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How To Read Shipbuilding Drawings (Part 1)

by

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Shipbuilding drawings (or plans) are the detailed directions to building the ship. The types of these plans can be broken down into various groups to convey information pertinent to the design engineers and the various craft personnel that do the construction. Drawings, along with the calculations supporting them, are produced by either an outside design firm, the engineering department in the shipyard, or both. There are often many subcontractors who do design work in specific fields in addition to those personnel at the shipbuilder's yard. This class will be concerned with how to read the drawings only; an educated skill which a surprising number of crafts people don't possess. Part 1 will discuss the drawings common to the Preliminary Design stage, with Part 2 discussing the Contract Design stage, and Part 3 discussing the Detail Design stage.

The drawings in some ways are like those of other architecture and engineering disciplines, but they differ in ways specific to the marine field. Like most architecture and engineering drawings,

- they are drawn to ANSI standards of letter height, and typical architectural scales in the U.S. unless they are drawn to typical metric scales.

- there is a title block usually to the right showing what firm drew the plan, their contact information, the drawing scale, issue date, title, project name, the drafter's initials or name, the checker and/or supervisor's initials or name, drawing number, project number, revision indicator, and often what the computer file name is.

- There is a frame around the drawing showing a zone breakdown by letter and numbers for microfilming and so that a particular area of the drawing can be referred to in revision notes in the revision block in the upper right.

- Revisions are either numbered or lettered, and it is best to have all sheets the same revision number or letter to avoid confusion as revisions to some pages but not others are made. Those pages that are not revised but advance a letter or number with the set, have a notation such as "no changes this sheet" in the revision block.

- The revision block has notes to describe each change made to the drawing since the last issue, and there are often triangular or other shaped symbols telling the revision indicator and note number to aid the reader in understanding what was recently changed. These revision notes save the reader a lot of time understanding the specific changes if they are already familiar with the previous revision.

- Project and drawing number format varies with the firm, but often is a combination of project number, drawing number, and perhaps alphabetical characters to indicate, for example, S for structure, P for piping, E for electrical, etc.

- There may be detailed views drawn in different scales to provide more information. There is a Bill of Materials indicating item part number, item description, quantity required, make, model, material specifications, and any remarks or notes necessary.
- There is a set of General Notes, usually only on sheet 1, and a block indicating distribution of the various revisions, to whom or what department, how many copies, and revision issue date.
- There is often a list of numbered reference drawings on the first sheet near the title block to allow the drafter to refer to these other drawings by reference number instead of always having to write out the drawing name.

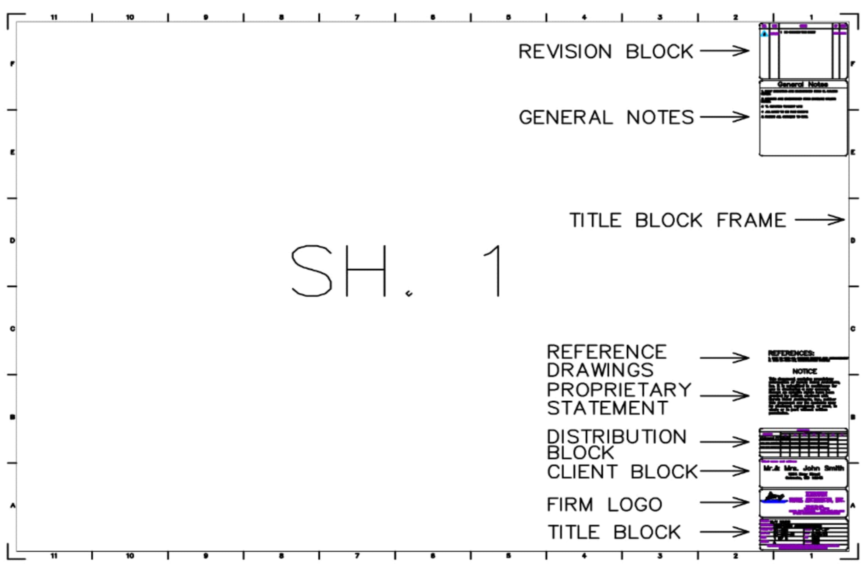

FIGURE 1

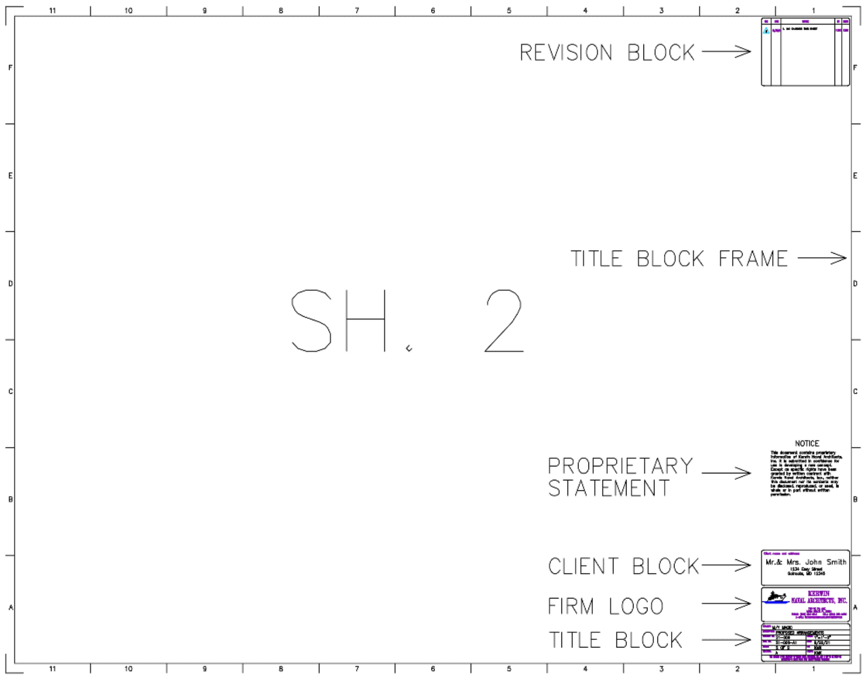

FIGURE 2

What is different are the specific traditional ways that marine drawings show the design and construction information.

The design generally proceeds in three phases: Preliminary Design, Contract Design, and Construction Detail Design. The Preliminary drawings are just that-preliminary conceptual work that should not be used for construction because they require further development and integration with other drawings to follow. These are often inaccurate in small aspects by the time construction starts, so one should be careful during the later stages to use only drawings developed during the stage of design they are currently in. Smart shipyards often have a drawing file manager who makes sure that when a new drawing is issued, all previous revisions (as far as possible) are returned or have been destroyed so that mistakes using the wrong drawings are minimized.

Glossary

- Aft-the direction toward the back end of the ship. Aft is an abbreviation for “after” and the two are used interchangeably in nautical terminology.
- Aft Perpendicular (AP)-Generally where the rudder stock is located no matter if a structural frame is there or not. In the wooden ships of the past, this was where the rudder was hung on the ship, and it is also where ships in countries other than the U.S. often began the erection of the frames.
- Amidships or Midships-the halfway point of the length of the Design Waterline (DWL).
- Ballast-solid weights and/or liquid weight carried as extra weight in the bottom of the hull to improve the stability and trim of a vessel.

