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Large Floating Dry Docks for Large Ships

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Advances in floating dry docks and transfer systems enable the floating docks to meet new needs of launching and repairing the very large vessels so important in today's shipping, as demonstrated at several U. S. yards. At most sites, floating dry docks are competitive economically with both basin dry docks and shallow basin building docks. They can be designed to handle as large ships as necessary, are relatively expandable, can be sold and moved, use free water space instead of valuable real estate, and can assume controlled drag and list. They can be built in two sections to give the versatility of independent use and so improve the duty factor. With modern transfer systems, floating docks offer a convenient way to build in the yard and safely launch into (or retrieve from) the water. Steel docks with present-day hull protection should serve efficiently for 50 years or more, an acceptable period in view of ever-changing industry needs.

Introduction

VAST CHANGES have taken place in worldwide shipping during the past 15 to 20 years. We have seen the gradual disappearance of the once proud passenger liners and the great battleships of recent wars. In their place we see mammoth oil tankers drawing as much as 75 ft of water when loaded, containerships with cargo stacked up high, nuclear submarines heavier than many cruisers, and weird surface-effect craft which weigh very little but which draw considerable water. Now the LNG ships and LASH ships are being built to carry enormous volumes of cargo with dimensions very different from those of previous ships.

So our shipbuilding industry and our ship repair plants have to provide the means to build and maintain the new fleet. The need has caused the engineering profession to seek new ways of building, launching, and accommodating the new ships.

This paper is concerned with the large floating dry dock as one very attractive solution to the needs of the maritime industry for ship launching and ship repair.

Background

In spite of laudable efforts being made to cut down on the need to drydock ships, it is still considered a necessity by the shipping and insurance industries that all ships, large or small, go into dock from time to time for inspection, repair, or hull painting.

Smaller vessels have a multitude of docks to accommodate them, but the very large modern ships find few repair docks large enough or deep enough to take them, especially if they are carrying cargo, as may be the case with container vessels.

In the past, ships were built on inclined launchways, which were very economical and fitted quite well the methods of construction of that time; also, the loadings were reasonable. Places like the Clyde, St. Nazaire, Dunkirk, San Diego, and Chester, Pennsylvania are still finding the inclined ways adequate, although the sizes of the vessels they are building are at about the limit for this method. The huge ships of the modern age, both naval and commercial, are seldom built on launchways, since it has been found that costs and risks are too great and that there are limitations of crane access at the head end of the built-up ways. For these and other reasons, both the U. S. Navy and commercial shipyards developed building basins of shallow draft for ship construction and launching by simple flotation.

For the most part, these large basins have been built of the pressure-relieving type, as we see at Bremerton, Washington (U. S. Navy), Quincy, Massachusetts (General Dynamics), and Sparrows Point, Maryland (Bethlehem Steel). An early one, which was abandoned over ten years ago, was built by New York Shipbuilding Company at Camden, New Jersey.

With the continued demand to get more docks of large size in service and because of many limitations inherent in the basin dock concept, several shipyards have gone ahead with the construction of large floating docks beyond 30,000 tons lifting capacity (Table 1). These yards are the pioneers in exploring the suitability of the floating dry dock approach toward solving the pressing problems posed by the rapid increase in average new-ship size. Actually, there is no fundamental reason why steel floating docks cannot be built to lift the largest ships afloat.

What, then, has limited the use of large floating dry docks, and why are we seeing more being constructed today? The answer to the first question, briefly, is in several parts: In the past, costs for labor and material were such that basins were usually cheaper, especially for the sizes needed; floating docks were made of timber, and available sizes were limiting; transfer systems had not been sufficiently developed, so the build-then-launch procedure had not been perfected for the floating docks; and, at least in Norway, the material quarried from a basin dock site was a very valuable by-product! Today there are more and more large floating dry docks because some of the foregoing negative factors have changed, including the relative cost situation for docks for large ships, and because the floating dock offers versatility, ease of enlargement, and the practicality of being relocatable.

When a new dry dock facility is contemplated—

If a basin dry dock is being considered, the geotechnical factors are vital and may make the project either attractive or undesirable. We have recently been doing a preliminary study for such a dock, where exploration of the actual subbottom

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conditions revealed that construction costs would be much greater than those initially assumed.

Natural harbors in North America, except for Puget Sound and Halifax, are generally of shallow draft compared with those in the Mediterranean and the Pacific. This has meant that dredging would be required for a deep berth to permit a large floating dock to submerge; dredging is costly and nowadays involves environmental restrictions. In such cases there may be a preference for a basin dock, having a lesser depth requirement.

In recent years, the shallow-depth problem has been partly overcome, however, by making the floating dry dock capable of translating away from its berth to deep water a few hundred feet out for submergence. The deep water may be a natural condition, as at Halifax Shipyards or Avondale Shipyards at New Orleans, or a dredged pocket as at Litton Shipyard at Pascagoula, Mississippi.

In any case, an important economy is that shallow berth bulkheads are far less expensive than deepwater bulkheads, and sometimes major environmental disturbance by deep dredging is avoided.

In cases where the water is very deep adjacent to shore, then the floating dry dock becomes an ideal solution and it is even possible to build the dock with prestressed concrete pontoons instead of steel to reduce maintenance costs and use of critical materials. Such docks have already been designed to lift tankers of 80,000 tons light weight (corresponding to deadweight tonnage of up to 350,000 tons) using the composite concrete-pontoon, steel-wing concept, with the cost about equal to or slightly less than for all-steel construction. The limiting factor is that pontoon depth must be much greater than for an all-steel dock, so that only a deep berth can take the dock.

