Types of Floating Drydock

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1 Introduction

A common method of docking ships is by using floating drydocks. Floating drydocks have been built to cater for all sizes of vessel ranging in lift capacities from only a few hundred tonnes to more than 100,000 tonnes, sufficient to dock some of the largest vessels afloat. The floating dock had its origins in the 18th Century; developing further through the 19th century as ship and floating dock construction changed from timber to predominantly iron and then steel followed by a rapid growth in size.

Floating Docks are buoyant structures consisting of one or more sections. They are usually in the form of a rectangular U shape with the lower portions consisting of one or more pontoons on which are mounted sidewalls. These sections are compartmented and can be filled or emptied of water in a controlled manner to sink or raise the dock. The two most common types of floating dock today are the sectional pontoon and the box dock, which are described in this paper, but there are also many other varieties of floating dock, which have evolved over the years. Whilst some types may no longer be practical and confined to history, others may offer alternative solutions or ideas to the box and sectional pontoon docks

2 Early Development

Before the advent of floating docks, ships would be hauled out clear of the tide but as ship size increased this could no longer be easily done and instead they would be grounded at high tide and worked on between tides. This evolved into the construction of a hollowed out berth, which could be dammed at the seaward end to prevent flooding between tides and, eventually, this developed into the graving dry-dock.

There is an apocryphal tale of the origin of floating docks at the time of Peter the Great when the captain of a British ship visiting Cronstradt Harbour required docking for repairs to the copper sheathing. Owing to a lack of tides, the conventional method of grounding at high tide was not practical, so he purchased a hulk named the “Camel”, stripped out the decks and interior, cut off one end and fitted a gate. He then berthed his vessel inside, closed the gate and pumped the water out.

It is because of the ability to provide a docking solution in the absence of tides that floating docks were particularly popular with countries that had little in the way of tidal range such as in the Baltic or where the ground conditions were poor, since the floating dock is independent of the ground conditions.

The first floating dock in the United Kingdom was built in 1776 by a shipwright named Robert Aldersley, which was followed a few years later by Christopher Watson’s

Figure 1: ‘Camel’ type dock at Wyvenhoe, UK, circa 1900

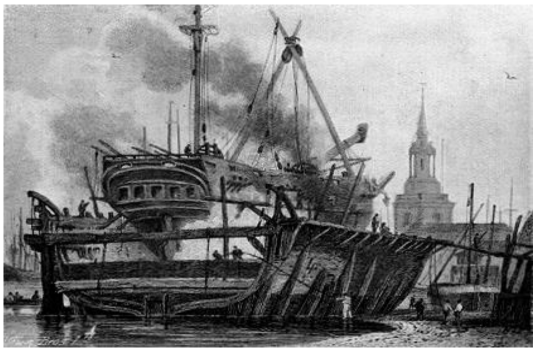


Figure 2: Watson’s Floating Dock on the River Thames, Circa 1780s

floating dock on the River Thames and the subject of a patent by him in 1785. Ref Figure 2. Further docks were constructed along similar lines at other ports. These early docks would have been difficult to control and ensure stability whilst later docks were kept steady by working between parallel rows of vertical piling.

In 1809 Trevithick and Dickinson proposed (but not built) a 220 feet long floating dock consisting of a wrought iron pontoon with air chambers at the sides for floating the dock when the pontoon was full of water. The floats were ballasted with just enough water to make the dock marginally under neutral buoyancy allowing the dock to be raised or lowered by ropes. When docking, the pontoon was raised by the ropes until touching the vessel and then the water in the pontoon was pumped out lifting the vessel out of the water.

In the United States, Captain John Thomas developed the sectional dock, which he patented in 1834. Other sectional docks followed. For example, in 1839 the New York Sectional Dock Company had a sectional dock built to the plans of Phineas Burgess and Daniel Dodge. Another typical example was the Philadelphia Sectional Dock built in 1847 for the United States Government and illustrated in figure 3. The sectional dock consists of a number of sections over the dock length, with the number of sections adjusted to suit the length of ship to be docked. Each section consisted of a wooden pontoon with a hollow open lattice tower on each side within which a steel tank/float could be worked up or down using a rack and pinion arrangement. On top of each tower was housed the pumping machinery. To work the dock, the pontoon was flooded, but being of timber construction, the pontoon will not become fully immersed by this action alone. Water was then pumped into the floats until the pontoon was immersed. The floats were then raised within the towers causing the pontoon to lower. The ship was then brought into the dock and the floats lowered causing the pontoon to rise until bearing on the ship. The water was then pumped from the pontoon lifting the ship clear of the water. In the case of the Philadelphia dock, it was then towed to shore and lowered onto a gridiron for the purpose of transferring ships ashore.

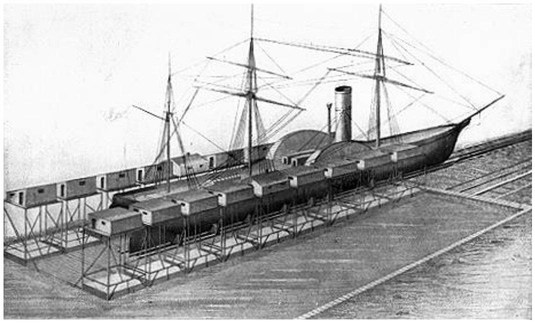


Figure 3: Philadelphia Sectional Dock, built 1847

In the St. Thomas (West Indies) floating dock built in 1867, Sir Frederick Bramwell made a significant modification to the sectional dock concept when he used a continuous open lattice girder over the dock length instead of separate towers whilst maintaining the separate pontoon sections, which allowed self docking of individual pontoons. This overcame a shortcoming in the sectional dock by providing longitudinal strength. Ref Figure 4.

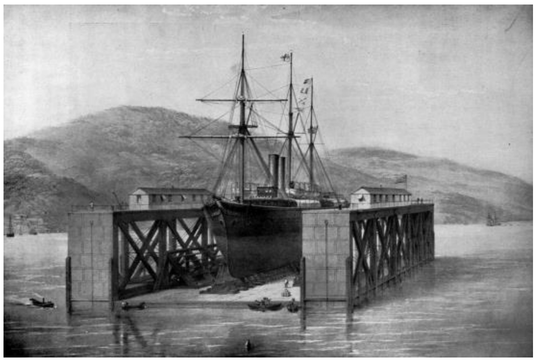


Figure 4: Bramwell's St. Thomas Floating Dock

Another early type of floating dock was the balance dock invented by John S. Gilbert in 1839 and constructed for the American Government at Portsmouth in 1848. This dock was built in one piece with the sidewalls closed in, i.e. similar to the modern box dock. A watertight deck was provided near the top of the sidewalls walls to form an upper chamber. To sink the dock, the pontoon was flooded, but being of timber, required the addition of water ballast in the upper chambers to submerge the pontoon. Adjusting the amount of water in the upper chambers controlled the heel and trim, i.e. the balance from which the dock derives its name. The dock was fitted with end gates, so that when lifting heavy ships, the gates could be closed and the water within the dockwell pumped out.

A further development of the balance dock was the first Bermuda Dock designed by Campbell using a U section instead of a rectangular section. Ref Figure 5. The dock was constructed of iron and had number of decks and longitudinal bulkheads to provide numerous watertight compartments that not only enabled operation as a balance dock, but also, by only pumping water into the upper chamber on one side whilst keeping the other compartments empty, the dock could be heeled for careening to expose the underside for maintenance. Although careening was demonstrated in Portsmouth Harbour, UK, prior to towing to Bermuda in 1869, it was considered too difficult and risky to attempt thereafter. As a consequence, when the iron hull eventually began to corrode, the pontoon and sidewalls were filled with concrete to form a graving dock. The dock was also provided with end gates to enable heavy ships to be lifted.