- Baseline-the horizontal line which the hull sits on. This is the lowest reference line shown in the Profile and Body Plan views of all drawings.
- Beam-the transverse structural member that supports a deck.
- Bilge-the lower edge and bottom of the hull. On the inside of the hull where there is not a tank, condensation and oily water may collect here. Figure 3 on the right shows a round bilge ship hull, which is designed for more efficient hull resistance compared to a chin-bilge hull
- Bilge Keel-a structural appendage along the middle of each side of the ship underwater that resists the rolling of the ship.
- Body Plan-a fore-and aft elevation on the Hull Lines plan showing the shape of the hull at various points along the length as if a plane is passed through like slices of bread.
- Bow Thruster-a propulsion device mounted transversely in the ship at the bow that assists in maneuvering in port.
- Bridge-space at or near the top of the ship containing the controls to drive the ship. Also called the Pilothouse of Wheelhouse.
- Bulkhead-a transverse or longitudinal structural load-bearing wall that prevents twisting of the hull at sea, and in the case of watertight bulkheads, prevents the flow of leaking seawater or fire forward or aft to the next watertight compartment.
- Bulwark-the structural “fence” around the weather deck that keeps seawater from coming aboard
- Centerline-this is the vertical reference line on center of the hull. This is the 0’-0” Buttock, and is shown in the Plan View and Body Plan of all drawings.
- Chine-a joint of the bottom and side plates of the hull that creates a hard corner rather than a curved shape in the transverse direction. Due to the relative difficulty of bending metal plates in both the fore and aft, and transverse directions, chine hulls are a way to make construction faster and less expensive. The tradeoff is a loss of some hydrodynamic efficiency, resulting in higher hull resistance and therefore more power is required to make design speed compared to a round bilge hull. A compromise between the two types is a double chine hull, where a flat plate between the two chines approximates the benefits of a round bilge, but it is simpler to construct.
- Classification-a design and construction standard that forms the basis of design for a ship and a mark of quality for the insurer and owner. There are various Classification societies that publish design guides, provide technical review, and surveyors to assure that the ship is designed and built to their standards. Most ships are designed and built to Class standards, but not all are. Drawings and calculations showing that the vessel meets Class standards are submitted for review and approval in the Contract phase of design (which see in Part 2)
- Cofferdam-an open space in the bilge between tanks that holds pumps, bilge suction pipes, transfer pipes, and electronic sensors for depth

- Collision Bulkhead-the first bulkhead in a ship, located by regulations at 5-10% of the length of the LWL. It is generally 1.5 times the strength of the other watertight bulkheads.
- Deck-a horizontal floor (in building terms) in or on the hull.
- Design Waterline (DWL)-the Naval Architect's intended maximum draft of the ship
- Draft-the depth of water to which the vessel can safely and legally be loaded. This varies slightly with seasons due to water temperature and salinity, and it is marked as such along with the Plimsoll Mark. This is generally synonymous with the Load Waterline Length (LWL)
- Floor-the vertical web near the centerline, of a transverse frame (not a deck!).
- Forward -the direction toward the front end of the ship.
- Forward Perpendicular (FP)-the forward-most hull frame location in the hull, numbered as Frame 0 on American surface ships
- Frame-A structural rib located transversely in the hull.
- Girder-a major longitudinal load-bearing structural member that supports the hull bottom and decks over a wide and long area. They have a deeper web depth than longitudinal stringers or stiffeners.
- Longitudinal Center of Buoyancy (LCB)- the longitudinal distance of the location of the center of the buoyant forces on the immersed volume of the hull from the vertical datum (FP, AP, or Midships).
- Longitudinal Center of Flotation (LCF)- the longitudinal distance of a point on the top waterline of the immersed hull, measured from the longitudinal reference datum, about which the hull trims when acted upon by the separation distance between the LCG and LCB. It is similar to a teeter-totter pivot point. The LCF is seldom the same distance from the longitudinal reference point as the LCB.
- Longitudinal Center of Gravity (LCG)-this is the position of the forward or aft location of each item accounted for in the weight estimate, and the total ship, measured from the longitudinal reference axis. If a midship reference axis is being used, distances of weight items and/or the ship forward of amidships are considered negative, and distances measured aft of amidships are considered aft so that aft trim, which is generally desirable, is positive.
- Longitudinal Framing System-a system of structural framing that is used on long and relatively narrow ships such as tankers, ore freighters, destroyers, cruisers, and aircraft carriers. It utilizes deep longitudinal girders and ring frames
- Longitudinal Stringer or Stiffener-a longitudinal structural member that stiffens shell and deck plate.
- Particulars-the important overall dimensions, capacities, design speed, and Classification notations of the ship.
- Plan View-a view on a drawing looking up or down.

- Plimsoll Mark- This is a painted symbol located amidships on the LWL is named for its inventor, looking like a circle with a backwards C to the left and a forward C to the right. This symbol and accompanying water level marks show the legal limits of draft that the ship can be loaded to. This location is sometimes used in weight estimates if the stability calculations base trim about the midship point rather than either forward or aft perpendicular.
- Port side-the left side of the ship when looking forward. Often abbreviated as PS.
- Profile View-an elevation view on a drawing showing the ship from the side looking inboard or outboard.
- Rabbet Line-the intersection line between the side of the keel and the bottom shell of the hull.
- Reference Axes-As shown in Figure 3, the longitudinal centerline at the base of the ship is called the baseline. All vertical and transverse references are made relative to the baseline. This is abbreviated as BL. The start of the longitudinal axis in American surface ships is generally at a position near the bow, called the Forward Perpendicular. This is abbreviated FP, and it is usually located at the intersection of the design waterline (DWL) and the stem (forward-most vertical structure of the bow). Measurements from the FP proceed aft on American surface ships. Vessels designed and built elsewhere, and all submarines, usually use the aft perpendicular (AP) as the start of the longitudinal reference axis by long-time custom. The location of this historically was where the rudder post was located, but modern ships may have an arbitrary or frame location used for this such as 95-96% of the waterline length.
- Ring Frame-a structural frame that repeats every 3 or 4 regular frames in a longitudinal-type framing system, that is the transverse version of a girder in that it supports the girders over a length of several regular frames. These are commonly used in tankers, ore carriers, and similar cargo ships where the depth of the ring frames do not interfere with the interior living space of the crew and passengers.
- Roll-the tendency of the ship to roll from side to side at sea.
- Scantlings-the nautical term for the structural members of a hull.
- Stabilizer Fin-a wing-like appendage that is actuated by hydraulics or electric motors, that counteracts or reduces the rolling of the ship.
- Starboard-the right side of the ship when looking forward. Often abbreviated as Stbd or SS.
- Superstructure-deckhouse structure on the weather deck that is as wide as the hull. This is often forward on the hull.
- Tangent Line-the intersection between a radiused edge and a flat surface.
- Tank-a container to hold fluids such as fuel, fresh water, grey water (drain water), black water (sewage), water ballast, hydraulic, lubricating, or dirty oils, and oily bilge water. Tanks built into the structure are integral, others are drop-in tanks.
- Tanktop-the structural plating that forms the top of a tank.

