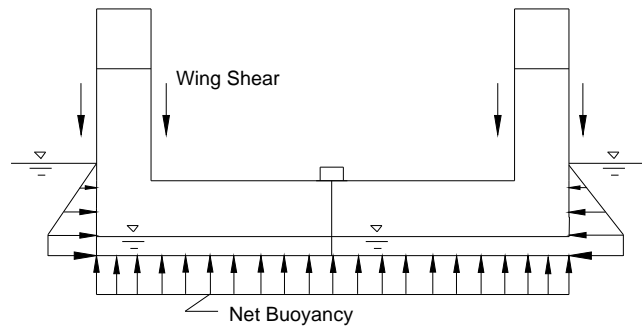
NET LOADING
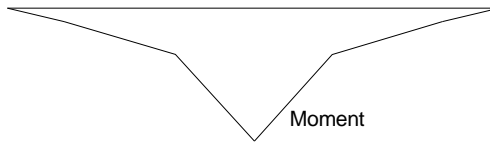
Moment

MOMENT DIAGRAM

REVERSE BENDING CONDITION

FIGURE 1.16

<u>Transverse Bending Limits</u>

All dry docks, in their present condition, should be rated for a maximum allowable load per foot along the keel. As long as this limit is not exceeded anywhere along the keel line and the dock is deballasted properly, the dock structure should not be overstressed by transverse bending.

Local Strength

The dry dock must have sufficient strength to resist local loading conditions caused by:

- ➢ Hydrostatic pressure on shell
- ➢ Hydrostatic pressure on internal bulkheads
- ➢ Keel block loads
- ➢ Side block loads
- ➢ Vehicle loads on pontoon deck
- ➢ Crane wheel loads on wing deck
- ➢ Mooring loads
- ➢ Ice loads

The maximum hydrostatic pressure on the exterior shell occurs at the partial load, maximum head condition described previously.

Above the maximum draft waterline, the exterior shell should be designed for a minimum head, usually about 10 feet.

Hydrostatic pressure on the internal bulkheads is caused by differentially deballasting between adjacent tanks.

Internal pressure on the safety deck occurs when the deck is "pressed up" at full submergence of the dock. The upward pressure on the safety deck is equal to the difference between the height of the external water and the height of the internal water in the wing.

EXTERNAL INTERNAL
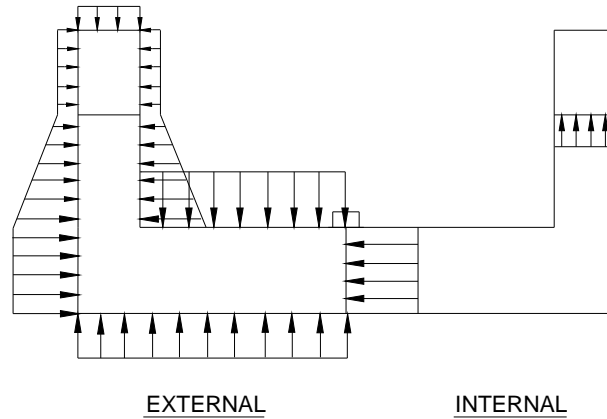
COMPOSITE HEAD PRESSURE DIAGRAM

FIGURE 1.17

Stability

Unlike the other types of dock structures, a floating dry dock must not only have the strength and dimensions for docking a vessel, it must also be stable throughout the entire docking or undocking procedure.

To insure stability, the ship/dock combination must maintain a minimum GM throughout the evolution. GM is the measure of stability.

The required minimum GM varies with the size of the floating dock.

Below is the curve of minimum GM as required by both ABS and the U.S. Navy's MIL-STD-1625C Certification Program.
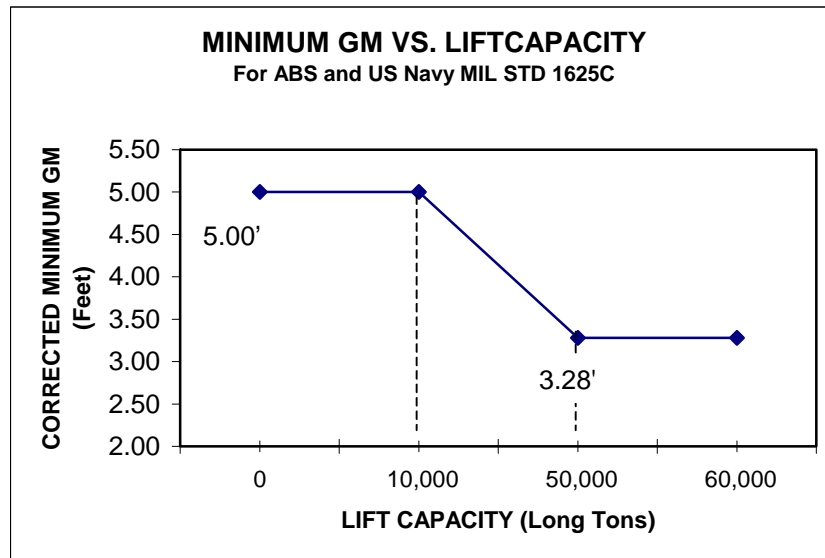
FIGURE 1.18

With any positive GM the ship/dock system will be stable. The minimum is required to account for any unknowns when evaluating the docking.

Typical unknowns:

- ➤ Exact vessel KG and Weight

- ➤ Free surface effects on the vessel

- ➤ Dock KG

- ➤ Dock Weight

Stability of the ship/dock system is usually investigated for 5 separate phases of the docking or undocking procedure.

These phases are:

- ➤ Dry Dock at full submergence – No ship

- ➤ Partial lift of ship – ship has been lifted approximately ½ its docking draft

- ➤ External waterline at top of the keel blocks

- ➤ External waterline just over pontoon deck

- ➤ Dock at normal operating draft

Phase 3 or 4 is usually the phase of minimum stability.

Phase 1

Phase 2

Phase 3
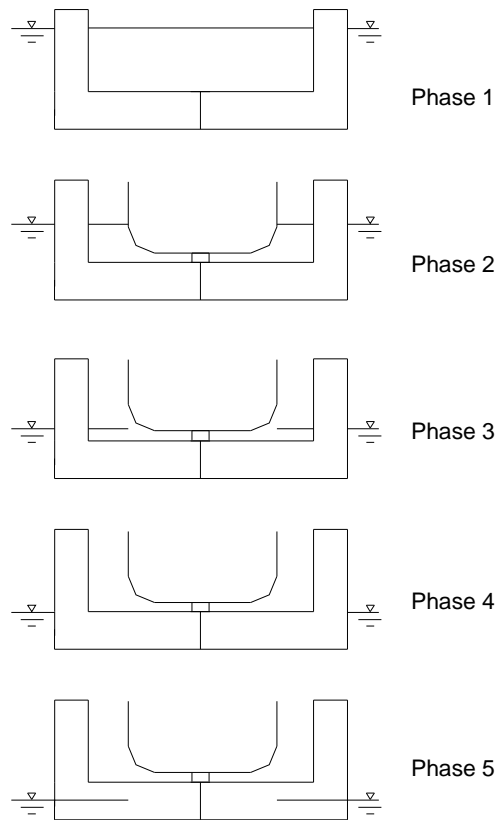
Phase 4

Phase 5

FIVE PHASES OF STABILITY

FIGURE 1.19

Stability for a floating dry dock is a function of the water-plane cut by the dock. In the minimum stability phases, only the wing walls cut the water-plane and provide the stabilizing force. As can be seen in the figure "WATERPLANES", as the dock takes on a list, the wing wall on the low side gets deeper in the water and a stabilizing buoyant force develops which tries to right the dock. The wing on the high side is loosing buoyancy which also has a stabilizing effect. The wider and further away from centerline the wing is, the more stable the dock is.

Just as in a ship, the free liquids in the large ballast tanks of a dry dock greatly reduce stability. As can be seen below, as the dock lists the water levels out. A wedge of water has shifted from the high side to the low side. This shifts the center of gravity towards the low side and tends to increase the list – a de-stabilizing effect.
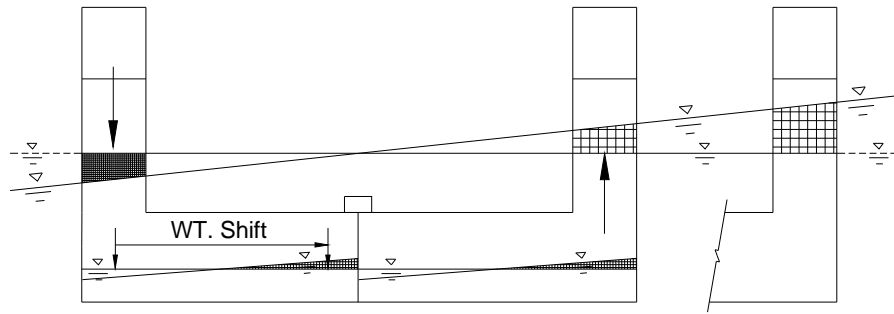
WATERPLANES

FIGURE 1.20

The following equation is used to calculate stability:

$$GM = KB + BM - KG$$

Where:

KB = the height of the vertical center of buoyancy of the immersed portion of the dry dock above the dock's keel

BM = the height of the transverse metacenter above the vertical center of buoyancy and is equal to the net moment of transverse inertia (Inet) divided by the displaced volume (V)

KG = the height of the center of weight of all components of the ship/dock system above the dock's keel.

The ship/dock system includes the following:

➢ Dry dock

➢ Dry dock equipment

➢ Internal ballast water

➢ Mud

➢ Ship
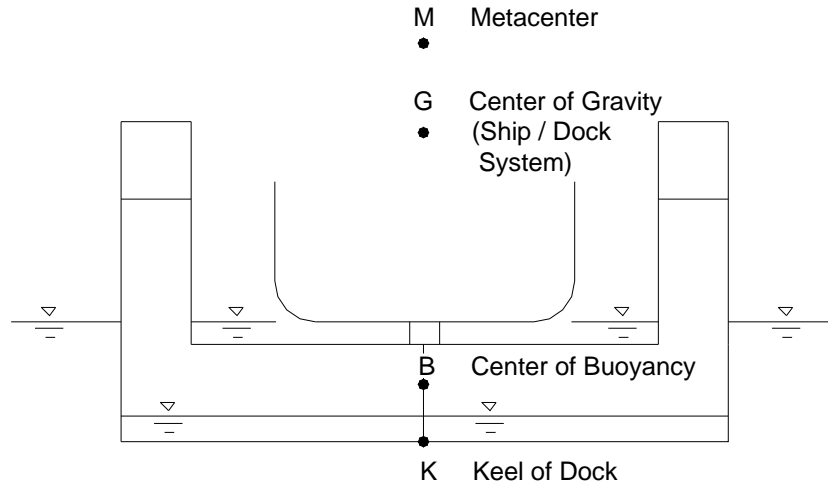
POINTS IN STABILITY

FIGURE 1.21

Due to the large water-planes within the dry dock, it is extremely important to adjust the GM for this contained water. Refer to Section 5 on stability for more details.

To ease the stability evaluation process, all floating dry docks should have a "KG vs. Weight" curve. The curve is developed for a particular dry dock's minimum stability phase. Once this curve is developed, any vessel's weight and KG (adjusted for free liquids) can be plotted.

If it plots below the curve then stability for that particular vessel is acceptable. If it plots above the curve then stability is unacceptable and the docking should not be performed.

When using the curve be sure to note the height of keel block used in developing the curve and adjust the results if the height of keel actually used is different than the one used in the curve.

For example, in the table shown below an 18,000 ton vessel could have a maximum vertical center of gravity above its keel of about 31 feet. Since the table was developed using a keel block height of 5 feet this is the actual maximum vertical center of gravity for a vessel docked on 5 foot blocks. If, for some reason, the vessel had to be docked on 9 foot high keel blocks the maximum allowable VCG would have to be adjusted to account for the ship sitting higher in the dock.

The adjustment would be

$5 - 9 = -4$ feet

Thus the maximum allowable VCG for an 18,000 ton vessel on 9 foot blocks would be

$31 - 4 = 27$ feet
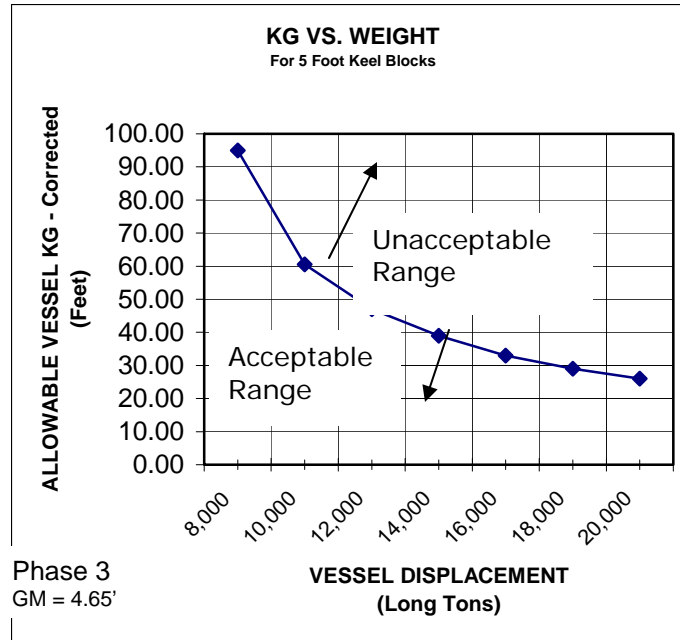
FIGURE 1.22

Please note that some KG versus Weight curves are developed for the vessel KG above the pontoon deck. In this case you need to add the keel block height to the vessel VCG and then enter the table to check acceptability.

Floating Dry Dock Operation

A floating dry dock operates on Archimedes' Principle.

It must displace a volume of water equal in weight to its own weight plus the weight of the vessel being lifted plus the weight of any internal ballast water.

The dock is operated by opening the flood valves and flooding the internal ballast tanks by gravity to submerge the dock. As the dock is going down, varying the rate of flooding of individual ballast compartments can control list, trim and deflection of the dock.

The method of controlling the flooding rates depends on the type of ballasting system of the dock. There are 2 basic types of ballasting systems:

➢ A Valve Controlled Dock is ballasted or deballasted through a manifold arrangement of piping and valves. The rate of flooding or pumping is controlled by varying the position of valves to each individual ballast tanks.

➢ A Pump Controlled Dock has one pump and one flood valve per ballast compartment. The rate of flooding is controlled by turning on a pump while the flood valve is still open and the rate of pumping is controlled by opening the flood valve with the pump still running.

Usually ballasting and deballasting are controlled from a central control house located on the wingwall. At this location all pumps and valves can be operated remotely and ballast levels can be monitored.

All floating dry docks should have water level and draft indicating systems that accurately show water levels in each ballast tank and the draft of the dock at six locations – forward, amidships and aft on the port and starboard sides.

Without such a system, it is difficult to tell whether a valve is stuck or pump is clogged, etc., and whether a particular ballast tank is flooding or pumping.

Lack of such knowledge could result in a catastrophe.

All longer floating docks should have a monitoring system for measuring the deflection along the wings.

The longitudinal deflection of the dock wingwall is a direct indication of longitudinal stress in the wingwall. Thus, limiting deflection limits stress.

The most economical method of measuring deflection is by mounting a transit and targets along each wing deck. Deflection should be measured along both wingwalls.

Prior to docking a vessel on a floating dock, the following minimum calculations should be performed:

- ➢ Stability of the vessel afloat

- ➢ Stability of the vessel at landing on blocks

- ➢ Stability of the vessel at hauling of the side blocks

- ➢ Stability of the ship/dock system at the 5 phases

- ➢ Block loading calculations

- ➢ Develop pumping plan

- ➢ Hurricane/Earthquake overturning calcs

Materials

Docks have been constructed out of wood, iron, steel and concrete.

Wood was used extensively for floating dry dock construction from the 1800's to World War II. Typically, as the dock aged, the wooden wing walls would deteriorate while the pontoon structure remained in good condition. The owners of the dry dock would remove the rotten wing walls and replace them with continuous steel wings to form a Rennie type dock and extend its life.

A few wooden docks are still in use today.
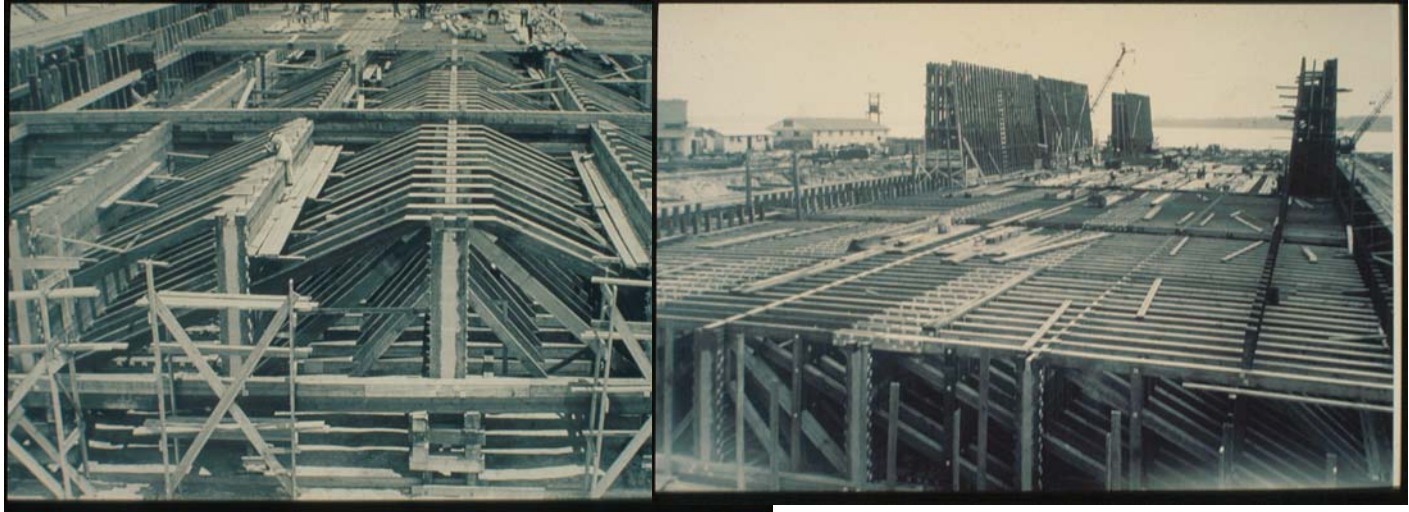
INTERNAL FRAMING OF A WOODEN PONTOON

After World War II wood was replaced by then steel as a material of choice for dry docks.

TYPICAL FRAMING OF A STEEL PONTOON

 Almost all floating docks built today are built out of steel.

Concrete has also been used to construct floating docks. The major drawback in using concrete is its weight. The large weight requires a much deeper pontoon to lift the same capacity as a steel dock. Increased pontoon depth increases dredging requirements, pier height etc. which increases cost.

For a rule of thumb:

A concrete dock weighs about 3 times its lift capacity. (6,000 tons capacity concrete dock weighs 18,000 tons)

A timber dock weighs about 70% of its lift capacity. (6,000 tons capacity timber dock weighs 4,200 tons)

A steel dock weighs about 35% of its lift capacity. (6,000 tons steel dock weighs 2,100 tons)

1.3 – MARINE RAILWAYS

A marine railway is a mechanical means of hoisting a ship out of the water along an inclined plane.

Lift capacities range from 100 to 6,000 tons.

Theoretically, even larger sizes are possible, but generally the floating dock becomes a more economical alternative.

Advantages of a marine railway:

> ➤ Low initial construction cost

> ➤ Fast operating

> ➤ The track slope can fit the natural slope of the shore in many cases. This eliminates or reduces dredging or bulk-heading requirements.

> ➤ Vessels can be transferred to and from the shore relatively easily.

> ➤ Vessels longer than the dock cradle can be docked by overhanging the bow and/or stern.

Disadvantages of a marine railway:

> ➤ The track is a fixed structure and cannot be moved easily. This makes it harder to sell, thus harder to finance.

> ➤ It is a mechanical system that requires periodic replacement of some moving parts (hauling chains, rollers, etc.)

> ➤ Underwater maintenance is required.

> ➤ The vessels can damage the track.

Marine Railway Design

A marine railway dry dock consists of:

➤ Cradle

➤ Inclined track on a foundation

➤ Hauling chain

➤ Hauling machine

MARINE RAILWAY
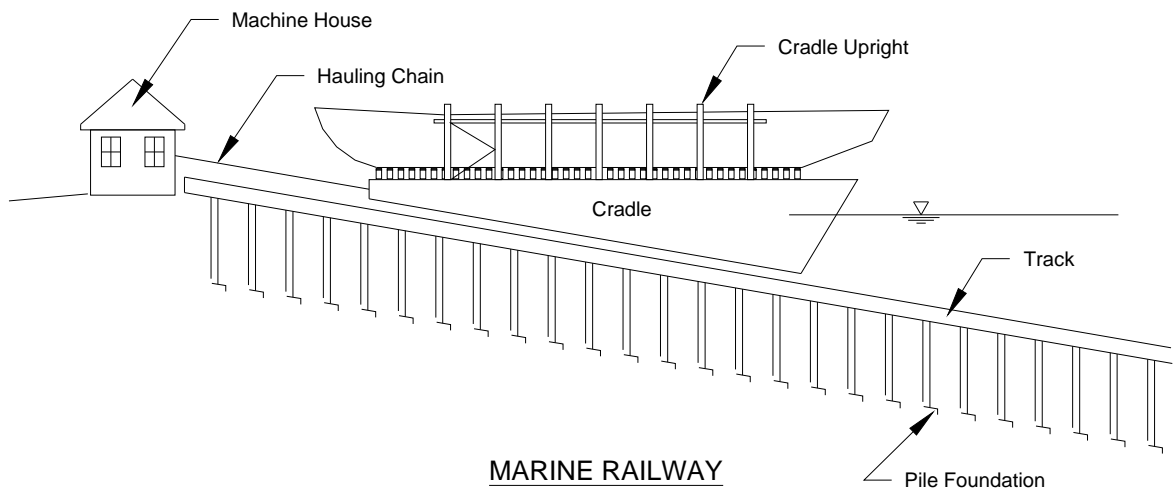
FIGURE 1.23

The cradle, which rolls on rollers or wheels, is lowered into the water along an inclined track until sufficient water over the cradle is achieved.

The ship is floated over the cradle and tied to the uprights. The cradle is hauled up the track and the vessel grounds onto the blocks.

After complete grounding on the keel blocks, the side blocks are brought to bear and the hauling continues until the cradle is full up.

Track Layout

Ideally, the slope of the track should be selected to fit the natural slope of the particular site to minimize dredging and yet provide the required drafts over the blocks for docking the vessel.

Realistically, trade-offs usually have to be made between the length and slope.

For example, a very shallow track may fit the topography very well but requires a long track thus more piles, more track beams, and longer hauling and backing chains. A steeper track will be shorter but the aft cradle build up is now taller, requiring longer and heavier columns, and the track must go even deeper to provide the same depth of water over the cradle deck.

The steeper track, not fitting the topography, will require dredging.

Other criteria to consider when laying out the track are: channel lines, pier-head lines, property lines, direction and speed of currents, etc.

For railways that required dredging to install the track it is probable that the dredged hole will fill with sediment overtime. Depending on the site this could happen very quickly. It is important to regularly inspect the rails for mud build up. Mud over the rails is a common reason for cradle derailment.
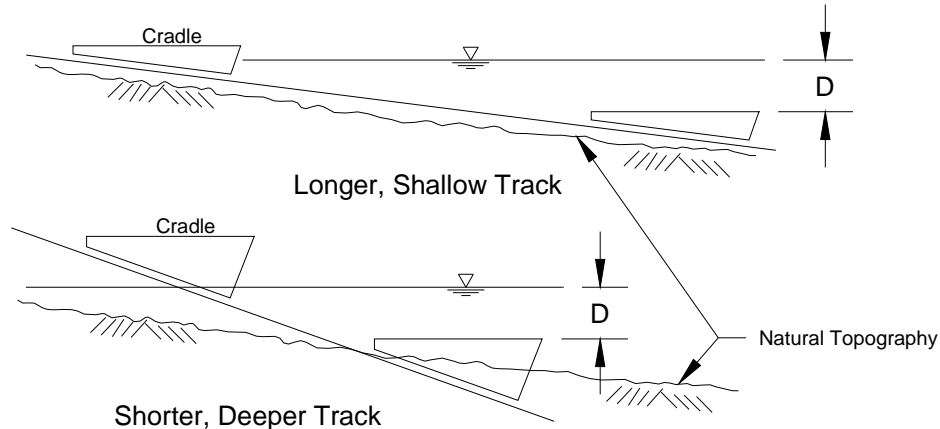
TRACK LAYOUT

FIGURE 1.24

Sometimes the track will be laid out as an arc of a circle instead of a straight-line slope.

This provides 3 benefits:

1. The cradle deck can be horizontal in the full up position allowing vessel transfer to shore and easy access. As the cradle is lowered down the track, the aft end rotates downward, providing deeper water over the aft end of the dock. This puts the block line on a trim, which can more closely match the

trim of the vessel being docked. This reduces grounding stability problems and knuckle loads.

2. The cradle build-up aft is less, so the track does not have to go as deep or far to get the same water over the deck.

3. As the cradle is hauled up the track, the actual incline of the track is getting less. Thus, less hauling power is required as the full weight of the vessel transfers from the water to the cradle.

CURVED TRACK
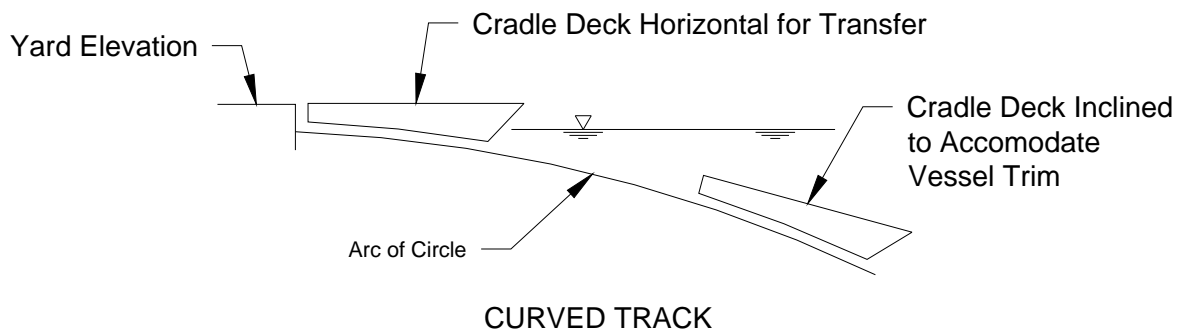
FIGURE 1.25

On tracks built with a curve it is important to realize that the angle of the keel line to horizontal will constantly change as the cradle moves up or down the track. When docking a vessel (even one with no trim) you must determine at what point along the track the vessel will land first on the blocks. Then you must figure the angle of the keel line at that point along the track and compare the angle to the vessel's trim (the angle of the vessel's keel). The difference between the two slopes is the trim that must be removed for complete landing of the vessel. The trim removed is the value used in calculating landing stability and sue or skeg loading. See Sections 4 Block Loading and 5 Stability for additional information on this problem.

Track Foundation

The type of foundation for the marine railway is dependent on soil conditions and size of vessels being lifted.

Typical marine railway foundations are:

➢ Railroad tie timber "sleepers" – for very light loads

➢ Concrete spread footings – light to moderate loads

➢ Timber piles – moderate to heavy loads

➢ Steel piles – heavy to very heavy loads

➢ Concrete piles – heavy to very heavy loads

The loading on the foundation varies throughout the length of the track. At the end of the track, only submerged weight of the cradle needs to be supported.

As the cradle moves inshore and the vessel begins to be lifted, its weight is gradually transferred onto the cradle.

At the point the ship's keel breaks water, its full weight is on the cradle and the remaining portion of the track and foundation must be designed for this condition.
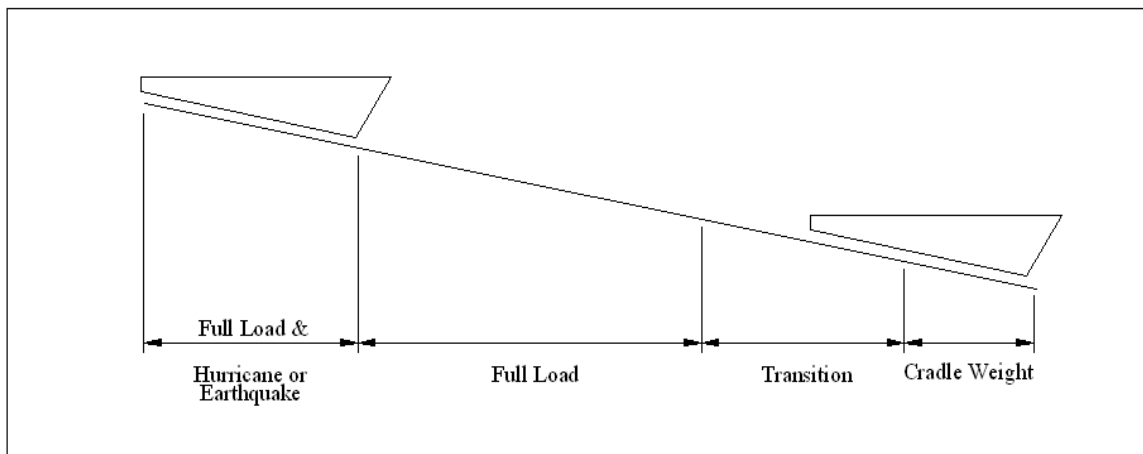
TYPICAL VARIATIONS IN FOUNDATION LOADS

FIGURE 1.26

The foundation under the cradle in the full up condition should also be investigated for additional loads induced by hurricane winds or earthquakes with a capacity vessel aboard.

Most large railways are founded on piles. Steel, concrete or wooden piles can be used. Steel or wood are most frequently used offshore because they are easier to cut to exact grade underwater than concrete.

Concrete piles can be used above low water where they can be cast into the concrete track.

Piles are usually spaced between 3 to 8 feet.

Many railways use a single row of piles under each track. This eliminates the need for cap beams but requires strict tolerances when driving piles to insure the track falls directly over the line of piles.

To loosen the driving tolerances a little, a wide bonnet can be placed over the pile. This provides a wide shelf for the track to sit on.

If the pile is driven out of tolerance, a cap beam is installed to bridge across to the other line of piles.

Track Beams

The track can be constructed out of wood, steel, concrete or some combination.

The track should be designed for the same loading arrangement as the foundation.

Most large docks today have steel tracks for their offshore portion and concrete above the low waterline. This eliminates much of the steel in the tidal and splash zones where steel is quickly corroded.

Steel offshore sections can be fabricated on the shore (in the dry) in sections of 40 to 60 feet length. Then they can be lowered onto the pile bonnets and fastened. This eliminates much of the underwater assembly work.

Installation of the track offshore can be done by either lowering it using a crane or floating it into place.

Attached to the top of the track is the rail on which the cradle runs. The rail can be either a crane rail (for wheels) or a flat plate (for rollers).

It is recommended that a cushion be designed into the track/foundation system to help distribute any load concentrations.

This helps prevent overload to the rollers or wheel, piles, cradle columns etc.

On timber tracks, the timber is the cushion.

On steel tracks, a rubber pad placed between the pile and the bottom of the track beam is usually adequate.

On concrete tracks, a rubber pad between the rail plate and concrete is needed.

The pulling of the loaded cradle up the track creates a longitudinal friction force along the axis of the track beam.

This force is equal to about 2% - 3% of the cradle plus ship weight if rollers are used and 5% if wheels are used.

To balance this force the track should be tied into the hauling machine foundation by struts at the head of the track.

This eliminates the tendency to pull the track off the piles.
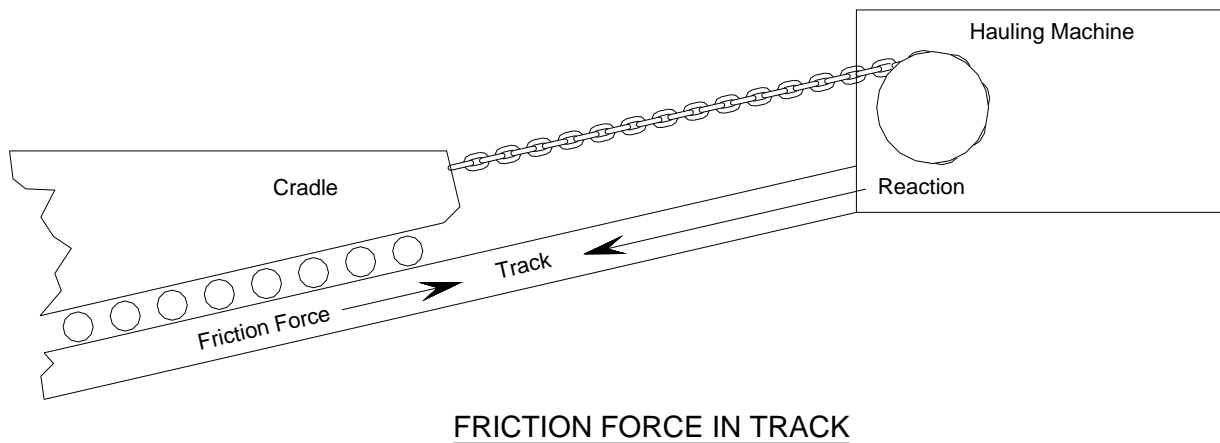
FRICTION FORCE IN TRACK

FIGURE 1.27

Rollers and Wheels

The marine railway cradle runs on a system of rollers and wheels.

Rollers are generally used for larger capacity railways because they cause less friction than wheels and they tend to distribute the load more evenly along the track since they are placed closer together.

The design load per foot value dictates roller width and spacing. Rollers are usually spaced 12 to 18 inches apart. Co-efficient of friction for rollers is 1-2%.

CRANDALL roller is good for about 1 kip/inch of tread width.

Minimum width = 6 inches

Maximum width = 14 inches

Some smaller railways use wheels.

Disadvantages of using wheels are:

> ➢ Greater friction

> ➢ More expensive

> ➢ Cause higher point loads; requires stronger track beams and foundation

Cradle

The cradle is the platform that holds the vessel from the time it grounds out on the blocks.

The cradle must have strength and stability to support the ship and yet be flexible in longitudinal bending and torsion to accommodate any irregularities that may occur in the track's line and grade.

The gauge of the cradle runners must be wide enough to provide stability against overturning from wind, current and earthquakes.

As a general rule, the gauge of the marine railway should always be about half the beam of the widest vessel to be docked or about a third of the width of the cradle.

The cradle beams should be designed to take 100% of the rated load per foot times the beam spacing.

The load should be concentrated at the centerline of the beam.

The beams must also be designed for bilge block loads positioned outboard of the columns and bending due to line pull or fender impact on the uprights.

There is a column under each cradle beam at the runner. Each column should be designed for half the load on the cradle beam it supports plus any additional loading from hurricane or earthquake tipping forces.
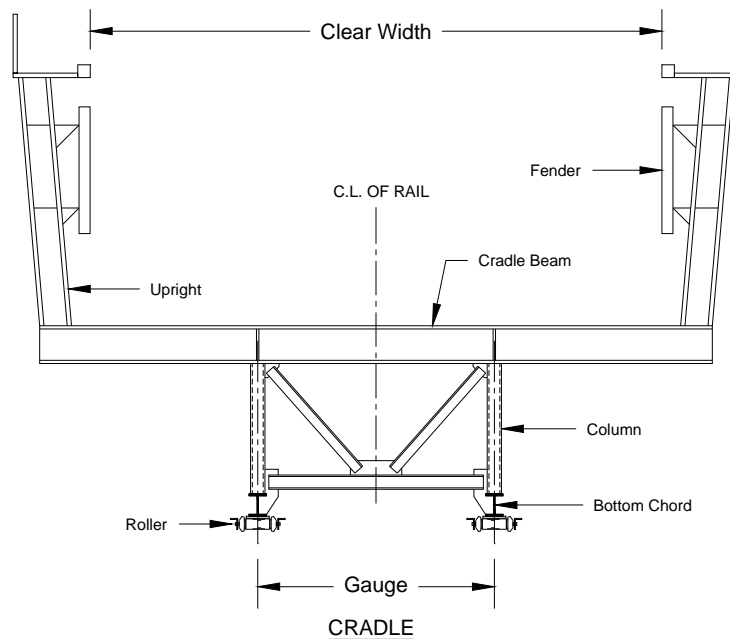
FIGURE 1.28

The upright columns support the docking platform, which is used by the dock crew for the line handling. They should be designed to resist the pull from the lines and fender impact from the vessel.

Hauling Machine

The hauling machine is a large capacity winch designed to pull the cradle with the capacity ship aboard.

The machine consists of an electric motor, which drives a speed reducer and a train of gears.

The gears turn the chain wheels, which drives the chain.

An automatic brake is provided to hold the cradle whenever power to the motor is interrupted.

The load on the winch (chain load) is a function of the cradle and vessel weight, the gradient (slope of track), and the friction in the system.

$$\text{Chain Load} = (W \times \text{Slope}) + (W \times C_f)$$

Where:

W = weight of cradle, ship & chains

Slope = 1/??

C_f = Coeff. Of friction

=> 0.02 – 0.04 for rollers

=> 0.03 - 0.05 for wheels

When investigating the stresses in the chain, the chain load should be increased by 10% to account for local stress due to chain bending on the wheel.

The required horsepower of the electric motor is a function of the pull on the chain times the speed of haul.

Experience has shown that a speed that raises the cradle 1 vertical foot per minute reduces the tendency of the cradle to surge.

Example:

For a slope of 1 in 20, the ideal hauling speed is 20-ft per minute.

Chain

Chain material and manufacturing have improved greatly over the years.

In order of their development:

➢ Wrought iron chain – Not as strong as steel, no longer available

➢ Cast iron chain – Stronger than wrought iron but could contain slag pockets and other imperfections that could cause failure

➢ Welded steel chain – Made from forged bars, does not have slag pockets

➢ Welded alloy steel chain – Very high strength, developed for the oilrig industry

In addition to strength, marine railway hauling chain needs uniformity of link shape.

Links that are too small may bind on the chain wheel tooth and fail to engage properly.

Links that are too big will not seat right on the chain wheel, causing movement and snapping and possible overloading of the teeth.

Hauling chain is always arranged in an endless loop. This insures that the cradle can be backed down the track even if debris on the track prevents the cradle from moving by gravity.

The hauling chain is used for hauling the cradle up the slope and the backing chain pulls the cradle down the slope if gravity does not overcome friction.
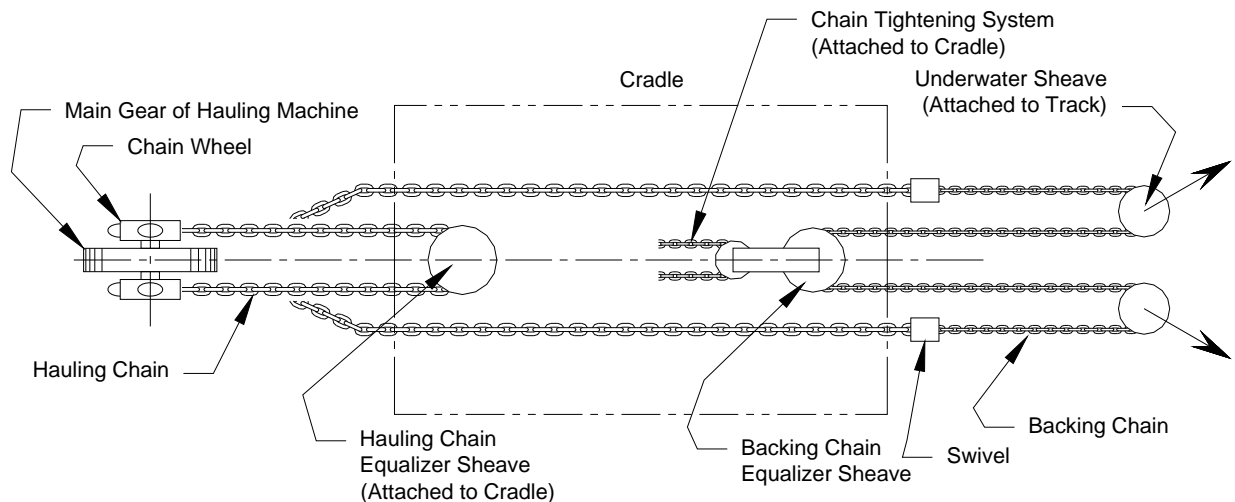
TYPICAL TWO CHAIN REEVING DIAGRAM

FIGURE 1.29

For a multiple part chain system, all chains must be equalized. If they are not, small differences in chain dimensions would eventually loosen one or more chains, overloading others.

Before the chain goes over the chain wheel, it should be washed to remove sand and grit, which greatly increase wear. The chain should be oiled at the grips just prior to going around the wheel.

To support the chain and prevent it from eventually cutting through the track cross ties, chain slides are provided on each cross tie.

Wire Rope

In general, wire rope should NOT be used for hauling marine railway cradles.

Salt water tends to corrode wire rope quickly and there is no way of determining its strength once it has been in use, without removing it and testing.

Chain, on the other hand, can be measured in place and its strength can be calculated.

If wire rope is used,

"Synchrolift" recommends removing and full load testing the wire rope every 3 years.

"Marine Travel Lift" recommends replacing wire rope every 5 years, although in their case the wire rope does not go into the seawater. Child's Engineering recommends testing and replacing wire ropes at least every 2 years when used in salt water.

1.4 – VERTICAL LIFTS

A vertical lift is a mechanical means of hoisting a ship out of the water vertically.

The dock consists of:

> ➢ Platform
>
> ➢ Hoisting mechanism
>
> ➢ Hoist support pier

The platform is lowered into the water until sufficient water over the blocks is achieved. The ship is floated over the platform and centered. The platform is raised, grounding the vessel on the blocks.

As the vessel is raised, all motors are synchronized to insure they each haul at the same rate no matter what the load on each of them is. This insures that no unit gets overloaded.

Advantages of a vertical lift:

> ➢ Very fast operating
>
> ➢ Easy to transfer
>
> ➢ Can be trimmed to match vessel trim

Disadvantages of a vertical lift:

> ➢ Very high initial cost
>
> ➢ High maintenance cost
>
> ➢ High tech machinery requirements
>
> ➢ Fixed structure – hard to relocate
>
> ➢ Hard to dredge under platform

The most popular type of vertical lift is SYNCROLIFT.

Sizes range from 100 tons to 24,000 tons

Platform

Platform length need not be longer than the maximum keel bearing length i.e. the ship can be overhanging fore and aft unless the dock has end transfer. In that case, the overhang is limited to offshore end only.

Platform clear width is based on maximum anticipated beam plus 2-3 feet clearance needed for hauling vessels while docking.

Additional space for working clearance is not needed if the vessel is to be transferred off the dock to the shore.

It is desirable to keep platform width to a minimum to reduce the size of the platform's transverse beams.

The platform must have transverse strength to support the ship at its centerline while lifting the platform at its edges.

It must also be flexible in the longitudinal direction to accommodate docking vessels with a hog or sag.

The platform is comprised of a series of transverse beams on either side.

The platform can be split into multiple sections for docking 2 smaller vessels or allowing the lowering of one section to clear obstructions such as sonar domes.

The platform can be raised clear out of the water for maintenance.

Platform decking is usually designed for light loads, man-lifts etc.

Hoisting Mechanism

The hoisting mechanism consists of a series of synchronous electric motor hoisting units all connected to a central control panel.

All motors operate at the same rate regardless of the amount of weight each is lifting.

The hoisting mechanism consists of:

> ➢ Synchronous electric motor

> ➢ Automatic brake

> ➢ Gearing

> ➢ Wire rope drum

> ➢ Ratchet and Paul backstop

- ➢ Sheaves

- ➢ Load cell

The hoist drum drives a multiple part wire rope reeling system that lifts the platform.

The cable drum is grooved and provides for the maximum amount of travel with a single layer on the drum.

Each hoist has 2 separate braking systems:

- ➢ Automatic disc brake – Releases when power is applied; engages by spring action when power is disconnected.

- ➢ Ratchet &Paul – Prevents the drum from unwinding under all conditions except when the platform is intentionally being lowered.

A load cell is incorporated into the wire rope sheave system so the actual load on each cable can be monitored at all times.

This is also a convenient way to measure the vessel's weight.

Vertical Lift Wire Rope

The wire ropes should be designed for severe marine environment. Individual wires should be galvanized.

Synchrolift recommends removing and testing to full load a percentage of all cables every 3 years.

Since this can be a costly maintenance requirement, others have tried other types of lifting mechanisms with limited success:

- ➢ Jacking bar

- ➢ Jacking chain

All hoisting units are supported on a pier or deck on either side of the platform.

A single person from the control house can control all hoisting units.

1.5 – MARINE TRAVEL LIFTS

A marine travel lift is a vertical lift on wheels.

Instead of a structurally rigid platform to support the vessel, nylon straps are usually used.

The slings are lowered into the water until sufficient water over the slings is achieved.

The ship is floated over the slings and centered. The slings are raised to lift the vessel. Once the ship is at yard's elevation, the travel lift can be moved under its own power to place the ship on fixed blocks in a storage berth.

The most popular type of travel lift is the "Marine travel lift" of Sturgeon Bay, Wisconsin.

Capacities range from 7 to 500 tons.

The travel lift consists of:

➢ Structural frame on wheels

➢ Wire rope hoists

➢ Adjustable slings

➢ Support pier

Advantages of the travel lift are:

➢ Very fast operating

➢ Many berths can utilize one lift

➢ Can be trimmed to match vessel trim

➢ Wire rope does not go into the water

➢ Rubber tires can be driven on relatively rough surfaces

➢ Lift can be relocated relatively easily (not support piers)

➢ Easy to dredge under

➢ Machinery can be driven to a storage shed and stored away from the elements

Disadvantages of the travel lift are:

➢ High initial cost

➢ High maintenance cost

➢ Low capacity

Width between the legs must be sufficient to allow maximum beam vessel to enter between support piers plus room for block, tackle and slings.

The width also must be kept to a minimum however, since the allowable load on the slings diminishes as the sling angle increases.

The structural frame length need not be any greater than the length needed to give the slings a good spread on the ship.

The ship may extend beyond the frame fore and aft.

The front transverse support bar must be high enough or forward enough to clear any superstructure.

Wire rope hoist and Slings

The wire rope hoist and slings are rigged such that the sling loads are equalized into a 2-point lift.

In this manner, no one sling can be overloaded by variable hoisting rates.

Prior to docking a vessel the slings should be positioned such that all slings take approximately the same load (+/- 25%).

Example:

Sling A takes 1/3rd the load.

Slings B & C (which are equalized) should be positioned to take 2/3rd the load.

If the angle of the sling to the vertical leg exceeds 15 degrees, the allowable load per sling must be reduced.

This is because the horizontal component of the sling puts excessive strain on the frame.

A sample reduction in allowable load versus sling angle is shown below:
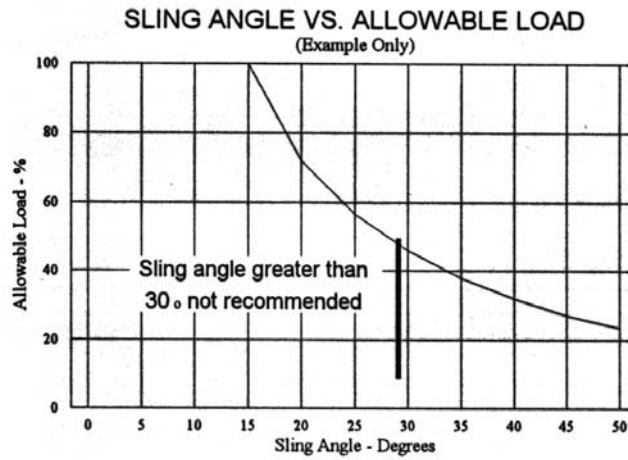
FIGURE 1.30

2.0 - DOCKING PLANS

The docking plan is used to obtain most of the information needed to plan the drydocking of that vessel. Care should be taken to insure you are using the latest revision of the plan.

2.1 – Docking Plan

Title Block - Be sure you are using the correct plan and the latest revision.

FIGURE 2.1

References – Check here if additional information for specific items is needed.

NO.	TITLE	CAGE CODE	MFR OR CONTR NO.	NAVSEA NO.
10	NAVSEA TECHNICAL MANUAL FOR SONAR DOME RUBBER WINDOW	——	————	S9165−AE−MMA−010/ SDRW−1
9	STANDARD NAVY DOCKING DRAWING−SURFACE SHIPS	34293	————	803−5184106
8	NAVSEA TECHNICAL MANUAL (DOCKING INSTRUCTIONS)	——	————	S9086−7G−STM−000/ CH−997R2
7	TEMPORARY HERCULITE SUN SCREEN FOR SONAR DOME	34293	————	602−4590931
6	SLING SUPPORT FOR SONAR DOME RUBBER WINDOW	34293	————	906−6035584
5	ARR OF ATTACH TO SUIT PROP SHAFT, SHIPPING & UPSHIPPING	34293	M−KH−HAE0−07	243−7059932
4	LOCATION OF SEA CONNECTIONS	34293	M−TP−PN00−02	163−7060354
3	CURVES OF FORM	34293	M−KH−0000−19	801−7059906
2	MASKER AIR HULL EMITTERS	34293	D−KS−SP00−01	551−7060057
1	FAB & INSTL OF SHIPS NAME & DRAFT MARKINGS	34293	M−BH−IDG0−01	602−7058601

REFERENCES

FIGURE 2.2

General Notes - Always read this section because it gives important information about draft marks, dimensions, blocks, etc. The following are typical items found in the General Notes:

GENERAL NOTES

1. DRAFT MARKS
   A. ALL DRAFT MARKS ARE ARABIC NUMERALS. NAVIGATIONAL DRAFT MARKS ARE DESIGNATED BY "PROJ" SIX INCHES ABOVE UPPERMOST MARK.
   B. CORRECTIONS TO DRAFT READINGS FOR CALCULATIVE PURPOSES ARE FORWARD 0 INCHES, AMIDSHIPS 0 INCHES, AFT 0 INCHES.

2. DIMENSIONS
   A. LONGITUDINAL LOCATIONS OF ALL ITEMS ARE GIVEN FROM THE STERN REFERENCE POINT (SRP), AFTER END OF MAIN DECK AT CL.
   B. HEIGHTS OF ALL ITEMS ARE GIVEN FROM THE BOTTOM OF THE KEEL AMID-SHIPS EXTENDED, EXCEPT AS NOTED.
   C. LONGITUDINAL LOCATIONS AND VERTICAL HEIGHTS OF SIDE BLOCKS ARE TAKEN TO THE AFTER SIDE OF BLOCKS.

3. COMPLETE PAINTING OF HULL
   IN ORDER TO CLEAN AND PAINT THE ENTIRE BOTTOM OF THE VESSEL IN THREE SUCCESSIVE DOCKINGS, THE FOLLOWING POSITIONS OF THE VESSEL ARE NECESSARY:
   A. 8 FT – SPACED SIDE BEARERS
      1. POSITION NUMBER 1: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 162'-6" AFT OF AFTER SIDE OF NUMBER 4 SIDE BLOCK.
      2. POSITION NUMBER 2: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 164'-6" AFT OF AFTER SIDE OF NUMBER 4 SIDE BLOCK.
      3. POSITION NUMBER 3: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 160'-6" AFT OF AFTER SIDE OF NUMBER 4 SIDE BLOCK.
   B. 12 AND 16 FT – SPACED SIDE BEARERS
      1. POSITION NUMBER 1: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 138'-6" AFT OF AFTER SIDE OF NUMBER 1 SIDE BLOCK.
      2. POSITION NUMBER 2: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 140'-6" AFT OF AFTER SIDE OF NUMBER 1 SIDE BLOCK.
      3. POSITION NUMBER 3: AFTER END OF MAIN DECK AT CL (SRP) IS PLACED 136'-6" AFT OF AFTER SIDE OF NUMBER 1 SIDE BLOCK.
   C. REPEAT CYCLE OF POSITIONS, ASCERTAINING FROM VESSEL THE POSITION USED AT LAST DOCKING.

4. PROPELLER AND OTHER APPENDAGES
   A. IN DETERMINING THE HEIGHT OF KEEL BLOCKS, CARE IS TO BE TAKEN THAT PROPELLER TIPS, SONAR DOME AND OTHER APPENDAGES CLEAR THE BOTTOM OF THE DOCK.
   B. MAXIMUM CLEARANCE IN WAY OF THE PROPELLERS IS OBTAINED BY POSITIONING THE SPINDLE AXIS OF THE NO.1 BLADE 21 DEGREES OUTBOARD OF TOP DEAD CENTER WITH BLADES AT 100% FORWARD PITCH.

5. BLOCKING
   A. THE BLOCKING SHOWN ON THIS PLAN IS THAT REQUIRED FOR DOCKING IN SEISMIC REGIONS UNDER ORDINARY, UNDAMAGED CONDITIONS FOR 8'-0", 12'-0" AND 16'-0" SPACED SIDE BEARERS.
   B. THE KEEL HEIGHT SHOWN IS THAT REQUIRED FOR MINIMUM CLEARANCE UNDER SONAR DOME FOR DOCKS WITHOUT PITS. FOR DOCKS WITH PITS, THE KEEL HEIGHT MAY BE REDUCED PROVIDING MINIMUM REQUIRED CLEARANCES ARE MAINTAINED (INCLUDING ALLOWANCES FOR HANDLING EQUIPMENT REQUIRED FOR REMOVAL OF SONAR DOME, PROPELLERS OR RUDDERS).
   C. KEEL BLOCKS
      1. KEEL BLOCKS, 42" (FORE AND AFT) X 36" MIN (ATHWARTSHIP) SHALL BE BUILT UP AS INDICATED IN TYPICAL SECTIONS AND SHALL BE ARRANGED IN PIERS OF HARD WOOD OR COMPOSITE CONSTRUCTION (CONCRETE AND WOOD). ALL KEEL BLOCKS ABOVE 8'-6" IN HEIGHT (I.E. DOCKS WITHOUT PITS) SHALL BE CRIBBED. KEEL BLOCKS SHALL BE MOUNTED WITH 2" MINIMUM SOFTWOOD CAPS.
      2. LONGITUDINAL KEEL BLOCK SPACING SHALL BE 6'-0" CENTER TO CENTER WITH 30" CLEAR SPAN BETWEEN. NOTE THAT REGULAR KEEL BLOCK SPACING FOR POSITION NO.2 BEGINS WITH NO.2 KEEL BLOCK. THE NO.1 KEEL BLOCK FOR POSITION NO.2 IS LOCATED 3'-0" AFT OF WHERE 6'-0" SPACING WOULD DICTATE.
      3. KEEL BLOCKS SHALL BE IN ACCORDANCE WITH THE FOLLOWING DRAWINGS AS APPLICABLE, OR SHALL BE OF A CONSTRUCTION THAT WILL PROVIDE EQUIVALENT STABILITY:

BUDOCK DWG NO.	TYPE DOCK	TYPE DOCKING BLOCKS
822374	GRAVING	COMPOSITE PIER TYPE WOOD AND CONCRETE
817336	GRAVING	TIMBER
797762	FLOATING	TIMBER
789241	FLOATING	

      4. NO BLOCKS OR SHORES ARE REQUIRED UNDER ORDINARY CONDITIONS OF DOCKING UNDER THE BOW FWD OF FRAME NO. 61 AND UNDER THE STERN AFT OF FRAME NO. 384.

GENERAL NOTES CONTINUED

  D. SIDE BLOCKS
    1. SIDE BLOCKS SHALL BE BUILT UP AS SHOWN IN TYPICAL SECTIONS OR IN A MANNER WHICH WILL PROVIDE EQUIVALENT TRANSVERSE STABILITY. IN ORDER TO PREVENT OVERTURNING, SIDE BLOCKS ABOVE 6'-0" IN HEIGHT (I.E. DOCKS WITHOUT PITS) SHALL BE TIED TOGETHER LONGITUDINALLY IN PAIRS BY MEANS OF STEEL TIE RODS, JOINED BY CRIBBING OR OTHER SUITABLE AND APPROVED MEANS. IF THE SIDE BLOCKS ARE HAUL BLOCKS, THEY MUST BE HAULED IN PAIRS.
    2. SIDE BLOCKS ARE NUMBERED FROM AFT TO FORWARD, WITH THE AFTMOST BLOCK FOR THE 12'-0" AND 16'-0" SPACING CONFIGURATION AS NO.1. TO MAINTAIN BLOCK NUMBERING CONSISTENCY BETWEEN THE 8'-0" AND 16'-0" SPACING ARRANGEMENTS, THE AFTMOST BLOCK FOR 8'-0" SPACING IS DESIGNATED AS NO.4 AND THE 16'-0" SPACED BLOCKS ARE DESIGNATED BY ODD NUMBERS ONLY.
    3. SIDE BLOCKS SPACED AT 8'-0" SHALL BE CENTERED AT 9'-0" AND 11'-3" OFF CENTERLINE; SIDE BLOCKS SPACED AT 12'-0" & 16'-0" SHALL BE CENTERED AT 17'-5", 19'-11" & 11'-3" OFF CENTERLINE; ALL SIDE BLOCKS SHALL BE 24" (FORE & AFT) & 36" (ATHWARTSHIP) AS INDICATED IN TABLE OF OFFSETS FOR SIDE BLOCKS AND BILGE KEEL.
    4. IF HAULED, SIDE BLOCKS LOCATED 19'-11" OFF CENTERLINE WILL NOT CLEAR THE BILGE KEEL UNLESS A HINGE OR SIMILAR ARRANGEMENT IS UTILIZED.
    5. SIDE BLOCKS SHALL BE MOUNTED WITH 2" MINIMUM TO 6" MAXIMUM THICKNESS SOFT WOOD CAPS.
    6. VALUES FOR BEVEL IN 24" ARE TAKEN AT CENTER OF BLOCK (POINT "A") AND DIRECTION IS INDICATED AS "+" UP AND "−" DOWN FROM THE HEIGHT GIVEN AT AFTER SIDE OF THE BLOCK IN THE TABLE OF OFFSETS.

    7. BLOCKS WITH CROSS-HATCHING ARE USED FOR 16'-0" SPACING ONLY. BLOCKS WITH * ARE USED FOR 8'-0" SPACING AND 16'-0" SPACING.
    8. THE SIDE BLOCK ARRANGEMENTS SHOWN ARE DESIGNED TO RESIST SEISMIC LOADING IN ACCORDANCE WITH REFERENCE 8. ANY ARRANGEMENT NOT SHOWN MUST BE CAREFULLY ASSESSED FOR COMPLIANCE WITH REFERENCE 8 AND FOR ADEQUACY OF SHIP STRUCTURE WHEN SUBJECTED TO THE LOADS DEFINED THEREIN.

  E. OMIT SIDE BLOCKS AS INDICATED IN TABLES OF OFFSETS AND KEEL BLOCKS AS INDICATED ON PLAN VIEW DUE TO INTERFERENCES WITH SHELL OPENINGS OR MASKER AIR EMITTER BELTS. THE REQUIREMENTS OF REFERENCE 8 MUST BE CONSIDERED IF ADDITIONAL BLOCKS ARE TO BE OMITTED.

6. TRIM AND HEEL
  A. THE TRIM SHALL BE KEPT AT A MINIMUM (NONE IF PRACTICABLE) TO PREVENT EXCESSIVE KEEL BLOCK PRESSURE WHEN DOCKING (SEE REF 8).
  B. THE SHIP SHALL NOT HAVE HEEL AND SHALL BE ACCURATELY PLACED IN THE DOCK.

7. THE STRUCTURAL STRENGTH OF THE HULL IS ADEQUATE TO SUPPORT THE SHIP WITH SONAR DOME, COMPT. 6-0-0-Q, FULL OF WATER WITHOUT ADDITIONAL BLOCKING; HOWEVER, IN ORDER TO PROTECT THE SONAR DOME RUBBER WINDOW (SDRW), THE FOLLOWING PROCEDURES SHALL BE FOLLOWED:
  A. DOCKING
    1. THE SONAR DOME SHALL BE COMPLETELY FILLED WITH WATER AND NORMALLY PRESSURIZED BY THE FIREMAIN. THE DOME SHALL REMAIN FULL UNTIL THE SHIP HAS LANDED ON THE BLOCKS. IF TRIM BY THE STERN IS REQUIRED, THE DOME MAY BE PARTIALLY OR COMPLETELY DEWATERED AND PRESSURIZED WITH AIR AT 15 (±1) PSIG IN ACCORDANCE WITH REFERENCE 10.
    2. TO AVOID OVERSTRESSING THE RUBBER WINDOW, THE SONAR DOME SHALL BE COMPLETELY DEWATERED AND PRESSURIZED WITH AIR AT 15 (±1) PSIG NO LATER THAN 3 HOURS AFTER THE RUBBER WINDOW HAS BEEN EXPOSED TO AIR.
    3. THE DOME SHOULD BE PRESSURIZED AT ALL TIMES WHILE THE SHIP IS IN THE DRYDOCK. IF THE DOME MUST BE DEPRESSURIZED FOR LONGER THAN 72 HOURS. THE DOME SHALL BE SUPPORTED IN ACCORDANCE WITH REFERENCES 6 & 10.

  B. UNDOCKING
    1. THE SONAR DOME SHOULD BE COMPLETELY FILLED WITH FRESH WATER AND NORMALLY PRESSURIZED BY THE FIREMAIN. FLOODING SHOULD BE COMPLETED BEFORE THE WATER LEVEL REACHES THE BOTTOM OF THE DOME, BUT THE RUBBER WINDOW SHALL NOT BE EXPOSED TO AIR FOR MORE THAN 3 HOURS AFTER THE DOME HAS BEEN HAS BEEN FLOODED.
    2. IF TRIM BY THE STERN IS REQUIRED. THE SONAR DOME MAY BE EMPTY OR PARTIALLY FLOODED AND PRESSURIZED WITH AIR AT 15 TO 22 PSIG IN ACCORDANCE WITH REFERENCE 10.
  C. RUBBER WINDOWS OR DOMES COVERED WITH NO-FOUL RUBBER REQUIRE PROTECTION FROM THE SUN. FOR PROTECTION SEE REFERENCE (7).
  D. CAUTION: TO AVOID COLLAPSING THE RUBBER WINDOW, MAINTAIN 15 TO 22 PSIG AIR PRESSURE AT ALL TIMES WHILE FLOODING OR DEWATERING THE SONAR DOME OR DURING SHIP DRY-DOCKING OPERATIONS.
  E. CAUTION: A CERTIFIED SONAR DOME PRESSURIZATION SYSTEM OPERATOR MUST BE PRESENT AT THE PRESSURIZATION CONTROL STATION DURING ALL DOCKING AND UNDOCKING EVOLUTIONS.

8. EXCEPT FOR DIMENSIONS CONTROLLING SIZE AND LOCATION OF BLOCKING, ALL DIMENSIONS ARE REFERENCE.

9. ABBREVIATIONS ARE PER MIL STANDARD 12 (D) EXCEPT: SRP-STERN REFERENCE POINT.

10. NUMBERS IN CIRCLES INDICATE ITEM NUMBERS IN "LIST OF SHELL OPENINGS BELOW 25 FT WL."

11. WHEN THE SHIP IS LIGHTENED FOR DOCKING, STABILITY MUST BE ASSESSED.

FIGURE 2.3

Table of Displacement and Other Properties – This table is used to obtain the hydrostatic properties of the vessel at any draft. It is based on the shape of the vessel's hull when floating at no trim. For a vessel with no trim (even draft), the hydrostatic properties can be obtained by using the draft of the ship and interpolating the values in the table.

If a vessel has trim, you must enter the draft at the Longitudinal Center of Floatation (LCF) into the table below to get the correct values for the vessel. This is because for any particular vessel displacement, the draft at the LCF does change even if weights on board are shifted, changing the trim of the vessel. You must, however, adjust the value of the Longitudinal Center of Buoyancy (LCB) obtained from the table to account for the trim. See Section 3.5 for more details on calculating LCB.

Enter draft at LCF

TABLE OF DISPLACEMENT AND OTHER PROPERTIES FOR DOCKING
NO CORRECTION FOR TRIM

| MEAN DRAFT IN FT | DISPLACEMENT IN LT | APPROX. MOMENT TO CHANGE TRIM 1 IN. –FT LT | LCB FWD OF STERN REF PT IN FT | LT PER INCH IMMERSION | LONG. CTR OF FLOTATION | | TRANSVERSE METACENTER |
					LCF AFT OF OO IN FT	LCF FWD OF SRP IN FT	FT ABOVE BASELINE
15.0	5250	946	251.06	42.80	6.84	233.22	28.09
16.0	5775	1037	249.23	44.70	10.10	229.96	28.25
17.0	6320	1140	247.31	46.40	13.64	226.42	28.42
18.0	6900	1256	245.38	48.40	17.60	222.46	28.60
19.0	7480	1375	243.36	50.20	21.13	218.93	28.76
20.0	8100	1438	241.46	51.35	22.26	217.80	28.83
21.0	8715	1489	239.72	52.25	22.60	217.46	28.89
22.0	9350	1532	238.24	53.20	22.54	217.52	28.95
23.0	9995	1568	236.91	53.85	22.20	217.86	29.01
24.0	10650	1602	235.78	54.55	21.77	218.29	29.11
25.0	11300	1637	234.79	55.25	21.36	218.70	29.25

FIGURE 2.4

Interpolation can be used to obtain properties for drafts between the points in the table. For example to get the displacement for the vessel with a 17.3 foot draft at the LCF you would interpolate between the 17.0 and 18.0 values:

(17.3-17.0) x (6900-6320) + 6320 = 6494 LT's

Docking Plan Elevation View (Side Profile View)

The side view shows:

➢ Location of Stern Reference Point (SRP) the point at which all longitudinal dimensions are referenced from.
➢ Location of Aft Perpendicular (AP)
➢ Location of stern draft marks
➢ Location of end of skeg
➢ Frame spacing
➢ Clearance required for shaft removal
➢ Clearance required for rudder removal
➢ Location of Forward Perpendicular (FP)
➢ Location of forward draft marks
➢ Location of last block

DOCKING DRAWING - ELEVATION VIEW

FIGURE 2.5

Plan View

The plan view shows:

- ➢ Location of side blocks
- ➢ Location of keel blocks
- ➢ Location of hull openings
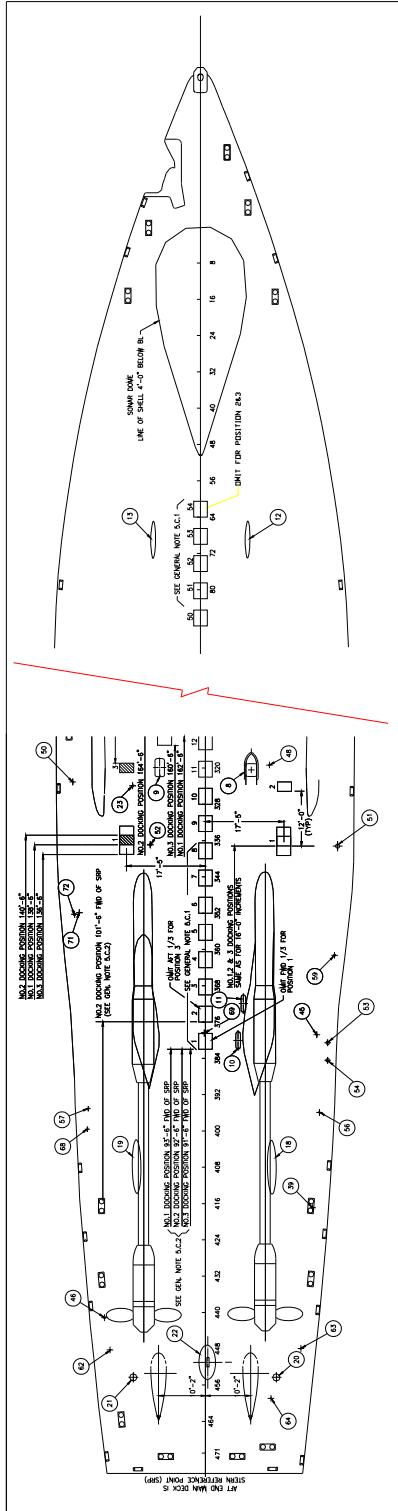
DOCKING DRAWING – PLAN VIEW

FIGURE 2.6

Hull Openings Below Waterline - Shows position of all hull protrusions and openings that are below the waterline. Use to insure no interference with blocks.

LIST OF SHELL OPENINGS BELOW 25'-0" WL

OPNG NO.	SERVICE	DIAMETER OF OPNG IN SHELL	REMARKS	SIDE OF SHIP P/S	LONG'L LOCATION CTR OF OPNG			FWD OF SRP TO CL OF OPNG			DISTANCE OFF CL OF SHIP			HEIGHT-BOT OF KEEL TO CL OPNG			REFERENCE NAVSEA NO.	CONTRACTOR DWG. NO.
					INCHES	F/A	FR. NO.	FT	INS	1/4	FT	INS	1/4	FT	INS	1/4		
1	SEACHEST – FIRE PUMP NO.1	34" X 21"	–	P	18	F	118	359	1	0	12	4	3	6	2	2	100-7060380	M-US-1420-01
2	SEACHEST – CENT SW CLG PUMP NO.1 & FIRE PUMP NO.2	46" X 25"	9'-1"X3'-0"	P	0	–	136	339	7	0	3	4	2	0	9	1	100-7060384	M-US-2110-01
3	SEACHEST – SSGTG CIRC CLG PUMP NO.1	20 1/2"X 20 1/2"	7'-1"X3'-0"	P	12	A	166	308	7	0	9	6	0	1	4	0	100-7060384	M-US-2110-01
4	SEACHEST – FIRE PUMP NO.3 & CLG PUMP NO.2	46" X 25"	9'-1"X3'-0"	P	0	–	188	287	7	0	5	7	2	0	4	0	100-7060389	M-US-2210-01
5	SEACHEST – CENT SW CLG PUMP NO.3	34" X 25"	8'-1"X3'-0"	S	18	F	228	249	1	0	12	4	2	1	1	1	100-7060394	M-US-2310-01
6	SEACHEST – CENT CLG PUMP NO.4 & FIRE PUMP NO.4	46" X 25"	9'-7"X3'-0"	S	24	A	268	205	7	0	5	7	2	0	5	0	100-7058575	M-US-2410-01
7	SEACHEST – SSGTG CIRC CLG PUMP NO.2	22" X 25"	7'-7"X3'-0"	S	60	A	276	194	7	0	7	10	2	0	10	1	100-7058575	M-US-2410-01
8	SEACHEST – SW CLG PUMP NO.5	34" X 25"	8'-1"X3'-0"	S	18	F	322	155	1	0	10	1	2	2	10	0	100-7060403	M-US-3110-01
9	SEACHEST – FIRE PUMP NO.5	46" X 25"	–	P	24	F	322	155	7	0	10	1	2	2	9	3	100-7060403	M-US-3110-01
10	SEACHEST – SSGTG CLG PUMP NO.3 & FIRE PUMP NO. 6	46" X 12"	–	S	24	A	378	95	7	0	7	10	2	8	2	0	100-7060412	M-US-3320-01
11	SEACHEST – FIRE PUMP NO. 6	46" X 12"	–	S	24	A	370	103	7	0	8	4	2	7	0	2	100-7060412	M-US-3320-01
12	CATHODIC PROTECTION (FORWARD SYSTEM)	1"	37.5 AMP ANODE 24" LG	S	0	–	69	406	7	0	10	5	0	11	9	1	600-7059070	M-IH-1320-01
13	CATHODIC PROTECTION (FORWARD SYSTEM)	1"	37.5 AMP ANODE 24" LG	P	0	–	69	406	7	0	10	5	0	11	9	1	600-7059070	M-IH-1320-01
14	CATHODIC PROTECTION (FORWARD SYSTEM)	N/A	REFERENCE CELL	S	0	–	197	278	7	0	25	9	3	12	2	1	600-7059084	M-IH-2220-01
15	CATHODIC PROTECTION (FORWARD SYSTEM)	N/A	REFERENCE CELL	P	0	–	197	278	7	0	25	9	3	12	2	1	600-7059084	M-IH-2220-01

FIGURE 2.7

Cross Section at Propellers - Use for docking clearance checks and removal clearances.

