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How Do You Start To Design A Ship?

by

Kevin M. Kerwin, PE

Where Do You Start To Design A Ship?

This course covers:

- The Design Spiral
- Concurrent Design
- Particulars
- Coefficients of Form
- Block Coefficient
- Midship Coefficient
- Prismatic Coefficient
- Vertical Prismatic Coefficient
- Waterplane Coefficient
- Volumetric Coefficient
- Selection of Machinery Type
- Powering, Resistance, and Propulsion
- Range and Fuel Capacity
- Weight Estimate
- Hydrostatics and Stability

When designing ship hulls, the Naval Architect starts with a design rationale that has been tested over time to achieve successful results. There are two methods currently in use, the traditional one which is the Design Spiral, and Concurrent Design, which is a newer method that has resulted from the ability to do all design using computers, and which requires a greater degree of constant communication. This class will discuss the relative merits and disadvantages of both methods, and it will then get into shortcuts to design.

The Design Spiral

The Design Spiral concept is based on an outside starting point, followed by subsequent further detailed design elements that circle around a central target point, all the while zeroing in on the successful solution. Graphically, the concept looks like this:

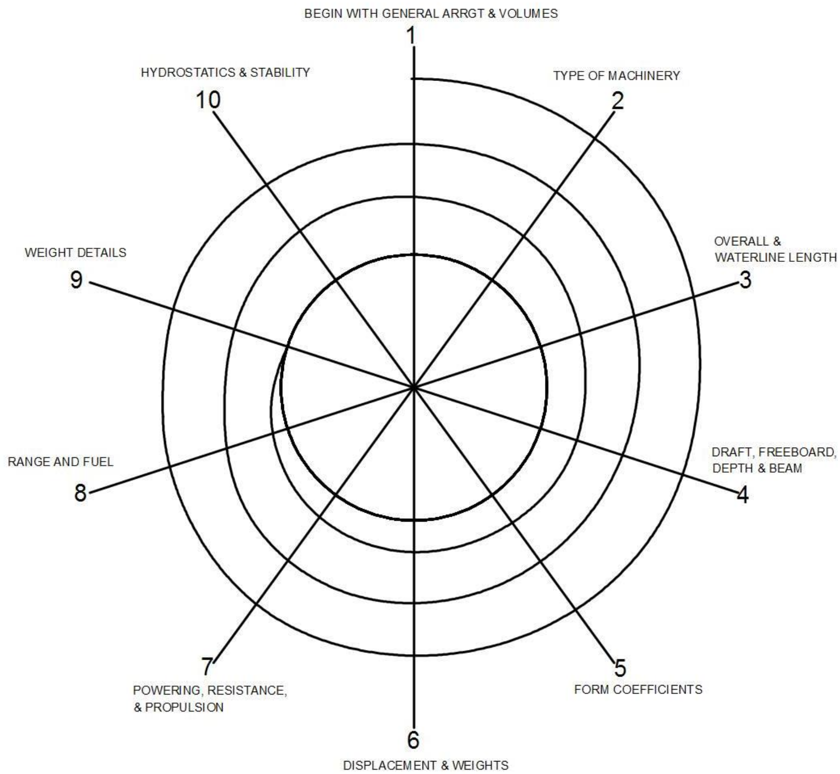

Figure 1: Design Spiral

The Design Spiral starts with a determination of the Particulars that the ship will have. These include the Length Overall, Full Load or Design Waterline length, overall beam or breadth, hull depth, design maximum draft, cargo capacity or Deadweight, passenger capacity, crew capacity, speed, and range, proceeding clockwise around as shown by the numbers. These are the subjects shown on the outer rim of the spiral. The Preliminary drawings showing the following are started:

Outboard Profile and Arrangement
Inboard Profile and Arrangement
Machinery Arrangement
Hull Lines

The following calculations are started:
Weight Estimate
Hull Parametric Study using typical coefficients of form

Hydrostatics and Stability
Hull Resistance, required power, and fuel consumption

As the design develops, the subjects are revisited to make any revisions necessary that result from further details being completed. Descriptions of the information included on each of the drawings and calculations in a Preliminary Design are included in my class number 441, "How To Read Shipbuilding Drawings, Part 1". After two or three trips around the design spiral, the Naval Architect will be zeroed in on the inner circle, where the Preliminary design can be presented to the client for their comments and suggested changes (if any). This method is generally used with a small design team, and the design proceeds in a consecutive, or serial manner.