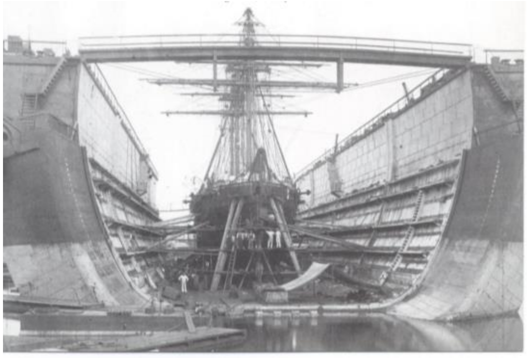


Figure 5. Campbell's Bermuda Floating Dock, 1888

G.B. Rennie further developed the balance dock when he designed a floating dock for Carthagena in 1859. Instead of timber, he used iron and to prevent the dock from sinking, he introduced an air chamber in the upper sidewall to control the sinking of the dock, instead of pumping water into the upper chambers in the sidewall. This development represents the basis for the first modern floating dock. Rennie later took this a step further by keeping the sidewall continuous but sectioning the pontoon so that any pontoon could be removed for docking on the remainder and now known as the sectional pontoon type floating dock.

The main customers for early iron/steel floating docks were warships, in particular the ironclads, and, with their growing size, greater lifts were required. Many of the early docks were able to achieve greater lifts by the use of dock gates at each end of the dock. In these instances, the dock would be pumped up and the water in the dockwell would be pumped out. Thus the dock could obtain a lift far greater than would be available at her normal freeboard. For example, Clark & Standfield's Havana dock of 1897 had a lift capacity of 10,000TLC dock but could, with pound, lift 12,000 tonnes subject to any strength limitations.

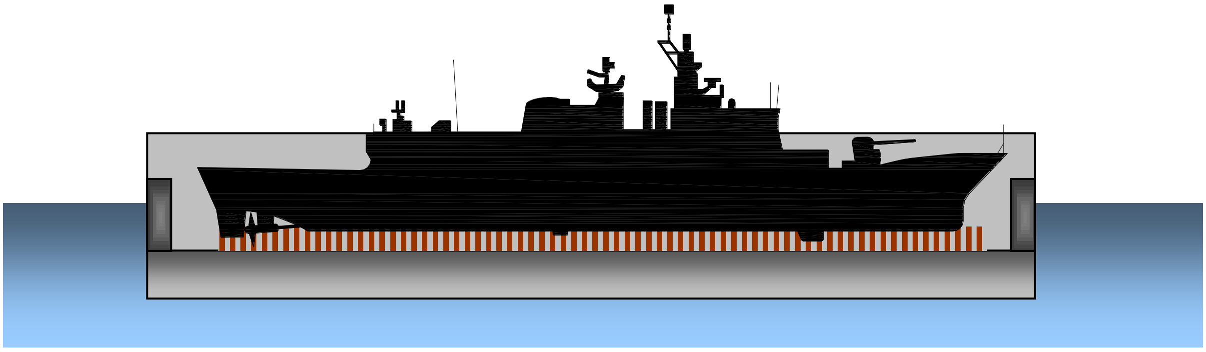


Figure 6: Floating Dock With End Gates Creating A Pound

Floating docks continue to be popular for a variety of reasons such as:

1. Self contained structure not affected by geology of foundations or seismic events such as graving docks and shiplifts. Dock may be placed in deepwater, e.g. fjords, with little problem.

2. Can be heeled or trimmed to match that of a damaged vessel

3. Valuable asset, as it can be sold and towed to a new home with relative ease.

4. Mobility - docks can be moved if a yard decides to reorganise or transferred from one site to another where an operator has a number of yards. Docking operations can be carried out in deep water and then the dock can be moved to shallower water at the dockside.

5. Control - Providing there is sufficient water depth, the depth of water within the dock is entirely at the control of the dock and not subject to tidal variations.

6 Reliability - Docks have a long history of successful operation. They do not require large amounts of machinery. For example a large floating dock may need only 6 pumps and in the event of failure an adjacent pump can be used. This contrasts with shiplifts, for example, where the breakdown of any one of a large number of winches would incapacitate the facility.

7 Cost - Docks are undoubtedly cheaper to build than graving docks and are not preceded by large amounts of civil engineering work required by shiplifts, graving docks, and marine railways.

8 Longevity - there are many docks still in operation after 50 or more years, and in some instances up to 90 years. With modern preservation techniques such longevity should increase.

9 Flexibility – can be used for shore transfer of ships and/or as a ship repair platform They can also dock vessels longer than the dock.

By its nature, a floating dock reflects the developments in ship size and proportions. Today, there is a trend towards much wider floating drydocks due to increasing width of vessels, requirement for greater access around a ship in drydock, and more multi hull craft and semi-submersible platforms.

3 Influences on Dock Type

When considering the type of dock, there are a number of factors that will influence the choice. Principal among these are:

a) Longitudinal Strength

There has been a long running debate on the importance of longitudinal strength in floating docks. The two schools of thought are that either the dock should have strength assuming the ship is completely flexible or that the dock should be flexible since the dock should maintain any inbuilt deflection a ship has when floating. The latter tends to favour sectional docks that are loosely connected which have no longitudinal strength and were once popular in the United States. This is reflected in the approach taken by the classification societies. The American Bureau of Shipping have no minimum strength criteria, i.e. bending moment based upon lift capacity and dock length, whereas others, for example the European Classification Societies do require a minimum standard.

Most docks today are provided with some form of continuity in the sidewall and longitudinal strength is important to withstand the uneven loading that usually occurs during docking. In addition, docks that require to be towed from builders yard to owners site need to consider longitudinal strength to resist wave bending and which is a function of dock displacement and length. Longitudinal wave bending for towage is often far more severe than that required for lifting ships.

As the lift capacity of a floating dock increases, the required longitudinal strength also increases. For small docks, other factors such as hydrostatic loads and minimum steel thickness dominate whereas for the larger docks the need to provide longitudinal strength will dominate much of the scantlings and the weight of steel has a large influence on the cost of a dock.

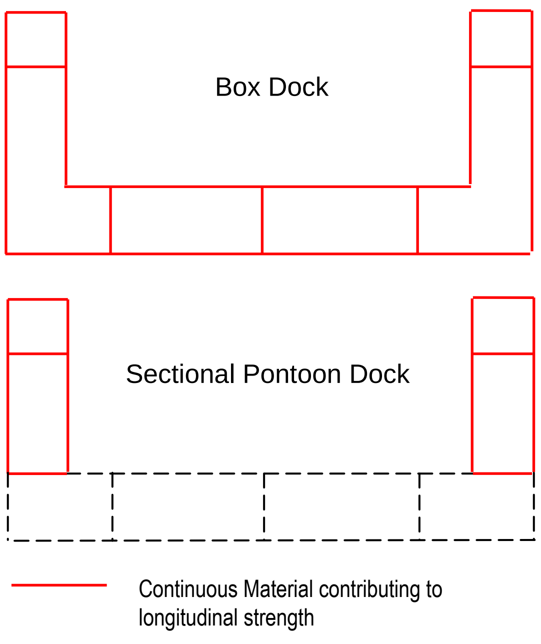


Figure 7: Longitudinal Material In Docks

The box dock is the strongest form of dock as the pontoon and sidewall contribute to longitudinal strength, whereas, for example, in the sectional pontoon dock, only the sidewalls, being continuous, can contribute to longitudinal strength. Thus, to make up this deficiency, the sidewall requires being of greater construction adding to the weight and cost of construction. Other self-docking types are designed to provide longitudinal continuity in both the pontoon and sidewalls over a major portion of dock length to accommodate longitudinal strength requirements.

For wet tows, sectioning of the dock reduces wave bending and is considered where there may be difficulty in achieving sufficient strength. Dry tows are now often used for the medium to small size docks using heavy lift ships so that only longitudinal strength for docking is necessary.

b) Maintenance

One of the common problems of maintaining a floating dock is the absence of any nearby docking facility large enough to accommodate the dock. For this reason, many types of floating dock have evolved to overcome this by providing arrangements for self-docking. For early floating docks, the ability to self-dock was considered essential and much ingenuity was spent in achieving this. However, with time, the quality of steel preparation, preservative coatings and cathodic protection have led to major advances in the dock life. It is also a feature that most corrosion on docks occur in areas that can be accessed whilst afloat, i.e. the internal sidewall structures and pontoon deck. Thus many a dock is provided with a self-docking capability only for it to be never used.

c) Construction

The method of construction may influence choice of dock type. A dock can often be too large to construct and launch due to limiting size of the building berths. This can be overcome by building the dock in sections that can be launched and assembled together afloat. Sectional Pontoon and sectional box docks are suited to this approach where connections can be made above water.