SECTION AT FR 440.70
LOOKING FORWARD
PROPELLER SHOWN IN
RECOMMENDED DOCKING POSITION
PORT SIMILAR BUT OPPOSITE
SCALE: 1/4"=1'-0"
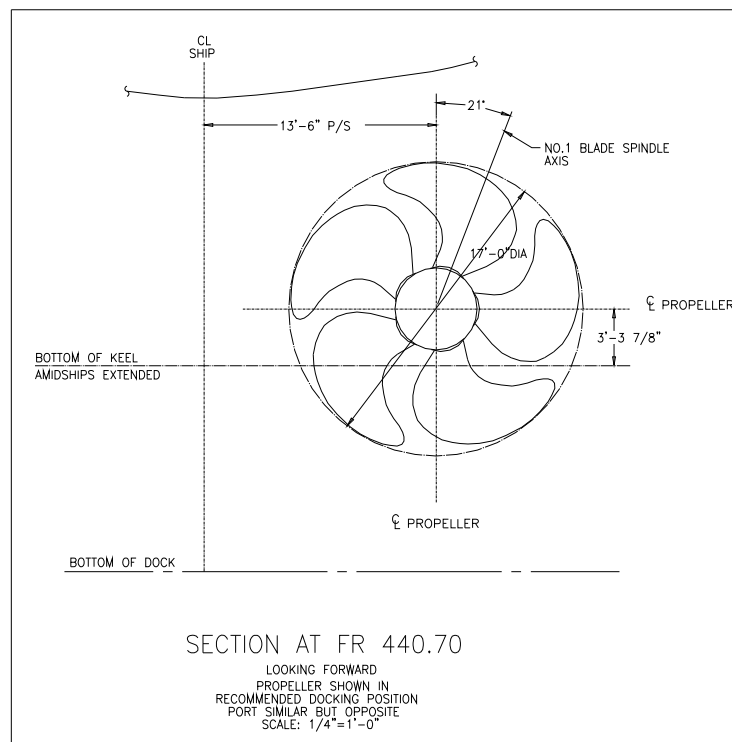
FIGURE 2.8

Keel Profile – Variations in keel block height from a theoretical straight line are shown in the detail "Keel Profile". This accounts for a vessel's sag or hog or other variations in the keel line. The baseline keel block height is adjusted to account for these variations.

KEEL PROFILE
VERTICAL SCALE: FULL
HORIZONTAL SCALE: 1/8"=1'-0"
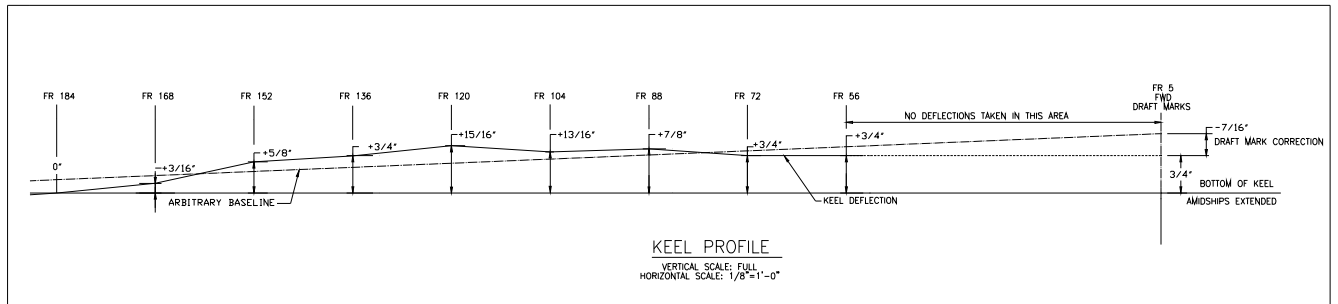
FIGURE 2.9

Blocking Position – To facilitate the complete painting of the bottom, two or more different positions for the vessel on the blocks may be indicated in the drawings and in the Table of offsets. U.S. Navy vessels usually have 3 positions, Position 1, Position 2 and Position 3. Be sure to obtain the correct docking position for this contract before proceeding with planning of the docking.

FIGURE 2.10

Table of Offsets for Side Blocks – Gives information needed for locating and constructing side blocks. Also may give bilge keel dimensions for checking clearances.

Dimensions are usually given as:

> ➢ Feet – Inches – 16[ths]

Or

> ➢ Feet – Inches –8[ths]

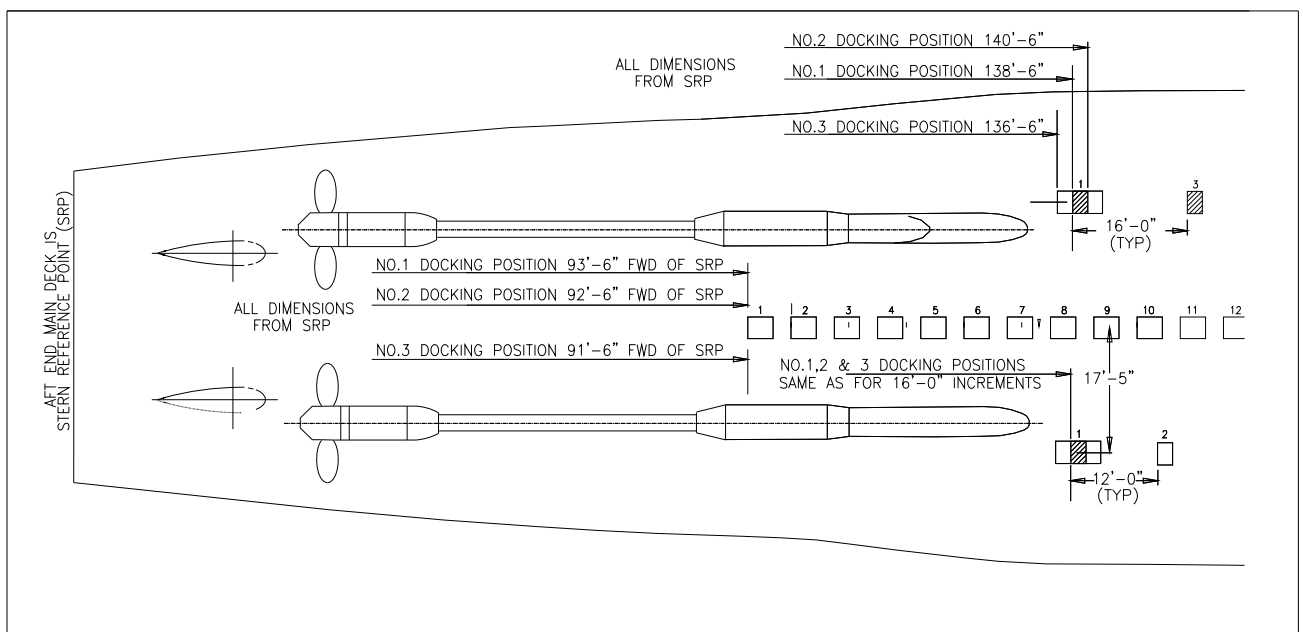| SIDE OF SHIP	BLOCK NO.	FWD OF SRP			HALF BR	POINT "A"			HALF BR	POINT "B"			HALF BR	POINT "C"			BEVEL IN 24" FOR ABC	BILGE KEEL					
						HEIGHT				HEIGHT				HEIGHT				DIM "D"			DIM "E"		
		FT	IN	1/16		FT	IN	1/16		FT	IN	1/16		FT	IN	1/16		FT	IN	1/16	FT	IN	1/16
P	4	162	6	0	9'–0"	1	11	2	7'–6"	1	5	12	10'–6"	2	5	1	–1 1/16	25	1	6	7	4	10
S		↓				1	11	2		1	5	12		2	5	1	–1 1/16	25	1	6	7	4	3
P	5	170	6	0		1	6	13		1	2	3		1	11	14	–7/8	25	2	13	6	9	4
S		↓				1	6	11		1	2	1		1	11	12	–7/8	25	2	13	6	9	1
P	6	178	6	0	11'–3"	1	10	3	9'–9"	1	5	8	12'–9"	2	3	12	–1	25	4	1	6	2	7
S		↓				1	10	0		1	5	5		2	3	9	–1	25	4	1	6	2	3
P	7	186	6	0		1	6	11		1	2	9		1	11	9	–13/16	25	5	4	5	8	6
S		↓				1	6	8		1	2	6		1	11	6	–13/16	25	5	4	5	8	3
P	8	194	6	0		1	3	11		1	0	1		1	8	0	–11/16	25	6	6	5	3	13
S		↓				OMIT	–	–		OMIT	–	–		OMIT	–	–	–	25	6	6	5	3	11
P	9	202	6	0		1	1	4		0	10	1		1	5	1	–9/16	25	7	7	5	0	7
S		↓				1	1	2		0	9	15		1	4	15	–9/16	25	7	7	5	0	5
P	10	210	6	0		0	11	10		0	8	12		1	3	2	–3/8	25	8	7	4	9	11
S		↓				0	11	6		0	8	8		1	2	14	–3/8	25	8	7	4	9	10

TABLE OF OFFSETS FOR SIDE BLOCKS & BILGE KEEL FOR POSITION 1
INTERVALS GIVEN IN INCREMENTS OF 8'–0"

FIGURE 2.11

Each block usually has three points, "A", "B", and "C". These points are located on the aft side of the block. The table gives the longitudinal dimension from the SRP to the aft side of the block where these point are located. Each point's height above base line and half breadth distance from vessel centerline is given in the table. The base line is usually the bottom of keel amidships extended.

FIGURE 2.12

The table also gives the bevel at each point. This is the slope of the block in the forward and aft direction.

LONGITUDINAL ELEVATION OF SIDE BLOCK SHOWING BEVEL

FIGURE 2.13

If there is a bilge keel in the location of the side block the table will give its position relative to the ship's baseline and centerline. This is important when determining clearances between ship and blocks.
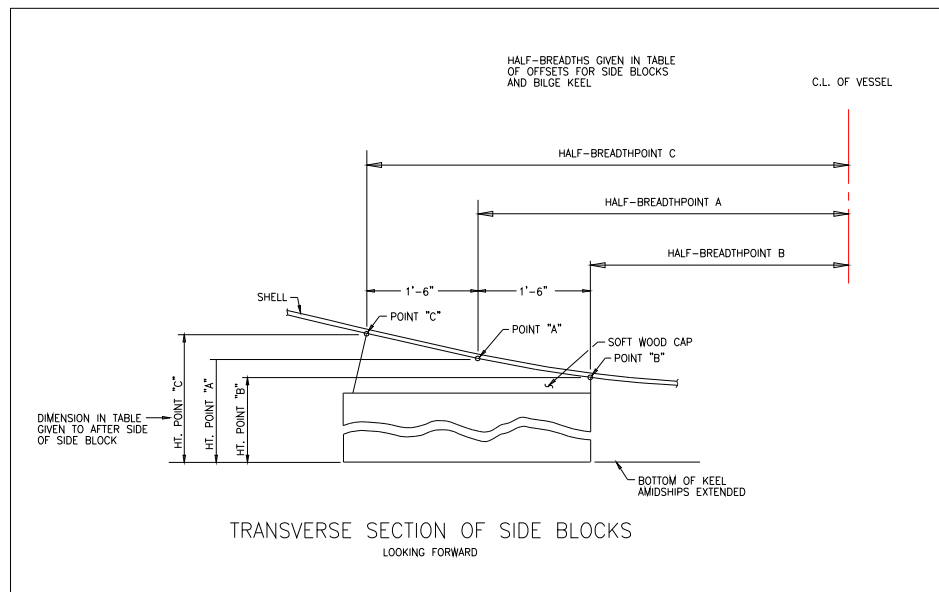

TRANSVERSE SECTION AT BILGE KEEL

FIGURE 2.14

Block Pressure - Table of Average Block Pressures – Shows block areas and average block pressures with fully loaded ship.

BEARING ON SHELL PLATE IN WAY OF BLOCKS			
SUPPORT	8 FT SPACING	12 FT SPACING	16 FT SPACING
SIDE BLOCKS NET BEARING AREA 24" X 36"	26784 IN^2 186 FT^2	22464 IN^2 156 FT^2	17280 IN^2 120 FT^2
KEEL BLOCKS NET BEARING AREA 12" AVG X 42" (AFT FR 354)	2520 IN^2 17.50 FT^2	2520 IN^2 17.50 FT^2	2520 IN^2 17.50 FT^2
KEEL BLOCKS NET BEARING AREA 24" X 42" (FWD FR 354)	42336 IN^2 294 FT^2	42336 IN^2 294 FT^2	42336 IN^2 294 FT^2
TOTAL BEARING AREA	71640 IN^2 497.50 FT^2	67320 IN^2 467.50 FT^2	62136 IN^2 431.50 FT^2
BEARING PER SQ FT BLOCKING	18.59 LT/FT^2	19.79 LT/FT^2	21.44 LT/FT^2
BEARING PER SQ IN BLOCKING	289.2 LBS/IN^2	307.8 LBS/IN^2	333.5 LBS/IN^2

BASED ON FULL LOAD DISPLACEMENT = 9250 L. TONS
ALL BEARINGS BASED ON DOCKING POSITION NO. 2.

FIGURE 2.15

CAUTION – Average block pressure is just the weight of the vessel divided by the total bearing area. It does not account for eccentrically loaded blocks and thus does not give an indication of actual block pressures. Use the trapezoidal load equation (or other more detailed methods) to determine more accurate block loads.

The U.S. Navy requires the average bearing stress to be less than 20.0 Long Tons per Foot[2].

Trim Tables – Trim tables are sometime provided to show the increase in draft at the sonar dome or propellers caused when the vessel is floating at a trim. This data is helpful when calculating clearances of these objects during docking, undocking and landing.

TRIM BY BOW DEPTH REQUIRED BELOW BOTTOM OF KEEL FOR 2" CLEARANCE OF SONAR DOME BOTTOM			
TRIM FT	FEET	INCHES	EIGHTHS
0	10	1	5
1	10	3	0
2	10	4	3
3	10	5	6

FIGURE 2.16

TRIM BY STERN DEPTH REQUIRED BELOW BOTTOM OF KEEL FOR 2" CLEARANCE OF PROPELLER TIP (ONE BLADE DOWN)			
TRIM FT	FEET	INCHES	EIGHTHS
0	5	4	3
1	5	5	7
2	5	7	2
3	5	8	5

FIGURE 2.17

2.2 – Modifying the Docking Plan

Many times a vessel with a docking plan developed with certain English or Metric spacing for its side blocks will be entering a dry dock with frames spacing unequal to the docking plan's side block spacing. It is imperative that all blocking must fall over a strength point in the dock and under a strength point in the ship. In order to achieve this, the ship's original docking plan must be modified to suit the dry dock.

Whenever the original vessel docking plan is modified to suit a dry dock the following criteria should be met:

➤ The total number of blocks used should provide enough timber bearing area against the hull to limit the maximum bearing stress to 20 long tons/Ft^2 or less. This insures the hull will not have excessive loads that could damage it. This can be checked by dividing the vessel's docking weight by the total bearing area of all blocks (Keel and side).

➤ If keel blocks have been omitted or repositioned the load per foot along the keel should be calculated (using the trapezoidal loading equation or other appropriate method) to insure the dock's rated load per foot is not exceeded.

➤ The new position of the side blocks must be checked to insure they fall under a strength point in the vessel (usually a longitudinal girder) and over a strength point in the dock (usually a transverse frame).
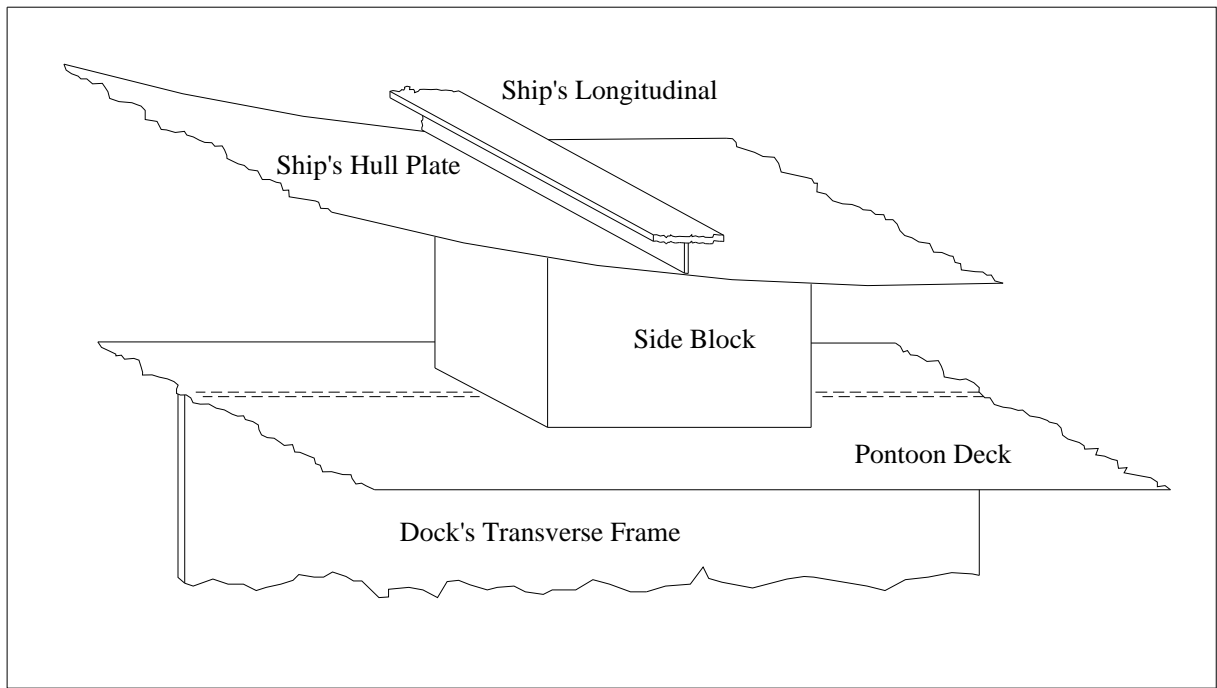
FIGURE 2.18

➢ You must insure the side blocks do not interfere with an underwater hull opening or protrusion in their the new positions. The new position of the side block should be cross checked with the "List of Shell Openings Below The waterline".

➢ The heights and offsets of the blocks for their new position must be determined by interpolating between the two closest positions given in the table, one position either side of the desired location. The docking plan usually gives multiple locations for various blocks. (Positions 1, 2 and 3 for 8', 12' and 16' spacing for example.) Check all tables for the closest block position just forward and just aft of the desired position. Use these closest blocks for interpolating the new heights.

CAUTION – When interpolating block heights, the position of the known blocks used for interpolating should be within a reasonable distance of the block being calculated. Also, be sure that the half breadths for all blocks used in the interpolation are the same or nearly the same. Otherwise you run the risk of using two blocks that are located on different longitudinals in the vessel and the resulting location for the new block will fall between longitudinals which is what you do not want. You must insure that the new block position falls under structure in the vessel. (Usually a longitudinal girder.)

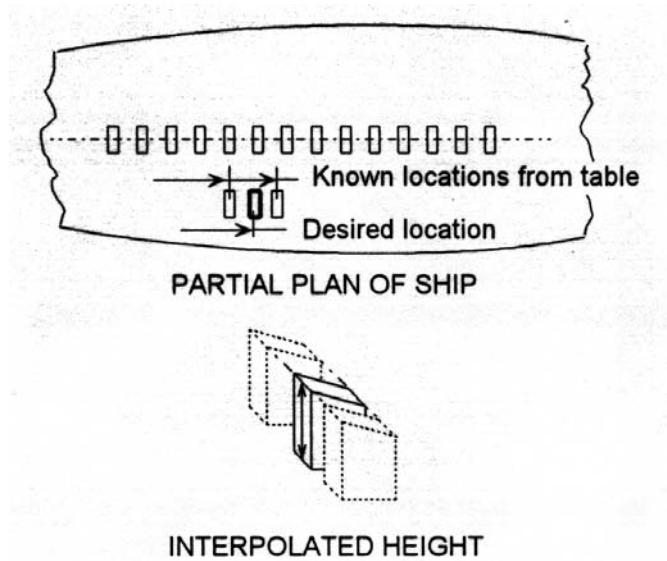PARTIAL PLAN OF SHIP

INTERPOLATED HEIGHT

FIGURE 2.19

If all known points of side block heights and offsets are plotted, side block curves can be developed. These can be used for interpolating heights and offsets graphically.
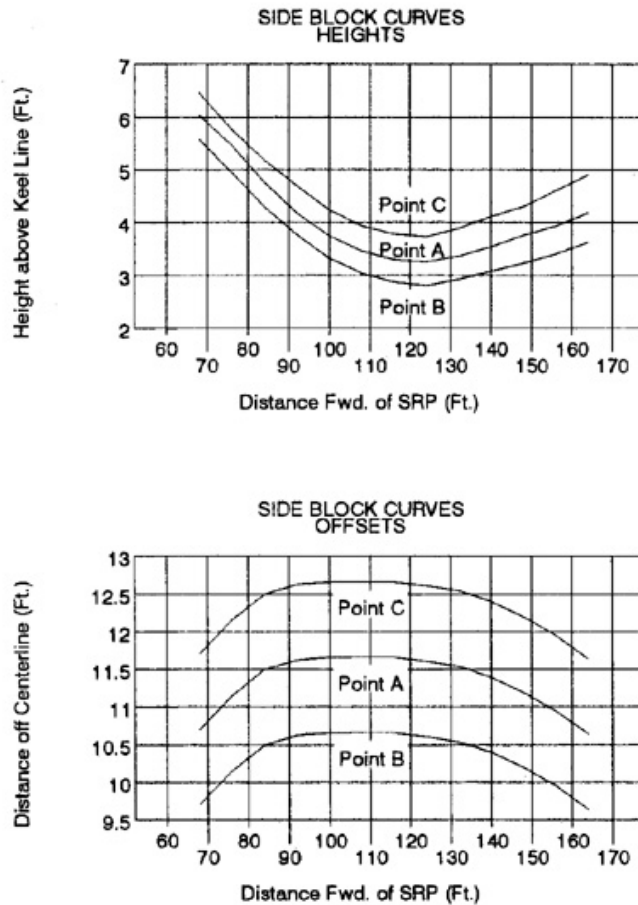

SIDE BLOCK CURVES
HEIGHTS

SIDE BLOCK CURVES
OFFSETS

FIGURE 2.20

➢ A sufficient number of side blocks must be provided Port and Starboard to resist hurricane and earthquake overturning forces. See Chapter 4.

2.3 – When There is No Docking Plan

Docking a vessel without a docking plan is risky as there is no easy way to determine vessel properties, location of hull openings below the waterline, ship's strong points for block locations etc. Many commercial vessels have no docking plan or an incomplete docking plan that forces the dockmaster to estimate vessel properties and obtain block information by other means.

It is important to remember that the information that you will use in planning the docking will be estimates. You want to remain well below the limits of the dry dock when planning a docking in this way.

The first step is to try to get as much information as possible on the vessel. This can be done by:

➢ Contacting yard where ship was last dry docked. Talk to dockmaster
➢ Consulting previous docking reports or docking plans of sister ships.
➢ Contacting shipyard where ship was built.

Estimate Basic Vessel Characteristics

You can estimate the docking weight of the vessel by field measurement of drafts (D), length @ waterline (L) and beam (B).

The estimated weight is =

➢ L x B x D x B_{coef}. / 35 (salt water)

➢ L x B x D x B_{coef}. / 36 (fresh water)

Where B_{coef} is the block coefficient for this particular hull form. See Section 3 for more information on how to estimate displacement using block coefficients.

Estimate Block Loading

Dividing the estimated weight by the keel block length results in the average load per foot on the blocks. If this is near the dock's limit you probably shouldn't dock the vessel as the maximum load may be greater due to the eccentricity of the vessel's LCG with the center of blocking. If the average load per foot is well below the dock's limit than you can calculate what eccentricity the vessel COULD have before exceeding the dock's limit. If this eccentricity is very large and there seams to be no reason for the vessel to have a large eccentric loading than the load per foot is probably acceptable.

See Section 4 for more information on block loading.

<u>**Stability Check**</u>

There is no easy way to estimate the vessel's vertical center of gravity without information from the ship. You can probably assume the vessel is stable when she arrives at the shipyard. You must minimize all destabilizing effects when docking the ship. This includes:

> ➢ Keep docking trim to a minimum (Keel block line should match vessel trim)
> ➢ Pull sliding side blocks before lifting vessel too much
> ➢ Eliminate free liquids on board
> ➢ Undock in the same condition as docking

For floating docks consult the KG vs. Wt. Curve for the FDD – does maximum allowable KG for the estimated displacement seem comfortable for this vessel?

See Section 5 for more information on stability.

<u>**Layout of Blocking:**</u>

It is extremely difficult to get accurate measurements of the vessels hull for constructing fixed side blocks. Some methods tried in the past are:

> ➢ Measure heights & offsets from within ship (Usually has many obstructions)
> ➢ Measure heights & offsets from exterior (Very inaccurate due to wind, waves etc.)
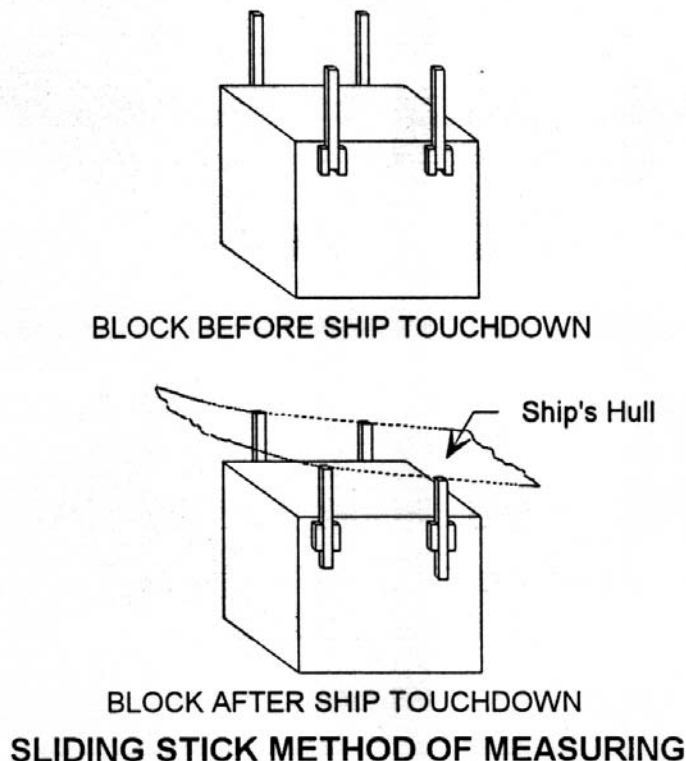> ➢ Sliding stick method of measuring heights (See Figure below)

BLOCK BEFORE SHIP TOUCHDOWN

BLOCK AFTER SHIP TOUCHDOWN

SLIDING STICK METHOD OF MEASURING

FIGURE 2.21

In the sliding stick method side blocks are positioned with no caps. Sliding sticks extend up beyond the point of contact with the vessel when the vessel has landed on the keel blocks. The vessel is brought in the dock and landed on the keel blocks but not lifted more than a few inches. The hull shape depresses the sliding sticks in the shape of the hull. The vessel is removed from the dock, the dock pumped up and the side blocks built to the shape of the sticks.

Whenever possible sliding side blocks should be used when docking a vessel of unknown shape. Round caps contact the hull as the blocks are pulled in. Because round caps only provide a small bearing area they can only support light loads.

In any event plenty of soft wood should be used in the block build to allow for crush of blocks estimated too high.

Divers should always be used to check the fit of the blocks at the time of landing the vessel.

3.0 – SHIP CHARACTERISTICS IMPORTANT TO DRY DOCKING

The vessel's dimensions, strength, and hydrostatic properties will have a profound effect on how that vessel is docked. These characteristics must be determined, or estimated, before detailed planning of the drydocking can begin.

3.1 – Dimensions & Clearances

Obviously, one of the first things to check before docking a vessel are dimensions and clearances – can the ship fit in the dry dock?
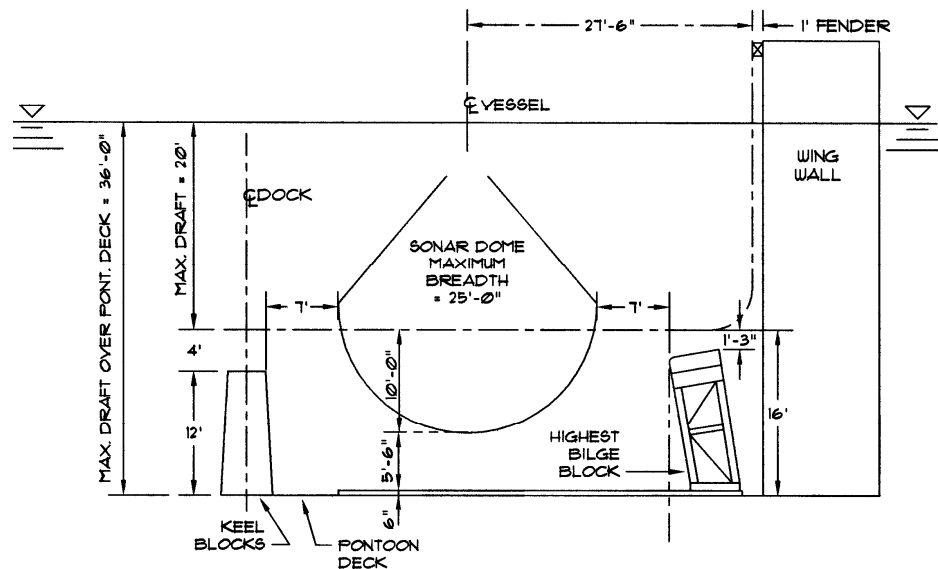
VESSEL CLEARANCES

FIGURE 3.1

Is the beam of the vessel less than the clear width of the dock with enough room for positioning the vessel? Is there enough room along the sides for working on the vessel?

For a basin type dock, is the vessel length less that the clear dock length?

For docks that allow vessel overhang, is the vessel keel block length less than the dock supporting length?

Does the draft of the vessel and the depth of water over the dock blocks allow enough clearance between ship and blocks? Be sure to allow for all hull protrusions such as fin stabilizers, sonar domes, propellers, etc. Usually 12" of vertical clearance between the ship and blocks is sufficient. Lateral clearance (side to side) between ship and blocks should be greater. The actual minimum acceptable lateral clearance is dependent on the degree of control the dockmaster has on the vessel as it enters the dock. For example, smaller

clearances may be acceptable if a centering trolley or breasting roller is to be used to guide the vessel into dock versus using typical breasting and springing lines.

Hull openings & protrusions must clear blocks as the ship lands. Divers should be used to check if the ship is positioned right and if the proper blocks have been omitted before the ship is brought to bear on the blocks.

Most information required to check clearances can be found on a good docking plan. For information not on the plan, physical measurements of the vessel can be made.

A diver's check of the fit of the blocks before landing and just after landing is always recommended. The docking plan may be wrong, the blocks may be built wrong, the ship may be positioned wrong or debris may be caught between the vessel and blocks. The only way to determine this is with a diver's check.

3.2 – Ship Strength

A floating vessel is supported continuously over its immersed portions. Water pressure gradually increases from 0 at the waterline to it's maximum at the ships keel. This results in a uniform cradling of the hull by the water, supporting the ship with relatively small forces over a large area.

When the vessel is drydocked, that support is substituted with a small number of point loads at the location of the keel and side blocks. See Figure 3.2.

It is the dockmaster's responsibility to insure the blocks are placed in such a manner as to not overstress the vessel's hull.
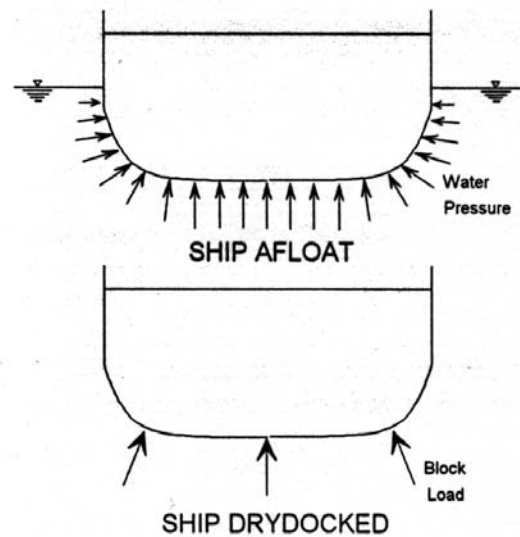
FIGURE 3.2

Fortunately, the ship has been designed to withstand the harsh environment of the sea which results in an extremely rigid structure quite suitable for docking. This rigidity results in the distribution of concentrated weights due to machinery, fuel, cargo, etc. to a fairly uniform load along the keel block line.

This is the fundamental premise for the trapezoidal block load calculations that we derived in Section 4, "Block Loading".

The vessel's centerline keel is usually (but not always) strong enough to be supported by blocking anywhere along its length.

FIGURE 3.3

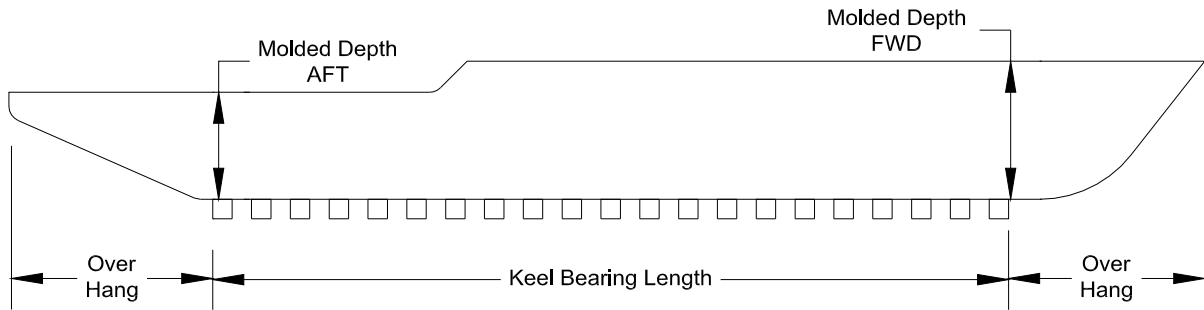Many times the keel bearing length of the dry dock is shorter than the vessel being docked. This requires the ship to overhang the keel blocks at one or both ends. See Figure 3.3.

The ship's longitudinal strength is usually great enough to permit an overhang.

RULE OF THUMB: Vessel Overhangs

A safe overhang for an UNLOADED vessel is 1.5 to 2 times it's molded depth.

Heavy weights, cargo, fuel, ballast, ect. should not be located on the overhung portions of the vessel.

Placement of the side blocks, must be done with care or damage to the hull may result. Side blocks must be located over a strength member of the dry dock (such as a transverse frame) AND under a strength member in the ship (such as a longitudinal frame).

It is unlikely that the frame spacing in the ship will match the frame spacing in the dry dock. This makes it difficult to align transverse frames of the ship with transverse frames of the dock. By selecting transverse frames in the dry dock and longitudinal frames in the ship, the blocks can be placed at their intersection and be located at a strength points of both ship and dock. See Figure 3.4.
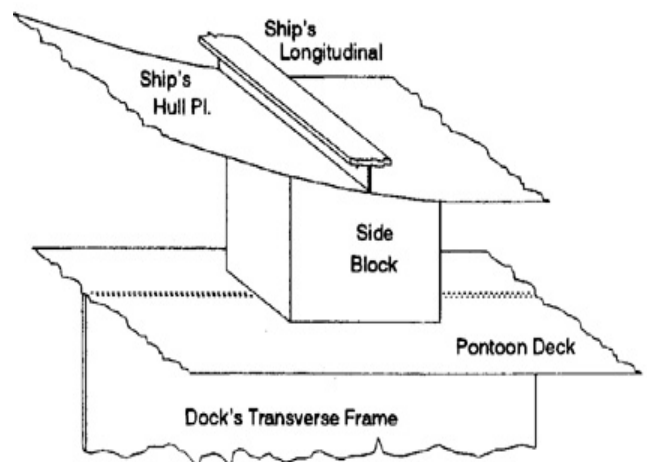

FIGURE 3. 4

3.3 - Hydrostatic Properties

The hydrostatic properties that are important to drydocking are:

- ➤ **DISPLACEMENT** – the actual weight of the vessel as she floats. It is called displacement because the vessel displaces a volume of water that weighs exactly what the ship weighs.

- ➤ **LONGITUDINAL CENTER OF BUOYANCY (LCB)** – the point in the ship's water plane at which the vessel rotates if weights are shifted on board. This is the only point on the vessel where the draft does not change when weights are shifted on board.

- ➤ **MOMENT TO CHANGE TRIM 1" (MT1)** – is the moment that must be applied to the vessel to change its trim 1".

- ➤ **TONS PER INCH IMMERSION (TPI)** – is the amount the displacement increases (in tons) by increasing the draft 1".

- ➤ **KB** – is the height of the center of buoyancy above the vessel's keel.

- ➤ **KM** – is the height of the transverse metacenter above the vessel's keel.

3.4 – Calculation of Displacement

According to Archimedes' Principle:

> *"A body immersed in a fluid is buoyed up by a force that equals the weight of the displaced fluid."*

Therefore, if we can calculate the volume of the vessel's hull below the waterline, and we know the density of that water, we can determine the exact weight of the vessel by multiplying that volume by the density (unit weight).

The volume of the hull below the waterline is the volume of water that is displaced by the vessel, hence the term "Displacement".

Most docking plans will have a "Table of Displacements" which list the exact displacement at various drafts. See Table 3.1.

The table is set up for drafts at the longitudinal center of floatation (LCF). This is because the LCF is the point the vessel rotates about if weights are shifted on board. Thus, for any given displacement of the vessel, the draft at the LCF will remain the same no matter how the weight is positioned on board.

If weight is shifted from stern to bow, the draft forward will increase, the draft aft will decrease but the draft at the LCF will remain the same (since this is the point the vessel rotates about). See figure 3.5.
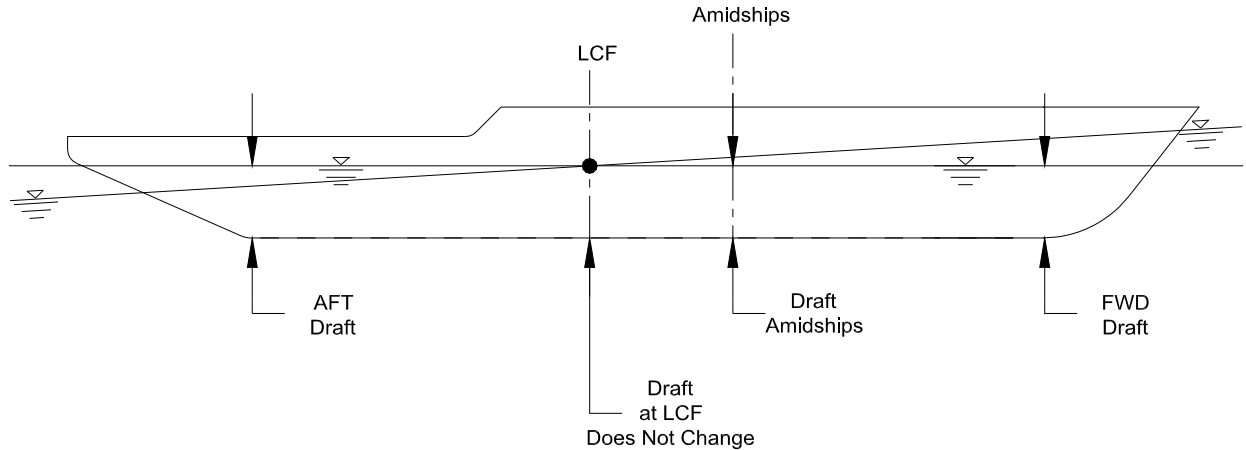
FIGURE 3.5

Hence, for a vessel with a certain displacement, the draft at the LCF will remain the same no matter what trim the vessel is in or alternatively, if the draft at the LCF is used to enter the "Table of Displacements", the resulting displacement will be correct for the vessel no matter what its trim.

If the vessel is not on a trim, then the draft is the draft at the LCF, and the "Table of Displacement" can be entered directly to determine the vessel's displacement. Straight line interpolation can be used to determine displacements for drafts falling between the data points.

For vessels with a trim, the draft at the LCF must be determined, and that draft entered into the table. It is best to demonstrate this with an example.

EXAMPLE – CALCULATING DISPLACEMENT

Given:
Draft Fwd. = 18.0 feet, Draft Aft = 20.0 feet
Mean Draft = (18.0 + 20.0)/2 = 19.0 feet

Enter "Table of Displacements" with mean draft of 19.0'.

TABLE 3.1

TABLE OF DISPLACEMENT AND OTHER PROPERTIES						
Mean Draft (Ft)	Displ (LTs)	MT1 (Ft-LT)	LCB FWD of SRP (Ft)	TPI (LTs)	LCF Aft of Amidships (Ft)	LCF FWD of SRP (Ft)
17.0	6390	1371	247.0	48.55	37.75	199.75
18.0	6980	1475	243.0	50.05	41.60	195.90
19.0	7270	1522	240.0	50.80	42.60	194.90
20.0	8075	1552	237.0	51.35	42.75	194.75
21.0	8815	1578	235.0	51.75	42.75	194.75

Find that LCF is 194.9' forward of SRP at draft of 19.0'.

From Docking Plan:

> ➢ Distance between draft marks = 475 feet
> ➢ Distance SRP to Aft draft mark = 12 feet

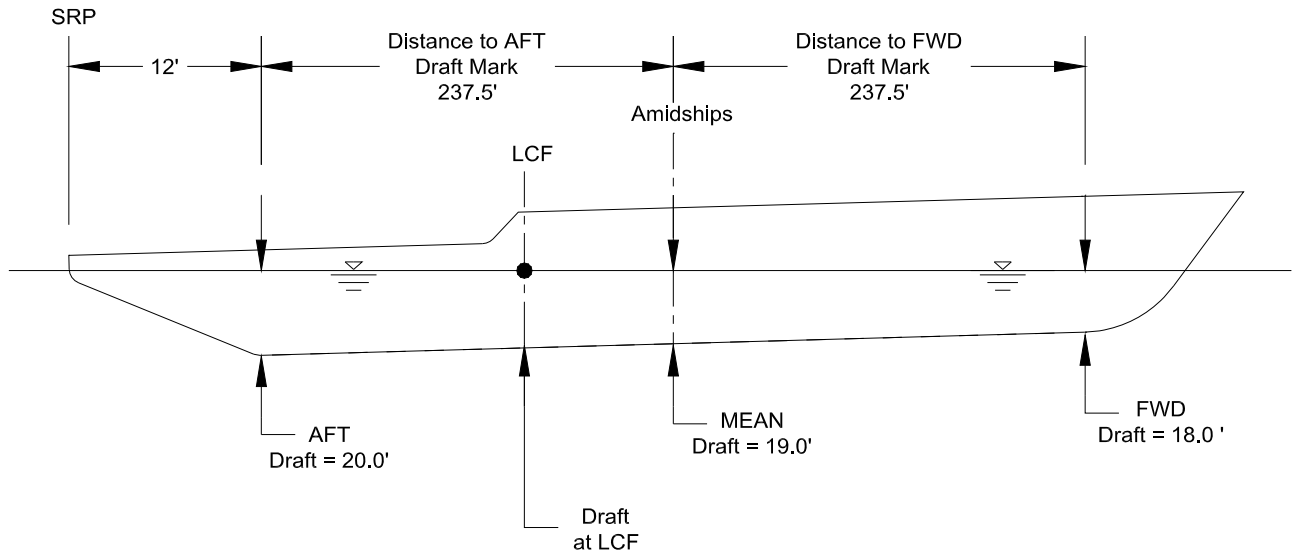Therefore, LCF is (194.9 – 12.0) = 182.9' forward of aft draft mark.

FIGURE 3.6

To figure the new draft of LCF (182.9' FWD of aft draft mark):

> ➢ The draft is decreasing at a rate of 2.0 feet in 475 feet as we go forward on the ship (20'-18' in a length between draft marks = 475').
> ➢ This is a rate of 2.0'/475' or 0.00421 feet/foot x 182.9' = 0.77 feet at the LCF.
> ➢ So the draft at the LCF is 20 – 0.77 = 19.23 feet.

The "Table of Displacements" can be entered with the draft at LCF to find the actual displacement of the vessel.

Draft at LCF = 19.23'.

> ➢ Displacement at 19.0 feet = 7270 LT.
> ➢ Displacement at 20.0 feet = 8075 LT.

Interpolate:

> ➢ 0.23 x (8075 – 7270) + 7270 = 7455 LT.

Calculation of Displacement When Hydrostatic Properties Are Not Available

For some vessels, the "Table of Displacements" may not be available. The displacement of the vessel can still be roughly estimated without this table however.

According to Archimedes' Principle, the weight of the vessel is equal to its displaced volume times the unit weight of water. If we can estimate the displaced volume of water (volume of the hull below the water line), we can estimate the weight of the vessel.

Multiplying the vessel's length, beam, and draft gives the volume of a rectangle of the same dimensions. The immersed portion of the ship fits into this rectangle, but its volume is not as great as the rectangle's due to the shape of the vessel. See Figure 3.7.

The volume of the ship can be approximated by multiplying the volume of the rectangle by a "Block Coefficient" (C_b) to account for volume of the rectangle not included in the ship (shaded portions of Figure 3.7).
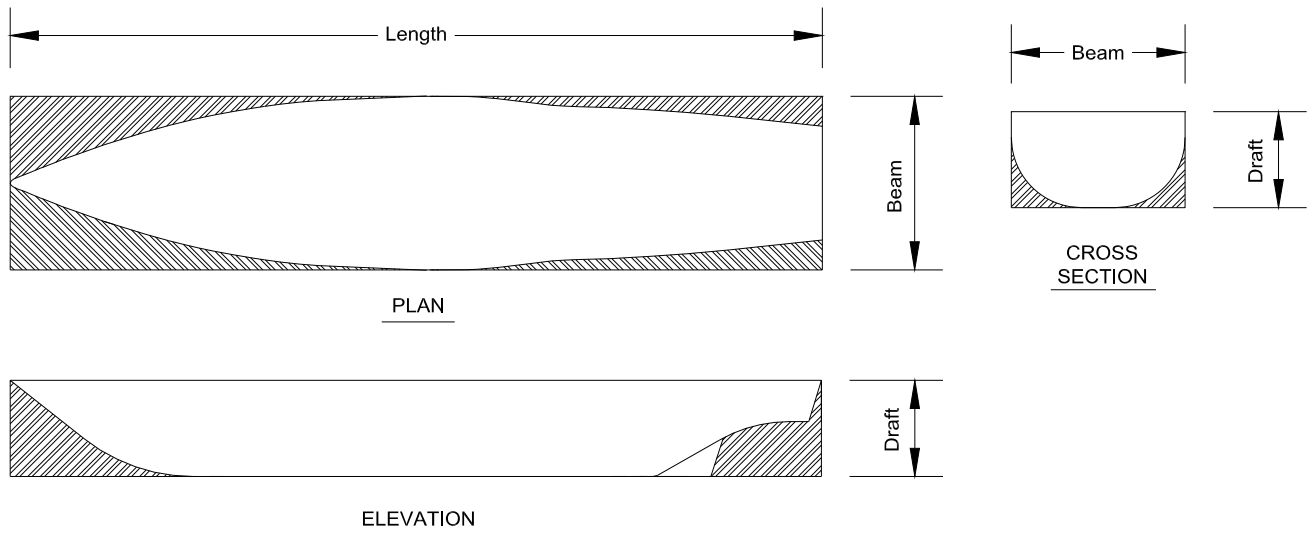

FIGURE 3.7

The block coefficient is dependent on the shape of the vessel below the waterline and is different for different types of vessels. The more shape a vessel has the lower the block coefficient will be since the vessel fills a smaller percentage of the rectangle.

A barge that is fairly rectangular may have a block coefficient of 0.90 or 0.95 while a finely shaped ferry boat may have one of 0.43.

A vessel's block coefficient may also change with draft. The deeper the draft, the "boxier" the vessel is, percentage wise, so its block coefficient will be higher.

With the volume displaced by the ship known, its weight can be calculated by multiplying the volume by the weight of water per cubic foot.

The equation to estimate the ship's weight in long tons using the block coefficient is:

Weight $_{Ship}$ = C_b x L x B x D x 62.4 x S.G. / 2240

Where:

C_b = Block Coefficient from Table 3.2
L = Length of vessel at waterline in feet
B = Beam of vessel at waterline in feet
D = Average draft of vessel in feet
62.4 = Weight of fresh water in Lbs/Ft^3
S.G. = Specific gravity of the water the vessel is floating in
      S.G. = 1.0 for fresh water
      S.G. = 1.025 for salt water
      S.G. can be anywhere in between for brackish – use 1.012 as estimate
2240 = No. of pounds in a long ton

For typical Block Coefficients of various types of vessels see the "Block Coefficient Table" in Table 3.2. (From Crandall 1978)

TABLE 3.2

| TYPICAL BLOCK COEFFICIENTS Ships in Light Condition	
Great Lakes Freighters and Tankers	0.73 - 0.75
Ocean Cargo Ships	0.50 - 0.65
Ocean Tankers	0.60 – 0.70
Ocean Tugs and Trawlers	0.54 – 0.56
Passenger Liners	0.55 – 0.60
Ferry Boats	0.42 – 0.44
Harbor Tow Boats	0.50 – 0.52
Fishing Schooners	0.40 – 0.45
Naval Destroyers	0.52
Naval Cruisers	0.57
Coast Guard Cutters	0.51
VLCC & ULCC	0.78 – 0.80
LNG Ships	0.65 – 0.70
Bulk Carriers	0.71 - 0.77

3.5 – Longitudinal Center of Buoyancy (LCB)

In order to calculate the load the vessel imposes along the keel block line we need to know not only the weight of the vessel, but also the location of its effective center, longitudinally on the ship. Refer to Chapter 4, "Block Loading."

In a floating body at rest, the location of the center of gravity (effective center of all weights) must exactly coincide with the center of buoyancy which supports that weight. Thus the longitudinal center of gravity (LCG) of a vessel must fall directly over the longitudinal center of buoyancy (LCB). The longitudinal center of buoyancy is the longitudinal center of the volume of the immerse portion of the hull.

This longitudinal center of volume has been pre-calculated for various drafts of the vessel assuming the vessel has no trim. See Figure 9. If the vessel is actually floating with no trim, the center of volume, (which is the center of buoyancy), for that particular draft, has been pre-calculated and can be picked directly off the table by interpolation. See Table 3.1.
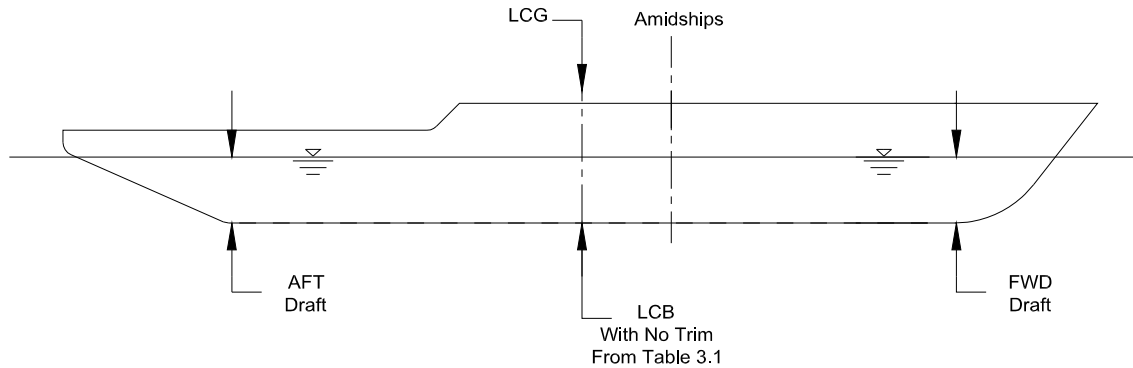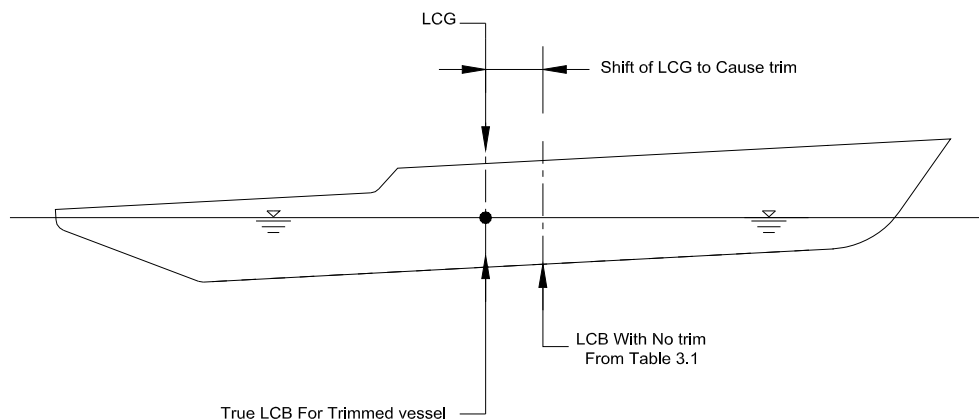

LCG - VESSEL WITH NO TRIM

FIGURE 3.8

The center of gravity must be directly over the center of buoyancy, so, for a vessel with no trim, the LCG is equal to the LCB picked directly off the table.

If the weight on the vessel is distributed such that its longitudinal center of gravity does not fall directly over the LCB of the vessel with no trim, then the vessel must take on a trim to shift the center of buoyancy to align directly under the LCG. See Figure 3.9.

The amount of trim will depend on the amount the LCG has been shifted from the theoretical LCB with no trim.

LCG - VESSEL WITH TRIM

FIGURE 3.9

The shift of the LCG from the no-trim location can be determined using the moment to trim values for the vessel.

The Moment to trim 1" (MT1) is the moment which must be applied to the vessel to cause a 1" trim between its perpendiculars. Multiplying the moment to trim 1" (MT1) by the vessel's actual trim between perpendiculars in inches, results in the moment which must be applied to the vessel to cause the trim. This moment is caused by the entire weight of the vessel theoretically being shifted aft (or forward for a trim by the bow) from the no-trim LCB position until the trim is achieved. See Figure 3.9. Moment is equal to force times distance, and in this case the force is equal to the weight of the vessel (displacement) and the distance is equal to the shift of the LCG from the no-trim LCB position.

With the total moment to cause the trim known, (MT1 x trim in inches) and the displacement known, the shift can be calculated by the equation:

Shift of LCG = Moment to cause trim/Displacement

Shift of LCG = (MT1 * TRIM) / Displacement

This gives the actual location of the longitudinal center of gravity (LCG) for the vessel floating at that trim.

CALCULATION – SHIFT OF LCG

From previous Example:
  ➢ Displacement = 7,455 Long Tons
  ➢ Draft @ LCF = 19.23 feet
  ➢ Trim = 2.0 feet

Enter "Table of Displacement" to get:
  ➢ LCB @ 19.0' Draft = 240' Fwd SRP
  ➢ LCB @ 20.0' Draft = 237' Fwd SRP
  ➢ MT1 @ 19.0' Draft = 1522 Ft.-LT
  ➢ MT1 @ 20.0' Draft = 1552 Ft.-LT

Interpolate to get properties at 19.23' Draft:
  ➢ LCB @ 19.23' Draft (No Trim) = 240-[(.23)(240-237)] = 239.31' Fwd SRP
  ➢ MT1 @ 19.23' Draft = 1,522+[(.23)(1,552-1,522)] = 1,528.9 Ft.-LT

Vessel Trim = 2'

Moment required to cause 2.0' trim = 2.0' x 12"/' x 1,528.9 Ft.-LT/" = 36,693 Ft.-LT

Moment = Force x Distance ➔ Moment = Displacement x Shift
  ➢ 36,693 Ft.-LT = 7,455 LT x Shift
  ➢ Shift = 36, 693 Ft.-LT / 7,455 LT = **4.92 feet (Aft)**

Final location of LCB (or LCG):
  ➢ 239.31' – 4.92' = 234.39' Fwd of SRP

3.6 – KM and Stability

When investigating stability of a floating body, two points are critical, M and G. (Refer to Figure 3.10.)

M is the Transverse Metacenter, which is the point in which vertical lines through the center of buoyancy (B) will pass for any small angle of list. (< 7 to 10 degrees).

G is the location of the vertical center of gravity of the vessel and all weights aboard the vessel.
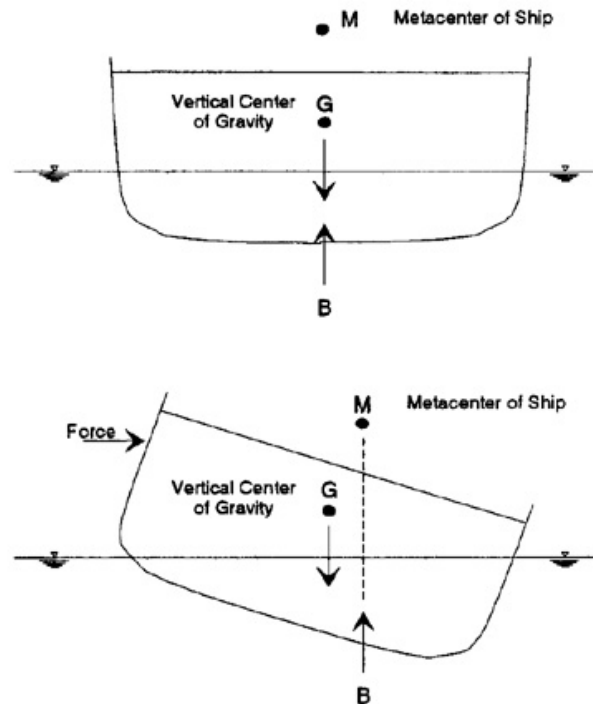

FIGURE 3.10

It can be seen from Figure 3.11 that as long as the center of gravity (G) of the vessel falls below the Transverse Metacenter (M), a restoring moment will develop between the weight and the buoyancy when an external tipping force (such as wind) causes a slight list. This restoring moment tends to reduce the list and right the vessel back to its original upright position.
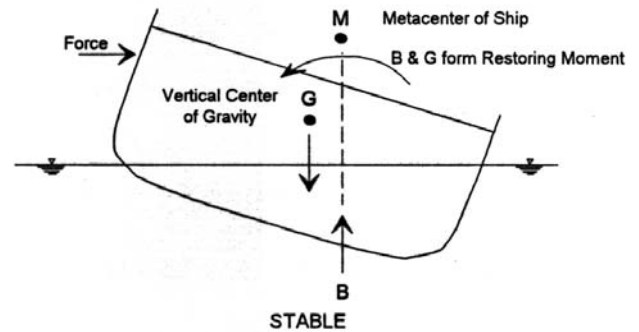
When the center of gravity (G) of the vessel falls above the Transverse Metacenter (M), any slight list will result in the weight and buoyancy forming an additional tipping moment. See Figure 11. This moment tends to increase the list resulting in the vessel turning over. The vessel is not stable.
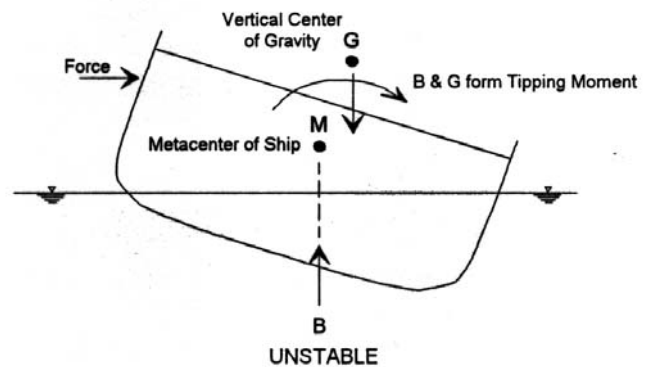
For calculation purposes the points G and M are usually referenced to the keel of the vessel designated as K. See Figure 3.13. Thus, the distance KM refers to the height of the Transverse Metacenter (M) above the ship's keel (K). The distance KG refers to the height of the ship's vertical center of gravity (G) above the ship's keel (K).

The measurement KM is a function of the ship's hull shape below the waterline and will vary as the ship's draft varies. Thus for any particular draft, a vessel will have a set KM. The values of KM for a particular ship at varying drafts can be found on the ship's D & O curves (Displacement & Other Curves) and may also be in the damage control or stability books.
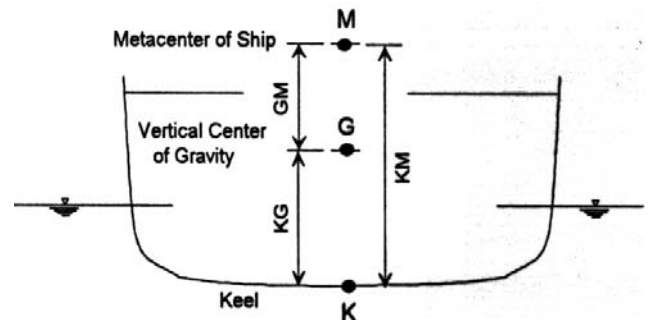
Unfortunately, the values of KM are not usually found on the docking plan.

The measurement KG is a function of the vertical center of gravity of the vessel and all weights on the vessel. This height varies as weight is added, removed or shifted.

FIGURE 3.11

FIGURE 3.12

FIGURE 3.13

The measurement GM is the Basic index of stability and it is the distance between the transverse metacenter (M) and the vertical center of gravity (G).

$$GM = KM - KG$$

If the transverse metacenter (M) is ABOVE the center of gravity (G) then GM is positive and the vessel is stable. If the transverse metacenter (M) is BELOW the center of gravity (G) then GM is negative and the vessel is not stable. See Figure 3.12.

Please refer to Chapter 5, "Stability" for more information on vessel stability afloat and during drydocking.

3.7 – KB

KB is the vertical height of the center of buoyancy (centroid of the underwater hull) above the keel (K). It is used in determining the value of KM, if KM has not been pre-calculated.

$$KM = KB + BM$$

3.8 – Stern Reference Point (SRP)

The Stern Reference Point is usually the aftmost point on the vessel. Usually, all longitudinal dimensions on the blocking plan are referenced to the SRP.

3.9 – Aft Perpendicular (AP) and Forward Perpendicular (FP)

The aft perpendicular (AP) is defined as a vertical line through the intersection of the Designed Water Line (DWL) and the after side of the straight portion of the rudder post.

The forward perpendicular (FP) is defined as a vertical line through the intersection of the Designed Water Line (DWL) and the forward side of the stem.

The location of the AP and FP is needed when calculating trim of a vessel because the moment to trim 1 inch is defined as the moment required to cause a trim of 1" **between the AP and FP** and not the trim between draft marks.

3.10 – Amidships

Amidships is usually defined as halfway between the vessels perpendiculars.
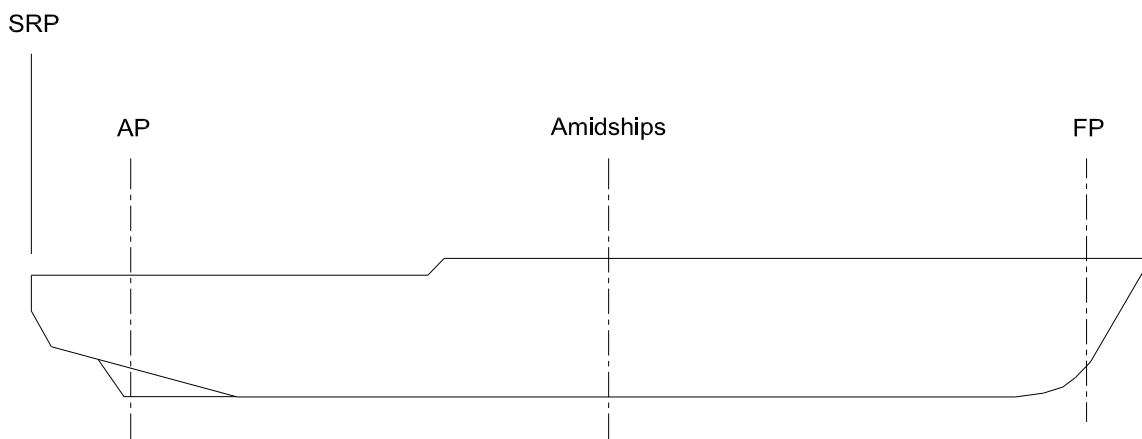
LOCATION OF SRP, AP, FP & AMIDSHIPS

FIGURE 3.14

4.0 – BLOCK LOADING

It is very important for a dockmaster to understand how vessel blocking behaves under load and to realize how various factors can affect the amount of load taken by a block. The trapezoidal loading equation can be a good approximation of load along a keel line but you must understand its limitations and resort to more complex calculations if these limitations are not met.

All blocks act like giant springs and any block under load will compress (squeeze) some amount. The amount of squeeze depends on the pressure on the block and the block's modulus of elasticity (which is the block's degree of stiffness or "squeezability").

Thus two blocks built of the same materials (having the same modulus of elasticity) will compress the same amount under the same load. Two blocks built of different materials will compress varying amount under the same load or, alternatively, it will take a greater load to compress the stiffer block the same amount as the less stiff block.

This fundamental principle enables us to determine the actual load on the blocks under a ship and build a blocking system that adequately distributes the vessel's weight in a manner we can estimate. Knowing the loading on blocks is essential to insuring the blocks, dock and ship are not overloaded.

Many factors can affect the load on a block.

These include:

- ➢ Block's initial height relative to other blocks
- ➢ Bearing area of ship on block
- ➢ Types of material the block is constructed of
- ➢ Position of block under ship
- ➢ Weight & LCG of ship

4.1 – Block's Initial Height Relative to the Others

Ideally, all block heights under the vessel should be such that the keel and side blocks form a cradle which is the exact shape as the vessel being docked. If this were the case, and the ship was positioned correctly in the cradle, all blocks would take their portion of the ship's load as determined by their size, relative stiffness and position under the ship.

Unfortunately some blocks result being higher or lower than their ideal height because of:

- ➢ Tolerances required in building and placing blocks
- ➢ Irregularities in the shape of the vessel's hull
- ➢ Errors in positioning the vessel on the blocks

The higher blocks end up taking greater load than the others since the total squeeze of the high block is greater than the total squeeze of the others.
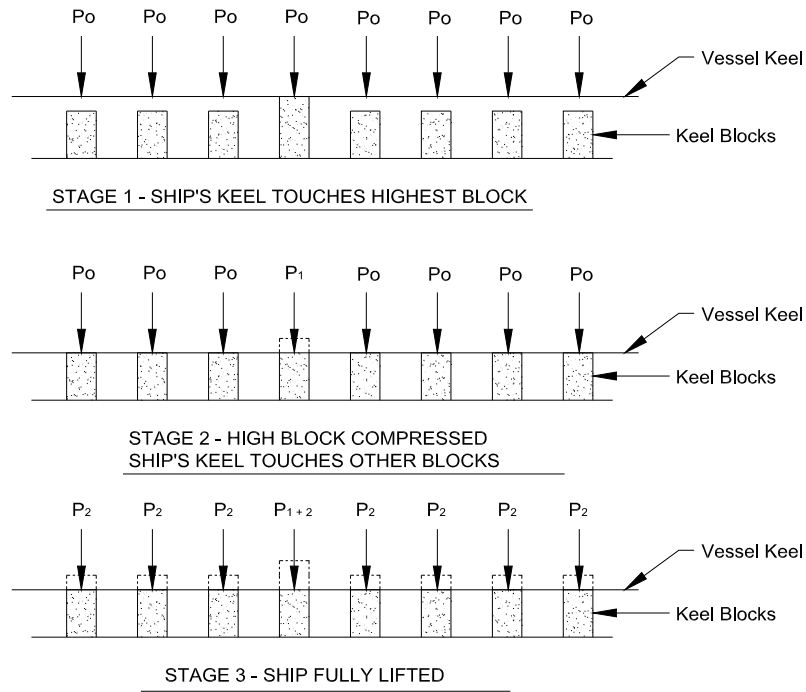

Po   Po   Po   Po   Po   Po   Po   Po
— Vessel Keel
— Keel Blocks

STAGE 1 - SHIP'S KEEL TOUCHES HIGHEST BLOCK

Po   Po   Po P_1 Po   Po   Po   Po
— Vessel Keel
— Keel Blocks

STAGE 2 - HIGH BLOCK COMPRESSED
SHIP'S KEEL TOUCHES OTHER BLOCKS

P_2 P_2 P_2 P_{1+2} P_2 P_2 P_2 P_2
— Vessel Keel
— Keel Blocks

STAGE 3 - SHIP FULLY LIFTED

FIGURE 4.1

In the Figure 4.1, P_0 is equal to no load on the block, the vessel has not touched, or is just starting to touch the block. This is depicted in Stage 1.

P_1 is equal to the load required to compress the one high block to the correct height of the other blocks. At that point the ship's hull is just starting to contact the other blocks. This is depicted as Stage 2.

P_2 is the load required to compress each block to its final height after the ship has been fully lifted. Because the ship is so rigid, all blocks within a short distance of one another will compress approximately the same amount from this step on. Thus all blocks will have an added load P_2.

It is fairly obvious that the one high block must have an initial load (P_1) to squeeze it down to the correct height along with its normal portion of the load to lift the ship (P_2). This results in the high block taking a greater total load than the other blocks. The magnitude of the increase in load on the high block is a function of the error in height and the stiffness of the blocks.

Alternatively, if a block is too low in relation to the others, it will take less load than the others.

The magnitude of the increase in load due to errors in height is difficult to calculate. However, if all blocks are built to strict tolerances, and a softwood cap is used to allow crushing of wood that might be too high, the effects of slight variations in height of about ¼" can usually be neglected.

Using a 2" softwood cap on top of the blocks is generally sufficient for allowing crush due to errors in height, irregularities in the ship's hull and minor errors in placing the vessel on the blocks.

These topics will be discussed in greater detail in Section 7, "Block Construction".

4.2 – Bearing Area of Ship of Block

The total load on a block is a function of the pressure on that block times the area of pressure. The pressure on the block is a function of the amount of squeeze the block has taken (and its materials of construction). Thus, a block with smaller bearing area located between two blocks with larger bearing areas will take a smaller total load than the larger blocks. This is because the squeeze of all three blocks must be approximately the same due to the stiffness of the vessel. If the squeeze is the same, then the pressure on the blocks is the same (assuming they are constructed of the same materials).

The total load on each block is it's pressure times it's area, so the block with the smaller area will take a smaller total load.
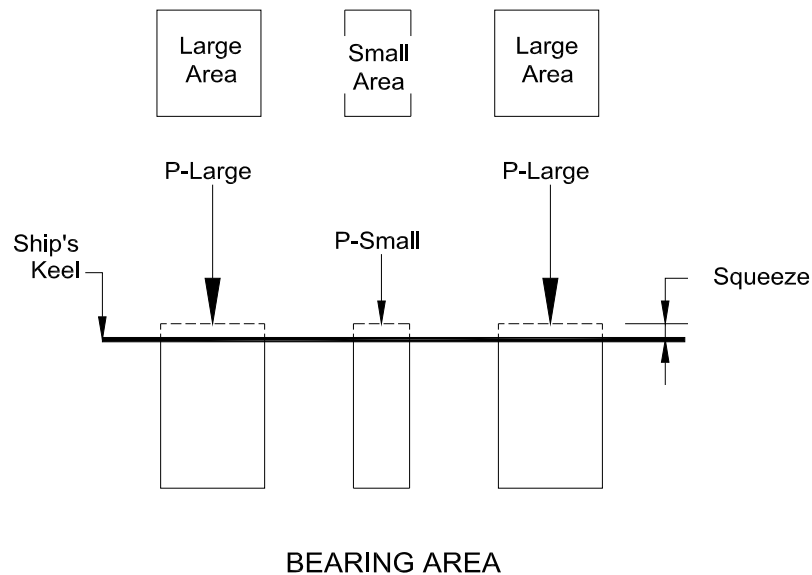

BEARING AREA

FIGURE 4. 2

Alternatively, for any given load P, a block with a smaller bearing area will squeeze more than one with a larger bearing area. This is important to remember when docking vessels with a bar keel or narrow skeg aft.

