Dry Docking for Naval Architects



Source:
https://www.gac.com/poland/shipping/dry-docking-support

Agenda

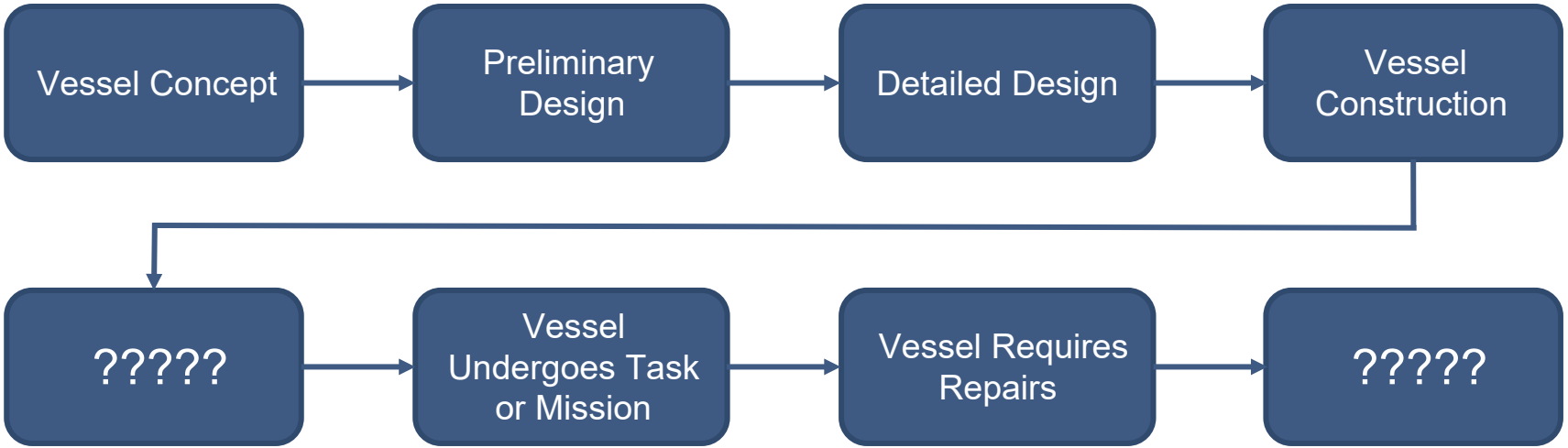
- **Introduction to Dry Docking**
  - Importance and History
- **Types of Dry Docks**
  - Graving Dry Docks
  - Floating Dry Docks
  - Vertical Shiplifts
  - Other Methods
- **Dry Docking Components**
  - Blocks and Block Composition
  - Transport Systems
- **Dry Docking Procedure**
  - Docking Plan
  - Docking Operation
  - Exceptional Circumstances
- **Predicting Behaviors and Loads during Dry Docking**
  - Stability during Dry Docking
  - Blocking Loads during Dry Docking

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Introduction to Dry Docking

- Beginning to understand the design and construction aspects of building a vessel, but the following logistical questions still remain…



