



The Society of Naval Architects and Marine Engineers

CRITERIA FOR CAPACITY CERTIFICATION OF DRY DOCKS
AND SIGNIFICANCE OF CLASSIFICATION AND
U. S. NAVY STANDARDS AS THEY AFFECT SHIP SAFETY

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ABSTRACT

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Extremely expensive and sensitive warships as well as valuable merchant ships are being docked in a wide variety of dry docks, many of them not originally built for the modern vessels and often operated by crews with very rudimentary training and experience and with limited engineering back up. Only since 1973 has Lloyd's Register of Shipping had published rules for steel floating dry docks, and the ABS rules were only created very recently. Following the example of the 5th Naval District, NAVSEA in Washington started the MIL-STD-1625 code using very limited personnel and funds to prepare a dry dock certification program to attempt to insure ship safety in all docks.

It is a serious mistake to think that certification is a cure-all. Adequate qualification of the docking crew is just as important, including skill in dealing with special problems with special ships.

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Accidents have occurred in basin or graving docks where vessels have dropped because of block instability or vessel instability following grounding. The same has taken place on floating and railway dry docks. Vertical lifts have had cable or tackle failure due to unforeseen load concentrations.

The greater number of these accidents were not due to dry dock inadequacy but rather to dockmaster inexperience or lack of facilities maintenance. Sometimes, particularly for marine railways and vertical lifts, the vessel was far too heavy and no verification was made beforehand.

Sometimes after the ship had been properly lifted the dock was overloaded by tank testing of the vessel. In fixed docks this can be very serious both for ship and dock.

It is obvious, therefore, that certification of docks must be supplemented by the certification of the docking crew with proper maintenance as well.

When one considers the operation of drydocking a ship, it helps to go back to when the ship was built to review the conditions and strength at time of launch.

In general, a vessel is built on a straight row of blocks either inclined or horizontal. The empty ship has a fairly uniform load, except perhaps for the engine room. Its buoyancy, however, is much greater amidships than at the extremities; therefore, the vessel generally floats with a negative bend, or hog. For wooden vessels the hog is a few feet. For welded steel hulls, it is a few inches.

When the ship is fully loaded it probably experiences a sag or positive bend. And when it encounters a storm at sea the hog and sag bending becomes a severe problem, especially with the fatigue of constant flexing.

So when we are asked to dock the ship in quiet water with no cargo aboard, it is evident that conditions are much better than for the vessel at sea. Docking of loaded vessels must receive special care and analysis. And we must not forget that the rigid ship when empty of cargo can easily span gaps approximating her own molded depth with very little concern for overstress.

It is therefore common to omit blocks where hull repairs are to be done, provided some extra support is added adjacent to the repair area. It is primarily when severe hull cutting is to be done that longitudinal dock strength is vital and careful analysis is required.

Dry docks fall into four categories and each must be analyzed differently to establish the safe total capacity and the lineal load concentration limit.

No. 1 is the basin or graving dock, where the total capacity is a proportion of the water volume of the basin at mean high tide, usually between one quarter and one half the length x width x draft over blocks. The load concentration capacity is generally that which the blocks and foundation under the blocks can carry and should be so determined, and the total of these represents a reasonable and safe rating. However, when extra blocks are used the rating can be safely increased provided the block capacity does not exceed that which the vessel hull can withstand. The longitudinal strength to distribute load concentrations is generally quite adequate.

No. 2 is the floating dry dock whose capacity for maximum load is the net displacement of the pontoon usually at 12" or 30 cm freeboard. LRS and ABS do rate docks commercially at 3" or 7.5 cm freeboard, especially for steel docks which have good watertight ballast tanks.

The average capacity per unit of length is generally based on the net displacement at zero freeboard and represents the greatest uplift possible by virtue of Archimedes' Principle. It is possible, however, to exceed this limit in cases where an individual block such as a poppet support can spread its reaction along the centerline dock girders where extra buoyancy is available.