Concurrent Design

Concurrent Design is a method devised to save time in design, and this method is now being used at many shipyards and design offices, aided by the ability to have a single "smart" design model which has imbedded calculations, Bills of Materials, and manufacturing process plans on a central computer network. All working members can work on the design concurrently, that is, all at once. It decreases product development time and time to completion, leading to reduced time and labor cost and improved productivity. This method of design is a long term strategy, which is fundamentally different from serial design and the initial implementation can be challenging because as you might imagine, this takes more management of personnel and communication between the design team members on a constant basis, with many agreements made about whose priorities shall take precedence in the design. In theory it removes the need for design revisions by creating the right product the first time around. The first successful project designed this way was the Boeing 777, which was designed by multiple geographically disparate design offices and eliminated the need for mockups by using the digital model. Such design takes a large design staff to work and an appreciation for engineering by the manufacturing members of the company building the product. I have not worked in an office that uses this method, so I cannot vouch for its efficiency in ship design, however there seem to be a lot of design problems that have occurred in recent large U.S. military projects that use this method, and I can only speculate that the communication issues necessary to use this method may be some of the problem, aside from the usual performance specifications that are challenging to meet.

In both design methods, there is a Preliminary design stage, a Contract design stage, and a Detail design stage, separated by design reviews with the client. Unlike Boeing, marine designs are seldom produced on speculation as a new product to sell-rather, they are most often produced on a contract with an outside client. The Contract design stage involves further detailed design of additional parts of the ship in schematic form and with Bills of Materials for desired /recommended equipment and specifications so that a shipbuilder can accurately bid to construct the ship. The Detail design stage occurs after the build contract award, and includes the exact locations and real dimensions of all of the structure, piping systems, machinery, electrical and electronics systems, and final naval architecture details including weight estimates, stability, seakeeping analyses, etc. Details of the drawings and calculations included in these stages of design can be found in my classes "How To Read Shipbuilding Drawings", Parts 2, 3, and 4.

Particulars and Coefficients of Form

The Particulars are developed by comparison of the hull being designed to other similar hulls as a shortcut to obtaining a successful result. Other factors, such as how long the client's seawall or pier is, what capacity of cargo and/or passengers make the economics work, what their water depth at the dock is, how wide a channel they have to navigate in, and how low the bridges at either end of the voyage are, also have some bearing on the Particulars of a ship. Once the Particulars are determined by studies of the economics and operational limitations of the vessel, one proceeds to using the Coefficients of Form to refine the hull. The Coefficients of Form have been developed as an aid to performing parametric design and scaling using non-dimensional means. These coefficients are useful in expressing the fullness of the hull and its waterlines and sections, and for developing power estimates. The various types of ships often fall into family relationships of these coefficients depending on their speed, cargo capacity, and other factors; knowing the family ranges of the various hull types makes the task of starting a hull design easier.

Block Coefficient

The Block Coefficient, abbreviated as Cb, is a measure of the fullness of a hull relative to a rectangular cube formed by multiplying the vessel's full load waterline length * width * full load draft. The equation for this is:

$Cb=V/(L*B*T)$, where V is the immersed volume at full load draft,
L is the full load waterline length,
B is the overall breadth or beam,
T is the full load draft.