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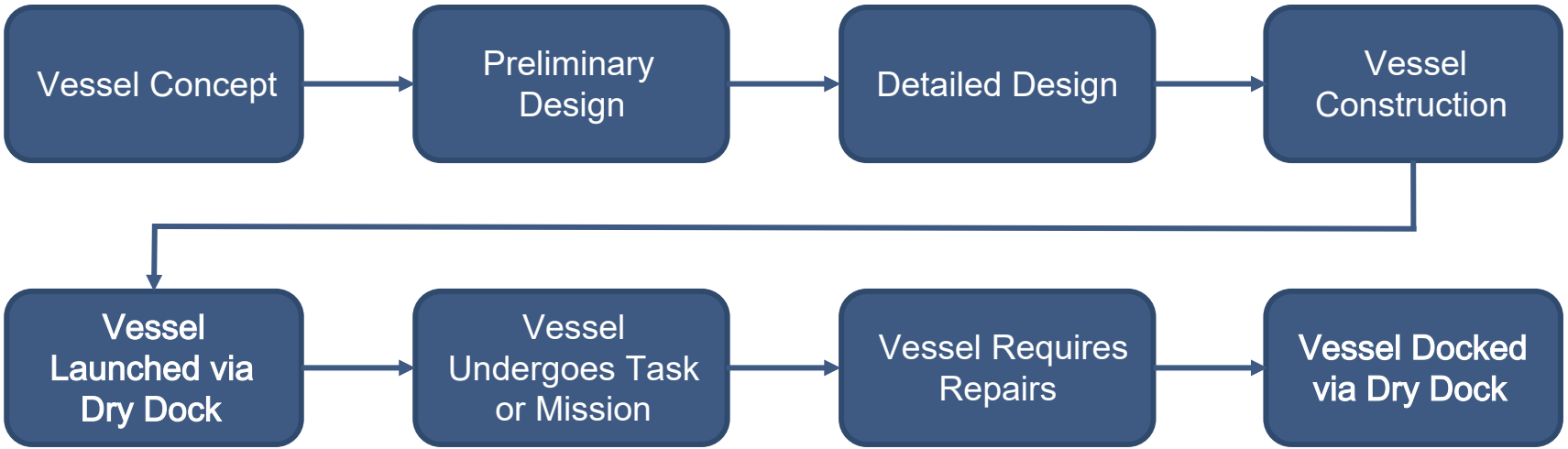
How do these massive vessels first enter the water from the shipyard?

What happens when the vessel needs repairs and/or retrofits?

And perhaps most importantly…

How do we guarantee the safety of the vessel and engineers involved throughout this process?

…the answer is of course **Dry Docks**



Importance of Dry Docking

- Dry docks are an essential tool in all aspects of the maritime industry
- **Two** primary purposes:
  - Responsible for **launching new construction vessels** from ship building yards
  - Used to remove the vessel from the water to undergo **out-of-water inspections, repairs, maintenance, and retrofits**
- A dry dock is used to launch the vessel, then repeatedly throughout its lifetime, typically **every 5 years** depending on the vessel type and corresponding regulations



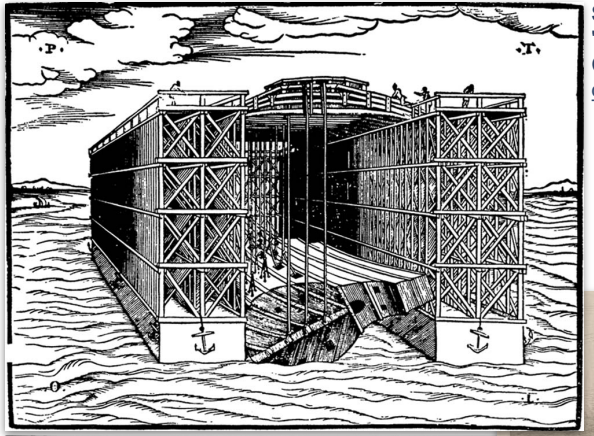
Importance of Dry Docking

- A cargo ship with the average lifespan of **25-30 years may be dry docked 6+ times** throughout its lifetime

- Reasons that a ship may require dry docking for repair or maintenance may include, but are not limited to, the following:
  - Reapplication of **paint and/or antifouling**
  - **Engine** component removal, replacements or **retrofits**
  - Hull or protrusion **repairs**
  - Vessel **surveys or inspections**
    - Hull survey
    - Rudder inspection
    - Propeller inspection
    - Anchor and chain survey

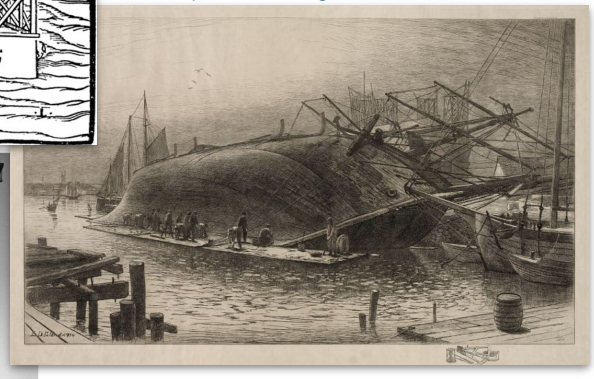
Brief History and History of Dry Docking

- Versions of dry docking have existed for thousands of years
  - Common early methods were careening and grounding
- First recorded graving dock was built in 1495
- First marine railway in 1818
- First concept of floating drydocks in 1560



Source: Sarton, George (1946), "Floating Docks in the Sixteenth Century", Isis, 36 (3/4): 153–154, doi:10.1086/347934

Source: Eldred, L. D. (1914), “Hove down”, [Photograph] Retrieved from the Library of Congress, https://www.loc.gov/item/2003666824/.