- Transverse Framing System-a system of structural framing similar to the human body, where there is a backbone (the keel), closely spaced ribs (the frames), and skin (the hull plating) and decks. This is more common in short, wider ships, especially those like car ferries, passenger ships, and yachts.
- Trim-the fore and aft balance of the ship. Bow-down (forward) trim is down at the bow, stern-down (aft) trim is down at the stern. Aft trim is generally preferable to keep the propeller(s) submerged.
- Weather Deck-the highest deck in the hull, which is exposed to the weather.

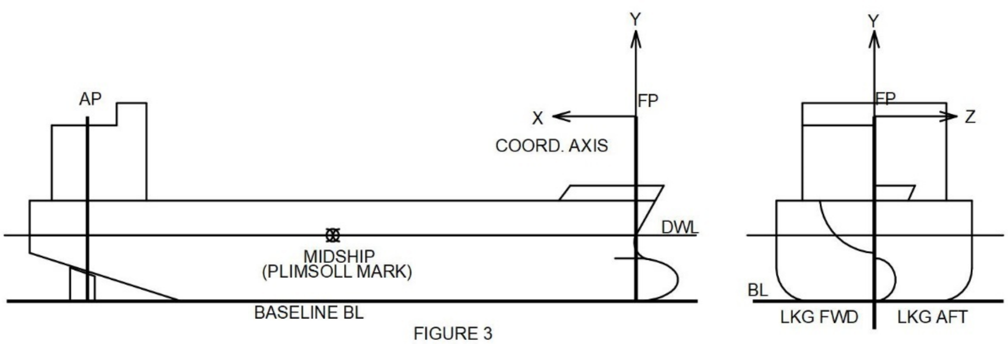

FIGURE 3

Preliminary Design

All drawings start with a set of reference axes: Baseline (BL), Forward Perpendicular (FP), Aft Perpendicular (AP), Midship location (looks like a circle with forward and backward letter C's), the Design or Load Waterline (DWL or LWL). Establishing these datum points and lines is extremely important because the location of everything, and the weights of all parts are referenced to these. The vessel's stability, or tendency to stay upright and behave properly, in spite of the forces of sea, loading, and wind pressure, is dependent on knowing where a proper center of gravity for the design must be.

The drawing set of a Preliminary design consists of a small number of sheets showing generalized details of the ship as follows:

- Hull Lines and Offsets
- Outboard Profile and Arrangement
- Inboard Profile and Arrangement
- Interior Design Renderings if the vessel is a yacht or passenger ship
- Exterior Artistic Rendering if the vessel is a yacht or passenger ship
- Machinery Arrangement
- Tank and Ballast Plan

- Preliminary Weight Estimate
- Preliminary Speed/Range/Power/Fuel Consumption Calculations
- Preliminary Stability Estimate

The Purpose of the Preliminary stage of design is to work out the feasibility of the concept, that is, to come up with a set of plans and supporting calculations which show whether or not the design is a practical solution to the client's needs to make the speed, carry the cargo and/or passengers, and return a profit (if necessary) that meets the client's economic purpose.

Hull Lines and Table of Offsets

The Hull Lines and Table of Offsets drawings are special drawings that show in 3 views, the 3-dimensional shape of the hull and superstructure, and provides the hull surface dimensions. This plan is the basis of all further design of the ship because it defines the outer envelope and appendages of the ship. The presentation is easiest to understand if one imagines slicing a loaf of bread in various ways, showing the slice lines as they would look from 3 different directions. Before the advent of 2D computer graphics, these drawings were traditionally drawn by 2D projection from one view to each of the other views so that any intersecting point matches the locations in the other views. These views are called the Profile, Plan View, and Body Plan. The Body Plan is often shown to the right of either the Profile or Plan View, but sometimes above them at the center of the ship. The right side of the Body Plan shows the ship looking aft from the bow aft to amidships (Station 5, see below), and the left side shows the stern looking forward to Station 6 (see below) from aft. Figure 4 shows the lines plan of a fishing schooner, but engine-driven ships are similarly shown. The concept of this is that geometric planes are passed through the 3D hull and the lines of intersection where the edge of the plane passes through the outer edge of the hull and/or superstructure, and these lines of intersection are what is shown on the Lines Plan. Imagine slicing a loaf of bread three different ways. The Plan View is drawn above the centerline of the vessel to allow several Diagonal lines to be drawn below the centerline. The Diagonals are a check for hull fairness; they are drawn first on the Body Plan at some angle like 45 and 60 degrees down from the DWL out to the Baseline, with the resulting intersection points projected to the lower part of the Plan View. Traditional Lines Plans are drawn this way because the drafter working by hand on a drafting board could use straight edges, triangles, and other drafting tools to project points from one of the three views to the other two views, ensuring an accurate 3D representation of the hull shape.

The hull is traditionally divided into 10 equal spaces along the DWL length on the Profile and Plan Views, with additional equal spaces and half-spaces where needed for additional definition in highly curved areas at the bow and stern. This was done so that when manual calculations of the hydrostatics were done, the calculations were not too onerous. Vertical lines at the edges of the spaces are called stations, and they are numbered 0 to 10 starting at the forward end on American surface ships and at the aft end on non-American surface ships and all submarines. As a historical aside, American submarines are drawn the other way because the first practical Navy submarine was designed by John Holland, an Irishman who first found no interest by the British Navy in his design, so he presented them to the U.S. Navy, after which the first U.S. Naval submarine built was designed and built by Holland, as the U.S.S. Holland in 1900. And as another historical note, American ship construction progress has traditionally started after keel laying by standing up the frames of a ship at the forward end, so the first frame is the Forward Perpendicular (FP); others started the hull frames at the aft end, known as the Aft Perpendicular (AP) because this is where the rudder was hung. Stations forward of the FP are given negative numbers in U.S. practice, and stations aft of the AP are given continuing numbers such as 11 and 12. Half stations are denoted as such. The stations thus are the intersection points of thin planes passed transversely through the hull, and their shape as they intersect the hull are projected onto the Body Plan so that they look like slices of bread if the hull was sliced lengthwise on the stations.

Other lines drawn on the Hull Lines plan are Waterlines and Buttocks. Horizontal planes passing transversely through the hull are called waterplanes, and are labeled as such, or abbreviated by WP. These are numbered from the Baseline (BL) up to the highest point on the hull or superstructure, in equal intervals such as 1 foot or 100 centimeters, labeled as Butt 1'-0" or Butt 100cm. The outlines of these intersections with the hull are shown on the Plan View and the plane lines are shown as straight lines in the Profile and Body Plan views.

The Buttocks are the projected cut lines of vertical planes passing longitudinally through the hull. These are numbered from the Centerline (CL) outward on both sides of the hull in equal intervals similarly to the waterplanes as 1 foot or 100 centimeters. The outlines of these intersections with the hull are shown on the Profile View and the plane lines are shown as straight lines in the Plan View and Body Plan.