Sectioning of a dock may assist in delivery of the dock to site by allowing sections to be rearranged on heavy lift ship and then reassembled at site.

d) Location

Location can affect dock choice in a number of ways. Firstly, if the dock is in a non-sheltered location, additional strength for wave bending and freeboard may be required. Secondly, where there are space restrictions, for example in a narrow river, an offshore dock may be more appropriate. Thirdly, available water depth may rule out the deeper drafts required for concrete docks as opposed to steel. Fourthly, large docking facilities nearby, may remove the need for self-docking capability.

e) Usage

How the dock is to be used will also influence choice. Where it is envisaged that hull repairs may be necessary for docked ships which will temporarily affect the ship’s longitudinal strength, it will be necessary for the dock to carry the longitudinal bending moments. In this instance, sectional docks would not be appropriate.

4 Types of Construction

One method of classifying docks is by their construction as follows:

a) <u>Wooden Floating Docks</u>

Until the 1850s all floating docks were of wooden construction. However, due to their buoyancy they required water to be pumped into the sidewalls to lower them whereas other types are lowered by free flooding alone. With the introduction of iron and then steel in the construction of ships and the resulting increase in ship size, wooden floating docks were gradually replaced with iron and then steel, as the wooden docks were no longer considered practical to cater for the increased loads.

During WWII the US Government instigated a major dock-building program and, due to a shortage of materials, a number of the resulting YFDs (Yard Floating Docks) were sectional docks of timber construction, the largest having a lift capacity of 20,000 tons. However, since then no significant timber floating drydocks have been constructed.

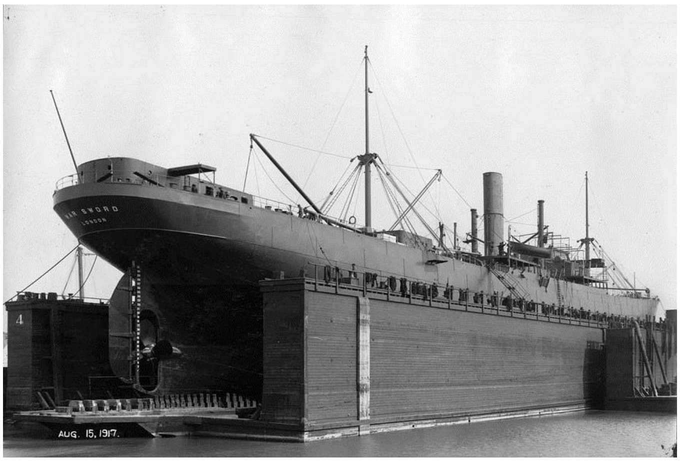


Figure 8: Timber Floating Dock, 1917

b) <u>Steel Floating Docks</u>

G.B. Rennie introduced all iron docks circa 1860, which then gradually replaced the timber docks. Eventually, steel replaced iron and today the majority of floating docks are of steel construction. For these docks, the dock is lowered by free flooding and pumping is only used to raise the dock. In some early docks, the ballast tanks extended up to the top deck with the potential for oversinking. However, today all docks adopt Rennie's air chambers in the top of the sidewall with the introduction of a safety deck in the sidewall forming the crown of the tank and limiting the amount of ballast whilst providing space for machinery etc. This was further enhanced by providing an air cushion in the tanks to control, more precisely the maximum amount of ballast that can enter the dock.

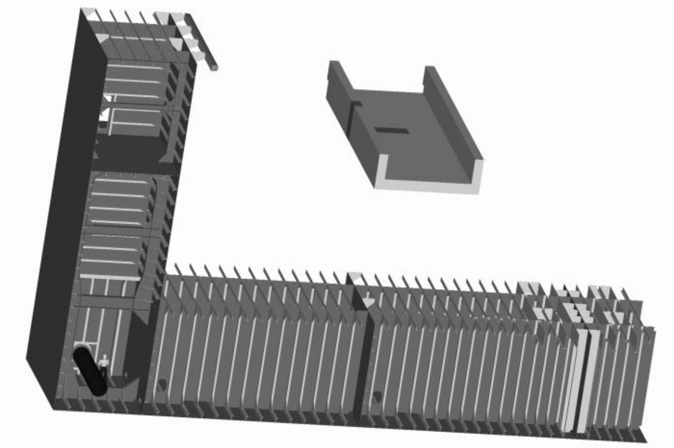


Figure 9: Section of a Typical Steel Floating Dock with top deck and pontoon deck removed for clarity.

For shipyards, construction of steel floating docks is relatively straightforward consisting of stiffened steel panels with none of the curvature (2D and 3D) involved in ship construction.

c) <u>Tubular Construction</u>

The use of steel tubes to reduce construction costs has been around for a long time. The earliest examples were proposed by John Standfield in the late 1800s for his depositing dock and subsequently for conventional double wall floating docks. However, there are problems associated with strength, stability and working area for machinery etc that has meant that they have only been used for very small docks (i.e. lift capacities in the order of hundreds of tonnes).

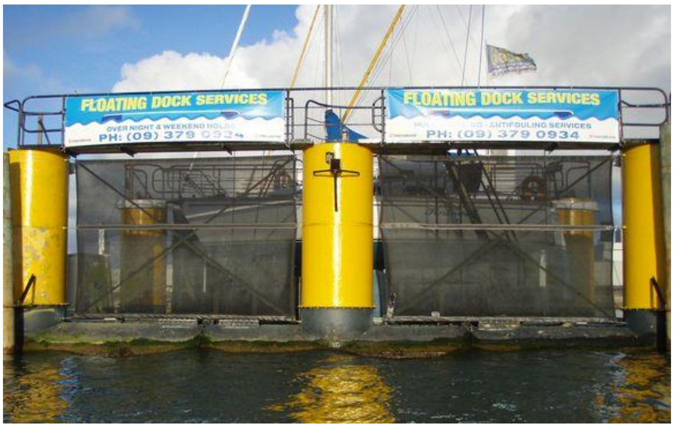


Figure 10 Tubular Steel Dock for lifting yachts, Westhaven, New Zealand

d) Concrete Floating Docks

A number of reinforced concrete docks were introduced during WWII by both the US and British governments as a result of steel shortages and lack of capacity in the steel shipbuilding yards. However, their size was limited due to problems associated with the use of concrete:

- Concrete structures are considerably less elastic so that monitoring deflection, as a means of controlling loading, was not practical. Instead, the docks were ballasted to strict pumping schedules.
- Structure was very heavy compared to steel docks requiring much deeper pontoons and hence greater water depth at site. This also required greater power from the pumps, as the hydrostatic heads were much greater.
- Difficult to repair compared with steel docks.
- Poor strength in tension. This limited size as larger docks experience much larger longitudinal bending moments for both towage and whilst docking ships.

Figure 11: 100,000TLC Concrete Floating Dock (Rear Dock), Tuzla Shipyard

The use of pre-stressed concrete can be used to overcome the poor tensile strength properties of concrete. This was used in one of the largest docks in the world, the former concrete floating dock in Genoa, and now in Tuzla, Turkey. Concrete Docks are considerably heavier, requiring far greater pontoon depth.

Overall Dock weight		
Lift Capacity tons	Steel Dock	Concrete Dock
800	923	2750
100,000	30,000	130,000

Furthermore, concrete floating docks are also subject to deterioration from both carbonation and chlorides. Over the years, the chlorides in seawater gradually penetrate through the concrete. Once they reach the reinforcement, the reinforcement will expand with corrosion causing the concrete to crack.