Source: https://dp.la/item/a7890e8161fbbec9ccebf1bb51eab1c1

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Types of Dry Docks used Today

- Three primary dry docking methods are used in modern shipyards today
  - **Graving Dry Dock**
  - **Floating Dry Dock**
  - **Vertical Shiplift Systems**

- Other methods include
  - Marine Railway
  - Mobile Boat Hoist



Source: https://www.noatum.com/en/the-history-and-evolution-of-dry-docking/

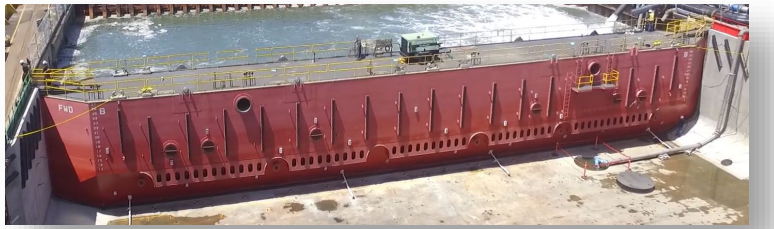
Graving Dry Docks



https://www.youtube.com/watch?v=jkjM9hRQ89A

Graving Dry Docks

- Commonly referred to as a “**basin**” or “traditional” dry dock
- Large, reinforced, typically concrete basin positioned below the water-level along the nearby waterfront
- Pumps fixed throughout the dock drain water from the basin during operation
- A dock gate or **closure gate seals the basin** from the waterfront but may open to allow water and/or the vessel to enter or leave the dock
    - Most common closure gate is a **Floating Caisson Gate**: a buoyant gate that can be ballasted and pulled into position
    - **Valves on gate** can be opened to **flood basin** during operation



Source: https://hegerdrydock.com/portfolio/nassco-san-diego-cadry-dock-no-1/

Graving Dry Docks - Types of Dock Gates

- **Mitre Gates:** Pair of symmetrical, swinging gates hinged along the dock walls
  - Localized loads on dock walls
- **Flap Gates:** Single, rigid gate hinged at the bottom to swing up or downward
  - Costly operation and maintenance
- **Sliding Caisson Gates:** Gate that slides or rolls along its base, into or out of position
  - Quick operation
- **Floating Caisson Gates:** Buoyant gate that can be ballasted and pulled into position
  - Most common type of basin closure gate
- **Set in Place Gates:** Gate that can be lifted into our out of position
  - Often used as an intermediate gate

Operation of Graving Dry Docks - New Construction

- Order of operations varies slightly between new construction and dry docked vessels:
- New construction:
  - Vessel is **constructed on keel blocks**
    - Engineers develop **blocking plan** to determine **allowable local loads** on hull
    - Typically blocks are placed such that they lie below **transverse or longitudinal frames**
    - Blocks may be left out or removed to facilitate painting, appendages, etc.
  - Vessel is **secured in position to the shore and held in place**
  - **Basin is flooded** via pumps or opening of dock gate valves
  - **Hydrostatics lift vessel** off of blocks
  - Vessel is towed or **navigated out of the dry dock**

Operation of Graving Dry Docks - Dry Docking Existing Vessels

- Dry docking existing vessels:
  - **Blocks are arranged** on the basin floor based on the vessel's **docking plan**
  - **Basin is flooded** via pumps or opening of dock gate valves
  - Vessel is **ballasted** to approximately **even keel**
  - Vessel is **positioned above the keel blocks** and **secured in place**
  - **Dock gate is closed** and seels the basin from the waterfront
  - **Diver(s)** are deployed to ensure the **keel is properly positioned** above blocks
  - **Pumps lower the water level inside the basin**, slowly lowering the vessel onto the blocks
    - Mooring lines may need to be adjusted throughout process
  - Basin is drained completely, ensuring the vessel **remains stable** throughout
  - Block-keel contact is examined to ensure the keel is safely cradled