The bearing area is the area of contact of the keel on the block (not the full block area).

When the bearing area is small, the pressure on the timber is large, causing a large squeeze and sometimes crushing of the wood.
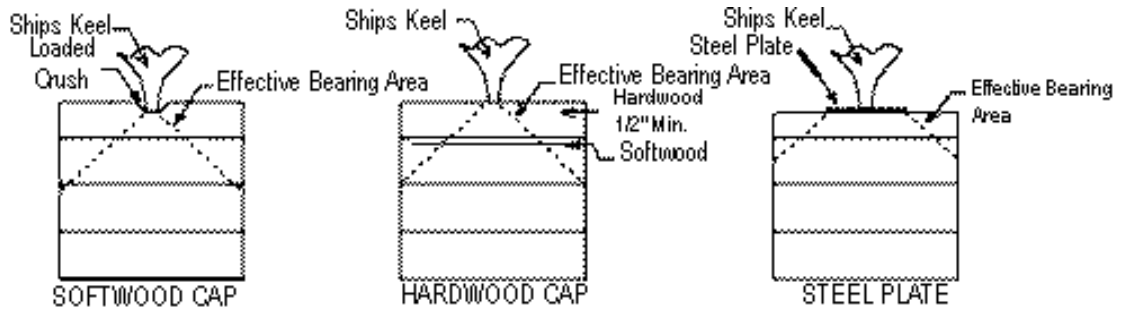
FIGURE 4. 3

To prevent localized crushing of the softwood timber cap, a layer of hardwood or a steel plate can be placed on top of the block to distribute the load over a larger area and reduce the pressure on the softwood to acceptable values. The hardwood should be at least 12" thick to prevent breakage and to distribute the load over a larger area of the softwood, which should be placed below the hardwood cap.

In many instances the loading from a narrow keel will overstress even a hardwood cap. In these cases a steel plate can be used on top of the block. The plate must be thick enough to spread the load over a sufficient area of timber to prevent crushing without bending the plate. Typical thicknesses of plate range from 1" to 3" depending on the load, width of plate versus width of keel, and allowable bearing pressure of the timber on which the plate is placed.

4.3 – Types of Materials

The relative stiffness of the materials the block is constructed of can have an effect on the load the block will take. It takes a larger force to squeeze a stiffer block (such as one constructed with a large concrete or steel base), versus one with a smaller modulus of elasticity (such as one constructed of all timber).
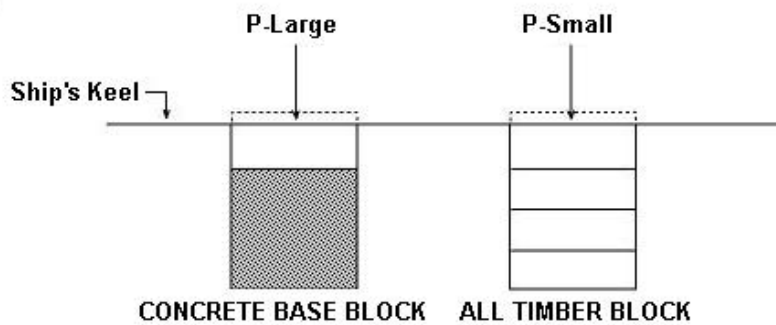

FIGURE 4. 4

From this it can be seen that all blocks in a keel line should usually be built of similar materials. Should a block with concrete (or steel) base be added into a keel track built of all timber blocks, an extremely high load will develop at the concrete block, possibly damaging the block, ship or dock.

Alternatively, if an all timber block is added into a keel track built of blocks with concrete or steel bases, the timber block will take a much smaller load relative to the others.
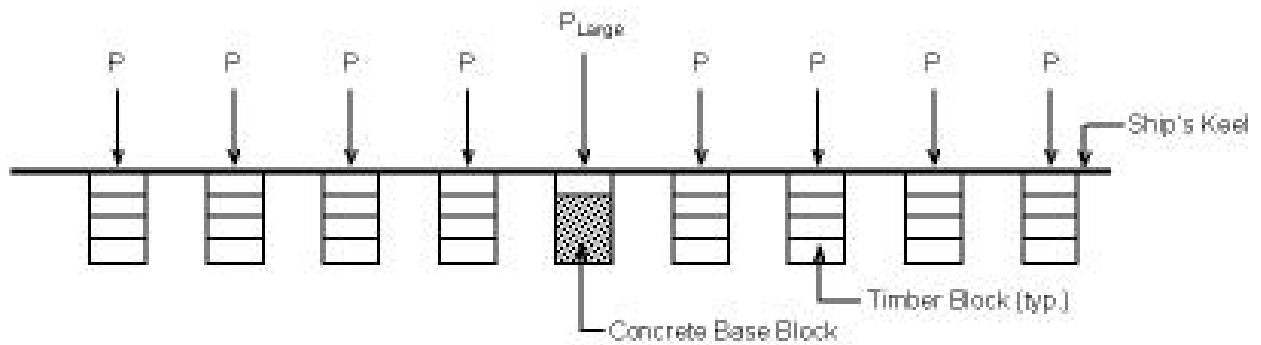

FIGURE 4. 5

This same reasoning should be used when building side blocks.

Ideally, the side blocks should never be built stiffer than the keel blocks or else the side blocks will take a larger portion of the load, possibly overloading the vessel. A less stiff side block can be assured by using the same number or, or more, layers of timber in the side blocks than in the keel.

This is usually the case anyway since side blocks are always the same height or higher than the keel.

Problems can arise, however, when alternate, stiffer bases are used for the side blocks but no the keel.

FIGURE 4. 6

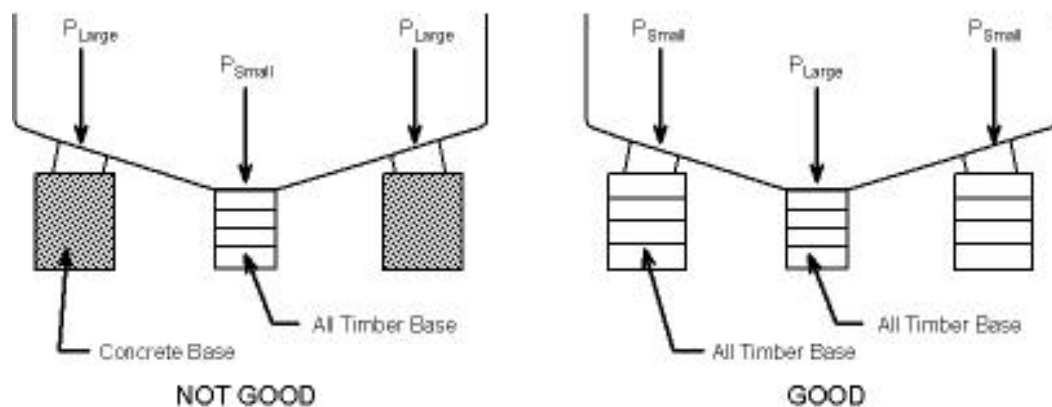### 4.4 – Position of Block Under the Ship and Weight of Ship

The preceding sections discussed the effect that block height, bearing area, and materials of construction have on the load the block receives.

Calculating the actual increase or decrease in load due to these variables is complex and beyond the scope of this paper. (These calculations will be discussed in greater detail in block construction lecture.)

In general, by using:

> ➢ Blocks of similar design
> ➢ Blocks built to within the proper height tolerances

these variables can be neglected and the load on the blocks can be approximated by their position under the vessel and the weight of the vessel.

The weight distribution of a vessel usually resembles a "Skyline" (See Figure 4.7) with:

> ➢ High loads at engine room & machinery compartments
> ➢ Lower loads at empty compartments and open spaces.

When the vessel is docked on blocks, the weight of the vessel must be resisted by the block system.

From the previous section, we know the blocks will squeeze under the load and the amount of squeeze is directly proportional to the amount of load on the block.

The ship is a rigid structure whose keel is a straight line that cannot deflect very much in the distance between keel blocks. Thus for any two blocks next to one another, their squeeze under the weight of the ship must be approximately equal due to the ship's rigidity, and hence the load on the two blocks must be approximately equal.

Figure 4.7 below illustrates this theory. The blocks at points A and B must deflect (squeeze) the same amount (approximately) due to the straight keel and ship's rigidity.
If the deflection of the blocks is the same, then the load on the blocks must be the same, even though the portion of ship's weight directly over B is much greater than the portion of ships weight directly over A.
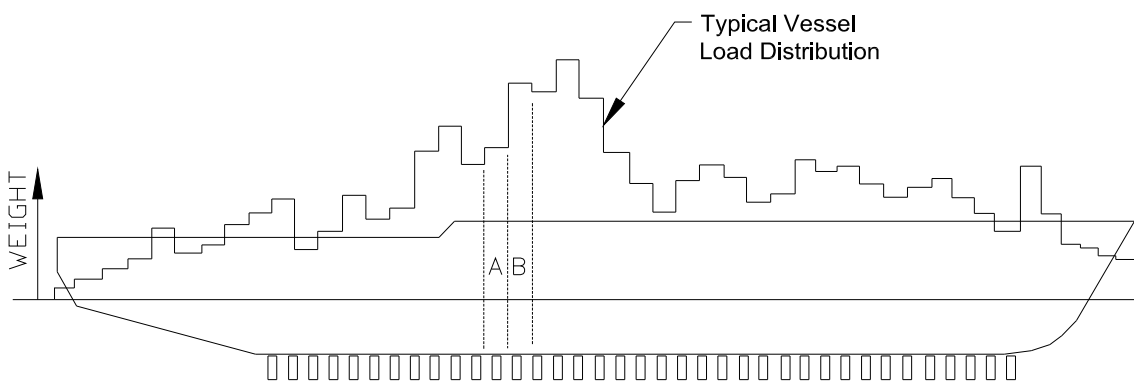

FIGURE 4.7

Thus, the load on the block line cannot be the irregular "skyline" load but must be a smooth straight line loading.

If the longitudinal center of gravity of the ship, LCG, (the center of all weights on the ship, including the ship), is located directly over the center of keel line, then the ship will squeeze all blocks equally.

Since all blocks are squeezed equally, all blocks will have the same load and the load distribution diagram will be rectangular in shape, as shown in Figure 4-8.
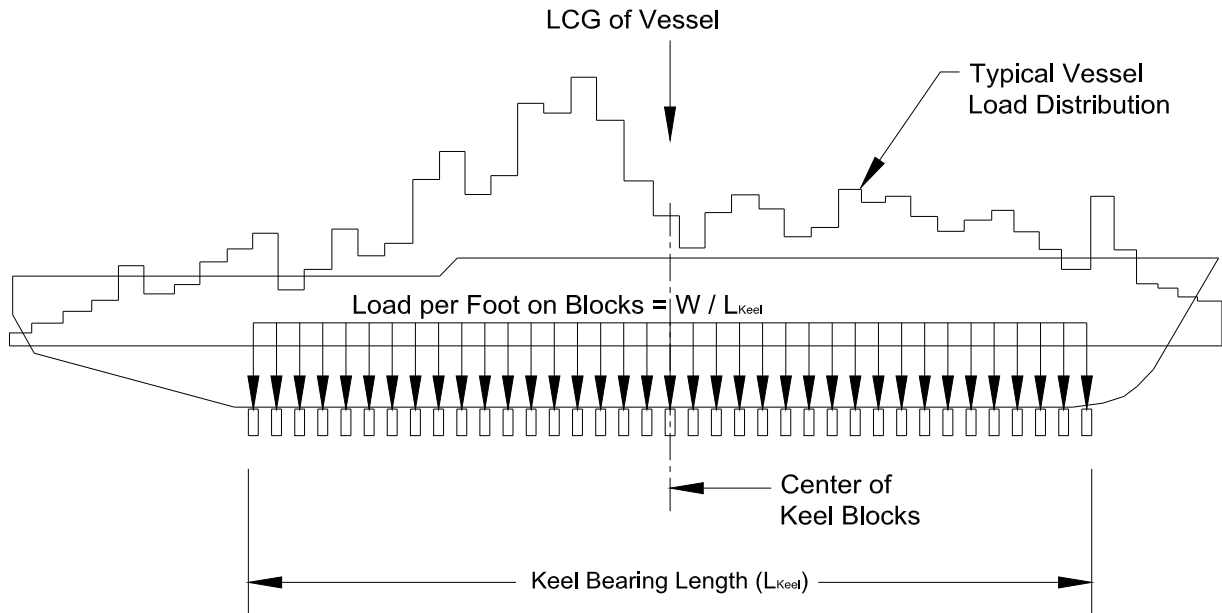
FIGURE 4. 8

In this case the load per linear foot on the block line is constant and equal to the sip weight (W) divided by the keel bearing length (L_{Keel}).

$$\text{Load per Foot} = W / L_{keel}$$

For most dockings however, the longitudinal center of gravity (LCG) of the vessel does not fall directly over the center of clocks, it falls some distance forward or aft of the center blocks. When this occurs, the load on the blocks is not uniform, but greater at one end than the other. Thus the blocks actually squeeze more at one end than the other.

The ship, being a rigid body with a keel that is assumed a straight line, causes the block line to squeeze in a sloping straight line.

FIGURE 4. 9

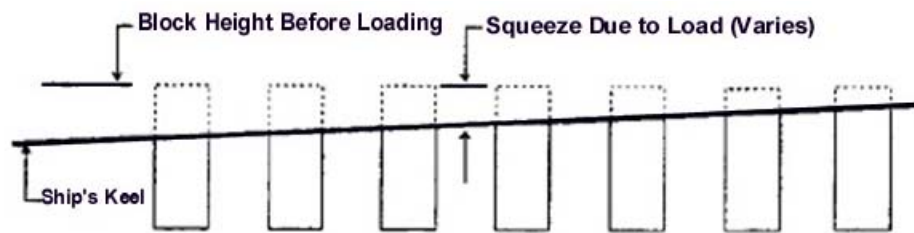Since the load on any block is a function of the squeeze of that block, the load along the keel line must gradually be increasing or decreasing in the same straight line manner.

This results in a trapezoidal shaped loading on the blocks as shown in the Figure 4.10.
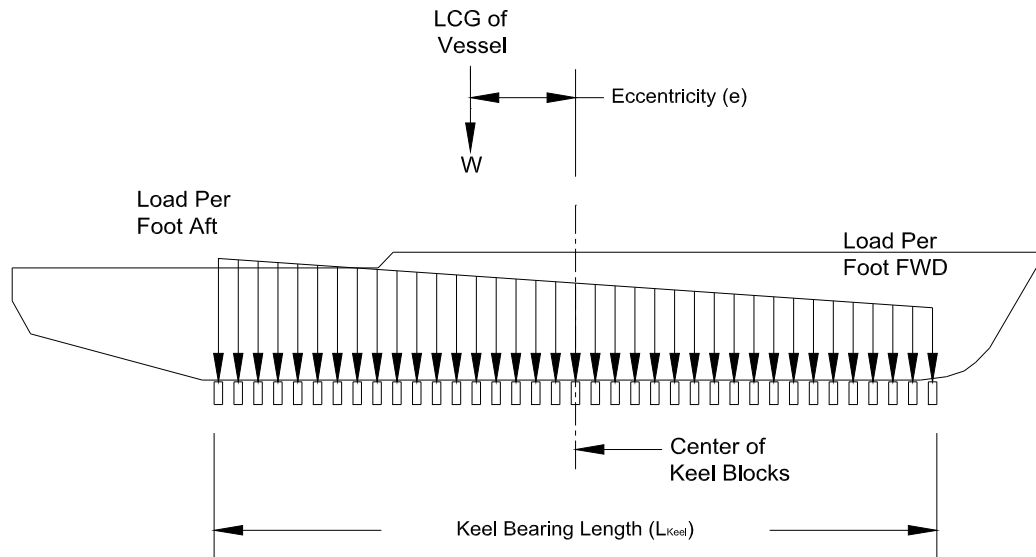

FIGURE 4. 10

The further the vessel's LCG is from the center of keel bearing length, the greater in the increase and decrease of the load per foot at each end of the block line.

4.5 – Trapezoidal Loading Equation

The magnitude of the load per foot on the keel line can be calculated by two equations. These two equations cover half of the keel line.   Using the "Center of the Blocks" as the dividing line, the governing equations are as shown below:

At the end of the keel line closest to the LCG:

$$\text{Load per Foot} = W/L_{keel} + 6 \times W \times e/(L_{keel})^2$$

At the end of the keel line farthest from the LCG:

$$\text{Load per Foot} = W/L_{keel} - 6 \times W \times e/(L_{keel})^2$$

Where:

> ➢ W = Ship Weight in Long Tons
> ➢ L_{keel} = Keel bearing length (distance from first keel block to last keel block)
> ➢ e = Distance from centerline of keel bearing length to vessel LCG (See Figure 4.10)

This analysis is called the "Trapezoidal Load Distribution" and can be used for most typical dockings to determine the load on the blocks and dry dock and to develop pumping plans for floating dry docks.

Trapezoidal Load Distribution is derived from eccentrically loaded column formula:

$$P/A \ +/- \ Mc/I$$

The analysis assumes the ship is infinitely stiff and the blocks are all of uniform size, materials, and spacing. It also assumes that 100 percent of the load goes into the keel blocks.

These equations are not valid if:

> ➤ The longitudinal strength of the ship is impaired due to damage or cutting.
> ➤ The blocks are not all constructed similarly.
> ➤ The block spacing is not uniform.
> ➤ The bearing area varies on top of the block (bar keel at one end, etc.)
> ➤ The vessel over hangs the keel blocks by more than twice its molded depth.
> ➤ The ship has a large initial hog or sag and the keel line is built straight.
> ➤ A floating dock is not dewatered according to the trapezoidal results.

The load on any one block is equal to the portion of the trapezoidal load directly over that block (from centerline of the gap between blocks aft to centerline of the gap between blocks forward See figure below).
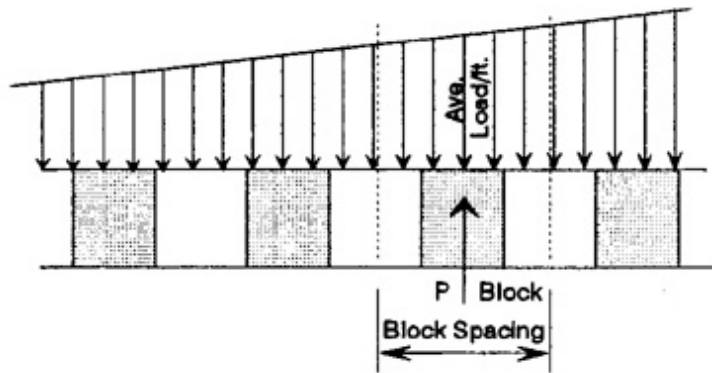
FIGURE 4. 11

EXAMPLE – TRAPEZOIDAL LOADING
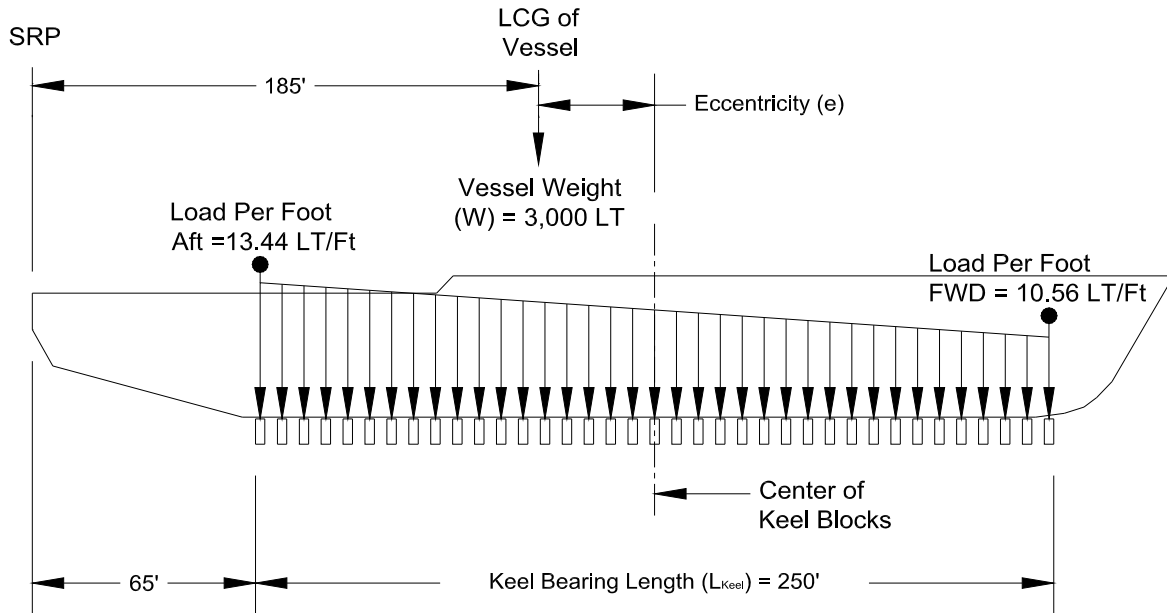
FIGURE 4. 12

Given:

- ➢ W = 3000 LT
- ➢ LCG = 185' FWD of SRP
- ➢ Distance between SRP and aft face of first keel block = 65'
- ➢ L_{keel} = 250'

Determine "e":
- ➢ e = (250'/2 + 65')- 185' = 5'

Calculate Loads:

$$\text{Load (LT/Ft)} = W/L \ +/- \ (6 \times W \times e) / L_{keel}^2$$

At the end closest the LCG (In this case it is the AFT portion of the Keel Line):

- ➢ Load = 3000 LT / 250' + (6 x 3000 LT x 5') / 250'2
- ➢ Load = 12 + 1.44 = 13.44 LT / Ft. Aft

At the end farthest from the LCG (In this case it is the FWD portion of the keel line):

- ➢ Load = 3000 LT / 250' - (6 x 3000 LT x 5') / 250'2
- ➢ Load = 12 – 1.44 = 10.56 LT / Ft. Fwd.

4.6 – Interrupted Keel Bearing

In some instances, keel blocks must be omitted to allow clearance for sonar domes or other appendages that hang below the hull or to allow access for repairing that area of the keel. Omitting some blocks will obviously increase the load on the remaining blocks. The amount of this increase will depend on the number of blocks left out and their position along the keel line. In general, the closer the omitted blocks are to the forward or aft end of the keel line, the greater the increase on the remaining blocks will be.

The method of determining the loading on a continuous block line was discussed in the previous section. The block loading is calculated by using the trapezoidal loading equation:

$$\text{Load} = W/L + 6 \times W \times e / L^2$$
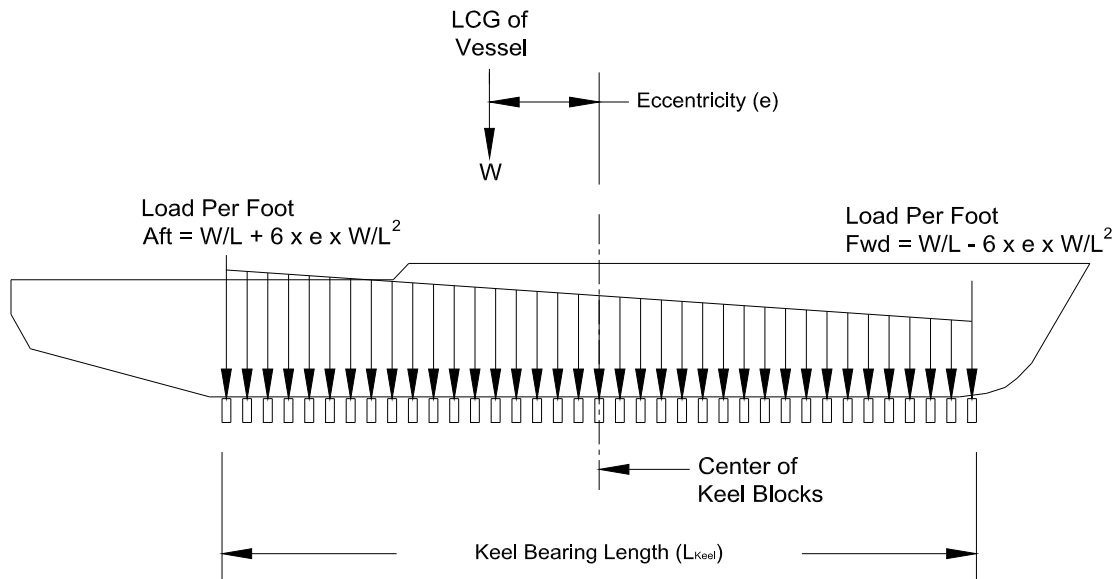
As shown in below.

FIGURE 4. 13

Where:

> ➢ W = Ship Weight in Long Tons
> ➢ L_{keel} = Keel Bearing Length
> ➢ e = Distance from centerline of keel bearing length to vessel LCG

This equation is derived from the fundamental equation for eccentrically loaded columns:

$$P/A + M \times c/I$$

Where:

- ➢ P = Load
- ➢ A = Cross sectional area of column
- ➢ M = Moment due to eccentric load = P x e
- ➢ c = Distance from centroid of area to edge
- ➢ I = Moment of inertia of column

ACTUAL KEEL LINE
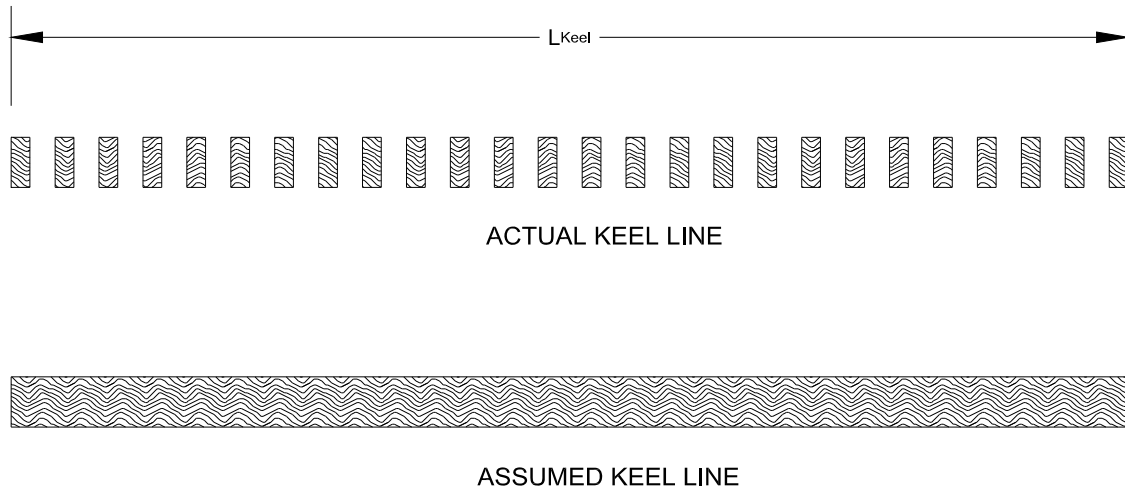
ASSUMED KEEL LINE

FIGURE 4. 14

For a keel line with regularly spaced blocks and no large gaps, the keel line can be assumed to be one continuous rectangle with width of 1.

The center of blocks is the center of the rectangle and the moment of inertia of a rectangle about its own axis is the base times the height cubed divided by 12 or:

$$I = width \times L^3 / 12$$

Moment (M) is force times distance and the moment on the keel blocks is equal to the ship's weight (W) or (force) times the distance the center of gravity of the ship's weight is from the center of blocks (e) or:

$$M = W \times e$$

Area of the rectangle is equal to length times width or:

$$A = L \times width$$

C is the distance from centroid of area to end of the rectangle or:

$$C = L/2$$

Substituting these values into the equation

$$P/A + M \times c / I$$

You get:

$$W/ (L \times width) + W \times e \times (L/2) / (width \times L^3 / 12)$$

If the width of all the blocks is the same, you can use 1 for the width and the result of the equation will be in tons per foot of length (instead of tons per square foot).

Using width = 1 and simplifying results in the trapezoidal equation:

$$Load = W/L + 6 \times W \times e / L^2$$

This is a good approximation of the ship's loading along the blocks if the blocks are spaced regularly and block bearing width is constant. If block's are omitted, gaps are created in the keel line, and the assumption that the block line is a single rectangle is no longer valid.

With a gap, the block line must be considered as two (or more) rectangles with spaces between them. See Figure 4.14. This causes two changes in the analyses method. First, the center of the blocks is no longer at ½ the keel length (1/2 L) and must be calculated. Second, the moment of inertia about the center of blocks must be calculated for all rectangle segments.

ACTUAL KEEL LINE

ASSUMED KEEL LINE
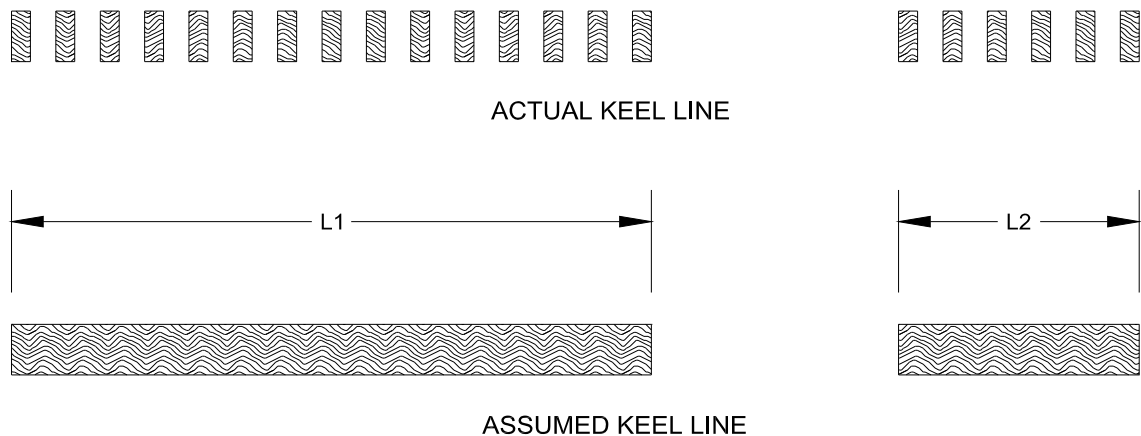
FIGURE 4. 15

First, the center of blocks must be calculated. This can be done by taking the sum of each rectangle's area times it's distance from any arbitrary point and dividing by the total area of all the rectangles. Usually, the arbitrary point is taken as one end of the keel line.

EXAMPLE – TRAPEZOIDAL LOADING WITH INTERUPTED KEEL LINE

Figure 4.16 below shows the block arrangement that will be used to dock a 3000-ton vessel.

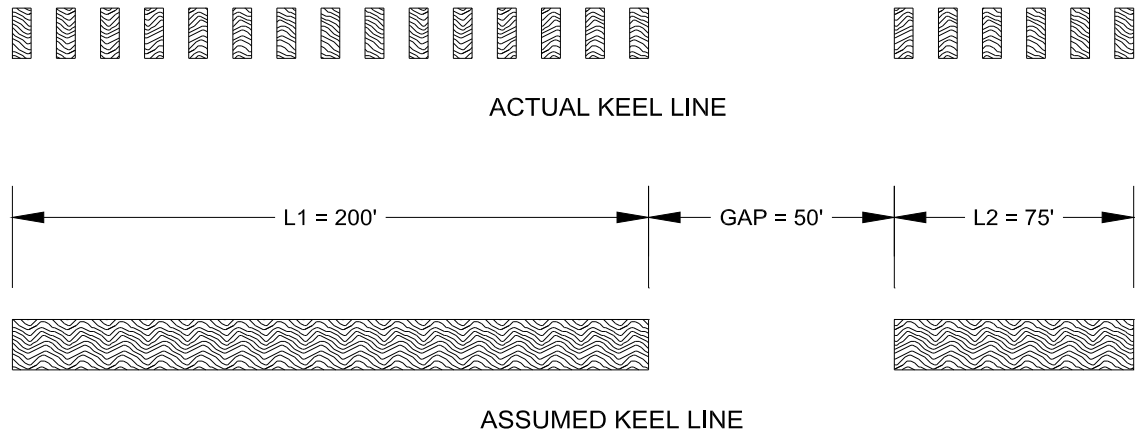**FIGURE 4. 16**

The center of all blocks must be calculated first. This is done by multiplying the area of each rectangle by its distance from any arbitrary point, adding these values together, and dividing by the total area of blocks. See Figure 4.17.
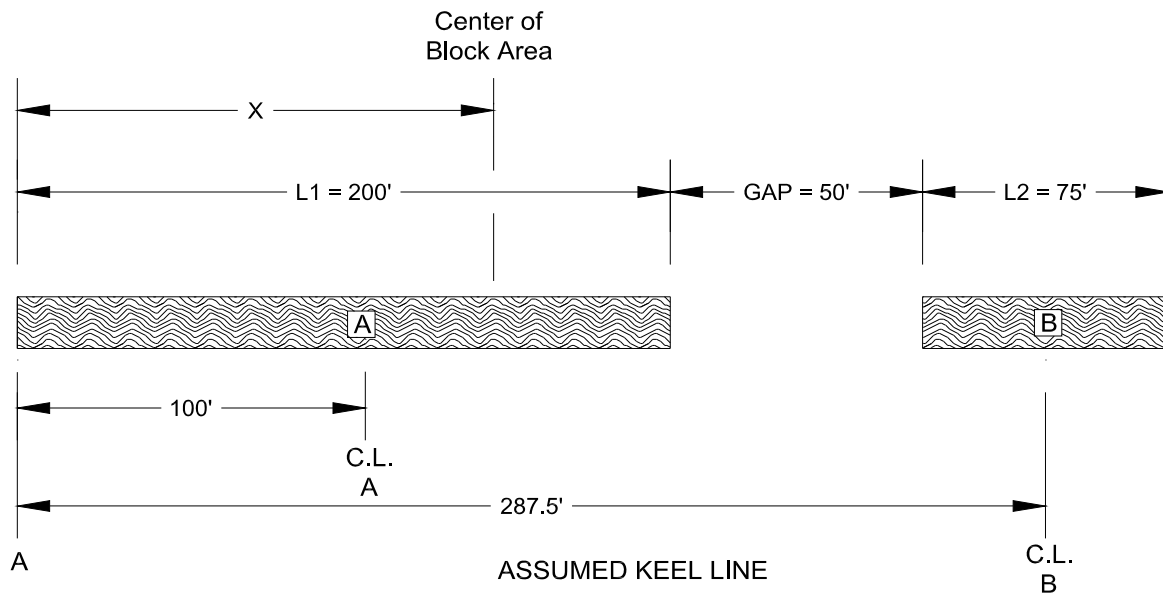
FIGURE 4. 17

Find center of block area in relation to Point A, the aft end of the keel line. Since all blocks are the same width, the width can be assumed as 1.

$$X = \frac{200' \times 1' \times 100' + 75' \times 1' \times 287.5'}{200' \times 1' + 75' \times 1'}$$

X = 156.14'

"X" is the distance from the center of block area is from Point A, the end of the keel line.

Next, the moment of inertia of all rectangles about the center of block area must be calculated. The moment of inertia of a rectangle about an arbitrary axis is

$$I = b \times h^3 / 12 + A \times d^2$$

Where:

- ➤ b = Base of the rectangle or width of the block, can be assumed 1 if all block widths are constant
- ➤ h = Height of the rectangle or length of the block line segment
- ➤ A = Area of the rectangle
- ➤ d = Distance the center of the rectangle is from the axis being investigated (center of block area in this case)

Calculation of "d" Figure 4.18):

- ➤ d = (Distance to Center of Blocks) – (Distance to center of Block A or B)

- ➤ d_1 = 151.14' – 100' = 51.14'
- ➤ d_2 = 151.14' – 287.5' = -136.36'
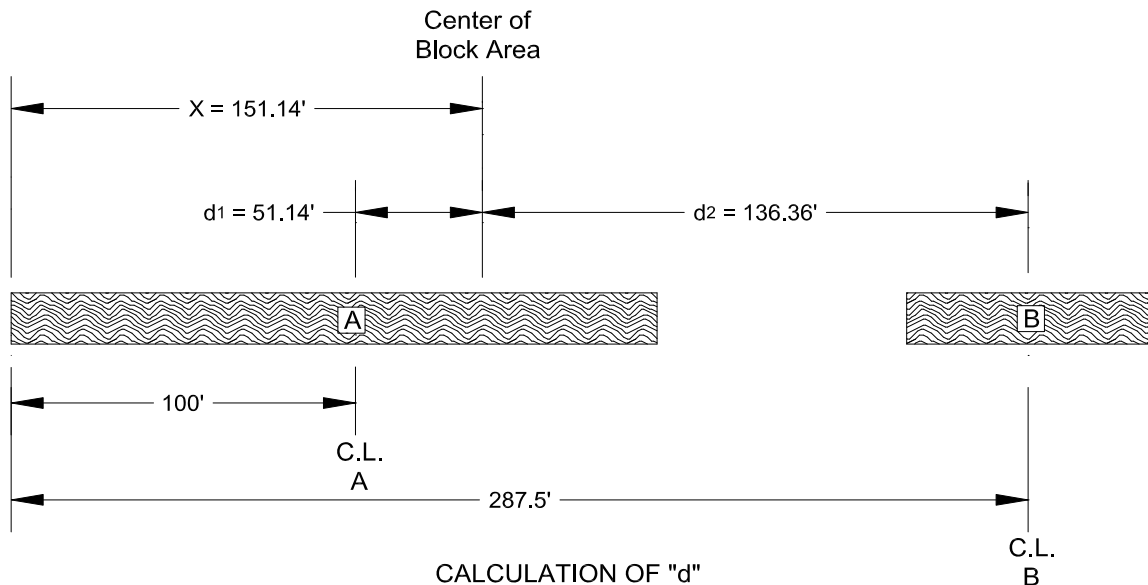
CALCULATION OF "d"

FIGURE 4. 18

Calculation of I:

Moment of inertia of rectangle A:

- $I_A = w \times L^3 / 12 + (L \times w) \times d^2$
- $I_A = 1 \times 200^3 / 12 + 200 \times 1 \times 51.14^2$
- $I_A = 1,189,727 \text{ Ft}^4$

Moment of inertia of rectangle B:

- $I_B = w \times L^3 / 12 + (L \times w) \times d^2$
- $I_B = 1 \times 75^3 / 12 + 75 \times 1 \times 136.36^2$
- $I_B = 1,429,710 \text{ Ft}^4$

The total moment of inertia for all blocks is the sum of the individual moments or:

- I total $_{A+B} = 1,189,727 \text{ Ft}^4 + 1,429,710 \text{ Ft}^4$
- I total $_{A+B} = 2,619,437 \text{ Ft}^4$

Calculation of e (Figure 4.19):

We need to calculate the eccentricity (e), which is the distance the longitudinal center of gravity of the vessel (LCG) is from the center of the keel bearing area (See Figure 4-19). The location of the LCG is dependent on how the vessel is loaded and can be determined using the vessel's drafts and hydrostatic properties of the hull. See Section 3.5 "Longitudinal Center of Buoyancy" for more information on how to determine the location of the LCG. In this example the LCG of the vessel falls 160 feet forward of the end of the block line (Point A).
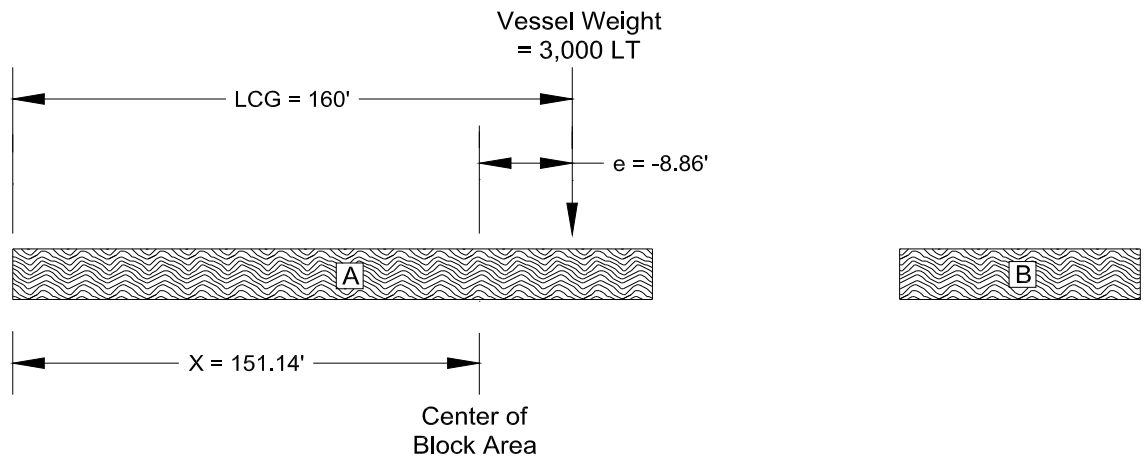
CALCULATION OF "e"

FIGURE 4. 19

e = 151.14' − 160.0 = -8.86' (Forward)

Since the LCG of the vessel falls forward of the center of blocking the greater load end of the trapezoid will be at the bow.

Calculation of "c" (Figure 4.20):

- $c_A = X = 151.14'$
- $c_B = 200.00 - 151.14 = 48.86'$
- $c_C = 200.00 + 50.00 - 151.14 = 98.86'$
- $c_D = 200.00 + 50.00 + 75 - 151.14 = 173.86'$
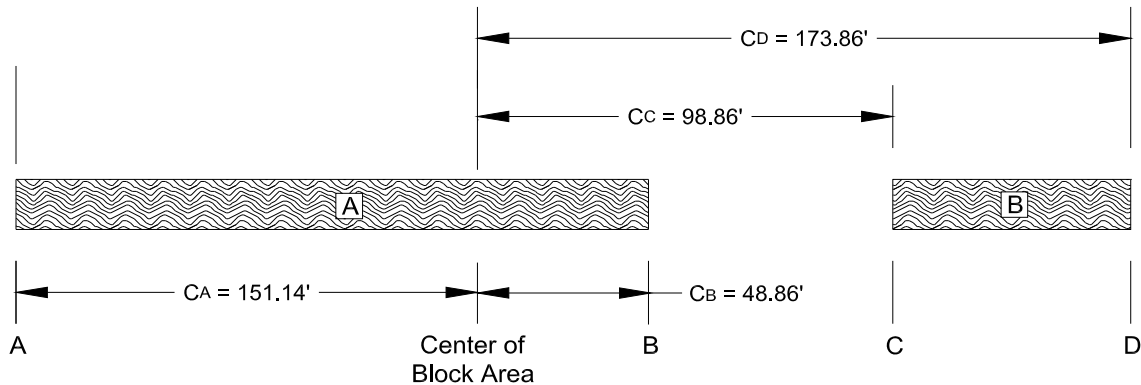
CALCULATION OF "c"

FIGURE 4. 20

We now have all the values needed to plug into the eccentrically loaded column equation and obtain the values of the trapezoid at the ends of the block segments:

$$P/A \pm M \times c / I \qquad Or \qquad W/A \pm W \times e \times c / I$$

Where:

- W = vessel wt. = 3,000 LT
- A = block area = 200 x 1' + 75 x 1' = 275 ft.^{2}
- e = eccentricity = 8.86 Ft.
- I = moment of inertia = 2,619,437 Ft.^{4}
- c = the distance from the center of block area to the point being investigated. Points calculated are usually the ends of each rectangle. See figure 4.20.

Because we have used a value of 1 for the width of all blocks throughout these calculations, the equation produces a result in long tons per foot of block length (as opposed to long tons per square foot of blocking).

Load at A (The W x e x c / I term is subtracted because the LCG falls on the other side of the block line center):

- $= W/A + W \times e \times c_A / I$
- = 3,000/275 - 3,000 x 8.86 x 151.54/2,619,437
- = 9.371 LTs/Ft.

Load at B (The W x e x c / I term is added because the LCG falls on the same side of the block line center):

- $\quad$ = W/A + W x e x c_B / I
- $\quad$ = 3,000/275 + 3,000 x 8.86 x 48.46/2,619,437
- $\quad$ = 11.401 LTs/Ft.

Load at C(The W x e x c / I term is added because the LCG falls on the same side of the block line center):

- $\quad$ = W/A + W x e x c_C / I
- $\quad$ = 3,000/275 + 3,000 x −8.86 x −98.86/2,619,437
- $\quad$ = 11.912 LTs/Ft.

Load at D(The W x e x c / I term is added because the LCG falls on the same side of the block line center):

- $\quad$ = W/A + W x e x c_D / I
- $\quad$ = 3,000/275 + 3,000 x −8.86 x −173.86/2,619,437
- $\quad$ = 12.673 LTs/Ft.

This loading is summarized below.

LOAD SUMMARY

FIGURE 4. 21

Check to insure block load equals ship weight.

Average load on A to B

- $\quad$ = (9.37 + 11.40)/2
- $\quad$ = 10.39 LT/Ft.

Total load on A to B

> ➤ = Average Load x Block length
> ➤ = 10.39 LT/Ft. x 200 Ft.
> ➤ = 2,078 LT

Average load on C to D

> ➤ = (11.91 + 12.67)/2
> ➤ = 12.29 LT/Ft.

Total load on C to D
*

> ➤ = Average Load x Block length
> ➤ = 12.29 LT/Ft. x 75 Ft.
> ➤ = 922 LT

Total block load = 2,078 + 922 = 3,000 LT

Ship weight = 3,000 tons **OK**

IMPACT OF GAP

To see the effect of removing keel blocks, we will now do block loading calculations for the same vessel on the 325' foot block line but will not leave out the 50 foot of blocks as before. Figure 4.22 below shows the loading condition (it is the same as above but with out the 50' gap).
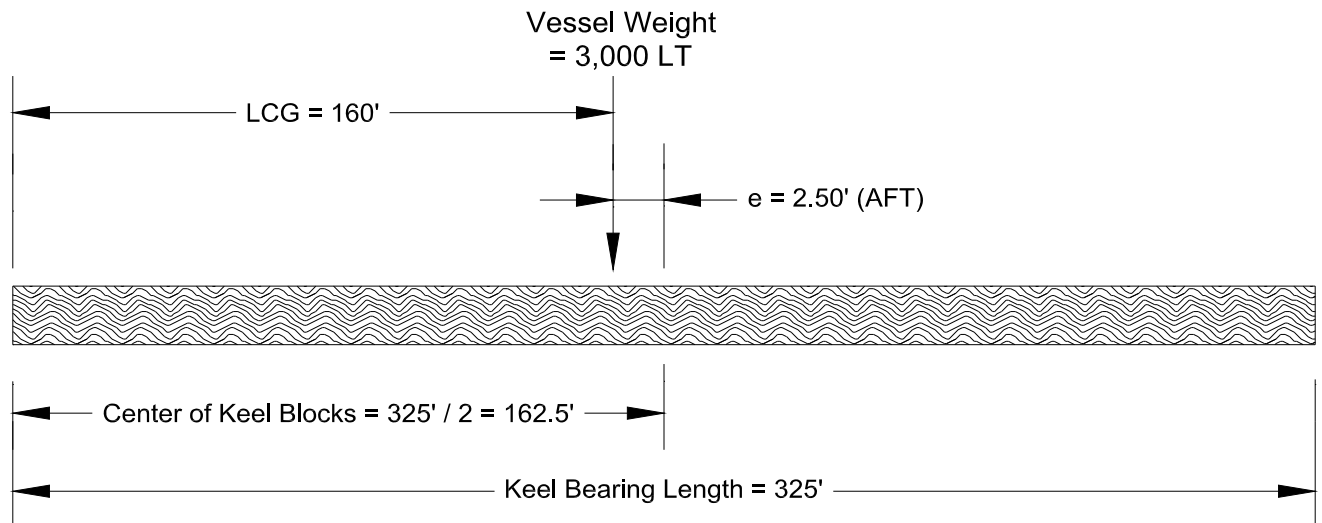
LOADING CONDITION - NO GAP

FIGURE 4. 22

The block loading is calculated by using the trapezoidal loading equation:

$$\text{Load} = W/L +/- 6 \times W \times e / L^2$$

Where:

- ➤ W = 3,000 LT
- ➤ L = 325 Ft.
- ➤ e = 2.5

Load = $3000/325 \pm 6 \times 3000 \times 2.5 / 325^2$

- ➤ = 9.66 LT/Ft. Aft
- ➤ = 8.80 LT/Ft. Fwd

Figure 4.23 compares the loading imposed by the same vessel on a continuous block line and one with a 50' gap in it.
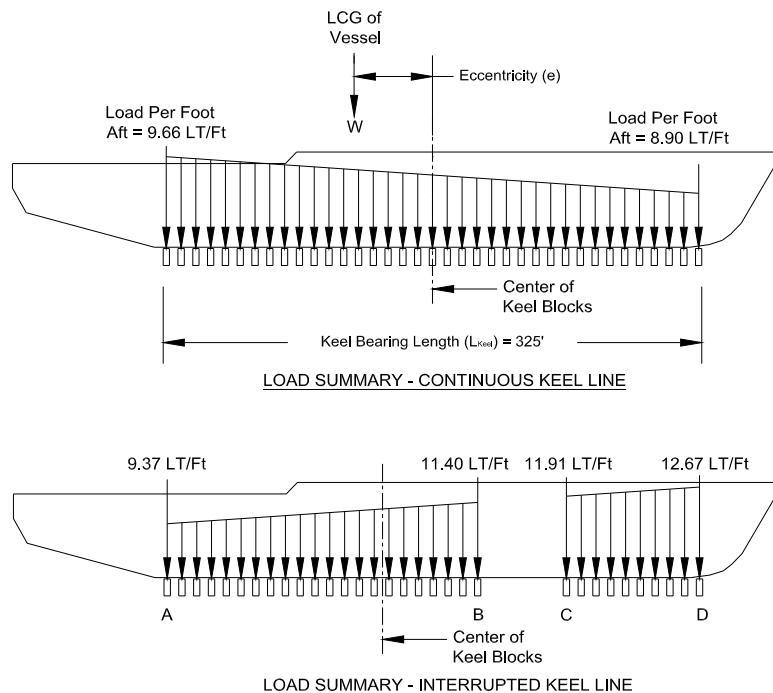
FIGURE 4. 23

As can be seen by comparing the two loading summaries, leaving a 50 foot gap in the keel line can drastically change the loading along the keel. It will also effect the deballasting plan if the vessel is being lifted in a floating dry dock.

4.7 – Varying Width Keel

Some vessels have a narrow skeg aft but flare to a wider flat bottom in the forward portion of the hull. The bearing area on the keel blocks is much smaller at the narrow skeg. This effects the location of the center of blocks and can result in very high stresses on the timber, possible causing crushing.

The method of determining the loading on a continuous block line of uniform width is discussed previously. With a varying width keel, however, the different widths of keel bearing area must be accounted for. The loading along the keel must be calculated as a load per square foot and not a load per foot (as was done for the "normal" trapezoidal loading condition).

This causes two changes in the analyses method. First, the center of the blocks is no longer at ½ the keel length (½ L) so it must be calculated. Second, the moment of inertia about the center of blocks must be calculated for all rectangle segments. Actual widths for each rectangular segment must be used in the calculations.
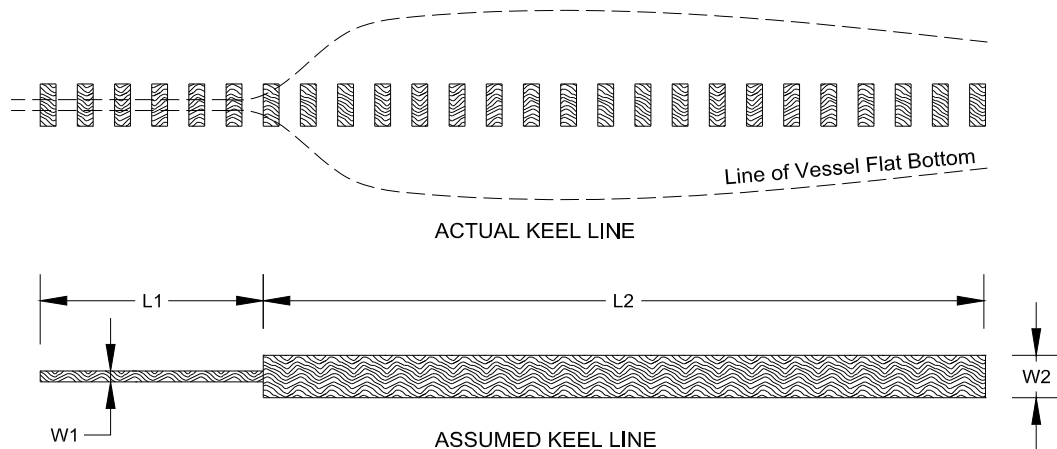
FIGURE 4. 24

First, the center of blocks must be calculated. This can be done by taking the sum of each rectangle's area times it's distance from any arbitrary point and dividing by the total area of all the rectangles. Usually, the arbitrary point is taken as one end of the keel line.

CALCULATION – NARROWING KEEL BLOCK LOAD

Figure 4-25 shows the block arrangement that will be used to dock a 3,000 ton vessel.
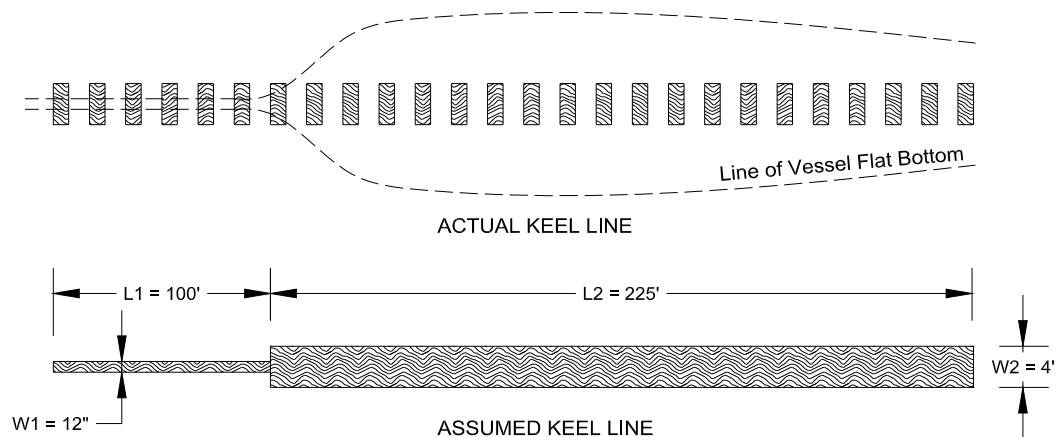
FIGURE 4.25

The center of all blocks must be calculated first. This is done by multiplying the area of each rectangle by its distance from any arbitrary point, adding these values together, and dividing by the total area of blocks. See Figure below.
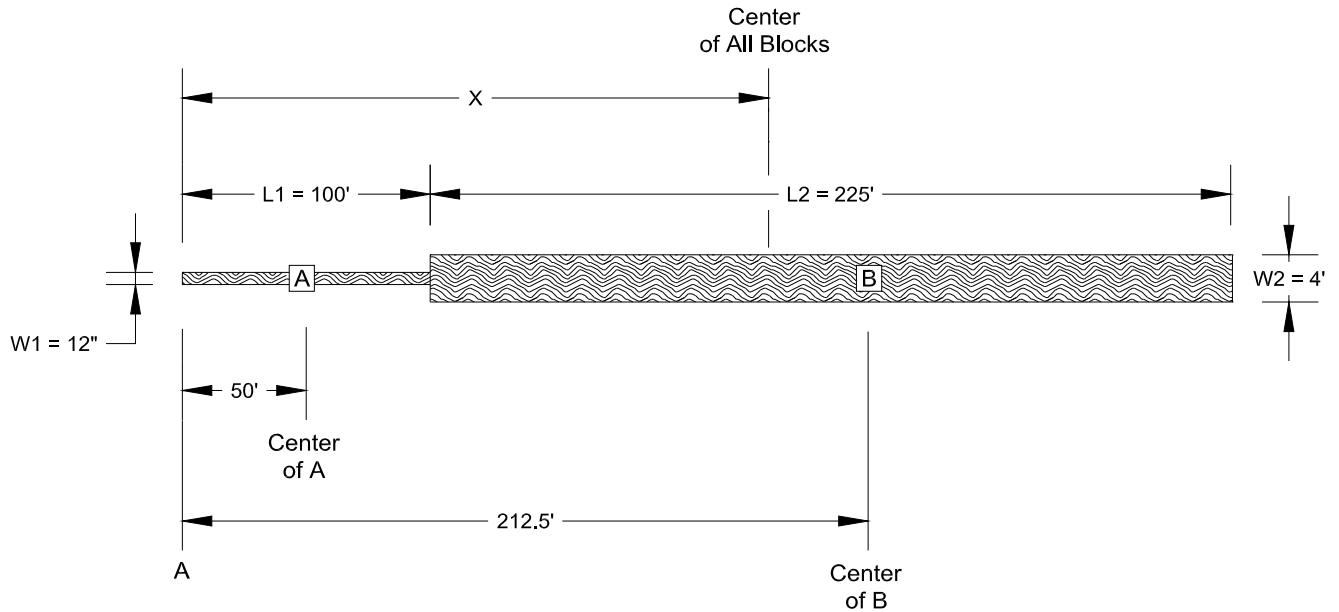
CENTER OF BLOCKING

FIGURE 4. 26

Calculate Center of Blocking:

Find center of block area in relation to Point A, the aft end of the keel line. Since all blocks are not the same width, the width of each rectangle must be entered into the equation.

$$X = \frac{100' \times 1' \times 50' + 225' \times 4' \times 212.5'}{100' \times 1' = 225' \times 4'}$$

X = 196.25'

"X" is the distance the center of block area is from Point A, the end of the keel line.

Next, the moment of inertia of all rectangles about the center of block area must be calculated.

The moment of inertia of a rectangle about an arbitrary axis is:

$$I = b \times h^3 / 12 + A \times d^2$$

Where:

> ➤ b = Base of the rectangle, which is the width of the vessel's bearing area on the block (W)
> ➤ h = Height of the rectangle or length of the block line segment (L)
> ➤ A = Area of the rectangle (W x L)
> ➤ d = Distance the center of the rectangle is from the axis being investigated (center of block area in this case)

Calculation of "d" (Figure 4.27):

> ➤ d1 = 212.5' – 196.25' = 16.25'
> ➤ d2 = 196.25' – 50 = 146.25'
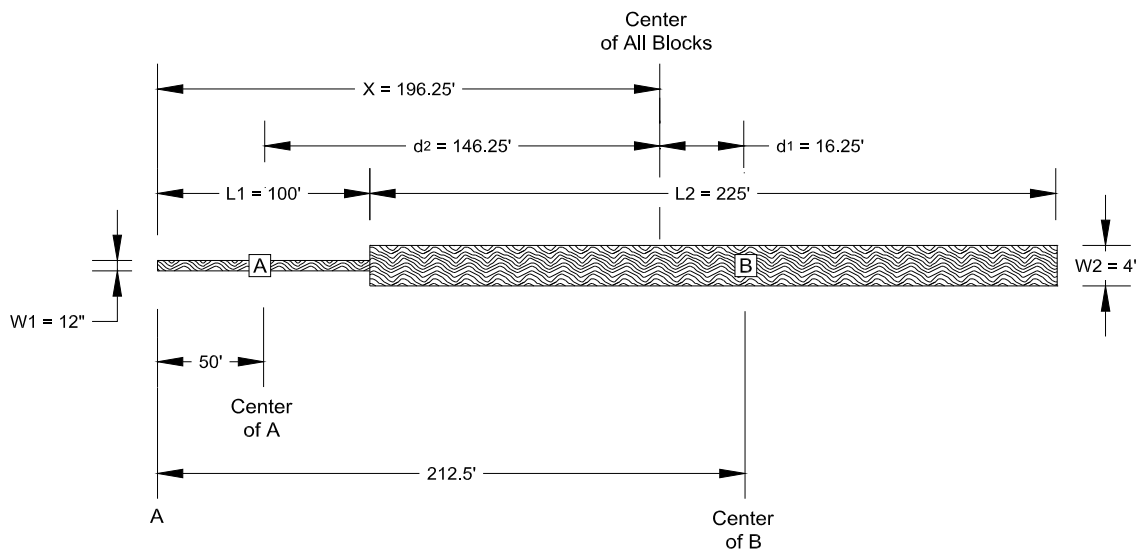
CALCULATION OF "d"

FIGURE 4.27

Calculation of "I"

Moment of inertia of rectangle A:

> ➤ $I_A = 1 \times 100^3 / 12 + 100 \times 1 \times 146.25^2$
> ➤ $I_A = 2,222,240$ Ft.^{4}

Moment of inertia of rectangle B:
> ➤ $I_B = 4 \times 225^3 / 12 + 225 \times 4 \times 16.25^2$
> ➤ $I_B = 4,034,531$ Ft.^{4}

The total moment of inertia for all blocks is the sum of the individual moments or:
> ➤ $I_{TOTAL\ A + B} = 2,222,240$ Ft.^{4} + 4,034,531 Ft.^{4}
> ➤ $I_{TOTAL\ A + B} = 6,256,771$ Ft.^{4}

Calculation of "e" (Figure 4.28):

We need to calculate the eccentricity (e), which is the distance the longitudinal center of gravity of the vessel (LCG) is from the center of keel bearing area.

The location of the LCG is dependent on how the vessel is loaded and can be determined using the vessel's drafts and hydrostatic properties of the hull. See Section 3.5 "Longitudinal Center of Buoyancy" for more information on how to determine the location of the LCG.

For this example, the vessel's LCG is 160 feet forward of Point A.
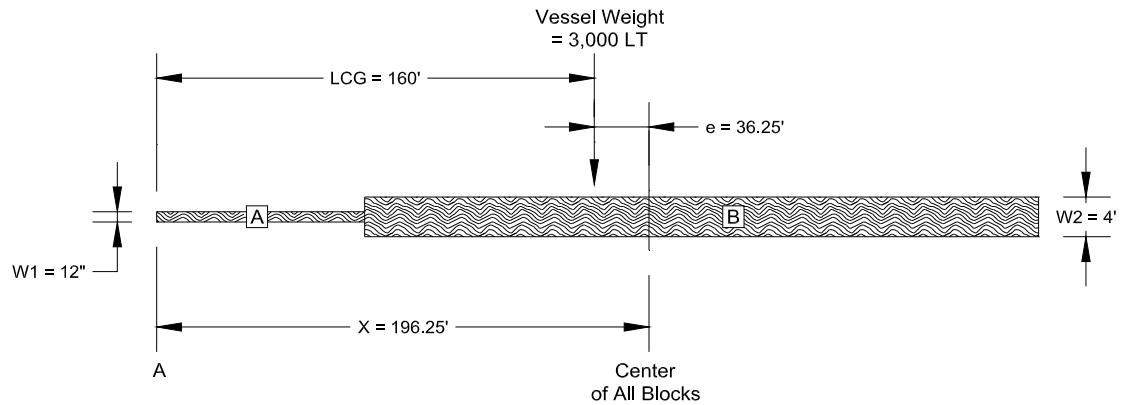
CALCULATION OF "e"

FIGURE 4.28

➢ e = 196.25' – 160.0' = 8.86'

Calculation of "c" (Figure 4.29):

➢ C_A = X = 196.25'
➢ C_B = 196.25 – 100 = 96.25'
➢ C_C = 325 – 196.25 = 128.75'
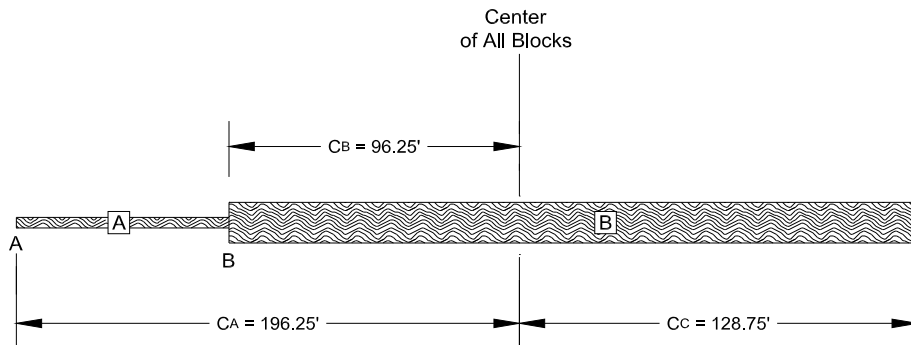
CALCULATION OF "c"

FIGURE 4.29

We now have all the values needed to plug into the eccentrically loaded column equation:

$$P/A = M \times c / I \qquad \text{Or} \qquad W/A + W \times e \times c / I$$

Where:

- ➢ W = vessel vt. = 3,000 LT
- ➢ A = block area = 100 x 1' + 225 x 4' = 1000 Ft.^{2}
- ➢ e = eccentricity = 36.25 Ft.
- ➢ I = moment of inertia = 6,256,771 Ft.^{4}
- ➢ C = The distance from the center of block area to the point being investigated. Points calculated are usually the ends of each rectangle. See Figure 4.29.

We can now calculate the load per square foot (pressure) at points A, B, and C.

Load at A (The W x e x c / I term is added because the LCG falls on the same side of the block center):

- ➢ = W/A + W x e x c_A / I
- ➢ = 3,000/1000 + 3,000 x 36.25 x 196.25/6,256,771
- ➢ = 6.411 LT/Ft.^{2}

Load at B (The W x e x c / I term is subtracted because the LCG falls on the other side of the block center):

- ➢ = W/A - W x e x c_B / I
- ➢ = 3,000/1000 – 3,000 x 36.25 x 128.75/6,256,771
- ➢ = 4.673 LT/Ft.2

Load at C (The W x e x c / I term is subtracted because the LCG falls on the other side of the block center):

- ➢ = W/A - W x e x c_C / I
- ➢ = 3,000/1000 – 3,000 x 36.25 x 128.75/6,256,771
- ➢ = 0.762 LT/Ft.2

This loading pressure diagram is summarized Figure 4.30.
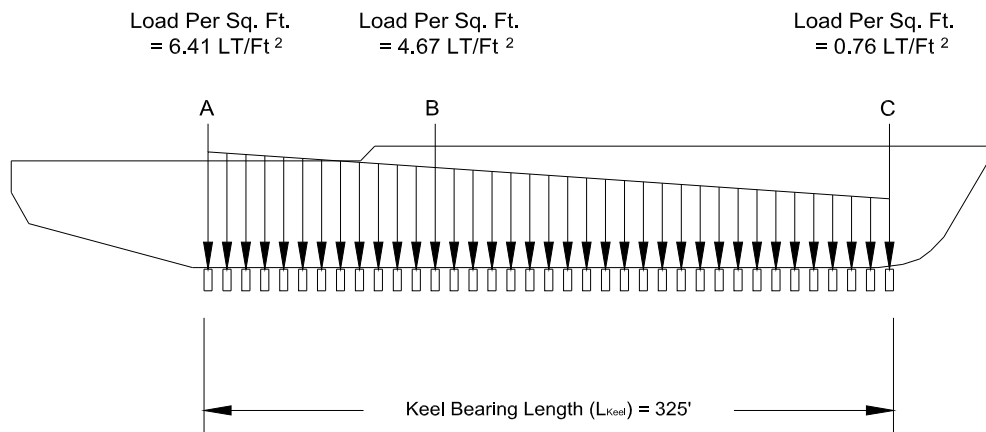
FIGURE 4.30

Load Per Foot Summary

It is important to remember that this load is in long tons per square foot of bearing area on the keel blocks. To get the loading per foot of keel length, these values must be multiplied by the width of the keel bearing at each block.

The width of keel bearing for the first 100 feet of keel at the aft end, between Points A and B, is 1 foot.

Thus the load per foot at Point A is:

> ➢ 6.411 LT/Ft.^{2} x 1 Ft. = 6.411 LT/Ft.

The load per foot at Point B, aft side is:

> ➢ 4.637 LT/Ft.^{2} x 1 Ft. = 4.673 LT/Ft.

The width of keel bearing at the remaining portions of keel, between Points B and C, is 4 feet.

Thus the load per foot at Point B, forward side is:

> ➢ 4.673 LT/Ft.^{2} x 4 Ft. = 18.69 LT/Ft.

The load per foot at Point C is:

> ➢ 0.762 LT/Ft.^{2} x 4 Ft. = 3.048 LT/Ft.

This loading is summarized in Figure 4.31.

FIGURE 4. 31

Check to insure block load equals ship weight.

Average load on A to B

> ➢ = (6.41 + 4.67)/2
> ➢ = 5.54 LT/Ft.

Times block length of 100 Ft.

> ➢ = 5.54 LT/Ft. x 100 Ft.
> ➢ = 554 LT Total Load on A to B

Average load on B to C

> ➢ = (18.69 + 3.04)/2
> ➢ = 10.87 LT/Ft.

Times block length of 225 Ft.

> ➢ = 10.87 LT/Ft. x 225 Ft.
> ➢ = 2,446 LT Total Load on B to C

Total block load on all blocks

> ➢ = 554 + 2,446
> ➢ = 3,000 LT

Ship weight = 3,000 tons OK

The maximum block load aft is 6.41 LT/Ft. times the block spacing. The block spacing in this example is 4 foot so the maximum load is 4' x 6.41 LT/Ft. = 25.64 LT.

The maximum pressure on the timber is 25.64 LT divided by the bearing area, which is 1 foot wide by 1 foot long (144 in.^{2})

> ➢ = 25.64 LT x 2240 lbs/LT / 144 In.2
> ➢ = 399 psi

399 psi is an acceptable pressure for Douglas fir.

The maximum block load at Point B is 18.69 LT/Ft. times the block spacing. The block spacing is 4 foot so the maximum load is 4' x 18.69 LT/Ft. = 74.76 LT.

The maximum pressure on the timber is 74.76 LT divided by the bearing area which is 4 foot wide by 1 foot long (576 in.^{2})

> ➢ = 74.76 LT x 2240 lbs/LT /. 576 in.2
> ➢ = 290 psi

290 psi is an acceptable pressure for Douglas fir.

To see the effect of varying the width of the keel, we will now do block loading calculations for the same vessel on the 325 foot block line but will assume a uniform 4' wide keel.

IMPACT OF VARYING KEEL WIDTH

Figure 4.32 compares the block imposed by a vessel with a uniform width keel and the same vessel assuming the skeg is much narrower.
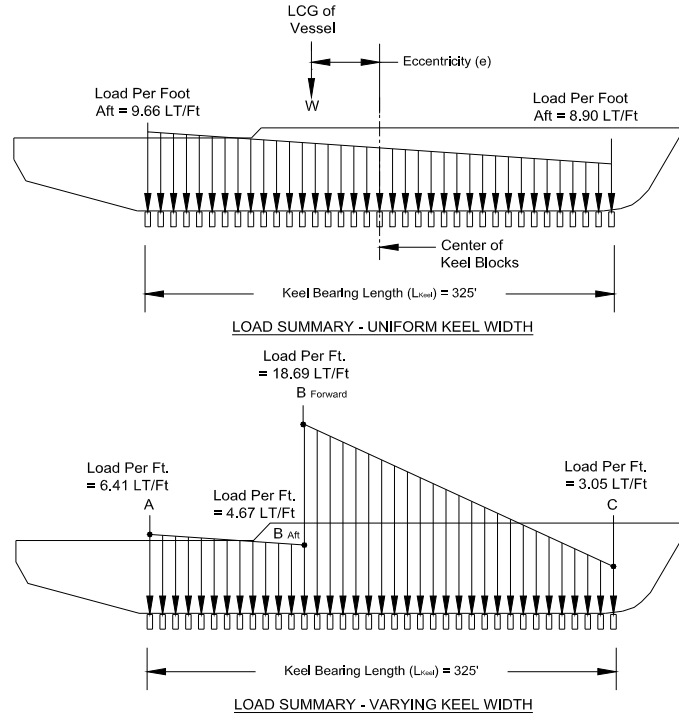
FIGURE 4. 32

As can be seen by comparing the two loading summaries, a varying width keel can drastically change the loading along the keel. It will also effect the deballasting plan if the vessel is being lifted in a floating dry dock.