Shipyards may be devoted strictly to new vessel construction or entirely to ship repair. The fortunes of business, however, suggest a combined capability so that the plant can concentrate on new construction and switch to conversion and repair when the market so demands.

A dry dock used to repair operating ships, which usually are carrying some supplies, fuel, etc., must have a draft over blocks at high tide significantly greater—perhaps of the order of 20–30 percent greater—than that required for a dock used only for shipbuilding and launching, where the ships handled, not yet fully equipped, will draw correspondingly less water. Structural requirements make the total cost of a basin dock increase approximately as the square of the depth; greater depth of a floating dock, on the other hand, results principally in a need for increasing the height of the wings, so that the total cost (which includes the pontoon) is less than linearly proportional to the capacity. Thus, although shallow basins are still often economically practical for shipbuilding, deeper ones needed for repair, particularly of some of today's ships with deep draft, are in general no longer competitive with floating docks having similar capabilities.

Fear of "political" considerations may influence the selection of a dock system—a basin is permanently fixed and cannot be taken away, as can a floating dock, for reasons of national emergency or in payment of debts.

More often, however, the floating dock's mobility is an important plus factor. The dock can be moved operationally, as from shore berth to deepwater position; it may be moved to serve more than one berth; and, most important, it can be sold when no longer needed, to be relocated at another yard with no loss of usefulness or value. Investment in a floating dock, then, can be recovered.

As a free but controlled floating body, the floating dry dock is also able to take a drag and list matching those of the vessel to be lifted. This ability precludes the need to ballast and deballast the ship for docking.

The mooring of large floating docks capable of assuming variable attitudes when submerged requires two-point statically-determinate attachment with adequate bearing for wind and current forces. The old-type spuds result in very poor structural attachment and are not recommended. Articulated ball-and-socket connections as used by Sun Shipbuilding & Dry Dock Company at Chester, Pennsylvania, or the GHH design with rubber pads in a square frame against a large steel cylinder, are considered the most suitable for large docks. If proper rubber mountings are used, the flexibility of such moorings is ideal in the case of earthquakes, since dock acceleration can be held as low as 0.1 g when ground acceleration is as high as 0.6 g.

The basic nature of a floating dry dock results in another important advantage. Dry docks for large ships are bound to occupy a substantial area. Real estate along the waterfront is very valuable, especially if the shipyard is confined to a narrow harbor frontage as we see in many instances. These conditions cause planners to endeavor to reach out into the harbor itself for the additional real estate required, as at Sparrows Point, Bremerton, and elsewhere.

With large floating dry docks in United States harbors, we find an interesting advantage in that they are considered to be floating vessels and are therefore allowed to occupy water space in navigable waters. This concession is based on their ability to be moved out of the way whenever the navigable

Table 1 Dimensions of large floating dry docks

Dock	Length over Pontoon	Pontoon Cross Section	℄ to ℄ Clear Width	Lifting Capacity 12" Freeboard	Remarks
Sun #3	782'	172' × 16'	140'	44,000 T	One Piece
Sun #4	700'	229' × 21'	197'	70,000 T	2-350' Sections
Bethlehem S.F.	800'	186' × 20'	150'	60,000 T	One Piece
Litton	960'	212' × 24'	180'	57,000 T	Rennie-Removable Wing for Side Transfer
Avondale	900'	260' × 32'	220'	81,000 T	One Piece Side Transfer
Genoa *	1000'	265' × 40'	215'	100,000 T	Concrete Prestressed
Jacksonville	770'	180' × 16.5'	144'	33,000 T	GHH One Piece
Maryland	770'	180' × 16.5'	150'	39,000 T	GHH One Piece