Diagonal Planes are often added to Lines Plans that have hulls with a lot of curvature to confirm the fairness of hull curvature through the bilges. Figure 4 shows 3 diagonal planes on the Body Plan which pass through the hull from forward to aft, but at an angle to the rest of the grid. The diagonals are drawn to pass orthogonally through the bilges on the Body Plan, and they are projected onto the space below the Plan View centerline.

Additional defining lines drawn on the Hull Lines Plan are the intersections of weather deck edges and breaks where it steps up or down, deck camber, bulwarks, transom outline, chines, knuckles, bow thruster tunnels, stabilizer fins, rudders, penetrations in the keel or skeg for the propeller, bilge keel outlines, transducers and other appendages are also shown on the Hull Lines plan. It is also convenient to mark the structural frame locations on the plan so that these can be referred to during construction; the Stations are not of much use today because computers do the calculation now. In fact, the Stations are of no use to the building personnel, only the Naval Architects, so they are not shown on any other drawings of the entire construction drawing set.

Now that 3D computer graphics have supplanted traditional board drafting, hulls are developed on specialized computer programs that can show the hull in its 3-dimensional form, and they can provide planar slices of the hull in any imaginable location as needed for further development. However, the traditional Hull Lines plan still finds use in understanding hull details in the shipyard building areas where paper copies are needed and computers may not be available, or where modifications are being done to vessels built before the 1990's when computer-aided design came to the forefront. So, while most ships today are designed in 3D, it is still useful to understand how to read a traditional lines plan, because the computer models may not have 3 views, but they are still drawn showing buttocks, waterlines, and frames in place of stations. Figure 6 is an example of the page showing the locations of Waterlines passing through Station 1.

Modern steel and aluminum ships generally have less curvature than wood of fiberglass ones, so their Hull Lines plans are somewhat simpler in detail. Diagonals may not be necessary in the former, and many workboats built in metal have either one or two chines instead of curved bilges to make construction easier.

FIGURE 4

The Table of Offsets shows measurements of the 3D coordinates of hundreds of points of each waterline, buttock, centerline profile, keel, deck edge, bulwarks, etcetera at each Station and along the defining edges on the surface of the hull. Locations forward of the FP, if it is the starting point, are given negative station and frame numbers, and vice versa if the AP is the longitudinal reference point. These are the numerical measurements used to scale the plans to full size in the traditional Mold Loft, where the ship parts were drawn full size on the floor to make the patterns necessary to cut the metal parts. The traditional format of the numbers in a Table of Offsets as read as x-x-x, for example 10-3-3, where the 10 is the number of feet, the first 3 is the number of inches, and the last 3 is the number of 1/8ths of an inch. The table consists of rows and columns, where the columns are Station numbers, and the rows correspond to either Buttocks or Waterlines where they intersect the Stations. Computers do this work now, so the table format is different, giving rows of decimal numbers in X, Y, and Z coordinates; but the Table of Offsets still finds use in developing structural parts later in the design stage.

Modern 3D design techniques allow direct transfer of the XYZ surface data to Numerical Control cutting equipment, but this drawing is still produced for future use where dimensional knowledge of the hull and superstructure surface position is required, such as developing stiffeners to fit the curvature of the hull. A more modern Table of Offsets developed from a 3D surface model may have a different format (Figure 6), where the table is a booklet of pages, with each page showing the half-breadth (half of the hull beam), heights above baseline, and a breakpoint indicator at the deck, for each station, such as:

	STATIONS	-1	0	1	2	3	4	5	6	7	8	9	10	11	11.5	12
HEIGHTS ABOVE BL	TOP OF RAIL	9-4-5	9-1-3+	8-10-3	8-7-4+	8-5-3	8-3-3	8-1-5	8-0-4	7-11-4	7-11-1	7-11-3	8-0-0	8-1-3	8-2-2	8-3-2
	TOP OF DECK	9-1-5	8-10-4+	8-7-4	8-5-0	8-3-0	8-1-1	7-11-5	7-10-4	7-9-7	7-9-6+	7-10-0	7-10-5	9-0-0	8-0-7+	8-1-7+
	6'-0" BUTT	------	------	------	7-7-4	5-10-1+	4-10-0+	4-4-1	4-3-0	4-5-2	4-10-6	5-6-7	6-7-3	------	------	------
	4'-6" BUTT	------	------	7-5-6+	8-9-3	4-9-1	4-1-0+	3-9-1	3-8-6	3-11-3+	4-4-5	5-0-0	5-8-7	6-7-3	7-4-4	------
	3'-0" BUTT	------	7-9-7	5-11-6+	4-10-1+	4-0-4	3-6-4	3-3-7	3-3-4	3-6-3	4-0-0	4-8-0	5-4-7	6-1-6	6-6-4	6-11-5+
	1'-6" BUTT	8-5-4+	6-3-2	4-11-0	4-0-4	3-5-3	3-0-3	2-10-0	2-10-3	3-1-3	3-7-6	4-4-4	5-2-3+	5-11-3	6-3-6	6-8-0
	RABBET LINE	7-0-4	5-2-2	4-2-5+	3-6-4	STRAIGHT LINE			STRAIGHT LINE		1-6-4	DEVELOP FULL SIZE				
	TANGENT LINE	------	------	------	3-5-0	2-11-0	2-1-6	1-0-0	0-10-2	0-8-1	------	------	------	------	------	------
	PROFILE	6-10-1+	5-0-0	4-0-6	3-4-2	2-7-0	1-6-4	0-4-6	0-4-0	0-2-6	0-5-6	0-8-0	5-0-0	5-9-4	6-2-0	6-6-5
HALF-BREADTHS FROM CL	TOP OF DECK	0-4-6	1-7-0	2-6-0	3-2-2	3-8-4	4-0-4+	4-2-4+	4-2-6	4-2-2	4-0-2	3-8-4	3-2-6	2-6-6	2-2-0	1-8-6
	12'-0" WL	0-8-4	1-1-2	2-2-7	3-1-1	3-8-2	------	------	------	------	------	------	------	------	------	------
	11'-0" WL	0-3-2	0-7-7	1-10-4	2-10-2	3-6-6	4-0-0	4-2-7	4-3-4	4-3-0	4-0-6	3-8-5	3-2-3	2-5-2	1-11-4	1-4-4
	10'-0" WL	------	0-1-7	1-4-5	2-6-0	3-4-0	3-10-5	4-2-4	4-3-5	4-3-0	4-0-2	3-7-1	2-11-2	1-10-2	0-10-4	------
	9'-0" WL	------	0-7-3	0-9-5	1-11-4+	2-11-2	3-7-6+	4-0-6	4-2-3	4-1-3	3-9-4	3-2-0+	2-0-1	------	------	------
	8'-0" WL	------	------	1-1-0	1-2-2	2-3-2	3-1-6	3-8-2	3-10-4	3-8-4	3-2-0	1-11-5	------	------	------	------
	7'-0" WL	------	------	0-2-6	0-3-1	1-3-5	2-3-0	2-10-1	3-0-0	2-7-7	1-8-0	0-7-2	------	------	------	------
	6'-0" WL	------	------	0-3-0	0-8-1	'1-0-7	1-10-6	2-4-5	2-5-3	1-11-0	0-8-5	0-1-5	------	------	------	------
	5'-0" WL	------	------	------	------	0-1-6	0-7-4	0-10-3	0-9-5	0-6-5	0-3-6	0-1-1	------	------	------	------
	4'-0" WL	------	------	------	------	------	0-2-5	0-4-3	0-4-2	0-3-4	0-2-2	0-0-6	------	------	------	------
	3'-0" WL	------	------	------	------	------	------	0-3-2	0-3-3+	0-2-6	0-1-6	0-0-4	------	------	------	------
	2'-0" WL	------	------	------	------	------	------	0-1-3	0-3-5	0-3-0	0-1-4	------	------	------	------	------
	1'-0" WL	------	------	------	------	------	------	------	0-1-2	0-2-5	0-1-0	------	------	------	------	------
	RABBET LINE	DEVELOP FULL SIZE										0-4-2	0-3-6	0-2-6	0-2-1	------
	KEEL FLAT	------	------	------	------	------	------	------	------	0-0-2	0-0-4	------	------	------	------	------
	DIAG. 1	0-4-2	1-6-7	2-7-5	3-7-0	4-4-1	4-11-7	5-4-7	56-5	5-5-1	5-1-0	4-6-3	3-10-3	3-1-0	2-7-6	2-2-2
	DIAG. 2	0-3-0	1-4-7	2-4-2	3-1-6+	3-10-2	4-4-6	4-8-3	4-9-0	4-6-4	4-1-2	3-5-4	2-8-0	1-9-4	1-4-2	0-11-1
	DIAG. 3	------	------	0-8-6	1-4-4	1-11-0	2-3-6	2-6-2	2-6-3	2-3-4	1-9-4	1-0-1	------	------	------	------