Floating dry docks, like ships, are subject to hydrostatic stability limitations, but when a dock is properly designed, this is rarely critical; but it should be confirmed for a capacity ship

The longitudinal strength is clearly specified by LRS rules, and a properly designed dock can easily cope with irregularities of keel loading. Only the recent U. S. Navy MIL-STD-1625 rules have introduced special damage control regulations, which for the most part do not apply to a majority of existing docks, but are very pertinent for new docks destined to accommodate U. S. Navy ships.

No. 3 is the vertical lift or Syncrolift dock, consisting of a longitudinally flexible platform raised and lowered by a multiplicity of wire cable hoists, each pair connected to heavy transverse beams. This mechanical lift dock has its capacity per beam or per unit of length clearly defined by the hoist and cable block capacity. There is no structure available to redistribute load concentrations. Hence the capacity has to be computed by the unit length capacity times the keel length of the vessel being lifted. Therefore a total capacity has really no meaning.

No. 4 is the marine railway dry dock, where the ship load concentrations are carried to a track foundation underwater by a cradle frame, while the hauling for a total specified capacity is provided by a single machine using one or more chains to pull the ship and cradle up an inclined plane on the low friction interface of free rollers. This concept has certain special advantages. It permits the cradle, track and foundation to have 50% more capacity for large ship load concentrations while the hauling portion is only for total weight. The mechanical advantage of the inclined ways can be built on a curve to achieve vessel rotation from its floating attitude to horizontal. This feature is important when dealing with the grounding instability of vessels that float with a keel declivity, since we can obtain parallel grounding which would be difficult for a graving dock or vertical lift.

The classification societies have rules for floating dry docks only and some do not address the question of stability. None call for criteria for blocking strength or block stability. There are no society rules for shiplifts, railway dry docks or basin dry docks, although they have been certified. When a dock is to be classed, the particular society carries out a rather thorough analysis and investigation of the design and construction, and its local office does a complete survey of the workmanship to insure meeting the full intent of the design before granting the ~~+~~ A1 rating. Although the societies do not guarantee anything, their classing is accepted by owners and insurers as sufficient certification.

The requirement to certify dry docks for docking U. S. naval ships has been in effect for over two decades starting in the 5th Naval District. At that time a simple letter of certification by a qualified registered engineer indicating his estimate of safe lifting capacity was all that was needed. By and large, this greatly improved the safety situation but it applied only to commercial shipyards wanting to bid on naval ship overhaul.

The Naval Facilities Engineering Command (NAVFACS) which oversees the civil engineering projects for the Naval Sea Systems Command (NAVSEA) was originally the only unit responsible for all dry docks under their old name of Bureau of Yards and Docks. And they still are the authority for certification of graving docks, marine railways, vertical lifts and the mooring of floating dry docks.

The portion of the MIL-STD pertaining to these truly civil engineering facilities has presented almost no problems except perhaps in the realm of earthquake analysis.

With the advent of nuclear power great concern has been expressed regarding failures due to earthquakes. This concern has overflowed into the domain of dry docks on the assumption that nuclear-powered warships may be in dock. However, the only important nuclear ships are submarines which are restricted to a very few specific shipyards and aircraft carriers which also are very restricted. Only a handful of other surface warships are nuclear-powered. Hence we can state that most commercial yards will never have to dock a nuclear-powered ship.

Since the very safest place for a ship during an earthquake is afloat then it is also very safe in a floating dry dock, provided its moorings are designed with elastic or break-free connections to limit peak acceleration to 0.10 G or less. Such forces are well within the state-of-the-art and so present no threat to the ship or dock.

Fixed docks, on the otherhand, must resist the full effect of earthquakes. The record to date shows that we have very little to worry about. Large, flat-bottomed ships just slide slightly. Overturning forces seem to have been well enough resisted by side block support. The accelerations expected during an earthquake vary from 0.2 G up to 0.6 G. If the aspect ratio of the blocking is about 2 to 1 (vertical to horizontal) there is little risk of block instability. It does require the blocking to be sound and adequate.

In 1974, NAVSEA issued their first version of the MIL-STD-1625. It was very controversial and severely criticized by the industry, resulting in a major revision "A" issued in September 1976 and presently in effect. Even now a "B" revision is expected to be issued at the end of 1984 which attempts to improve the earlier restrictions.