* Under Construction

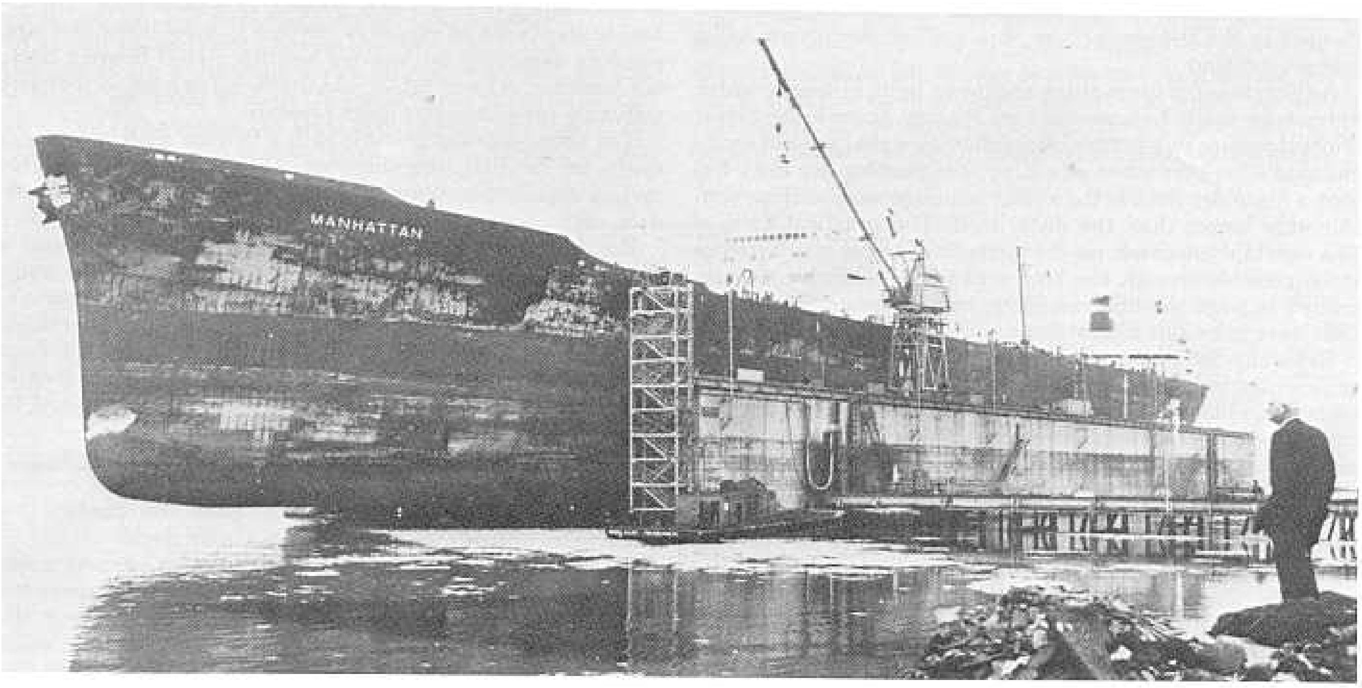

Fig. 1 *Manhattan* photographed in Sun floating dry dock, showing forward overhang

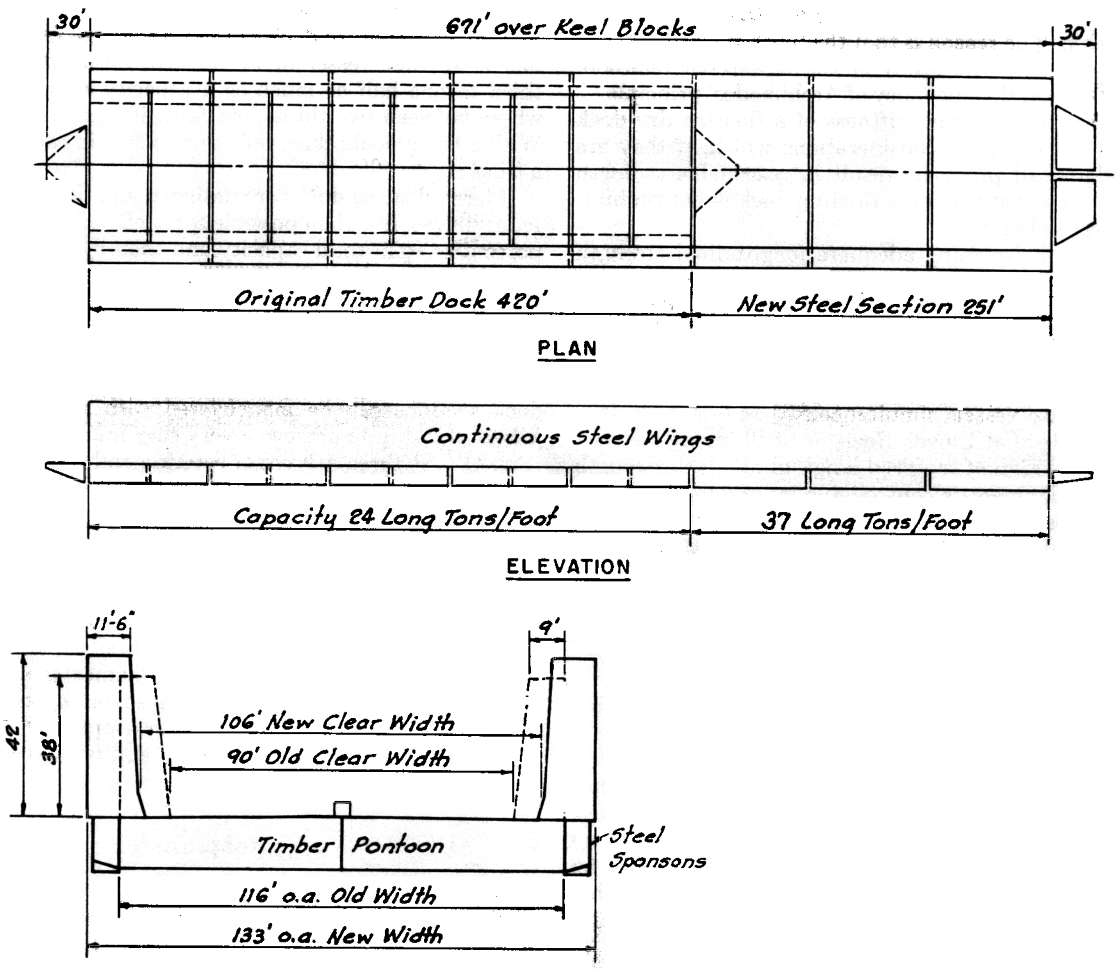

Fig. 2 Floating dry dock before and after enlargement

area is to be dredged. Sun has taken advantage of this to moor its dock in the Delaware River, thus adding over 3 acres to its operational land.

Although many large ships are being built in basins which are not too costly because they are shallow, there is the threat of obsolescence due to the fixed dimensions that are not easily changed. One very great advantage the floating dry dock has over a basin dry dock is the ability to accommodate ships considerably longer than the dock itself. The practical limit of this capability depends on the strength of the ship. There has to be possible enough blocking area to keep block pressures limited to what the hull can carry, and the unsupported ship ends have to be able to cantilever without undue strain.