FIGURE 5

Station Name: S1 x=1.500 Indicator:b

	Half-Breadth	Height Above Baseline	Breakpoint Indicator
1	0.0000	3.6314	b
2	0.0244	3.7065	b
3	0.1893	4.2298	b
4	0.3300	4.7052	b
5	0.4503	5.1450	b
6	0.5133	5.3902	b
7	0.5586	5.5723	b
8	0.3716	5.5907	b
9	0.1854	5.6090	b
10	0.0000	5.6272	b

FIGURE 6

Outboard Profile and Arrangement

This drawing shows the outside views of the ship, looking at the profile, down onto the ship as a plan view, and often with fore and aft views similarly to a Body Plan. The drawing is a direct descendant from the Hull Lines drawing, and it uses the same reference axes. If the Hull Lines plan did not show the structural frame locations, these are added to this drawing. As many design details as can be known at the Preliminary stage are shown on this drawing, such as the superstructure, masts, navigation lights, doors, windows, portlights, paint scheme, DWL, interior decks and engine profile drawn in hidden line, shafts, propellers, rudders, stabilizers, bow thrusters, and all other items one would see on the side and from above the ship.

In the Preliminary stage of design many details are simplified because this is a drawing to get the client interested, work out the feasibility of the concept, but not to build from yet. The outboard profile is the right (starboard) side elevation of the ship, traditionally drawn with the bow to the right, in the lower part of the drawing. The top-down view (Plan View) is drawn above the outboard profile, with the frame locations for both views lined up vertically. Sometimes forward and aft elevations split at the centerline are also shown to the right of the outboard profile to clarify details at the ends of the vessel. Important dimensions are shown on this drawing which end up being used for calculations and other drawings. These dimensions, known as Particulars, such as length overall, length between perpendiculars, length on design waterline, design draft, overall height above water (air draft), Molded Beam, design maximum displacement, hull depth, total fuel, fresh water, gray water (soapy/drain water), black water (sewage) capacities, cargo deadweight tonnage, passenger capacity, sail area, car and/or truck capacity, engine horsepower, speed, Flag, Classification notations, and gross tonnage are shown in this list.

These days, much of the drawing is done in 3D, so a 3D model of the ship is done first, and 2D views as above are projected onto the drawing sheet to provide a medium for review and marking up. Traditionally, paper drawing copies have been issued to all interested parties, but this is evolving into creating complete 3D models for distribution and construction without any paper drawings being issued. As you can imagine, this takes a LOT of computer power.

Figure 7 shows a typical Outboard Profile and Arrangement drawing, including Particulars, of a bulk carrier of cargos such as wheat, cement, iron ore, etcetera, which are loaded without containments into the rectangular cargo holds by conveyor belts or hoses.

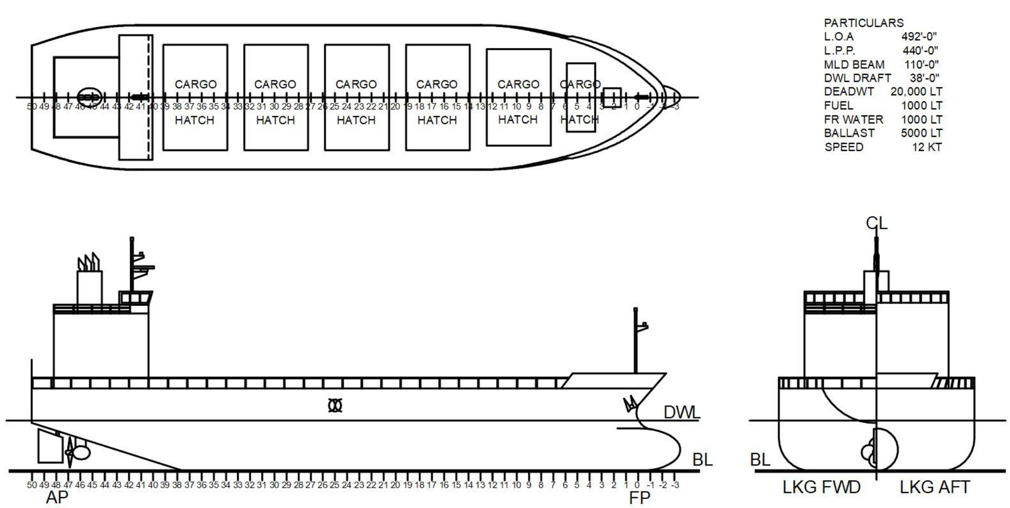

FIGURE 7

Inboard Profile and Arrangement

This drawing shows the inside (usually centerline) elevation of the ship, the interior decks of the hull and superstructure, and sometimes the bilge plan below the lowermost deck. In the inboard profile one can see the relative heights of decks, tank tops (the tops of tanks which are not decks), ladders, elevators, and stairs, major bulkheads, mast support, engine foundations and some of the propulsion system, exhaust outline, elevators, portlights, windows, side hatches, nomenclature and uses of the various compartments, and many other details. Sometimes additional inboard elevations at noted distances off centerline are also shown to clarify outboard features which may be hidden by centerline passage bulkheads or other structure.