Because many commercial docks date back to 1918 and 1942, waivers had to be given which will remain in effect as long as the dock in question continues in use with the same owner at the same site. Each new dock at the time of certification must meet whatever version of the standard was in effect then.

What does this all mean?

First, it is NAVSEA which will determine the capacity and issue the certificate, not any engineering consultant.

No new floating docks can be built of timber and meet the code. Even floating docks made of concrete are almost impossible to be made to meet the code.

The portion of the MIL-STD dealing with floating dry docks, which are totally under NAVSEA jurisdiction, seems to present the greatest problems, and the most severe trouble is in the domain of damage stability. But we can always design a new dock to meet the code and since all existing docks either meet the "A" version or were granted waivers earlier, it is not that significant. If a dock should actually list 15 degrees with a capacity ship as presently called for, the vessel would slide off and smash the dock.

There are still requirements which must be modified to be realistic and reasonable without jeopardizing the vessel safety.

The United States private shipyards should welcome the demand that their docks be properly certified for their own protection. Countless times we have found docks in poor condition which would never have been restored if the certification program had not been imposed.

But it is a serious mistake to think the certification is a cure all. The greatest weakness lies in the ability of the docking crew. And occasionally the Navy itself has had inadequate, inexperienced personnel.

Presently NAVSEA is certifying dry docks for total capacity without specifying the load per lineal foot limits. Since the CG47 and the DD963 ships have stern knuckle loads far exceeding the average, this demands that the dock must have a total capacity two to three times the actual ship weight.

As an aside, all reference to certified tonnage must be that weight which the dock can carry. Any reference to deadweight is not correct since it is a unit of volume where 100 cubic feet of cargo space is rated as a ton. This confusion has caused trouble many times, especially when we are seeking vessel light weight and the only data is net or gross registered tons.

We firmly believe it is imperative, particularly for marine railways and ship lifts, that their capacity per lineal foot be specified in the certification.

For about 100 years, Crandall Dry Dock Engineers, Inc. has used the basic linear equation of $P/L + M/S$ to establish a rational trapezoidal weight diagram for vessel load distribution. This method has the advantage of being easy to compute once the ship's drafts are known and the LCG and total weight ascertained from the docking plan data and hence can be legally used to compute a reasonable load concentration.

Now we agree that our linear assumption is not a perfect answer, but if the dock in question is required to have its blocking capable of 100% overload without exceeding the yield strength or the elastic limits then this blocking can transmit the peak loads to the supporting dock floor where the prime function is to carry the total ship weight. The attached sketch shows an envelope of the various peak loadings a typical ship might exert versus the lineal distribution. For floating dry docks, as long as the dock LCB can be made to be equal and opposite to the vessel LCG by differential ballasting, the vessel can be safely lifted provided the total displacement available is equal or greater than the total weight.

It is only critical with ship lifts that the hoists, cables and beams must carry the peak intensity since the platforms have little or no stiffness for longitudinal load transfer. Already ship lifts have had failures due to load concentration and there have been blocking failures for the same reason in basin docks and railways.

At present there is some controversy regarding the actual load intensities of a modern warship on the blocks and people are doing computer analysis and testing to endeavor to know more precisely what to expect. Most of this work is almost useless because they have no data on the straightness of the ship due to its original construction, its variation in loading, the thermal effects and the opposing uplift of a dock with differential pumping.

For years the U. S. Navy has used 20 long tons per square foot as their criterion for block pressure. This is equal to 311 lbs./sq. in. Recent tests of oak in side grain loadings shows the elastic limit in compression to be about 700 lbs./sq. in. Therefore any dock designed to carry a ship assuming the linear load distribution with block pressure not exceeding 20 long tons per square foot is perfectly capable of supporting local load intensities due to overhang, hog, sag, or keel irregularities as high as 45 long tons per square foot.