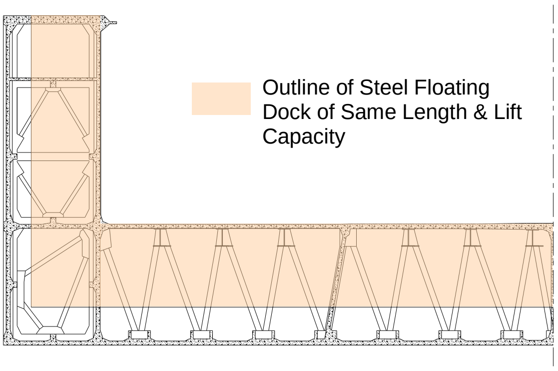


Figure 12 Half Cross Section of 100,000 TLC Prestressed Concrete Floating Dock with outline of steel dock of same lift capacity superimposed.

e) <u>Composite Floating Docks.</u>

To overcome some of the deficiencies of a concrete dock, there are examples of sectional pontoon (Rennie) type docks where the sidewall is of steel construction and the pontoons of concrete construction. The Steel sidewalls will deflect in the same manner as a steel dock allowing longitudinal deflections to be used to control longitudinal bending by means of differential ballasting. However, the pontoons are subject to transverse bending moments and in larger docks will require some form of pre-stressing. Many of the comments and limitations relating to concrete docks also apply.

There are also instances of sectional pontoon (Rennie) type docks involving continuous steel sidewalls on sectional timber pontoons.

5 Floating Docks without Sidewalls

A floating dock without sidewalls consists of a single pontoon and is often referred to as a slave dock. By itself, it cannot be controlled during raising or lowering, and therefore relies on additional means by which control and stability can be achieved: either using tides or another dry-dock facility.

An early example of a slave dock was used with Edwin Clark's Hydraulic Shiplift built at the Victoria Docks, London, in 1857. He used a number of slave docks so that more than one ship could be drydocked at one time, whilst requiring only one shiplift to undertake the docking evolutions. Slave docks have been used ever since and permit afloat repairs without the expense of a complete floating dock; useful if an afloat repair may take a long time, e.g. a naval refit or historic ship repair, rather than tying up a docking facility for a length of time and are considerably cheaper than a floating dock.

The slave dock consists of a large rectangular pontoon, which is sometimes subdivided into a number of watertight compartments. Each watertight compartment is connected to the sea via a valve. The typical docking process in a graving dock, for example, is illustrated in figure 13:

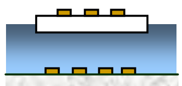
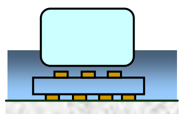
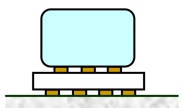
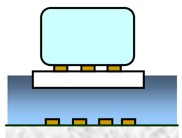
a) Slave dock brought into the dry-dock and dock water pumped out.	
b) After docking the slave dock, compartment valves opened.	
c) Drydock flooded but open compartment valves allow flooding of compartments preventing slave dock from rising. d) Vessel berthed over slave dock	
e) Dock water pumped out causing vessel to be docked onto slave dock. The open compartment valves allow the water in the compartments to drain out.	
f) When Compartments dry, valves closed to prevent flooding of compartments. g) Drydock flooded causing slave dock to float with vessel.	

Figure 13: Slave Dock Operations

The same process can be used with a shiplift or floating dock. Where there is a large tidal range, the process can also use the tides. In this case, the pontoon is grounded, usually on a gridiron, just above the low water mark and the valves opened. As the tide rises, the compartments fill with water leaving the pontoon on the seabed. Around high tide, the vessel to be docked is brought over the pontoon. As the tide falls, the vessel is left resting on the pontoon and by low tide; the pontoon compartments will have drained as well. The valves are then closed so that as the tide rises, the pontoon, now buoyant, is raised complete with ship. This system is currently used by a ship repairer on the River Thames.

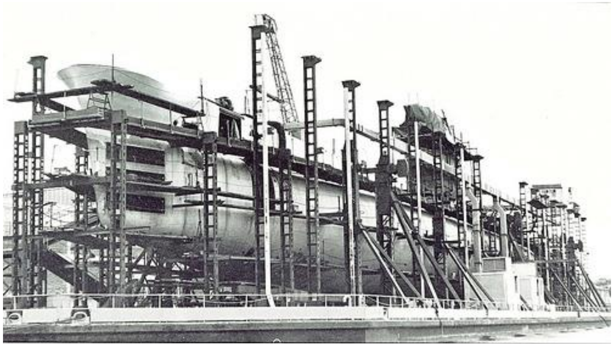


Figure 14: HMAS Oxley refit on Cockatoo Island's Slave Dock

6 Floating Docks with Single Sidewalls

There is a group of floating docks that have only one sidewall, all invented and developed by Clark & Standfield. To provide stability during lowering and raising, the docks rely on external steadying facilities through parallel rule type connecting booms. However, with only one sidewall, there is a saving in structure, whilst offering some advantages over other dock types as vessels can be brought onto the dock athwartships. There are three types:

i) Depositing Floating Dock

The depositing floating dock was developed from John Standfield's ideas for a floating dock for depositing ships onto shore side gridirons clear of the water. One dock could therefore effectively dry-dock a number of vessels at the same time.

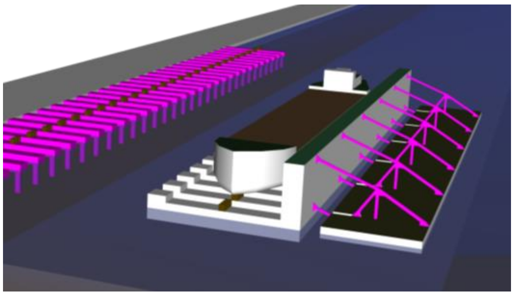


Figure 15 Depositing Floating Dock

The first floating dock of this type was constructed by Clark & Standfield for the Imperial Russian Navy. However, it was provided with an additional innovation in that the finger pontoons were bolted to the sidewall allowing some of them to be removed and attached to the remaining finger pontoons to increase the dock width for the docking of the circular ironclads.

The largest dock of this type had a lifting capacity of 6600 tonnes

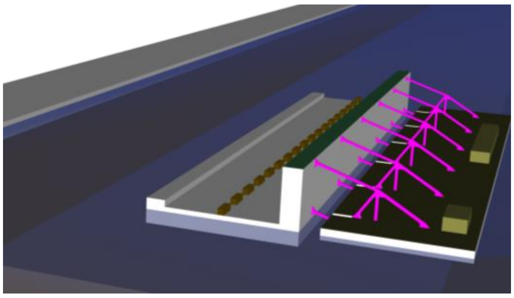


Figure 16 Outrigger Floating Dock

ii) Outrigger Floating Dock

The outrigger floating dock evolved from the depositing dock. Instead of finger pontoons, the dock was provided with a single pontoon. This meant that the dock could no longer deposit ships ashore, but for the same lifting capacity, required less depth of pontoon. The stabilising pontoon could be used for workshops and machinery; effectively providing a complete afloat repair yard.

iii) Offshore Floating Dock

Figure 17 Offshore Floating Dock

The offshore floating dock was a further development of the outrigger dock. Instead of using a pontoon to provide stability, the parallel arms were attached to shore columns. To prevent, excessive loads developing in the columns, each upper boom is attached to a weighted cam. This allows the dock to heel in the same way as a double wall floating dock so that keeping the dock upright ensures correct balance of ballast water and therefore minimal loading in the shore columns. Without such feature, large and potentially destructive loads could develop unnoticed in the shore columns.

This dock has proved particularly popular in rivers where space is at a premium since vessels can be brought in sideways. The dock does not require clear space at one end to bring ships onto the dock nor protrudes as far from shore due to no outer sidewall.

The single wall floating docks can be made self-docking where they are made up of two or more sections in their length. An example of a single wall floating dock being self-docked is shown in figure 18.