Generally the shape of a ship lends itself very well to being sufficiently supported along its fullest cross sections, where many bilge blocks and even several rows of keel blocks can be used. The bow and stern extremities, being sharp, can only be carried economically by centerline keel blocks. In this way, adequate blocking area is possible, even in a short dry dock.

The ship overhang beyond the end keel block can extend about one and one half times the girder depth of the ship (main deck to keel), with low stress amounting to about 5000 psi. This seems reasonable when one considers the much greater hull stresses experienced by the ship at sea, where dynamic conditions make the stress even worse and the ship may be carrying four to five times its own hull weight in cargo. The *Manhattan* (Fig. 1) was lifted with 97 ft of overhang, and an LHA with 132 ft of overhang forward.

With a floating dry dock, ship overhang cannot cause a severe block pressure on the extreme blocks, especially if the dock has much less longitudinal stiffness than that of the overhanging ship. The reason is that the block pressure is controlled by the hydrostatic uplift of the dewatered pontoon, which cannot exceed the buoyancy of Archimedes' principle.

The degree of longitudinal stiffness of a floating dry dock ties in with other strength considerations which, if they are analyzed and viewed properly, result in reasonable strength requirements such that the large floating dock is not prohibitively expensive to build.

The question of designing adequate longitudinal strength for a floating dry dock is often raised. There are two schools of thought: one favors strong and rigid docks; the other, very flexible and sometimes disconnected sections. Actually, the only conditions which require strength are towing at sea, and docking damaged vessels, vessels with very irregular weight distribution, or two vessels simultaneously on one dock. It is interesting to note that Lloyds Register of Shipping has just announced a reduction of required longitudinal dock strength provided wing alignment is controllable by variable dewatering of dock compartments. This change is for docks exceeding 40,000 tons capacity, where the old rules would make the section modulus requirements extremely heavy and uneconomical.

A basic consideration in the longitudinal strength of a floating dry dock is the relative stiffness (moment of inertia) of the ship and the dry dock.

This can also be considered on the basis of the relative depth of the dry dock as a girder and the ship structure as a superimposed girder. For very large ships as, for example, the *Manhattan* in the one-piece No. 3 dry dock at Sun, the ship had a stiffness from five to ten times that of the dry dock and a girder depth ratio of about 2 to 1. Therefore, one can say with no hesitation that a capacity ship in dock will always be overstressed long before the dock is at maximum allowable longitudinal stress. (Proper deballasting, however, can and should be used to keep stresses reasonable.)

There is a characteristic of steel floating docks that is useful in holding block pressures at acceptable values. A steel ship will hog or sag because of temperature changes when exposed to sun heating or radiational cooling. In a basin dock, this behavior may cause an excessive increase in some block loadings, possibly damaging the vessel's hull. In a steel floating dock, the tendency is for the dock and the vessel to bend in the same way, thus relieving extra block pressure.

The ship overhang possible with a floating dock not only is useful for handling long ships but is also sometimes useful for certain repair operations, such as removing or installing rudders, etc.

Besides coping with excessive ship length by overhang, a floating dry dock can very easily be lengthened by the addition of more sections; several yards have done this (for an example, see Fig. 2). This approach results in another interesting and economically useful practice, that of building the dock initially, for example, only two-thirds of its ultimate length, with later sections to be added when the need arises and financing permits.

A floating dock can also be modified fairly easily to accommodate vessels of greater draft, and within limits it is often possible to increase its clear width. Such size changes are much more difficult to carry out with a basin dock.

Starting with a facility big enough to meet current needs and having the possibility to expand makes good economic sense. There is another economic consideration where the floating dry dock shows up well. A dry dock, like any other equipment, must be utilized as many days as possible per year. It is not generally considered a profitable operation in itself but rather a necessary device to enable ships to be repaired. It is ship repair and construction which is the prime source of income.

Since docking charges are proportional to vessel size, it is further important to dock as large a *tonnage* per year as possible. A smaller vessel to be docked, although weighing one third to one half as much as a capacity ship, may be somewhere between two thirds and four fifths as long as the dock. With a basin dock, then, only one such ship can be handled at a time.

If large floating docks are designed and built as two autonomous halves, it is then possible for each half to lift a ship of 30 percent or so of total capacity and thereby make much better use of the large dock. This requires that the two halves be separated to accommodate the large vessel overhang which takes place (Fig. 3). Some shipyards also find the idea of two equal halves very useful when cutting or jumboizing ships or to enable transfer from shore of one half of a ship. Then the two dock sections can be maneuvered with their superimposed halves of a ship to achieve a very easy hull welding amidships (Fig. 4). The three degrees of rotation and translation possible with two floating bodies has proved very valuable for joining ship sections. Here is a feature which cannot be duplicated on a land slab or in the bottom of a basin dry dock.

Whether the whole dock or a part is used for a small ship, the floating dock has the advantage that operational costs (pumping energy) are proportional to vessel weight, rather than the inverse, as is true of basin docks.

With respect to operation, the dockmaster and crew of a large floating dry dock probably need more skill than those docking ships in a basin. This is not a problem if the dock is well designed and has adequate stability, operating curves, and good water-level controls.

Vessel transfer

The concept of building a ship in a flat area above sea level with no major restrictions of width, length or depth, where vehicles, cranes, and personnel can move in any direction without having to go up or down, and where only horizontal translation is needed to join ship modules, is most attractive for new construction. Also, if major ship conversions can be made in a similar manner, important savings can be realized.