Therefore we recommend that the MIL-STD-1625B contain a requirement of a load per foot limit for all docks based on a calculation of load by the equation as follows:

$$\text{Load per ft.} = \frac{\text{vessel wt.}}{\text{bearing length}} + \frac{\text{vessel wt.} \times \text{eccentricity} \times 6}{(\text{bearing length})^2},$$

or for cases where eccentricity exceeds $\frac{\text{bearing length}}{6}$:

$$\frac{2 \times \text{vessel wt.}}{2 \times \text{bearing length}}$$

In this way any naval architect can readily compute the load concentrations to confirm if they exceed or not the certification given by NAVSEA.

Military certification by NAVSEA has often been a case for existing docks of reducing capacity below that for which a dock was built, but to date it has only been for total capacity with no restrictions as to tons per lineal bearing. And since no specific method of load concentration computation is called for, it is still an easy matter to overload a vertical lift dock, railway dry dock, or floating dry dock with a warship having a short and undercut keel.

The way a ship is placed and supported on a dock can greatly change its load distribution and therefore whenever a capacity vessel is under consideration for docking, a careful review of all conditions by a qualified engineer can make an enormous difference in the success or failure of the docking. This has become an important demand which not only avoids serious trouble but also frequently enables a yard to dock a vessel it previously considered to be unsafe.

We have seen many times when a shipyard with a dock adequate to lift a vessel in light condition was denied or stricken from the bidders list because the ship weight was for fully loaded condition. It would seem logical for the various SupShips offices to be given a reasonable listing of light weights based on displacement and drafts with only those loads that have to be left on board and that the full load only be used for emergency dockings.

For those concerned with grounding stability as a vessel is lifted on the keel blocks alone, a good rule of thumb is that negative stability will not occur so long as the vessel's center of gravity is not raised more than 75% of the floating transverse G.M. A dangerous condition is when the ship is raised too high with the flat keel providing some added stability which then can trigger a falling over if and when some vessel list is induced which exceeds the keel bearing stability.

A good dock in the hands of an inexperienced crew is more dangerous than a mediocre dock in the hands of a skilled crew. The dockmaster must have good understanding of ships and ship handling as well as docks and dock handling. He must know how to compute vessel weight and load distribution and how this relates to the dock and dock blocking. He needs to have available engineering support to confirm his own judgment whenever in doubt.

In general, the certification by MIL-STD and the classification society surveys every five years or less provide the essential maintenance protection, but the safety of the ship is still 90% in the hands of the dockmaster and his crew.

APPENDIX

TYPICAL DRY DOCK ACCIDENTS

Ira Bushey, Brooklyn, New York	<u>Anton Brun</u> rolled over in 5000-ton dock due to valve leakage.
Hoboken, New Jersey	<u>Oslo Fjord</u> rolled over.
Lunenburg, Nova Scotia	Corvette <u>Sackville</u> fell off cradle blocks and ran away. The dock was ruined.
Marystown, Newfoundland	Vertical lift dropped vessel with serious damage to vessel and dock
Vancouver, British Columbia	Vertical lift failed to lift heavy tug due to severe load concentration.
New Orleans, Louisiana	Tried to haul 1200-ton vessel on 500-ton railway causing foundation collapse.
Norfolk, Virginia	Truss top chords of floating dry dock broken by use of fixed bilge blocks demanded by Navy inspectors against normal dock procedures.
Mobile Alabama	Reaction overstress on dry dock when undocking due to seaweed invasion and the inexperience of the assistant dockmaster.
Oyster Bay, New York	360-ton river tug <u>Esso Maryland</u> went through cradle of 500-ton dock; this was caused by incorrect load distribution assumption.
Baltimore, Maryland	<u>Moormac Penn</u> rolled over due to instability and excess displacement of ship.
Seattle, Washington	YFD-23 took 14 degree list with <u>CGT Renaissance</u> due to incorrect data in operations manual; \$3,000,000 law suit for demurrage.
Sydney, Nova Scotia	<u>Bedeck</u> rolled over due to ballast removal when refloated.