Figure 18 -Single Wall Floating Dock – Self Docking Method

7 Floating Docks with Double Sidewalls

These are the conventional docks (balance docks). There are, however, a variety of types, which have largely evolved to cater for maintainability by means of self docking whilst still providing longitudinal strength: a factor that becomes of increasing significance with increasing size resulting from ship docking loads and wave bending when considering towage.

i) Box Floating Dock

The box dock is one of the most common and strongest forms of floating dock and is depicted in figure 19. The dock is made of a single section with the sidewalls forming an integral part of the pontoon. Therefore, all longitudinal material in the pontoon and sidewall contribute to longitudinal strength. It is less costly than other forms of dock.

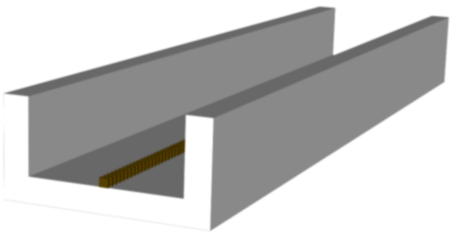


Figure 19 Box Type Dock

As dock size increases, longitudinal strength becomes a dominant feature and therefore, because of its strength, it is more economical for the construction of large docks. Most large docks are of this form.

This type of dock is not self-docking. However, with modern coatings, and the fact that most corrosion in docks occurs above the waterline where it is accessible, the need for self docking is not considered of such importance.

ii) Sectional Pontoon Floating Dock

Probably the second most common type of floating dock is the sectional pontoon floating dock developed by G.B. Rennie; sometimes referred to as the Rennie type. It is the most popular form of self-docking dock. The dock consists of a series of pontoons on which is mounted a continuous sidewall over the dock length. The pontoons are bolted to the sidewall. Its popularity is the fact that the bolted connections are easy to access. It is also popular for docks launched in sections for the ease by which it can be assembled afloat.

Since the longitudinal strength in way of the gaps between the pontoons is limited by the available depth of sidewall, it generally requires a greater amount of steel in the sidewalls to achieve comparable strength to the box dock. For this reason, large floating docks are more likely to be of the box type.

Self-docking is accomplished by detaching a pontoon and docking it on the remainder.

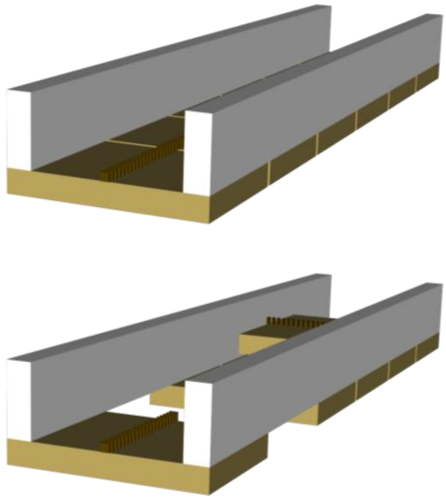


Figure 20: Sectional Pontoon Floating Dock (Rennie Type)

iii) 2-Unit Dock

The two-unit dock consists of two fully functional and independent (of each other) floating docks that can be combined to form a single floating dock. Generally they are matched in their transverse section although it can be used to link two different docks, e.g. old with new. They can operate separately or together. The docks can be linked by welded or bolted splice plates. However, in Clark & Standfield docks, they use a rocking joint that allows quick connection /disconnection without welding or bolting. This type of arrangement is particularly useful where the majority of vessels to be drydocked are small with only the occasional large vessel.

Figure 21: Example of a Two Unit Floating Dock Showing Rocking Joint Castings at End of Sidewall

The Australian Marine Complex floating dock is designed as a 2-unit dock – the first section is used primarily for docking smaller vessels and shore transfer. The other section, for which construction has not started, will dock larger vessels but without shore transfer but when combined with the second unit can dock panamax size vessels. The computerised control systems enable the combined docks to be operated from one control room.

iv) Sectional Docks

The sectional dock is a dock consisting of a series of rectangular U shaped sections. They were usually capable of being self-docked by removing a section and docking on the remainder. There are a number of variants within this category:

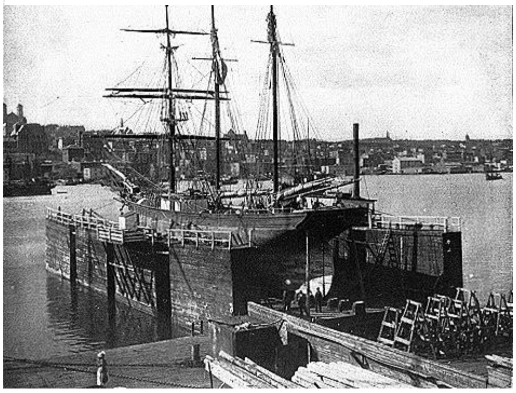


Figure 22: Timber Sectional Dock in Newfoundland – early 1900s

Type (a) Series of sections loosely connected, each with its own dewatering system. This type was often used for the early timber balance docks. However, there were problems with keeping the sections aligned when docking a vessel and ensuring each section took its own share of the load.

Type (b) Series of sections connected by rocking joints. This kept the sections better aligned but the dock has no longitudinal strength since no bending moments can be transmitted from one section to the next; only shear forces via the rocking joints. Not suitable for repair of damaged ships were their longitudinal strength has been impaired. The rocking joints allow quick connection/disconnection.

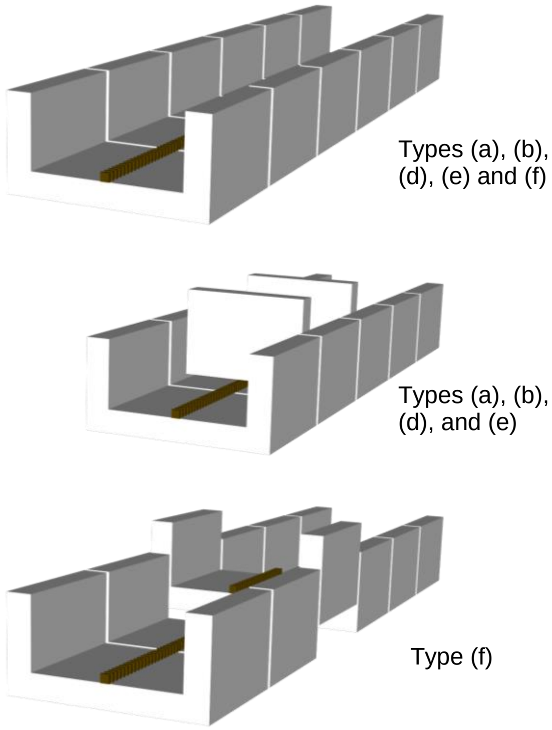


Figure 23 Sectional Floating Dock Type A, B, D, E & F

Type (c) A variant of (a) and (b) is shown in figure 24. The pontoon of each section projects beyond the sidewalls longitudinally. These projections are used to support the section being docked.

Type (d) Series of sections connected by welded splices plates at the top of the sidewall and at the bottom of the sidewall at about pontoon deck level. This system is used with American AB Floating docks and, more recently, other docks such as the 40,000TLC Floating Dock at Metro Machines, Norfolk.

Type (e) Developed by L. Clark. Consists of a series of sections connected by bolts around the hull shell (pontoon bottom and deck, Sidewall sides and top deck). Because the sections are connected around the whole transverse section, the dock has good longitudinal strength. The joints between plating are provided with a seal. When bringing the sections together, the top bolts were fastened first and then the section trimmed until a tight seal was made at the bottom allowing the water in the section to be pumped out so that the bolts could be fastened in the dry. All bolting was internal.