The only requirement to make the foregoing conditions possible is a means of lowering a ship into the sea—and, for conversion, of reversing so as to lift a ship out of water up to yard elevation. This process has been very successfully carried out for over 50 years with marine railway dry docks of up to 8000 tons capacity. The Marine Industries Limited shipyard at Sorel in Quebec Province is our best example of this concept, where six acres of flat storage area on each side of their 90 by 420 ft cradle is used to build, convert and repair vessels all year round. It has been operating this way since 1942. The railway is capable of lifting ships 16 ft above low river stage.

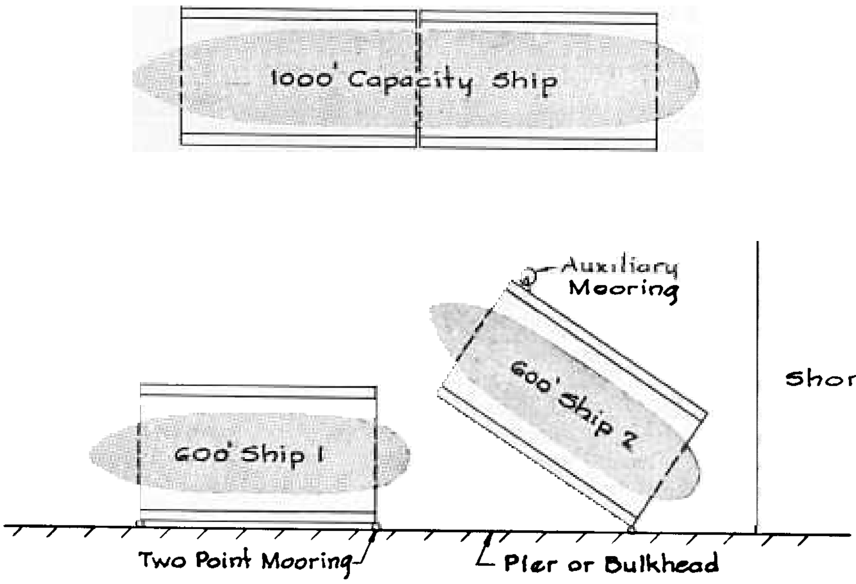

Fig. 3 Method of docking longer vessels on halves of the dry dock

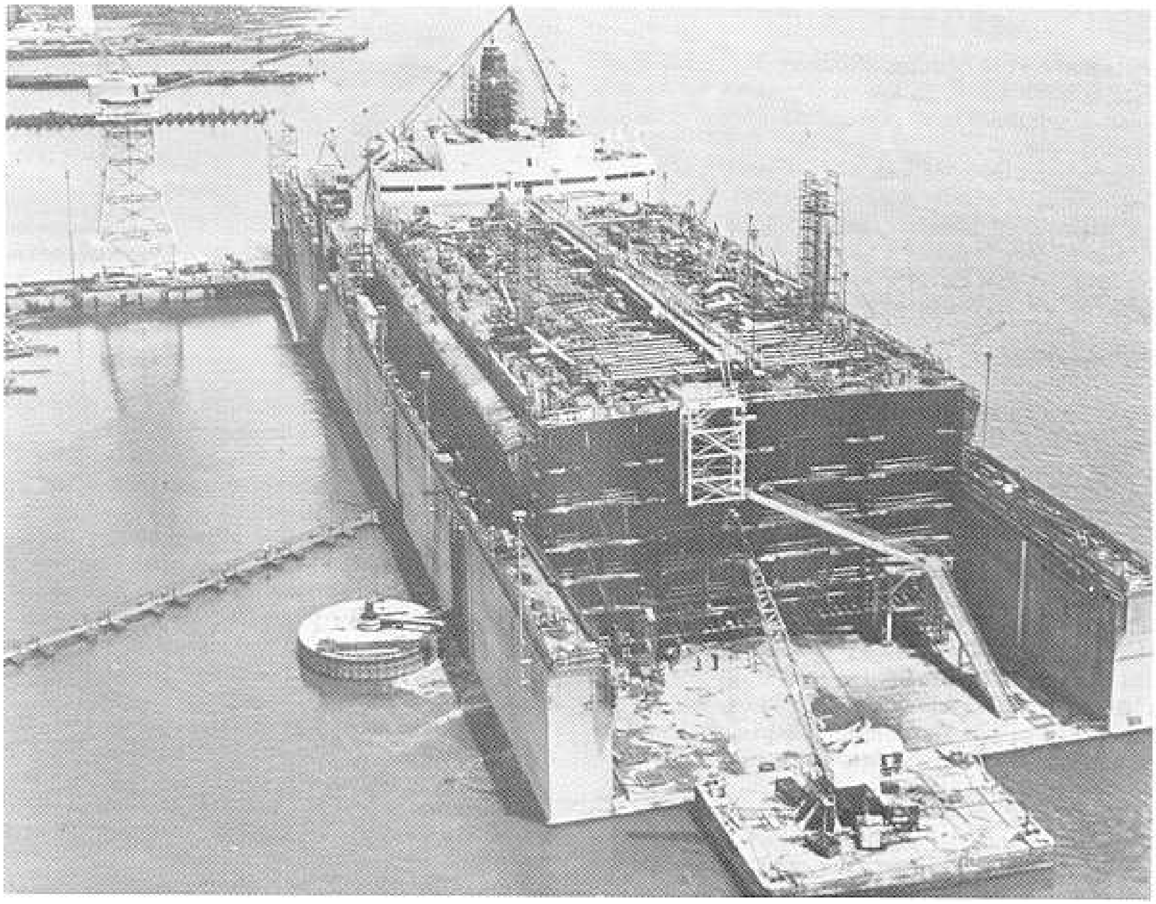
Fig. 4 *Manhattan* photographed on Sun floating dry dock before addition of new bow section

The weight of very large ships far exceeds the mechanical lift capability of marine railways or vertical ship elevators. Only the floating dry dock or basin dry dock can be used to accommodate them.