Advantages of Graving Dry Docks

Advantages	Disadvantages
(+) Can accommodate wide range of vessel sizes	**(-)** Bottleneck of shipyard operation
(+) Long operational life expectancy	**(-)** Vessel must remain in basin throughout construction or repairs
(+) Relatively low maintenance	**(-)** Occupies valuable waterfront
(+) Simple operation minimizes risk of damage	**(-)** High initial construction costs

Floating Dry Docks



https://www.youtubeeducation.com/watch?v=YX8h-bfrAr4

Floating Dry Docks

- Large, buoyant platform, or pontoon, with vertical “wing walls” along its long edges
- Arrangement of **ballast tanks throughout the pontoon** used to submerge, float, trim, or heel the dry dock as necessary
    - Operation of ballast pumps may be conducted from a deckhouse on the “wing deck”
    - Pontoons can be lined with rails to facilitate the transfer of vessels to and from the shipyard
- Careful consideration for **stability, local strength, and longitudinal and transverse strength** must be made during design, construction and operation
- Three primary types of structural configurations and designs of floating docks:
    - **Box, Pontoon, and Sectional**

Floating Dry Docks - Floating Dock Types

- **Box Type**: Pontoon and wing walls are a single, rigid, continuous structure
  - High structural stiffness
- **Pontoon Type**: Continuous wing walls above noncontinuous, transversal pontoon segments
  - Longitudinal stiffness and rigidity comes entirely from wingwalls
  - Enables modularity and expansion of length of the pontoon
- **Sectional Type**: Both wingwalls and pontoon are noncontinuous and transversally segmented
  - “Locking logs” connect the segments but allow transfer of small moments and loads
  - Hinge pins connect the segments but do not allow moment transfer

Operation of Floating Dry Docks - New Construction

- Dry docking new construction vessels:
  - **Vessel is transferred from the shipyard** onto the pontoon of the dry dock, typically via rail
    - Keel blocks or rail strongbacks must be non-buoyant or fixed to the pontoon deck
    - Extensive consideration must be made into **minimizing heel and trim during transfer**
  - Vessel is **secured to the wing wall deck and held in place**
  - Dock may be **towed offshore** to deeper waters to accommodate draft at submersion
  - **Pumps systematically ballast** the dry dock until the pontoon deck is submerged below the draft of the vessel
    - Mooring lines may need to be adjusted throughout process
    - Ballasting operation is slow and methodical to **ensure stability is maintained**
  - Once supported **entirely by hydrostatic forces**, the vessel is navigated out of the dry dock

Operation of Floating Dry Docks - Existing Vessel

- Dry docking existing vessels:
  - **Blocks are fixed** on the pontoon deck in accordance to the vessel's **docking plan**
  - Dock may be **towed offshore** to deeper waters to accommodate draft at submersion
  - Dock may be **ballasted to match the vessel's trim**
  - **Pumps ballast** the pontoon and submerge the pontoon deck **below the vessel's draft**
  - Vessel is **positioned above the keel blocks** and **moored in place** along the wing deck
    - **Diver(s)** are deployed to ensure the **keel is properly positioned** above the blocks
  - **Pumps systematically deballast** the dry dock until the keel blocks contact the vessel's keel
    - Mooring lines may need to be adjusted throughout process
    - Deballasting operation is slow and methodical to **ensure stability is maintained**
  - Dry dock is towed back to shore and vessel is and, if the shipyard can facilitate transfer, the vessel can be transferred into the shipyard
    - Methodical ballasting or a shore ledge may be leveraged to minimize heel during transfer

Advantages of Floating Dry Docks

Advantages	Disadvantages
(+) Can accommodate a wide range of vessel sizes **(+)** Can be constructed at an external build site and towed to shipyard **(+)** If equipped, the vessel can be transferred out of the dry dock into the yard **(+)** Pontoon can be trimmed to accommodate vessel trim **(+)** Pontoon may be extended in length with the addition of pontoon segments	**(-)** Complex valve and pump systems require extensive maintenance **(-)** Dry docking process requires more thorough structural and stability considerations **(-)** Vessel transfer can be difficult due to resulting trim or heel **(-)** Submersion process requires deep draft near shipyard **(-)** Slow operation process