Individual plan views of decks line up on the longitudinal reference point as much as possible so one can see where each point in the ship is, over or under the other decks. The drawing is also directly descendant from the Hull Lines drawing, and it uses the same reference axes. If the Hull Lines plan did not show the structural frame locations, these are also added to this drawing, and the frames are shown in the profile view. As many design details as can be known at the Preliminary stage are shown on this drawing, such as the superstructure, masts, stairs, ladders, furniture, cabins, cargo holds, pilothouse, eating and entertainment spaces, doors, windows, portlights, structure, DWL, engine profile, shafts, propellers, rudders, stabilizers, bow thrusters, and all other items one would see if the outside (shell) plating was removed. Like the Outboard version, in the Preliminary stage of design many details are simplified, because this is a drawing to get the client interested, work out the feasibility of the concept, but not to build from yet. Figure 8 shows this drawing for the same ship shown in Figure 7.

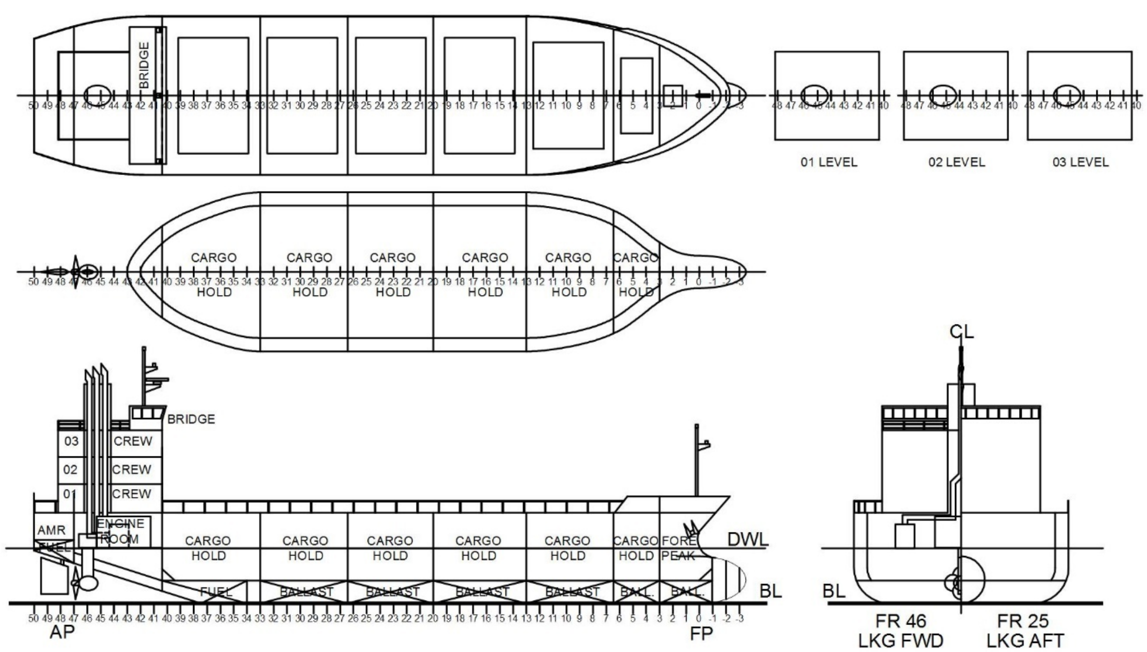

FIGURE 8

Interior Design (done in this stage for yachts, done in Contract stage for warships and commercial vessels)

On yachts, Interior Design is one of the important first steps in developing a concept that the client will sign a build contract for. This work is often done by outside design firms, and consists of space planning, artistic renderings of the various cabins and social spaces, furniture, appliance, and hardware selections, and sample boards of colors, textures, and materials to be used in each space. The information developed by the Interior Designer is integrated into the Inboard Profile and Arrangement drawing so that the two complement each other and develop in parallel. This set of drawings and materials texture boards shows the overall interior design concept of the vessel from a more artistic perspective that the usual engineering-type views. These instead can be perspectives, oblique views, sketches, photographs, both hand-drawn and computer-rendered. In yachts this is a very important marketing tool along with the Outboard Profile and Arrangement drawings, and as such can take the place of the Inboard Profile and Arrangement in the Preliminary stage. In Naval and commercial vessels, this set of drawings may be done later in the Contract phase of design since both utilize standardized commercially available furniture, bulkhead panel textures, and fixtures that are generally not expensive, custom-made pieces as in yachts.

On commercial vessels and warships, this stage is somewhat less important and is left to the Contract stage of design since most equipment and interior joinery (carpentry items) come out of catalogs rather than are custom designed as on yachts.

FIGURE 9

FIGURE 10

Exterior Design (often the same as the Outboard Profile drawing unless done by a stylist specialist)

In the case of yachts, the Exterior Design may be an artistic rendering of the yacht in a harbor or at sea, from any angle that suits the image wanting to be portrayed (Figure 11). This, along with the Interior Design drawings, are also one of the important first steps in developing a concept that the client will sign a build contract for. Nowadays these are often drawn by specialist yacht design firms made up of art/design school graduates or other artistic professionals, instead of Naval Architects, although some Naval Architects still specialize in the more artistic conceptual design aspects. Often there are multiple renderings including night drawings showing lighting. The information developed by the Exterior Designer is integrated into the Outboard Profile and Arrangement drawing so that the two complement each other and develop in parallel. Yachts are a special case where much of the time, form is everything and function follows. This is the other way around in Naval and commercial design, where function and profitability in build cost and operation are of paramount importance. In such cases design tends to follow function more than artistic features, and so they usually do not employ an exterior stylist separate from the Naval Architecture firm.

FIGURE 11: https://commons.wikimedia.org/wiki/File:SaintChristopherYachtRender.jpg

In Naval warship design, there are several schools of thought pertaining to their overall exterior styling. American naval surface ships tend to have hulls that are shaped to be easy to construct, produce an adequate speed in excess of 30 knots to keep up with the fleet, and have a deckhouse that appears to be a disparate stack of blocks shaped to provide the space needed for the equipment inside Furthermore, with the advent of rapid-firing guns and vertical-launch missiles, they appear to be barely armed even though they often have much more firepower than their predecessors.

FIGURE 12: https://commons.wikimedia.org/wiki/File:US_Navy_020617-N-5067K-004_The_Spruance-class_destroyer_USS_Kinkaid_(DD_965).jpg

FIGURE 13: https://commons.wikimedia.org/wiki/File:US_Navy_120109-N-CJ186-124_The_Arleigh_Burke-class_guided-missile_destroyer_USS_Spruance_(DDG_111)_transits_the_Pacific_Ocean_during_a_routine_unde.jpg

FIGURE 14: https://commons.wikimedia.org/wiki/File:The_Ticonderoga-class_cruiser_USS_Chosin_(14973399964).jpg

Only the Zumwalt class destroyers have an exterior specifically shaped to be stealthy to radar and as such in some ways look like post WWII Guppy II submarines, but with a reverse-raked bow that harkens back to the pre-WWI battleships and Roman rams.