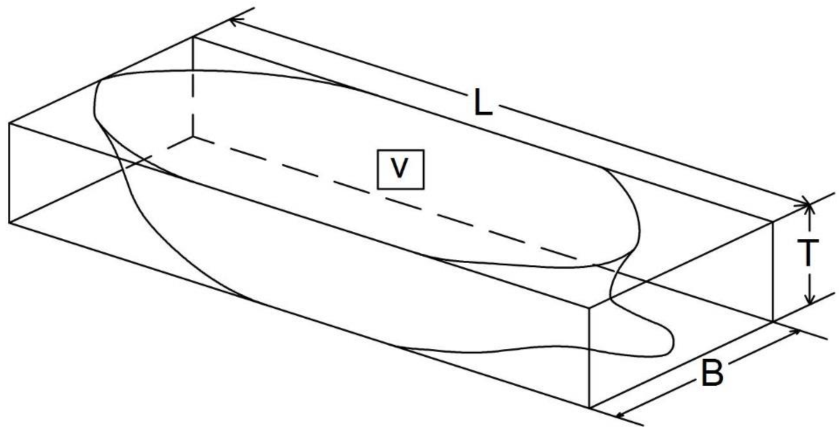

Figure 2: Block Coefficient

The value of Cb is always a decimal fraction less than 1, and always greater than 0. Very fine ships such as racing sailboats, double-ended ferries, destroyers and frigates, high speed yachts, icebreakers, and pre-nuclear age submarines have low values in the 0.35-0.5 range. Vessels in the 0.5-0.6 range include fast passenger liners, conventional tugboats and tractor tugs, cargo/passenger ships, roll on/roll off cargo and passenger ferries, fishing trawlers, naval replenishment ships, and naval Landing Ship Docks. Ships that fall in the range of 0.6 to 0.7 are container ships, general cargo ships, and offshore supply vessels. Examples of ships that fall in the range of 0.7 to 0.8 are petroleum product tankers, and LNG tankers. The fullest ships that fall in the range of 0.8 or more are Great Lakes ore carriers, dry bulk carriers, and crude oil tankers.

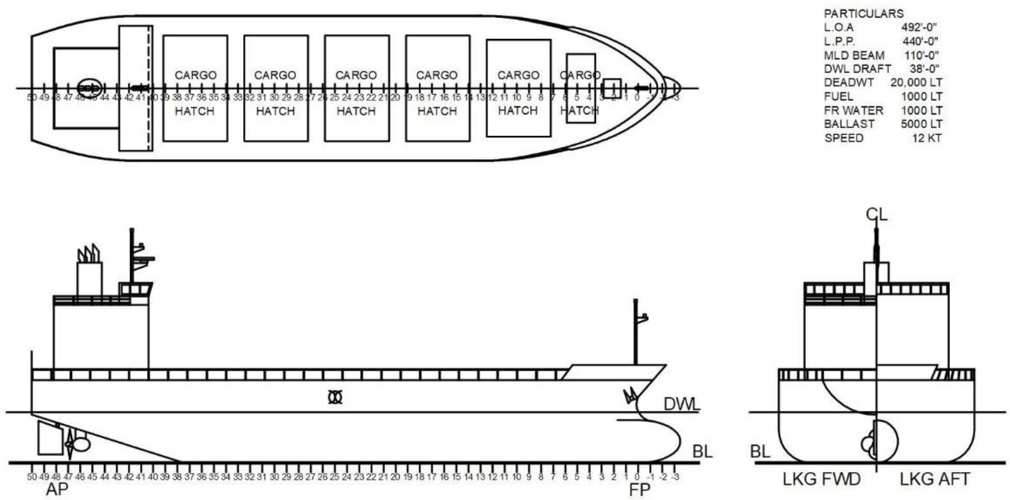

Figure 3: Azipod Drive Bulk Carrier

For the ship in Figure 3, the Cb=1,379,400 ft^3/(440'*110'*38')=0.75

Note that the ship in the figure has a bulbous bow, which is a feature that lowers hull resistance and thereby increases speed or lowers fuel consumption, by moving the bow wave forward of the stem. There are specific hull parameters in which these work best, and they generally work best on short, fat ship hulls. However, these days the very fullest ships like dry bulk carriers, where speed is not as critical as capacity, dispense with them altogether so that the bow volume does not reduce the cargo capacity. The fuller the ship is, the slower is her speed, and the higher is her Block Coefficient. So, when designing a hull with a designated speed and cargo type or capacity, the Block Coefficient range for each type is a handy guide for what the general proportions of the hull should be to be a successful design.

Midship Coefficient

The Midship Coefficient, abbreviated as Cm, is a cross section guide for designing the midship proportions. This coefficient is determined by dividing the immersed cross section by the overall breadth at the full load waterline*the full load draft. The equation for this is:

Cm=Immersed area of midship section/(B*T), where B is the overall breadth or beam,
T is the full load draft.