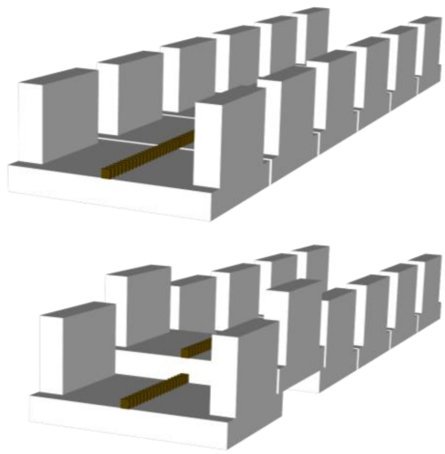


Figure 24 Sectional Dock Type C

Type (f) Developed by Cunningham. This was a sectional dock but used a different method for self docking. In this variant, the section to be docked is unfastened and allowed to ride up as the rest of the dock is sunk. The section is then refastened and the other sections pumped out bringing the section to be docked out of the water.

v) Dewey Floating Dock

The Dewey Floating dock, named after Admiral Dewey, USN, was built by the Maryland Steel Company to the design of one of its assistant engineers, Henrik F.Hansson. The main portion is formed into a single unit where the pontoon and sidewall are combined giving the ability to achieve similar strength to the box dock. A separate pontoon is provided, one at each end, each with its own sidewalls, which can be used to lift the main dock out of the water. The end pontoons are designed so that they can fit within the dock sidewalls when detached for self-docking. This type has been copied with some slight variations in more recent docks. However, the extra width of the end pontoons with their sidewalls increases the amount of steel structure with its associated cost. This cost would need to be weighed against the savings that can be made in the main portion when compared to other types such as the sectional pontoon (Rennie Type) dock.

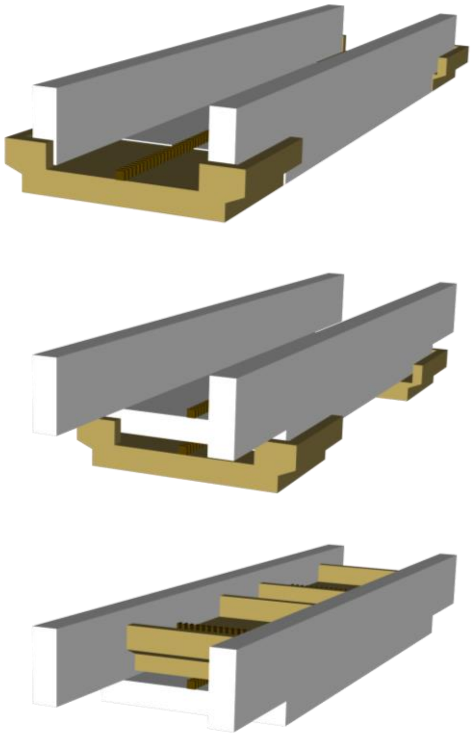


Figure 25: Dewey Type Floating Dock

Figure 26: 80,000 Tonne Lift Floating Dock for Sudoimport, Russia

In later versions, see Figure 26, the end pontoon sidewalls do not wrap around the ends of the main sidewalls.

vi) Bolted Sectional Dock (Clark Dock)

The bolted sectional dock, developed by L. Clark, was divided into preferably 3 sections designed to enable self-docking. When all 3 sections are disconnected, any one section can be docked by the remaining two. The dock was bolted internally around the hull envelope (pontoon and sidewall) so that both pontoon and sidewall would act to provide longitudinal strength across the joint. A rubber seal was provided in way of the joint to make the connection watertight. When connecting the upper bolts are fitted first and the dock then ballasted to apply pressure on the lower seal so that the internal water can be removed allowing the lower bolts in the pontoon to be fitted in the dry

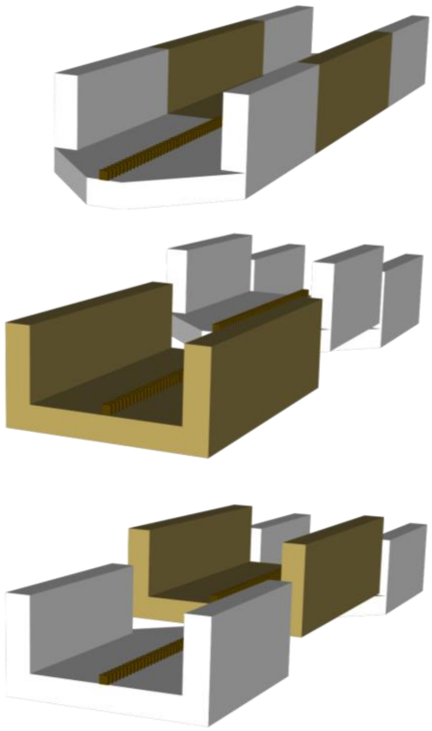


Figure 27 Bolted Sectional (Clark) Dock

vii) Floating Graving Dock

Dock developed by Clark & Standfield. The pontoon is in 3 sections, which are located between two continuous sidewalls rather than under as in the sectional pontoon dock. The greater depth of sidewall, compared to the sectional pontoon dock, offers greater economy of strength. Access to the underwater areas of the pontoon is achieved raising the pontoons. This is achieved by unbolting the pontoon connections to the sidewall, sinking the dock, and allowing the unfastened pontoon to float up to a higher position where it is then refastened to the sidewalls. The dock is then raised lifting the pontoon clear of the water. Access to the underside of the sidewall is by means of heeling, which is assisted by the fact that the pontoons extend below the bottom of the sidewall.

The first of these docks was built for the Spanish Government with a lift capacity of 10,000 tons. Other followed including an 18,000 ton dock for the US Government at Algiers in 1898 and a 16,500 ton dock for the British Admiralty, AFD1, at Bermuda in 1900

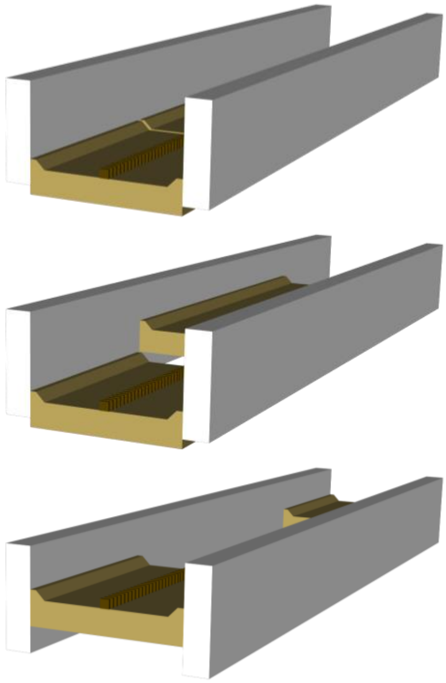


Figure 28 Floating Graving Dock

viii) AFDM Interlocking 3-Section Floating Docks

A number of the US Navy Medium Auxiliary Floating Docks, (original designation) used an interlocking 3-section floating dock. To avoid the additional steelwork associated with extending the beam of the end pontoons beyond the sidewalls, as in the “Dewey dock”, the dock uses an interlocking sidewall arrangement illustrated in figure 29 and 30

The dock has good longitudinal strength as the main central portion can utilise the continuous material in both the pontoon and sidewalls.

A number of these docks are in use today.