If a basin is used to do lifting it must be constructed with super flood capability, which is generally practical for only 5-ft to 10-ft lift at the most, often inadequate for a flat yard area facility.

The floating dry dock does achieve a major lifting, which can be made as much as 10 to 15 ft above water surface. The principle has been used by Maryland Shipbuilding & Drydock Company at Jacksonville and Baltimore, by Norfolk Shipbuilding & Drydock Corporation, and by Litton at Pascagoula with great success, and large floating docks have recently been put into service at New Orleans and Chester.

The floating dry dock for such uses must have its pontoon several feet deeper than that of a standard dock to provide the extra freeboard required to reach yard elevation at lowest water level. The alternative solution has been to build up the transfer ways on the deck of the pontoon to reach yard level, but in such cases the vessel being transferred must be substantially less in weight than the dock capacity for reasons of stability and limited submerged draft.

Since new vessels are generally launched long before their completion, their launch weight may be less than 75 percent of completed drydocking weight. Therefore it is very practical to use a floating dry dock to launch a vessel, taking advantage of the relatively great freeboard, and later to drydock the same vessel, now heavier because completed and outfitted, with normal freeboard.

A number of shipyards can use their dry docks to transfer and launch ships of only 15 to 40 percent of the dock lifting capacity because the launch system design requires so much freeboard as to be limiting. Litton's system at Pascagoula was designed to take advantage of a large fraction of the dock's capacity (Fig. 5).

The incremental cost of building a floating dock with transfer capability is quite small, as low as 5 percent where tide ranges are very small or up to 20 percent for modest tides and higher yard elevations.

When a ship reposes on a flat area, crane service is almost as easy as from the side of a basin dock, except that more gantry frame height is required to reach the top of the superstructure. Crane service to a vessel in a floating dry dock is not so good, but, on the other hand, it is less important, since adequate crane access can be provided at pierside after the ship is launched.

A transfer system served by a floating dry dock can be of several types and arrangements, depending on the site geometry, the ship-building process, and the waterfront space.

The vessel transfer can be done longitudinally, where the dock wings remain in place and the dock is designed symmetrically (Figs. 6 and 7).

Another possibility is sideways transfer (Fig. 8 and 9), in which the dock wing must be removed from one side and the pumping and flooding all done from the opposite side. This arrangement causes some inconvenience in operation but is sometimes better suited for a facility on a river.

In either case it is possible to have one dock serve several shore berths or to have a more extensive two-way translation system on land, or even a combination of these capabilities.

Our studies have shown that simple, direct transfer is the most economical. Two-directional transfer uses an inordinate amount of space and so should be avoided for large ships.

For actually moving large ships, there are three basic devices in common use, namely, grease, wheels, and free rollers. Sliding on Teflon is a possible way, but not practical for the application.

The least expensive capital investment is grease, but this entails large translation forces to overcome friction of from 4 to 20 percent of the load being moved.

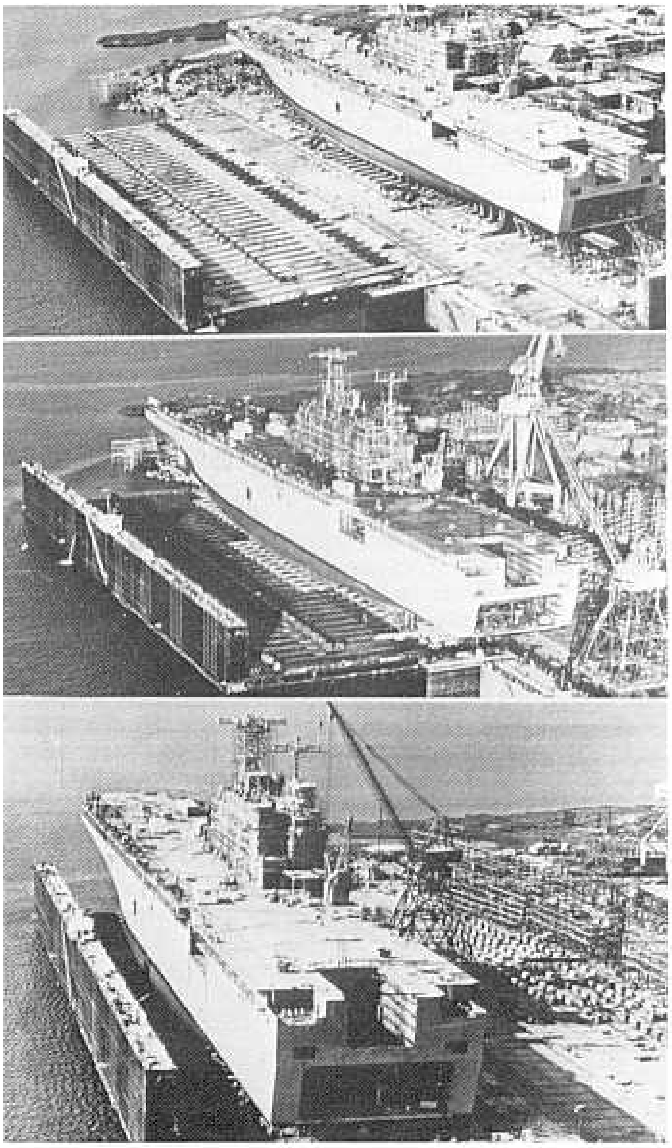

Fig. 5 Three stages of LHA transfer photographed at Litton's Pascagoula yard using 57,000-ton floating dry dock with side transfer capability

Wheels can be either self-propelled as made by Western Gear Corporation, or unpowered, so that separate propulsion is required. Also, wheels can be of the ordinary sleeve bearing type or with more expensive roller or ball bearings.