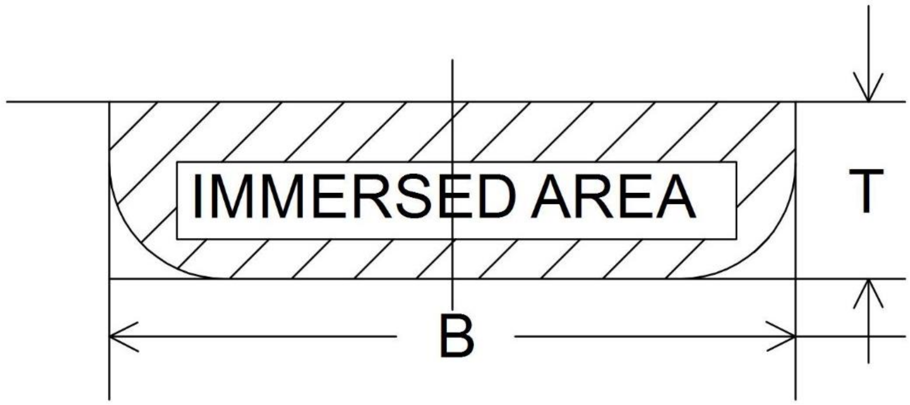

Figure 4: Midship Coefficient

The value of Cm is always a decimal fraction less than 1, and always greater than 0. Very fine ships such as racing sailboats, double-ended ferries, destroyers and frigates, high speed yachts, and pre-nuclear age submarines have low values in the 0.7-0.85 range. Vessels in the 0.85-0.9 range include conventional tugboats and tractor tugs, icebreakers, fishing trawlers. Ships that fall in the range of 0.9 to 0.95 are offshore supply vessels and naval Landing Ship Docks. The fullest ships that fall in the range of greater than 0.95 are passenger liners, Great Lakes ore carriers, container ships, general cargo ships, petroleum product tankers, LNG tankers, cargo/passenger ships, roll on/roll off cargo and passenger ferries, naval replenishment ships, and crude oil tankers. Again, the faster the ship, the lower the Midship Coefficient should be.

For the ship shown in Figure 3, the Cm=4013 ft^2/(110'*38')=0.96

Prismatic Coefficient

The Prismatic Coefficient, sometimes called the longitudinal Prismatic Coefficient and abbreviated as Cp, is a value that shows how far forward and aft the full midship cross section area is carried, or alternatively, is a measure of the fineness or fullness of the bow and stern hull lines. The value of Cp is always a decimal fraction less than 1, and always greater than 0. For example, fine hulls like racing sailboats and destroyers are widest at or slightly aft of amidships, but narrower forward and aft of the widest point. Petroleum tankers, on the other hand, are the same cross section area as amidships for most of their length, with short bow and stern lines fairings to aid the water flow around the hull.

This coefficient is determined by dividing the immersed volume at the full load waterline by the load waterline length*the midship cross section area to the full load waterline. The equation for this is:

Cp=Immersed volume V/(L*immersed midship area)