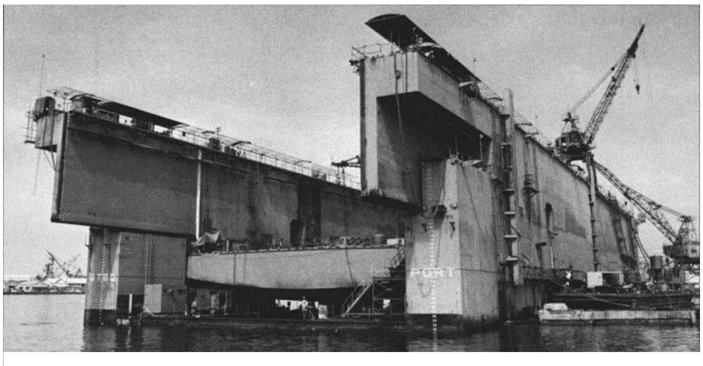
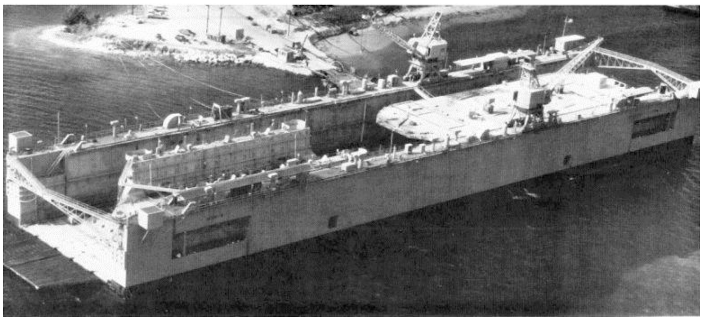


Figure 30: 7,000TLC Floating Dock AFDM5 Self Docking



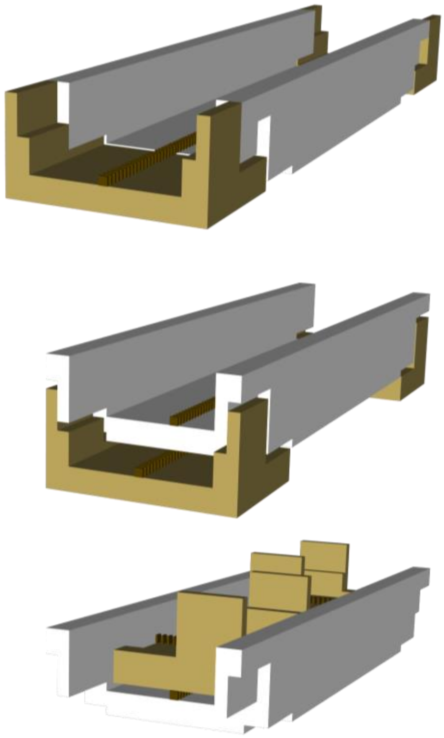


Figure 29: Interlocking 3-Section AFDM Dock

ix) Sliding Caisson Type

In the Sliding caisson floating dock, the main length of the dock’s sidewalls can be slid up or down and refastened at a different level to enable either the pontoon to be clear of the water (sidewalls lowered) or the sidewalls clear (sidewalls raised). This type only proved suitable for small lifts and the largest built had a lift capacity of 2,300 tonnes.

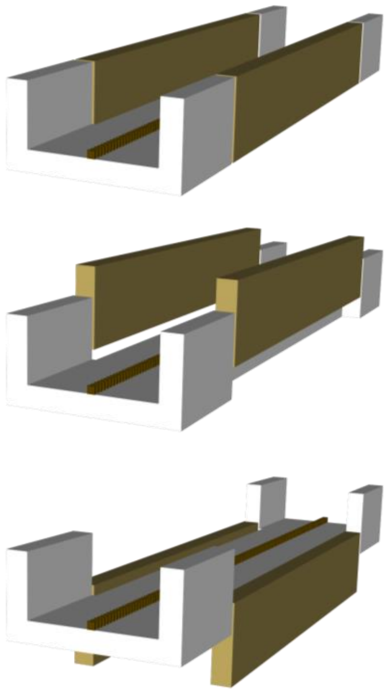


Figure 31: Sliding Caisson Floating Dock

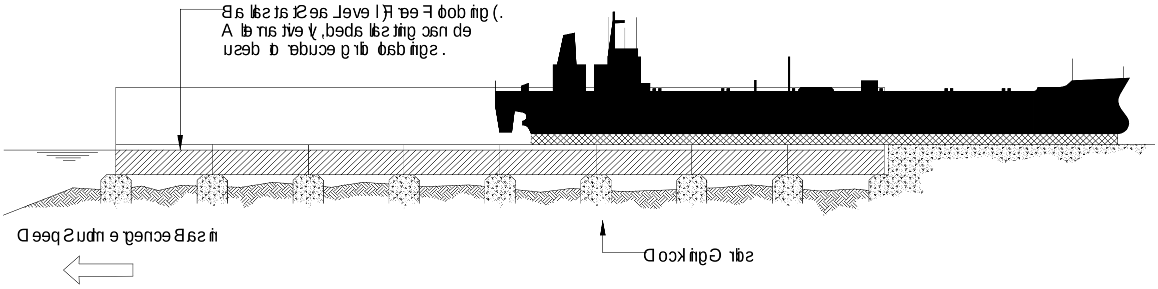
8 Shore Transfer Docks

A feature of docks is that they can be used for the shore transfer of ships. This is a feature that has been in use for many years as demonstrated by the Philadelphia Sectional dock of 1847 or the depositing type docks of John Standfield in the 1870s. More recently, there has been a resurgence in using floating docks for shore transfer, particularly as it is becoming easier to move ships ashore with modern yard equipment such as Self Propelled Modular Transporters (SPMTs).

There are various ways that a floating dock can undertake shore transfers and these are set out hereunder:

a) Gridiron

In this arrangement, the dock is lowered onto a gridiron so that the pontoon deck is level with the quayside. The tanks can be left to free flood so that tidal levels do not affect the dock. Ships can be transferred to or from shore without the need for ballasting. An example of this type of arrangement can be found at the Bath Iron Works.

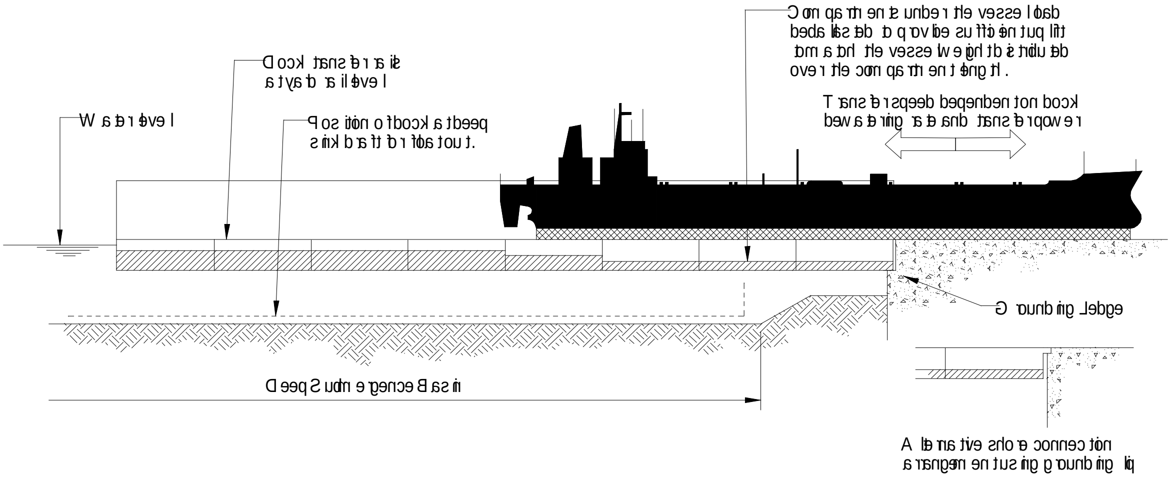


b) Ledge

In this type of dock, only the shore end of the dock is supported. This can be either in the form of a ledge on which the end bulkhead sits or a lip towards the upper part of the end pontoon bulkhead. If the dock is in a tidal area, it may be necessary to introduce a tidal pumping system, which automatically adjusts the ballast levels to compensate for changes in dock buoyancy due to changes in tide levels. Depending on circumstances, this

Figure 32: Longitudinal Transfer of Vessel onto 35,000 TLC Floating Dock in Philadelphia

may require a dedicated system additional to the main dewatering system.



In addition to controlling ballast levels for tidal changes, ballast water is continually adjusted to compensate for the changing loads due to the vessel during transfer. This is to ensure that loadings in the dock structure are kept within acceptable limits and that the dock remains level.

c) Sidewall Overhang

The sidewall overhang is similar to the ledge except that the sidewalls rest on the quayside to support the end of the dock. This is a system used by the Australian Marine Complex Floating Dock. In this case, hydraulic cylinders are provided on the underside of the sidewall, which allows for adjustment of levels to compensate for transverse deflections of the pontoon, whilst monitoring of pressure gives the bearing loads, it also assists in sharing the loads between the inner and outer sidewall.

d) Free Floating

In this instance, the dock is floating free without resting on any supports. A high degree of ballast control is required to maintain level floatation and the correct support to the vessel being transferred.