4.8 – Determining the No. of Side Blocks Req'd to Resist Hurricane Forces

During a hurricane or earthquake, lateral forces can develop which tend to tip the vessel off the keel blocks. The side blocks must resist their tipping force to keep the ship upright. The greater this force, the more side blocks will be required to resist it.

The examples in this section follow the methods described in the US Navy's Ships' Technical Manual S9086-7G-STM-010 Chapter 997 "Docking Instructions and Routine Work in Dry Dock" Appendix G.

When wind blows on the side of a vessel which has been drydocked, a force develops along the hull. This wind force tries to push the vessel off the blocks
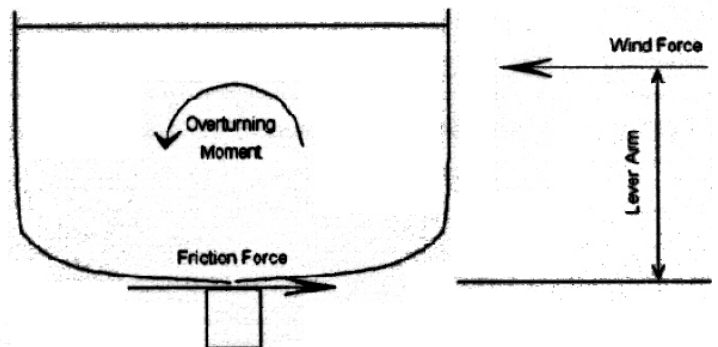
FIGURE 4. 33

laterally (sideways). Friction of the timber locking on the ship's keel is sufficient to keep the ship from sliding off the blocks.

The resisting friction force, located at the ship's keel, and the wind force, located above the keel at the center of broadside area, creates an overturning moment on the vessel which tends to roll the ship off of the keel blocks.

See Figure 4.33.

The magnitude of the wind force is equal to the force of the wind per square foot times the broadside area of the hull (including superstructure). This force effectively acts at the centroid of the broadside area. The friction force is equal and opposite to the wind force and it acts at the keel.

The overturning moment, (moment is force times distance) is equal to the wind force (or friction force) times the distance between the wind and friction forces. This distance is the distance from the keel to the centroid of the broadside area and is called the lever arm.

The force of the wind per square foot varies with wind speed. It can be calculated with the following equation:

$$P_{wind} = 0.004 \times V^2 \quad \text{[Equation 1]}$$

$$P_{wind} = \text{Force of wind in lbs/Ft.}^2 \text{ (psf)}$$

$$V = \text{wind speed in Knots}$$

Equation 1 is represented graphically in figure 4.34.
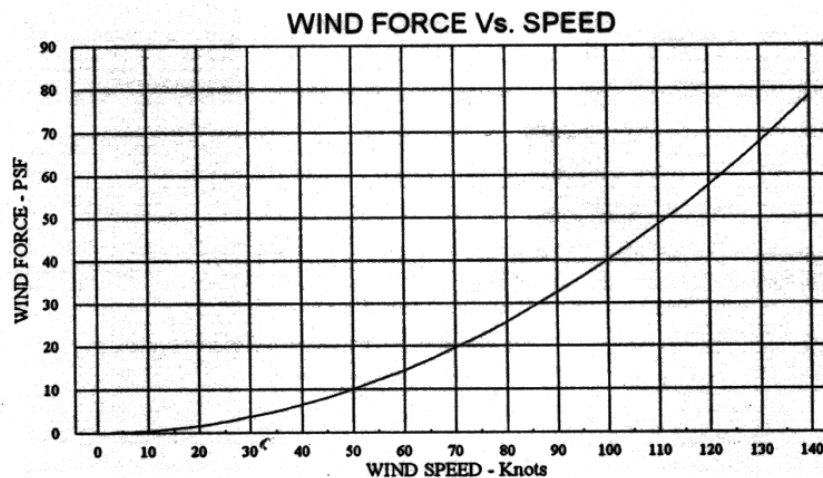
FIGURE 4. 34

To determine the total wind force on the hull and its effective location you must determine the total projected broadside area of the vessel and the centroid of that area.

This can be done by obtaining a profile view of the vessel's hull and superstructure. Each major segment of the vessel can be roughly approximated as a rectangle. See figure 4.35.

The area of each rectangle and its centroid above the ships keel (lever arm) can be approximated.

The centroid of the entire broadside area can be determined by dividing the sum of moments (area of each rectangle times the lever arm to the centroid of that rectangle) by the sum of the areas. The following is an example of this procedure.

Projected Area - FF1052
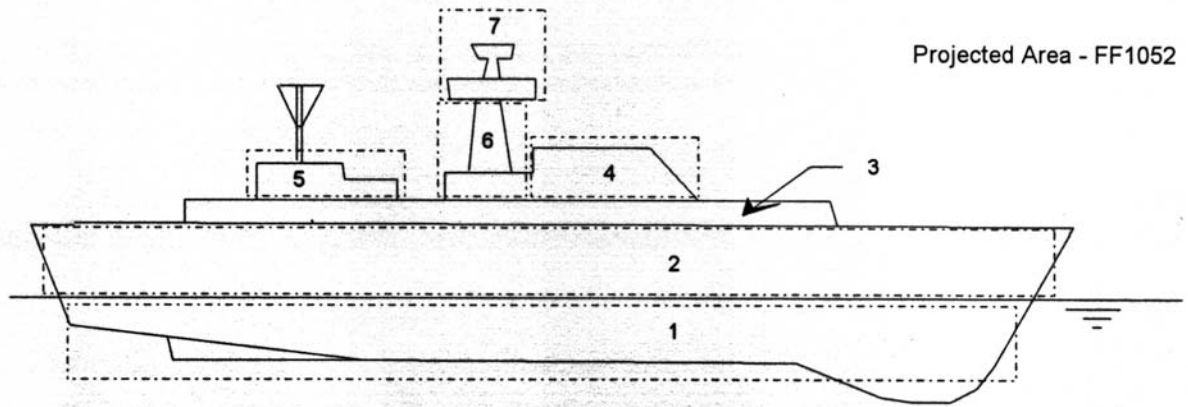
FIGURE 4. 35

The total area and distance to its centroid is calculated by:

Table 4. 1

WIND AREA CALCULATION - BROADSIDE			
Area No.	Projected Area (Ft^2)	Lever Arm Above Keel (Ft)	Moment Area x Arm Ft^3
1	5025	7.50	37687.5
2	7980	22.40	178752.0
3	2176	31.30	68108.8
4	1562	49.80	77787.6
5	739	43.80	32368.2
6	712	77.20	54966.4
7	182	97.20	17690.4
Totals	18376		467360.9

Centroid of area above keel = Lever Arm

➤ Lever Arm = Moment/Area = 467,360.9 / 18,376 = 25.43
➤ Lever Arm = 25.43 Ft. (Above Keel)

For a wind speed of 100 knots, the wind pressure per square foot on the vessel is:

> $P_{wind} = 0.004 \times V^2$
> $= 0.004 \times 100^2$
> $= 40.0$ PSF

(Actual wind speed used should be based on maximum anticipated wind speed for docking site)

The total force on the vessel is the wind pressure times the projected area:

> $Force_{wind} = P_{wind} \times Area$
> $= 40.00$ psi $\times 18,376$ Ft$^{.2}$
> $= 735,040$ lbs

This force acts at the centroid of area which is 25.43 feet above the keel. This distance is called the lever arm.

The overturning moment is the total force times the lever arm.

> Overturning moment = force x lever arm
> $= 735,040$ lbs $\times 25.43$ feet.
> $= 18,694,436$ Ft.-lbs

This overturning moment must be resisted by an equal and opposite righting moment provided by the side blocks.

The righting moment is equal to the force in the side blocks times the distance from the side blocks to the point at which the vessel tends to tip. This point is the center of the keel block (ship's centerline) and the distance is the half breadth of the side blocks. See figure 4.36.

Since the righting moment is equal to the overturning moment, which has been calculated, and the half breadth of the side blocks is known, the force in the side blocks due to wind can be calculated.
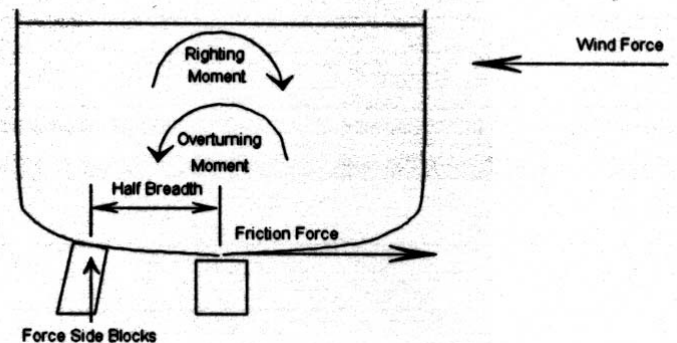
FIGURE 4. 36

Righting Moment = Force in side blocks x Half breadth of side blocks

---

Calculate force on side blocks due to wind:

> Righting Moment = Force on side blocks x ½ breadth of side blocks
> Righting Moment = Overturning Moment
> Force on side blocks (due to wind) = Overturning moment / half breadth

---

For the example used above the half breadth (C.L. of keel block to C.L. of side blocks) of the side blocks is obtained from the docking plan and found to be 10 feet.

The total overturning moment due to a 100 knot wind was calculated to be 18,694,463 Ft.-lbs.

The righting moment provided by the side blocks must equal the overturning moment or 18,694,462 ft.-lbs.

The righting moment is equal to the force in the side blocks times their half breadth or

> ➢ 18,694,463 = Force in side Blocks x 10.0 Feet

Solving for Force in side blocks,

> ➢ Force on side blocks (due to wind) = Overturning moment / half breadth
> ➢ = 18,694,436 Ft.-lbs / 10.0 Ft.
> ➢ = 1,869,443 lbs

This is the force on the side blocks along one side of the vessel due to a 100 knot wind blowing broadside against the hull. Before the wind even blows, however, the side blocks will have an initial load on them from the dead weight of the vessel. The actual portion of the ship's weight which the side blocks take is dependent on many factors. See the "Block Loading" section for a detailed discussion of block loads. For the purpose of these calculations, the Navy manual Chapter 997 arbitrarily assumes 15% of the ship's weight is taken by the side blocks. This means the side blocks on one side of the vessel take 7.5% of the vessel's docking weight. This must be added to the force on the blocks due to wind to get the total force on the side blocks.

For the example:

Given:

> ➢ The ship's docking weight is 4255 long tons.
> ➢ = 4255 LT x 2240 lbs/LT = 9,531,200 lbs

Portion of ship's weight on one side of side blocks = ship's wt x 7.5%

> ➢ = 9,531,200 x 0.075 = 714,840 lbs

Total force on side blocks = Force due to wind + force due to dead weight

> ➢ = 1,869,443 + 714,840 = 2,584,283 lbs

All the side blocks along one side of the vessel must be capable of supporting this load. The allowable load for each side block can be determined and thus, the number of blocks required to support the total load can be calculated.

The allowable load for each side block is based on the bearing area of the timber cap against the hull multiplied by the pressure that is allowed on the timber cap.

The bearing area is the length of the cap times the width of the cap (assuming 100% effective area of contact).

Chapter 997 allows the pressure on the timber to be taken as the proportional limit of the timber. This is a much higher pressure than the working loads used for other block loading calculations. This may cause permanent crushing of the wood during a hurricane or earthquake, but the blocks should not fail. This is considered acceptable due to the infrequent nature of earthquakes or hurricanes.

It is also extremely important that the entire side block be designed as a column capable of resisting the full block load without failure.

For the example:

> ➢ Side block bearing area = L x W
> ➢ = 18" x 28" = 504 In.^{2}

Timber cap is Douglas Fir with proportional limit = 800 psi.

> ➢ Allowable load per block = bearing area x proportional limit
> ➢ = 504 in.^{2} x 800 psi = 403,200 lbs

Number of side blocks required = Total load on side blocks / Allow. Load per block

> ➢ = 2,584,283 lbs / 403,200 lbs = 6.4 blocks

USE 7 BLOCKS PER SIDE TO RESIST HURRICANE WINDS

4.9 – Determining the No. of Side Blocks Req'd to Resist Earthquake Forces

The method used to determine the number of side blocks required to resist earthquake forces is similar to the method described above for hurricane forces. The only difference is the way the overturning moment is calculated. In the case of earthquakes, a horizontal force is imparted on the ship due to the lateral acceleration of the ground or dock. The magnitude of this force is a function of the magnitude of the ground acceleration. Chapter 997 assumes the magnitude of the horizontal force to be equal to 0.2 times the weight of the ship. This force is effectively applied at the center of gravity of the ship. As with the hurricane forces, friction between the hull and the keel blocks keep the ship from sliding sideways, but the horizontal force at the center of gravity and the equal but opposite force of friction at the keel, create an overturning moment which tends to tip the ship about the keel blocks. See Figure 4.37. The lever arm in this case is the distance between the keel of the vessel and its vertical center of gravity, or KG of the vessel. Refer to the section on "Stability" for a discussion on determining the vertical center of gravity.
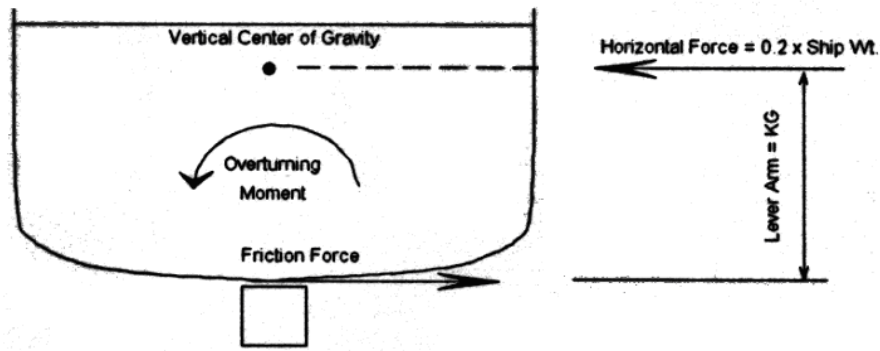
FIGURE 4. 37

The overturning moment is the horizontal force times the lever arm.

- ➢   Horizontal force is = 0.2 x ship wt.
- ➢   Lever arm is = KG

For example, given the following:

- ➢   Ship Wt. = 4255 long tons = 9,531,200lbs
- ➢   Ship KG = 17.45 feet

Overturning moment =

- ➢   = Horizontal force x lever arm
- ➢   = 0.2 x 9,531,200 lbs x 17.45 ft.
- ➢   = 33,263,888 Ft.-lbs

This overturning moment must be resisted by an equal and opposite righting moment provided by the side blocks.

The righting moment is equal to the force in the side blocks times the distance from the side blocks to the point at which the vessel tends to tip. This point is the center of the keel block (ship's centerline) and the distance is the half breadth of the side blocks.

Righting Moment = Force in side blocks x ½ breadth of side blocks

Since the righting moment is equal to the overturning moment which has been calculated, and the half breadth of the side blocks is known, the force in the side blocks due to earthquake can be calculated.

For the example used above the half breadth (C.L. of keel block to C.L. of side blocks) of the side blocks is obtained from the docking plan and found to be 10 feet.

Given:
- ➢ Half breadth = 10.0 feet.

Force on side blocks (due to earthquake)

- ➢ = 33,263,888 Ft.-lbs / 10.0 Ft.
- ➢ = 3,326,389 lbs

As with the hurricane example, the initial force on the side blocks due to the weight of the vessel is assumed to be 7.5% per side.

Given:

- ➢ Ship's docking weight = 4255 long tons.
- ➢ Ship's docking weight = 4255 LT x 2240 Lbs/LT
- ➢ Ship's docking weight = 9,531,200 lbs

Portion of ship's weight on one side of side blocks

- ➢ Side block load = ship's wt. X 7.5%
- ➢ Side block load = 9,531,200 x .075
- ➢ Side block load = 714,840 lbs

The allowable load per block was calculated for hurricane loads and remains the same:

- ➢ Allowable load per block = bearing area x proportional limit
- ➢ = 504 In.^{2} x 800 psi
- ➢ = 403,200 lbs

Number of side blocks required

- ➢ = Total force on side blocks / Allow. Load per block
- ➢ = (Force due earthquake + Force due to ship's weight)/ Allow. Load per block
- ➢ = (3,326,389 Lbs + 714,840 Lbs) / 403,200 Lbs
- ➢ = 4,041,229 Lbs / 403,200 Lbs
- ➢ = 10.0 Blocks

USE 10 BLOCKS PER SIDE TO RESIST EARTHQUAKES

Earthquake loading controls!

It is important to remember that the above analyses determines the minimum number of side blocks required based on the strength of the timber in the caps. The entire side block should also be checked for column strength and stability is discussed in the "Blocking Construction" section.

5.0 – STABILITY

Although the vessel is usually in a stable condition when it arrives, its stability characteristics will change (become less stable) as it sits down on the blocks. The vessel must be firmly cradled in the side blocks before it loses the stabilizing effect of the water. The point at which this happens can be calculated so the side blocks can be brought to bear against the hull before instability occurs.

Once in dock, the only way to insure the vessel will be stable upon refloating is to keep careful track of all weight changes on the vessel and calculate its GM (measure of stability) before undocking.

Most accidents attributed to instability occur during the undocking of the vessel because the changes in weight have not been monitored and the new stability characteristics were not recalculated.

To insure the vessel maintains positive stability throughout the docking and undocking evolutions, its stability should be checked for the following conditions:

Docking

> ➢ Ship afloat (baseline condition)
> ➢ Ship at keel touch down
> ➢ Ship at time of hauling of side blocks
> ➢ Ship's draft at 0 GM (point of instability)

Undocking

> ➢ Ship just prior to keel lift off
> ➢ Ship afloat

For floating dry docks, stability of the combined ship/dock system must be also checked.

5.1 – Stability of Vessel Afloat

A vessel afloat usually will have positive stability when it arrives at the dock. In rare instances, the ship may actually have a negative GM (negative stability) while it is afloat. One indication of negative stability is the vessel listing from one side to another for no apparent reason (called lolling).

A ship with negative stability is unsafe to dock.

The stability characteristics of the vessel while afloat are used as a basis in all subsequent stability calculations so it is important to obtain accurate information for this phase.

When investigating stability of a floating body, two points are critical.
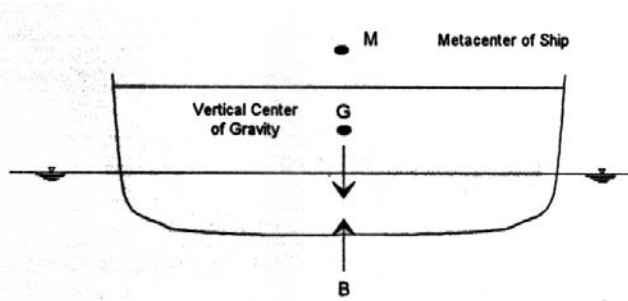
FIGURE 5. 1

FIGURE 5. 2

FIGURE 5. 3

M is the Transverse Metacenter, which is the point in which vertical lines through the center of buoyancy will pass for any small angle of list. (< 7 to 10 degrees). This has also been described as the point about which the vessels rotates for small angles of heel.

G is the location of the vertical center of gravity of the vessel and all weights aboard the vessel.

It can be seen from Figures 5.1 through 5.2 that as long as the center of gravity (G) of the vessel falls below the Transverse Metacenter (M), a restoring moment will develop between the weight and the buoyancy when an external tipping force (such as wind) causes a slight list. (Figure 5.2)

This restoring moment tends to reduce the list and right the vessel back to its original upright position .
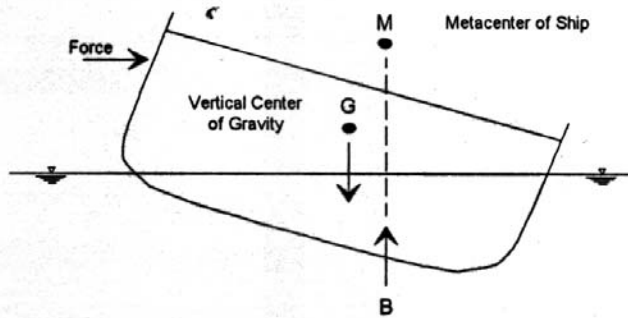
When the center of gravity (G) of the vessel falls above the Transverse Metacenter (M), any slight list will result in the weight and buoyancy forming an additional tipping moment (Figure 5.3).

This moment tends to increase the list resulting in the vessel turning over. The vessel is not stable.

For calculation purposes the points G and M are usually referenced to the keel of the vessel designated as K.
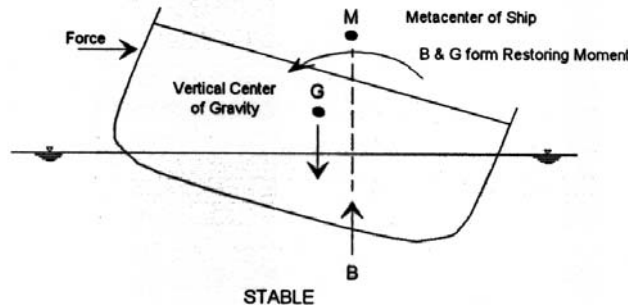
Thus, the distance KM refers to the height of the Transverse Metacenter (M) above the ship's keel (K). (Figure 5.4) The measurement KM is function of the ship's hull shape below the waterline and will vary as the ship's draft varies. Thus for any particular draft, a vessel will have a set KM.

The distance KG refers to the height of the ship's vertical center of gravity (G) above the ship's keel. (Figure 5.4)
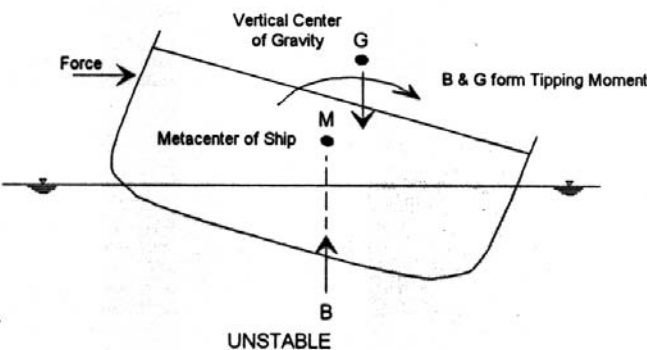
The values of KM for a particular ship at varying drafts can be found on the ship's D & O Curves (Displacement & Other Curves) and may also be in the damage control or stability books.

The measurement KG is the vertical center of gravity of the vessel and all weights on the vessel.

This height varies as weight is added, removed or shifted on the vessel
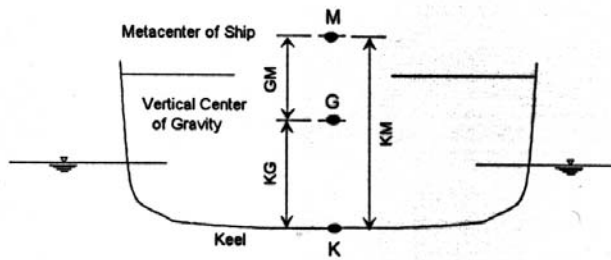
The measurement GM is the basic index of stability and it is the distance between the transverse Metacenter (M) and the vertical center of gravity (G).

$$GM = KM - KG$$

FIGURE 5. 4

If the transverse metacenter (M) is ABOVE the center of gravity (G) then GM is positive and the vessel is stable.

If the transverse metacenter (M) is BELOW the center of gravity (G) then GM is negative and the vessel is not stable.

As stated above, the measurement KG is the height above the keel of the vertical center of gravity of the vessel and all weights on the vessel and will vary as weight is added, removed or shifted on the vessel.

The KG at the time of docking must be determined by a weight and vertical moment study of the ship's present loading condition. Normally, the KG of the ship in light condition is available.

The weight and vertical moment of all additional items that are on the ship at drydocking must be added to this value to determine the actual KG.

EXAMPLE - KG CALCULATION:

Table 5. 1

ITEM	WEIGHT (LT)	KG (FT)	WT X KG (FT-LT)
Ligthship	10,000	28.00	280,000
Crew	15	36.50	548
Provisions	70	26.00	1,820
Stores	55	35.00	1,925
Cargo	375	19.50	7,313
Fuel	325	8.50	2,763
Ballast	250	7.75	1,938
Total (Sum Columns)	11,090		296,305

The overall KG of the ship (KG_{Ship}) is obtained by summing all the moments (Wt. x KG) and dividing by the total weight.

$$KG_{ship} = (Total\ Wt.\ x\ KG)/(Total\ Wt.)$$

➤ KG_{ship} = 296,305/11,090
➤ KG_{ship} = 26.72 Feet

Adjustment of KG for Free Surface Effects

The KG must be "adjusted" if any free liquids are on board the ship.

Free liquids are described as any liquids in tanks that are not completely full.

The motion of the liquid in any partially filled tank as the ship is inclined, (listed), causes the center of gravity of the liquid to shift towards the low side.

This causes the ship's overall center of gravity to shift towards the low side, increasing the tendency to list. (Figure 5.5)

This destabilizing effect is called the **free surface effect.**

In some cases the shift of the center of gravity can be great enough to cause the vessel to become unstable.
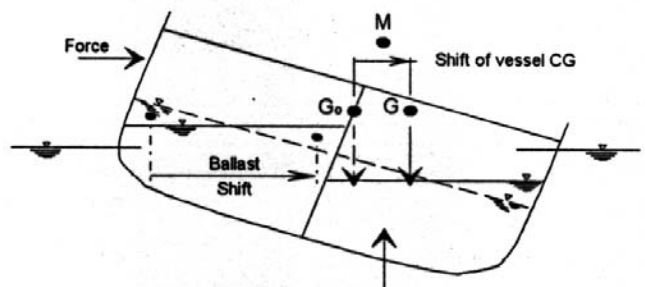
FIGURE 5. 5

To calculate the effects that free liquids have on the stability of a floating body it is usually assumed that the center of gravity (G) has risen a certain amount. This is called the virtual rise of G. The new position of G is called **G_V**.

From Figure 5.6, it can be seen that shifting the center of gravity to the side a certain amount has the same effect on stability as raising the center of gravity.

For any angle of list the actual center of gravity shifts to the low side due to the leveling out of the liquids on board. The more the vessel lists, the more the center of gravity shifts towards the low side. It can be seen from Figure 5.6 that assuming the center of gravity has risen has the same effect. A vertical line representing gravity acts through the actual shifted G location and the assumed risen position, thus resulting in the same effect. The virtual rise of G, or the distance G appears to have risen due to the shifting of liquids during a list is called the "free surface correction" to the distance KG

G_o = Original location of CG

G = Actual location of CG with ballast shifted

G_v = Assumed location of CG for calculations
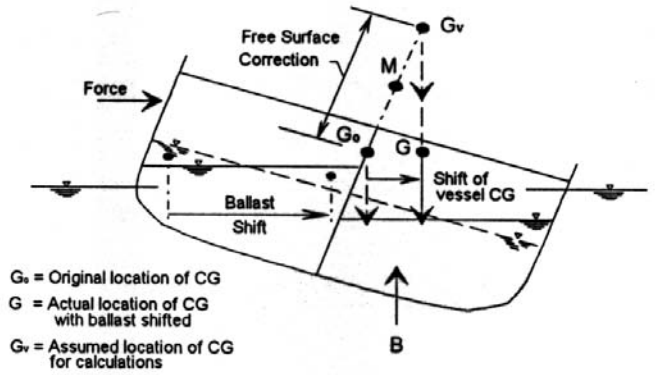
FIGURE 5.6

The free surface correction is equal to the sum of all the Vertical Moments of Free Surface of all tanks with free liquids, divided by the total displacement of the vessel.

F.S.Corr. = Sum of Moments / Displacement

The calculation of the vertical moment of free surface for a complex shaped tank like that on a vessel is complicated and beyond the scope of this lecture. The ship's stability booklet or damage control booklet, however should list moments of free surface values for each tank on board the vessel. These can be looked up for all partially filled tanks, added together and the free surface correction determined by dividing by the ship's displacement.

It is important to note that a tank that is completely full does not have any free surface effect. This is because the tank top prevents the water at thigh side from running to the low side, hence no shift of weights.

EXAMPLE– SHIP'S FREE SURFACE CORRECTION:

Table 5. 2

TANK NO.	GALLONS	% FULL	VERT. MOM. OF F.S. (FT-LT)
5-56-0	4,670	35.00	294
5-64-0	17,850	100.00	0
5-84-1	13,755	69.00	482
5-84-2	13,755	69.00	482
5-164-1	0	0.0	0
5-164-2	0	0.0	0
5-250-1	0	0.0	0
5-250-2	0	0.0	0
Total (Sum Columns)			1258

If displacement of the vessel = 11,090 LT,

The free surface correction = Sum of Vert. Moments / Displacement

- ➤ Free surface correction = 1258 Ft.-LT / 11,090 LT
- ➤ = 0.11 Ft.

If the KG of the vessel is = 26.72 feet, then the KG corrected for free liquids is:

$$KG_{corrected} = KGship + F.S.\ Correction$$

- ➤ $KG_{corrected}$ = 26.72 + 0.11
- ➤ $KG_{corrected}$ = 26.82 Feet

A KG that has been corrected for free liquids is referred to as "KG Corrected" or "Corrected KG".

NOTE: Since partially filled tanks make the vessel less stable, it is good practice to minimize the free surface effects by minimizing the number of partially filled tanks.

It is recommended that tanks be completely full or completely empty if at all possible before docking the vessel.

If no stability data is available, the GM of the vessel can be estimated by sallying the vessel (running the crew across the beam of the ship or by lifting and lowering weights on one side of the vessel).

A sufficient roll should be developed such that several cycles can be measured before dampening effects occur. Using the average time in seconds, T, for a period of roll, (maximum list on one side to maximum list on the other and back), GM can be calculated with the formula:

$$GM = (C^2 \times B^2) / T^2$$

Where:

- ➤ B = Beam in feet
- ➤ T = Period of roll for one complete cycle (one side to the other and back) in seconds
- ➤ C is from the table below:

Table 5. 3 – From U.S. Navy Chapter 997 Manual

C	
SHIP TYPE	**C**
Auxiliaries	0.44
Aircraft Carriers	0.58
Cruisers	0.43
DD 692	0.42
Destroyers (Other)	0.44
Destroyers Escorts	0.45
Landing Ships	0.46
Patrol Craft	0.47
Submarines	
(Body of Revolution hull)	0.41
(Other Fleet Type)	0.36
Tugs	0.40

Once the stability of the vessel afloat has been determined, that condition is used as a basis for all subsequent stability calculations during docking and undocking prior to drydocking.

For this reason it is important to obtain accurate information on the actual condition of the ship.

5.2 – Stability of Vessel at Time of Keel Touch Down

When a ship enters a dock it generally has a trim relative to the dry dock's keel block line. (This is not the case for floating dry docks which can be put on a trim to match the vessel's trim.) The trim is usually (but not always) by the stern, hence the vessel's skeg makes first contact with the blocks.

As the docking continues, a force develops at the skeg (called **knuckle reaction**) which rotates the ship until the vessel's keel has made contact with the keel blocks all along its full length.

This is called the point of keel touch down.
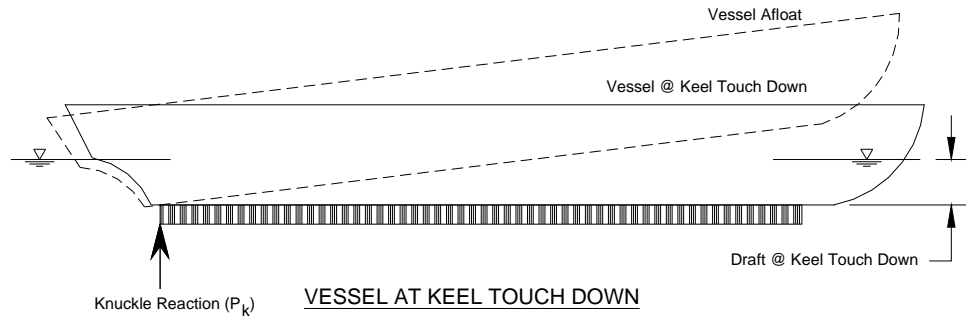
FIGURE 5. 7

The force exerted by the blocks on the ship's skeg has the same effect on the vessel's KG as would the removal of a corresponding weight on the vessel located at the vessel's keel. Removing weight low in a ship raises its center of gravity which increases its KG, decreases its GM, thus making the vessel less stable. This raising of the KG due to the knuckle load is called a "Virtual rise in KG". The new effective location of center of gravity due to the knuckle reaction is called the "Virtual Center of Gravity" and the new KG is referred to as KG_V.

The vessel's new KG (KG_V) is determined in the same manner the original KG was determined, only this time the knuckle reaction is assumed to be weight removed. The weight is assumed to be located at the keel of the vessel.

FIGURE 5. 8

STABILITY
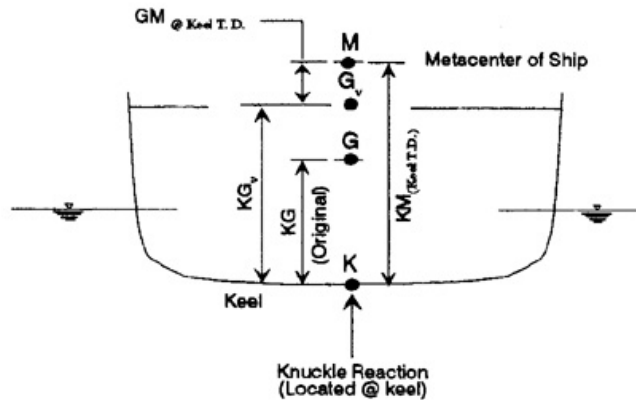
EXAMPLE - KG$_V$ KNUCKLE REACTION CALCULATION

Table 5. 4

ITEM	WEIGHT (LT)	KG (FT)	WT X KG
Ship Afloat	11,090	26.72	296,325
Knuckle Reaction	-115	0.00	0
Total (Sum Columns)	10,975		296,325

$$KG_V = (\text{Total Wt.} \times KG)/(\text{Total Wt.})$$

- ➢ KG$_V$ = 296,325 Ft.-LT / 10,975 Ft. =
- ➢ KG$_V$ = 27.00 Feet

The free surface correction previously calculated must be added to KG$_V$ to account for free surface effects. Thus the GM of the vessel at keel touch down can be calculated by:

$$GM_{\text{keel t.d.}} = KM_{\text{keel t.d.}} - KG_V - \text{F.S. Correction}$$

The KM at keel touch down (KM$_{\text{keel t.d.}}$) may be slightly different from the KM of the vessel afloat, since the draft of the ship will have changed. The draft at keel touch down can be determined from the new vessel displacement at keel touch down.

The new displacement is the original displacement minus the knuckle load.

- ➢ (11,090 – 115 = 10,975 LT in the example.)

The KM at this new draft (KM$_{\text{keel t.d}}$) can be looked up and used in the above equation.

The magnitude of the knuckle reaction must be calculated for use in the above calcs. This is done in the following manner:

- ➢ Determine the trim of the vessel afloat.
- ➢ Determine the trim of the vessel landed on the blocks (0 for level keel blocks).
- ➢ Determine the trim needed to be removed (trim afloat – trim landed)
- ➢ Determine the vessel's Longitudinal Center of Floatation (LCF) for its docking draft. (This usually can be interpolated from the "Table of Displacements & Other Properties" on the docking plan.)
- ➢ Determine the vessel's Moment to Trim One Inch (MT1) for its docking draft. (This usually can be interpolated from the "Table of Displacements and & Other Properties" on the docking plan.)
- ➢ Multiply the Moment of Trim One Inch by the trim needed to be removed (in inches). This results in the total trimming moment that needs to be imparted to the vessel to remove its trim relative to the block line. This is the point the ship has just touched down on the blocks.

The total trimming moment must be imparted by the knuckle reaction. This force acts at the first keel block and rotates the ship about its LCF. (Figure 5.9)

Since moment is equal to force x distance, the force of the knuckle reaction times the distance the first block is from the LCF must equal the total trimming moment needed.

KNUCKLE REACTION TO REMOVE TRIM
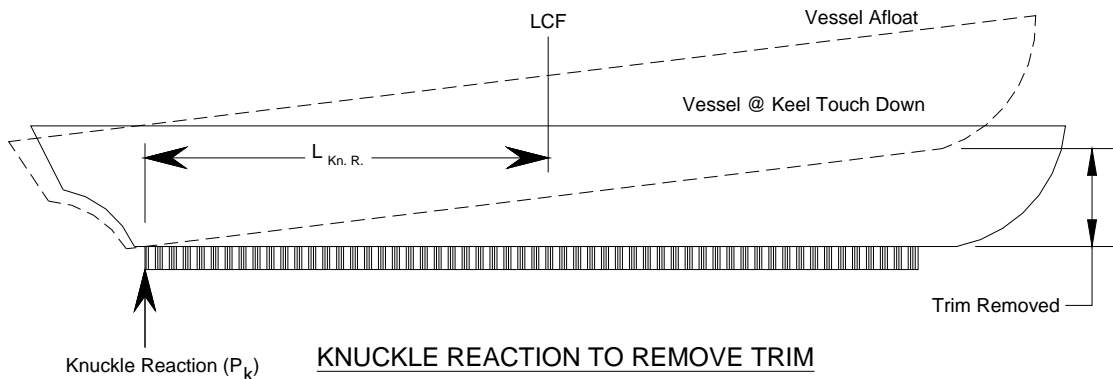
FIGURE 5. 9

Total Trimming Moment = Force x Distance = Knuckle Reaction x $L_{Kn\,r}$

Or

Knuckle Reaction = Total Trimming Moment / $L_{kn.r.}$

Where $L_{kn.r.}$ = Distance from the LCF to 1st keel block

Since any knuckle reaction reduces the stability of the vessel it is best to try and minimize the reaction by minimizing the relative trim of the vessel to the block line.

Rule of Thumb: Trim of Vessel

Trim of vessel relative to blockline should not exceed 1 foot for every 100 feet of vessel length.

This can be done by:

- ➤ Ballasting the vessel to match trim of blockline
- ➤ Building the slope of the block line to match vessel trim
- ➤ Matching the trim of the vessel with the trim of the dock (Floating Docks only)

The U.S Navy's Chapter 997, Section 997-2.5.5.2.3.2, Part c has the following equation to estimate maximum allowable trim:

- ➤ $t_a = 0.03 \times L^2 / MT1"$

Where:

- ➤ t_a = Allowable trim between perpendiculars
- ➤ L = Length between perpendiculars
- ➤ MT1" = Moment to trim 1" in Ft.-Tons/In.

5.3 – Stability of Vessel at Time of Hauling Side Blocks

If the vessel is being docked on fixed blocks, it will be cradled in the side blocks by the time the keel touches down on the keel track. If hauling side blocks are used however, the ship must be lifted an additional amount to be sure she is well seated on the keel blocks before the side blocks are brought to bear. This lifting imparts additional load at the keel and raises the vessel's virtual KG in the same manner as the knuckle load did.

The vessel's stability must be investigated at the time the side blocks are pulled in and brought to bear against the hull.

Vessel on Keel Blocks

Additional Lift

Draft @ Side Block Hauling

Draft @ Keel Touch Down

Knuckle Reaction (P_k)

Reaction Due to Lift
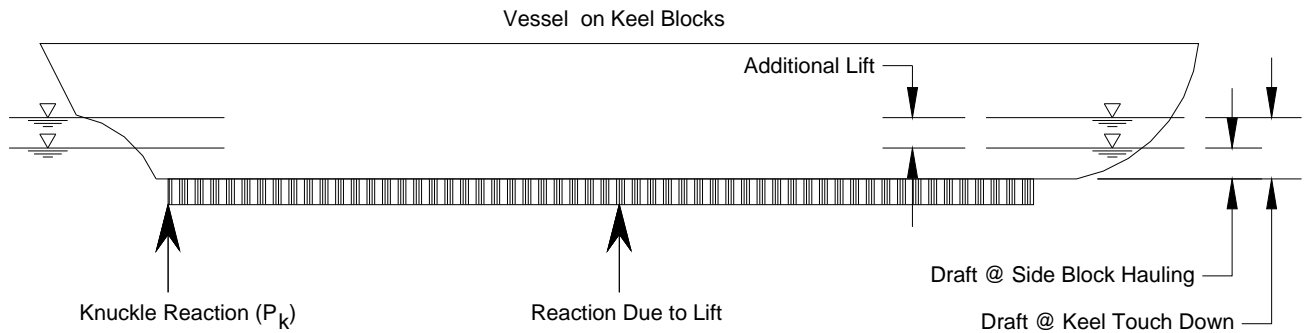
REACTION DUE TO ADDITIONAL LIFT

FIGURE 5. 10

The virtual rise in the KG is calculated in the same way as for the knuckle load calculation. The load imparted on the blocks is assumed to be weight removed from the vessel and located at the keel.

It is important to remember that if a knuckle load has been imparted to the vessel to remove trim, that load must also be removed in the calculation

The reaction due to lift is determined by subtracting the vessel's displacement at the draft when the side blocks are pulled, from the displacement at the draft at keel touch down.
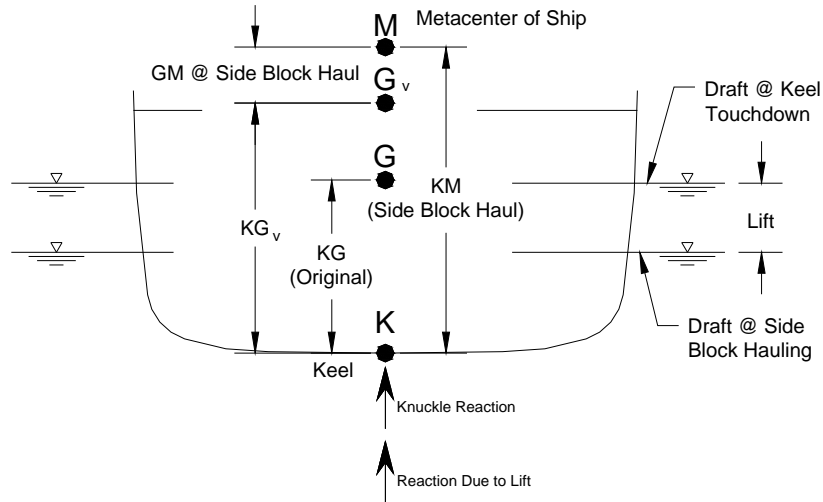
VIRTUAL RISE OF CENTER OF GRAVITY

FIGURE 5.11

EXAMPLE - KG$_V$ LIFT REACTION

Table 5. 5

ITEM	WEIGHT (LT)	KG (FT)	WT X KG (FT-LT)
Ship Afloat	11,090	26.72	296,325
Knuckle Reaction	-115	0.00	0
Lift Reaction	-350	0.00	0
Total (Sum Columns)	10,625		296,325

KG$_V$ = (Total Wt. x KG) / (Total Wt.)

➢ KG$_V$ = 296,325 / 10,625
➢ KG$_V$ = 27.89 Feet

The free surface correction previously calculated must be added to KG$_V$ to account for free surface effects.

Thus the GM of the vessel at the time of side block haul can be calculated by:

GMside block haul = KM$_{side block haul}$ – KG$_V$ – F.S. Correction

The KM at the time of side block haul (KM$_{side block haul}$) will be different from the KM of the vessel afloat since the draft of the ship will have changed.

The draft at the time of side block haul is known and the KM at this draft (KM$_{side block haul}$) can be looked up and used in the above equation.

5.4 – Draft At 0 GM (Point of Instability)

The draft at which the ship's GM goes to 0 should be determined. This is the point at which the ship goes unstable assuming the side blocks were never pulled. The Navy also uses this draft to determine if the vessel has adequate stability for drydocking.

Although the side blocks should be pulled well before this point, it is good to know where this critical draft is, as many times dockings do not go exactly as planned. The draft at 0 GM is determined by trial and error.

The calculation is performed in the same manner as the previous GM at the time of side block haul calculations, only the draft of the vessel is incrementally decreased. The calculation is repeated with progressively smaller drafts until the GM goes to 0. This is the draft at 0 GM or the **draft at instability**.

Chapter 997 Section 2.5.4.4 defines the following as acceptable stability criteria for the draft at instability:

> **2.5.4.4.1 If the difference between the draft at landing and the draft at instability is 1 foot or greater, then the ship has acceptable stability for landing on the keel blocks fore and aft and, subsequently, hauling the side blocks.**

> **2.5.4.4.2 If the difference between the draft at landing and the draft at instability is less than one foot but equal to or greater than 6 inches, then pre-positioned (prior to the ship landing fore and aft) side blocks are required for acceptable stability.**

> **2.5.4.4.3 If the difference between the draft at landing and the draft at instability is less than 6 inches, then the ship does not have acceptable stability.**

5.5 – Vessel Stability at Undocking

Once the vessel is in dry dock, the only way to insure it will be stable upon refloating is to keep accurate records of all weight changes (additions, removal, shifts) and changes in liquid loading condition. With these records, new vessel displacement, LCG, TCG, KG and KG corrected can be calculated. With this information the vessel's list, trim, drafts and GM upon refloating can be calculated.

SUGGESTION:

> **The Port Engineer/Docking Officer/Docking Observer should confirm with the Dock Master the lowest change in weight that will be reported for the purposes of tracking weight changes while in dock.**

The procedure for these calculations will be discussed in detail in Section 6 "Predicting Vessel Condition at Time of Undocking".

If the ship is predicted to float with a trim relative to the keel block line, the GM at the time the bow is just about to lift off the blocks must be determined. This is calculated in the same manner as the GM at keel touch down.

The predicted trim at refloating (relative to the block line) is "removed" by the knuckle reaction in the first block. The vessel's KG_V and GM can then be calculated in the same manner as the keel touch down analyses. For floating docks, the dock should be trimmed to match the vessel's predicted trim which eliminates the knuckle reaction.

SUGGESTION:

> **If possible, the vessel should be undocked in the same condition as it was docked. This will insure the same stability throughout the undocking that was achieved in the docking.**

5.6 – Example of Grounding Stability Calculation

PROBLEM:

An FFG – 1052 Class frigate is to be drydocked in a basin dock with the following drafts"

> ➢ Docking Draft Forward: 10' – 10"
> ➢ Docking Draft Aft: 14' – 1"

Determine whether the vessel has adequate stability for docking with hauling side blocks.

Table 5. 6 – From Docking Plan "Table of Displacements"/ KM Obtained from "Damage Control Booklet"

MEAN DRAFT (FT.)	DISPL. SW (LT)	MOM. TRIM 1 INCH (FT-LT)	LCB AFT OF MDSHP (FT.)	LCF AFT OF MDSHP (FT.)	TONS/IN. IMMERSION (LT)	KM (FT.)
11.0	2512	517.0	-14.70	11.50	28.10	22.65
12.0	2871	588.0	-11.20	15.90	29.90	22.60
13.0	3235	672.0	-7.60	20.90	31.50	22.50
14.0	3625	761.0	-4.30	25.80	33.00	22.40
15.0	4018	807.0	-1.30	27.30	33.90	22.20
16.0	4440	830.0	1.30	27.10	34.30	21.90
17.0	4850	848.0	3.50	26.60	34.70	21.50

From the Damage Control Officer aboard the ship, the following info is obtained:

> ➢ KG = 19.75 Ft.
> ➢ Two tanks have free liquids in them with vertical moment of free surface equal to 340 and 290 Ft. – LT.

Calculate Mean Draft:

> ➢ (10.83 + 14.08) / 2 = 12.45 Ft.

From "Table of Displacements" find LCF for Draft = 12.45 Ft.

> ➢ By interpolation of LCF @ 13 Ft. and 12 Ft.
> ➢ LCF = [(20.90 – 15.90) x (12.45 – 12.0)] + 15.90
> ➢ LCF = 18.15 Ft. aft of amidships

Calculate location of Mean Draft relative to amidships:

From the Docking Plan, the distance between draft marks is 405 Ft. with amidships centered between draft marks. Therefore, Mean Draft is at amidships.
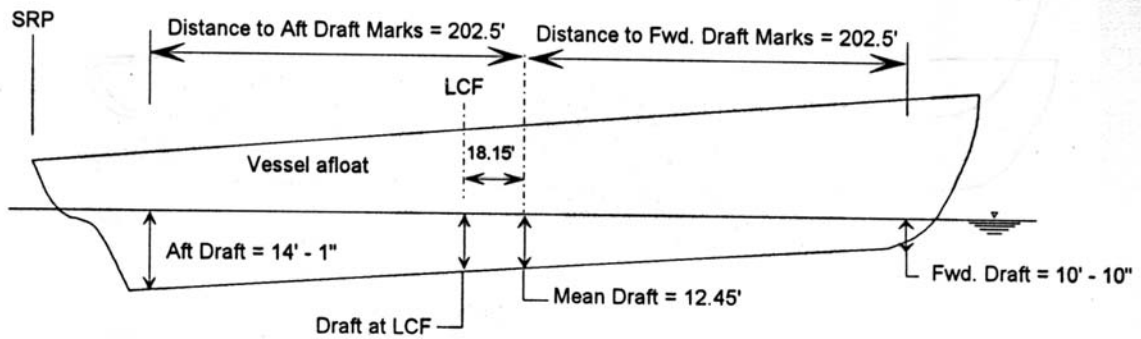
FIGURE 5. 12

Calculate Draft at LCF:

> ➢ = [(14.08 – 10.83) / 405] x 18.15 + 12.45
> ➢ = 12.60 Ft.

Now re-enter the "Table of Displacements" using the draft at LCF and find vessel properties:

> ➢ Draft at LCF = 12.60 Ft.
> ➢ Interpolate between 13.0 and 12.0 ft. drafts
> ➢ Displacement = [(3235 – 2871) x 0.60] + 2871 = 3089 LT
> ➢ MT1 = [(672 – 588) x 0.60] + 588 = 638 Ft. – LT
> ➢ TPI = [(31.50 – 29.90) x 0.60] + 22.90 = 30.86 LT
> ➢ KM = [(22.50 – 22.60) x 0.60] + 22.60 = 22.54 LT

Calculate rise of KG due to free surface effects (Free Surface Correction):

> ➢ Total vertical moment = 340 + 290 = 630 Ft. – LT
> ➢ Free Surface Correction = Vert. Moment / Displacement = 630 / 3089 = 0.20 Ft.

Calculate GM_{Afloat} = KM – KG – F.S. Corr.

> ➢ = 22.54 – 19.75 – 0.20
> ➢ = 2.59 Ft.
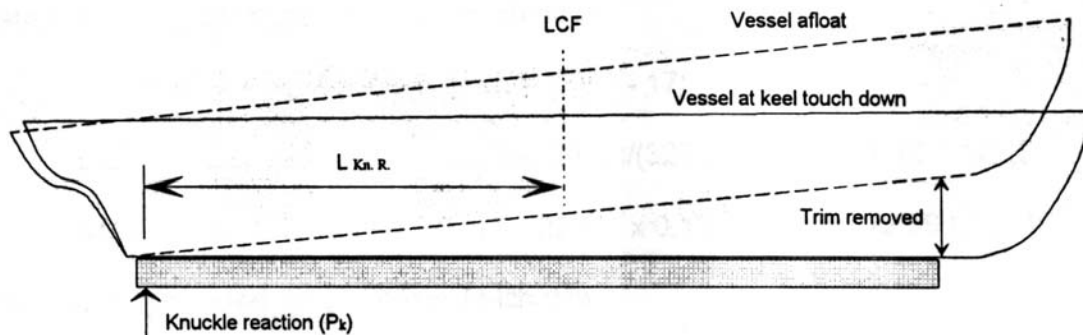
FIGURE 5. 13

Calculate Knuckle Reaction (P_K)

Given:

From Docking Plan, distance from LCF to first Keel block ($L_{Kn\ R}$) is determined to be 142 feet.

➢ The trim to be removed is the vessel trim (14'-1" – 10'-10") = 3'-3" = 39"
➢ The moment to change trim 1" is 638 Ft.-LT (From above)

So the moment to remove a trim of 39" is 39" x 638 Ft.-LT / " = 24,882 Ft.-LT

The moment to remove trim is caused by the Knuckle Reaction (P_K) acting about the LCF, a distance of 142' away.

Knuckle Reaction x Distance = Moment to remove trim

➢ P_K x 142' = 24,882 Ft.-LT
➢ P_K x 24,882 Ft.-LT / 142'
➢ P_K = 175 LT

Calculate new KG (KG_V) of vessel:

KG_V CALCULATION

Table 5. 7

ITEM	WEIGHT (LT)	KG (FT.)	WT. X KG (FT.-LT)
Ship afloat	3,089	19.75	61,008
Knuckle R.	-175	0.00	0
Total	2,914		61,008

➢ KG_V = (Total Wt. x KG) / (Total Wt.)
➢ KG_V = 61,008 Ft.-LT / 2,914 Ft.
➢ KG_V = 20.94 Feet

Calculate KM of grounded vessel at keel touch down:

➢ Displacement at keel touchdown = 3,089 – 175 = 2,914 LT
➢ Draft at Displ. of 2,914 LT = [(2,941 – 2871) / (3235 – 2871) x 1] + 12 = 12.12 Ft.
➢ KM at Draft of 12.12 Ft. = [(22.50 – 22.60) x 0.12] + 22.60 = 22.59 LT

Calculate GM of grounded vessel at keel touch down:
➢ $GM_{Keel\ T.D.}$ = $KM_{Keel\ T.D.}$ – KGV – F.S. Correction
➢ $GM_{Keel\ T.D.}$ = 22.59 –20.94 – 0.20 = 1.45 Ft. ➔ OK

Assume vessel is lifted another 12" after keel touch down before hauling side blocks.

(12" of lift is the minimum lift for hauling blocks required by Chapter 997)

- ➢ Draft at Keel touch down = 12.12 Ft. (from above)
- ➢ Draft at time of side block haul = 12.12 Ft. – 1.0 Ft. = 11.12 Ft.
- ➢ Displ. At Draft of 11.12 Ft. = [(2871 – 2512) x 0.12] + 2512 = 2555 LT
- ➢ Force required to lift vessel 12" = 2914 – 2555 = 359 LT

Calculate new KG (KGV) of vessel:

Table 5. 8

ITEM	WEIGHT (LT)	KG (FT.)	WT. X KG (FT. – LT)
Ship Afloat	3,089	19.75	61,008
Knuckle R.	-175	0.00	0
Add. Lift	-359	0.00	0
Total	2,555		61,008

- ➢ KGV = (Total Wt. x KG) / (Total Wt.) =
- ➢ KGV = 61,008 Ft.-LT / 2,555 Ft. =
- ➢ KGV = 23.88 Feet

Calculate KM of vessel at time of side block haul:

- ➢ Displacement at time of side block haul = 3,089 – 175 – 359 = 2,555 LT
- ➢ Draft at Displ. Of 2,555 LT = 11.12 Ft. (from above)
- ➢ KM at Draft of 11.12 Ft. = p(22.60 – 22.65) x 0.12] + 22.65 = 22.64 LT

Calculate GM of vessel at time of side block haul:

- ➢ $GM_{SideBLK} = KM_{SideBLK} – KGV – F.S. Correction$
- ➢ $GM_{SideBLK} = 22.64 – 23.38 – 0.20 = -0.94$ Ft. Negative (NG)
- ➢ Try fixed blocks or reduce trim

Try using fixed blocks

Assume vessel is lifted another 6" after keel touch down before hauling side blocks.

(6" of lift is the minimum lift for fixed blocks required by Chapter 997)

- ➢ Draft at Keel touch down = 12.12 Ft. (from above)
- ➢ Draft at time of side block haul = 12.12 Ft. – 0.5 Ft. = 11.62 Ft.
- ➢ Displ. At Draft of 11.62 Ft. = [(2871 – 2512) x 0.62] + 2512 = 2734 LT
- ➢ Force required to lift vessel 6" = 2914 – 2734 = 180 LT

Calculate new KG (KGV) of vessel:

Table 5. 9

ITEM	WEIGHT (LT)	KG (FT.)	WT. X KG (FT. – LT)
Ship Afloat	3,089	19.75	61,008
Knuckle R.	-175	0.00	0
Add. Lift	-180	0.00	0
Total	2,734		61,008

- ➢ KGV = (Total Wt. x KG) / (Total Wt.) =
- ➢ KGV = 61,008 Ft.-LT / 2,734 Ft. =
- ➢ KGV = 21.31 Feet

Calculate KM of vessel at time of side block haul:

- ➢ Displacement at time of side block haul = 3,089 – 175 – 180 = 2,734 LT
- ➢ Draft at Displ. Of 2,734 LT = 11.62 Ft. (from above)
- ➢ KM at Draft of 11.62 Ft. = p(22.60 – 22.65) x 0.62] + 22.65 = 22.62 LT

Calculate GM of vessel at time of side block haul:

- ➢ $GM_{SideBLK} = KM_{SideBLK} - KGV - $ F.S. Correction
- ➢ $GM_{SideBLK} = 22.62 - 21.31 - 0.20 = 0.11$ Ft. > 0 OK for fixed blocks
- ➢ Use fixed blocks

5.7 – Stability of Floating Docks

Unlike the other types of dock structures, a floating dry dock must not only have the strength and dimensions for docking a vessel, it must also be stable throughout the entire docking or undocking evolution.

To insure stability, the ship/dock combination must maintain a minimum GM throughout the evolution. GM is the measure of stability. Stability of the ship/dock system is usually investigated for five separate phases of the docking or undocking evolution.

These phases are:

➢ (1) Dry dock at full submergence – no ship

➢ (2) Partial lift of ship – ship has been lifted approximately ½ its docking draft.

➢ (3) External waterline at top of keel blocks.

➢ (4) External waterline just over pontoon deck.

➢ (5) Dock at normal operating draft.

PHASE 1

PHASE 2

PHASE 3
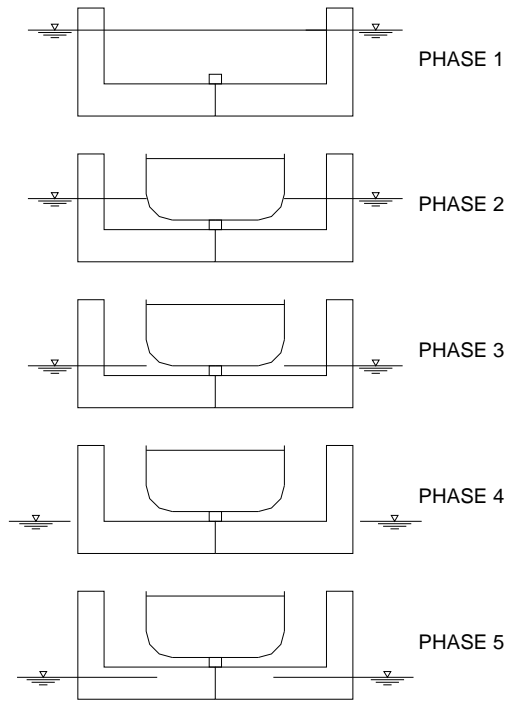
PHASE 4

PHASE 5

5 PHASES OF STABILITY

FIGURE 5. 14

Phase 3 or 4 is usually the phase of minimum stability.

The required minimum GM varies with the size of the floating dock. Below is the curve of minimum GM as required by both ABS and the US Navy's MIL-STD-1625C Certification Program.

MINIMUM GM vs. LIFT CAPACITY
Per ABS and US NAVY MIL-STD-1625C
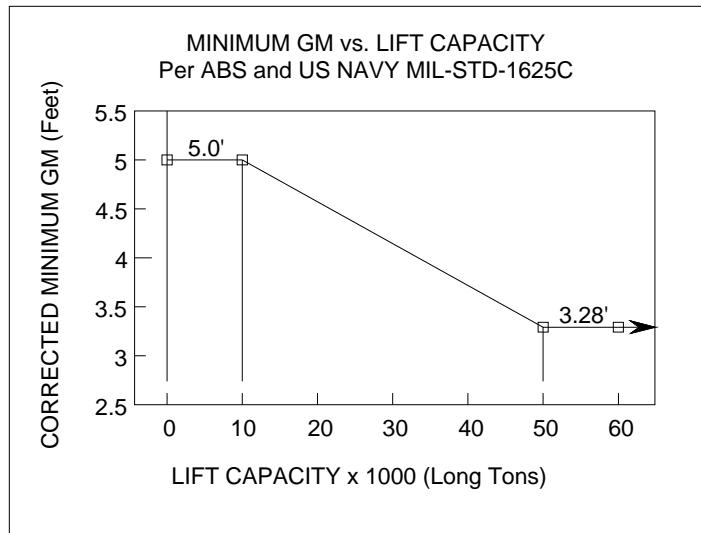
FIGURE 5. 15

With any positive GM the ship/dock system will be theoretically stable. The minimum is required to account for any unknowns when evaluating the docking.

Typical unknowns:

> ➢ Exact vessel KG and weight
> ➢ Free surface effects on vessel
> ➢ Dock KG
> ➢ Dock weight

RULE OF THUMB - Stability

> **Stability for a floating dry dock is provided by the waterplane cut by the dock. If waterplane area increases, then stability increases. If waterplane area decreases then stability decreases.**

In the minimum stability phases, (phases 3 and 4), only the wing walls cut the waterplane and provide the stabilizing force.

The wider and further away from centerline the wing is, the more stable the dock is. As can be seen in the figure below, for any angle of list the wing that is further away from centerline will have greater volume of added submergence, hence a greater force trying to right the listing dock.
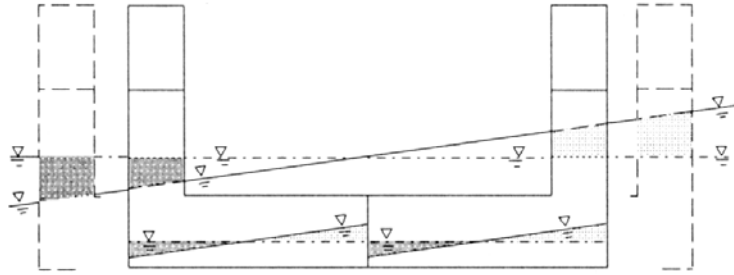
WATERPLANES

FIGURE 5. 16

Just as in a ship, the free liquids in the large ballast tanks of a dry dock greatly reduces its stability. The wider the ballast tanks are, the more the ballast can shift at any given angle of list.

RULE OF THUMB – Tank Size & FSC

>   **The wider the ballast tanks, the greater the transverse free surface effect resulting in a less stable dock (for a constant wing width).**

GM for the ship/dock system is determined by the same equation as that for vessels:

$$GM = KM - KG_{adjust}$$

Where:
- ➢ KM is the distance from the keel to the transverse metacenter for the dry dock at the draft of the phase you are investigating.
- ➢ KG_{adjust} is the vertical center of gravity of the dry dock, ship being lifted and internal ballast water in the dock, adjusted for the free liquids in the ballast tanks.
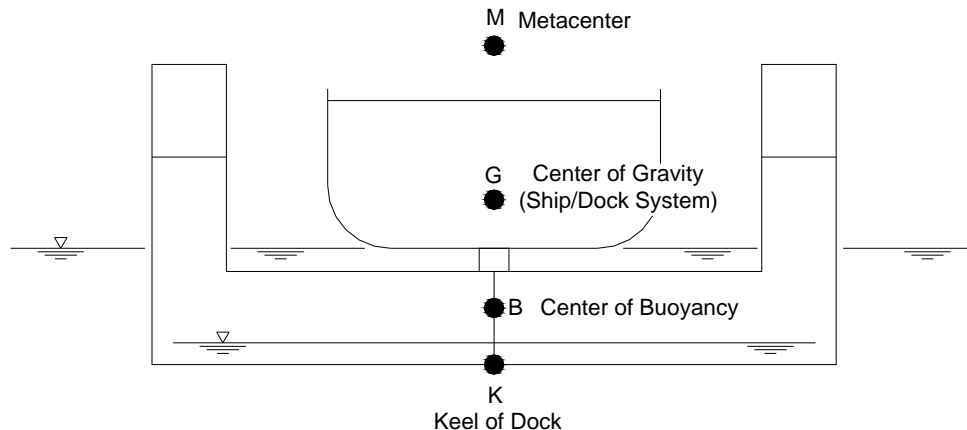
POINTS IN STABILITY

FIGURE 5. 17

Some docks will have their KM and vertical moments of free surface pre-calculated for various drafts of the dock or depth of contained water. For these docks, the GM can be found in the same manner as previously discussed for ships. The dock's KM is found for the particular draft it is at. The ship/dock system's KG (dock, ship, & contained water) is corrected for free surface by the value:

$$\text{F.S. Corr.} = \text{sum of Vert. Mom. / Disp.}$$

For dock's that do not have the KM or vertical moments of free surface pre-calculated, and are rectangular in shape, these properties can be calculated.

$$KM = KB + BM$$

Where:

> **KB** = the height of the vertical center of buoyancy of the immersed portion of the dry dock above the dock's keel.
> **BM** = the height of the transverse metacenter above the vertical center of buoyancy and is equal to the moment of transverse inertia of the waterplane cut by the dock, ($I_{pos.}$) divided by the displaced volume (V).

For rectangular dock, the moment of transverse inertia of the water plane cut by the dock, ($I_{pos.}$) is equal to:

$$I_{pos.} = \text{Sum of } b \times h^3 / 12 + A \times D^2$$

Where:

> B = length of waterplane
> H = width of waterplane
> A = Area of waterplane = b x h
> D = Distance from centerline of dock to center of waterplane

CALCULATION – FLOATING DRYDOCK STABILITY – PHASE 3

For a rectangular dock at Phase 3, external water at the top of keel blocks, the water plane cut by the dock is the area of the wing walls in plan.
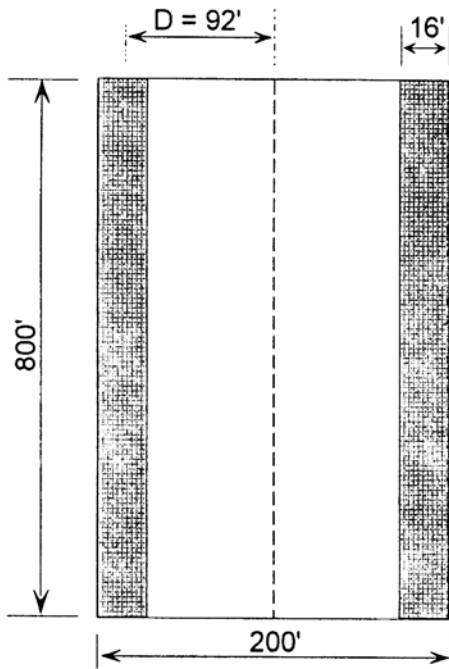
FIGURE 5. 18

$$I_{Pos.} = \text{Sum of } b \times h^3 / 12 + A \times D^2$$

Where:

- b = Length of waterplane = 800'
- h = width of waterplane = 16'
- A = Area of waterplane = $b \times h$ = 16' x 800'
- D = Distance from centerline of dock to center of waterplane = 92'

Times 2 for two wing planes

$$I_{Pos.} = 2 \times [(800 \times 16^3 / 12) + (800 \times 16 \times 92^2]$$

- $I_{Pos.}$ = 217,220,000 Ft^4

If the displacement of the dry dock at Phase 3 is 3,200,000 Ft^3 then:

$$BM = I_{Pos.} / \text{Displaced Volume}$$

- BM = 217,220,000 Ft^4 / 3,200,000 Ft^3
- BM = 67.88 Ft.

If the Center of Buoyancy (KB) is at 9' above the keel then:

$$KM = KB + BM$$

- KM = 9 + 67.88
- KM = 76.88 Ft.

The vertical moment of free surface ($I_{Neg.}$) for the ballast tanks can be calculated by:

$$I_{Neg.} = \text{Sum of } b \times h^3 / 12$$

Where:

- b = length of waterplane in ballast tank
- h = width of waterplane in ballast tank

For rectangular dock with ballast water in each of the pontoon tanks as shown:
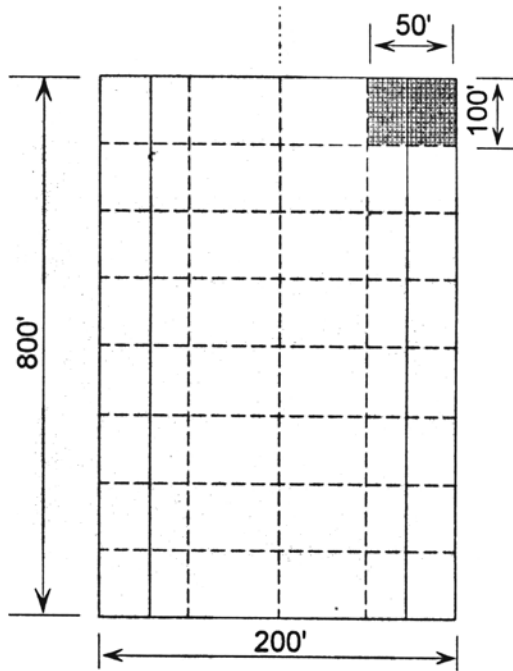
$$I_{Neg.} = \text{Sum of } b \times h^3 / 12$$

Where:

➢   b = length of waterplane = 100'
➢   h = width of waterplane = 50'
➢   Times 32 similar tanks

$$I_{Neg.} = 32 \times [100 \times 50^3 / 12] = 33{,}333{,}333 \text{ Ft}^4$$

If the displacement of the dry dock at Phase 3 is 3,200,000 Ft^3 then:

$$\text{F.S.Corr.} = I_{Neg} / \text{displaced volume}$$

➢   F.S.Corr. = 33,333,333 Ft^4 / 3,200,000 Ft.^{3}
➢   F.S.Corr. = 10.42 Ft.

FIGURE 5. 19

If KG of the system at Phase 3 is 46.5 Ft., then:

$$GM = KM - KG - \text{F.S. Corr.}$$

GM = 76.88 – 46.50 – 10.42 = 19.96 Ft.

To ease the stability evaluation process, all floating docks should have a "KG vs. Weight" curve. The curve is developed for a particular dry dock's minimum stability phase. Once this curve is developed, any vessel's weight and KG (adjusted for free liquids) can be plotted. If it plots below the curve then stability for that particular vessel is acceptable. If it plots above the curve then stability is unacceptable and the docking should not be performed.

KG vs. WEIGHT
5 FOOT KEEL BLOCKS

Phase 3
GM = 4.65
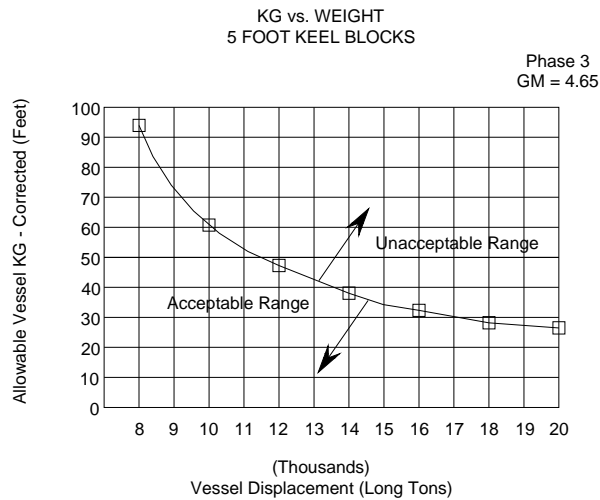
KG vs. WEIGHT CURVE

FIGURE 5. 20

5.8 Multiplication Effect

When undocking a vessel, the ship/dock system goes from having a very large GM (very stable) with its pontoon deck out of the water, to close to its minimum GM once the pontoon deck goes under water.