Vertical Shiplift Systems



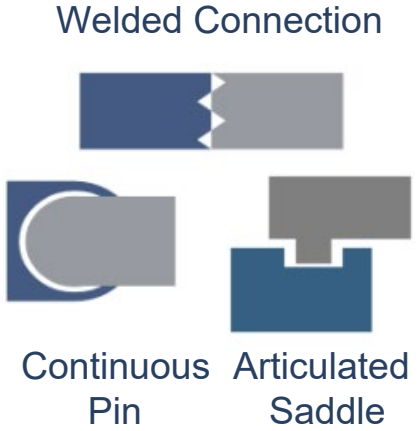
https://www.youtube.com/watch?v=xRcBhXKhtr4

Vertical Shiplift Systems

- Large, reinforced **platform that can be raised and lowered** to the vessels draft and up to the height of the shipyard
- A series of (typically synchronous) symmetrical **electro-mechanical hoists** are installed on piers on either side of the platform
    - The hoists are attached via **steel wire rope** to the ends of the platform's **main transverse beams**
    - Lifting capacity of the system depends on the lifting capacity of the hoist pairs and the longitudinal space between hoist connections
- Differences between shiplift platforms lie in the **connection points** between platform segments

Vertical Shiplift Systems - Platform Connection Types

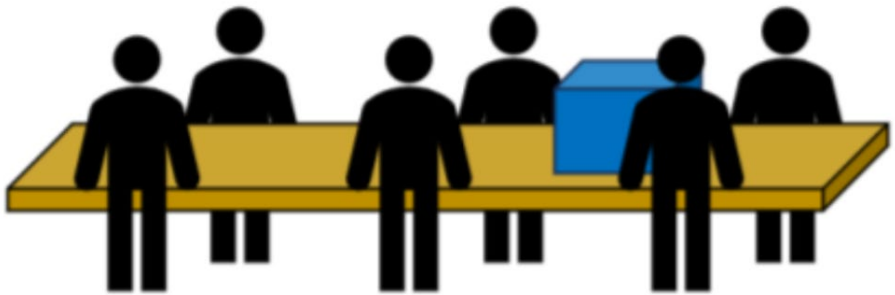
- "Rigid" Platform Section Connection
  - **Welded connection point**
  - Entire platform acts as a single, rigid entity
  - Allows **both force *and* moment transfer** between sections
- "Articulated" Platform Section Connection
  - **Rotational pin** or effectively articulated saddle connection points
  - Only allows **force transfer** between segments
    - Allows **operator to monitor loads** on each transverse segment based on the loads on the hoist sets
      - Informs the operator of unexpected or indefinite vessel loads to prevent the hull from becoming overloaded



Vertical Shiplift Systems - Platform Connection Example

- Intuitive way to understand the difference between platform connections is to imagine a banquet dining table with separated leafs representing an **articulated platform**
  - A heavy item somewhere on the table represents an **overloaded keel block**
  - People lifting along the sides represent **individual hoists**

- As each set of people lift their leaf (segment), they will be able to tell on which leaf the heavy item sits (overloaded block)
- **If the table was <u>not</u> split into leafs, (rigid platform) the location of th heavy item would be indeterminate**



Operation of Shiplift Platforms

- **Vessel is transferred from the shipyard** onto the platform of the shiplift
  - A variety of railed or wheeled transport methods may be used and removed prior to operation of the dock
- Vessel is **secured in piers and held in place**
- Synchronous hoists lower the entire platform at the same speed
  - **If the platform is articulated**, loads on each set of **hoists are monitored** to prevent overloading of keel blocks, the vessel's hull, or the hoists themselves
- Once the vessel is resting in the water entirely from hydrostatic forces, the mooring is decoupled
- The vessel may then be navigated out of the dry dock