In general wheels are the most costly, because of both the wheels themselves and the trackage on which they must travel. They are subject to limited load capacity and brinelling under long-duration load and vibration; and the transfer cars have a costly structure. The capital investment is indeed very high.

A free roller system is of intermediate cost. Its primitive, simple construction can survive abuse, overload, neglect and saltwater immersion, not always the case with wheels. Other than during the initial break-free movement, its low friction remains in the $1\frac{1}{2}$ to $2\frac{1}{2}$ percent range, depending on the quality of the rollers and rolling surfaces.

Teflon, as a low-friction sliding medium, requires extreme cleanliness, perfect machined surfaces, and an accurate inter-

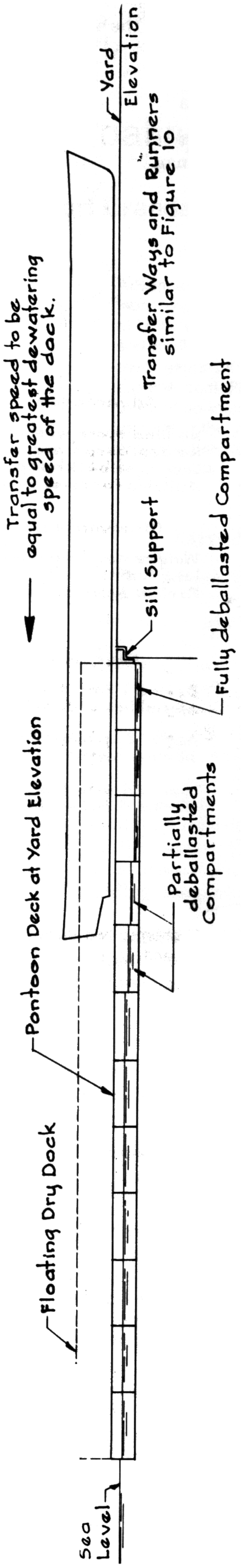

Fig. 7 End transfer to floating dry dock

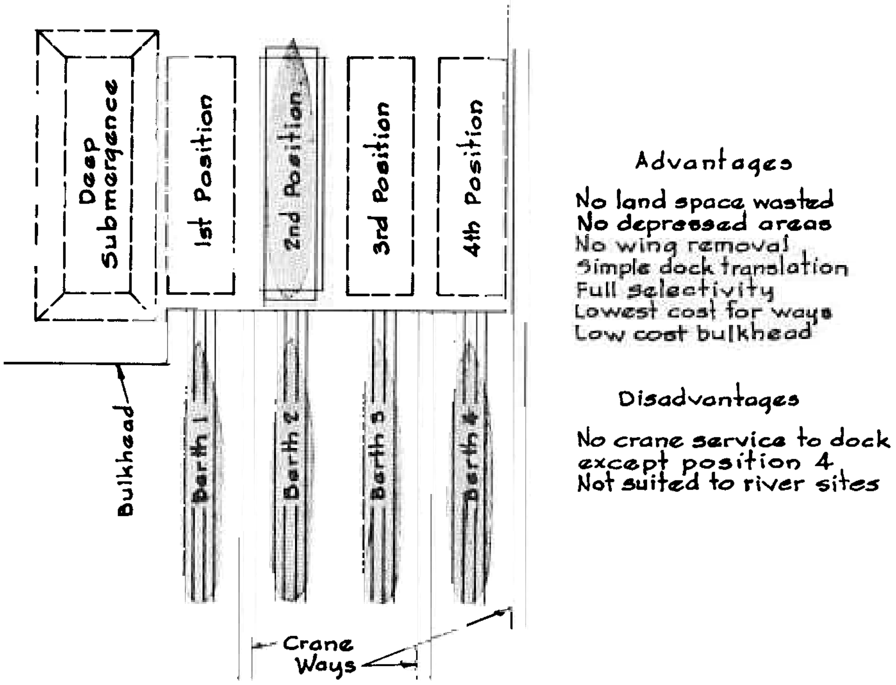

Fig. 6 Floating dry dock end transfer scheme: four dock positions, four or eight berths on land

face. It is not considered economical for long-distance translation (beyond one ship length). It is subject to severe damage by abrasion, and since the exposure conditions of shipbuilding and repair are often crude and imperfect from neglect and abuse, the precise Teflon system does not stand up very long and is costly in the first place.

Transferring a ship from shore to a floating dry dock requires that the dock pontoon be at or close to yard elevation, with enough residual pontoon displacement to carry the weight of the ship as it moves aboard and equivalent ballast water is removed. Propulsion can be with jacks, wire rope tackle or chains properly equalized and synchronized.

For greatest security an underwater foundation is advisable where possible, and especially for large-capacity vessels. It is wise also to provide suitable sill bearing for the floating dry dock at one end to insure shear transfer, especially for side transfer where the sideways weight distribution is very uncertain. Elastic timber block support is essential to cushion load concentrations against both ship and dock.