This is important, since any list the dock has prior to submerging the pontoon deck will be multiplied by the ratio of the GM with the deck out of the water to the GM with the deck submerged.

The ratio of the GM with deck out of water at 0 freeboard to the GM with deck awash (Phase 4) is called the multiplication effect.

EXAMPLE – MULTIPLICATION EFFECT CALCULATIONS

Given:

➢ A dock has a GM of 60.0 at 0 freeboard with the pontoon deck out of water and a GM of 12.0 with the deck submerged.

The multiplication effect = GM Phase 4 / GM Phase 3

➢ Multiplication Effect = 60.0 / 12.0
➢ Multiplication Effect = 5.0

If the dock has a 6" list prior to deck submergence, then the list will be 5.0 x 6" = 30." after the deck goes under.

If the dock is submerged with no trim, the transition from zero freeboard to deck awash happens very quickly and there is little time for the dock operator to correct the list.

If the dock is submerged with a trim, however, the large waterplane of the pontoon deck is lost gradually and the list develops more slowly so the operator has more time to correct for it. It is generally recommended to submerge a floating dock with a slight trim until the point when the vessel's hull enters the water. This will slow down the multiplication effect and give the operator more time to correct lift. If the operator does not take corrective action, the list after submergence with a trim will be the same as the list after submergence with no trim. Submerging on a trim just slows down the multiplication effect and gives the operator time to take corrective action.

SUGGESTION:

> **When undocking in a floating dock, a slight trim on the dock as it is submerged will help to slow down the multiplication effect and allow the dockmaster to take more effective corrective action if a list develops. The trim should stay on the dock until the hull starts to enter the water.**

CAUTION:

Some shorter docks are less stable longitudinally than transversely. These docks should not be submerged on a trim as this will cause the trim to multiply.

6.0 – PREDICTING VESSEL CONDITION

6.1 – Establishing the Baseline Docking Condition

Once the vessel is on the blocks, the only way to determine the condition is to monitor all weight changes on the vessel.   With these changes known, it is possible to calculate the new condition of the vessel and its drafts, trim, list and GM at the time of undocking.   All calculations are start with the actual condition of the vessel at the time of docking.   This is called the **baseline docking condition**.

It is extremely important to have accurate data on the vessel in this condition, as any error here, will be carried through to the undocking condition.

Fortunately, the displacement, longitudinal center of gravity (LCG) and transverse center of gravity (TCG) of the vessel can be determined very accurately by measuring the vessel's drafts and list, and using the vessel's "Table of Displacement and Other Properties" to calculate the condition of the ship for those particular drafts.   This information can then be used as a check of the "Weight Survey" data to insure all weights have been properly accounted for.

The "Table of Displacements and Other Properties" is usually located on the docking plan and lists the vessel's displacement, moment to trim 1" (MT1), longitudinal center of buoyancy (LCB), tons per inch immersion (TPI), and longitudinal center of flotation (LCF) at various drafts. It is important to note that the table is developed for the vessel's draft at the longitudinal center of flotation (LCF) and assuming no trim.

For vessels with a trim, the draft at the LCF must be found, and the table entered using this value.   The longitudinal center of buoyancy (LCB) shown in the table must be adjusted to compensate for the trim.   In the example below, the ship's drafts are measured as 12.00 feet forward and 14.75 feet aft with a ½ degree list to starboard.

By noting the position of the draft marks on the vessel, the draft amidships can be calculated. In this case, the draft marks are located equal distance from amidships, so the draft at amidships is the average draft of 13.375 feet.

The approximate location for the longitudinal center of flotation (LCF) can be found by entering the "Table of Displacement and Other Properties" with the amidship draft of 13.375 feet and interpolating between the LCFs at drafts of 13.0 feet and 14.0 feet.   The location is approximate because the table is developed for drafts at the LCF, which we do not yet know.

By using the amidship draft, which we do know, we obtain an approximate answer which is close enough for our purposes. From Table 6.1 we get:

> ➢ LCF at 13.0' Draft = 20.90 ft aft amidships
> ➢ LCF at 14.0' Draft = 25.80 ft aft amidships

By interpolating:

> ➢   LCF at 13.375' Draft = 22.74 ft aft amidships

FIGURE 6. 1

Table 6. 1

TABLE OF DISPLACEMENT & OTHER PROPERTIES (FROM TRIM & STABILITY BOOKLET OR DOCKING PLAN) FOR VESSEL WITH NO TRIM						FROM STABILITY BOOKLET
Mean Draft (FT)	Disp. SW (LT)	MT1 (FT-LT)	LCB aft mdiship (FT)	LCF aft midship (FT)	TPI (LT)	KM (FT)
11.0	2512	517	-14.7	11.5	28.1	22.00
12.0	2871	588	-11.2	15.9	29.9	22.20
13.0	3235	672	-7.6	20.9	31.5	22.30
14.0	3625	761	-4.3	25.8	33.0	22.40
15.0	4018	807	-1.3	27.3	33.9	22.50
16.0	4440	830	1.3	27.1	34.3	22.58
17.0	4850	848	3.5	26.6	34.7	22.65

We can now calculate the draft at the LCF since we now know its location relative to the forward and aft drafts.

Draft @ LCF = (Trim/Dist between draft marks) x (Dist LCF from amidships) + Draft amidships

➢ Draft @ LCF = [(2.75/405) x 22.74] + 13.375
➢ Draft @ LCF = 13.53 Ft.

This is the draft that should be used to enter the table with, and determine the vessel's condition assuming no trim.
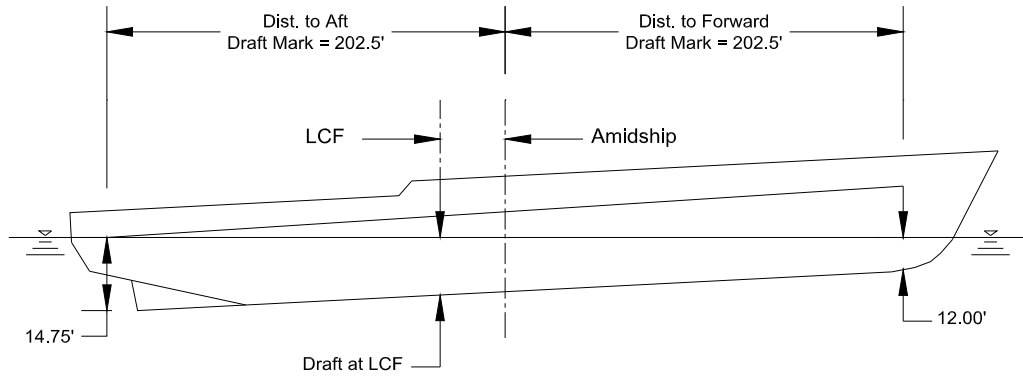
Table 6. 2

TABLE OF DISPLACEMENT & OTHER PROPERTIES (FROM TRIM & STABILITY BOOKLET OR DOCKING PLAN) FOR VESSEL WITH NO TRIM							FROM STABILITY BOOKLET
Mean Draft (FT)	**Disp. SW (LT)**	**MT1 (FT-LT)**	**LCB aft mdiship (FT)**	**LCF aft midship (FT)**	**TPI (LT)**		**KM (FT)**
From Table 6.1 obtain the Known properties for 13 and 14 foot drafts:							
13.0	3235	672	-7.6	20.9	31.5		22.30
14.0	3625	761	-4.3	25.8	33.0		22.40
By Interpolation: (Draft = 13.53 FT, known) calculate properties for 13.53 foot draft:							
13.53	3441.5	719.1	-5.85	23.49	32.29		22.35

The results from the table are for a vessel without any trim.

The displacement, moment to trim 1 inch, LCF and tons per inch immersion are fairly accurate for modest amounts of trim but the longitudinal center of buoyancy must be adjusted to account for the trim. This is done in the following way:

In a floating body at rest, the location of the center of gravity (effective center of all weights) must exactly coincide with the center of buoyancy, which supports that weight. Thus the longitudinal center of gravity (LCG) of a vessel must fall directly over the longitudinal center of buoyancy (LCB).

The longitudinal center of buoyancy is the longitudinal center of the volume of the immersed portion of the hull. This longitudinal center of volume has been pre-calculated for various drafts of the vessel assuming the vessel has no trim.

If the vessel is actually floating with no trim, the center of volume, (which is the center of buoyancy), for that particular draft, has been pre-calculated and can be picked directly off the table by interpolation. The center of gravity must be directly over the center of buoyancy, so, for a vessel with no trim, the LCG is equal to the LCB picked directly off the table.
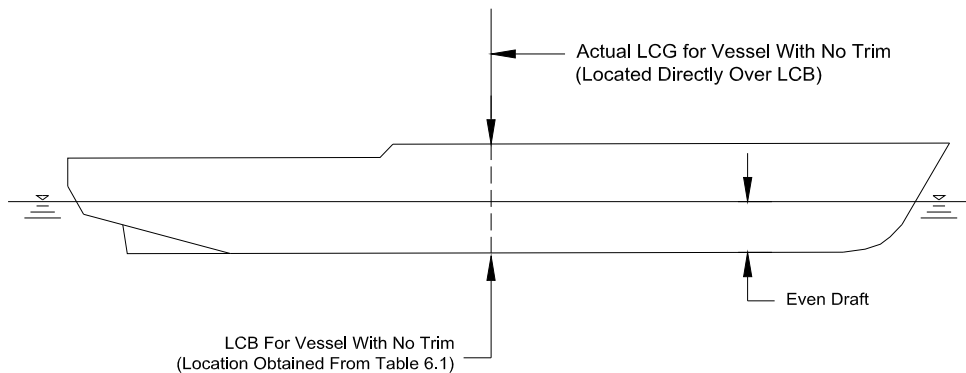

Actual LCG for Vessel With No Trim (Located Directly Over LCB)

Even Draft

LCB For Vessel With No Trim (Location Obtained From Table 6.1)

FIGURE 6. 2

If the weight on the vessel is distributed such that its longitudinal center of gravity does not fall directly over the LCB of the vessel with no trim, then the vessel must take on a trim to shift the center of buoyancy to align directly under the LCG. The amount of trim will depend on the amount that the LCG has been shifted from the theoretical LCB with no trim.
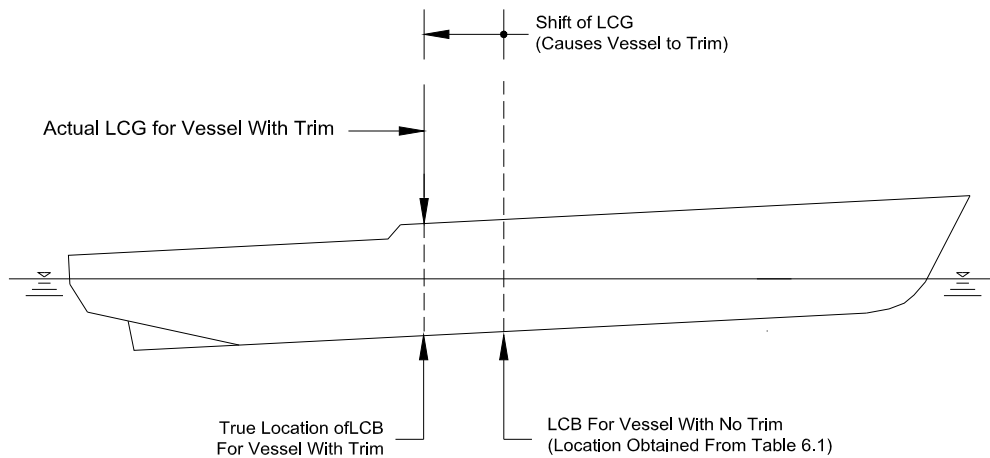
FIGURE 6. 3

The shift of the LCG from the no-trim location can be determined using the moment to trim values for the vessel. The moment to trim 1-inch value is the moment that must be applied to the vessel to cause a 1-inch trim between its perpendiculars.

Multiplying the moment to trim 1-inch by the vessel's actual trim between perpendiculars in inches, results in the moment that must be applied to the vessel to cause that amount of trim. This moment is caused by the entire weight of the vessel theoretically being shifted aft (or forward for a trim by the bow) from the no-trim position until the trim is achieved.

Moment is equal to force times distance, and in this case the force is equal to the weight of the vessel (displacement) and the distance is equal to the shift of the LCG from the no-trim position. With the total moment to cause the trim known (MT1 x trim in inches) and the displacement known, the shift can be calculated by:

Shift of LCG from no-trim position = Moment to cause trim / displacement

For the example:

> ➢ MT1 = 719.1 Ft.-LT (from Table 6.2)
> ➢ Trim between draft marks = 14.75 – 12.0 = 2.75 Ft.
> ➢ Distance between draft marks = 405.0 Ft. (from docking plan)
> ➢ Distance between perpendiculars = 390.0 Ft. (from docking plan)

Trim between perpendiculars

> ➢ = (2.75 / 405) x 390 = 2.65 Ft.
> ➢ = 2.65 Ft. x 12In./Ft. = 31.78 In.

NOTE: Trim between perpendiculars is used when calculating moment to cause trim not the trim between draft marks!

Moment to cause 31.78" trim

> ➢ = MT1 x trim
> ➢ = 719.1 Ft.-LT / In. x 31.78 In.
> ➢ = 22,851.4 Ft.-LT

Vessel displacement = 3,441.5 LT

Shift of LCG

> ➢ = Moment / Displacement
> ➢ = 22,851.4 Ft.-LT / 3,441.5
> ➢ = 6.64 Ft. Aft

The location of the LCG (LCB) in the no-trim condition is -5.85 Ft. (fwd of amidships) (interpolated in Table 6.2).

The location of LCG (LCB) in trimmed condition is –5.85 plus the shift to cause the trim or:

> ➢ = -5.85 + 6.64
> ➢ = 0.79 Ft. Aft of amidships

To summarize, by using the measured drafts of the vessel and the "Table of Displacement & Other Properties" we can accurately calculate the vessel's displacement and its location of longitudinal center of gravity. It tells us nothing about the vessel's vertical center of gravity (VCG) which is needed for determining GM. To calculate VCG, a weight survey must be conducted on the vessel.

A weight survey is a list of all weights on board the ship (including the dead weight of the ship) along with each item's vertical center of gravity (VCG), longitudinal center of gravity (LCG), and transverse center of gravity (TCG). Multiplying each item's weight by it's VCG, LCG, and TCG, results in the Vertical Moment, Longitudinal Moment and Transverse Moment. Adding each type of moment and dividing by the total weight results in the overall VCG, LCG, and TCG for the vessel in its pre-docking condition.

The total weight and LCG from the weight survey can then be compared to the total weight and LCB (which is equal to LCG) obtained from the drafts and "Table of Displacements & Other Properties".

RULE OF THUMB: Weight Surveys

> **If the total weight from the weight survey is NOT within 3% of the total weight calculated using the measured drafts, then the weight survey is not accurate enough and a further study of loads on the vessel must be made. If the total weight from the weight survey IS within 3% of the total weight calculated using the measured drafts, then the weight survey is accurate enough for our purposes.**

The weight obtained using the drafts is more accurate, however, so an adjustment should be made to the weight obtained in the weight survey to get it to equal the weight calculated using the drafts.

The weight survey for the example is shown in Table 6.3.

Table 6. 3

WEIGHT SURVEY								
Pre-Docking Condition	**Weight (W)** **(LT)**	**VCG** **(FT)**	**VCG-Mom** **W x VCG** **(FT-LT)**	**LCG** **(Aft Amid)** **(FT)**	**LCG-Mom** **W x LCG** **(FT-LT)**	**TCG** **P-,S+** **(FT)**	**TCG-Mom** **W x TCG** **(FT-LT)**	**Free Surface** **(FT-LT)**
Lightship Condition (Mean) (From Stability Booklet)	3194.0	19.21	61357	-0.64	-2044	0.10	319	
Crew & Effects	32.5	22.38	728	-15.40	-501	3.10	101	
Ammunition	0.0	23.91	0	-106.75	0	0.00	0	
Provision & Stores	43.1	16.11	694	97.60	4206	-3.02	-130	
General Stores	23.2	21.81	505	7.30	169	0.73	17	
Liquids in Storage tanks	52.2	7.12	372	1.12	58	-1.92	-100	733
TOTAL	**3345.0**	**19.03**	**63656**	**0.56**	**1888**	**0.06**	**207**	**733**

> ➢ Weight calculated using drafts = 3,441 LT (Interpolated in Table 6.2)
> ➢ Weight calculated in weight survey = 3,345 LT (From Table 6.3)
> ➢ Difference = 96 LT which is 2.80% of Total Weight <3.0% OK

The difference between the two methods of determining weight is less than 3% so the weight survey is accurate enough.

The weight calculated using the drafts is the true weight of the vessel however, so an adjustment of 96 long tons should be added to the weight survey. This will insure the weight determined in the weight survey reflects the true weight of the vessel.

The LCG and TCG of the adjustment weight should be varied until the overall LCG and list of the ship calculated from the weight survey, match the LCG and list of the ship as measured from the drafts. The VCG of the adjustment weight should be equal to the VCG of the vessel without the adjustment added. This will insure the adjustment weight will not effect the calculated VCG.

NOTE: The adjustment weight should never affect the vertical center of gravity of the vessel.

Table 6. 4

WEIGHT COMPARISON								
	Weight (W) **(LT)**	**VCG** **(FT)**	**VCG-Mom** **W x VCG** **(FT-LT)**	**LCG** **(Aft Amid)** **(FT)**	**LCG-Mom** **W x LCG** **(FT-LT)**	**TCG** **P-,S+** **(FT)**	**TCG-Mom** **W x TCG** **(FT-LT)**	**Free Surface** **(FT-LT)**
From Weight Survey	3345.0	19.03	63656	0.56	1888	0.06	207	733
Adjustment	96.4	19.03	1835	8.50	819	-1.18	-114	
TOTAL From Weight Survey With Adjustment	3441.4	19.03	65490	0.79	2707	0.03	93	733
Vary weight, LCG and TCG of "Adjustment" until Survey weight, LCG and list equals that as calculated from drafts								

Calculated from measured drafts	3441.4	?		0.79			93 ½ deg list	

It can be seen from Table 6.4 the 96.4 long tons must be added to the weight survey in order to get the weight survey to "jibe" with the weight calculated using the measured drafts. In addition, this theoretical 96.4 long tons must be placed 8.5 feet aft of amidships to get the resultant LCG for the vessel to equal 0.79 feet the value that's needed to cause the observed trim. Also, the adjustment must be placed 1.18 feet to port to obtain the observed ½ degree list to starboard. This is determined from the equation:

$$LIST = \frac{HeelingMoment}{Sin1° \times Disp \times GM} \qquad \text{OR}$$

Heeling Moment = LIST x Sin 1o x Displ x GM

Where:

➢ Sin 1° = 0.01745
➢ Displacement = 3441.5 Long tons
➢ Observed list = ½ degree to starboard

and

GM is calculated from the equation:

GM = KM – KG – Free Surface Correction

Where:

➢ KM is a constant for a particular draft and = 22.35 interpolated in Table 6.2

➢ KG is the VCG of the vessel = 19.03 feet (from Table 6.4)

➢ Free Surface Correction = sum of vertical moments of F.S / Displ.
   o = 733 Ft.-LT / 3441 LT
   o = 0.21 feet

Therefore:

GM = KM – KG – FS Correction

➢ = 22.35' – 19.03' – 0.21'
➢ = 3.11 feet

Therefore, the required heeling moment to cause a ½ degree list =

Heeling Moment = 0.5 x 0.01745 x 3441.5 x 3.11 = 93 Ft.-LTs

The initial weight taken off shows the transverse moment (TCG – Moment) as 207 Ft.-LTs. This would result in a vessel list of:

$$LIST = \frac{HeelingMoment}{Sin1° \times Disp \times GM} \quad = \quad \frac{207 \text{ Ft-LTs}}{0.01745 \times 3441.5 \times 3.11}$$

= 1.1 degrees to starboard

We know 207 Ft.-LTs cannot be the actual transverse moment since the measured list of the vessel is 0.5 degrees to starboard. Thus, the transverse moment in the weight estimate must be adjusted to equal 93 Ft-LTs. This is done by placing the location of the adjustment weight where it will result in a transverse moment of 203 – 93 = - 114 Ft.-LTs resulting in an overall transverse moment of 93 Ft.-LTs. (See Table 6.4)

We now have established and verified the Baseline Docking Condition as:

Table 6. 5

	Weight (LT)	VCG (FT)	VCG-Mom (FT-LT)	LCG (Aft Amid) (FT)	LCG-Mom (FT-LT)	TCG P-,S+ (FT)	TCG-Mom (FT-LT)	Free Surface (FT-LT)
BASELINE DOCKING CONDITION								
From Weight Survey (Confirmed by draft measurements)	3441.4	19.03	65490	0.79	2707	0.03	93	733

This is the actual condition of the vessel at the time of drydocking. If no weight is shifted, added, or removed from the vessel while it is in dry dock, the vessel will float at the exact same drafts, list and trim when it is undocked.

If, however, weight is added, removed or shifted, then the condition of the vessel will change and new drafts, list, trim and GM must be calculated for undocking. The only way to make these calculations is to keep track of all weight changes.

6.2 – Tracking the Effects of Weight Changes

The vertical, longitudinal and transverse location of all weight additions and removals should be recorded. Weights that are shifted on the vessel can be considered a removal from one location and an addition at another location. New total weight, VCG, LCG, and TCG for the vessel can then be calculated in the same manner the original weight survey was done.

In the example, the vessel had some steel plate removed, lifeboats removed, a portable generator added on the main deck, and steel plate added. Also, some cargo was shifted aft and 5 tons of potable water was removed from a tank that was previously 100% full. That tank is now partially full and its free surface effects must be accounted for.

These weight changes are summarized in the following tables.

Table 6.6 shows items that have been removed while the vessel has been in dock.

Table 6. 6

WEIGHT REMOVALS								
Item Removed	Weight (W) (LT)	VCG (FT)	VCG-Mom W x VCG (FT-LT)	LCG (Aft Amid) (FT)	LCG-Mom W x LCG (FT-LT)	TCG P-,S+ (FT)	TCG-Mom W x TCG (FT-LT)	Free Surface (FT-LT)
Steel Plate	-12.0	23.70	-284	35.50	-426	-11.00	132	
Life Boats	-3.3	39.00	-129	-8.50	28	-19.00	63	
Cargo (Shifted)	-19.0	15.30	-291	-54.0	1026	0.00	0	
Potable Water	-5.0	3.80	-19	78.00	-390	12.00	-60	565
TOTAL – ITEMS REMOVED	**-39.3**	**18.39**	**-723**	**-6.06**	**238**	**-3.43**	**135**	**565**

Table 6.7 shows items that have been added while the vessel has been in dock.

Table 6. 7

WEIGHT ADDITIONS								
Item Added	Weight (W) (LT)	VCG (FT)	VCG-Mom W x VCG (FT-LT)	LCG (Aft Amid) (FT)	LCG-Mom W x LCG (FT-LT)	TCG P-,S+ (FT)	TCG-Mom W x TCG (FT-LT)	Free Surface (FT-LT)
Steel Plate	32.0	23.20	742	35.50	1136	-6.00	-192	
Portable Generator	5.2	36.00	187	-105.00	-546	-18.00	-94	
Cargo (Shifted)	19.0	15.30	291	36.9	701	0.00	0	
TOTAL – ITEMS ADDED	**56.2**	**31.05**	**1220**	**32.85**	**1291**	**-7.27**	**286**	**0**

Thus the Condition of the vessel at undocking is:

Table 6. 8

UNDOCKING CONDITION								
	Weight (W) (LT)	VCG (FT)	VCG-Mom W x VCG (FT-LT)	LCG (Aft Amid) (FT)	LCG-Mom W x LCG (FT-LT)	TCG P-,S+ (FT)	TCG-Mom W x TCG (FT-LT)	Free Surface (FT-LT)
Baseline Condition	3441.4	19.03	65490	0.79	2707	0.03	93	733
Weights Removed	-39.3	18.39	-723	-6.06	238	-3.43	135	565
Weights Added	56.2	31.05	1220	32.85	1291	-7.27	-286	0
TOTAL – UNDOCKING CONDITION	**3458.3**	**19.08**	**65988**	**1.23**	**4236**	**-0.02**	**-58**	**1298**

6.3 - Calculating Vessel Drafts At Float Off

After establishing the undocking condition, we must find the draft at which the vessel displaces an equivalent amount of water. Enter the "Table of Displacement & Other Properties" (Table

6.1) with the vessels new weight of 3458 LT and find the draft at which the vessel displaces this weight.

It can be seen that the draft falls between 13 and 14 feet and by interpolation: the exact draft is 13.57 feet. Interpolate the other properties for the vessel with a 13.57-foot draft. Table 6.9 shows the interpolated results.

Table 6. 9

INTERPOLATION OF VESSEL PROPERTIES AT CALCULATED DISPL						
(VESSEL DISPLACEMENT = 3458.3 LT)						
FOR VESSEL WITH NO TRIM						
Draft @ LCF (FT)	**Disp. SW (LT)**	**MT1 (FT-LT)**	**LCB aft mdiship (FT)**	**LCF aft midship (FT)**	**TPI (LT)**	**KM (FT)**
From Table 6.2						
13.0	3235	672	-7.6	20.9	31.5	22.30
14.0	3625	761	-4.3	25.8	33.0	22.40
By Interpolation: (Displ = 3458.3 LT, known)						
13.57	3458.3	723.0	-5.71	23.71	32.36	22.36

Note that the LCB in the Table 6.9 (-5.71 Ft.) does not equal the LCG of the vessel in the undocking condition (1.23 Ft.in Table 6.8). The table is for a no trim condition.

The vessel must therefore have a trim to align the true LCB and LCG. The amount of trim is determined in the following manner:

The buoyancy, located at the LCB (no trim), and the ship's weight located at the LCG (Undocking Condition), imparts a moment to the ship, creating a trim. This moment is equal to the distance between the LCB (with No Tim), and the LCG (Undocking Condition) or shift, times the vessel's weight.

The amount of trim in inches is equal to the moment divided by the moment to trim 1 inch.

For the example:

Distance between $LCB_{no\ trim}$ and LCG

> ➤ = 1.23 – (-5.71)
> ➤ = 6.94 Ft.

Trimming Moment = Vessel Wt. x 6.94'

> ➤ = 3458 LT x 6.94'
> ➤ = 23,999 Ft.-LT

Moment to trim 1 inch (MT1) = 723 Ft.-LT (Interpolate in Table 6.9)

Trim between perpendiculars

- ➢ = Trimming Moment / MT1
- ➢ = 23,999 Ft.-LT / 723 Ft.-LT / In.
- ➢ = 33.2 In.

Distance between perpendiculars = 390 feet (From docking plan)

Distance between draft marks = 405 feet (From docking plan)

Trim between draft marks

- ➢ = (405/390) x 33.2
- ➢ = 34.5 Inches

We know the draft at the LCF is 13.57 feet, the LCF is 23.71 feet aft of amidships, the trim is 34.5 inches and the forward and aft draft marks are 205.5 feet either side of amidships. From this, the forward and aft drafts can be calculated.

Draft Fwd.

- ➢ = 13.57 – ((34.5/405) x (205.5 + 23.71)) / 12
- ➢ = 11.94 feet

Draft Aft

- ➢ = 13.57 + ((34.5/405) x (205.5 - 23.71)) / 12
- ➢ = 14.86 feet

6.4 - Calculating Vessel Stability at Float Off

GM is calculated from the equation:

$$GM = KM - KG - Free\ Surface\ Correction$$

Where:

- ➢ KM is determined for the draft at the LCF = 13.57 feet to be 22.36 feet by interpolation in Table 6.9.
- ➢ KG = VCG = 19.08 feet (From Table 6.8)

Free surface correction

- ➢ = Free Surface / Displacement
- ➢ = 1298 Ft.-LT / 3458 LT
- ➢ = 0.38 feet.

Therefore:

GM = KM – KG – FS Correction

- ➢ = 22.36' – 19.08' – 0.38'
- ➢ = 2.90 feet

Vessel has adequate stability afloat.

6.5 - Calculating Vessel List at Float Off

The list can be calculated from the equation:

$$LIST = \frac{HeelingMoment}{Sin1° \times Disp \times GM}$$

> ➢ = -58 / (0.01745 x 3458 x 2.90)
> ➢ = -0.033 degrees (to Port) (P-, S+)

Vessel has acceptable list.

6.6 - Summary of Vessel Condition at Float Off

A summary of the condition of the vessel at undocking is:

> ➢ Displacement = 3458.3 Long Tons
> ➢ Draft Forward = 11.94 feet
> ➢ Draft Aft = 14.86 feet
> ➢ Trim = 2.92 feet (between draft marks)
> ➢ List = 0.33 degrees to Port
> ➢ GM (Afloat) = 2.90 feet

7.0 – BLOCK CONSTRUCTION

7.1 – Principles and Concepts

The blocking system must be designed and built to insure the vessel is adequately supported for the entire time the vessel is in dry dock. Forces effecting block load may include winds, earthquake, listing or trimming of a floating dock, adding, removing or shifting of weights on the vessel, etc. The blocks should support the anticipated loads without any excessive crushing of the timber. Also, each individual block should be capable of severe overload (at least twice the calculated load) without complete failure as a column.

Just as important as block strength is block stability, the blocks must not have any tendency to topple over under load. Proper sizing and arrangement of blocks can prevent instability problems.

Blocks support the weight of the docked vessel while positioning it at a convenient height for worker access.

A properly built blocking system will:

> ➢ Support the vertical loads imparted by the vessel at all phases of docking without undue crushing of the timbers or deformation of the hull.

> ➢ Provide stability to prevent the vessel from tipping over in high winds, earthquakes, or shifting of weights on board the vessel.

> ➢ Provide a cushion to distribute load concentrations caused by hull distortions, or errors in block height, position or contours.

> ➢ Leave as much room as possible under the vessel free from obstructions to ease cleaning, painting and/or repair of the hull.

> ➢ Provide adequate clearances between blocks and vessel during docking and undocking. Sometimes blocks must be modified to get this clearance.

The dockmaster is responsible for planning the blocking system for each vessel he is to dock to insure these conditions are met.

This requires determining the type, size, number, heights, position and cribbing requirements of both the keel blocks and side blocks.

After the blocking system is constructed, the dockmaster must conduct an independent check of the blocks to ensure that the docking plan has been properly implemented. This includes re-measuring the positions and heights of all blocks.

It is also highly recommended to use divers to check the fit of the blocks on the vessel just prior to landing and just after she has landed.

As soon as the vessel is docked, the dockmaster must examine all blocks for proper fit and any irregularities corrected. In some extreme cases, it may be necessary to abort the docking and re-float the ship.

7.2 – Types of Blocks

There are many different types of keel and side blocks (see pictures below).

Types of keel blocks include:

Concrete/timber Composite Block
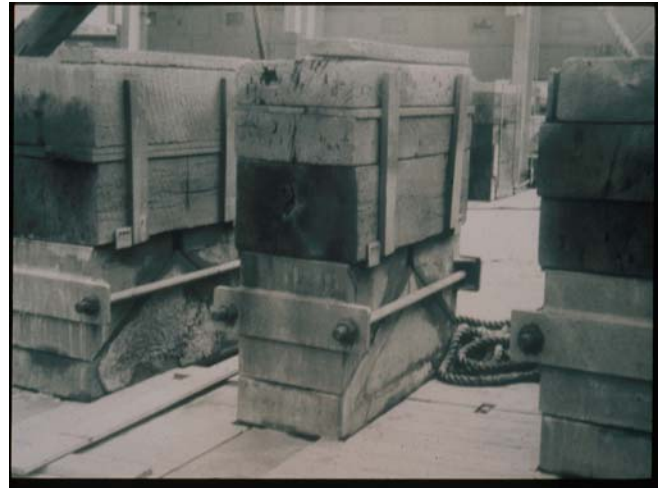
Wedge Release Block

All Timber Blocks

High Keel Towers

STACKING OF CONCRETE COMPOSITE BLOCKS

Types of side blocks include:

SLIDING RELEASING BILGE BLOCK

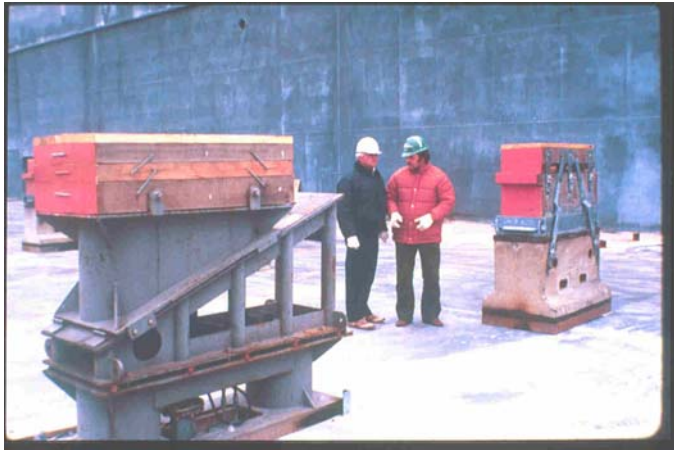**CRANDALL HIGH SLIDING BLOCK**

DUTCH TYPE SLIDING BLOCK

GERMAN TYPE ADJUSTABLE BILGE BLOCK
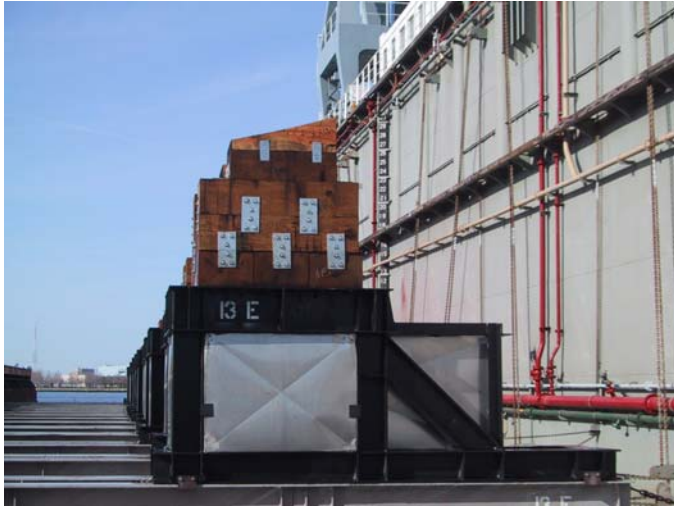
SLIDING STEEL TOWER
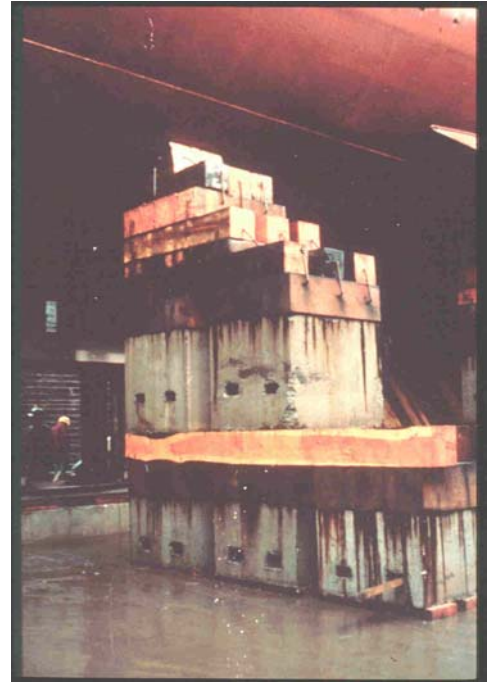
STACKED CONCRETE COMPOSITE BLOCKS

HYDRAULIC CYLINDER

7.3 – Blocking Materials

Blocks are usually constructed of timber, or a composite of timber, concrete, and/or steel. Rubber has also been used in lieu of timber. The timber or rubber provides the elasticity needed in the system to allow for irregularities in the hull or small errors in block height or position without unduly overloading the vessel's hull or the dry dock structure.

7.3 a – Timber Properties

All timber used in the construction of blocks should be select structural grade quality.

Timber is generally divided into two categories; hardwoods and softwoods. Soft woods are generally used for the soft cap at the top of the block and hardwood used below the cap.

The US Navy has conducted several studies on the allowable stress for hard and soft woods. Table 7.1 shows allowable design values from a proposed Military Handbook "Requirements For Dry Dock Blocking Systems" April 1982.

Table 7.1

SPECIES	TYPE	ALLOW STRESS (psi)
Azobe (Ekki)	Hardwood	700
California Laurel	Hardwood	775
Ohia	Hardwood	650
Oak	Hardwood	60
Douglas Fir	Softwood	440
Pine, Eastern White	Softwood	150
Pine, Southern Yellow	Softwood	150

Table 7.2 shows the test results from compression tests on new and used oak and Douglas fir presented in Military Handbook 826(SH) "Strength Properties of Drydocking Timbers and Blocks" October 1991.

Table 7.2

SPECIES	TYPE	PROP LIMIT (psi)
Oak (New)	Hardwood	322 -710
Oak (Used)	Hardwood	241-821
Douglas Fir (New)	Softwood	258-533
Douglas Fir (Used)	Softwood	279-570

The handbook states "design values for used timbers should be taken very conservatively from the low end of the strength range…. Design values for new timbers should be taken from the middle of the range…"

Chapter 997 Section 2.5.2.2 states "For the purposes keel docking blocks, the safe allowable timber compressive stress for distributed loading, taken as the fiber stress at the proportional limit of Douglas fir is 370 psi." This assumes uniform pressure over the whole top of a 42" x 48" block.

For a narrow keel width Chapter 997 allows a higher compressive stress under the loaded portion of the block. Section 2.5.2.3 allows the following stresses versus keel width:

Table 7.3

KEEL WIDTH	ALLOW AVE. STRESS OVER 4' WIDE BLOCK (psi)	STESS UNDER LOADED AREA (psi)
4 + Foot Width	370	370
3 Foot Width	370	493
2 Foot Width	227	454
1 Foot Width	184	736

It can be seen from the above table that the strength properties of wood varies considerably. Major differences exists between species, among members of the same species and even between new and used timbers. For this reason it is very difficult to state an exact design value for timber. In general, commercial shipyards will limit the compressive stress on the blocks to the values in Table 7.1 or other timber manual references. The Navy will limit loading to the limits of Chapter 997 (Table 7.3) with the additional stipulation the average load on the blocks does not exceed 20 long tons per square foot (311 psi)

Generally, locally available woods are used.

Allowable compression perpendicular to the grain range from:

- 150 psi to 590 psi for Softwoods

- 600 psi to 800 psi for Hardwoods

As timber is loaded, the wood is compressed (squeezed). Up to a certain pressure, the timber will compress under load and then rebound to its original thickness when the load is removed. This is called the elastic range of the wood. (see Figure 7.1 Stress – Strain Curves below). If the pressure in the elastic ransge is exceeded, the timber will keep compressing, but by crushing of the cells in the timber. When the pressure is removed after crushing the cells, the timber rebounds somewhat, but does not return to its original thickness. The timber has been permanently crushed. This is called the compressive range of the wood.

The elastic and compressive ranges are different for different types of wood. Stress – Strain curves for oak, a hardwood, and white pine, a softwood, are shown below to illustrate the different curves. (Per Crandall Dry Dock testing)
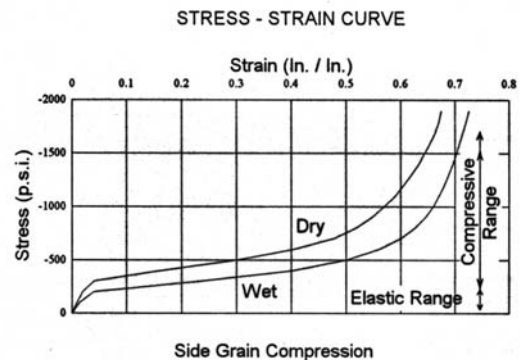

STRESS-STRAIN CURVE FOR OAK

These curves show the amount of squeeze (compression) that will occur to a 1" thick block of timber for any given pressure (stress). For example, a 1" thick piece of oak with 600-psi pressure on it will squeeze 0.02 inches. (Refer to Stress – Strain Curve for oak). This is in the elastic range so the timber will not crush.

A 1" thick piece of white pine (dry) with 600-psi pressure on it will squeeze 0.4 inches. (Refer to Stress – Strain Curve for White Pine). This is the compressive range so the timber will be permanently crushed by this load.

If the oak timber is 12" thick, then the board, under the same load, will squeeze 0.02 inches for each inch of thickness or 0.02 in/in. x 12 in. = 0.24 inches.
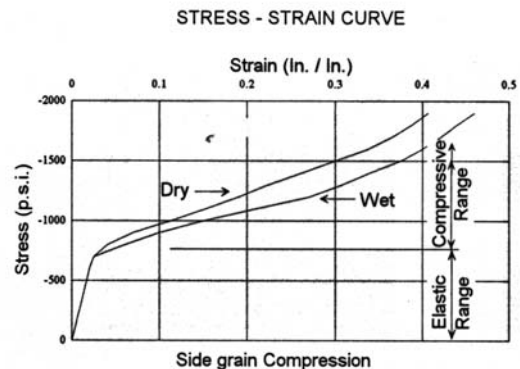
STRESS-STRAIN CURVE FOR WHITE PINE

FIGURE 7-1

A 12" thick piece of white pine will squeeze 0.4 inches for each inch of thickness or 0.4 in/in. x 12in. = 4.8 inches.

By looking at the stress-strain curve for pine it is easy to see why softwood is used as a crushing layer on top of most blocks. If one block happens to be built too high, the vessel lands on the high block first and the load on that block quickly exceeds the elastic limit. However, once the elastic limit is exceeded, the block compresses quite a lot with very little additional pressure. This means the high block can squeeze down to the height of the other blocks without overloading the block too much.

If a stiffer wood were used, a much greater force would be required to get the same squeeze, possible causing damage to the vessel or dry dock structure.

Laminated wood blocks can be suitable alternative for solid wood timbers in keel and bilge blocks. Laminated wood blocks should meet the design standards of the National Forest Products Association's (NFPA) "National Design Specification for Wood Construction".

7.3 b – Concrete Properties

Concrete is used in the bases of many high capacity keel and side blocks. Concrete makes a very strong, stiff base that does not float so the bases do not have to be fastened to the dry dock deck.

ACI Standard 318 "Building Code for Reinforced Concrete" generally applies to the design of concrete base blocks.

Additional suggestions include:

  ➢ Concrete strength – 4000 psi minimum

  ➢ Concrete should have low water / cement ratio – consider water reducing agents

  ➢ Reinforcing steel to be galvanized

  ➢ Minimum cover over reinforcement should be 3"

It is important to remember that concrete base blocks are very stiff. For this reason, concrete base blocks should never be mixed in with all timber blocks. If this is done, the concrete base blocks will take a much high load than all the timber blocks, and possibly cause damage to the vessel hull or dry dock structure. See section 4.3 for more information on this effect.

7.3 c – Structural Steel Properties

Structural steel is used in the bases of many high (over 8'-6" tall) keel and side blocks. The structural steel towers can take very high loads but are much lighter than stacking concrete base blocks on top of one another to achieve the desired height. (The weight of stacked concrete blocks can effect the lift capacity of floating docks.)

AISC Standard "Specification for the Design, Fabrication and Erection of Structural Steel Buildings" and related standards as published in the AISC "Manual of Steel Construction" generally applies to the design of steel base blocks.

Additional suggestions include:

> ➤ Use ASTM A-36 plain carbon steel

> ➤ Minimum steel thickness of 3/8"

> ➤ Detail members so they can be readily inspected, cleaned and repainted

> ➤ Avoid creating pockets or depressions which collect water, mud and debris

As with concrete base blocks, its important not to mix steel base blocks with all timber blocks. The stiffer steel base blocks will take a much greater load than the all timber blocks.

7.4 – Fastenings

All fastenings should be galvanized or corrosion resistant steel with a minimum ½ " nominal diameter.

Vertical fasteners tying layers of timber together should terminate at least 2" below the surface of the wood. This will insure the fasteners do not punch up above the timber surface when the block is squeezed under load. See Figure below.

Metal scabbing plate should have a minimum thickness of 3/8 " to minimize bending of the plate. Use oversized or slotted holes to allow blocks to squeeze without bending the plate.

Wood battens should be a minimum of ½" thick plywood or 5/8" thick softwood.

FASTENING DETAILS

FIGURE 7-2

7.5 – Construction of Keel Blocks

7.5 a – Allowable Load on Keel Blocks

The allowable working capacity of the keel block is equal to the allowable bearing pressure on the softwood cap times the area bearing against the hull. Thus if a softwood with and allowable bearing pressure (compression perpendicular to the grain), of 350 psi is used on a 3' x 6' block, the allowable load on the block is:

3' x 12"/1' x 6' x 12"/1' x 350 psi = 907,200 lbs

or

907,200 lbs / 2240 lbs / LT = 405 Long Tons

The keel block (below the softwood cap) should be capable of resisting a much greater load without failure, in case of overload of the soft wood cap. In general, the block should be capable of resisting at least twice the allowable working load without failing or buckling.

Keel blocks should be spaced close enough together along the keel track to insure the allowable working capacity of the block is not exceeded by the vessel loading.

Blocks on the aft end of the keel line must be checked for the knuckle reaction when docking a vessel on a trim relative to the keel line. See Section 5.2, "Stability of Vessel at Time of Keel Touch Down" for information on how to calculate knuckle reaction.

All blocks in the same keel line should have the same elastic deflection properties; i.e., all blocks should squeeze the same amount under similar loads. This usually achieved by using similar blocks in the keel track. For example, do not use some concrete base blocks mixed in with all timber blocks.

7.5 b – Tolerances of Keel Blocks

To insure the vessel is cradled uniformly on the blocks and to prevent a few high blocks from taking too much load or a few low blocks from not bearing against the hull, all blocks should be built to strict tolerances.

The usual tolerances for keel block builds are:

Height = +/- ¼"

Longitudinal position = +/- 1"

Transverse position = +/- ½"

7.5 c – Keel Block Stability

Keel blocks must not only be strong enough individually to take the expected loads, the entire blocking system must be stable enough to prevent the blocks from toppling over.

To insure block stability, the ratio of uncribbed height to width (or length) must not exceed 2.0 for all individual blocks. The ratio of uncribbed height to width (or length) is called "Aspect Ratio". See figure below.

Blocks exceeding this ratio in the transverse direction must be stacked pyramid style or be suitable braced.

The U.S. navy's Chapter 997 recommend the following when using high keel blocks:

a. "Blocks in excess of 6 feet in height but below 8 feet 6 inches in height shall be
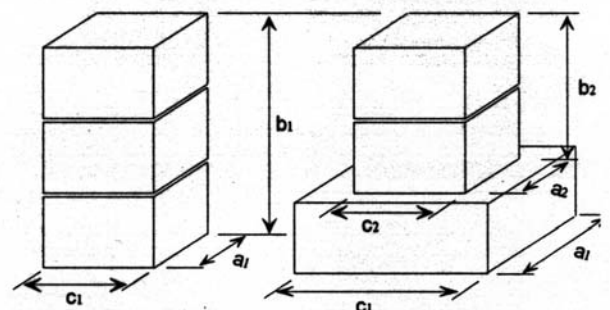
If b_1/a_1 and b_1/c_1 and b_2/a_2 and b_2/c_2 < 2.0 OK

If b_1/a_1 or b_1/c_1 or b_2/a_2 or b_2/c_2 > 2.0 NG

ASPECT RATIO

FIGURE 7-3

considered high blocks. Blocks which are 8 feet 6 inches or greater in height shall be considered extra high blocks.

b. *High keel blocks shall be cribbed or butted in the aft one-third and forward one-third of the keel block line. All extra high keel blocks shall be cribbed or butted.*

c. *Side blocks over 6 feet in height (measured from the bottom of the block to the highest corner of the soft cap) shall be tied together longitudinally in pairs by means of steel bracing, or joined by cribbing, or be constructed as individual pyramids. If the side blocks are haul blocks, they must be hauled in pairs."*

7.5 d – Keel Block Cribbing

Cribbing should be sound select structural grade hardwood between 3 and 14 inches thick. 12 inch minimum thickness is recommended for cribbing of all timber blocks.

Cribbing can be achieved in either of two ways:

TWO COLUMN CRIBBING

➤ **Two-column cribbing** ties blocks together in pairs in the longitudinal direction. See Figure 7-4 "Two-column cribbing".

FIGURE 7-4

The cribbing timbers should be continuous with no splices, running from one block edge to the opposite edge of the other block. There should be no voids between the superimposed blocks.

➤ **Continuous cribbing** spans more than two blocks. See Figure 7-5 "Continuous Cribbing".

The cribbing timbers should be of a length equal to a multiple of the block spacing and should be butted at the blocks center. There should be no voids between the superimposed blocks.
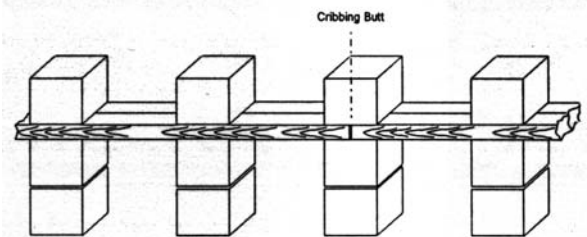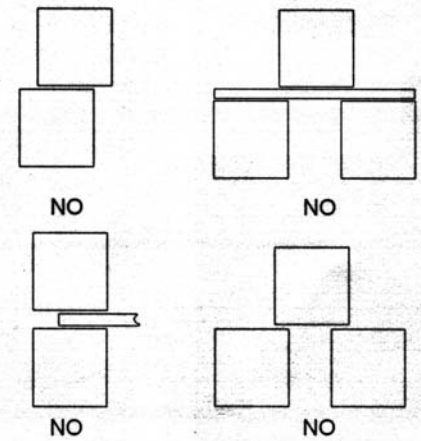
FIGURE 7-5

Any "all timber" blocking greater than 3 feet high should be cribbed longitudinally. Cribbing for "all timber" keel blocks should be a minimum of 12" thick and securely fastened to the blocks above and below.

7.5 e – Stacking of Concrete/Timber Composite Keel Blocks

When stacking Concrete/Timber Composite (CTC) blocks the aspect ratio limits previously discussed must be met. Blocks should not be stacked or cribbed in such a manner as to induce bending loads in the blocks or timbers.

To prevent bending, any stacked block should be fully supported under its entire base to avoid bridging and overhang of the upper block. See Figure below.

There should always be a timber layer between any concrete and/or steel surfaces.

BAD STACKING OF CTC BLOCKS

FIGURE 7-6

7.5 f – Steel Tower Blocks

Steel tower blocks are intended for use in supporting vessels with high block requirements – generally greater than 10 feet.

They are very useful in situations where the large weight of pyramid stacks of concrete blocks can not be tolerated (such as floating docks of limited capacity).

STEEL TOWER BLOCK

7.5 g – Sand Blocks

Sand blocks are used in situations where removal of the block under load is anticipated. The block has a layer of sand or gravel contained in a metal frame. To remove the block, the steel frame is opened and the sand is washed out. With the sand washed out, the wood above drops several inches into the frame, relieving the load on the block.
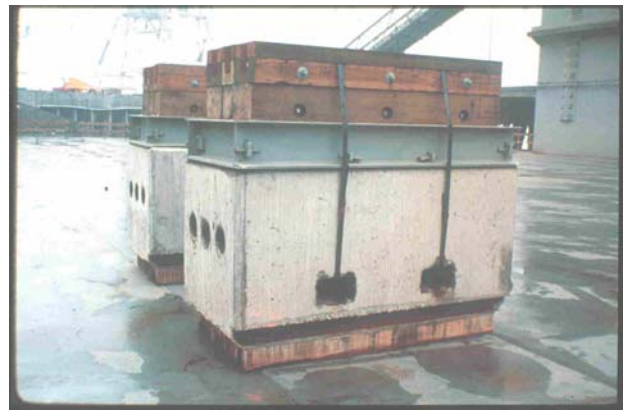
SAND BLOCK

7.5 h – Keel Block Soft Caps

Soft caps should be used on all keel blocks.

The soft cap is a layer of timber with a lower allowable compressive stress than the other timber in the base block. (the base block is a harder wood than the soft cap). The soft cap helps distribute the block load over the bearing surface of the block and ship, acting as a bedding compound to bridge minor surface irregularities and to squeeze out high spots in the blocking system without overloading the base block. The soft cap also acts to distribute the knuckle load of a vessel being docked with a trim relative to the block line over several of the aft keel blocks.

The minimum thickness of the soft cap should be about 2". This allows enough squeeze to smooth block/ship surface irregularities and to fasten the cap to the base block. The maximum thickness of the soft cap should be about 6". This minimizes the squeeze of the blocks under load and helps block stability.

The type of material and thickness of the soft caps should be approximately the same to insure proportional loading of all keel blocks.

The bearing area of the cap must be sufficient to assure the docking loads do not exceed the wood's design value in compression, perpendicular to the grain.

The soft cap is generally placed on top of the block so that it bears directly against the ship's hull. In some cases, however, the vessel's keel may be narrower than the block and the load on the block high enough to overstress the softwood directly under the keel. (Crushing of the softwood will occur.)

In this case, a hardwood layer can be used on top of the softwood layer to spread the concentrated keel load over greater area of softwood. See figure below.


TIMBER CRUSHED AT NARROW KEEL

The horizontal spread of the load in each direction can be assumed to be equal to the height of the spreader layer. (45-degree distribution).

The hardwood spreader layer should be at least 12" thick to prevent breakage.

In cases of extreme high bearing pressure, even the hardwood spreader can be overstressed directly under the keel. In this case, a steel plate or angles can be used on top of the hardwood spreader layer to distribute
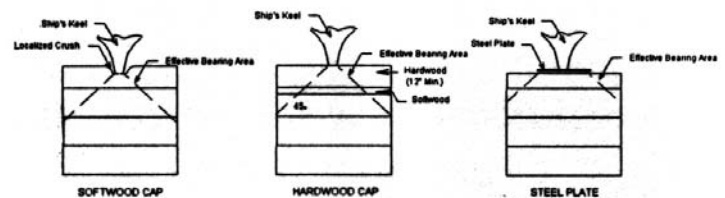

NARROW SKEG ON BLOCK

FIGURE 7-7

the keel load over a greater area of hardwood. The spreader plate or angles must be of sufficient thickness to spread the load over the required bearing area of wood without bending and crushing into the wood itself.

Materials used for soft caps should have an allowable design stress limit, perpendicular to the grain, of below 600 psi.

Ideally, the material will crush as necessary for about half its original thickness at no more than about twice its maximum elastic range or stress.
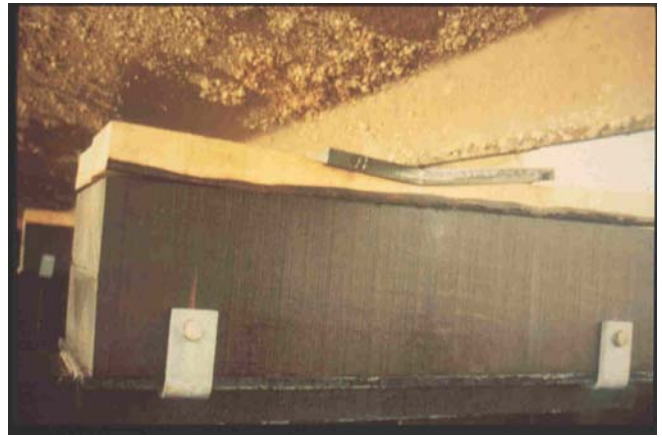
STEEL PLATE AT NARROW KEEL

Woods generally used for soft caps are Douglas Fir, Hemlock, Tamarack, Long Leaf Pine, White Pine, and Southern Yellow Pine.

7.6 – Construction of Side Blocks

7.6 a – Allowable Load on Side Blocks

The allowable working capacity of the side block is equal to the allowable bearing pressure on the softwood cap times the area bearing against the hull.

The side block (below the softwood cap) should be capable of resisting a much greater load without failure, in case of overload of the softwood cap.

The number of side blocks on each side of the vessel must be sufficient to resist hurricane and earthquake forces. See Section 4.8 "Determining the Number of Side Blocks Required to Resist Hurricanes". And Section 4.9 "Determining the Number or Side Blocks Required to Resist Earthquakes Forces".

The side blocks should have the same or smaller modulus of elasticity than the keel blocks. See Section 4.3 "Types of Materials".

This means it should take a smaller force to squeeze the side blocks the same amount the keel blocks squeezed.

This can be achieved by using the same type base for the side block as the keel block. Since side blocks are usually a greater height than the keel blocks, this insures there will be more layers of timber or thicker layers of timbers in the side blocks, resulting in a less stiff side block.

7.6 b – Tolerances of Side Blocks

To insure the vessel is cradled uniformly on the blocks and to prevent a few high blocks from taking too much load or a few low blocks from not bearing against the hull, all side blocks should be built to strict tolerances.

The usual tolerances for side block builds are:

For each A, B and C dimension:

Height = +/- ¼"

Longitudinal position = +/- 1"

Transverse position = +/- ½"

7.6 c – Stability of Side Blocks

To insure stability of the side block under load, the line of force, which is perpendicular to the hull at the center of the block, must fall within the middle third of the block at all points along its height. See figure below.

If this is not the case, the inside edge of the block may tend to lift up, creating an unstable situation.

To prevent the block from "Kicking out" at the base, the angle of the block from vertical must not exceed 15 to 20 degrees.

This is due to the fact that the coefficient of friction between wood and steel is approximately between 0.35 and 0.40, meaning the block will slide when the horizontal force is about 35 to 40% of the vertical force.
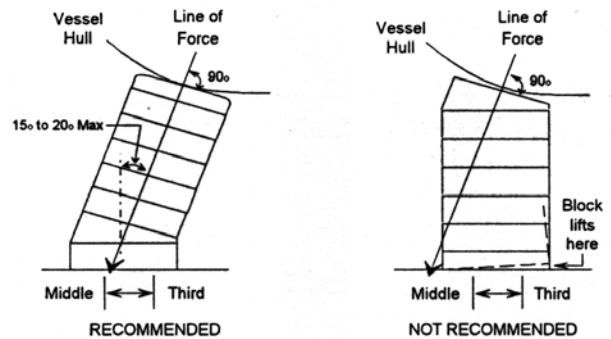
LINE OF FORCE

FIGURE 7-8

This occurs at about 20 degrees. (Tangent of 20 degrees is 0.36)

If the angle of the block exceeds 20 degrees from vertical, some positive means of holding the block from sliding should be used. (Chains, pawls clips welded to deck, ect.)

Side blocks above 6 feet in height should be braced in pairs with cribbing, steel angles, rods, etc.

7.6 d – Side Block Soft Caps

Soft caps should be used on all side blocks.

The soft cap distributes the block load over the bearing surface of the block and ship, acting as a bedding compound to bridge minor surface irregularities. The minimum thickness of the soft cap is about 2" on the short side of the block.

The maximum thickness of the soft cap is about 6" on the short side of the block with no maximum for the high side.

There are 3 types of caps for side blocks: (See Figure 7-9).

The **tangent type** with a straight sloping softwood contact face, which crushes to the actual curvature of the hull under load. (Not to be used for sharply curving hulls)

The **fitted block** has the shape of the cap pre-cut to the curvature of the hull.

And the **universal round cap** or pillow block for light loads which has no pre-measured shape.

The cap may be reused if there is no apparent damage or deterioration or if the damaged area can be planed off leaving at least 2" of sound material at the low end.
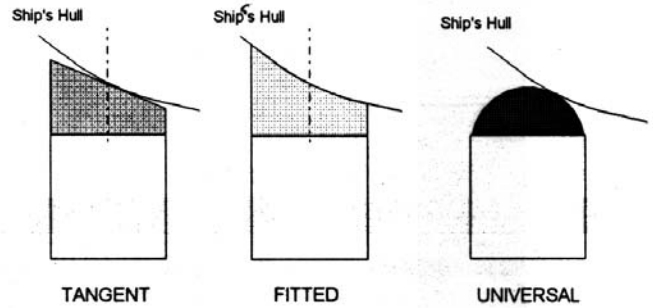
SIDE BLOCK CAPS

FIGURE 7-9

TANGENT TYPE SIDE BLOCK

FITTED TYPE SIDE BLOCK

ROUND CAP

8.0 – DOCKING PROCEDURES

Docking procedures include:

➢ Advance preparation

➢ Preparation of docking Facility

➢ Pre-docking checks

➢ Docking operation

➢ Post docking checks and actions

8.1 – Advance Preparation

Advance preparation is probably the most critical step in the docking procedure.

Advance preparation includes gathering the information required for planning the docking and conducting a docking conference to insure all parties are informed as to the procedures of the docking.

Information helpful for planning docking includes:

➢ Place & date of last drydocking

➢ Last docking position

➢ Copies of last two docking reports (Navy)

➢ Paint history

➢ Tank sounding report

➢ Data on ship alterations which may affect docking but not shown on plan

➢ Data for preparing block load and stability calculations

The docking conference is held prior to docking to insure all parties are informed as to the procedures of the docking.

Items to be discussed during the conference include:

➢ Ensure facility certification (Navy)

➢ Adequacy of the facility – how will deficiencies be rectified?

➢ Availability of latest docking plan

- ➢ Availability of qualified personnel

- ➢ Details of docking

  - o Where lines attach to ship
  - o Who will handle the lines
  - o When will blocks be hauled
  - o What draft dock will be submerged to
  - o Will divers be used – what will they check
  - o Will ship need cool down period

- ➢ Time and date

- ➢ Tugs and pilots required

- ➢ Conformation of docking drafts, list and trim

- ➢ Gangways and utilities to be furnished

8.2 – Preparation of Docking Facility

Preparing the facility for docking includes:

- ➢ Building the blocks per the proper docking plan

- ➢ Placing marks for position ship

- ➢ Preparing centering devices

- ➢ Layout of lines for ship handling

- ➢ Preparing ship for docking

8.3 – Pre-Docking Checks

Pre-docking checks include:

- ➢ Independent check of block heights and offsets

- ➢ Check on water depth availability

- ➢ Check clearances with available water depth

- ➢ Check marks for positioning ship

- ➢ Check crane clearances

- ➢ Check layout of lines

- ➢ Check centering devices

8.4 – The Docking Operation

The actual docking operation includes:

➢ Procedures check with crew

➢ Communications check

➢ Stationing of personnel

➢ Weather check, go or no go

➢ Verify docking drafts (as the ship approaches the dock)

➢ Transition from tug to lines

➢ Formal exchange of responsibility and operational control passes from the ship's captain to the dockmaster "As the extremity if the ship first to enter the dock reaches the dock sill, and the ship is pointed fair for entering the dock." Chapter 997 Section 2.3.7

➢ Centering of ship

➢ Correcting for List – Attempting to land a vessel with a list by centering it in the dry dock by measuring to the centerline line of the ship above the waterline will result in the vessel landing of center due to its list. The centering measurement must be corrected to account for the centerline of the keel being tilted away from the centerline of the vessel above water. Figure 8-1 shows this correction.
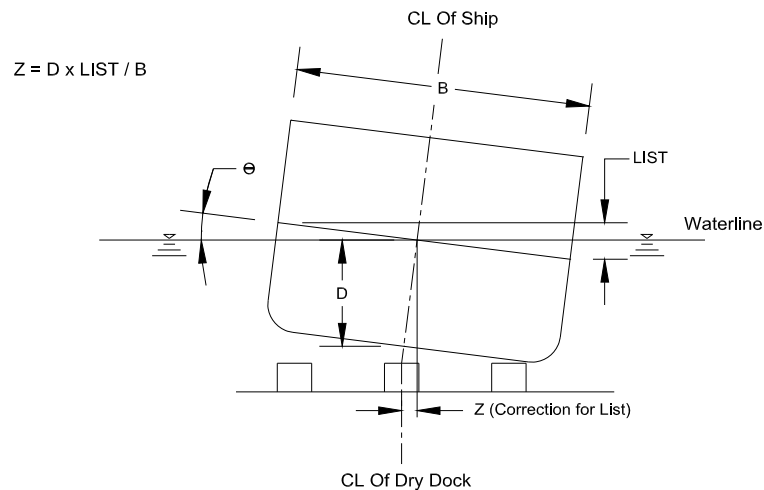
CORRECTING FOR LIST

FIGURE 8-1

Correction for list Z = D x List / Beam

D = Distance from keel to point of measurement (Feet)
List = Difference in draft port and draft starboard amidships
Beam = Beam of the ship
Z = The correction to be applied athwartship in the direction of the low side

➢ Landing of ship

    o Proper draft for landing – The dockmaster shall verify the ship lands (Starts to rise out of the water) at the correct water level in the dock. If the ship rises too early there could be something caught between the vessel and blocks and the operation should be stopped and the situation investigated.

    o Diver checks

➢ Check line tension during landing

➢ Installation of gangways, utilities and ground cable

8.5 – Post Docking Checks

Post-docking checks include:

➢ Examination of blocks

➢ Check dock freeboards and ballast levels

➢ Make corrections to docking plan

➢ Monitor weight changes

9.0 – VESSEL HANDLING

9.1 – Vessel Handling

Bringing a vessel into dock through block obstructions can be difficult. Many obstructions must be avoided – most of the time these are underwater and not visible when docking the vessel. Good control and advanced planning is essential.

Typical line positions when bringing a vessel into dock are shown in Figure 9-1. As the ship is brought into the dock, lines on either side are "walked" down the sides from cleat to cleat.

Lines can be kept slack until vessel has to be moved over in one direction or the other. The line on that side can be held ("checked") until it tightens and pulls the ship in that direction. The line must be loosened before the vessel comes too far over and over correction occurs.

Once the vessel is in its approximate position longitudinally, the best arrangement for final positioning is shown in step 6.

4 breasting lines, 1 at each quarter of the vessel and 90 degrees to the longitudinal axis, are used for centering the vessel side to side.

2 (or 4) spring lines for positioning the vessel longitudinally.

Some situations require a greater degree of accuracy when bringing the vessel into dock. (Such as threading a sonar dome between high blocks)

In this case a breasting roller, attached to the ship, can be used to provide a hard contact between the ship and fender.

This allows for more accurate positioning transversely when bringing in the ship.

Another way to more accurately position the vessel is to use a centering trolley, which keeps the ship in transverse position as the trolley rolls down the dock sides.
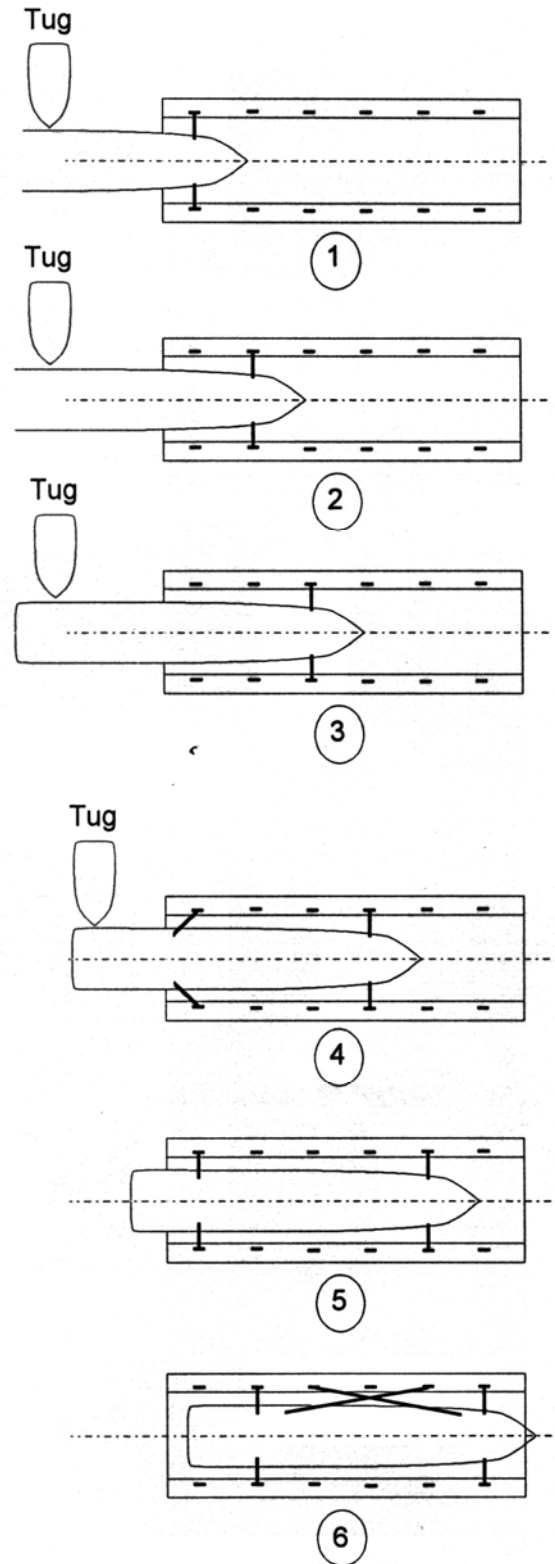
LINE POSITIONING

FIGURE 9-1

Some methods that can be used for final positioning of the ship include:

- ➢ Optical sighting

- ➢ Floating buoys (not accurate due to wind & current)

- ➢ Bootjacks for marine railways

- ➢ Transverse cable with plumb bob

- ➢ Physical measurements

- ➢ Sonar devices

- ➢ Verification by divers (mark blocks)

9.2 – Ropes

When working with rope, it is best to:

- ➢ Keep working loads low (10 to 20% of breaking strength)

- ➢ Reverse ropes regularly

- ➢ Inspect ropes regularly

- ➢ Uses splices (not knots) to join ropes

- ➢ Avoid abrasive conditions (dragging thru sandblast grit)

- ➢ Use properly sized hardware

- ➢ Replace rope when worn

For 4.5 In. circumference

TYPE	WT/100' (Lbs)	STRNGTH (Lbs)
Manila	60.0	18,500
Nylon	55.5	46,000
Polyester	63.0	39,000
Polypropyl.	44.0	26,000
Kevlar	54.0	100,000

FIGURE 9-2

Types of rope and their comparative strengths are shown in Figure 9-2.

10.0 – DEVELOPING A PUMPING PLAN

Whenever a vessel is being docked or undocked on a floating dry dock, the dock operator should follow a pre-calculated pumping plan, which shows the desired water levels in each ballast tank at predetermined drafts of the dry dock. The water levels shown in the pumping plan are theoretical values for that particular ship weight distribution and draft of dry dock, for which the dry dock will have minimum bending stresses.

The pumping plan should be used as a guide only. During the docking or undocking operation, the actual water levels may have to deviate from the plan somewhat to counter deflection, list or trim observed in the dry dock. (Observed deflection, list and/or trim of the dock always controls over theoretical calculations). Also, the method of venting a tank during pumping or flooding may also affect the reading on the tank level indicator. If the deviation from the plan is excessive, however, the operation should be stopped and the situation evaluated to determine why there is such a large discrepancy.

The pumping plan should provide the dock operator with the desired water levels of each dry dock ballast tank for a series of dock drafts as the ship is lifted out of, or submerged into, the water. The water level in each compartment is calculated to provide a buoyant lift in that compartment exactly equal to the load over the compartment. Doing this keeps the longitudinal bending stresses in the dry dock to a minimum.

To prepare the pumping plan, you must first select the dock drafts for which you will calculate water levels in the ballast tanks.

After the dock drafts are selected, you can determine how much the ship has been lifted at each draft, and thus determine the load that the ship imparts to each ballast tank.

With the draft and load on the dock known, the water levels in each compartment can be calculated such that buoyancy is exactly equal to weight. It is important to remember that the weight of the dry dock itself must also be lifted.

10.1 – Selecting Dock Drafts for Pumping Plan

Any dock drafts may be selected for computing water levels. Certain dock drafts are critical to the docking or undocking operation, however, and should be included in any pumping plan.