Advantages of Vertical Shiplift Platforms

Advantages	Disadvantages
(+) Vessel can easily be transferred onto and off of shiplift platform **(+)** Additional platforms segments can be added to accommodate longer vessels **(+)** Quick operation process **(+)** Articulated platforms give valuable insight into loading on platform segments **(+)** Flexible orientation and footprint enables easy integration into shipyard **(+)** Occupies minimal shipyard waterfront	**(-)** Mechanical and electrical systems require maintenance **(-)** Capacity of shiplift limited by the width of the platform

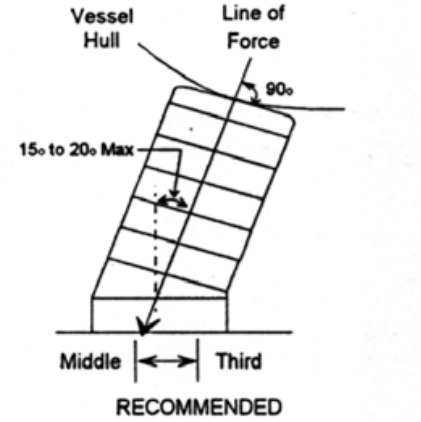
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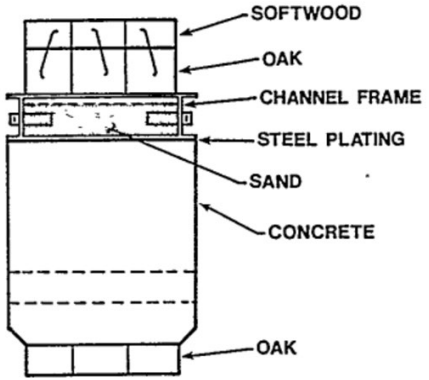
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Dry Docking Components: Blocks

Blocks are used to support the vessel during dry docking. The two types of blocks are keel blocks and side blocks. The blocks are typically built with the following materials:

- Soft wood
- Hard wood
- Steel
- Concrete

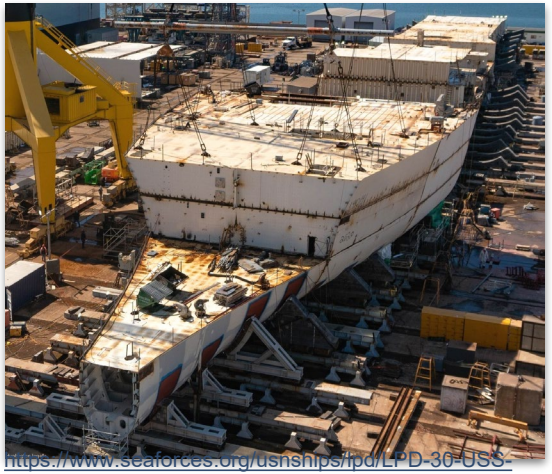




Dry Docking Components: Transport Systems

In order to maneuver vessels in a shipyard, facilities may use the following transport systems:

- Railed or wheeled strongback cradles
- Hydraulic lift cars
- Self propelled modular transporters



Source: Ingalls Shipyard, https://www.seaforces.org/usnships/lpd/LPD-30-USS-Harrisburg.htm



Source: Pearlson Shiplift Corporation, https://shiplift.com/transfer-systems/

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Blocking Plan

- Portion of the docking plan that outlines the blocking arrangements for a vessel to prepare for dry docking
- Not independent from the docking plan
- Typically consists of drawings of the elevation, docking plan, and keel profile
- Table of offsets and the table of block pressures is included
- Allows the shipyard know exactly where to place each block on the dry dock
- Corresponding height of each block is based on the keel profile drawing and the height of the vessel’s bilge.

Docking Plan

- Encompasses most of the information necessary to plan the dry docking of a vessel
- Unique and essential to each vessel
- Typically completed by naval architects or the shipyard that the vessel originated from
- Revisions may be necessary throughout the life of the vessel for changes in the weight distribution, trim, or other physical characteristics of the vessel

Exceptional Circumstances

The following events could lead to complications in the dry docking process

- Weather conditions
- Modification of the blocking arrangement due to damage or maintenance
- Considerable list or trim
    - Centerline is corrected before the vessel can be placed on the blocks
- Incomplete vessel information or docking plans
    - Using the Heger manual, vessel characteristics and block loads can be estimated by a shipyard to create a blocking plan

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Stability of Dry Docks

The stability of a vessel in dry dock depends on the transverse cross section of the vessel, the center of gravity,and the metacenter.