Shelburne, Nova Scotia	1900-ton drill rig service vessel had skeg go through blocking of 3000-ton marine railway dry dock due to incorrect load distribution analysis, i.e., none at all.
Erie Basin, Brooklyn, New York	10,000-ton to 12,000-ton MSC vessel <u>Range Sentinel</u> fell off 8' high timber blocks in basin due to inadequate block stability and pushed keel 12" into hull.
Pascagoula, Mississippi	Dock broke due to unauthorized structural changes and dockmaster errors.
Rockland, Maine	Leaking timber barge emergency-docked on inclined railway collapsed cradle and blocking two hours after successful haul due to interior water flow through leaky bulkheads.
Trincomalee, Ceylon	Admiralty Floating Dry Dock No. 23 sank out of site and ruined HMS <u>Valiant</u> in its second drydocking in 1942.

TYPICAL SUCCESSFUL, DIFFICULT DOCKINGS

NORSHIPCO
Norfolk, Virginia

Pioneer Mill cut on old timber dock and jumboized by careful analysis and good engineering control.

Lockheed Shipbuilding
Seattle, Washington

Huff dock lifts Polar Star with special poppet and stern support. Critical destroyer tender with 42' VK6G docked by very careful procedure and analysis.

Atlantic Dry Dock Corporation
Ft. George Island, Florida

FFG-7 docked 9' above cradle deck using original 15' high bilge blocks. Very well rehearsed operation.

Avondale Shipyard
New Orleans, Louisiana

Docked a very unstable vessel by 40' drag of dock for parallel grounding.

Port of Portland
Portland, Oregon

Docked Glomar Explorer 12' above deck with no keel blocks for extensive length.

Pennsylvania Shipbuilding
(formerly Sun Ship)
Chester, Pennsylvania

At Chester, the Manhattan was enlarged with new bow by using a separate bow section. Skilled operation by Captain Ferrell.

Electric Boat
General Dynamics Corporation
Groton, Connecticut

3300-ton Sea Wolf docked on 2500-ton CRANDALL railway with success by careful analysis and control.

DRY DOCK FACTORS OF SAFETY

In general, factor of safety is defined as $\frac{\text{Ultimate Load}}{\text{Working Load}}$

However, the critical factor for dry dock safety $\frac{\text{Load at Yield}}{\text{Working Load}}$

I shall call this Factor to Yield.

We can approximately list these as follows

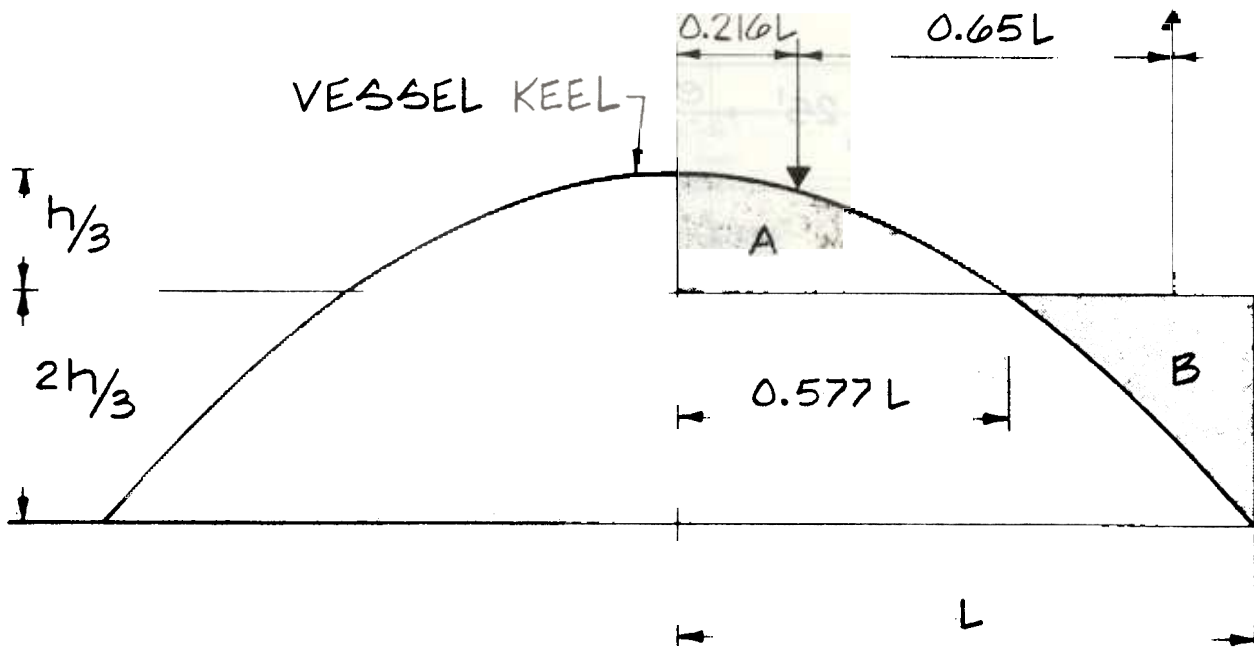
	<u>Factor of Safety</u>	<u>Factor to Yield</u>
Graving dock floor	3.5	1.8
Graving dock pile foundation	2.0	1.
Marine railway cradle steel	4.0	2.0
Marine railway hauling machine	4.0	2.0
Marine railway chains*	2.6-4.0	1.3-1.8
Marine railway pile foundation	2.5	2.0
Vertical lift platform steel	4.0	2.0
Vertical lift hoist and cables**		
Vertical lift pile foundation	2.0	1.5
Floating Dock in steel***	4.0	1.5-2.0