These critical drafts include:

1. Maximum Draft

   The dock at its maximum submergence (for this particular operation), and trimmed to match the docking vessel's trim. See Figure 10.1-1

   The dock draft should be deep enough to provide clearance between the ship and blocks while bringing the vessel into dock.
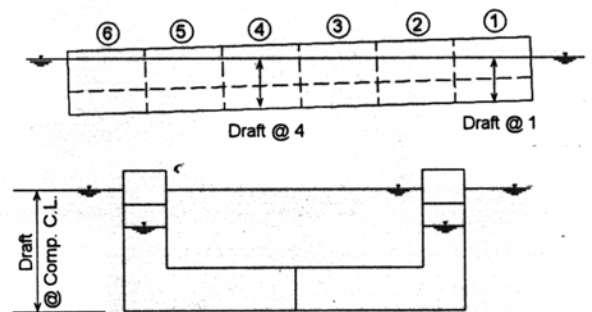

FIGURE 10.1-1

If the dock is to be placed on a trim, the draft at the centerline of each ballast compartment must be determined.

2. Vessel Keel Touchdown

    The draft of the dry dock at the point the vessel's keel is just touching the keel blocks should be calculated. If the vessel has a trim, the dock's trim should be matched to the same slope so all blocks touch at once. See figure 10.1-2.
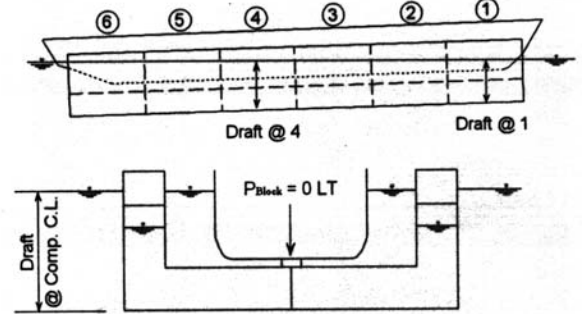

FIGURE 10.1-2

3. Vessel Lifted ½ its Draft

    The draft of the dry dock at the point the vessel has been lifted approximately ½ its draft should be calculated. See figure 10.1-3.
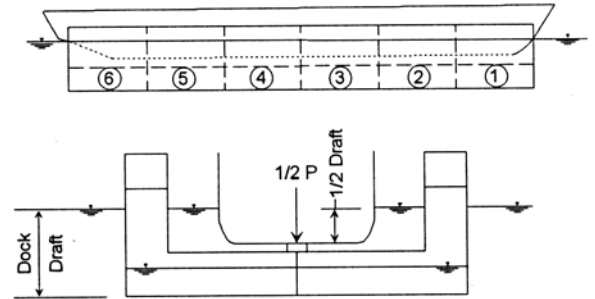
FIGURE 10.1-3

4. Vessel Keel @ Waterline

    The draft of the dry dock at the point the vessel's keel (or top of keel blocks) is at the waterline. This is the point the full load of the vessel is on the dock. See Figure 10.1-4.
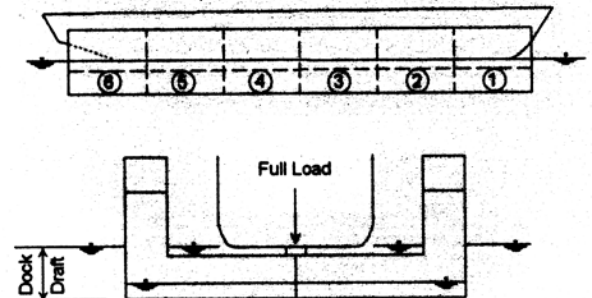
FIGURE 10.1-4

5. Dock at Operating Draft

The final draft of the dock after the ship has been fully lifted must be determined. See figure 10.1-5. For Navy certified docks the minimum pontoon deck freeboard is 12 inches for docks with 12,000 ton lift capacity or less, 18 inches for docks with 18,000 to lift capacity or more. See MIL STD and a linear progression of between 12 and 18" for docks 12,000 to 18,000 ton lift capacity. See MIL STD 1625C Section 5.3.3.1 a.
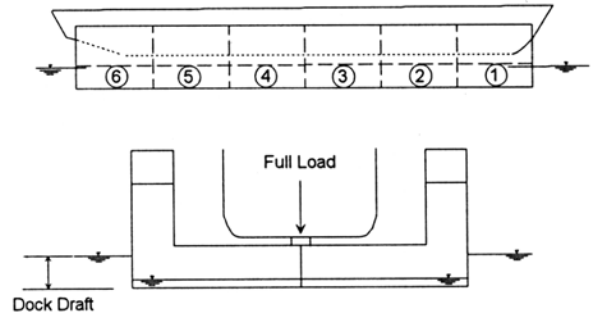

FIGURE 10.1-5

10.2 – Determining the Load on the Compartments

All compartments must lift their own dead weight (the weight of the dock) at all times. For boxed shaped docks, it is usually sufficient to assume the dock's weight is equally distributed over its pontoon length. Any large loads located over one ballast tank (such as a wing wall crane) should be attributed to that compartment only.

For example refer to Figure 10.2-1

Dock weight attributable to each compartment can be figured by:

Dock weight per foot is:

FIGURE 10.2-1

Dock weight / Pontoon length

= 7200 LT / 600' = 12 LT/Ft.

Dock weight per compartment:

-   Compartment 1, Starboard
    12 LT/Ft. x 100' / 2 sides = 600 LT

-   Compartment 1, Port
    12 LT/Ft. X 100' / 2 sides = 600 LT
    Add Wing Crane weight =   200 LT
                              800 LT

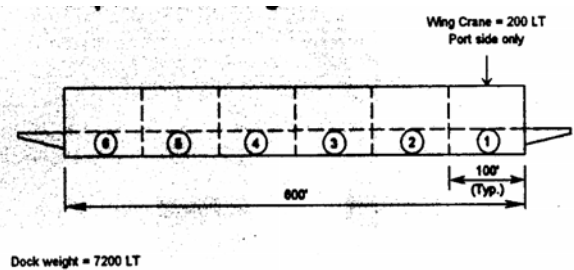-   Compartment 2, 3, 4, 5, and 6, Port & Stbd.
    12 LT/Ft. x 100' / 2 sides = 600 LT

Prior to the point at which the vessel's keel touches the blocks (Draft 2 above), there is no ship weight on the blocks and the only load the dock has to lift is its own weight.

From the point of keel touchdown, until the vessel's keel emerges from the water, (draft 4 above), the vessel's load on the blocks is steadily increasing.

From the time the vessel's keel emerges from the water, the full load of the ship is on the blocks. See figure 10.2-2.

Between the time of keel touch down and keel emergence from the water, the actual percentage of ship's load on the blocks is a function of the amount the ship has been lifted and the shape of the ship's hull.
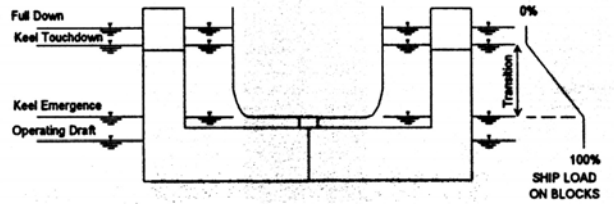

FIGURE 10.2-2

The load on the blocks at a particular ships draft will be the displacement of the ship afloat minus the displacement of the ship at the draft being investigated. If no information on the ship's displacement is known, a rough approximation of the load can be made by assuming the load increases in linear proportion to the amount the ship has been lifted.

This means that if the ship has been lifted 25% of its draft, we can assume 25% of the ships weight is on the blocks. If the ship has been lifted 50% of its draft, we can assume 50% of the ship's weight is on the blocks, etc.

If the vessel's hydrostatic properties are known it is more accurate to calculate the actual weight on the blocks due to the lift. The weight on the blocks at any particular ship draft is equal to the displacement of the vessel afloat minus the displacement of the vessel at the draft being investigated.

Load on blocks = Displacement Afloat – Displacement @ New Draft

The Longitudinal Center of Gravity (LCG) for the weight on the blocks can be calculated. We know the weight and LCG of the load on the blocks when combined with the weight and LCG of the displacement at the new draft must result in the weight and LCG of the vessel afloat. See Table 7.1.

Table 7.1

ITEM	Weight	LCG	Wt x LCG
Condition at New Draft	Known	Known	Known
Block Load	Known	??	LCG x Wt
Condition Afloat	Known	Known	Known

Therefore the LCG of the weight on the blocks can be determined by:

$$(Wt_{@\ new\ Draft} \times LCG_{@\ new\ Draft} + Block\ Load \times LCG_{Block\ Load}) = (Weight_{Afloat} \times LCG_{Afloat})$$

or

$$LCG_{Block\ Load} = ((Weight_{Afloat} \times LCG_{Afloat}) - (Wt_{@\ new\ Draft} \times LCG_{@\ new\ Draft})) / Block\ Load$$

With the LCG of the block load known, an eccentricity (e) can be determined and the trapezoidal load distribution calculated for this intermediate draft.

Once the ship's keel emerges from the water, 100% of the ship's weight is on the blocks.

We must now determine what portion of the block load is over each ballast compartment.

The load per foot along the keel block line can be calculated using the trapezoidal loading formula:

$$W / L \pm 6 \times e \times W / L^2$$

Where:

W = Ship Wt. In LT
L = Keel bearing length
e = Dist. From C.L. keel bearing length to vessel LCG

See Figure 10.2-3
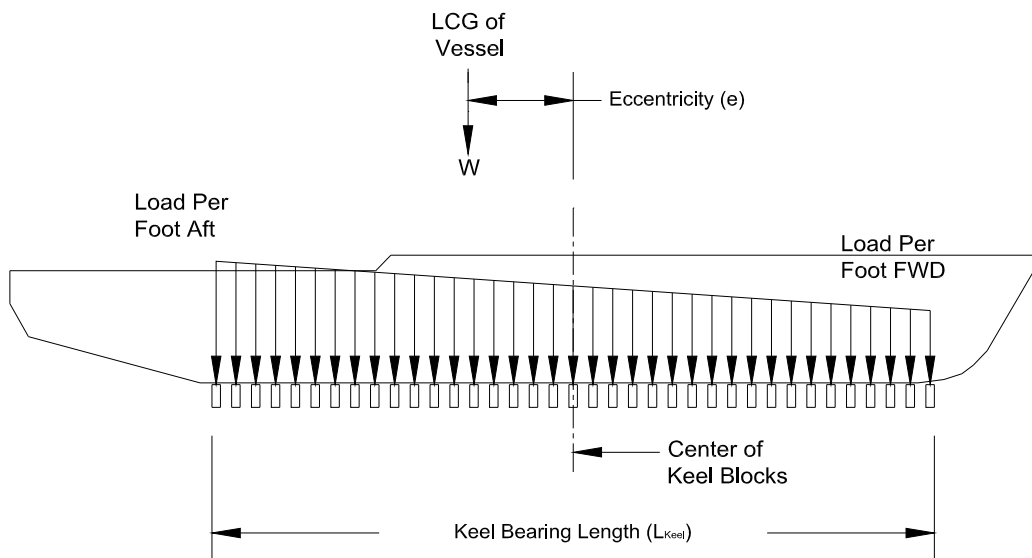
FIGURE 10.2-3

Block loading and the trapezoidal loading formula are discussed in detail in Section 4.5 "Trapezoidal Loading Equation".

The trapezoidal load distribution diagram can be placed on the dry dock pontoon in the position where the ship will be docked. The portion of this load that is directly over a compartment is the buoyancy that is required in that compartment to lift the ship.
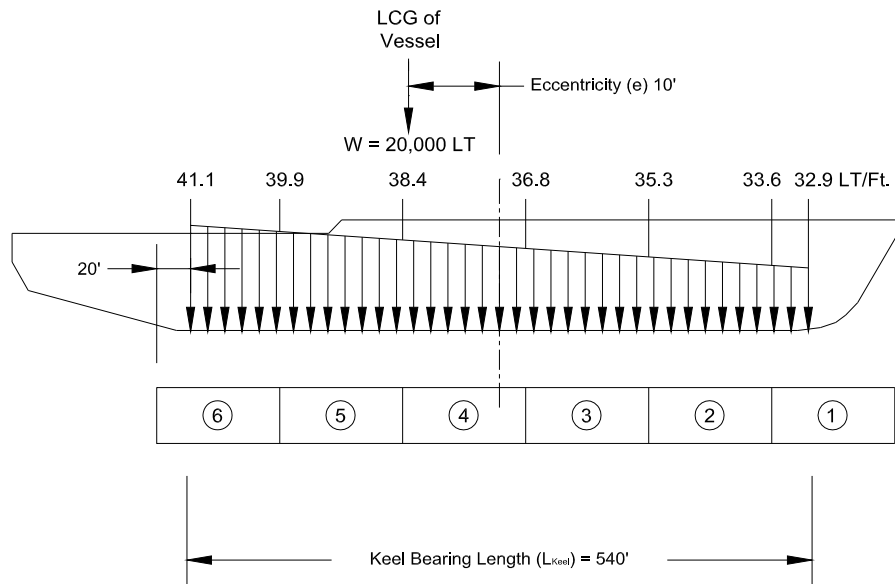
See Figure 10.2-4.

FIGURE 10.2-4

10.3 – Determining the Height of Internal Water

For each draft of the dry dock that is being investigated, the displacement of the portion of the dock at each ballast compartment can be calculated. See Figure 10.3-1. This is the gross buoyant uplift of that ballast compartment.
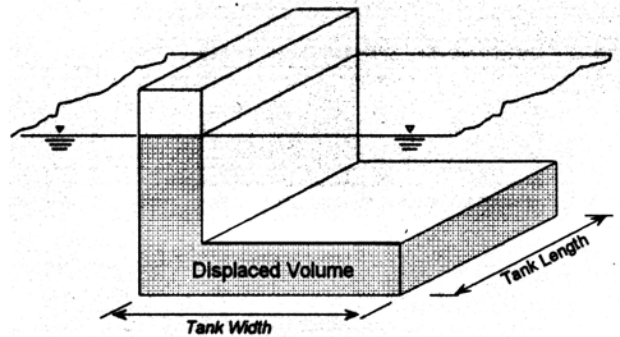
Since the dock is in equilibrium, the gross buoyant uplift must be exactly equal to the portion of dock and ship weight attributed to that compartment and the weight of internal ballast water in the ballast tank.

The ship weight and dock weight are known so the weight of ballast water can be calculated.

Once the ballast water weight is known, its volume can be calculated by dividing the total ballast water weight by the unit weight of water.
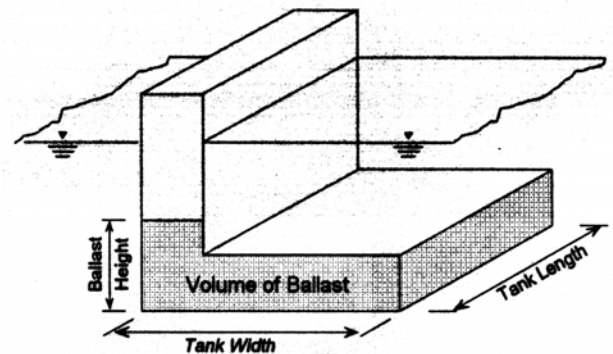
The total volume that the ballast water fills should be increased slightly to account for the volume of the structural steel, pumps, valves, pipes, etc. which are in the ballast tank which are taking up space that ballast water can't fill. This increase in volume is calculated by dividing the total volume of the tank by the tank's permeability. Permeability for a typical all steel dry dock ballast tank is 0.98. This can vary however if there are other things in the tank taking

FIGURE 10.3-1

FIGURE 10.3-2

up space (water tanks, chain lockers etc.)
With the volume of ballast water needed for a particular weight known, its height in the tank can be calculated.

If tanks tables are available for the dock the height of water in a particular tank that results in the needed ballast water weight can be looked up directly from the table.

This calculation is repeated for each ballast tank and for all drafts being investigated. The results can be summarized in a table for easy reference during dock operation. See Figure 10.3-3.

Usually, port and starboard tanks will have the same water level, so one table can be used for both port and starboard tanks.

A sample pumping-plan is shown in the "Problems" section.

NOTES	DOCK DRAFT	6	5	4	3	2	1	SHIP DRAFT
Full Submerg.								
Keel Touch								
1/2 Draft								
Top of Blocks								
Pontoon Deck								
Operat. Draft								

FIGURE 10.3-3

10.4 – Use of Lift Curves in Developing a Pumping Plan

A major part of the work involved in developing pumping plans is the calculation of the displacement of the dock and the resultant ballast water level for a particular load and draft of dock. To eliminate the need for these calculations, lift curves can be developed for each ballast tank. These curves will directly indicate the height of ballast water required to provide a certain lift at a certain draft.

Thus, once the ship weight on a particular tank is known, the ballast water level required to produce the corresponding buoyant lift can easily be determined.

10.4 a – Developing the Lift Curves

Lift curves must be developed for each ballast tank (or transverse set of ballast tanks), of a dry dock.

The easiest way of initially preparing the curves is to physically measure the internal ballast water heights for all ballast tanks at various dock drafts. See Figure 10.4-1.

It is best to verify the accuracy of the water level indicating system with tape measurements before proceeding.

To develop the lift curves, first plot the dock's drafts on a vertical axis of a graph. Use a separate graph for each ballast tank or transverse group of ballast tanks.
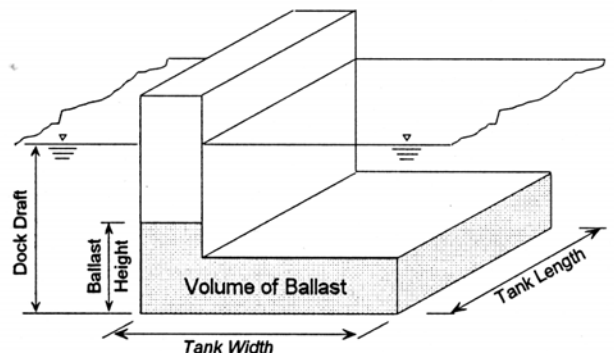
FIGURE 10.4-1

Next to the dock draft vertical scale, plot the height of ballast water that was measured at that draft. Measurements should be taken at about 2 foot increments of draft and plotted at 5-foot increments or less. See Figure 10.4-2.

Once the height of ballast water is measured, the volume and weight of the water in the tank at that height can be calculated.
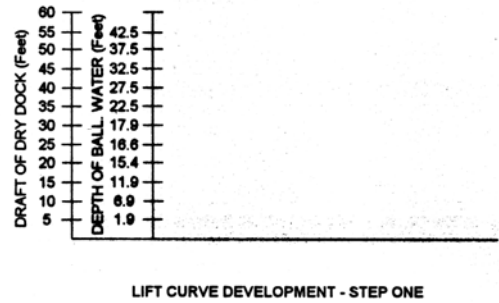
LIFT CURVE DEVELOPMENT - STEP ONE

FIGURE 10.4-2

For each interval of height, the weight of the water in the tank at that height should be plotted on the horizontal axis of the graph. This is called the ballast water weight curve.
See Figure 10.4-3.

LIFT CURVE DEVELOPMENT - STEP TWO
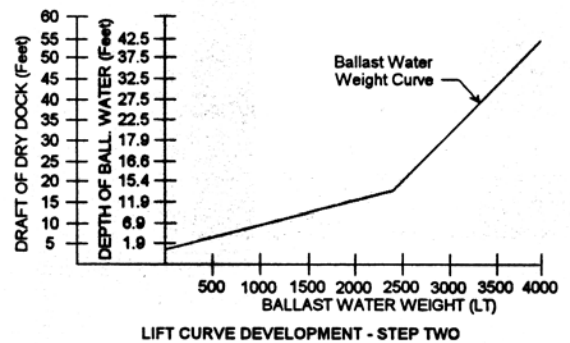
FIGURE 10.4-3

Lines representing the top of pontoon and top of keel blocks can now be drawn on the graph to complete it. See Figure 10.4-4.
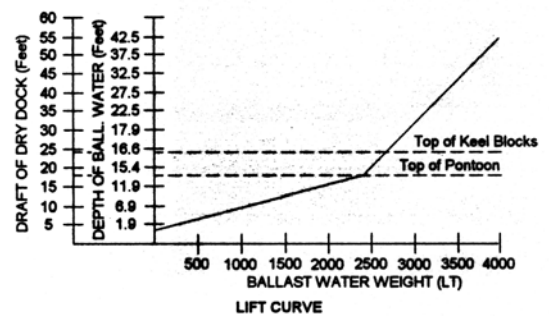
LIFT CURVE

FIGURE 10.4-4

A separate curve should be prepared for each ballast tank or transverse group of ballast tanks. See Figure 10.4-5. Note that some lift curves are developed for groups of transverse tanks.
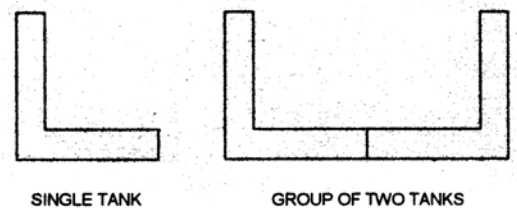
SINGLE TANK   GROUP OF TWO TANKS

FIGURE 10.4-5

10.5 – Using the Lift Curves

Once the lift curves have been developed for all compartments of the dry dock, they can be used to easily prepare pumping plans.

The shipload on each compartment must first be determined as described in Section 4, "Block Loading" Lecture.

The shipload over any compartment must be compensated by removing the exact same weight of ballast water from the ballast compartment directly below.

This can be done graphically on the lift curve as follows:

➢ For dock drafts deeper than the draft of the dock at the time the ships keel just touches the blocks, there is no load on the compartment. (Ship is afloat.) The intersection of the dock draft at keel touchdown and the ballast water weight curve should be marked. See Point A on Figure 10.5-1. This is the point load begins to come onto the dock, thus ballast water must be removed to compensate.

➢ From the point the ship's keel touches the blocks until the time the ship's keel emerges from the water, the load on the blocks is gradually increasing from 0 to its maximum. From the point the keel emerges until the ship is fully lifted, the full load is on the compartment. On the lift curve, plot the intersection of the ballast water weight curve and the dock draft with water at top of keel blocks. See Point B on figure 10.5-1. From this point subtract the total weight on the compartment by moving horizontally to left the equivalent number of tons (to scale) and plot this point. See Point C on figure 10.5-1.
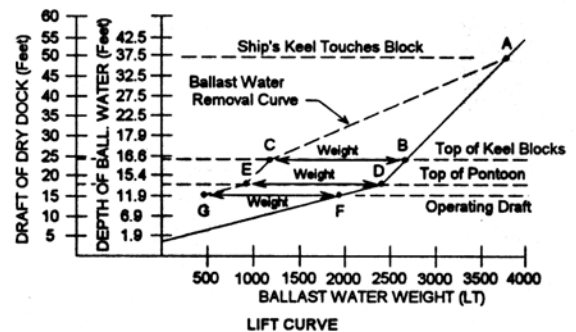

FIGURE 10.5-1

➢ Next, plot the intersection of the ballast water weight curve and the dock draft with water at top of pontoon. See Point D on figure 10.5-1. From this point subtract the total weight on the compartment by moving horizontally to left the equivalent number of tons (to scale) and plot this point. See Point E on figure 10.5-1.

➢ Next, plot the intersection of the ballast water weight curve and the dock draft at full up operating draft. See Point F on figure 10.5-1. From this point subtract the total weight on the compartment by moving horizontally to left the equivalent number of tons (to scale) and plot this point. See Point G on Figure 10.5-1.

➢ Connect points A, C, E, and G to give a graphical representation of the ballast water to be removed to lift the weight on that compartment at any dock draft. (Dashed line ACEG). This is called the ballast water removal curve.

The height of ballast water at any dock draft required to lift this particular load can now be determined.

> ➤ Find the intersection of the dock draft being investigated and the ballast water removal curve (curve ACEG). Dock draft is 30 feet for this example. See Point A in Figure 10.5-2.

> ➤ Follow straight down vertically until it intersects with the ballast water weight curve. See Point B in Figure 10.5-2. This is the weight of ballast water required in the tank.

FIGURE 10.5-2

> ➤ Follow straight over horizontally to the left and read the height of ballast water required for this weight for the "Depth of Ballast Water" Scale. The ballast water height required for the example is about 10.7 feet.
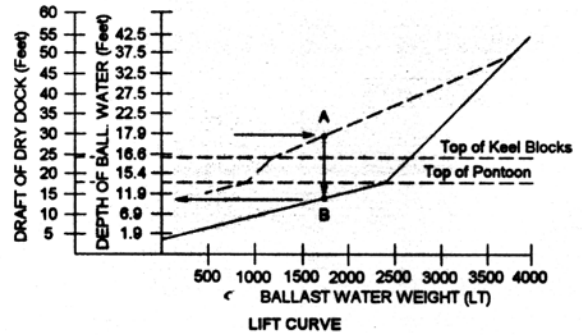
This may be repeated at any dock draft to determine the height of ballast water required to produce that lift.

A different curve is developed for each ballast tank or group of ballast tanks. The process is repeated for all tanks and all drafts being investigated. The results should be put in a summary table that the dock operator can refer to easily during the operation. See Figure 10.5-3.

If the weight and or LCG of the vessel changes while its in dry dock a new pumping plan should be developed for the undocking condition.

NOTES	DOCK DRAFT	TANK GROUP						SHIP DRAFT
		6	5	4	3	2	1	
Full Submerg.								
Keel Touch								
1/2 Draft								
Top of Blocks								
Pontoon Deck								
Operat. Draft								

FIGURE 10.5-3

10.6 – Effects of Venting On Tank Level Readings

All ballast tanks must be vented to allow air out of the tank as water comes in and allow air into the tank as water is pumped out. Many ballast tanks will have the vent tube extend down below the top of the tank. If this is the case, when the ballast water level reaches the bottom of the vent tube when flooding the tank, air can no longer escape. Water is still forced into the tank from the pressure differential between outside and inside water. This pressure squeezes

the trapped air at the tank top increasing its pressure. The system balances when the trapped air has enough pressure to resist the outside water pressure and no water can enter.

If the tank level indicator (TLI) works on the principle of measure the water pressure to determine its height (King Gage. Petrometer, pressure transducers, etc.) the indicator will "feel" the pressure from the water column AND the increased pressure from the trapped air. The TLI will read a higher water level than what is actually there. If the system is balanced, the TLI will read the outside water depth.

Figure 10.6-1 shows a ballast tank being flooded where the vent is still exposed. Air at the top of the tank can escape as water comes in. The air pressure at the top of the tank is atmospheric, i.e. equal to the outside air pressure. The TLI reads the actual water depth.
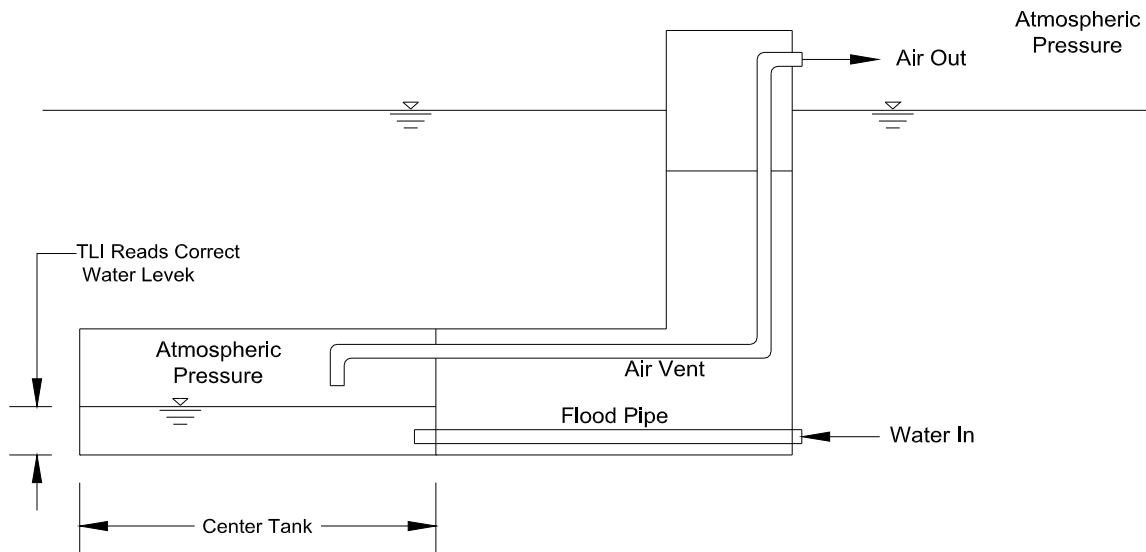

FIGURE 10.6-1

Figure 10.6-2 shows the same tank after the inside water level has risen to cover the end of the vent tube.

The air in the tank cannot escape now. As water enters the tank through the flood pipe the level rises and squeezes the bubble of air at the top of the tank pressurizing it. The system balances and water stops entering when the air pressure at the top of the tank plus the depth of water in the tank equals the pressure of the outside water level. Water will actually rise up the vent pipe and stabilize at the level of the outside water. The TLI will read a greater depth than the actual water depth due to the pressurized air in the tank. The TLI will read the outside water depth if the system is balanced.

TLI Reads HIGHER
Than Actual Water Level
Reads Outside Waterlevel When Balanced

Atmospheric
Pressure

Water Level in Vent Tube
Equals Outside Level When
Balanced

Pressurized Air

Air Vent

Flood Pipe

Water Stps Entering
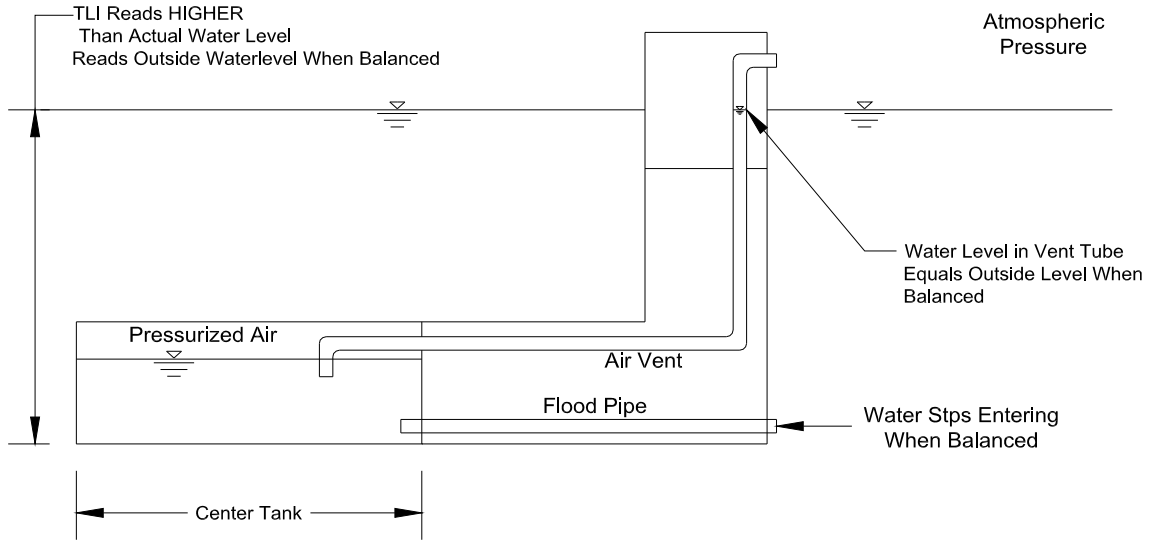When Balanced

Center Tank

FIGURE 10.6-2

It is important to understand how the venting effects the TLI readings so as not to be concerned that the waterlevels are "way off" from the pumping plan. Fortunately the pressurizing of air only happens when the tank is nearing full (depends on length of vent tube below tank top). This usually occurs when the dock is deep and the water and there is little to no ship weight on the dock.

11.0 – DRY DOCK CERTIFICATIONS

All dry docks should have their lift capacities certified by an independent company or agency that is experienced in the design and inspection of that particular type of dry dock. Although dockmasters should be familiar with the condition of their dry dock at all times, they are not structural or marine engineers and should not be expected to assess the significance of the dock's deterioration as it relates to its structural or mechanical limitations.

Maintaining a dry dock's certification forces an independent, periodic review of the dock's material condition. This allows the dockmaster to address areas that may be deteriorating or wearing before they become a serious problem. The inspection report, issued with the certification, gives upper management the information they need to make informed decisions on how to spend money maintaining their dock.

The certification document can provide peace of mind to any prospective client considering putting his vessel on the drydock. With a certified dock, it is not only the shipyard saying the dock is adequate to lift his vessel, but an independent, reputable, engineering firm. Also, the dock's owner, mortgage company, or leasing company may insist on having the dock certified to insure it is being properly maintained.

All dry docks should be certified for allowable total lift AND allowable load per foot, as a minimum. This gives the dockmaster the information needed to ensure that the structure and mechanical components will not be overstressed by docking a vessel that is too heavy for the facility.

Floating dry dock certifications must also detail hydrostatic and stability limitations. This is usually done in the form of a "KG versus Weight Curve" which details the highest KG a vessel of a certain weight may have and still maintain the minimum required GM for the ship – dock system.

See Section 12 for discussions on how a dry dock is rated.

The certification should be based on the facility's current physical condition. This means the certifying agent must perform a material condition survey of the facility on a regular basis.

In general, there are two types of certifications:

-   Commercial Certifications

-   Certification by the U.S. Navy under the MIL-STD 1625C "Drydocking Facilities Safety Certification Criteria for Docking U.S. Navy Ships".

A commercial certification is easier to obtain than the Navy Certification, (less stringent criteria usually has to be met for a commercial certification), but Naval ships cannot be docked on any dock that is not Navy certified.

Only the U.S. Navy can issue a Navy certification, however it is the shipyard's responsibility to prepare all the required calculations and other information for their review. The Navy does not perform any calculations themselves.

11.1 – Commercial Certification

Private companies such as American Bureau of Shipping (ABS), Lloyds Register of Shipping, or HEGER DRY DOCK. INC issue Commercial Certifications. Each has their own particular set of requirements which must be met before the certification will be issued.

A commercial certification is usually accepted by insurance or leasing companies, commercial vessel owners, and sometimes by the Coast Guard and the Military Sea Lift Command (MSC). (Some of the latest contracts by the MSC are calling for the dock's to be Navy certified before docking the vessel.)

In general, a commercial certification requires:

➢ A material condition survey of the dock to ascertain its present condition.

➢ Witness a dry dock operation, if possible.

➢ Structural calculations to determine maximum lift and load per foot.

➢ Hydrostatic and stability calculations (for floating docks)

➢ Review of operating procedures.

A material condition survey is necessary to determine the present condition of the facility. All structural calculations are based on the present condition of the dock.

If certification is justified, a certificate is issued stating the maximum capacity of the facility, maximum allowable load per foot, duration of the certification and any additional conditions to sustain certification. The certification should be stamped by a Registered Professional Engineer (P.E.). See Figure 11.1-1.

A KG versus Weight Curve should also be issued with all floating dock certifications to insure vessels being docked have adequate ship/dock stability. See figure 11.1-2. See Section 5.7 "Stability of Floating Docks" for information on how to use KG versus Weight Curves.
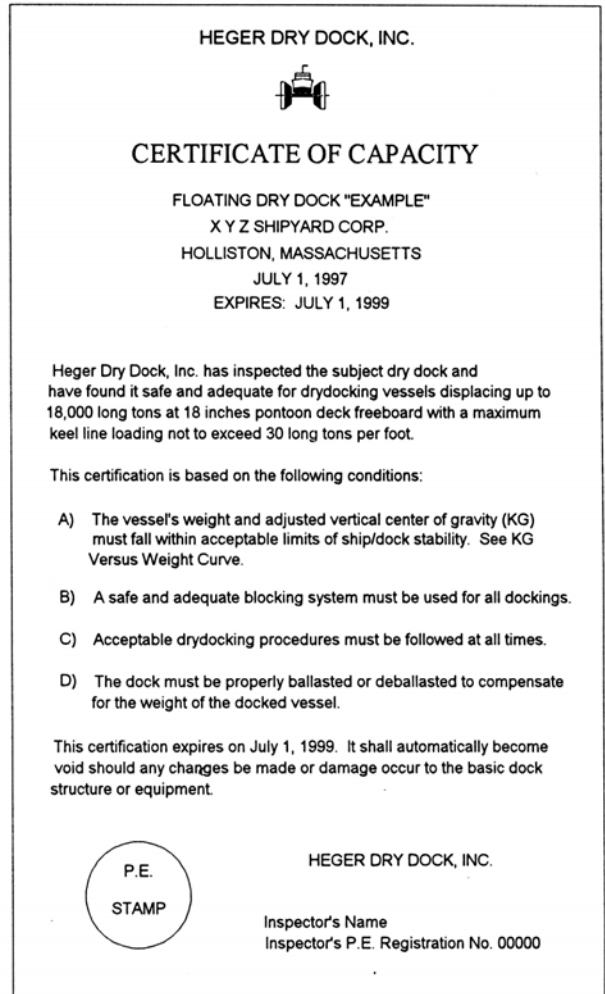

HEGER DRY DOCK, INC.

CERTIFICATE OF CAPACITY

FLOATING DRY DOCK "EXAMPLE"
X Y Z SHIPYARD CORP.
HOLLISTON, MASSACHUSETTS
JULY 1, 1997
EXPIRES: JULY 1, 1999

Heger Dry Dock, Inc. has inspected the subject dry dock and have found it safe and adequate for drydocking vessels displacing up to 18,000 long tons at 18 inches pontoon deck freeboard with a maximum keel line loading not to exceed 30 long tons per foot.

This certification is based on the following conditions:

A) The vessel's weight and adjusted vertical center of gravity (KG) must fall within acceptable limits of ship/dock stability. See KG Versus Weight Curve.

B) A safe and adequate blocking system must be used for all dockings.

C) Acceptable drydocking procedures must be followed at all times.

D) The dock must be properly ballasted or deballasted to compensate for the weight of the docked vessel.

This certification expires on July 1, 1999. It shall automatically become void should any changes be made or damage occur to the basic dock structure or equipment.

P.E.
STAMP

HEGER DRY DOCK, INC.

Inspector's Name
Inspector's P.E. Registration No. 00000

FIGURE 11.1-1
SAMPLE CERTIFICATION
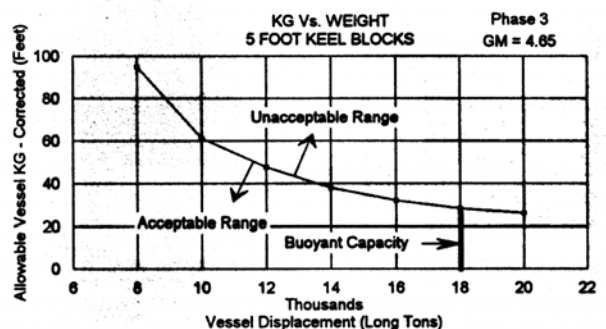

FIGURE 11.1-2
SAMPLE KG VS. WT. CURVE

The duration of the certification is generally between 1 and 5 years depending on the condition of the facility and/or other conditions. Re-certification generally requires another material condition survey prior to the expiration of the original certification.

The U.S. navy does not accept commercial certifications. Before docking U.S. Naval vessels, a dock MUST be certified by the Navy.

11.2 – U.S. Navy Certification

The U.S. Navy requires all dry docks, buildingways, or launchways which are to dock or launch naval vessels over 500 tons to meet the requirements of MIL-STD 1625C "Drydocking Facilities Safety Certification Criteria for Docking U.S. Navy Ships". Ships under 500 tons have reduced requirements that must be met.

The purpose of the Safety certification Program is to insure the safety of U.S. Navy ships during docking, undocking and while in dry dock.

To obtain certification under MIL-STD 1625C the docking facility must submit a Facility Certification Report (FCR) which addresses all the requirements of 1625C. This is a detailed, complex, document addressing all aspects of the dry dock's design, operation, condition and personnel.

The shipyard is responsible for preparing the report which demonstrates to the Navy the dry dock is safe to lift capacity vessels AND meets all the requirements of MIL-STD 1625C.

The usual format and contents of a FCR is:

Front Matter
- Cover sheet
- Cover letter
- Proprietary data list
- Surveyor's endorsement
- FCR revision sheets
- List of contents

Main Body of Report
- Summary
- General Description

Enclosures
- Historical data
- Design data
- Operational limitations
- Organization and manning
- Normal maintenance schedule & procedure
- Operating procedures
- Protection of the ship during the lay period
- Survey results
- Corrective action plan
- Monitoring plan

Folded Drawings

Most of the information on the dry dock is found in the "Enclosures" portion of the document. This section includes:

<u>Historical Data</u>

- Dates of initial design and construction
- Role of classification societies in design
- Dates and descriptions of major modifications to the dock
- Descriptions and dates of any accidents which resulted in more than $50,000 damage. Description of repairs and steps taken to prevent recurrence.
- History of past dockings including dates, docking displacements, and type of vessels.

<u>Design Data</u>

Structural, mechanical and hydrostatic design data that substantiates the facility, in its present condition, can handle vessels with a displacement equal to the rated capacity of the dock must be included.

Structural, mechanical and hydrostatic design data that substantiates the facility, in its present condition, meets all the rules and requirements of MIL-STD 1625C must be included. Some docks not specifically designed to meet the requirements of 1625C may have trouble satisfying all the rules without some modifications or reduction in certified capacity.

Some of the requirements that can be difficult for existing docks to meet are:

➢ Damaged Stability Requirements
   Section 5.3.3.1 (c)

   Floating docks are required to survive theoretical flooding of a certain number of ballast compartments without listing, heeling or submerging a certain amount. Many existing docks can only meet this rule by assuming a high pontoon deck freeboard in its initial (operating) condition. The higher freeboard usually means a lower rated capacity for the dock.

➢ Fire Protection Systems
   Sections 5.3.14, 6.3.9, & 7.3.11

   Detailed flow, pressure and outlet location requirements are given. Flow and pressure requirements must be met with one fire pump assumed not operational. Many docks require additional stations and/or pumps to meet these requirements.

➢ Corrosion Criteria
   Section 5.6.5.1.6

   In general, steel strength members which have lost 25% or more metal thickness will be considered unsatisfactory.

➤ Earthquake Criteria
Section 5.3.11.1, 6.3.3.6, & 7.3.2.1

Criteria depends on location.

Operational Limitations

Operational limitations which are necessary for the safe operation of the facility must be listed and posted.

These include:
- Wind, tide and current
- Block Loading
- Local strength limits
- List and trim limits (for FDD's)
- Available water over blocks
- Overall capacity
- Other limitations

Organization and Manning

A manning procedure which describes stations to be manned, functions to be performed, and qualification criteria for personnel manning those stations must be provided.

Resumes of personnel manning strategic positions must be provided to demonstrate qualification criteria is met.

Normal Maintenance Schedule and Procedures

A description of major maintenance procedures and schedules should be provided.

Operating Procedures

Complete detailed operating procedures for the docking facility must be included.

The procedures should:

a) Assign responsibility for each phase of the evolution.

b) Detail step by step procedures for operating the dock.

c) Require verification signatures on check sheets for all required docking / undocking checks.

d) Detail emergency procedures for:
   o Fire
   o Flooding

      o Loss of communication
      o Loss of power
      o System or component failure

Protection of the Ship During the Lay Period

Complete detailed procedures for protecting the ship while in dry dock must be included in the FCR.

The procedures should:

   a) Describe security patrols and fire watch (including equipment available to them).

   b) Describe system for preventing unauthorized operation of the dock.

   c) Describe disaster plans including:
         o Power loss
         o Fire
         o Hurricane
         o Earthquake

Material Condition Survey

This is the only portion of FCR document that the shipyard cannot prepare themselves. The facility must be surveyed by an independent, qualified engineering firm. A survey report by that firm must be included in the FCR.

The survey report should contain:

   - Dates of the survey
   - Scope of the survey
   - Experience and qualifications of the surveyors and divers and their organizations
   - Summary checkoff lists
   - Recommendations on required repairs or modifications
   - Conclusions and evaluations of survey results
   - Letter of endorsement endorsing a recommended rated capacity for the facility.

The Navy should be notified of the schedule for the material condition inspection so they can arrange to have a representative present during the survey.

Corrective Action Plan

The Corrective Action Plan should detail the procedures and schedule for making any repairs or modifications to those items in the facility which were found unsatisfactory. These are items which would render the facility unsafe for docking capacity vessel unless they are repaired.

Monitoring Plan

The Monitoring Plan should detail the procedures and schedule for monitoring those items in the facility which were found marginal in the survey and may become unsatisfactory within the certification time period.

11.3 – Time Frame for Navy Certification

Depending on the amount of initial information available on the dry dock, it can take 2 to 6 months for the shipyard and its consultants to prepare the Facility Certification Report (FCR).

Once the FCR document is submitted to the Navy, they have 120 days to review it and respond. Usually they will request additional information from the shipyard before they issue the certification. The shipyard has 120 days to respond but can usually submit their answer within a month. The Navy gets another 120 days to respond to this new information. If their request for additional information has been satisfactorily answered they will issue a certification, if not, they may ask for even more info. This, of course, delays the certification process.

It is a good idea to allow 8 months to a year from the time of submittal of the FCR to the time of certification.

11.4 – Re-certification

The length of the certification depends on the condition of the facility but does not exceed five years commencing from the completion date of the material condition survey.

The certification may be renewed by submitting a Facility Re-certification Report (FRR) or may be extended by implementing the Maintenance Program.

Facility Re-certification Report (FRR)

The Facility Re-certification Report is a resubmittal of the original FCR with the appropriate information updated or modified to suit any conditions they may have changed since the original submittal.

Updates should include:

a) Revised Historical Data
b) New Material Condition Survey
c) Description of changes to structure, personnel and procedures

The FRR should be submitted at least 6 months prior to expiration of the original certification.

11.5 – Maintenance Program

The Maintenance Program provides a means for a facility to sustain certification without periodic submittals of FRRs.

Following initial certification, an operator has 1 year to elect to participate in the maintenance program.

To participate in the maintenance program an operator must:

- Implement a preventative maintenance program
- Maintain updated operating procedures with all changes formally controlled and implemented.
- Establish a configuration control board which reviews, approves and records all changes made to the dry dock. Control inspections will be conducted by qualified personnel.
- Establish a system for documenting, tracking and correcting any deficiencies that are reported.
- Maintain updated personnel qualification data.
- Record and report accidents.

Once an operator's maintenance program has been accepted by the Navy, they will periodically audit the operator once every two years.

The audit evaluates the effectiveness of the program and includes:

- Material Condition Survey
- Examination of maintenance program documentation
- Examination of operational records
- Observation of a docking or undocking
- Evaluation of control, operating and maintenance procedures
- Examination of actions to resolve deficiencies.

12.0 – DRY DOCK RATINGS

All docks should have at least two rated capacities:

1) Total Load Rating

    This is the maximum vessel weight the dock can safely lift.

2) Maximum Load per Foot

    This is the maximum load per foot along the length of the dock that the structure is capable of safely supporting.

    Except for possibly for basin docks, the maximum load per foot rating should be greater than the total load rating divided by the dock length.

    This allows for:

    ➢ Docking of capacity or near capacity ships with keel line shorter than the dock length.

    ➢ Higher loadings at one end of block line due to eccentric LCG of ship on keel block line.

    ➢ Unanticipated higher loadings due to block, ship or dock irregularities.

See Figure 12-1.

12.1 – Rating of Floating Docks

The "Total Load Rating" for a floating dock is usually determined by its buoyant capacity at a certain pontoon deck freeboard.

The total load rating should state what freeboard was assumed in determining it.

(10,000 LT @ 18" freeboard)

The draft of the dock at the rated freeboard is

10,000 LT CAPACITY DOCK

Rated Load / Ft. = 25 LT / Ft.

Nominal Load / Ft. = 10,000/500' = 20 LT / Ft.

500'

RATED CAPACITY

400'

25 LT / Ft.

500'

SHORT CAPACITY SHIP

25 LT / Ft.

500'

NONUNIFORM LOADING

FIGURE 12-1

Operating Freeboard

Pontoon Deck

Available Buoyancy

Residual Ballast Water

Min. Draft - No ship
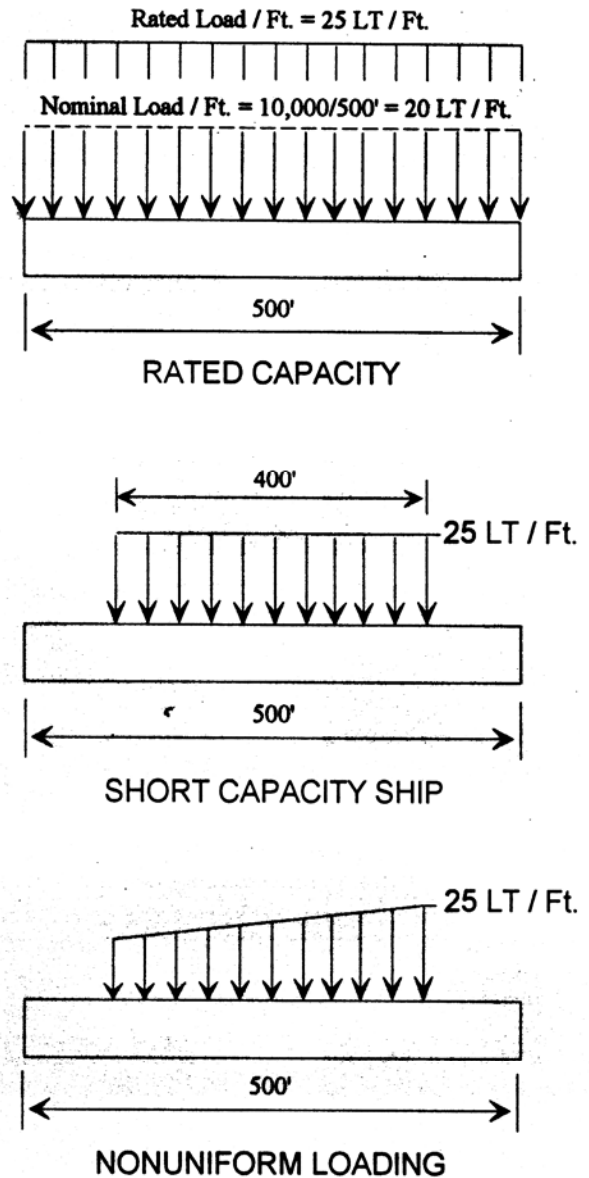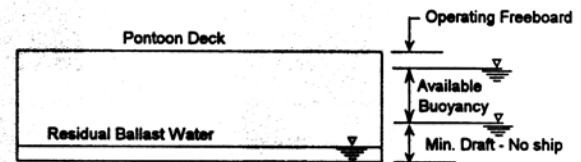
TOTAL LOAD RATING = AVAILABLE BOUYANCY @ OPERATING FREEBOARD

AVAILABLE BUOYANCY

FIGURE 12-2

called the "Operating Draft".

Buoyant capacity is determined by:

> Dock Displacement @ operating draft – dock displacement @ minimum draft achieved using main pumps. See Figure 12-2.

The operating freeboard used to determine the "Total Load Rating" can vary.

ABS uses a minimum of 12" at the rated lift capacity. The Navy uses a variable freeboard based on rated capacity as shown in Figure 12-3.
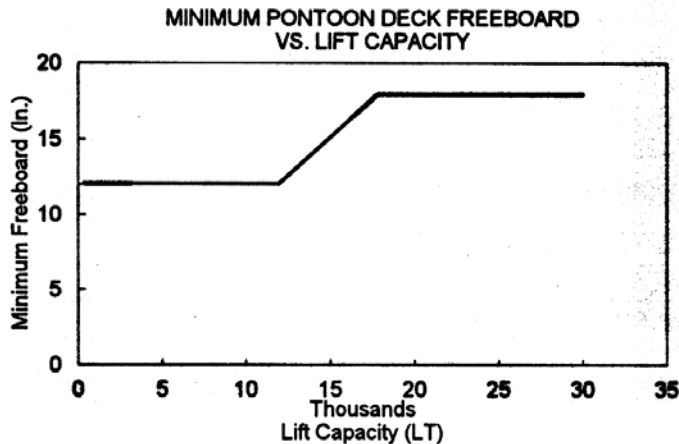
FIGURE 12-3

Some shipyards will use the 0" freeboard rated capacity to advertise their docks to make it appear larger.

At least 6" of pontoon deck freeboard should be maintained to help prevent:

> ➢ Submergence of pontoon deck if dock leaks

> ➢ Waves washing onto pontoon deck

Some yards, particularly in Europe, reduce the buoyant capacity of the dock by a certain percentage when rating the dock.

This leaves reserve ballast in the tanks and allows differentially deballasting of the pontoon to account for varying weights of the ship. (Trapezoidal loading, shorter keel bearing lengths etc.)

Docks rated in this way can lift a greater variety of capacity vessels.

The maximum load per foot rating should be greater than the total load rating divided by the dock length.

This allows for:

> ➢ Docking of capacity or near capacity ships with keel line shorter than the dock length.

> ➢ Higher loadings aft due to eccentric LCG of ship on keel block line.

> ➢ Unanticipated higher loadings due to block, ship or dock irregularities.

The rated load per foot is based on the lesser of:

> ➢ The shortest capacity ship that can be docked without overstressing the dock in longitudinal bending

> ➢ Capacity of the blocks

> ➤ Capacity of the dock's local structure
> ➤ Capacity of the dock in transverse bending

In addition to the load ratings, a floating dock may be limited by its stability. Usually, a KG versus Weight Curve is given as part of the certification. This curve shows the maximum vertical center of gravity (KG) a vessel of a particular weight can have while still maintaining at least the minimum required GM for the ship-dock system. See Figure 12-4. To use the curve, plot the intersection of the vessels docking displacement (weight) and its vertical center of gravity (KG). If the point falls on or below the curve then the dock has sufficient stability to maintain at least the GM for which the curve was developed (GM = 4.65 Feet in the example of Figure 12-4.) If the point falls above the curve then the dock does not have sufficient stability to dock this vessel at that weight and KG.
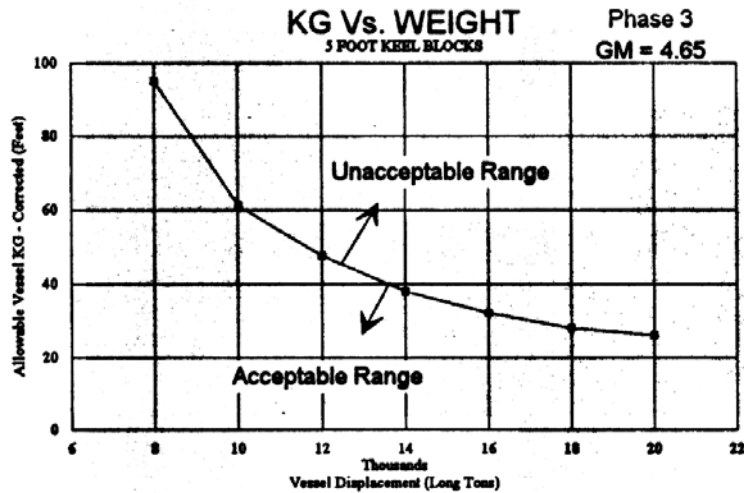
FIGURE 12-4

12.2 – Rating of Basin Docks

The "Total Load Rating" for a basin dock is generally its maximum rated load per foot times the effective length of over the keel blocks.

The maximum load per foot is based on the lesser of:

> ➤ Strength of the dry dock floor

> ➤ Capacity of the blocks

> ➤ Capacity of the dry dock foundation

12.3 – Rating of Marine Railways

The "Total Load Rating" for a marine railway is the maximum ship weight the dock can lift.

It is based on the lesser of:

  ➢ Working strength of the hauling chain
  ➢ Strength of the hauling connection to the cradle
  ➢ Capacity of the hauling machine

The maximum load per foot rating should be greater than the total load rating divided by the dock length.

This allows for:

  ➢ docking of capacity or near capacity ships with keel line shorter than the dock length.

  ➢ Higher loadings aft due to eccentric LCG of ship on keel block line.

  ➢ Unanticipated higher loadings due to block, ship or dock irregularities.

The rated load per foot is based on the lesser of:

  ➢ Strength of the cradle beams

  ➢ Strength of the runner columns

  ➢ Strength of the bottom chord of the runner

  ➢ Roller or wheel capacity

  ➢ Strength of the track

  ➢ Foundation capacity

  ➢ Capacity of the blocks

12.4 – Rating of Vertical Lift

The "Total Load Rating" for a vertical lift is the maximum ship weight the dock can lift.

It is based on the maximum load per foot rating times the length of platform

The maximum load per foot rating is based on the lesser of:

  ➢ Strength of the platform beams

  ➢ Working strength of the lifting cables rigging (wire rope, connections etc.)

  ➢ Capacity of the lifting winches

  ➢ Strength of the supporting deck

  ➢ Foundation capacity

  ➢ Capacity of the blocks

13.0 – DRY DOCK INSPECTIONS

Dry docks are structures with sufficient dimensions and strength, (and displacement and stability in the case of floating docks), to lift a vessel from the water. As with any structure in the marine environment, a dry dock will deteriorate over time, and gradually loose its ability to lift vessels. Periodic inspections of the dry dock insure the dock's ability to lift ships of the certified capacity.

A material condition survey by an independent company experienced in the design of the particular dry dock should be conducted on a regular basis. This inspection establishes the certified lift capacity of the dry dock and highlights areas of the dock to be monitored in the interval between inspections. See Section 11, "Dry Dock Certifications" and Section 12, "Rating of Dry Docks". Intervals between inspections by the independent surveyor may vary between 1 and 5 years depending on the dock's condition. The Dockmaster should conduct his own "in-house" inspections in this interval. (At least once a year but more frequently if problems are noticed.)

13.1 – Floating Dry Dock Inspections

The intent of floating dry dock inspection is to establish the as-is condition of the dock's structural and mechanical components.

Inspection of a floating dock generally consists of:

- ➢ General topside structural inspection of:

  - o Wing and Safety Decks
  - o Pontoon Deck
  - o Shell Plate
  - o Machinery Spaces
  - o Mooring
  - o Blocking

- ➢ Internal structural inspection of ballast tanks and buoyancy chambers

- ➢ Underwater Inspection (optional)

- ➢ Testing of all main mechanical and electrical equipment

- ➢ Witness a dock operation in which all mechanical equipment is run

- ➢ Soundings around dock basin and entrance channel to dock

- ➢ Leak Tests (if required)

- ➢ Freeboard measurements with dock pumped to its minimum draft using main deballasting pumps. (Establishes buoyant lift capacity)

Dry docks can be constructed of steel, concrete, timber or some combination. The modes of deterioration in the dry dock will vary depending on the materials of construction.

13.1 a – Structural Inspection – Steel Hull

A steel hulled dry dock deteriorates at varying rates throughout the hull. Many times badly corroded steel will be found near steel with little to no corrosion.

In general, some areas of the dock almost always corrode faster than other areas. These areas of high corrosion in a steel floating dock are (see figure 13.1-1):

> ➢ The pontoon deck, usually one of the first areas to show heavy corrosion.
>
> ➢ The intersection of the inboard wing wall and the pontoon deck.
>
> ➢ The intersection of the safety deck and the wing wall side shell plate and/or vertical frames (from the safety deck up about 6")
>
> ➢ The internal portion of the wing wall from the pontoon deck level up to about 10 feet below the safety deck.
>
> ➢ Areas around flood valves, pump intakes or other areas where water is moving at higher velocities.
>
> ➢ Elbows and tees of ballasting piping.
>
> ➢ Areas near dissimilar metals such as pump bearings, valve reach rod supports, ect…
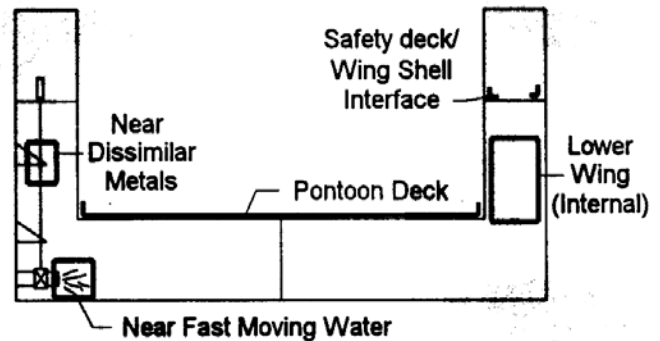
AREAS OF HIGH CORROSION

FIGURE 13.1-1

During the inspection, the condition of plating, framing and other structural members should be examined. Use a hammer to dislodge rust, as thickness of rust can be deceiving.

Note percentages of total area that are corroded.

Note corrosion using the following reference guide (in order of severity):

Light rust film – Light colored staining of steel

Moderate rust film – Light rust powder on steel

Heavy rust film – Heavy rust powder on steel

Rust Bubbles – Small bubbles of rust in isolated areas of plate that have most of its protective coating intact. Can vary from light, a few bubbles over a large area, to heavy, many bubbles almost touching each other.

Light Rust Scale – Thin sheet of rust formed on steel, sheet can be broken off in small pieces with hammer. Minor loss of metal thickness from original steel.

Moderate Rust Scale – Thicker sheets of rust formed on steel, sheets can be broken off in larger pieces with hammer. Moderate loss of metal thickness from original steel.

Heavy Rust Scale – Multiple, thick sheets of rust formed on steel, sheets may have pulled away from steel under their own weight, large sheets of rust can be peeled away with hand. Significant loss of metal thickness from original steel.

Knife Edged – Edge of flange or other member tapered down (by corrosion) to a thin, sharp edge.

Isolated Hole – Small hole in steel due to corrosion.

"Lace Curtain" Holes – Large number of small to medium size holes in plate creating a "lace curtain" (see through effect)

Complete Wastage – Large holes in plate or structural member with significant portion gone.

Use ultrasonic thickness measurements and/or calipers to physically measure thickness in areas of high corrosion.

The number and frequency of readings will vary as to the condition of the dock and purpose of inspection. Steel that still retains all of its protective coating or steel with many holes through it may require no readings because the condition is obvious. Steel that is questionable and due for repair may require many readings to establish the zones for replacement.

Usually a grid pattern is established and readings are taken at those intervals. A reading every 10 feet longitudinally and 5 feet transversely for example, or 3 readings on the web of each vertical, 1 each in the upper, middle and lower zones for example.

LIGHT RUST SCALE

MODERATE RUST SCALE

HEAVY RUST SCALE

Defects or damage such as bent or buckled frames, plates, bulkheads ect., holes in plates ect., cracks in plating, framing or welds should be noted.

Wing Deck Area

The wing deck is the top structural flange of the dock which provides its longitudinal strength. This is an extremely important structural member and should not have any cracks, buckles, holes, or severe deterioration.

Check the deck for any large buckles that progress across the entire width of the deck (and usually down the wing sides). Check for cracks in plate. Buckling or cracking in the upper portions of the wing wall may be an indication of longitudinal overstress.

The longitudinal strength of the dry dock is severely impaired by buckling or cracking in the upper or lower regions of the wing. If buckling or cracking is found in this portion of the wing, the dry dock should not be used until the situation can be investigated more thoroughly and repairs made if necessary.

Check the condition of foundation plating around all cleats, bollards, winches, capstans, etc. Where the item is fastened to the deck is generally a high corrosion area.

Check the condition of fendering timber and attachment to wing. The wood tends to rot and steel tends to corrode where the wood and steel meet.

Check crane rails and fastenings, if any.

Safety Deck Area

A high corrosion area is the intersection of the safety deck plate and wing wall side shell and vertical frames up about 3 to 6 inches.

During the operational test, when the dock is fully submerged, check the safety deck for air or water leaks – particularly around packing glands. When the dock is fully down, air trapped below the safety deck is pressurized and will hiss through any holes in the safety deck.

RUST SCALE AT SAFETY DECK

Pontoon Deck Area

The pontoon deck is generally one of the first areas to show deterioration.

Heavy corrosion is not always evident, however, since rust scale is being continually worn away by high traffic, heavy wear, etc. UT deck to be sure of thickness.

Check for severe "washboarding" or dishing of deck plate caused by vehicular loads. Low points collect water and debris which accelerate corrosion.

Check for corrosion under keel blocks.

Check for signs of overload (buckling) under keel and side blocks.

Wing Sidewalls

Check for large buckles or cracks starting at the top or bottom of wing – indications of longitudinal overstress.

BUCKLING OF PONTOON DECK

A high corrosion area is the intersection of the inboard wing wall plate and the pontoon deck.

Pontoon Sides and Ends

Check for damage from collisions.

A high corrosion area is the "wind and water line" – the area around the waterline at the operating draft.

Ballast Compartments

Inspection for commercial certification requires internal inspection of 10 to 100% of ballast tanks depending on condition and age of dry dock.

Inspection for U.S. Navy's MIL-STD-1625C requires 100% of tanks to be looked at.

A Dockmaster conducting an "in-house" inspection should plan to look at all ballast tanks at least once a year.

A very high corrosion area is the zone inside the wing walls from the pontoon deck level to about 10 feet below the safety deck.

Other high corrosion zones are areas around flood valves, pump intakes or other areas where water is moving at higher velocities.

Check the condition of the ballast piping. Holes generally develop near tees and elbows or on the underside of the pipe first.

Check the condition of the valves; look for leaks at the seat.

Check the condition of the water level indicating system. Look for broken or kinked tubing, missing or mud-clogged air bells, ect.

Note any large buckled areas of the bottom plate and determine cause. Buckling due to longitudinal bending overstress will probably be a narrow buckle over a large portion of the width and probably located in the middle third of the dock lengthwise. Buckling due to grounding will be more localized and probably occur near the ends or sides of the dock.

Note depth of residual water and silt accumulation, particularly if doing a deadweight survey of the dry dock.

Note the location and magnitude of all leaks.

Take U.T. readings of bottom plate if required.

Buoyancy Chambers

NOTE WELL: Sealed buoyancy chambers do not get an exchange of air during dock operation like ballast tanks do. Air quality inside the chambers can be quite poor and dangerous. As with all tanks, ventilate well and have air tested before entering.

Check for leaks, corrosion, buckles, etc.

Underwater Inspection

Check for damage to hull, noting any cracks, buckles, dents, holes, leaks, etc.

Note condition of coatings.

Note amount of sea growth, corrosion, etc.

Inspect inlet and outlet screens for condition, debris and amount of sea growth – Is cleaning required for good waterflow?

13.1 b – Structural Inspection – Concrete Hull

A concrete hull is inspected in much the same way as a steel hull only the concrete must be checked for cracking and spalling instead of corrosion as in the steel hull.

Most concrete structures contain steel reinforcement in the concrete. To gain maximum strength from the concrete and steel combination, the steel is deliberately put as close to the surface of the concrete as possible.

SPALLING CONCRETE

Unfortunately, concrete is porous and will absorb water. In a marine environment, the

salt water will be absorbed by the concrete. If it reaches the steel reinforcement, the steel will corrode. When steel corrodes, the volume of rust produced is about 8 times the volume of original steel. This expansion cracks the concrete cover and eventually "pops" it off, exposing the rebar.

The first signs of deterioration occur as a series of parallel cracks running in the direction of the reinforcement.

In the second stage, a cleavage plan forms at the level of reinforcement and rust staining occurs along the cracks. The concrete will sound hollow when tapped with a hammer, and the cover can be easily hammered off.

In the last stages, the cover has spalled off exposing the rebar. The concrete is usually sound below the level of the rebars.

Corrosion of the rebars is the most common causes of concrete deterioration although it is not the only cause.

Other potential causes of concrete deterioration:

Pay particular attention to the cracks located in the strength zones of the dock (wing deck, pontoon deck, and pontoon bottom) and cracks that show signs of leakage.

Anchor bolts that are embedded in the concrete to anchor machinery, deck fittings, moorings, etc. tend to corrode at the interface of the concrete and attached item. Corrosion is not always evident.

CAUSE	SYMPTOMS
Poor construction	Cracks
Drying shrinkage	Cracks
Temperature Stresses	Cracks, Spalling
Absorption of moisture	Cracks
Chemical reactions	Cracks, Spalling Disintegration
Weathering	Spalling, Disint.
Erosion	Disintegration
Poor design	Cracks, Spalling Disintegration
Overload	Cracks, Spalling

CONCRETE FAILURE MODES

13.1 c – Structural Inspection – Timber Hull

Inspect timber, both inside the dock and out for rot and borers.

Inspect timber using a probe, core borer and/or hammer – borers are not always evident from the surface. Determine the depth at which sound wood is found below punky surface.

External Inspection

Inspect sheathing on end and sides for damage. Remove sheathing in one or two areas to check condition of tar coating, sheathing felt and timber planking beneath.

Pay particular attention to the wing planks and areas around the pontoon ends and sides form the pontoon deck area down about 12 to 18 inches. This area tends to dry out and seams open up causing leakage.

Note the condition of the sheathing on pontoon deck. This area gets heavy wear.

<u>Internal Inspection</u>

Check the joints of the timber transverse trusses closely for tightness. Ideally, joints should be tight, especially with the dock loaded. See Figure 13.1-2.

A timber dock is designed to act mainly in compression through the timbers, not through the fastenings. Therefore, the bigger the gaps at the joints in an unloaded dock, the more the dock has to deflect to close those gaps to take up the load. This works the dock's planking back and forth during loading and unloading and results in greater leakage rate. All timber docks leak somewhat, however.
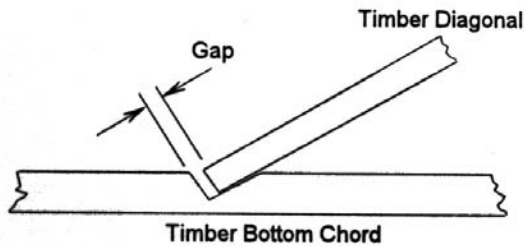
FIGURE 13.1-2

GAP IN TIMBER TRUSS

Because a timber dock is designed to act mainly in compression of the wood, not through the fastenings, the primary purpose of many fastenings is to hold the timber in place so it can act in compression. Moderate corrosion of these fastening is not too much of a concern as long as they remain capable of holding the timbers in place.

There are exceptions to this however. The bottom chord of the transverse truss usually has fish plates held with fasteners acting in tension. These must remain in good condition and tight.

Steel tie rods usually tie the top and bottom chords together and act as tension members for the transverse truss. These must remain in adequate condition and should not be loose..

Check the vertical tie rods for corrosion – they generally "neck down" as they pass into the timber.

Check the condition of the fastenings – they generally "neck down" at the interface of two timbers layers. Also, the threads tend to corrode and the nuts fall off.

<u>13.1 d – Mechanical Systems</u>

The main mechanical systems (pumps, valves, capstans, winches, moorings, ect.) are usually tested during the operational test of the dock. All systems are run and if they operate satisfactorily no further investigation is necessary. For an "in-house" inspection, the Dockmaster, who operates his dock on a regular basis, should be familiar with the workings of these items on the dock anyway.

Some items require periodic recalibration. About once a year, (or sooner if readings indicate potential problems), the water level indicating system should be checked. Physical measurements (by sounding tape) of the water level should be compared to the readouts in

the control room at various drafts of the dock. Adjustments to the system should be made if necessary.

About once a year, (or sooner if readings indicate potential problems), the deflection monitoring system should be checked. Measurements of the actual dock deflections by surveyor's level should be compared to the readings from the deflection monitoring system. Adjustments to the system should be made if necessary.

13.1 e – Operational Test

During the inspection, the dock should be submerged to its maximum draft, the valves closed and the dock held there for a period of time. (U.S. Navy suggests 45 minutes.) During submergence, valve operators and water level indicators should be checked. At full submergence the safety deck should be inspected for leaks and the draft of the dock monitored to establish whether the dock is leaking.

As the dock is pumped up, all pumps, discharge valves, etc. should be checked for proper operation.

If external leakage of the dock is suspected, an external leak test can be performed on the dock. In an external leak test, the dock is pumped to its minimum draft, all valves are closed and the ballast water levels monitored.

A rise in water levels indicates external leakage. The amount of rise in ballast water per set amount of time (6" in 30 minutes for example) should be recorded.

After enough time has elapsed to determine whether water is leaking and the rate of leakage is recorded, the dock should be lowered 1 or 2 feet, the valves closed and the monitoring repeated.