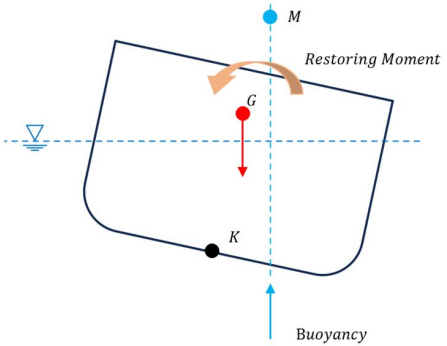
Sources of instability:

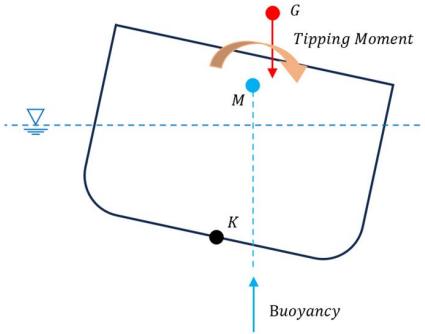
During the docking stage:

- Change of draft
- Contact between keel and docking blocks
- Free surface effect of liquid in tanks

During the undocking stage:

- Change of draft
- Vessel after modification or repairment





Stability of Floating Dry Docks

The stability of a floating dry dock is typically based on its phases, size, and free surface effect.

- Phases 3 and 4 are the least stable
- More waterplane area leads to more stability
- KG vs Weight plots are used to estimate stability

Phase 1: Submerged pontoon, no vessel



Phase 2: Partial lift of vessel



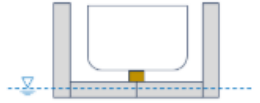
Phase 3: Pontoon waterline at top of keel blocks



Phase 4: Pontoon waterline even with pontoon deck



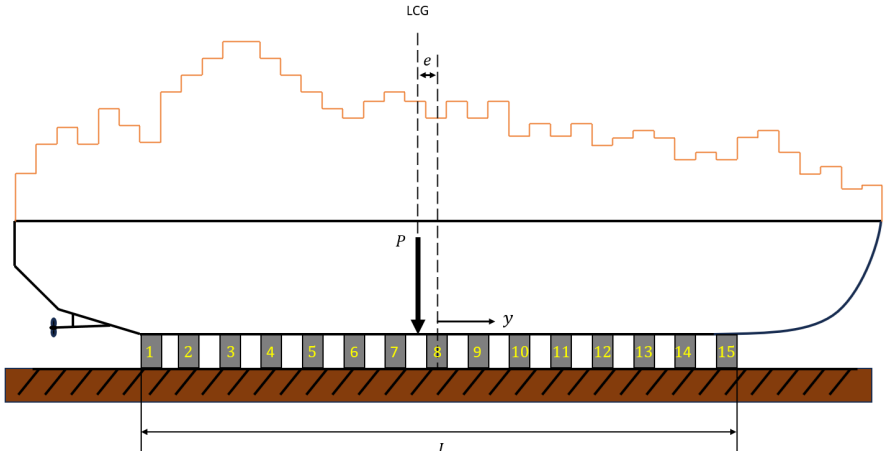
Phase 5: Pontoon at normal operating draft



Blockage Loads

Blockage load is the load that will be applied on each block

- Directly influenced by quantity and location
- Can be calculated using the trapezoidal and moment area methods
- Block material is important to knowing if the blocks can withstand the applied loads
- Soft caps are used at the top of the block to provide sufficient compliance during docking. Without compliance, high blocks or unexpected hull protrusions can cause local hull or block overloads.



Conclusion

Dry docks are a critical part of a vessel's lifetime. Not only does a vessel begin in a dry dock, but it is expected to return to undergo maintenance and repairs.

Understanding the operation of the most common types of dry docks and calculation methods is important for a naval architect due to the great deal of precautions and calculations needed to ensure that the process is carried out smoothly and safely.