* Lower range for cast steel chains. Higher range for welded ORQ chains.

** Load cells used to limit maximum loads.

***Total uplift restricted by displacement. Factor to yield dependent on plate stability for local loadings.

PARABOLIC VESSEL KEEL DUE TO HEATING



h = KEEL DEFORMATION DUE TO HEATING

$A=B$ = REACTION CHANGE FOR ELASTIC BLOCKING

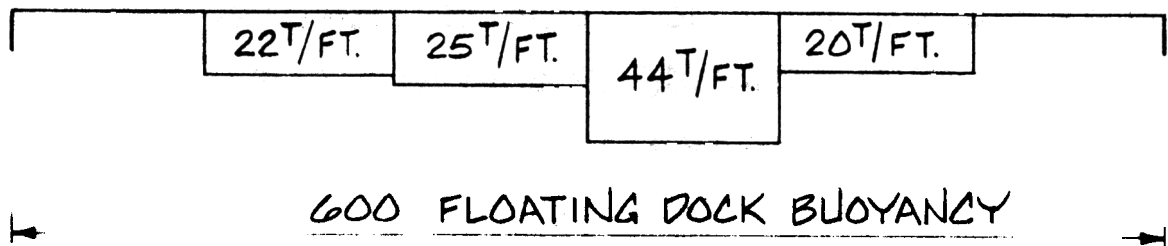
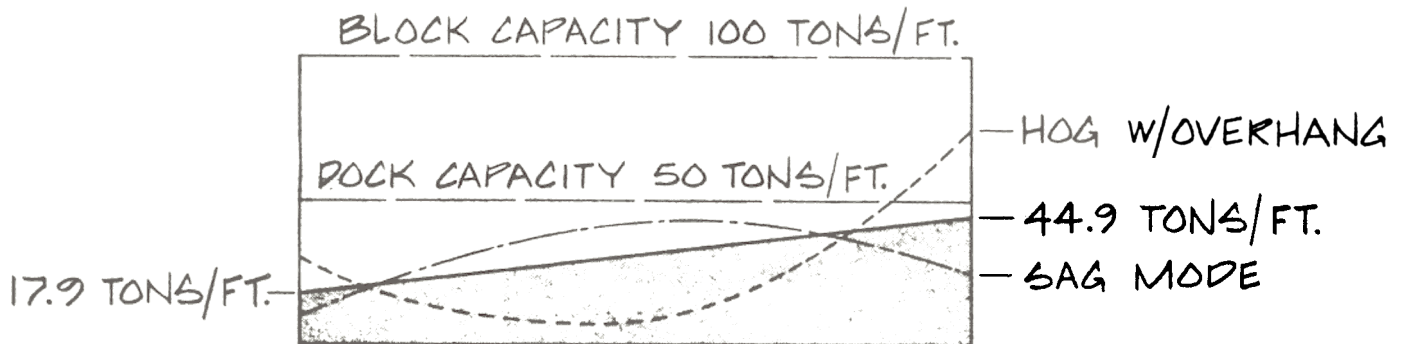
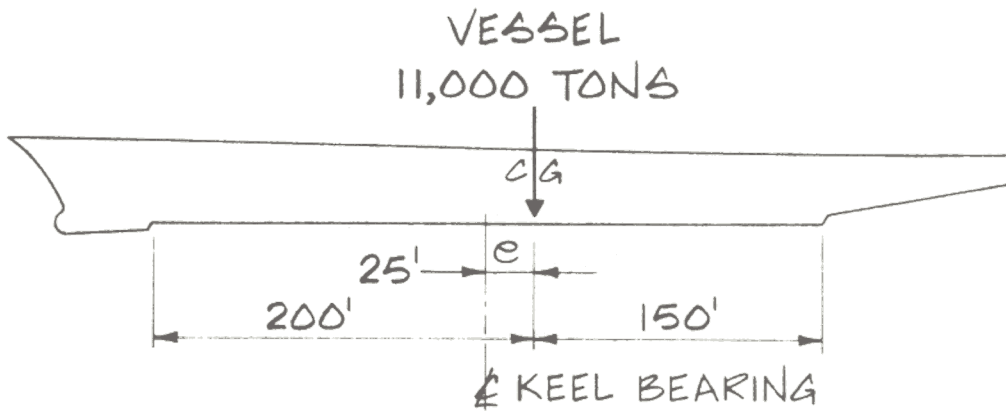
L = HALF KEEL BEARING LENGTH