The original methods of transfer involved the use of sliding ways or rail systems. These require high accuracy of transfer level between dock and shore. However, the use of SPMTs is becoming more common which have the capability of accommodating significant variations in level and therefore less sensitive to the level of the floating dock.

Figure 33: Australian Marine Complex Shore Transfer Dock's Sidewall Overhang

Virtually all shore transfer floating docks operate with end transfer; although there are can be the exception. An example of this is the Northrop Grumman Ship Systems Floating Dock at their Pascagoula yard where a side transfer is utilised. In this instance, the shoreside sidewall, in several longitudinal sections, is disconnected and removed so that the vessel can be slid transversely onto the dock before replacing the sidewall.

In most cases, after transfer operations the dock is required to be moved, usually by mooring lines, to deeper water where docking evolutions can be carried out to dock or undock the ship.

9 Mobile Floating Docks

Most floating docks are designed for service at a particular location with the designer providing sufficient strength to accommodate towage of the dock from the builders' yard to site. In the past this was by means of a wet tow, but more recently the use of heavy lift ships for the dry tow of the smaller docks has become popular and does not require the additional strength that is often required for a wet tow. Docks are not usually intended for voyages on a regular basis other than that required for transferring from a quayside to a deep sink basin.

Figure 34: ARDM 2

As early as 1870, Vice Admiral Sir E. Belcher proposed a self-propelled floating drydock using Ruthven hydraulic propulsion. G.B. Rennie proposed similar proposals in 1883 using hydraulic jet propulsion and with screw propellers by L. Clark in 1877. In practise, only Governments requiring supporting their navies overseas where friendly docking facilities may be scarce would require this facility. However, it was not until the 1930s that the US Government considered it desirable to have floating docks that could travel with or be quickly and easily transferred to the theatre of naval operations. With this in mind the ARDM floating docks were introduced followed by the AB floating docks encouraged by pacific operations during WWII.

Figure 35: AB Floating Dock

For mobility, the docks are required to have sufficient strength for sea loads such as wave induced bending moments and shaping to the hull to enhance towing or propulsion. In their simplest form these docks range from a basic floating dock to a fully functional ship where the boundaries between ship and floating dock become blurred. A number of examples are illustrated here:

<u>ARDM</u>

The US Governments ARDM (Auxiliary Repair Dock Mobile) floating docks, shown in figure 34, were designed as self-propelled floating drydocks but in practice the propulsion machinery was never fitted. Some were built of steel, others concrete. These docks were originally provided with a gate at the aft end.

<u>ABSD Floating Dock</u>

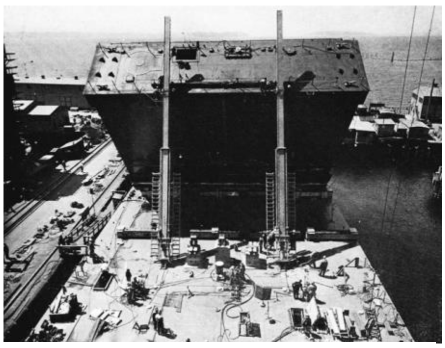


Figure 36: Hinging down the sidewall of an ABSD Floating Dock

The US Navy developed the ABSD (Advanced Base Sectional Dock) floating dock as a means of readily transporting a dock to an overseas location to form an advanced base during WWII. Developed along the lines of a sectional box, each pontoon was barge shaped for towability and the sidewalls could be hinged down for stability and reduced windage. In the case of the ABs the sections were built at a number of different yards and any number could be assembled to form a dock. The sidewalls were connected together by splice plates at their upper and lower ends. Each section had its own independent machinery compartment located in the pontoon, so in practice it was very labour intensive. It took about 60 days to assemble into a functioning floating dock.

A number of these docks are still in use.

Figure 37: Russian Ship Transporter

Admiralty Floating Dock No. 59

The UK's Admiralty Floating Dock No.59 was a 12,500 tonne lift capacity floating dock designed for lifting nuclear submarines. She was later fitted with a ship shape bow with the intended purpose that she could be towed to sea whilst carrying docked submarines although in practice this was never carried out.

Figure 38: Heavy Lift Ship Undocking The Australian Marine Complex Floating Dock

Heavy Lift Ships

The heavy lift ships that have developed over the last twenty years could also be considered a form of self-propelled floating drydock, as they are capable of undertaking docking evolutions. However, as they are self propelled seagoing vessels they are classed as ships. They are primarily used for transportation of large items by sea rather than dry-docking ships for repair. Figure 37 show a Russian Ship transporter that is in the form of a self propelled floating dock whereas Figure 38 shows a typical modern heavy lift ship.

10 Classification of U.S. and UK Government Floating Drydocks

The WW2 war program of floating drydocks required many different categories. The main categories used by the United States were:

1. ABSD -- Advance Base Sectional Dock.

   Mobile, military, steel dock, either (a) of ten sections of 10,000 tons lifting capacity each, or (b) of seven sections of 8,000 tons lifting capacity, for battleships, carriers, cruisers, and large auxiliaries.

2. ARD -- Auxiliary Repair Dock.

   Mobile, military, steel unit dock, ship-form hull, with a normal lifting capacity of 3,500 tons, for destroyers, submarines, and small auxiliaries.

3. ARDC -- Auxiliary Repair Dock, Concrete.

   Mobile, military concrete rectangular U section type, unit dock with faired bow and stern, 2,800 tons lifting capacity.

4. AFD -- Auxiliary Floating Dock.

   Mobile, military, steel rectangular U section type, unit dock, with faired bow and stern, of 1,000 tons lifting capacity.

5. AFDL -- Auxiliary Floating Dock, Lengthened.

   Mobile, steel rectangular U section type, unit dock, similar to AFD's, but lengthened and enlarged to provide 1,900 tons lifting capacity.

6. YFD -- Yard Floating Dock.

   This category included a wide variety of types, designed generally for yard or harbour use, with services supplied from shore. Among the principal types were 400-ton concrete trough docks; 1,000-ton, 3,000-ton and 5,000-ton one-piece timber trough docks; sectional timber docks ranging from 7,000 to 20,000 tons lifting capacity; and three-piece self-docking steel sectional docks of 14,000 to 18,000 tons lifting capacity.

These classifications were modified in 1946 into the following four classes:

AFDB Auxiliary Floating Drydock, Big. (30,000 tons and larger.)

AFDM Auxiliary Floating Drydock, Medium. (10,000 to 30,000 tons.)

AFDL Auxiliary Floating Drydock, Little. (Less than 10,000 tons.)

AFDL(C) Auxiliary Floating Drydock Little (Concrete).

The British Admiralty were less adventurous and all their docks were initially number sequentially starting with the Bermuda Floating Dock, AFD1, at the beginning of the 20^{th} Century. However, by the end of WWII various numbers assigned under the war building programme were either uncompleted or not started. As a consequence, the numbers for some of the cancelled docks were used after WWII with docks being numbered AFD58, AFD59, AFD60, AFD61, and AFD82. The latter two were only completed to the design stage.

11 Conclusions

Docks have evolved since their beginnings in the 1700s eventually leading to the balance docks that evolved into the modern floating docks today. Virtually all docks today are of the balance type along the principals of G.B. Rennie’s 1859 Carthagena Floating Dock. Since then, there have been many permutations, particularly in regard to self-docking.

Floating docks have proved to be extremely versatile offering a wide range of possibilities and features that can be tailored to suit individual circumstances. That they have been lifting small and large ships, including some of the largest built, for more than 200 years is a testament to their effectiveness and ability to adapt.

The use of modern machinery and computerised control systems has greatly improved the safety and ease with which floating docks can now be operated.

Paper read by David M. Westmore at the Drydock Conference, San Diego, USA, in February 2011