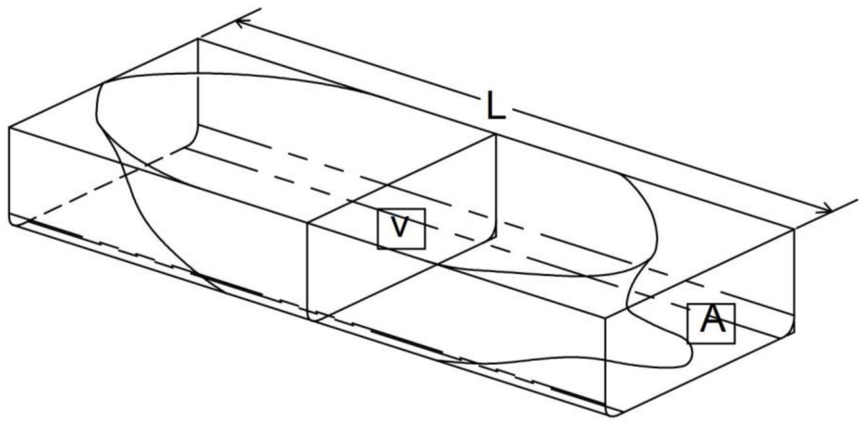

Figure 5: Prismatic Coefficient

The purpose of this coefficient is to give a coefficient for the longitudinal distribution of a ship's buoyancy. This coefficient is often used in speed studies to determine how much power is required. If a plot was made of the Cp for two different ships of the same length and displacement, but one fine-ended like a destroyer and the other like a tanker, the tanker would have a flat section in the middle of its length, whereas the destroyer would peak at the widest point of beam. The value of Cm is always a decimal fraction less than 1, and always greater than 0. Very fine ships such as racing sailboats, double-ended ferries, destroyers and frigates, high speed yachts, and pre-nuclear age submarines have low values in the 0.5 range, and full vessels in the 0.85-0.9 range include petroleum product tankers, LNG tankers, Great Lakes ore carriers, and crude oil tankers.

Waterplane Coefficient

The Waterplane Coefficient, abbreviated as Cwp, is the ratio between the waterplane area and the area of a rectangle formed by the waterline length*the waterline beam, or breadth. The value of Cwp is always a decimal fraction less than 1, and always greater than 0. This coefficient can be used at any draft. It is a measure of how full the waterplane area is. The equation for this is:

Cwp=Awp/(L*B), where Awp is the area of the full load draft waterplane,
L is the full load waterline length, and
B is the full load beam or breadth of the vessel.

Values at the design waterline generally range from 0.65 to 0.95 for the fullest ships.

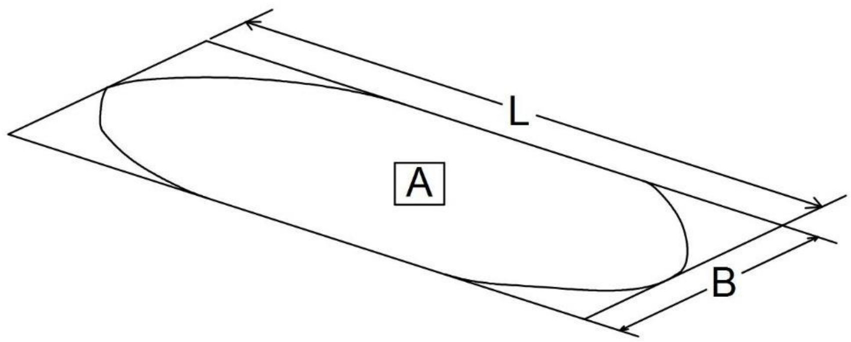

Figure 6: Waterplane Coefficient

Vertical Prismatic Coefficient

The vertical Prismatic Coefficient, abbreviated Cvp, is similar to the Cp, except that it is a ratio of the volume of displaced water to the volume of a cylindrical solid formed by a uniform waterplane cross section at full load draft multiplied by the full load draft. The value of Cvp is always a decimal fraction less than 1, and always greater than 0. The equation for this is:

Cvp=immersed volume V/(Cwp*L*B*T)=Cb/Cwp

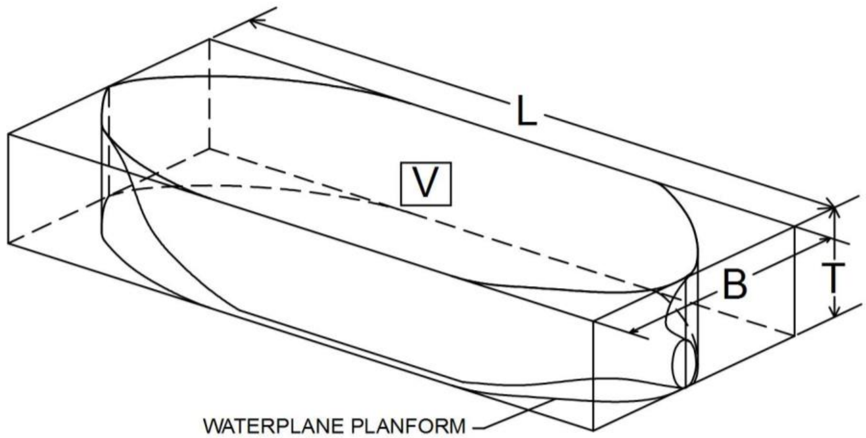

Figure 7: Vertical Prismatic Coefficient

Volumetric Coefficient

The Volumetric Coefficient, abbreviated as Cv, is a dimensionless way to express a ship's displacement in terms of its length. Ships with a low Cv are thin, like destroyers and racing sailboats, and ship with high Cv values are full like tankers. The values for Cv range from about 1 for the thinnest ships to about 15 for the fullest. The equation for this is:

Cv=V/(L/10)^3

The beauty of using dimensionless coefficients is that they are scalable without the need to deal with units. Say, for example, you have designed a cargo ship that was 500 feet long, and you client makes money with it, so a longer one is even more desirable. All one has to do is use the Coefficients of Form to scale the smaller ship up to the longer one, taking any draft or beam restrictions into account, and you have a good start at a successful design.

Selection of Machinery Type

In the past, the machinery type could be reciprocating (piston-driven) steam, steam turbines, diesel, diesel-electric usually only for submarines, and nuclear, which is a steam turbine alternative. Improvements in diesels in terms of larger power ratings and fuel efficiency have made them the pre-eminent choice, but with ecological concerns about greenhouse gases coming to the forefront, we are in an era of fundamental change and choices are heading toward diesel-electric hybrids, reciprocating engines that burn LNG, ammonia, or methanol, hydrogen fuel cells, a potential for new nuclear power, and sail assist are the modern choices. Solar cells are used for auxiliary power generation, but it is unlikely to ever be a widespread propulsion power generator except in very small vessels because of the large surface areas required, their low power production relative to sails, and similarly large battery banks needed to store the power.

Selection of which prime mover to use depends primarily on how much power can be developed for what price, how much space it takes for the machinery and the fuel, how complicated controlling emissions is, and what kinds of fuels that it uses are available. The big push underway from the environmentalists and the International Maritime Organization of the United Nations to lower greenhouse gas (carbon dioxide, nitrous oxide, and methane) is causing a monumental shift in propulsion technology to lower the emissions of the entire merchant shipping industry, which contributes (a paltry) 2-3% of total greenhouse gas emissions worldwide. Diesel fuel is and still will be the least flammable and most safely breathable fuel fumes available in the foreseeable future. In 2021 we are just at the beginning stages of having LNG available in a few ports and its use requires insulated piping and leak detection; methanol is somewhat widely available but is dangerous to carry and use, ammonia is being developed as a carbon-free fuel, and although ammonia is widely available because of the fertilizer industry, it is currently produced as an oil byproduct. It is also deadly to breathe in the concentrated amounts necessary to use as fuel. There is talk about making “green ammonia” in some other way, but that will take development of an entirely new technology. Hydrogen is not widely available, and it is invisible and highly flammable. Bio diesel and zero-carbon alternative fuels are just beginning to be developed in large enough quantities for limited use. So, as you can see, the need to replace fossil fuels has a long way to go before suitable alternatives are available and especially at costs lower than diesel and boiler fuel. Diesels will still be around for a while until these alternative propulsion methods get proven in commercial quantities and capabilities.

A conventional diesel power versus rpm, and power versus fuel consumption graph looks like this:

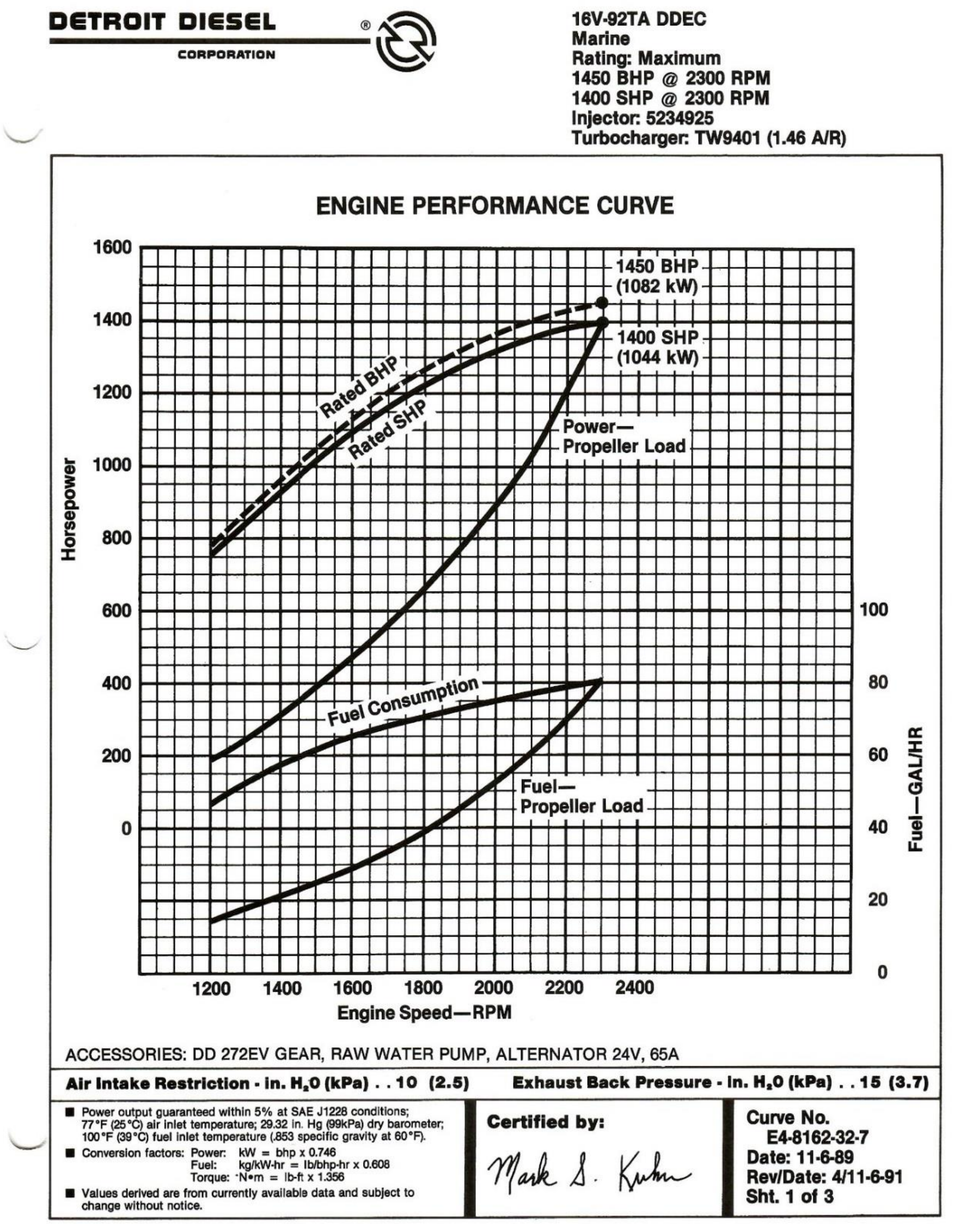

Figure 8: Typical Diesel Power vs RPM Graph For A High-Speed Vessel

The graph above shows the Brake Horsepower (BHP) rating, the Shaft Horsepower (SHP) rating, the Power-Propeller Load curve, the Fuel Consumption curve, and the Fuel-Propeller Load curve. The BHP curve is what the engine develops on a test stand with no transmission or attachments. The SHP curve is derated by 2-3% to account for gear losses through a transmission, and this is the rating curve that should be used for design and engine selection. The intersection at the upper right of the SHP and Propeller Load curves is the maximum rated power at the rpm that can be read below. In this case the maximum rating is 1400 shp at 2300 rpm. It should be noted that since this is a high speed vessel rating (see "Maximum" in the upper right corner text above the graph), this engine should be run at maximum power for only about 1 hour in 12 per day, with the rest at lower rpms. The Propeller Load curve is the power that the propeller uses at various rpms. The amount of surplus power that can be used to accelerate the vessel is the difference between the SHP curve minus the Propeller Load curve values. The Fuel Consumption curve is similar to the above in that this curve is what the engine burns on a test stand, and the Propeller-Fuel curve is what the vessel will actually burn at any rpm. At the rated power of 1400 shp, reading to the right, one can see that the fuel consumption is 80 gallons per hour. Note that in both sets of curves the lines meet at the maximum rating and rpm point where further power and fuel consumption is not possible. The continuous rating for this engine is at 1800 rpm. Reading the shaft horsepower up from this rpm, we see that the rated power would be about 1225 shp and the fuel consumption would be about 39 gallons per hour. The fuel consumption goes up really fast when running at maximum power versus continuous!