FIGURE 15: https://commons.wikimedia.org/wiki/File:USS_Diodon_(SS-349)_underway_c1953.jpg

FIGURE 16: https://commons.wikimedia.org/wiki/File:USS_Zumwalt_(DDG-1000)_departs_Bath_(Maine)_on_7_September_2016.JPG

FIGURE 17: https://commons.wikimedia.org/wiki/File:Polyphemus_in_drydock_Malta_3.jpg

Russian and other European warships, however, are designed to look aggressive, have the tops of deckhouses conforming to specific design curves, and are bristling with weapons.

FIGURE 18: https://commons.wikimedia.org/wiki/File:Kirov_class_cruiser.jpg

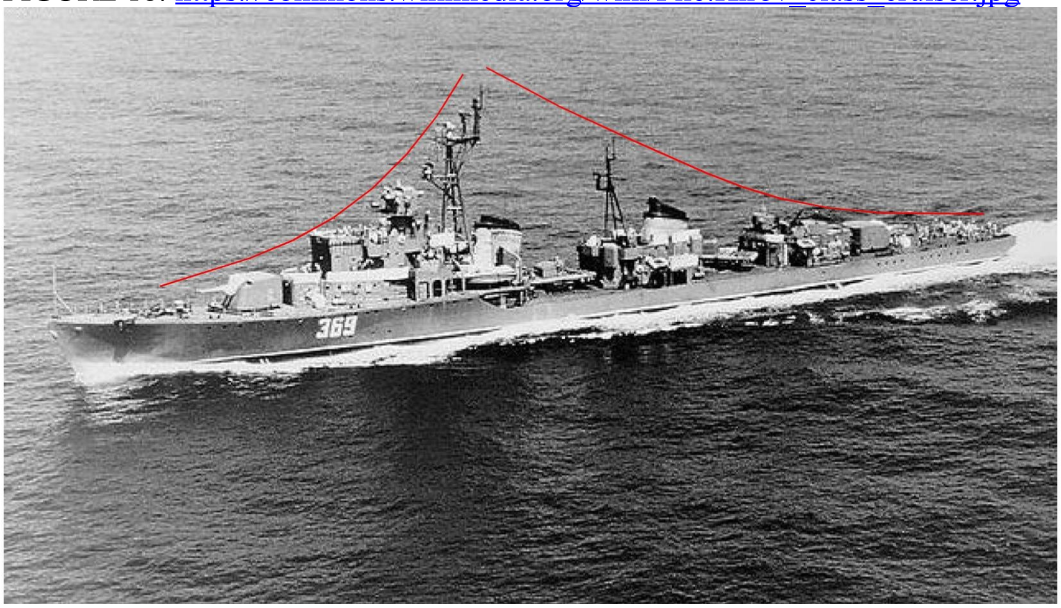

FIGURE 19

FIGURE 20: https://commons.wikimedia.org/wiki/File:Soviet_Riga-class_frigate_underway.jpg

Machinery Arrangement

The Preliminary Machinery Arrangement is drawn to a larger scale than the Arrangement drawings and only shows the machinery spaces such as the Engine Room, Auxiliary Machinery Room (AMR), Engineering Control Room, Battery Room if there is a separate space, and maybe the steering compartment at the aft end of the ship. This drawing shows a detailed plan view and port and starboard elevations, along with an equipment list, of all of the major equipment in the ship such as main engines, transmissions, shafting, propellers, steering gear, generators, switchboards, subpanel locations, water makers, heating, ventilating, and air conditioning (HVAC) equipment, pumps, hydraulic power units and reservoirs, stabilizer locations, air compressors, fuel/water separators, batteries for engine starting, sewage treatment plant (MSD), fuel and bilge manifolds, etc. The equipment list shows item numbers, quantity, item description, make and model, rating specifications, MIL-SPEC number if military, and other information necessary to identify the equipment. It should be cautioned, however that these equipment selections often change some during development, so do not use the preliminary machinery arrangement for critical construction decisions. Figure 21 shows the preliminary Machinery

Arrangement of a yacht, where vendor digital models of the main engines (in black), generators in sound covers (in red), steering gear (in red in the left plan), and some other major equipment is shown. Note that the frames numbers are shown on centerline so that the reader may be able to match where they are looking with the rest of the drawing set.

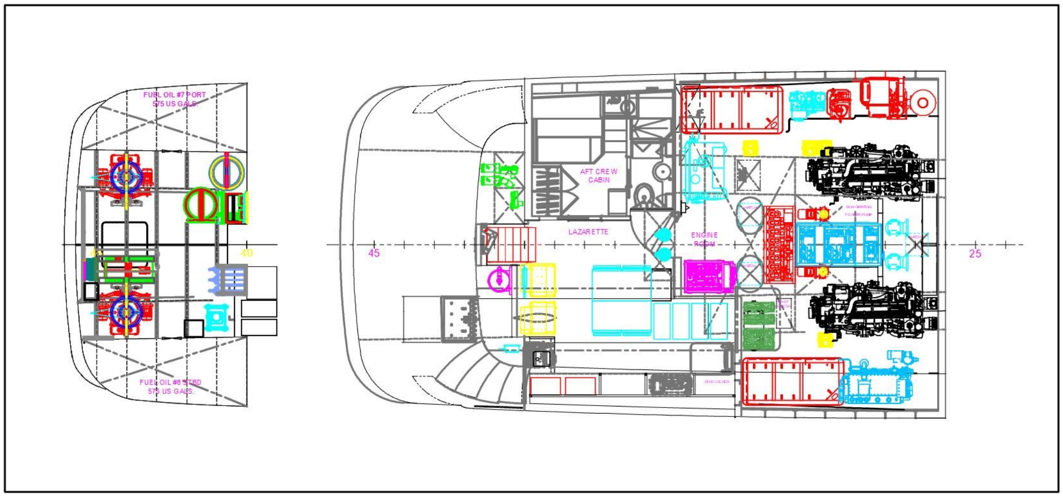

FIGURE 21

Tank and Ballast Plan

The Tank and Ballast drawing shows the tank layout in ship of all fuel storage, fuel day tank, and fuel cargo tanks, fresh water, gray water, black water, hydraulic reservoirs, dirty oil, clean lube oil, oily bilge water, and water ballast tanks. It is generally a bilge plan view of the ship with a few extra details of other tanks not located in the bottom. The need for liquid ballast tanks depends on the need to correct vessel trim, draft, and heel during various loading conditions, and most small vessels (under 200') do not need them. The smaller vessels use the fuel and freshwater tanks to control trim and heel, and don't usually need to deepen the draft because their cargo loads are not great. This preliminary plan does not usually show any ship service or transfer piping, filler pipes, sounding tubes (pipes for measuring fluid levels) or air vent pipe details, as these come in the Contract stage. Tanks carrying fuel, fresh water, sewage, gray water, hydraulic oil, and lube oil, plus cargo tanks if they carry liquid cargoes, are often outlined in heavy black line to make them stand out from the structure, and they are labeled as to contents and capacity, and have an X drawn in phantom line from opposite corners. Cofferdams are structural voids that contain bilge suctions and water depth transducers, and they are spaces between fuel and water tanks so they cannot leak into one another. Open bilge spaces, stabilizer locations, solid ballast, and closed voids are also shown on this plan.