This lowering and monitoring continues in steps until the dock is at full submergence.

With the testing complete, the results can be reviewed to determine exactly at what draft the leakage in the dock starts.

If internal leakage between watertight bulkheads is suspected, an internal leak test can be performed. In this test, the dock is submerged and then deballasted in a checkerboard fashion such that adjoining tanks will have different water levels. See figure 13.1-3.

Low	High	Low	High	Low	High
High	Low	High	Low	High	Low

FIGURE 13.1-3

NOTE WELL: When deballasting the tanks, do not exceed the allowable head on the watertight bulkheads.

If leakage occurs, the water level in the tank with more water will fall while the adjoining tank with lover water will rise. The leak will be in the bulkhead between these tanks.

13.1 f – Freeboard Readings

The buoyant capacity of the dock can change over time. The accumulation of mud, sandblast grit or other items, or the lack of ability of the pumping system to dewater the tanks as low as originally designed, can reduce the lift capacity. Therefore, the buoyant capacity should be periodically checked (once every few years).

The buoyancy available to lift the vessel is represented by the volume of the dock's pontoon above the waterline with the dock at it's minimum draft.

To determine the dock's buoyant capacity, pontoon deck freeboard readings must be taken after the dock has been pumped to its minimum draft (maximum freeboard).

With no ship on dock, the dock should be dewatered using the main deballasting pumps only. The dock pumped full up, freeboards should be measured at each corner.

Freeboard is the measurement from the lowest point on the pontoon deck (usually at the inside corner of the wing) to the water.

With this reading, you can determine the minimum draft of the dock and the buoyant capacity of the dock from the equation:

Capacity = Displ. @ operating draft – Displ @ Min. Draft

Or if it's a rectangular dock in sea water:

Capacity (LT) = L x W x (Ave F.B. – Operat. F.B.) / 35

13.2 Marine Railway Inspections

The intent of a marine railway inspection is to establish the "as-is" condition of the dock's structural and mechanical components.

Inspection of a marine railway generally consists of:

- ➢ General structural survey of

    - o Foundation (above & below water)
    - o Track (above & below water)
    - o Cradle
    - o Blocking

- ➢ Line & Grade Survey

- ➢ Inspection of roller or wheel system

- ➢ Inspection of hauling machine

➢ Inspection of wire rope or chain system

13.2 a – Foundation Inspection

The foundation is usually buried and hard to inspect. However, buried structures deteriorate much more slowly than those exposed.

A foundation failure should be evident by tell-tale signs on the track and excavation of the foundation is usually not required if these signs are not present. Any exposed foundation members should be inspected as described below for the track. The track should then be inspected for external signs that the foundation may have failed. These signs include:

➢ An out of grade track

➢ Large gaps between the track & foundation

➢ Structural failure of the track beams

If these signs are found, the condition of the foundation should be investigated more thoroughly.

13.2 b – Track Inspection

A marine railway track can be constructed of steel, concrete, timber or some combination of these. The modes of deterioration wil vary depending on the materials of construction.

Also, a track has three different environmental zones which can affect materials in different ways. See Figure 13.2-1.

These Zones are:

Underwater Zone – The portion of track and foundation that remains submerged at all times.

Splash and Tidal Zone – The portion of track, foundation and cradle that get wet from tidal variations and wave splash. This is usually the zone of heaviest deterioration.

TYPICAL DETERIORATION ZONES

FIGURE 13.2-1

Above the Splash Zone – The portion of track, foundation, cradle and hauling house that is above the heavy splash from waves.

Concrete Track

A concrete track is generally used above low water only (in the tidal, splash and above the splash zones).

Most concrete structures contain steel reinforcement in the concrete. To gain maximum strength from the concrete and steel combination, the steel is deliberately put as close to the surface of the concrete as possible.

Unfortunately, concrete is porous and will absorb water. In a marine environment, the salt water will be absorbed by the concrete. If the water reaches the steel reinforcement, the steel will corrode. When steel corrodes, the volume of rust produced is about 8 times the volume of original steel. This expansion cracks the concrete cover and eventually "pops" it off, exposing the rebar.

The first signs of deterioration occur as a series of parallel cracks running in the direction of the reinforcement.

In the second stage, a cleavage plane forms at the level of reinforcement and rust staining occurs along the cracks. The concrete will sound hollow when tapped with a hammer, and the cover can easily hammered off.

In the last stages, the cover has spalled off exposing the rebar. The concrete is usually sound below the level of the rebars.

Corrosion of the rebars is the most common causes of concrete deterioration although it is not the only cause. Other common causes of concrete deterioration are:

Pay particular attention to the splash and tidal zone as this is where corrosion, weathering, and impact from floating debris are generally greatest.

Anchor bolts that are embedded in the concrete to anchor rail plate or other fittings tend to corrode at the interface of the concrete and attached item. Corrosion is not always evident.

CAUSE	
Rebar corrosion	Cracks, Spalling Rust Stains
Poor construction	Cracks
Drying shrinkage	Cracks
Temperature Stresses	Cracks, Spalling
Absorption of moisture	Cracks
Chemical reactions	Cracks, Spalling Disintegration
Weathering	Spalling, Disint.
Erosion	Disintegration
Poor design	Cracks, Spalling Disintegration
Impact damage	Cracks, Spalling
Overload	Cracks, Spalling

CONCRETE FAILURE MODES

A concrete track should be inspected for:

➢ **Spalling** – Some spalling is OK but if spalling has progressed to undermine the rail plate or is exposing the rebar, it is time to repair. See Figure 13.2-2.

➢ **Major Cracking** – Indicates possible overload, foundation failure or impact damage.

➢ **Deteriorated Fastenings** – Rails can pull away from the concrete or become loose, a potential cause of derailment.
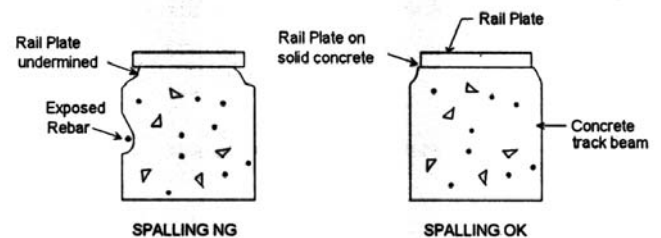
FIGURE 13.2-2

Steel Track

A steel tack deteriorates at varying rates over its length. Some areas of the track may look fine while other areas have heavy corrosion.

In general, the area of worst corrosion is usually the splash and tidal zone.

During the inspection, the condition of steel structural members should be examined. Use a hammer to dislodge rust, as thickness of rust can be deceiving.

Note percentages of total area that are corroded.

Note corrosion using the following reference guide (in order of severity):

Light rust film – Light colored staining of steel

Moderate rust film – Light rust powder on steel

Heavy rust film – Heavy rust powder on steel

Rust Bubbles – Small bubbles of rust in isolated areas of plate that have most of its protective coating intact. Can vary from light, a few bubbles over a large area, to heavy, many bubbles almost touching each other.

Light Rust Scale – Thin sheet of rust formed on steel, sheet can be broken off in small pieces with hammer. Minor loss of metal thickness from original steel.

Moderate Rust Scale – Thicker sheets of rust formed on steel, sheets can be broken off in larger pieces with hammer. Moderate loss of metal thickness from original steel.

Heavy Rust Scale – Multiple, thick sheets of rust formed on steel, sheets may have pulled away from steel under their own weight, large sheets of rust can be peeled away with hand. Significant loss of metal thickness from original steel.

Knife Edged – Edge of flange or other member tapered down (by corrosion) to a thin, sharp edge.

Isolated Hole – Small hole in steel due to corrosion.

"Lace Curtain" Holes – Large number of small to medium size holes in plate creating a "lace curtain" (see through effect)

Complete Wastage – Large holes in plate or structural member with significant portion gone.

Use ultrasonic thickness measurements and/or calipers to physically measure thickness in areas of high corrosion.

The number and frequency of readings will vary as to the condition of the dock and purpose of inspection. Steel that still retains all of its protective coating or steel with many holes through it may require no readings because the condition is obvious. Steel that is questionable and due for repair may require many readings to establish the zones for replacement.

A steel track should be inspected for:

ROLLED FLANGE   BENT FLANGE

FIGURE 13.2-3

  ➢ **Corroded steel** – as described above

  ➢ **Rolled top flange** – Overloading or off-center loading of the rail plate may cause the top flange of the track to roll or bend about the web of the beam. (see figure 13.2-3)

  ➢ **Missing rubber pads** – Some steel tracks on steel piles have rubber pads installed between the track and pile bonnets.
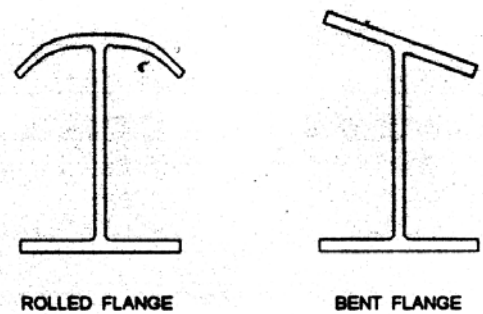
Wood Track

A wood track deteriorates in different ways in different zones of the track. Some areas of the track may look fine while other areas have heavy deterioration.

Inspect timber, for rot, marine borers and impact damage. Use a probe, core borer and/or hammer to test wood – Marine borers are not always evident from the surface. Determine the depth at which sound wood is found below punky surfaces.

Note the condition of track timber sheathing (if any). Remove sheathing in one or two areas to check condition of tar coating, sheathing felt and timber beneath.

Pay particular attention to the areas where the pile or other foundation supports the track. Look for excessive crushing.

A timber track should be inspected for:

  ➢ **Rotted Timbers** – Usually found above the splash zone.

  ➢ **Termites or Other Bugs** – Usually found above the splash zone.

  ➢ **Marine Borers** – Borers are usually found in the tidal and underwater zones in salt water only. Two common types of marine borers are the wood gribble, or limnoria, and the teredo or shipworm. Limnoria damage is readily evident with a visual inspection as loss of material occurs on the outside of the timber. The teredo is a mullusk, although it looks like a worm. They bore a tiny hole into the wood when young. As the teredo grows, it tunnels

LIMNORIA DAMAGE   TEREDO DAMAGE
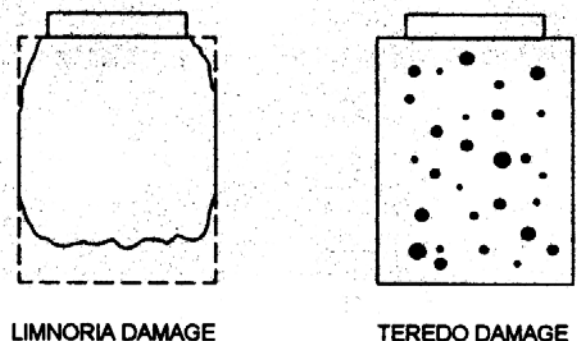
FIGURE 13.2-4

along the grain of the wood. Detection of teredos is difficult because most of the damage occurs inside the timber. A member may be riddled with holes but look fine from the outside. See Figure 13.2-4.
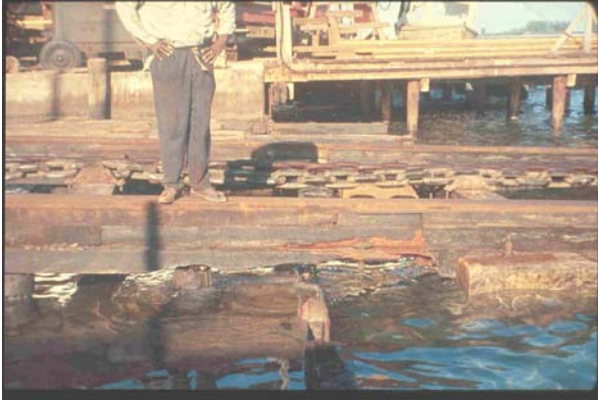
LIMNORIA DAMAGE

TOREDO DAMAGE

➢ **Rail Plate Squeeze** – The rail plate sometimes squeezes into the wood reducing the height of the top of plate above the wood. The roller flanges can then contact the wood and will wear grooves in the wood on either side of the rail plate. See figure 13.2-5. The roller flanges contacting the wood can create considerable additional friction that the hauling system must over come. This additional force could overload the hauling system. Also, roller flanges may tend to break more often.
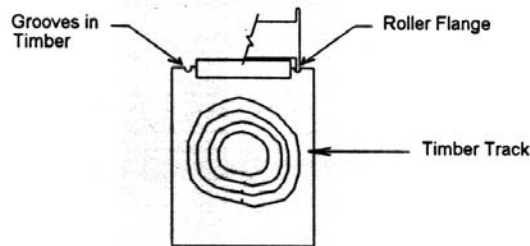
RAIL PLATE SQUEEZE

FIGURE 13.2-5

All Types of Tracks

All types of tracks should be checked for the following:

➢ **Ice damage** – check for damage by ice in the tidal zone. Damage may include bent of broken members, derailed roller frames, "jacking" of track up off of piles, or out of line or grade track.

➢ **Impact damage** – Check for damage by floating debris in tidal zone. Check for damage by anchors, vessel impact in tidal zone or underwater zone. Damage may include bent or broken members, derailed roller frames, or out of line grade or track.

➢ **Mud or Debris on Track** – Check for mud over the rail plate. Mud covering the track beams is OK as long as it does not cover the rail plates. (Mud will actually protect the track beams from deterioration). Mud on the track can cause the rollers to ride up on the mud and derail, possible causing a cradle derailment. If mud has built up greater than the level of the rollers, the cradle will have to push through this mud when backing down. This will add considerable force to the backing chain and underwater sheaves, possibly overloading them.

➢ **Gaps between pile and track beam** – Gaps between pile and track beam indicate shims have fallen out, pile has sunk, or track has come up. Track grade should be checked and shims inserted to suit. There should be no gaps between pile and track or track will deflect when loaded cradle travels over this area.

➢ **Chain slides** – Check for worn, loose, or missing chain slides.

All rail plates should be checked for the following, (see figure 13.2-6):

➢ **Crown** – The rail plate should be flat across their with a crown no greater than 3/16".

➢ **Thickness** – The rail plate thickness should not be less than ¾". Thin rail plate can curl up under weight and derail rollers and cradle. Thin rail plate can cause roller flanges to contact track beam.

➢ **Wear** – Signs of wear along the sides of the plate, usually in the form of a "J" groove, may indicate poor track alignment or out of gage track.

➢ **Fastenings** – Check to insure all rail plate fastenings are tight. Bolt heads can deteriorate (particularly in the tidal zone) and rail becomes loose. Loose rails can dislodge and derail rollers and cradle.
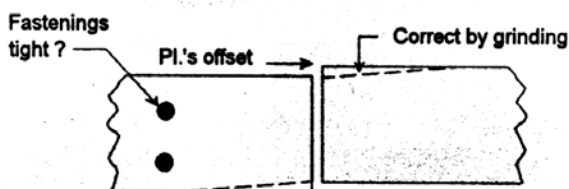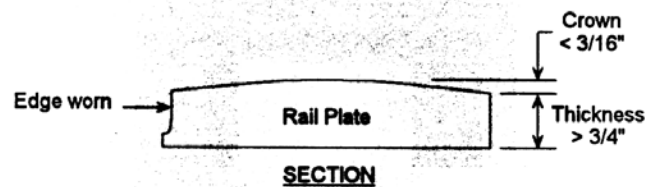
FIGURE 13.2-6
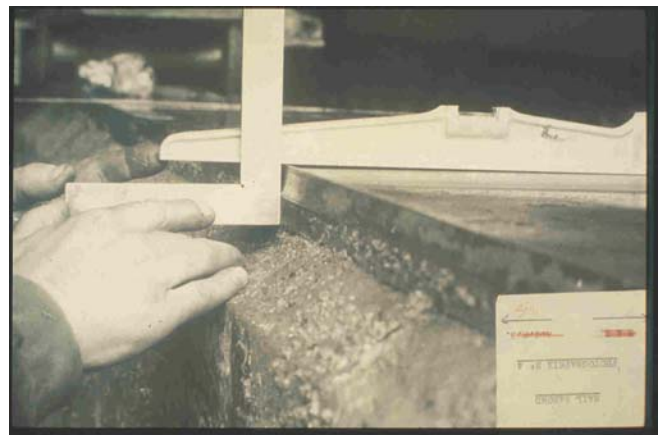
MEASURING RAIL PL. CROWN

➢ **Jogs or offsets** – Check for jogs or offsets in rail plate. A sudden change of thickness of rail plate (step up) will cause increase loading in roller at that point, possibly breaking the tread. If one plate is wider or offset such that plate sides are not in alignment, roller flanges can break when encountering this point. If jogs or offsets are found, plate should be ground down to provide a smooth transition.

13.2 c – Track Line and Grade

A detailed line and grade survey of the track (using surveyor's instruments) should be taken once every 5 years unless some unusual incident has occurred (overload, ship impact, derailment) or the dock's behavior indicates a problem.

Procedures for performing a line and grade survey are beyond the scope of this manual.

There are signs that can be looked for, however, that may indicate problems with the line and/or grade of the track.

Some of these signs are:

➢ As the cradle deck enters the water, both ends of each deck beam go under at the same time. If not, one side of the track may be lower than the other. (Or one side of the deck beam may be bent, but this can be checked with the cradle full up.)

➢ If blocks at the forward end of the cradle go underwater before the aft end it may be an indication of a low spot in the track. (blocks must be built level with no curvature in track.)

➢ When hauling a vessel, if the blocks pull away from the ship and then return in one area as the cradle passes over, there is a possibility of a low or high spot in the track at that location.

➢ Excessive wear in the roller flanges or many broken roller flanges may indicate a problem with line or gauge.

➢ Wear on the sides of the rail plate in one area (see figure 13.2-6) may indicate a problem with line or gauge.

➢ Many roller treads breaking in one spot may indicate a high spot.

13.2 d – Roller System

Due to friction, the roller frames tend to slip a little bit down the track during each cradle operation. Thus, after the cradle has been lowered and raised, the roller frames will not have returned to their original positions and will be slightly down the track (offshore). This distance, the "slip", gets greater with each cradle movement. When the rollers have slipped the distance of one roller frame, the frame farthest offshore should be disconnected and brought to the forward end of the roller train. This recycling helps to even out roller wear. (You must insure there are enough rollers beyond the end of the cradle to allow for maximum cradle submergence without overrunning the last roller.)

Roller should be checked for wear as follows:

➢ Are roller treads worn concave across their treads? Difference in roller diameter should not exceed 3/16".

Are roller treads worn excessively? Rollers can have a groove between the tread and flanges. When the tread has worn down to eliminate this groove, the roller should be replaced.

➤ Are roller treads broken? Note location of broken treads in roller train to assist in determining where the problem is.

➤ Are roller flanges worn or broken? Note location of broken flanges in roller train to assist in determining where the problem is.

➤ Are roller pintle worn? If the diameter of the bushing hole is more than ½" greater than the pintle diameter, the roller may become skewed on the rail which can accelerate wear and break roller flanges.

Bushings should be checked for wear as follows:

➤ Are bushings tight in roller frame angles?

BROKEN ROLLER FLANGES

➤ Are the bushing holes worn excessively? If the diameter of the bushing hole is more than ½" greater than the pintle diameter, the roller may become skewed on the rail which can accelerate wear and break roller flanges.

Roller frames should be checked for straightness, corrosion, and to insure they are properly connected.

13.2 e – Cradle Inspection

Look for corroded or rotted structural members, particularly at the waterline.

Look for cracked or buckled members particularly the cradle columns where they attach to the top and bottom of chords of the runners.

Check cradle shoe plate for wear and crowning in the same manner as the track rail plates.

Check the cradle bottom chord for rolled or bent flanges (steel cradle) or rail plate squeeze (timber cradle) in the same manner as the track beams.

Look for bent or sagging cradle deck beams.

CRACKED CRADLE COLUMN

Check cradle deck for broken or rotted planks and joists.
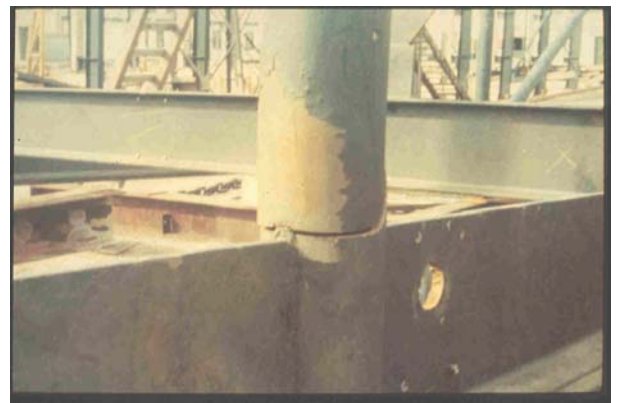
Look for bent, buckled, damaged or corroded upright beams and catwalk structure.

13.2f – Hauling Machine

The hauling machine consists of an electric motor with automatic brake, speed reducer, series of open gearing, chain wheel and chain.

The electric motor, brake, and speed reducer should be maintained per manufacturer's instructions.

Use Texaco Crator compound No. 2 on the open gears. Apply it hot so it flows into the gears.

Check the gears for wear and fit of the teeth. Too much slop increases tooth load and could cause tooth failure.

Check the bearings for overheating during the operation. Excessively worn or out of align bearings will heat up.

If the machine has a stop pawl, be sure the limit switch is working. The machine should not back down with the pawl engaged,

The brake should be adjusted to stop machine 2 to 3 seconds after power is cut.

13.2 g – Chain System

Refer to Figure 13.2-7 for chain system components.

TYPICAL TWO CHAIN REEVING DIAGRAM
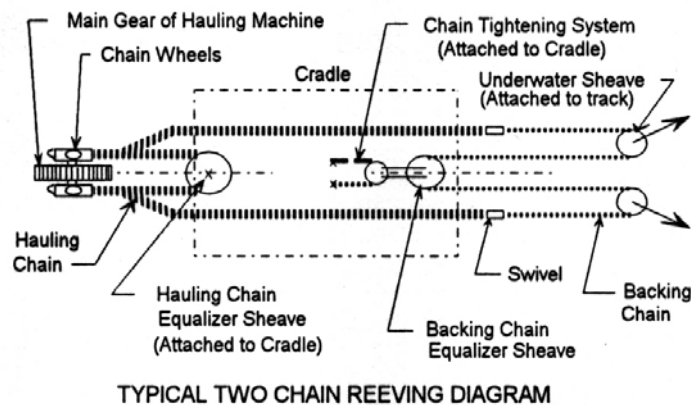
FIGURE 13.2-7

The fit of the chain over the chain wheel should be observed during an operation. As the chain and wheel wear, the chain becomes longer between links and the wheel's diameter becomes smaller, so the chain no longer fits properly on the wheel. See Figure 13.2-8.

Distance between chain links greater than 1/2 wheel diameter
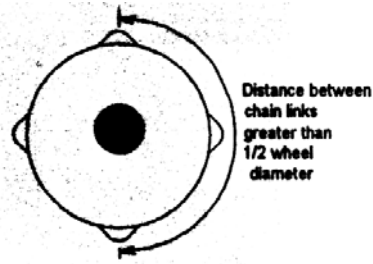
FIGURE 13.2-8

When this occurs, the chain may make a snapping noise as it passes over the wheel. This can be corrected by padding the chain wheel to increase its effective diameter. Careful measurements of the chain AND wheel are required!

The chain should be kept properly tensioned. It should come off the underside of the chainwheel fairly taught, without dragging in the first bay between the machine house and first crosstie. See figure 13.2-9.
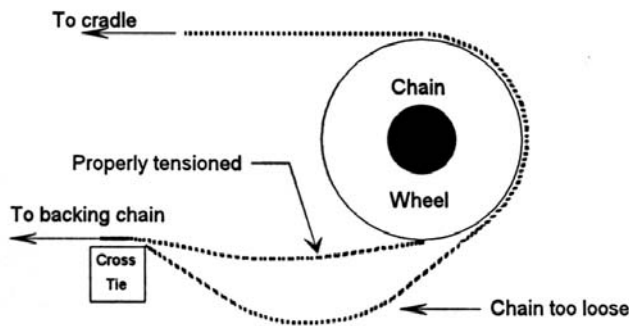
FIGURE 13.2-9

CHAIN TOO LOOSE

The hauling chain should not have any twist in it between the chain wheel and the point it is attached to the cradle (hauling connection).

Check the equalizer sheave, sheave case and pin for wear. Check the equalizer pin to be sure it is fully engaged and the retaining device is still working.

Check the underwater sheave, sheave case and pin for wear. Also examine the tie bars and connection to track.

The swivel and hauling shackle should be greased twice a year.

About every five years (more frequently for older docks), the hauling chain should be fully gaged and the capacity recalculated based on condition.
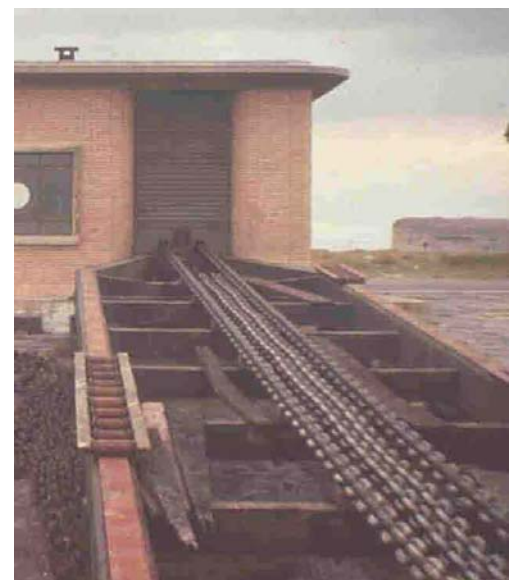
CHAIN PROPERLY TENSIONED

Measure the grips (double wire diameter) and link sides for wear. The capacity of the railway should be reduced to account for any loss of wire diameter of the hauling chain.

Measure the distance between 5 link lengths to determine chain stretch.

The backing chain should be inspected for wear and elongation due to overload.

13.3 – Basin Dock Inspections

Determine the type of basin dock. Different types require different analyses of results.

Inspection of a basin dock should include:

- ➤ General structural survey of the:
  - o Coping
  - o Sidewalls
  - o Galleries & alters
  - o Floors
  - o Drainage and filling tunnels
  - o Pump wells
  - o Entrance closure and seat
  - o Pumps, valves and sluice gates
  - o Capstans, winches, etc.

- ➤ Witness a dock operation in which all main mechanical equipment is run.

- ➤ Soundings around dock entrance.

Structural Inspection

General Concrete Deterioration

Most concrete structures contain steel reinforcement in the concrete.

To gain maximum strength from the concrete and steel combination, the steel is deliberately put as close to the surface of the concrete as possible.

Unfortunately, concrete is porous and will absorb water. In a marine environment, the salt water will be absorbed by the concrete. If it reaches the steel reinforcement, the steel will corrode. When steel corrodes, the volume of rust produced is about 8 times the volume of original steel. This expansion cracks the concrete cover and eventually "pops" it off, exposing the rebar.

CAUSE	SYMPTOMS
Poor construction	Cracks
Drying shrinkage	Cracks
Temperature Stresses	Cracks, Spalling
Absorption of moisture	Cracks
Chemical reactions	Cracks, Spalling Disintegration
Weathering	Spalling, Disint.
Erosion	Disintegration
Poor design	Cracks, Spalling Disintegration
Overload	Cracks, Spalling

CONCRETE FAILURE MODES

The first signs of deterioration occur as a series of parallel cracks running in the direction of the reinforcement. There may be some rust staining in the cracks. The concrete steel feels and sounds solid when struck with a hammer.

1ˢᵗ STAGE - GRACKS

In the second stage, a cleavage plane forms at the level of reinforcement and rust staining occurs along the cracks. The concrete will sound hollow when tapped with a hammer, and the cover can be easily hammered off.

2ⁿᵈ STAGE – CLEAVAGE PLANE

3rd STAGE – REBAR EXPOSED

In the last stages, the cover has spalled off exposing the rebar. The concrete should be sound below the level of the rebars.

Corrosion of the rebars is the most common causes of concrete deterioration although it is not the only cause.
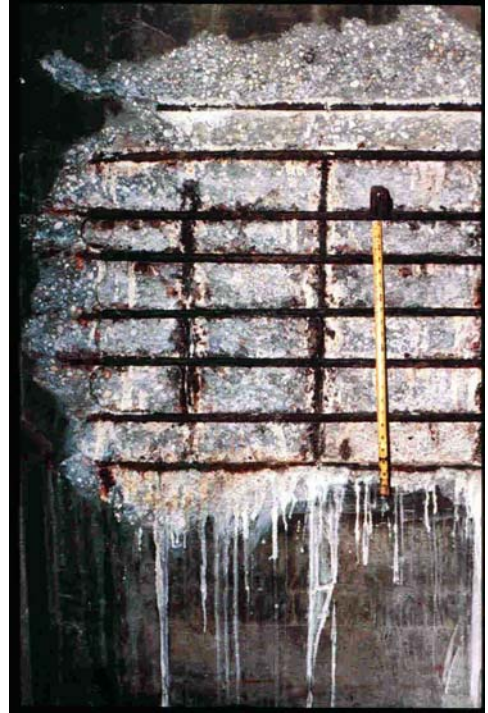
Coping

Check for cracks along entire length.

Note cracks that continue down side wall – an indication of settlement.

Note cracks caused by bulging of the wall – an indication of overload on wall.

Note rough edges at corner which may damage or snag lines.

Sidewalls

This is the area most subject to leakage.

Note all cracks, particularly those with leaks.

If prior records exist, try to determine if cracks are opening up and/or leakage is increasing.

Note amount of leakage and amount of sediment in leakage water.

  ➢ Sediment in leakage water could mean backfill behind wall is washing out.

Galleries and Alters

Same as for sidewalls.

<u>Floors</u>

Note all cracks, particularly those with leaks. Leakage could indicate under-drain system not working properly.

If prior records exist, try to determine if cracks are opening up and/or leakage is increasing.

Note amount of leakage and amount of sediment in leakage water.

> ➢ Sediment in leakage water could mean backfill under slab is washing out.

Note damage by dropped heavy weights.

Check slab settlement by survey.

Check relief pipes for clogs or excessive leakage.

Has the amount of water in the under drain system been increasing or decreasing? This could be an indication of a clog or failure of cut off wall. Check Records.

<u>Drainage Tunnels</u>

Inspect for leakage through expansion joints and cracks.

Note mud or sand accumulation.

<u>Pumpwell</u>

Inspect for leakage through expansion joints and cracks.

Inspect drainage and suction pits for mud or sand accumulation.

<u>Entrance Closure and Seat</u>

Inspect steel floating caissons in much the same way as steel floating docks.

Note leakage when gate is in place and dock is dewatered. Try to determine if leakage is due to damaged seat, damaged gasket, or other reason.

Check gasket when gate is removed or open. Is rubber hard, loose, or missing?

Check seat with gate closed or with caisson on the outer seat. Look for irregularities or damage that may cause leakage.

On hinged gates, check hinges for wear.

<u>13.3 b – Mechanical Systems</u>

The mechanical systems (pumps, valves, sluice gates, capstans, winches, etc.) are generally tested during the operational test of the dock.

All systems are run and if they operate satisfactorily, further investigation is not required.

Pumping, flooding times can be compared to original design values.

The sluice gates can be inspected from the filling tunnel. Note amount of leakage with gate closed. Note condition of guides.

13.3 c – Operational Test

During the inspection, the dock should be operated through one complete cycle. All equipment should be observed during operation.

13.3 d – Soundings

The depth of available water in front of the gate and in the approach channel should be measured.

13.4 – Block Inspection

There are three major categories to be concerned with when inspecting blocks:

- ➤ Condition of Materials

- ➤ Arrangement of blocks
  - o Aspect ratios met?
  - o Adequate cribbing?
  - o Line of force in the middle 1/3rd

- ➤ Block heights and offsets within tolerances

13.4 a – Condition of Materials

Timber

Check timber for excessive crushing, warping, cracking, checking, rot, or wear from dogging.

Check for loss of contact at edges.

In general, minor cracking is OK unless bearing area has been lost.

Timber should be sound – Check by hitting with hammer.

Concrete

Check concrete for cracking, spalling, exposed rebar, etc.

Some cracking and spalling is OK as long as it does not extend to bearing surface of timber.

Concrete should be sound – check by hitting with hammer.

Steel

Check steel for loss of metal thickness by corrosion, cracks, cracked welds, ect.

Fastenings

Check condition of fastenings.

Are timber blocks prevented from floating.

Hauling Block Hardware

Check condition of hauling block hardware.

➢ Corrosion of chains

➢ Do sheaves turn freely?

➢ Do cranks operate correctly?

13.4 b – Arrangement of Blocks

➢ Aspect ratios met? h/w < 2

➢ Adequate cribbing?

➢ Line of force in the middle 1/3rd

➢ Wood cushion between layers of steel and/or concrete?

➢ Soft caps OK?

➢ All keel blocks of the same design and materials to prevent "stiff" blocks from being overloaded?

➢ Side blocks less stiff than keel blocks? (by using more of softer wood)

13.4 c – Tolerances of Block Heights and Offsets

Usual tolerance for keel and side block builds are:

Height + ¼" each A, B, and C dimension

Longitudinal Position + 1"

Transverse Position + ½" (Half Breadth)

14.0 – DRY DOCK TRANSFER SYSTEMS

Utilizing a transfer system, a facility can add the capability of docking additional vessels at a much lower cost than adding additional dry docks.

In addition to being cheaper to build, transfer systems have many additional benefits including:

➢ Vessels can be blasted and painted on shore, away from the water, making it easier to contain environmentally sensitive materials.

➢ Only one dry dock needs to be maintained.

➢ Vessels are repaired at land level with no restrictive sidewalls; material handling around ship is easier.

➢ Repair berths do not occupy wet berth or pier space.

14.1 – Transfer Arrangement

Floating docks, marine railways, and vertical lifts can all utilize a transfer system. They can be designed for transfer at the time of initial construction or transfer can be added to an existing facility, many times relatively easily.

Most systems use one or more sets of fixed rails on shore, which align the rails on the dock.

Transfer off the dock can be done longitudinally or transversely. See figure 14.1-1.

There are many variations to these two basic transfer arrangements. The cheapest arrangement is to have one set of landside rails aligned with rails on the dock. The ship is pulled directly off the dock into its berth. If additional berths are required, the landside rails can be made longer and the first ship pulled farther on shore. See figure 14.1-2. The draw back to this arrangement is that the first ship is blocked by the second ship and cannot be undocked until the second ship is removed.

LONGITUDINAL TRANSFER

TRANSVERSE TRANSFER
FIGURE 14.1-1

To avoid trapping vessels in the inner berths, a cross transfer table can be added to the system. See figure 14.1-3 for longitudinal transfer with a cross transfer table. The ship is transferred off the dry dock onto the cross transfer table. With the ship on the table, the table is shifted laterally to align with any number or berths.
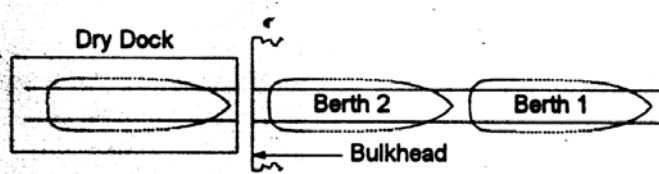
LONGITUDINAL TRANSFER
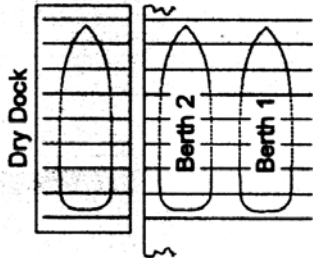
TRANSVERSE TRANSFER

MULTIPLE BERTHS
FIGURE 14.1-2
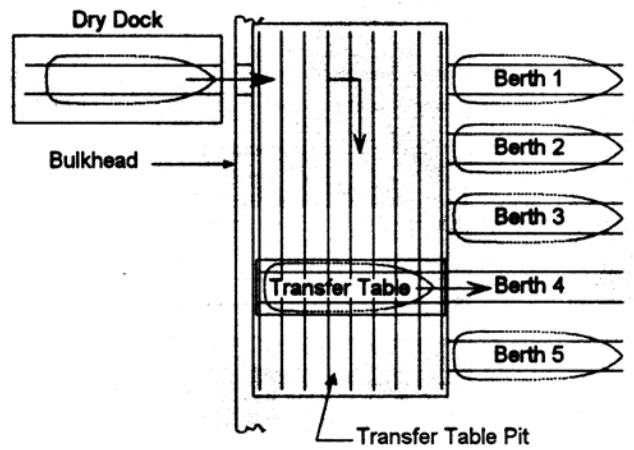
MULTIPLE BERTHS WITH TABLE
FIGURE 14.1-3

The cross transfer arrangement allows for very fast transfer of vessels to any number of berths. All ships are accessible for undocking at any time. The drawback however is cost. The cross transfer table is located in a pit and runs on rails. The rails usually required a pile foundation. The pit area must be kept clear for movement of the table. The result is a large costly area that cannot be used for any other purpose other than transfer.

14.2 – Vessel Transfer To And From Floating Docks

Most floating dry docks can be modified relatively inexpensively to allow longitudinal transfer to and from shore. A lip or shelf is usually provided at one end of the dock.

During transfer, the dock's lip rests on a shore side shelf. This keeps the top of rails on the dock aligned with the top of rails on shore. See figure 14.2-1.

The lip can be on the pontoon or extend off the end of the wings.
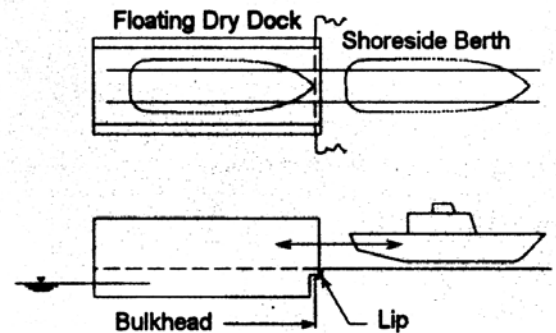
TRANSFER OFF OF FLOATING DOCK

FIGURE 14.2-1

During transfer, each compartment of the dry dock must be carefully ballasted to compensate for the vessel's weight moving off of, or on to, the dock. See figure 14.2-2. The rate of transfer must be carefully controlled so as not to exceed the rate that compensating ballast can be added or removed. Detailed pumping plans should be prepared in advance of the operation to assure proper water levels at all times.

To insure the dock remains level during the transfer it is advisable to monitor the dock's attitude with respect to the shore sideways. The easiest method for doing this uses a surveyor's level set up on shore with targets located on the dock's bow and stern. See Figure 14.2-3. With the dock level and at the correct draft, the targets read zero. As the vessel's weight is transferred, if the ballasting/deballasting is not correct, the dock will rise of fall to compensate. With proper monitoring, this movement can be seen and the ballasting corrected before overload to the dock, ship or transfer system occurs.

During transfer, the vessel's weight must be opposed by buoyancy from the pontoon directly under this weight. Also the rails on the pontoon must be kept level with the rails on shore. This is done by pumping the dock up to a freeboard that aligns the rails. Obviously, if the shore side rails are a large distance above the water elevation, the dock must be pumped to a very high freeboard just to align the rails. This can leave the dock with very little draft, thus the available buoyancy to support the vessel can be greatly reduced. Also, in areas with tidal variations it is a good idea to limit the transfer capacity to the available buoyancy of the dock at low tide. In this way, the dock can support the vessel through a complete tide cycle should the vessel get stuck half on the dock and half on shore.
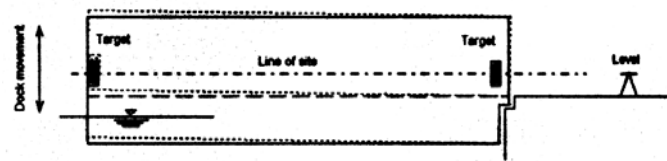
Taking the above considerations into account, floating docks usually have a transfer capacity that is somewhat less than their "normal" lift capacity.

One major benefit of using the floating dock for transfer, is the expensive cross transfer table and pit is not required. The dry dock itself can act as a table, aligning with any number of shore side berths. See figure 14.2-4.
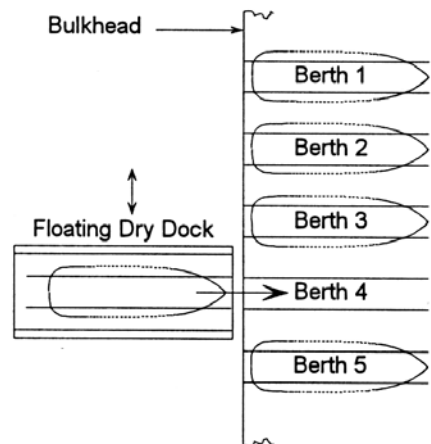
Some floating docks have been designed for side transfer. This obviously requires one side of the wing walls to be removable. Usually this wing is constructed in short segments that can be lifted on and off by crane. See figure 14.2-5.

Side transfer on a floating dock is generally more expensive to construct initially and more labor intensive to use since it involves removing a wing wall for transfer and replacing for launch.

TRANSFER ON OR OFF FLOATING DOCK

FIGURE 14.2-2

FIGURE 14.2-3

FIGURE 14.2-4

As with longitudinal transfer, the floating dock must be carefully deballasted to compensate for the vessel's weight being added or removed. This usually requires the dock to have four or more transverse watertight compartments.

SIDE TRANSFER OFF/ON TO FLOATING DOCK
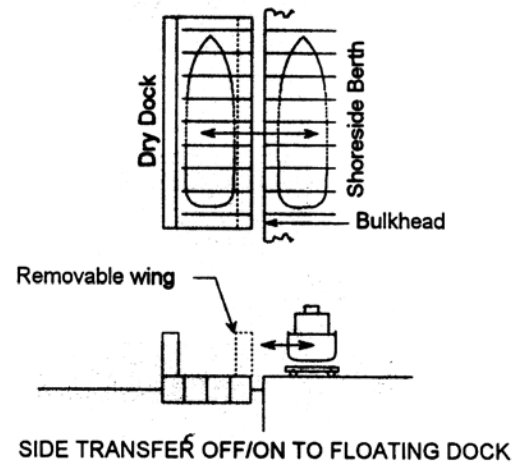
FIGURE 14.2-5

14.3 – Vessel Transfer To and From Marine Railways and Vertical Lifts

Vessel transfer to and from marine railways and vertical lifts is also feasible.

Both these types of lifts are founded on solid ground, so there is no need for ballasting or deballasting as the vessel is shifted. This makes operation of transferring vessel onto or off of a marine railway or vertical lift much simpler. With the lift in its full up position, the rails on the dock and shore are aligned. Usually a short piece of rail is placed in the gap between the shore and dock. The vessel then can be pulled on or off the dock.

Either longitudinal or transverse transfer is possible. With a marine railway, the machine house is generally located in front of the cradle and may make longitudinal transfer impossible.

In a new design, the machine house can be placed off to the side or kept low enough for the vessel to pass over it. For side transfer, a marine railway needs support on one side of the cradle beams to prevent the whole cradle from tipping over when the vessel's weight is shifted to that side. See figure 14.3-1.
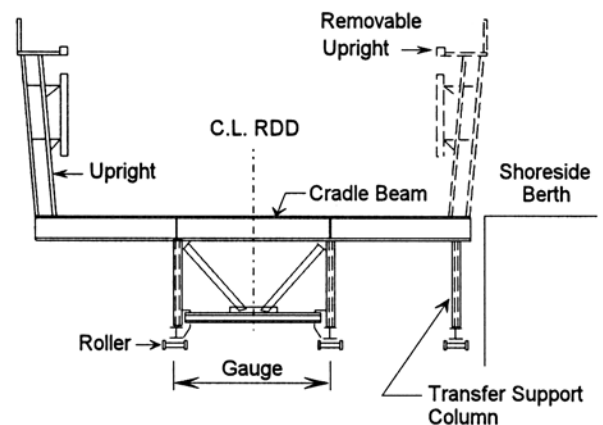
FIGURE 14.3-1

The cradle uprights on the side of transfer must be removable and are generally built in short sections capable of being lifted by crane.

With a vertical lift, it is usually easier to transfer the ship longitudinally. The lifting platform is open at the ends and can be positioned near the shore side bulkhead. Side transfer from a vertical lift is feasible but the platform lifting winches must be kept low enough for the vessel to pass over them.

14.4 – Transfer Cars

The transfer car is placed on the dry dock before docking the vessel. The ship is docked directly on the transfer car and once the dock is fully up, the car can be pulled into the transfer berth. Usually the car is not one big car that is sized for the biggest vessel to be transferred. It should consist of small units that can be added together to make larger cars as required by the vessel being transferred.

These are many types of cars including.

> ➢ Wheeled cars

> ➢ Beams on rollers

> ➢ Beams on greased ways

> ➢ Air pallets

> ➢ Water pallets

> ➢ Walking beams

14.5 – Propulsion Methods

Once the dock is in position, the transfer car must be pulled off of or onto the dock. The most common methods of pulling the car are:

> ➢ Wire rope winch

> ➢ Hydraulic pistons

> ➢ Tractors/bulldozers

> ➢ Individual powered bogeys.

TRANSFER OF JEAN ANNE

DOCKMASTER'S TRAINING SEMINAR

SOLVED PROBLEMS

TABLE OF CONTENTS

Page

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

1) Docking a Patrol Boat on a Marine Travel Lift

EXAMPLE PROBLEM 1 – DOCKING A VESSEL ON A MARINE TRAVEL LIFT

A marine travel lift is a vertical lift on wheels. Instead of a structurally rigid platform to support the vessel, nylon strap slings are usually used. The slings are lowered into the water until sufficient water depth over the slings is achieved. The ship is floated over the slings and centered. The slings are raised, lifting the vessel. After lifting the ship, the travel lift can be "driven" around the yard to deposit it onto storage blocks.

The travel lift consists of:

> Structural frame on wheels
>
> Wire rope hoists
>
> Adjustable slings
>
> Support pier

Vessel Clearance

Obviously, the vessel must fit within the lift's structure. The vessel beam must be less than the clear distance between the support piers on which the lift travels out over the water. The vessel's masts, and superstructure must clear the structural frame's cross strut both on entering the lift and during lifting.

A check of the overall dimensions of the vessel will confirm whether or not the vessel can properly fit in the lift. Sometimes, repositioning the vessel can avoid interferences with superstructure or masts.

Sling Loads

The travel lift will have a rated sling load for each sling that must not be exceeded. In addition, it is recommended that all slings have approximately the same load on each of them (within $\pm$ 25%)

For example, if a lift has two slings rated at 80 tons each, it is better to lift a 100 ton vessel with 50 tons on each sling than with one sling taking 70 tons and one sling taking 30 tons.

Ship loads can be adjusted by repositioning them relative to the vessel's longitudinal center of gravity (LCG). Moving a sling closer to the LCG increases its load, moving a sling away from the LCG reduces its load.

The following example shows how to do this with a two sling lift:

Example – Two Sling Lift

A 100-ton vessel is to be docked on a 150-ton capacity travel lift. Position the slings to balance the load within $\pm$ 25%.

To balance the load, each sling should be the same distance from the vessel's longitudinal center of gravity (LCG), one forward and one aft.

See Section 3.5, "Longitudinal Center of Buoyancy" for a discussion on how to determine the location of the vessel's LCG.

The slings should be placed on strong points of the hull such as bulkheads or ribs if possible. The distance between slings should be at least 50% of the vessel length (LBP) if possible.

In this example the best location for the forward sling is 25 feet forward of the LCG and for the aft sling is 30 feet aft of the LCG. See Figure 1.
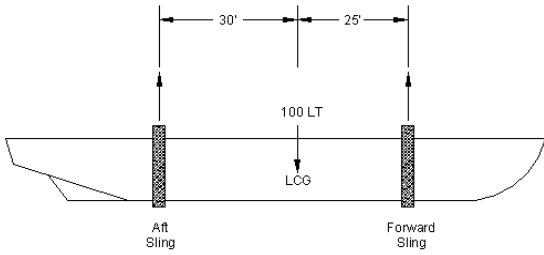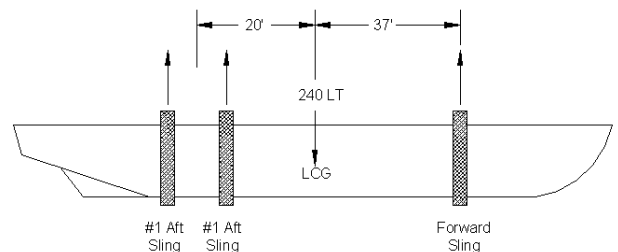
FIGURE 1

The load in the forward sling can be calculated by summing the moments about a point on the aft sling or:
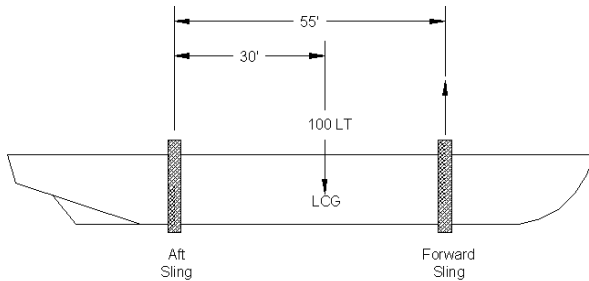
FIGURE 2

Moment down = 30' x 100 LT = 3,000'-LT
Moment up = 55' x Fwd. Load
Moment up must = moment down or:

3,000'-LT / 55' x Fwd. Load or

Fwd. Load = 3,000'-LT / 55' = 54.5 LT

The load in the aft sling can be calculated by summing the moments about a point on the forward sling (see Figure 3), or:

Moment down = 25' x 100 LT = 2500'-LT
Moment up = 55' x Aft load
Moment up must = Moment down or:

2,500'-LT = 55' x Aft load or

Aft load = 2,500'-LT / 55' = 45.5 LT
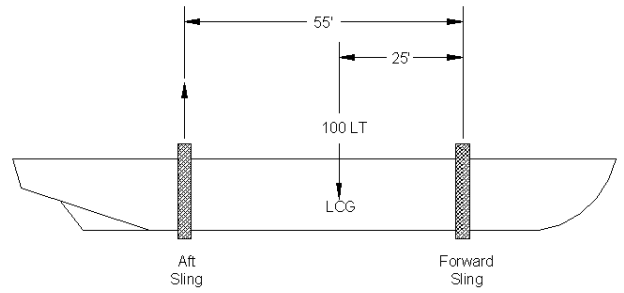
FIGURE 3

To check, add loads and verify they equal the vessel weight of 100 LT.

54.5 + 45.5 = 100 LT ➔ OK

Both slings within 25% of each other. ➔ OK

Example – Three Sling Lift

Some travel lifts have a set of three slings with the aft two slings equalized to insure they each take the same amount of load. In this case you still want each of the three slings to have about the same load. Because the aft two slings are equalized, you can assume they act as a single sling at their mid point. The problem then is similar to the above 2-sling example. The only difference is the aft double sling should take twice the load of the single forward sling. To do this, the center of the aft double sling should be about ½ the distance from the vessel's LCG as the forward single sling.

Figure 4 shows the example for a 3-sling lift. A 240-ton vessel on a 300-ton capacity travel lift (100 tons per sling).

FIGURE 4

The load in the forward sling can be calculated by summing the moments about the center of the aft double sling or:
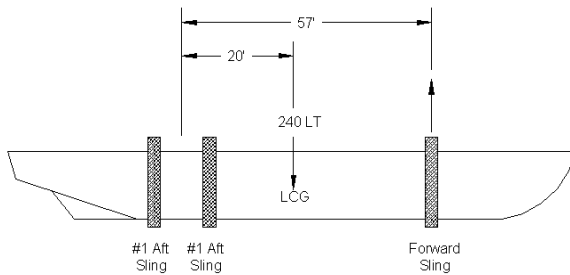
FIGURE 5

Moment down = 20' x 240 LT = 4,800'-LT
Moment up = 57' x Fwd. Load
Moment up must = moment down or:

4,800'-LT = 57' x Fwd. Load or

Fwd. Load = 4,800'-LT / 57' = 84.2 LT

The load in the double aft sling can be calculated by summing the moments about the point on the forward sling (see figure 6):

Moment down = 37' x 240 LT = 8,880'-LT
Moment up = 57' x Aft load
Moment up must = moment down or:

8,880'-LT = 57' x Aft load or

Aft load = 8,880'-LT / 57' = 155.8 LT

This load is divided equally between the two aft slings or:

155.8 / 2 = 77.9 LT ea.
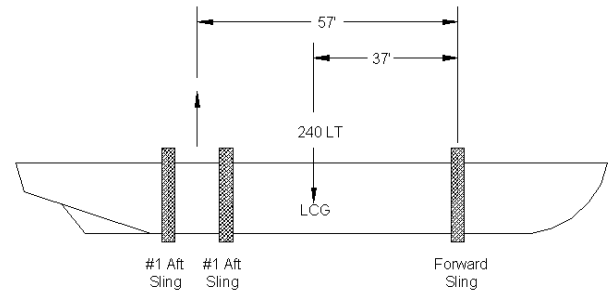
FIGURE 6

To check, add loads and verify they equal vessel weight of 240 LT.

84.2 + 77.9 + 77.9 = 240 LT ➔ OK

All slings within 25% of each other. ➔

Sling Angle

The travel lift should have a rated capacity for each sling. If the vessel is narrow and must be raised fairly high, the sling will not hang down nearly vertical but tend to pull the travel lift legs horizontally. See Figure 7. The legs are not as strong in this direction so the allowable sling load must be reduced if the angle of the sling to the leg (called sling angle) is in excess of 15 degrees.
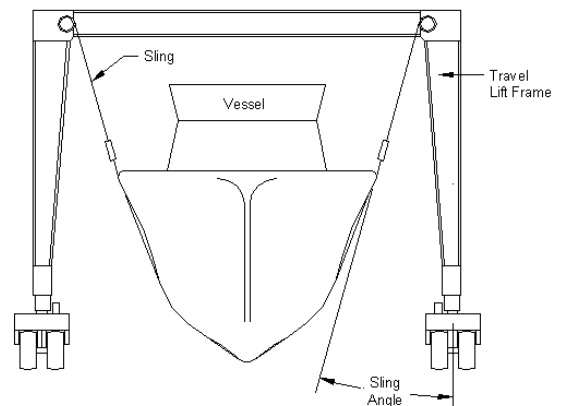
FIGURE 7

The travel lift should have a graph, which gives the allowable sling load for any sling angle.

Figure 8 shows a sample Load vs. Sling Angle graph.

SLING ANGLE VS. ALLOWABLE LOAD
(Example Only)
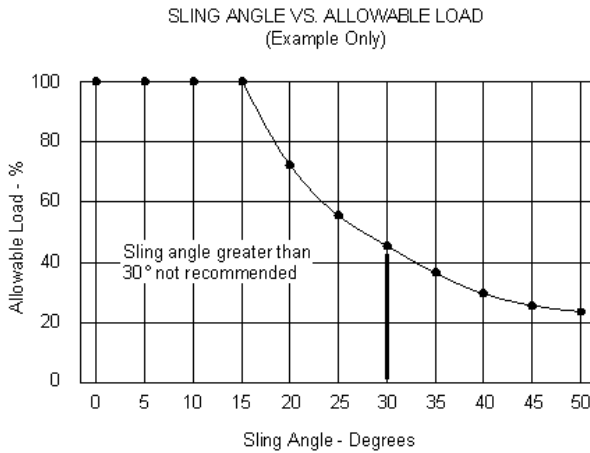
FIGURE 8

Vessel Strength Check

The slings should be positioned so as not to overstress the vessel either locally at the sling contact points or longitudinally, due to excessive overhang.

If possible, position slings at bulkheads or strong ribs in the vessel hull. A good spread between slings is required to prevent large overhangs to the bow or stern.

A detailed investigation of vessel strength is beyond the scope of this paper.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

2) Elastic Deflection of Blocks

EXAMPLE PROBLEM 2 – ELASTIC DEFLECTION OF BLOCKS

Any block under load will deflect (squeeze) some amount. The amount of squeeze depends on the pressure on the block and the block's modulus of elasticity (which is the block's degree of stiffness or "squeezability"). Thus two blocks built of the same materials (having the same modulus of elasticity) will compress the same amount under the same load. Two blocks built of different materials will compress varying amount under the same load or, alternatively, it will take a greater load to compress the stiffer block the same amount as the less stiff block.

To calculate the total deflection of the block, each level of differing material in the block must be considered. The squeeze of each level of different material is calculated. The total deflection of the block is the sum of each level's deflection.

The deflection of any level is equal to:

Load per sq. in. x thickness of material (In.)
Modulus of Elasticity

Modulus of Elasticity (E) is different for different materials. Some typical values are as follows:

Fir (side grain)	15,000 psi
Fir (end grain)	1,200,000 psi
Oak (side grain)	32,000 psi
Concrete	3,000,000 psi
Steel	29,000,000 psi

As you can see from the table, the modulus for timber varies depending on how the wood is loaded. Most blocks use timber on side grain compression (the wood is loaded on its side, perpendicular to the grain). Occasionally, wood is used on end (as in a column). In this case, the timber is much stiffer and a higher modulus of elasticity is used.

The modulus of elasticity for various types of wood in both side grain and end grain compression can be found in any timber manual.

The following example shows how to calculate the total deflection of two different types of keel blocks under the same load.

Example

Figure 1 shows two different types of keel blocks, each loaded to 200 long tons.
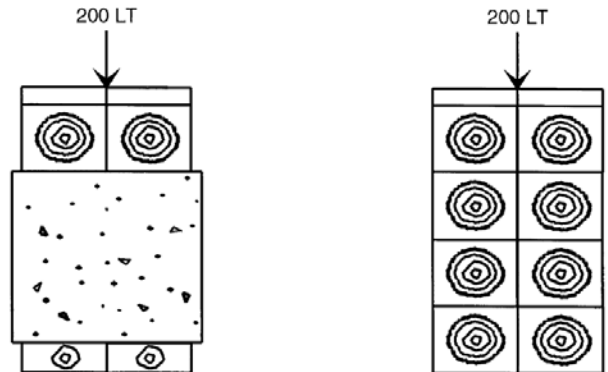
FIGURE 1

First we will calculate the deflection of the concrete base block. Figure 2 shows that block broken down into its various levels.
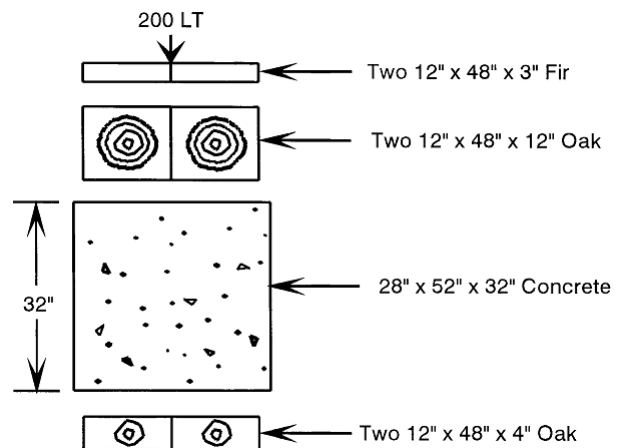
FIGURE 2

Convert long tons to pounds

200 LT x 2,240 lbs/LT = 448,000 lbs

Calculate deflection

$$\frac{\text{Load per sq. in. x thickness}}{\text{Modulus of Elasticity}} = \text{Deflection}$$

3" Fir

$$\frac{448,000/(2 \times 12" \times 48") \times 3"}{15,000} = .078"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

32" Concrete

$$\frac{448,000/(28" \times 48") \times 32"}{3,000,000} = .003"$$

4" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 4"}{32,000} = .049"$$

Total deflection of block is:

0.078" + 0.146" + 0.003" + 0.049" = 0.276"

Next we will calculate the deflection of the all timber keel block. Figure 3 shows that block broken down into its various levels.
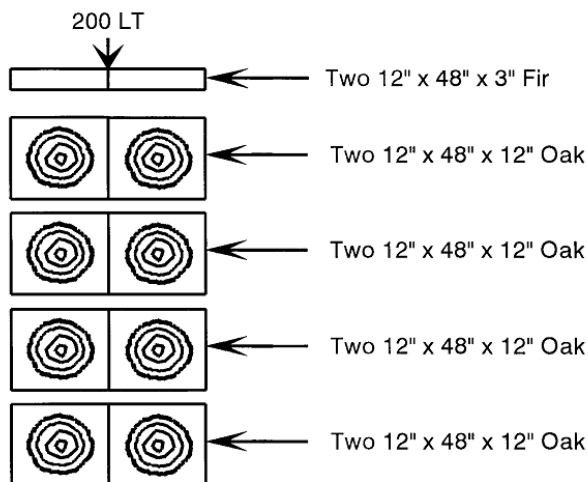
FIGURE 3
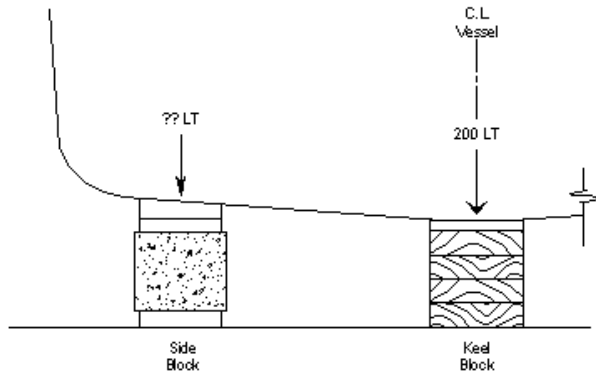
Calculate Deflection

3" Fir

$$\frac{448,000/(2 \times 12" \times 48") \times 3"}{15,000} = .078"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

Total deflection of block is:

0.078" + 0.146" + 0.146" + 0.146" + 0.146"

= 0.662"

It can be seen that the concrete base block, which is much stiffer, will squeeze much less than the all timber block under the same load.

Alternatively, it will take a much greater load to compress the concrete block to the level of the timber one.

If one concrete base block had been placed in a keel track with all timber blocks, the one concrete base block will take a much higher load than the surrounding timber ones. This is because all the blocks must deflect the same amount (approximately) due to the stiffness and straightness of the ship's keel.

In the above example, to get the concrete base block to squeeze the same amount as the timber, additional load must be put on that block.

The amount of that load is the ratio of the required deflection (0.662") to the calculated deflection (0.276") times the load to cause the calculated deflection (200 LT).

Load to cause 0.662" deflection =

(0.662"/0.276") x 200 = 480 LT

Thus, in this example, if one concrete base block is placed in among all timber blocks, it will take 2.4 times (480/200) more load than the all timber blocks surrounding it. This could possibly be overloading the dock structure.

From this example it can be seen that the keel track should always be constructed using similar type of blocks.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

3) Calculating Side Block Loads

EXAMPLE PROBLEM 3 – CALCULATING SIDE BLOCK LOAD

Example Problem 2 shows that any block under load will deflect (squeeze) some amount. The amount of squeeze depends on the pressure on the block and the block's modulus of elasticity (which is the block's degree of stiffness of "squeezability"). Thus two blocks built of the same materials (having the same modulus of elasticity) will compress the same amount under the same load. Two blocks built of different materials will compress varying amount under the same load or, alternatively, it will take a greater load to compress the stiffer block the same amount as the less stiff block.

Ideally, side blocks should be built so that they are less stiff than the keel blocks. Due to the stiffness of the vessel in the transverse direction, the side blocks will compress approximately the same amount as the keel blocks in the same location. (Refer to Figure 1.)
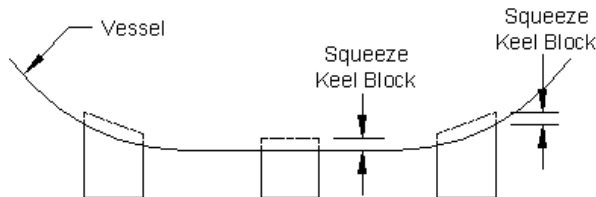
FIGURE 1

From the above rule, it can be seen that if the side blocks are built much stiffer than the keel blocks, it will require a much greater load on the side blocks to cause the same amount of compression. On the other hand, if the keel blocks are built stiffer than the side blocks, they will take a greater load. Since the keel of the vessel is usually much stronger than its sides (where the side blocks are located) this is the condition we want to induce. See Figure 2.
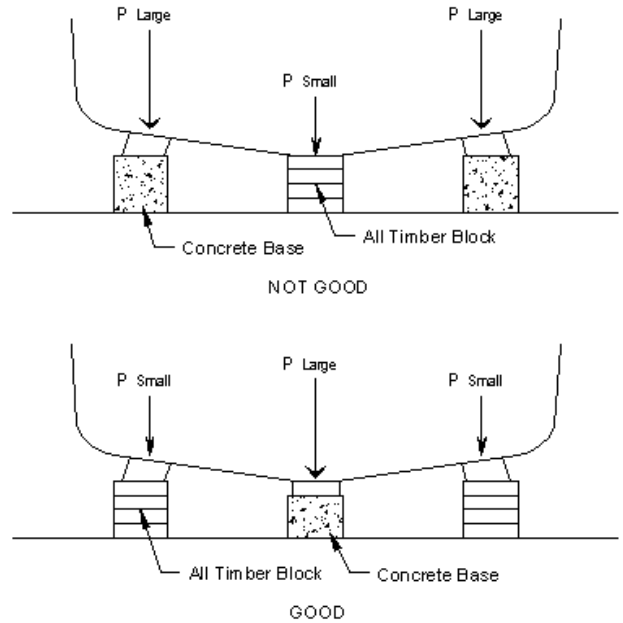
FIGURE 2

Example 2 calculated the amount a concrete/timber composite keel block and an all timber keel block will compress under a 200 long ton load.

The composite block compressed 0.276" and the all timber block compressed 0.662".

If side blocks are positioned either side of the keel, they must also compress the same amount as the keel blocks. Using the methods learned in the last issue, we can calculated the amount of load needed on the side block to cause the same amount of deflection.

The following example shows this method:

Example 1

A vessel is to be docked on an all timber keel track but use concrete/timber composite side blocks. The vessel loading imparts 200 long tons to each keel block. Check the loading on the blocks.

Figure 3 shows the blocks.

FIGURE 3

FIGURE 4

First calculate the deflection of the all timber keel block. Figure 4 shows that block broken down into its various levels.

Refer to Example 2 for the method used in calculating deflection.

To calculate the total deflection of the block, each level of differing material in the block must be considered. The squeeze of each level of different material is calculated. The total deflection of the block is the sum of each level's deflection.

The deflection of any level is equal to:

$$\frac{\text{Load per sq. in. x thickness of material (In.)}}{\text{Modulus of Elasticity}}$$

Modulus of Elasticity (E) is different for different materials. Some typical values are as follows:

Fir (side grain)	15,000 psi
Fir (end grain)	1,200,000 psi
Oak (side grain)	32,000 psi
Concrete	3,000,000 psi
Steel	29,000,000 psi

Convert long tons to pounds and calculate deflection:

200 LT x 2,240 lbs/LT = 448,000 lbs

3" Fir

$$\frac{448,000/(2 \times 12" \times 48") \times 3"}{15,000} = .078"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

Total deflection of block is:

0.078" + 0.146" + 0.146" + 0.146" + 0.146"

= 0.662"

Because the vessel is a rigid body, the side block must also deflect the same amount as the keel, or 0.662" in this case. See Figure 1.

At this point we have no idea what load will cause this deflection. We can apply any arbitrary load to the block and see what deflection results. The arbitrary load can be adjusted up or down to obtain the actual deflection desired.

For this example we will apply 100 long tons to the side block.

The deflection of the side block is calculated in the same way, breaking the block into levels and analyzing each level. See Figure 5.
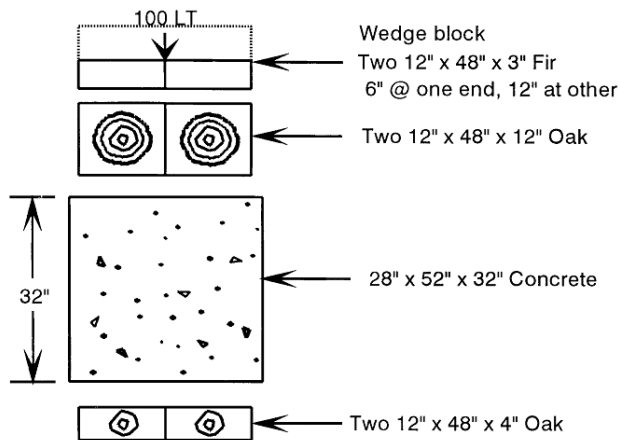
FIGURE 5

Convert long tons to pounds

100 LT x 2,240 lbs/LT = 224,000 lbs

Wedge Cap

One end is 6" thick, the other is 12". Use 6" for calculation.

$$\frac{224,000/(2 \times 12" \times 48") \times 6"}{15,000}$$
= .078"

12" Oak

$$\frac{224,000/(2 \times 12" \times 48") \times 12"}{32,000} = .073"$$

32" Concrete

$$\frac{224,000/(28" \times 52") \times 12"}{32,000} = .0016"$$

4" Oak

$$\frac{224,000/(2 \times 12" \times 48") \times 12"}{32,000} = .024"$$

Total deflection of block is:

0.078" + 0.073" + 0.0016" + 0.024" = 0.177"

This, of course, is not equal to the desired deflection of 0.662. A greater load must be applied to get a greater deflection. The actual load required is equal to the ratio of the desired deflection to the deflection obtained using the arbitrary load, times the arbitrary load or:

(0.662 / 0.177) x 100 LT = 374 long tons

This loading produces a stress of

(374 LT x 2,240 lbs/LT) / (2 x 12" x 48")
= 727 psi

on the timber. This is too high. To reduce the load on the side blocks, either stiffer keel blocks must be used or less stiff side blocks, try using stiffer keel blocks. Try concrete/timber composite bases for both keel and side blocks as shown in Figure 6.
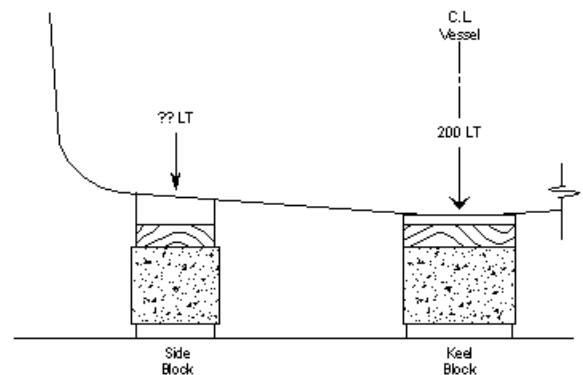
FIGURE 6

Calculate compression of concrete/timber keel block. The block layers are shown in Figure 7.
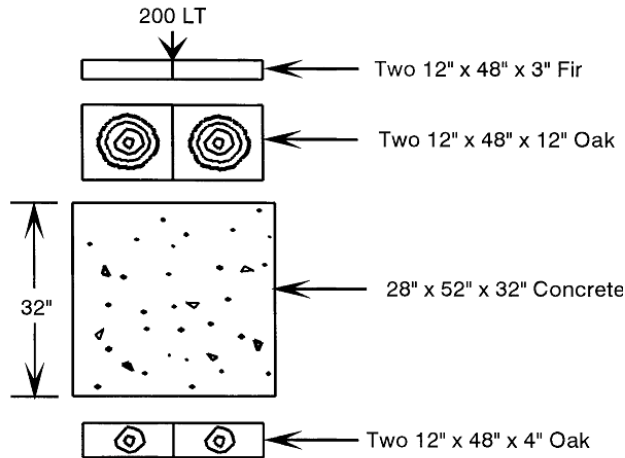
FIGURE 7

Convert long tons to pounds

200 LT x 2,240 lbs/LT = 448,000 lbs

Calculate Deflection

3" Fir

$$\frac{448,000/(2 \times 12" \times 48") \times 3"}{15,000} = .078"$$

12" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 12"}{32,000} = .146"$$

32" Concrete

$$\frac{448,000/(28" \times 48") \times 32"}{3,000,000} = .003"$$

4" Oak

$$\frac{448,000/(2 \times 12" \times 48") \times 4"}{32,000} = .049"$$

Total deflection of block is:

0.078" + 0.146" + 0.003" + 0.049" = 0.276"

The side blocks must compress this much. We have already calculated the compression of the side block under an arbitrary load of 100 LT. See page 3.