MOMENT AT SHIP $\& = A \times 0.65L$

A - REPRESENTS A REDUCTION IN BLOCK PRESSURE

B - REPRESENTS AN INCREASE IN BLOCK PRESSURE

VARIATIONS IN LOAD DISTRIBUTION



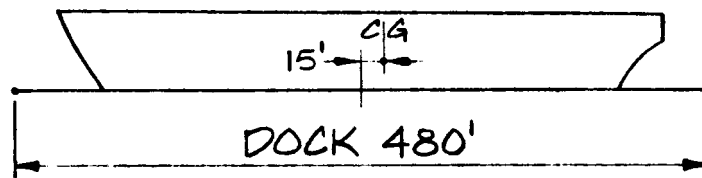
THE FLOATING DOCK STRUCTURE IS PERFECTLY CAPABLE OF DISTRIBUTING THE VESSEL LOAD TO THE WATER BUOYANCY.

NOTE: A DOCK OF ABOUT 30,000 TON LIFT IS NEEDED TO DOCK THIS 11,000 TON VESSEL

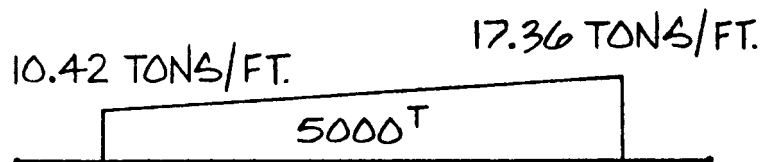
COMPARISON OF DOCK REQUIREMENTS TO DOCK
5000 TON LIGHT SHIP WEIGHT

ASSUMPTIONS~ TOTAL WEIGHT = 5000 LONG TONS
 KEEL BEARING LENGTH = 360'
 ECCENTRICITY LCG TO KEEL MIDLENGTH = 15'
 VESSEL LOA = 420'

VESSEL
DIAGRAM



VESSEL
LOADING

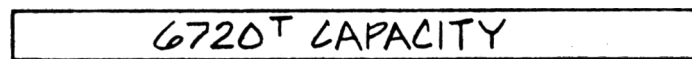


BASIN
DOCK



17.5 TONS/

FLOATING
DOCK



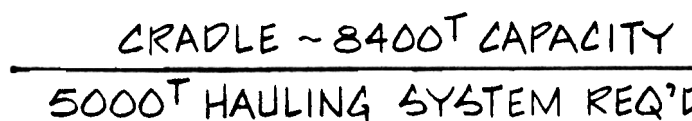
14 TONS/FT.