When planning the transfer, a weight diagram of the ship of a linear form and an equivalent buoyancy diagram for the dock by compartment lengths should be prepared. Dewatering rates must be programmed to equal the loading rates, and optical control maintained to detect and correct discrepancies which are bound to occur in vertical alignment.

After the vessel advances to engage the dock, the ship then serves as its own strength girder.

Maintenance and durability of large steel floating docks

Originally floating dry docks were always made self-docking because of the need to carry out maintenance on the wetted part of the dock. This was especially needed with timber pontoon docks. Only in fresh water, as in Germany and the Netherlands, were one-piece, non-self-docking steel docks used. Today, with the advent of superior zinc-rich coatings, epoxy and vinyl coatings, and very effective sandblasting for surface preparation, docks even for saltwater use are being built as one-piece structures too large to enter another dock for overhaul. The cost of a first-class coating which can last several decades is high but well worth it in the long run.

The introduction of cathodic protection and float-type protective coats which can be sprayed on the interior of compartments has resulted in some big docks with no "permanent" interior coatings. This is the case at Pascagoula, Chester, and San Francisco (Bethlehem Steel).

On the other hand, docks of the Port of Portland, Oregon, and of Maryland at both Baltimore and Jacksonville have been very thoroughly coated, even though they are in brackish or fresh water.

It is the author's opinion that all one-piece steel docks should be well coated inside and out, with cathodic protection provided to supplement the coating. Ships, whose interiors are not exposed to sea water, are fully painted, so why skimp on a dock which never comes out of the water?

Float-type coating may eventually be forbidden for environmental reasons, and it does not provide 100 percent protection. Also, to prevent its being discharged overboard, it denies removal of 2 to 3 ft of ballast water.

In any case, it is important to recognize that with the new coatings and other protection, a large steel dock does not have to be self-docking and can have a life of 50 years or more.

Conclusions

Although the large steel floating dry dock is not as long-lived as a basin dock, obsolescence of both is likely to enter long before this question becomes important. The floating dock should not be overlooked as an economical and very versatile facility for both launching new ships and docking for repair operations.

Floating docks can be made as large as necessary, are relatively expandable, can be sold and moved, use free water space instead of valuable real estate, and can assume controlled drag and list. Built in two sections, they can efficiently handle two small vessels simultaneously. When matched with modern transfer systems, they provide convenient launching and retrieval between yard and water.

New ship industry needs are showing the unexploited potential of floating dry docks.

Discussers

Thomas Doussan
Robert M. Cashman
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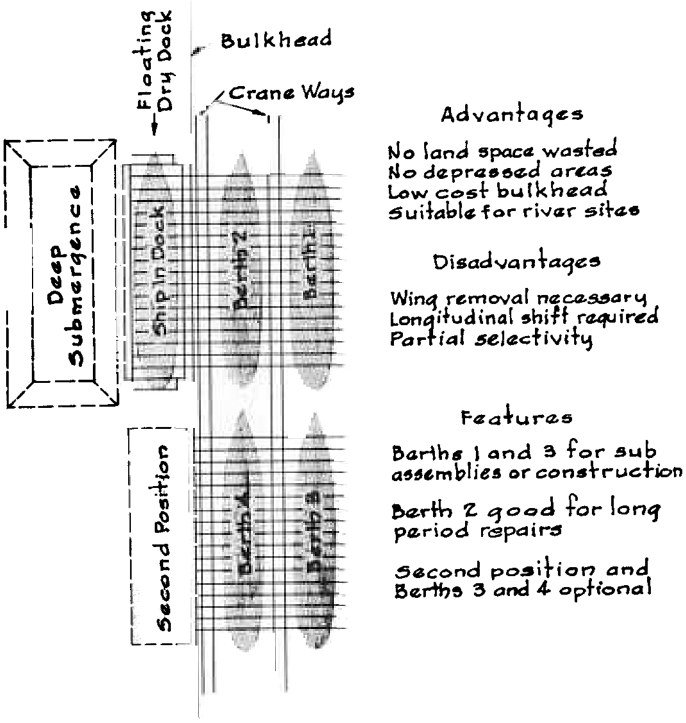

Fig. 8 Floating dry dock side transfer scheme: two dock positions, four ship berths on land

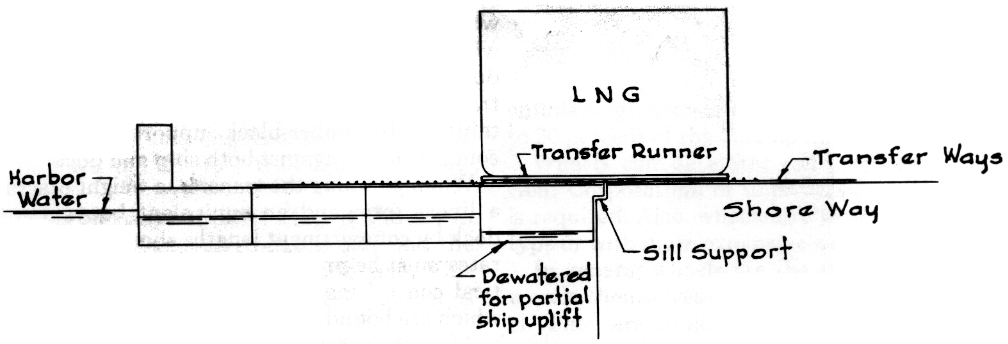

Fig. 9 Side transfer to floating dry dock