To get the load required to compress the side block 0.276" we multiply the ratio of the desired deflection to the deflection obtained using the arbitrary load, times the arbitrary load or:

(0.276 / 0.177) x 100 LT = 156 long tons

This loading produces a stress of

(156 LT x 2,240 lbs/LT) / (2 x 12" x 48")
= 303 psi

on the timber. This is acceptable. Use concrete/timber composite base blocks for both keel and side blocks.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

4) Reduction of High Intensity Load by Adding Ballast

EXAMPLE PROBLEM 4 – ADDITION OF BALLAST TO REDUCE HIGH INTENSITY LOAD

Adding ballast to reduce keel block loads may not seem to make sense at first. But, if the vessel is thought of as being balanced at the center of the keel blocks, similar to a "see-saw", the loading distribution becomes clearer. The vessel's longitudinal center of gravity (center of its weight referred to as LCG) will usually fall to one side or the other of the center of keel blocks. This causes the vessel to try and tip towards the heavy end (like a see-saw with more load on one side). The vessel does not actually tip of course, but this does impose a greater load on this end of the keel line. See Figure 1.
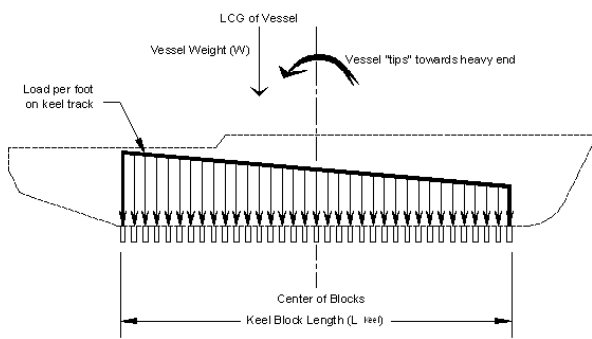
FIGURE 1
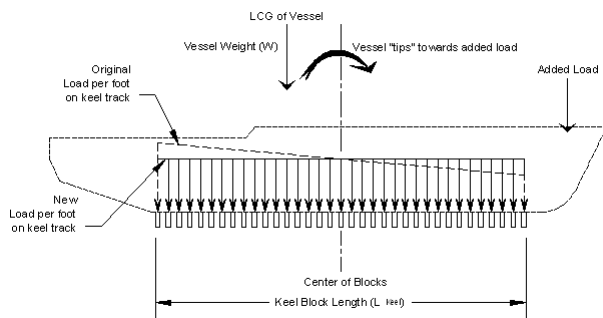
FIGURE 2

Adding ballast to the vessel at the "light" end will cause the vessel to try and tip back towards this end. This tends to increase the load per foot at the lighter end and decrease the load at the heavier end. See Figure 2.

Sometimes, the load per foot at the heavy end can exceed the rated capacity of the dock. Adding ballast to the vessel at the opposite end can, in some cases, reduce this high intensity load to within acceptable limits.

This is shown with the following example.

Example

A 4,000 long ton vessel is being docked on a floating dry dock with a rated capacity of 5,000 long tons and 15 long tons per foot. The vessel has the following docking characteristics:

Docking weight = ... 4,000 LT
LCG (fwd of ship) =............................ 162 Ft.
Last K. block (fwd of SRP) =............... 22 Ft.
First K. block (fwd of SRP) =............... 322 Ft.

All keel blocks spaced at 6'.

First, the load per foot on the keel line must be calculated. Because this is a typical docking with keel blocks spaced evenly, a trapezoidal load distribution can be assumed.

Refer to Section 4 "Block Loading" for a discussion on trapezoidal load distribution.

The load per foot at each end of the keel line can be calculated with the trapezoidal loading equation, which is:

$$W/L_{keel} + 6 \times W \times e/(L_{keel})^2$$

For the heavy end and

$$W/L_{keel} - 6 \times W \times e/(L_{keel})^2$$

For the light end, where,

W = Ship weight in long tons
L_{keel} = Keel bearing length in feet
e = eccentricity (difference from C.L. keel bearing to vessel LCG

See Figure 3
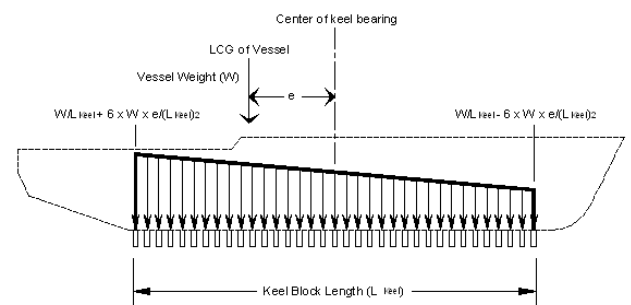
FIGURE 3

For the example:

W = ... 4000 LT
L_{keel} = 322' - 22' = ... 300 Ft.
e = 172' − 162' = ... 10 Ft. (Aft)

See Figure 4
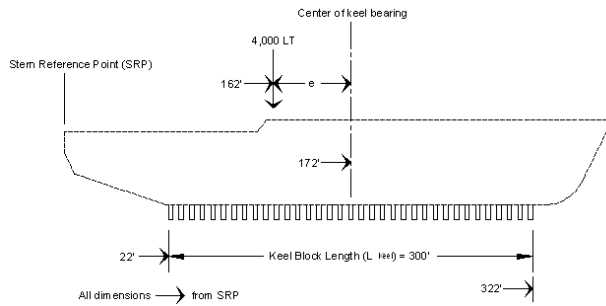
FIGURE 4

The loading aft for the example is:

4,000 LT/300' + 6 x 4,000 LT x 10' / $300'^2$
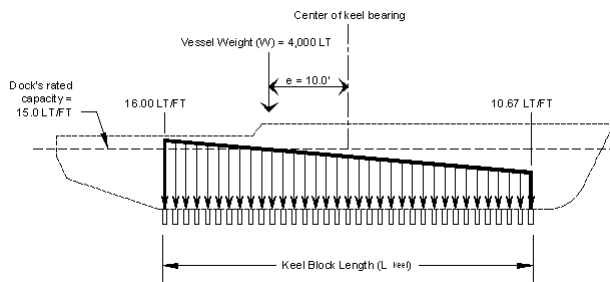= 13.33 + 2.66 = 16.0 LT/Ft.

See Figure 5.

FIGURE 5

As can be seen in Figure 5, the dock's rated capacity is exceeded at the aft end.

Try reducing the per foot load aft by adding ballast forward. The vessel has a forward peak tank that holds 150 long tons of ballast. Try filling this tank first.

Center of peak tank is located 355' forward of SRP. Filling this tank will shift the vessel's LCG forward, reducing the eccentricity (e).

To find the shift of the LCG as referenced to the SRP, sum moments about the SRP and divide by the total weight.

See Figure 6.
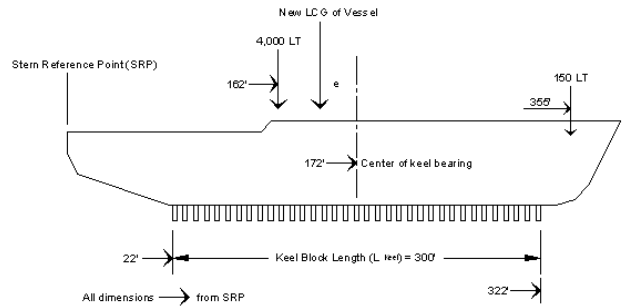
FIGURE 6

Moment is force (weight) x distance so:

M_1 = 4,000 LT x 162' =............. 648,000 Ft.-LT
M_2 = 150 LT x 355' =............... 53,250 Ft.-LT

Sum of Moments = ... 701,250 Ft.-LT

Total weight = 4,000 LT + 150 LT = 4,150 LT

New LCG = 701,250 Ft.-LT / 4,150 LT
= 168.98 Ft. fwd. Of SRP

A new eccentricity (e) can now be calculated.

e = 172' − 168.98' = 3.02 Ft.

The trapezoidal load can be recalculated using the new values for eccentricity (e) and ship weight (W).

W = ... 4150 LT
L_{keel} = 322' - 22' = ... 300 Ft.
e = 172' − 162' = ... 3.02 Ft. (Aft)

The loading aft for the example is:

4,150 LT / 300' + 6 x 4,150 LT x 3.02' / $300'^2$
= 13.38 + 0.84 = 14.67 LT/Ft.

The loading forward for the example is:

4,150 LT / 300' - 6 x 4,150 LT x 3.02' / 300'^{2}
= 13.38 - 0.84 = 12.99 LT/Ft.

See Figure 7.
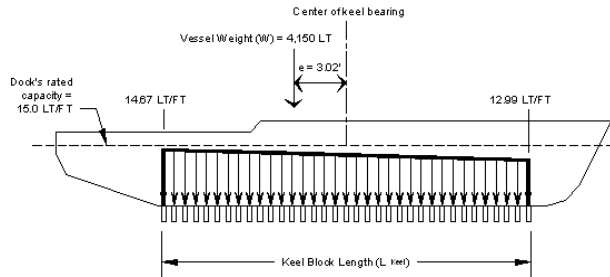
FIGURE 7

Both ends of the trapezoidal are now below the dock's rated capacity and the vessel can be docked.

Adding ballast to reduce high intensity loads at one end will only work if the dock's rated load per foot capacity is exceeded by a relatively short distance. This distance will vary depending on how close the average load per foot is to the dock's rated load. If the average load per foot, (W/L_{keel}), exceeds the docks' rated load per foot then this method will never work.

DRY DOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC DATA

5) Reduction of High Intensity Loads by Support Beyond the Knuckle

Section 4.5, "Trapezoidal Loading Equation" discusses how to calculate loading along the keel using the trapezoidal loading distribution equation. This equation tells us the maximum and minimum load at each end of the keel line. The loading along the keel line is assumed a straight line between these two end values.

The load per foot at each end of the keel line can be calculated with the trapezoidal loading equation, which is:

W = Ship weight in long tons
L_{keel} = Keel bearing length in feet
e = eccentricity (difference from C.L. keel bearing to vessel LCG

See Figure 1
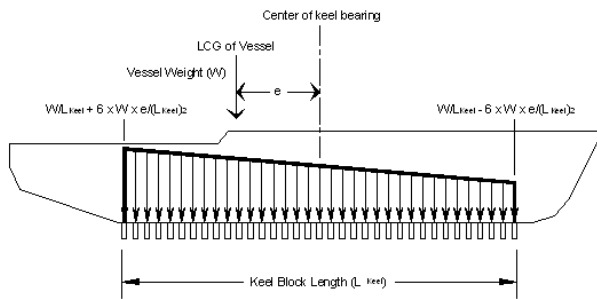
FIGURE 1

If the maximum load per foot given by the equation exceeds the rated load per foot capacity of the dry dock then the vessel should not be docked.

The maximum load per foot can be reduced however by extending the length of the keel line. If, for example, blocks are added at the heavy end of the vessel, the center of blocking shifts towards that end and the keel line gets

longer. See Figure 2. This reduces the eccentricity (e) and increases the keel bearing length (L_{keel}). When these new values are entered into the trapezoidal loading equation the maximum load per foot is reduced.
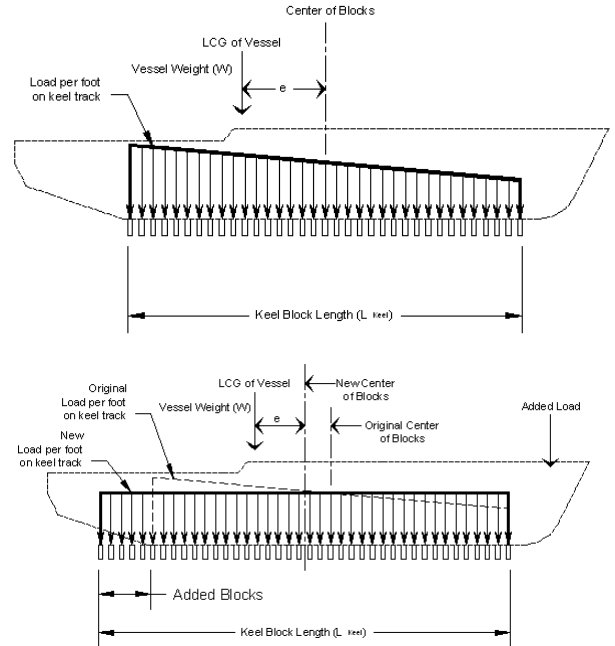
FIGURE 2

Example

A 5,000 long ton vessel is to be docked on a floating dry dock with a rated capacity of 5,500 long tons and 16 long tons per foot. The vessel has the following characteristics:

Docking weight = ... 5,000 LT
LCG (Fwd of SRP) = ... 175 Ft.
Last K.B. (fwd of SRP) = ... 35 Ft.
First K.B. (Fwd of SRP) = ... 335 Ft.

All keel blocks spaced at 6'.

First, the load per foot on the keel line must be calculated. Because this is a typical docking with keel blocks spaced evenly, a trapezoidal load distribution can be assumed.

For the example:

W = ... 5,000 LT
L_{keel} = 335' − 35' = ... 300 Ft.
Center of Blocks = 35+300/2 = 185 Ft. from SRP
e = 185' − 175' = ... 10 Ft. (Aft)

See Figure 3.

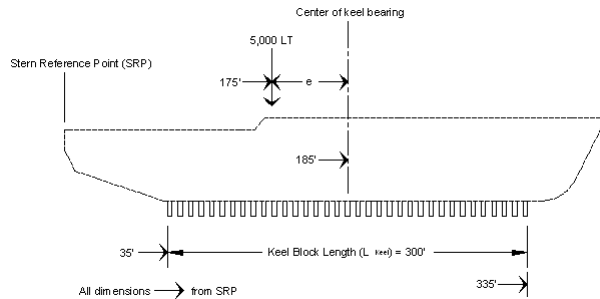

FIGURE 3

The loading aft for the example is:

5,000 LT / 300' + 6 x 5,000 LT x 10' / 300'^{2}
= 16.67 + 3.33 = 20.00 LT/Ft.

The loading fwd for the example is

5,000 LT / 300' - 6 x 5,000 LT x 10' / 300'^{2}
= 16.67 - 3.33 = 13.34 LT/Ft.

See Figure 4
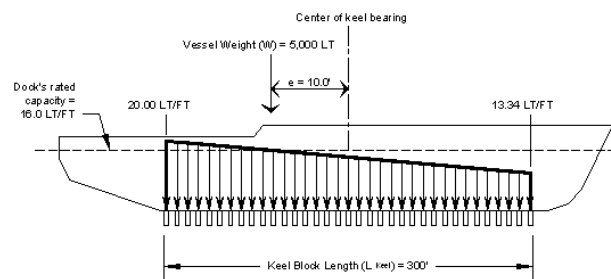
FIGURE 4

As can be seen in Figure 4, the dock's rated capacity is exceeded at the aft end.

Try reducing the per foot load aft by adding keel blocks aft. The flat keel ends so any added blocks will have to be shaped to the vessel's fantail slope.

Try adding 20 feet of blocking to the aft end.

This shifts the center of blocking 10 feet towards the aft end and places the center of blocking directly under the vessel's LCG (15' + 320'/2 = 175').

The new keel bearing length is 300' + 20' = 320'.
Refer to Figure 5.
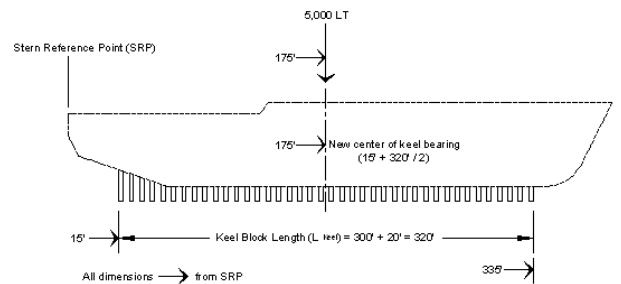
FIGURE 5

A new eccentricity (e) can now be calculated.

e = 175' −175' = 0.00 Ft.

The trapezoidal load can be recalculated using the new values for eccentricity (e) and keel bearing length (L_{keel}).

W = ... 5,000 LT
L_{keel} = 300' + 20' = ... 320 Ft.
E = 175' − 175' =................... 0.00 Ft.

The loading aft for the example is:

5,000 LT / 320' + 6 x 5,000 LT x 0.00' / 320'^{2}
= 15.63 + 0.00 = 15.63 LT/Ft.

The loading forward for the example is:

5,000 LT / 320' - 6 x 5,000 LT x 0.00' / 320'^{2}
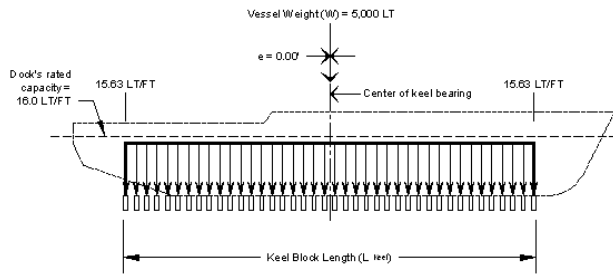= 15.63 - 0.00 = 15.63 LT/Ft.

See Figure 6.

FIGURE 6

Both ends of the trapezoid are now below the dock's rated capacity and the vessel can be docked.

For many vessels the "normal" keel will end at the first keel block and any additional blocks must be shaped to fit under the sloping fantail or other stern structure. IT is important to be sure that these added blocks are placed under strong points of the vessel that can take these loads.

Information on the shape of the vessel at this location may be difficult to obtain. For this reason it may be best to set these blocks 6 to 12 inches too low initially. Once the vessel is landed on the regular keel blocks and lifted a foot or so, divers can pack the gap with timber before raising the vessel the rest of the way.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

6) Interrupted Keel Bearing (Block Omissions)

EXAMPLE PROBLEM 6 – INTERRUPTED KEEL BEARING AREA

The figure below shows the block arrangement that will be used to dock a 3,000-ton vessel.
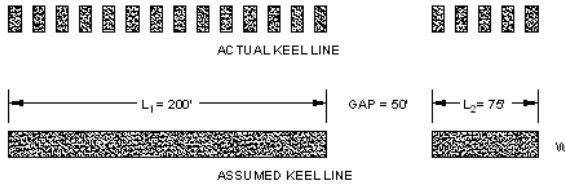
BLOCK DIMENSIONS

The center of all blocks must be calculated first. This is done by multiplying the area of each rectangle by its distance from any arbitrary point, adding these values together, and dividing by the total area of blocks. See below.
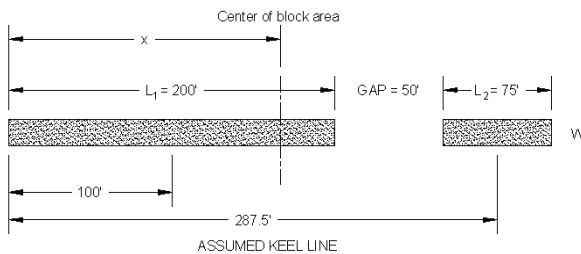
CENTER OF BLOCKS

Find center of block area in relation to Point A, the aft end of the keel line. Since all blocks are the same width, the width can be assumed as 1.

$$x = \frac{200' \times 1' \times 100' + 75' \times 1' \times 287.5'}{(200' \times 1' + 75' \times 1')}$$

$$= 151.14'$$

This is the distance the center of block area is from Point A, the end of the keel line.

Next, the moment of inertia of all rectangles about the center of block area must be calculated.

The moment of inertia of a rectangle about an arbitrary axis is:

$$I = b \times h^3 / 12 + A \times d^2$$

Where:

b = base of the rectangle or width of the block, can be assumed 1 if all block widths are constant

h = height of the rectangle or length of the block line segment

A = area of the rectangle

d = distance the center of the rectangle is from the axis being investigated (center of block area in this case)
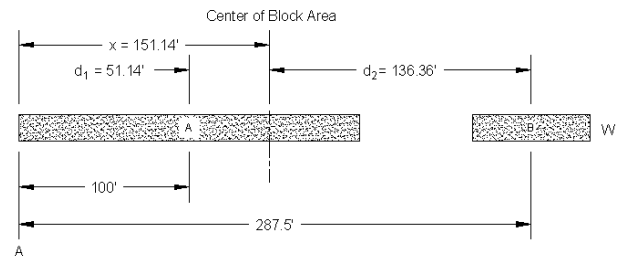
CALCULATION OF "d"

Moment of inertia of rectangle A:

$$I_A = 1 \times 200^3 / 12 + 200 \times 1 \times 51.14^2$$

$$I_A = 1,189,727 \text{ Ft.}^4$$

Moment of inertia of rectangle B:

$$I_B = 1 \times 75^3 / 12 + 75 \times 1 \times 136.36^2$$

$$I_B = 1,429,710 \text{ Ft.}^4$$

The total moment of inertia for all blocks is the sum of the individual moments or:

$$I_{total} = 1,189,727 \text{ Ft.}^4 + 1,429,710 \text{ Ft.}^4$$

$$I_{total} = 2,619,437 \text{ Ft.}^4$$

Finally, we need to calculate the eccentricity (e), which is the distance the longitudinal center of gravity of the vessel (LCG) is from the center of keel bearing area. See Figure "Calculation or e". The location of the LCG is dependent on how the vessel is loaded and can be determined using the vessel's drafts and hydrostatic properties of the hull. See Section 3.5 "Longitudinal Center of Buoyancy" for more information on how to determine the location of the LCG.
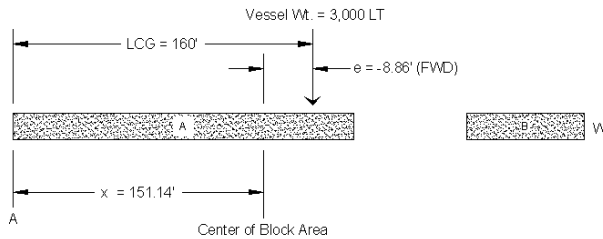
CALCULATION OF "e"

$e = 160' - 151.14' = 8.86'$

We now have all the values need to plug into the eccentrically loaded column equation:

$P/A \pm M \times c / I$

Or:

$W/A \pm W \times e \times c / I$

Where:

W = vessel wt. = 3000 LT

A = block area = 200 x 1' + 75 x 1' =
    = 275 Ft.^{2}

e = eccentricity = 8.86 Ft.

I = moment of inertia = 2,619,437 Ft.^{4}

c = the distance from the center of block area to the point being investigated. Points calculated are usually the ends of each rectangle. See Figure above.
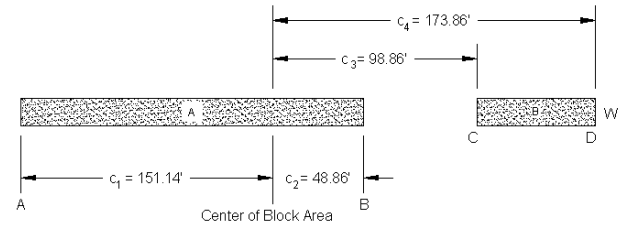
CALCULATION OF "c"

$c_1 = 151.14'$
$c_2 = 48.86'$
$c_3 = 98.86'$
$c_4 = 173.86'$

Because we have used a value of 1 for the width of all blocks throughout these calculations, the equation produces a result in long tons per foot of block length (as opposed to long tons per square foot of blocking).

Load at A:

$= 3,000 / 275 + 3,000 \times -8.86 \times 151.54 / 2,619,437$

    9.371 LTs/Ft.

Load at B:

$= 3,000 / 275 + 3,000 \times -8.86 \times -48.46 / 2,619,437$

    11.401 LTs/Ft.

Load at C:

$= 3,000 / 275 + 3,000 \times -8.86 \times -98.86 / 2,619,437$

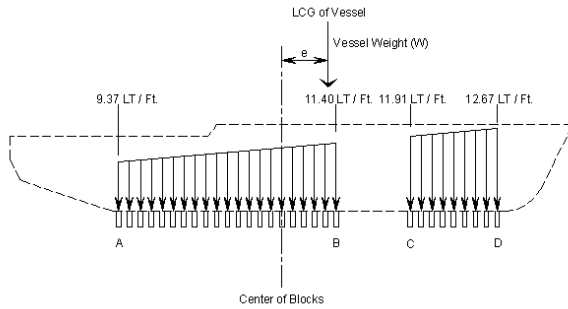   11.912 LTs/Ft.

Load at D:

$= 3,000 / 275 + 3,000 \times -8.86 \times -173.86 / 2,619,437$

    12.673 LTs/Ft.

This loading is summarized on the next page.

LOAD SUMMARY

Check to insure block load equals ship weight.

Average load on A to B = (9.37 + 11.40) / 2
       = 10.39 LT/Ft.

Times block length of 200 Ft. =
       = 10.64 LT/Ft. x 200 = 2,078 LT

Average load on C to D = (11.91 + 12.67) / 2
       = 12.29 LT/Ft.

Times block length of 75 Ft. =
       = 12.29 LT/Ft. x 75 ft. = 922 LT

Total block load = 2,078 + 922 = 3,000 LT

Ship weight = 3,000 tons ➔ OK

To see the effect of removing keel blocks, we will now do block loading calculations for the same vessel on the 325' block line but will not leave out the 50 foot of blocks as before.

The figure below shows the loading condition.
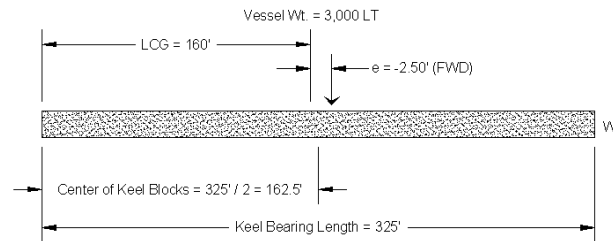
LOADING CONDITION – NO GAP

The block loading is calculated by using the trapezoidal loading equation:

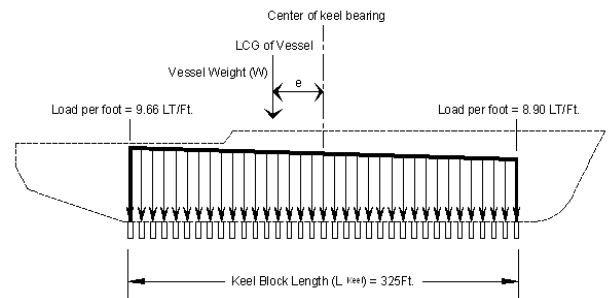$$W/L \pm 6 \times W \times e / L^2$$

Where:

W = 3,000 LT
L = 325 Ft.
e = 2.5

$3000/325 \pm 6 \times 3000 \times 2.5 / 325^2$

=   9.66 LT/Ft. Aft
=   8.80 LT/Ft. Fwd.

This loading is summarized below.

LOADING SUMMARY – NO GAP

As can be seen by comparing the two loading summaries, leaving a 50-foot gap in the keel drastically changes the loading along the keel.

It will also effect the deballasting plan if the vessel is being lifted in a floating dry dock.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLOVED PROBLEMS & MISC. DATA

7) Varying Width Keel Bearing

With a varying width keel the different widths of keel bearing area must be accounted for. The loading along the keel must be calculated as a load per square foot and not a load per foot (as was done for the "normal" trapezoidal loading calculation).

This causes two changes in the analyses method. First, the center of the blocks is no longer at ½ the keel length (½ L) so it must be calculated. Second, the moment of inertia about the center of blocks must be calculated for all rectangle segments. Actual widths for each rectangular segment must be used in the calculations.
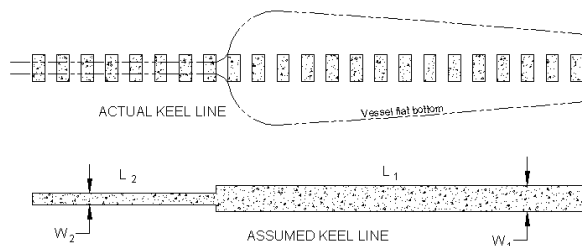

VARY WIDTH KEEL

First, the center of blocks must be calculated. This can be done by tanking the sum of each rectangle's area times it's distance form any arbitrary point and dividing by the total area of all the rectangles. Usually, the arbitrary point is taken as one end of the keel line.

The following example illustrates this method.

The next Figure shows the block arrangement that will be used to dock a 3,000-ton vessel.
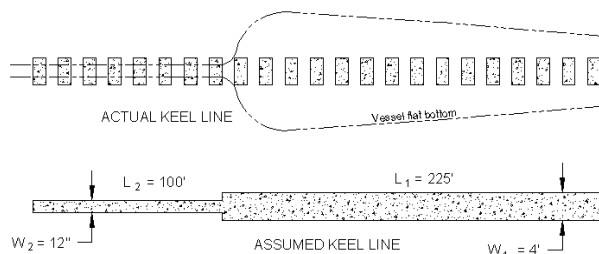
ACTUAL BEARING AREAS

The center of all blocks must be calculated first. This is done by multiplying the area of each rectangle by its distance from any arbitrary point, adding these values together, and dividing by the total area of blocks. See Figure below.
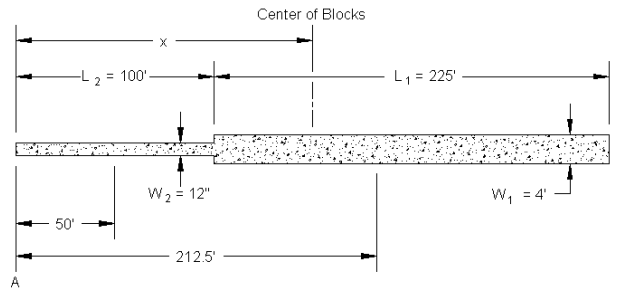
CALCULATE CENTER OF BLOCKS

CENTER OF BLOCKS

Find center of block area in relation to Point A, the aft end of the keel line. Since all blocks are not the same width, the width of each rectangle must be entered into the equation.

$$x = \frac{100' \times 1' \times 50' + 225' \times 4' \times 212.5'}{(100' \times 1' + 225' \times 4')}$$

$$x = 196.25'$$

This is the distance the center of block area from point A, the end of the keel line.

Next, the moment of inertia of all rectangles about the center of block area must be calculated.

The moment of inertia of a rectangle about an arbitrary axis is:

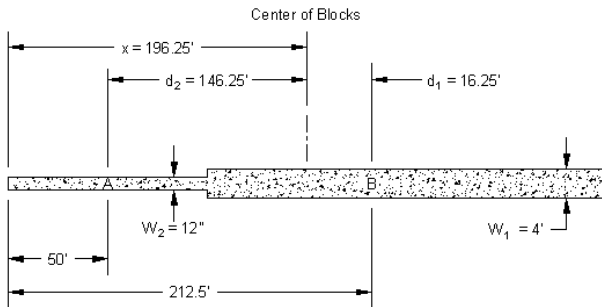$$I = b \times h^3 / 12 + A \times d^2$$

Where:

b = base of rectangle, which is the width of the vessel's bearing area on the block (W).

---

h = height of the rectangle or length of the block line segment (L)

A = Area of rectangle (W x L)

d = distance from center of the rectangle is from the axis being investigated (center of block area in this case)

Refer to Figure below.

CALCULATION OF "d"

Moment of inertia of rectangle A:

$$I_A = 1 \times 100^3 / 12 + 100 \times 1 \times 146.25^2$$

$$I_A = 2,222,240 \text{ Ft.}^4$$

Moment of inertia of rectangle B:

$$I_B = 4 \times 225^3 / 12 + 225 \times 4 \times 16.25^2$$

$$I_B = 4,034,531 \text{ Ft.}^4$$

The total moment of inertia for all blocks is the sum of the individual moments or:

$$I_{TOTAL} = 2,222,240 \text{ Ft.}^4 + 4,034,531 \text{ Ft.}^4$$

$$I_{TOTAL} = 6,256,771 \text{ Ft.}^4$$

Finally, we need to calculate the eccentricity (e), which is the distance the longitudinal center of gravity of the vessel (LCG) is from the center of keel bearing area.

The location of the LCG is dependent on how the vessel is loaded and can be determined using the vessel's drafts and hydrostatic properties of the hull. See The Docking Report, Volume 10, "Ship Characteristics Important to Drydocking" for more information on how to determine the location of the LCG.

For this example, the vessel's LCG is 160 feet forward of Point A.
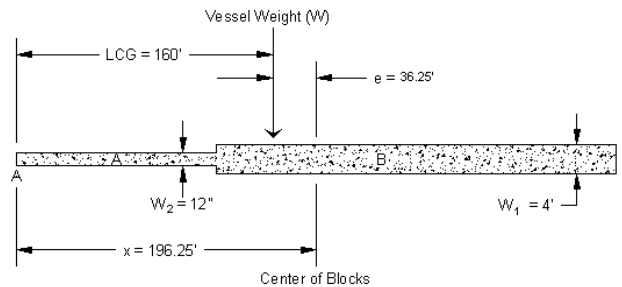
CALCULATION OF "e"

$$e = 196.25' - 160.0' = 8.86'$$

We now have all the values needed to plug into the eccentrically loaded column equation:

$$P/A \pm M \times c / I$$
Or:
$$W/A \pm W \times e \times c / I$$

Where:

W = vessel wt. = 3,000 LT

A = block area = 100 x 1' + 225 x 4' = =1000 Ft.^{2}

e = eccentricity = 36.25 Ft.

I = moment of inertia = 6,256,771 Ft.^{4}

c = the distance from the center of block area to the point being investigated. Points calculated are usually the ends of each rectangle. See next Figure.

Center of Blocks

$c_2 = 96.25'$
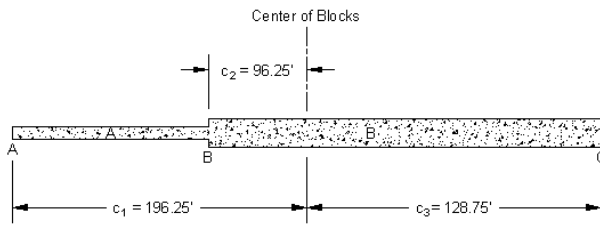
$c_1 = 196.25'$ $c_3 = 128.75'$

CALCULATION OF "c"

$c_1 = 196.25'$
$c_2 = 96.25'$
$c_1 = 128.75'$

We can now calculate the load per square foot (pressure) at points A, B, and C.

Load at A:

$= 3,000/1000 + 3,000 \times 36.25 \times 196.25/6,256,771$

$= 6.411 \text{ LT/Ft.}^2$

Load at B:

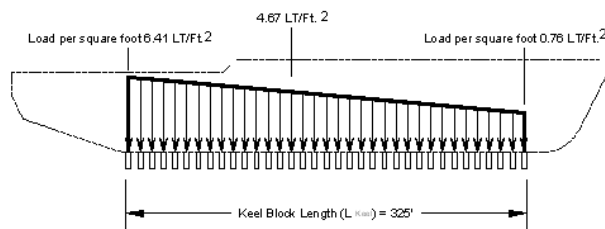$= 3,000/1000 + 3,000 \times 36.25 \times 96.25/6,256,771$

$= 4.673 \text{ LT/Ft.}^2$

Load at C:

$= 3,000/1000 + 3,000 \times 36.25 \times 128.75/6,256,771$

$= 0.762 \text{ LT/Ft.}^2$

This loading is summarized below.

Load per square foot 6.41 LT/Ft.^{2} 4.67 LT/Ft.^{2} Load per square foot 0.76 LT/Ft.^{2}

Keel Block Length (L $_{Keel}$) = 325'

LOAD PER SQ. FT. SUMMARY

It is important to remember that this load is in long tons per square foot of bearing area on the keel blocks. To get the loading per foot of keel length, these values must be multiplied by the width of the keel bearing at each block.

The width of keel bearing for the first 100 feet of keel at the aft end, between Points A and B, is 1 foot.

Thus the load per foot at Point A is:

$6.411 \text{ LT/Ft.}^2 \times 1 \text{ Ft.} = 6.411 \text{ LT/Ft.}$

The load per foot at Point B, aft side is:

$4.673 \text{ LT/Ft.}^2 \times 1 \text{ Ft.} = 4.673 \text{ Ft.}$

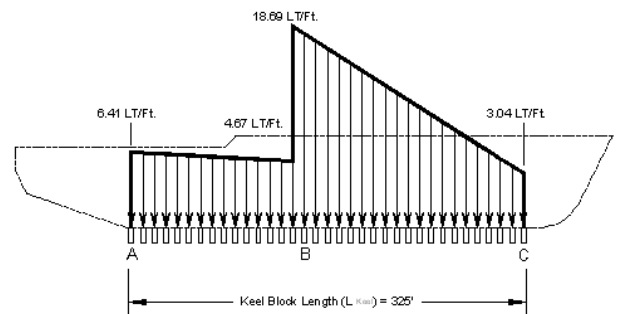The width of keel bearing at the remaining portions of keel, between Points B and C, is 4 feet.

Thus the load per foot at Point B, forward side is:

$4.673 \text{ LT/Ft.}^2 \times 4 \text{ Ft.} = 18.69 \text{ LT/Ft.}$

The load per foot at Point C is:

$0.762 \text{ LT/Ft.}^2 \times 4 \text{ Ft.} = 3.048 \text{ LT/Ft.}$

This loading is summarized below.

18.69 LT/Ft.

6.41 LT/Ft.   4.67 LT/Ft.   3.04 LT/Ft.

A   B   C

Keel Block Length (L $_{Keel}$) = 325'

LOAD PER FT. SUMMARY

Check to insure block load equals ship weight.

Average load on A to B = $(6.41 + 4.67)/2$
    = 5.54 LT/Ft.

Times block length of 100 Ft. =
    = 5.54 LT/Ft. x 100 Ft. = 554 LT

Average load on B to C = $(18.69 + 3.04)/2$
    = 10.87 LT/Ft.

Times block length of 225 Ft. =
    = 10.87 LT/Ft. x 225 Ft. = 2,446 LT

Total block load = 554 + 2,446 = 3,000 LT

Ship weight = 3,000 tons ➔ OK

The maximum block load aft is 6.41 LT/Ft. times the block spacing. The block spacing in this example is 4 foot so the maximum load is 4' x 6.41 LT/Ft. = 25.64 LT.

The maximum pressure on the timber is 25.64 LT divided by the bearing area, which is 1 foot wide by 1 foot long (144 in.^{2}):

25.64 LT x 2,240 lbs/LT / 144 in.^{2}

= 399 psi

Which is an acceptable pressure for Douglas Fir.

The maximum block load at Point B is 18.69 LT/Ft. times the block spacing. The block spacing is 4 foot so the maximum load is 4' x 18.69 LT/Ft. = 74.76 LT.

The maximum pressure on the timber is 74.76 LT divided by the bearing area, which is 4 foot wide by 1 foot long (576 in^2)

74.76 LT x 2,240 lbs/LT / 576 in^2

= 290 psi

Which is an acceptable pressure for Douglas Fir.

To see the effect of varying the width of the keel, we will now do block loading calculations for the same vessel on the 325' foot block line but will assume a uniform 4' wide keel.

The next Figure shows the loading condition.
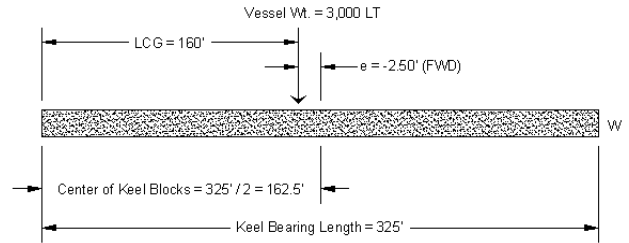
LOADING CONDITION – UNIFORM WIDTH

The block loading is calculated by using the trapezoidal loading equation:

$$W/L \pm 6 \times W \times e / L^2$$

Where:

W = 3,000 LT
L = 325 Ft.
e = 2.5

$3000/325 \pm 6 \times 3000 \times 2.5 / 325^2$
    =   9.66 LT/Ft. Aft
    =   8.80 LT/Ft. Fwd.

Results are shown in next Figure.
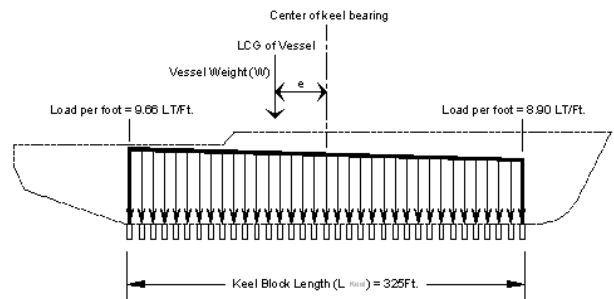
LOADING SUMMARY
UNIFORM WIDTH

As can be see by comparing the loading summaries varying the width of the keel drastically changes the loading along the keel. It will also effect the deballasting plan if the vessel is being lifted in a floating dry dock.

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

8) Computation of Knuckle Reaction

The magnitude of the knuckle reaction can be calculated for use in the following manner:

   Determine the trim of the vessel afloat.

   Determine the trim of the vessel landed on the blocks (0 for level keel blocks).

   Determine the trim needed to be removed (trim afloat – trim landed).

   Determine the vessel's Longitudinal Center of Floatation (LCF) for its docking draft. (This usually can be interpolated from the "Table of Displacements & Other Properties" on the docking plan.)

   Multiply the Moment to Trim One Inch by the trim needed to be removed (in inches). This results in the total trimming moment that needs to be imparted to the vessel to remove its trim relative to the block line. This is the point the ship has just touched down on the blocks.

The total trimming moment must be imparted by the knuckle reaction.

This force acts at the first keel block and rotates the ship about its LCF.

Since moment is equal to force x distance, the force of the knuckle reaction times the distance the first block is from the LCF must equal the total trimming moment needed.
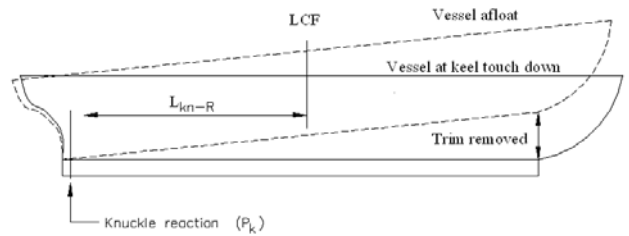
Total Trimming Moment = Force x Distance =

   = Knuckle Reaction x $L_{Kn. R.}$

   $L_{Kn. R.}$ = Dist. LCF to 1st keel block

Or:

   Knuckle Reaction =

   Total Trimming Moment / $L_{Kn. R.}$

Since any knuckle reaction reduces the stability of the vessel it is best to try and minimize the reaction by minimizing the relative trim of the vessel to the block line. Rule of Thumb: Trim of vessel relative to block line should not exceed 1 foot for every 100 feet of vessel length.

This can be done by:

   - Ballasting the vessel to match trim of block line.

   - Building the slope of the block line to match vessel trim.

   - Matching the trim of the vessel with the trim of the dock (floating docks only).

Example

Vessel Trim = 2'-6"

Moment to trim 1" = 725 Ft.-LT

Dist. LCF to aft block = 155 Ft.

Keel block line is level

Therefore:

Total trim to be removed = 2'-6" = 30"

Moment required to remove trim =

       30" x 725 Ft.-LT/In. = 21,750 Ft.-LT

Knuckle reaction needed to cause moment =

       Moment/Dist. = 21,750 Ft.-LT/155' =

       140 Long tons

DRYDOCKING SEMINAR

SUPPLEMENTARY SOLVED PROBLEMS & MISC. DATA

9) Preparation of a Pumping Plan

EXAMPLE PROBLEM 9 – PREPARATION OF A PUMPING PLAN

Given:

Ship Wt. = 20,000 LT
Draft Fwd. = 20.0 Ft.
Draft Aft = 24.0 Ft.
Distance between draft marks = 560 Ft.

Keel Bearing Length (L) = 540'
LCG located 10' aft of block centerline, e = 10'

Vessel to be docked on dry dock described in Figure E-1, first block 20' from end of dock.
Dock is in fresh water.
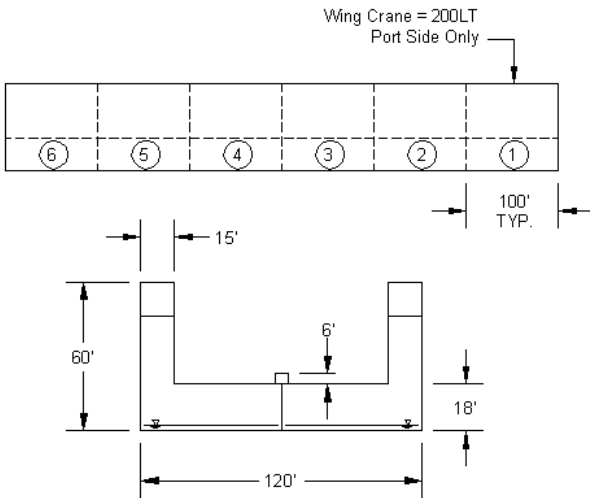Dock light weight = 7200 LT.

FIGURE E-1

Find Dock Weight Per Compartment

Dock weight attributable to each compartment can be figured by:

Dock weight per foot is:

   Dock weight / Pontoon Length

   = 7200 LT / 600' = 12 LT/Ft.

Dock weight per compartment:

   -   Compartment 1, Starboard

       12 LT/Ft. x 100' / 2 sides = 600 LT

   -   Compartment 2, Port

       12 LT/Ft. x 100' / 2 sides = 600 LT
       Add Wing Crane weight =   200 LT
                                  800 LT

   -   Compartment 2, 3, 4, 5, & 6, Port & Stbd.

       12 LT/Ft. x 100' / 2 sides = 600 LT

Find Ship Weight Per Compartment:

The load per foot along the keel block line can be calculated using the trapezoidal loading formula:

$$W / L \pm 6 \times e \times W / L^2$$

Where:

   W = Ship Wt. in LT
   L = Keel bearing length
   e = Dist. From C.L. keel bearing length to vessel LCG

Load per foot Aft:

   $20,000 / 540 + 6 \times 10 \times 20,000 / 540^2$

   = 41.15 LT/Ft.

Load per foot Fwd:

   $20,000 / 540 - 6 \times 10 \times 20,000 / 540^2$

   = 32.92 LT/Ft.

Intermediate values for load per foot at each of the dock watertight bulkheads can be found by interpolation. The results are shown in Figure E-2.
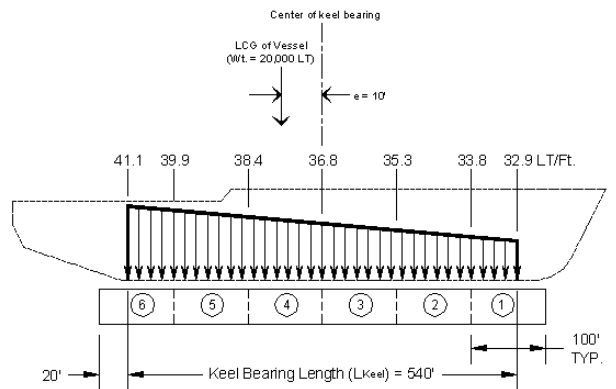

FIGURE E-2

Load on Compartment 1 Port & Stbd:
   (33.83 + 32.92) / 2 x 60' = 2003 LT
   = 1001.5 LT each side

Load on Compartment 2 Port & Stbd:
(35.34 + 33.83) / 2 x 100' = 3459 LT
= 1729.5 LT each side

Load on Compartment 3 Port & Stbd:
(36.86 + 35.34) / 2 x 100' = 3610 LT
= 1805.0 LT each side

Load on Compartment 4 Port & Stbd:
(38.39 + 36.86) / 2 x 100' = 3763 LT
= 1881.5 LT each side

Load on Compartment 5 Port & Stbd:
(39.9 + 38.39) / 2 x 100' = 3915 LT
= 1957.5 LT each side

Load on Compartment 6 Port & Stbd:
(41.15 + 39.9) / 2 x 80' = 3242 LT
= 1621.0 LT each side

Check Weight:
    2003
    3459
    3610
    3763
    3915
    <u>3242</u>
    19,992 LT
Actual Wt. = 20,000 LT   ➔ OK

Maximum Draft

Find Dock Drafts @ Maximum Draft:

Clear blocks by approximately 4'

Ship Draft Aft = 24.0'
Ship's Trim = (24.0 – 20.0) / 560 = 0.00714 Ft./Ft.

Dock Draft Aft:
    Ship Draft =   24.0 Ft.
    Clearance =   4.0 Ft.
    Block Height =   6.0 Ft.
    Pontoon Depth =   <u>18.0 Ft.</u>
                           52.0 Ft.

Dock Draft Fwd.:

    Put dock on same trim as ship.
    52.0 – (0.00714 x 600') = 47.71 Ft.

Interpolate drafts at centerline of each ballast tank. See Figure E-3.

FIGURE E-3
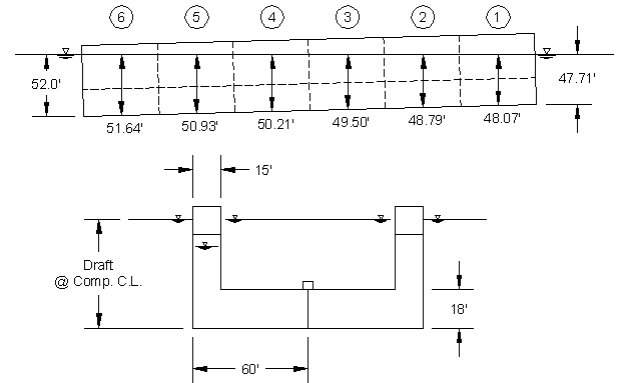
Find Displacements of Ballast Tanks:

Ballast Tank 1 P or S:

Pontoon =
    18.0' x 60.0' x 100.0' = 108,000 Ft.^{3}
Wing =
    (48.07' – 18.0') x 15.0' x 100.0' = 45,100 Ft.^{3}

Total = 108,000 + 45,100 = 153,100 Ft.^{3}

Multiply by unit weight of fresh water (Specific Gravity S.G. = 1.00) to get displacement in long tons. (Dock is located in fresh water.)

153,100Ft.^{3} x 62.4lbs/Ft.^{3} x S.G./2,240lbs/LT
= 4265 LT

Ballast Tank 2 P or S:

Pontoon =
    18.0' x 60.0' x 100.0' = 108,000 Ft.^{3}
Wing =
    (48.79' – 18.0') x 15.0' x 100.0' = 46,185 Ft.^{3}

Total = 108,000 + 46,185 = 154,185 Ft.^{3}

154,185Ft.^{3} x 62.4lbs/Ft.^{3} xS.G./2,240 lbs/LT
= 4,295 LT

Calculate other tanks in same manner:

Ballast Tank 3 P or S = 155,250 Ft.^{3} = 4325 LT
Ballast Tank 4 P or S = 156,315 Ft.^{3} = 4355 LT
Ballast Tank 5 P or S = 157,395 Ft.^{3} = 4385 LT
Ballast Tank 6 P or S = 158,460 Ft.^{3} = 4415 LT

Calculate Volume and Height of Ballast Water

The weight of the dock, ballast water and ship on any one section must equal the displacement of that section.

Therefore:

Displ. – Dock Wt. – Ship Wt. = Ballast Wt.

For Tank 1 Starboard:

Displacement =	4,265 LT
Dock Wt. =	-600 LT
Ship Wt. =	0 LT
Total Ballast Wt. =	3,665 LT

Total Ballast Volume = Wt. / Unit Wt.
= 3,665LT x 2,240lbs/LT / 62.4lbs/Ft.^{3} x S.G.
= 131,564 Ft.^{3}

Volume of Ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x 18' x 0.98' = 105,840 Ft.^{3}

Remaining Ballast in wing =
= 131,564 Ft.^{3} – 105,840 Ft.^{3} = 25,724 Ft.^{3}

Volume of ballast in wing = L x W_W x H_W x Perm.
H_W = 25,724 Ft.^{3} / (15' x 100' x .98) = 17.50'

Total height above pontoon base =
= 18.0' + 17.50' = 35.5' **Say 35.5Ft.**

For Tank 1 Port (Location of Wing Crane:

Displacement =	4,265 LT
Dock Wt. (With Crane wt.) =	-800 LT
Ship Wt. =	0 LT
Total Ballast Wt. =	3,465 LT

Total Ballast Volume = Wt. / Unit Wt.
= 3,465LT x 2,240lbs/LT / 62.4lbs/Ft.^{3} x S.G.
= 124,385 Ft.^{3}

Volume of Ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x 18' x 0.98' = 105,840 Ft.^{3}

Remaining Ballast in wing =
= 124,385 Ft.^{3} – 105,840 Ft.^{3} = 18,545 Ft.^{3}

Volume of ballast in wing = L x W_W x H_W x Perm.
H_W = 18,545 Ft.^{3} / (15' x 100' x .98) = 12.61'

Total height above pontoon base =
= 18.0' + 12.61' = 30.61'
Say 30.61 Ft.

Calculate other tanks in same manner:

Ballast Tank 2 P or S = 132,641 Ft.^{3} = 36.25 Ft.
Ballast Tank 3 P or S = 133,718 Ft.^{3} = 36.96 Ft.
Ballast Tank 4 P or S = 134,795 Ft.^{3} = 37.70 Ft.
Ballast Tank 5 P or S = 135,872 Ft.^{3} = 38.43 Ft.
Ballast Tank 6 P or S = 136,949 Ft.^{3} = 39.16 Ft.

Keel Touchdown
Find Dock Drafts

Ship Draft Aft = 24.0'
Ship's trim = (24.0 – 20.0)/560 = 0.00714 Ft./Ft.

Ship's Aft draft mark 10' in from end of dock when vessel lands on blocks.

Dock Draft @ Vessel's Aft Draft Mark:
Ship Draft =	24.0 Ft.
Clearance =	0.0 Ft.
Block Height =	6.0 Ft.
Pontoon Depth =	18.0 Ft.
	48.0 Ft.

Dock Draft Aft:

Put dock on same trim as ship.
48.07 + (0.00714 x 10') = 48.07 Ft.

Dock Draft Fwd.:

Put dock on same trim as ship.
48.07 – (0.00714 x 600') = 43.79 Ft.

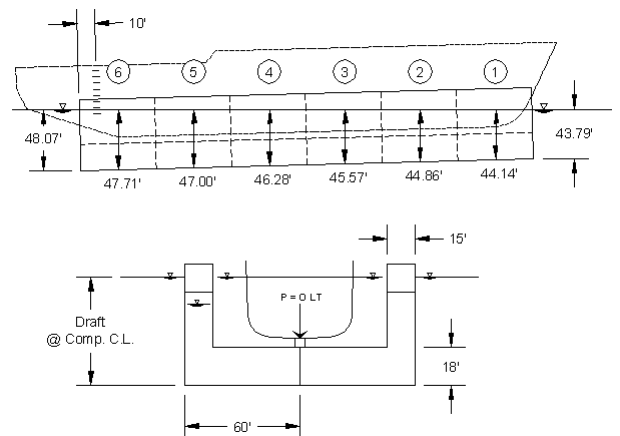Interpolate drafts at centerline of each ballast tank. See Figure E-4.

FIGURE E-4

Find Displacements of Ballast Tanks:

Ballast Tank 1 P or S:

Pontoon =
18.0' x 60.0' x 100.0' = 108,000 Ft.^{3}

Wing =
(44.14' − 18.0) x 15.0' x 100.0' = 39,210 Ft.^{3}

Total = 108,000 + 39,210 = 147,210 Ft.^{3}

Multiply by unit wt of water to get Displacement in LT. (s.G. = 1.00 for fresh water)

147,210Ft.^{3} x 62.4 lbs/Ft.^{3} x S.G./ 2240 lbs/LT
= 4100 LT

Calculate other tanks in same manner:

Ballast Tank 2 P or S = 148,290 Ft.^{3} = 4130 LT
Ballast Tank 3 P or S = 149,355 Ft.^{3} = 4160 LT
Ballast Tank 4 P or S = 150,420 Ft.^{3} = 4190 LT
Ballast Tank 5 P or S = 151,485 Ft.^{3} = 4220 LT
Ballast Tank 6 P or S = 152,550 Ft.^{3} = 4250 LT

Calculate Volume and Height of Ballast Water

The weight of the dock, ballast water and ship on any one section must equal the displacement of that section.

Therefore:
Displ. − Dock Wt. − Ship Wt. = Ballast Wt.

For Tank 1 Starboard:

Displacement =	4100 LT
Dock Wt. =	- 600 LT
Ship Wt. =	0 LT
Total Ballast Wt. =	3500 LT

Total Ballast volume = Wt./Unit Wt.
= 3500 LT x 2240 lbs/LT/ 62.4 lbs/Ft.^{3} x S.G.
= 125,641 Ft.^{3}

Volume of ballast in pont. = L x W$_P$ x H$_P$ x Perm.
= 100' x 60' x 18' x 0.98 = 105,840 Ft.^{3}

Remaining ballast in wing =
= 125,641 Ft.^{3} − 105,840 = 19,801 Ft.^{3}

Volume of ballast in wing =
= H$_w$ = 19,801 Ft.^{3} / (15' x 100' x .98) = 13.47'

Total height above pontoon base =
= 18.0' + 13.47' = 31.47'
Say 31.5

Calculate other tanks in same manner:

Ball Tank 1 P (Crane) = 118,461 Ft.^{3} = 26.59 Ft.
Ballast Tank 2 P or S = 126,717 Ft.^{3} = 32.20 Ft.
Ballast Tank 3 P or S = 127,793 Ft.^{3} = 32.94 Ft.
Ballast Tank 4 P or S = 128,869 Ft.^{3} = 33.67 Ft.
Ballast Tank 5 P or S = 129,945 Ft.^{3} = 34.40 Ft.
Ballast Tank 6 P or S = 131,021 Ft.^{3} = 35.13 Ft.

½ **Draft of Vessel**

Find Dock Drafts

Ship Draft Aft = 24.0'/2 = 12.0'
Ship Draft Fwd. = 20.0'/2 = 10.0'

Ship's trim = (12.0 − 10.0) / 560 =
= 0.00357 Ft. / Ft.

Ship's Aft draft mark 10' in from end of dock when vessel lands on blocks.

Dock Draft @ Vessel's Aft Draft Mark:
Ship draft =	12.0 Ft.
Block height =	6.0 Ft.
Pontoon depth =	18.0 Ft.
	36.0 Ft.

Dock Draft Aft:

Put dock on same trim as ship.

36.0 + (0.00357 x 10') = 36.04 Ft.

Dock Draft Fwd.:

Put dock on same trim as ship.

36.04 − (0.00357 x 600') = 33.90 Ft.

Interpolate drafts at centerline of each ballast tank.

Draft @ C.L. Tank 1 =	34.08 Ft.
Draft @ C.L. Tank 2 =	34.44 Ft.
Draft @ C.L. Tank 3 =	34.79 Ft.
Draft @ C.L. Tank 4 =	35.15 Ft.
Draft @ C.L. Tank 5 =	35.51 Ft.
Draft @ C.L. Tank 6 =	35.86 Ft.

Find Displacements of Ballast Tanks:

Calc. Displacement in same manner as above:

Ballast Tank 1 P or S = 132,060 Ft.^{3} = 3679 LT
Ballast Tank 2 P or S = 132,660 Ft.^{3} = 3695 LT
Ballast Tank 3 P or S = 133,185 Ft.^{3} = 3710 LT
Ballast Tank 4 P or S = 133,725 Ft.^{3} = 3725 LT
Ballast Tank 5 P or S = 134,265 Ft.^{3} = 3740 LT
Ballast Tank 6 P or S = 134,790 Ft.^{3} = 3755 LT

Calculate Volume and Height of Ballast Water

The weight of the dock, ballast water and ship on any one section must equal the displacement of that section.

Therefore:

   Displ – Dock Wt. – Ship Wt. = Ballast Wt.

The ship wt. on each tank group was calculated on pages 1 & 2

For Tank 1 Starboard:

Displacement =	3679 LT
Dock Wt. =	-600 LT
Ship Wt. (½ total)	-500.75 LT

Total Ballast Wt. =   2578.25 LT
Total Ballast volume = Wt./Unit Wt.
= 2578 LT x 2240 lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 92,543 Ft.^{3}

Volume of ballast in pontoon = L x W$_P$ x H$_P$ x Perm. = 100' x 60' x H$_P$ x 0.98 = 92,543 Ft.^{3}
H$_P$ = 15.74'

For Tank 1 Port (Wing Crane):

Displacement =	3679 LT
Dock Wt. (with Crane) =	-800 LT
Ship Wt. (½ total)	-500.75 LT

Total Ballast Wt. =   2378.25 LT
Total Ballast volume = Wt./Unit Wt.
= 2378 LT x 2240 lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 85,364 Ft.^{3}

Volume of ballast in pontoon = L x W$_P$ x H$_P$ x Perm. = 100' x 60' x H$_P$ x 0.98 = 85,364 Ft.^{3}
H$_P$ = 14.52'

For Tank 2 Port or Starboard:

Displacement =	3695 LT
Dock Wt. =	-600 LT
Ship Wt. (½ total)	-864.75 LT
Total Ballast Wt. =	2230.25 LT

Total Ballast volume = Wt./Unit Wt.
= 2230 LT x 2240 lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 80,051 Ft.^{3}

Volume of ballast in pontoon = L x W$_P$ x H$_P$ x Perm. = 100' x 60' x H$_P$ x 0.98 = 80,051 Ft.^{3}
H$_P$ = 13.61'

Calculate other tanks in same manner varying ship weight and displacement:

Ballast Tank 3 P or S = 79,244 Ft.^{3} = 13.48 Ft.
Ballast Tank 4 P or S = 78,409 Ft.^{3} = 13.33 Ft.
Ballast Tank 5 P or S = 77,583 Ft.^{3} = 13.19 Ft.
Ballast Tank 6 P or S = 84,170 Ft.^{3} = 14.31 Ft.

Vessel Keel @ Waterline

Find Dock Draft

Dock Draft (level):
Block Height =	6.0 Ft.
Pontoon Depth =	18.0 Ft.
	24.0 Ft.

Find Displacement of Ballast Tanks @ 24' Draft

Ballast Tanks 1 through 6, P or S:

Pontoon =
   18.0' x 60.0' x 100.0' = 108,000 Ft.^{3}
Wing =
   (24.00' – 18.0') x 15.0' x 100.0' = 9,000 Ft.^{3}

Total = 108,000 + 9,000 = 117,000 Ft.^{3}

   117,00 Ft.^{3} x 62.4 lbs/Ft.^{3} x S.G./ 2240 lbs/LT
                 = 3259 LT

Calculate Volume and Height of Ballast Water

   Displ. – Dock Wt. – Ship Wt. = Ballast Wt.

The ship wt. on each section was calculated on pages 1 and 2.

For Tank 1 Starboard:

Displacement =	3259 LT
Dock Wt. =	-600 LT
Ship Wt. (½ total) =	-1001.5 LT
Total Ballast Wt. =	1657.5 LT

Total Ballast volume = Wt./Unit Wt.
= 1657.5LT x 2240lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 59,500 Ft.^{3}

Volume of ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x H_P x 0.98 = 59,500 Ft.^{3}
H_P = 10.12'

For Tank 1 Port (With Wing Vrane):

Displacement =	3259 LT
Dock Wt. =	-800 LT
Ship Wt. (½ total) =	-1001.5 LT
Total Ballast Wt. =	1457.5 LT

Total Ballast volume = Wt./Unit Wt.
= 1457.5LT x 2240lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 52,320 Ft.^{3}

Volume of ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x H_P x 0.98 = 52,320 Ft.^{3}
H_P = 8.90'

Calculate other tanks in same manner varying ship weight:

Ballast Tank 2 P or S = 33,367 Ft.^{3} = 5.67 Ft.
Ballast Tank 3 P or S = 30,656 Ft.^{3} = 5.21 Ft.
Ballast Tank 4 P or S = 27,910 Ft.^{3} = 4.75 Ft.
Ballast Tank 5 P or S = 25,182 Ft.^{3} = 4.28 Ft.
Ballast Tank 6 P or S = 37,279 Ft.^{3} = 6.34 Ft.

Vessel Keel @ Waterline

Find Dock Draft

Dock Draft (level):
Freeboard =	-1.50 Ft.
Pontoon Depth =	18.0 Ft.
	16.5 Ft.

Find Displacement of Ballast Tanks @ Op Draft

Ballast Tanks 1 through 6, P or S:

Pontoon =
16.5' x 60.0' x 100.0' = 99,000 Ft.^{3}
Wing = 0

Total = 99,000 + 0 = 99,000 Ft.^{3}

99,00 Ft.^{3} x 62.4 lbs/Ft.^{3} x S.G./ 2240 lbs/LT
= 2758 LT

Calculate Volume and Height of Ballast Water

Displ. – Dock Wt. – Ship Wt. = Ballast Wt.

The ship wt. on each section was calculated on pages 1 and 2.

For Tank 1 Starboard:

Displacement =	2758 LT
Dock Wt. =	-600 LT
Ship Wt. (½ total) =	-1001.5 LT
Total Ballast Wt. =	1156.5 LT

Total Ballast volume = Wt./Unit Wt.
= 1156 LT x 2240 lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 41,515 Ft.^{3}

Volume of ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x H_P x 0.98 = 41,515 Ft.^{3}
H_P = 7.06'

For Tank 1 Port (With Wing Crane):

Displacement =	2758 LT
Dock Wt. =	-800 LT
Ship Wt. (½ total) =	-1001.5 LT
Total Ballast Wt. =	956.5 LT

Total Ballast volume = Wt./Unit Wt.
= 956 LT x 2240 lbs/LT / 62.4 lbs/Ft.^{3} x S.G.
= 34,335 Ft.^{3}

Volume of ballast in pont. = L x W_P x H_P x Perm.
= 100' x 60' x H_P x 0.98 = 34,335 Ft.^{3}
H_P = 5.84'

Calculate other tanks in same manner varying ship weight:

Ballast Tank 2 P or S = 15,382 Ft.^{3} = 2.62 Ft.
Ballast Tank 3 P or S = 12,672 Ft.^{3} = 2.16 Ft.
Ballast Tank 4 P or S = 9,925 Ft.^{3} = 1.69 Ft.
Ballast Tank 5 P or S = 7,197 Ft.^{3} = 1.22 Ft.
Ballast Tank 6 P or S = 19,295 Ft.^{3} = 3.28 Ft.

Pumping Plan Table

These results should be summarized in a pumping plan table as shown in Figure E-5.

NOTES	DOCK DRAFT	TANK GROUP						SHIP DRAFT
		6	5	4	3	2	1	
Full Submerg.	47.7' 52.0'	39.16'	38.43'	37.70'	36.96'	36.25'	30.6' / 35.5'	20.0' 24.0'
Keel Touch	43.8' 48.1'	35.13'	34.40'	33.67'	32.94'	32.20'	26.6' / 31.5'	20.0' 24.0'
Half Draft	33.9' 36.0'	14.31'	13.19'	13.33'	13.48'	13.61'	14.5' / 15.7'	10.0' 12.0'
Top of Blocks	24.0' 24.0'	6.34'	4.28'	4.75'	5.21'	5.67'	8.9' / 10.1'	0.0' 0.0'
Operat. Draft	16.5' 16.5'	3.28'	1.22'	1.69'	2.16'	2.62'	5.8' / 7.1'	0.0' 0.0'
							P / S	

Water Levels can be rounded to nearest ¼ foot if desired.

FIGURE E-5

Lift Curves

It is obvious from the above example that a large amount of the work involved in developing a pumping plan is calculating volumes of displacement and internal water and converting volumes to heights of ballast. For any particular dry dock, curves can be developed for each ballast tank, that show the height of ballast water that is required to provide a certain lift at any given draft of dock. This eliminates the need to calculate dock displacements, internal water volumes and heights.

An example pumping plan using lift curves follows.

Example of Use of Lift Curves

The same ship and dock used in the previous example will be used here. We will calculate the water levels for Compartment 6 P or S at the same dock drafts investigated previously.

The total load on Compartment 6 P or S was calculated as 1620 LT each side.

The drafts at which water levels were determined for Compartment 6 P or S were:

    Maximum Draft = 51.6'
    Draft @ Keel Touchdown = 47.7'
    Draft ½ Lift = 35.86'
    Vessel Keel @ Waterline = 24.0'
    Operating Draft = 16.5'

First, the ballast water removal curve should be plotted on the lift curve for Compartment 6.

- Plot the intersection of the ballast water weight curve and the dock draft at keel touchdown (47.7) See Point A on Figure 8.

- Plot the intersection of the ballast water weight curve and the dock draft with water at top of keel blocks (24.0'). See Point B on Figure 8. From this point subtract the total weight on the compartment by moving horizontally to left 1620 LT (to scale) and plot this point. See Point C on Figure 8

- Plot the intersection of the ballast water weight curve and the dock draft with water at top of pontoon (18.0'). See Point D on Figure 8. From this point subtract the total weight on the compartment by moving horizontally 1620 LT and plot this point. See Point E on Figure 8.

- Plot the intersection of the ballast water weight curve and the dock draft at full up operating draft (16.5'). See Point F on Figure 8. From this point subtract the total weight on the compartment by moving horizontally to left 1620 LT (to scale) and plot this point. See Point G on Figure 8.

- Connect points A, C, E, and G to give a graphical representation of the ballast water to be removed to lift the weight on

that compartment at any dock draft. (Dashed line ACEG). This is called the ballast water removal curve.
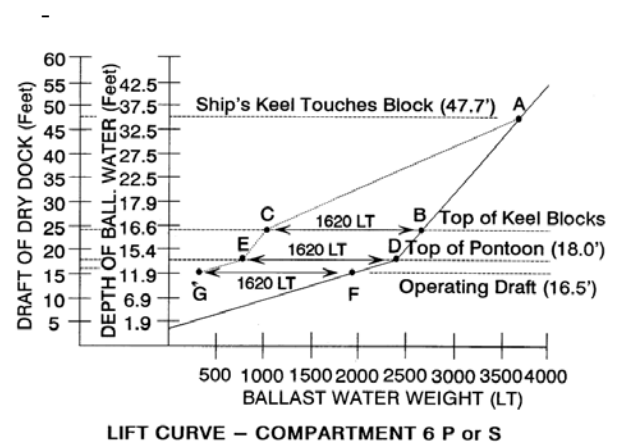

LIFT CURVE – COMPARTMENT 6 P or S

FIGURE 8

With the ballast water removal curve for 1620 LT drawn on the lift curve, the ballast water heights can be determined for the five dock drafts. See figure 9.
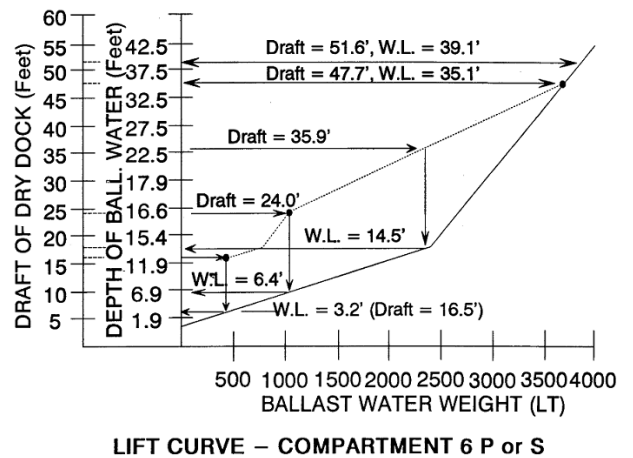

LIFT CURVE – COMPARTMENT 6 P or S

FIGURE 9

Using the lift curve, the following water levels are obtained for Compartment 6 P or S:

Draft	Water Level	
51.6'	39.1'	Max Draft
47.7'	35.1'	Touchdown
35.9'	14.5'	½ Lift
24.0'	6.4'	Top of Keel Blocks
16.5'	3.2'	Operating Draft

These compare favorably to the water levels obtained by calculation.