VERTICAL
LIFT



17.5 TONS/FT.

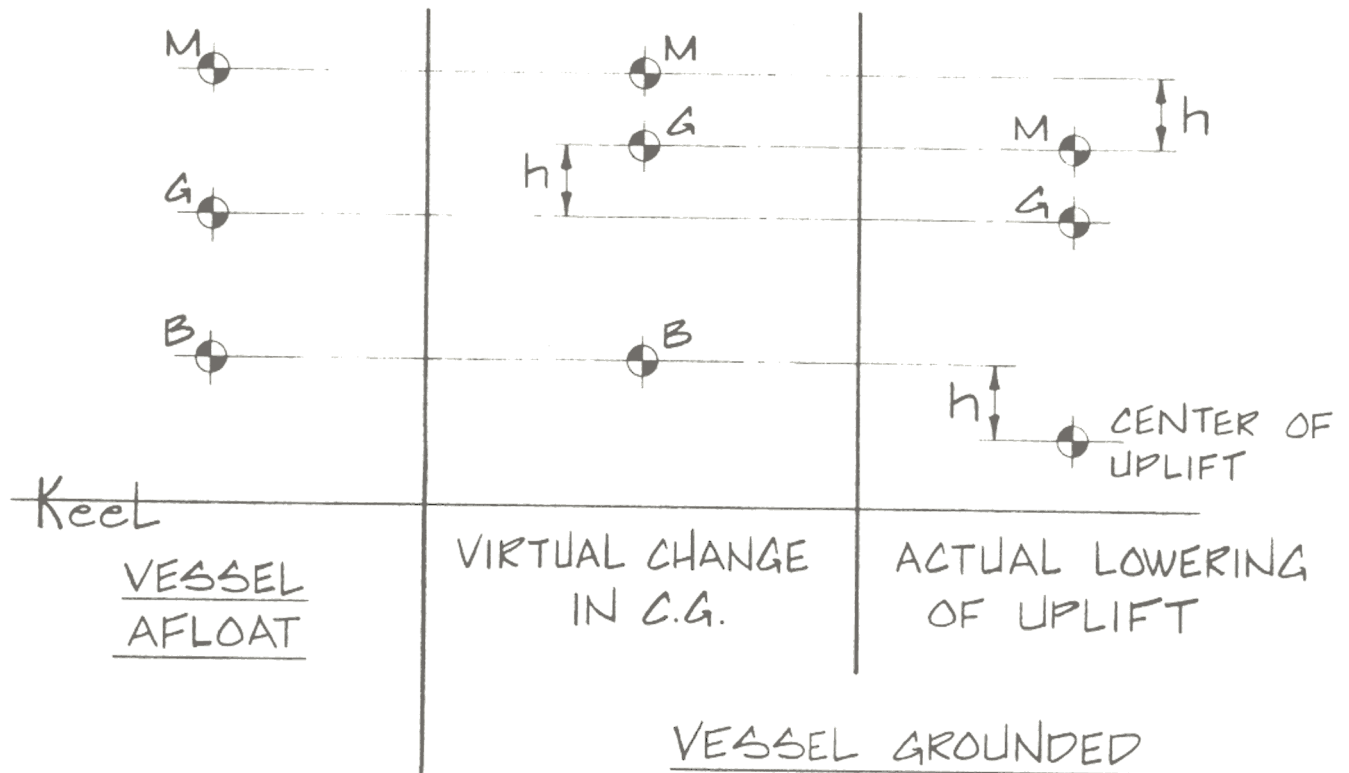
MARINE
RAILWAY



17.5 TONS/FT.

GROUNDING STABILITY OF SHIPS

ASSUMING HINGED KEEL BEARING



- BM \checkmark REMAINS ALMOST CONSTANT
- M METACENTER
- G CENTER OF GRAVITY
- B CENTER OF BUOYANCY OR UPLIFT
- h REDUCTION OF STABILITY