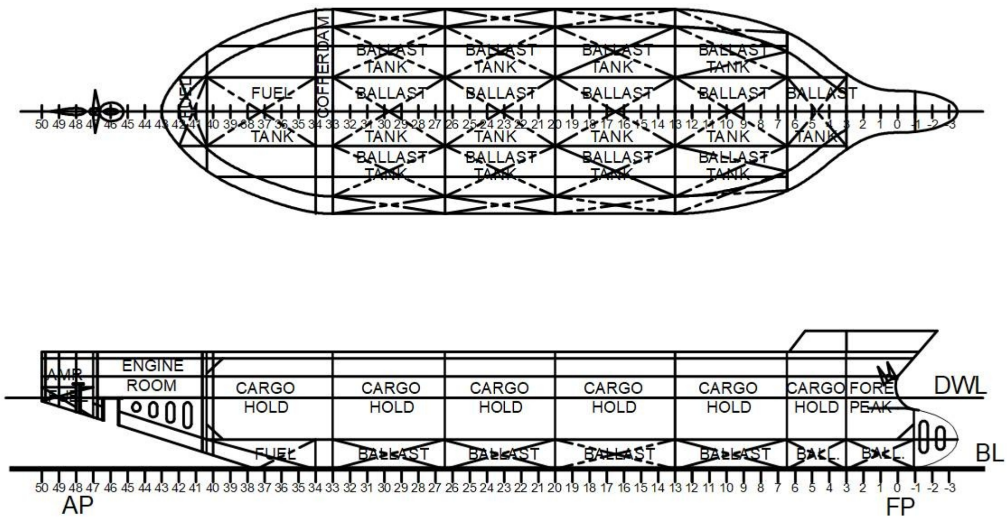

FIGURE 22

Preliminary Weight Estimate

The Preliminary Weight Estimate is numbered as a drawing, but it is actually a set of calculations that show the first estimate of the weight of the ship in all of its loading conditions. The weight estimate is performed on a spreadsheet, details of which can be found in my Suncam.com course number 436, Marine Weight Estimation and Control. The typical loading conditions are Light Weight, the empty weight of the ship, Departure, or 100% Load, Mid-Voyage, or 50% Load, and Arrival, or 10% Load.

Preliminary Speed/Range/Power/Fuel Consumption Calculations

The Preliminary Speed/Range/Power/Fuel Consumption calculations are also numbered as a drawing, they and are contained in a report consisting of the RPM/Horsepower/Fuel Consumption graph for the main engines, and a graph of estimated hull resistance versus horsepower. Figure 23 shows a typical speed versus power graph for a displacement-type hull. The ship's range is calculated from the fuel consumption, speed, and fuel capacity, less a 10% reserve. Again, like other drawings and calculations, these are preliminary in nature and are subject to refinement in the Contract stage of design.

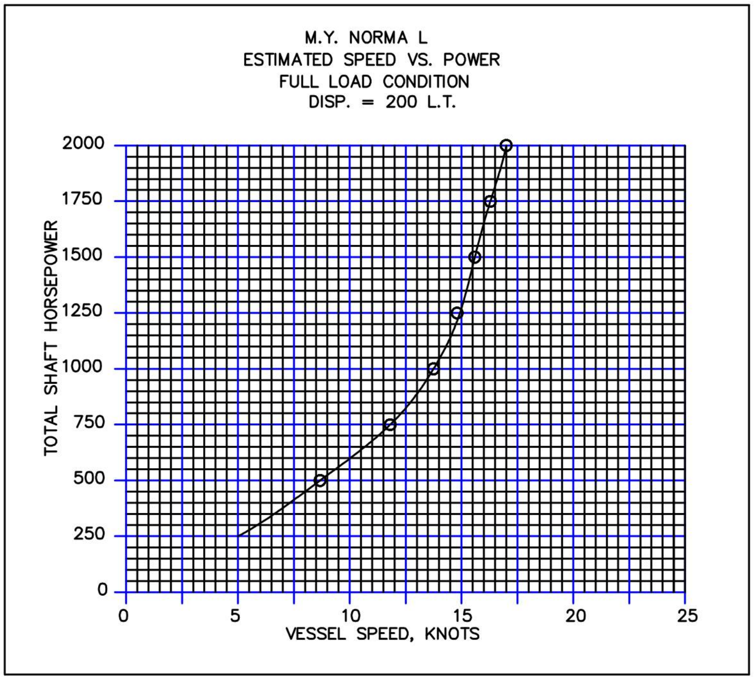

FIGURE 23

Once the Preliminary Design drawings are presented to the client, the results are discussed, and comments are received regarding the results. There are usually numerous changes, upgrades, and improvements that come out of this meeting, and these results provide the direction for the Contract Design phase. The ship often needs to be a little longer at this stage to make the arrangements work, the draft may need to be increased somewhat, and perhaps the fuel capacity may need to be increased to make the required range, for example.

Preliminary Stability Estimate

Stability is the ability of the ship to float at her designed waterline when loaded, and to stay upright when at sea. The Preliminary Stability calculations are developed from the Hull Lines and Offsets by using a computer to generate a 3D model and the preliminary weight estimate to calculate the immersed volume of the hull, its displacement, LCB, LCG, Moment to Trim 1", Change in Displacement per Inch of Trim, Longitudinal Metacenter, Transverse Metacenter, transverse center of gravity (TCG), and vertical center of gravity (VCG, or KG). A Table of Hydrostatics is developed showing these values at various drafts starting at the keel, up to the Design Waterline (DWL) at regular intervals such as 1". Calculations of the vessel's ability to resist rolling by outside forces such as wind and waves, are calculated from the hydrostatics. The computer model is also used to calculate the allowable distance between watertight bulkheads to prevent the hull from submerging underwater if damaged. These calculated distances are used to locate the watertight bulkheads shown in Figures 8 and 22. A report showing the ability of the ship to stay upright and stable, and to float with proper level trim at the DWL when fully loaded and at the various loading conditions shown in the preliminary weight estimate is written and delivered with the rest of the Preliminary drawings. The particulars of how this is done is shown in another course, Stability of Surface Ships, Suncam.com course number 443.

Contract Design Phase

Once the Preliminary design has been accepted by the client and orders are given to proceed further, a set of Contract Design drawings and calculations is begun. During the Contract design stage, refinements are made to the Preliminary drawings and calculations, more details such as piping schematics and electrical calculations are done, the weight, stability, and speed/power/range/fuel consumption estimates are updated as more details have become available, and the drawings necessary for a shipyard to bid on the build contract are produced. These drawings are also drawn to Classification requirements if the ship will be Classed by an organization like the American Bureau of Shipping. Further development of the design is done to each of the Preliminary drawings noted above, and many more are added. The Contract Design drawings will be discussed in Part 2 of “How To Read Shipyard Drawings”, Suncam.com course number 442.