Commercial ships generally use the continuous rating of the engine, an engine rating that can be used 24 hours a day, all year long. Tugboats and towboats, on the other hand, which push or tow large ships, barge strings, or tow offshore oil rigs and similar large floating objects, use a rating below the continuous one. Caterpillar, for instance, has 5 ratings for each engine, labeled A through E, where A is the pleasure boat rating, B is for patrol vessels, C is continuous, D is for harbor tugs, and E is for long distance towing vessels.

Diesels come in 2-stroke and 4-stroke types. The 2-strokes, like Detroit Diesels, fire on the first stroke by compression, and as the piston comes back up on the second stroke, the exhaust is scavenged from the cylinders. A 4-stroke is like an automotive engine, where is compresses the fuel on the first stroke, it fires, expanding the gasses and driving the piston downward turning the crankshaft, on the third stroke the piston goes up again, scavenging the exhaust gasses out the exhaust valves, and on the fourth stroke the piston goes down again, sucking the fuel/air mixture into the cylinder. Continuous development of these engines and their exhaust systems is improving their power generation, fuel efficiency, and lowering their emissions. There is much development also happening to allow these engines to run on low sulfur diesel fuels, LNG, methanol, and ammonia.

Diesel-electric hybrid systems are being touted in the press as new, but they are the system that has run diesel submarines for over 100 years. Submarines use this diesel generator system to run on diesels on the surface through electric propulsion motors, charging their large battery banks while they do so. Underwater, they run on battery power at slower speed until the batteries get low, where they surface to charge the batteries again. Diesel-electric surface ships have a similar layout, but they use the batteries while in port for slow speed maneuvering, in-port operation at the dock, and running short distances on batteries to lower overall emissions and fuel usage. More and more modern vessels are being built using this type of system partially because of the lower emissions, but also because the use of electric power instead of direct mechanical propulsion offers more variable available power for running everything else on the ship using electricity. Many offshore supply vessels and cruise ships now use electric rotating azipods to provide propulsion with improved maneuvering without the need for rudders.

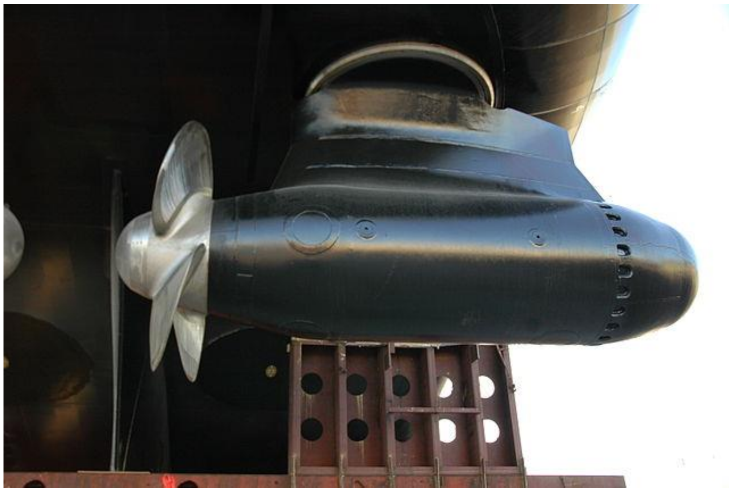

Figure 9: Azipod Thruster

Hydrogen fuel cells are currently being developed in larger and larger power outputs. These devices generate electricity by feeding hydrogen to the anode, and air is fed to the cathode. In a hydrogen fuel cell, a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat.

Powering, Resistance, and Propulsion

Powering and resistance figures are determined by several methods these days. The original way was to make a scale model of the ship, tow it in a special towing tank, and record the hull resistance (drag) data for various speeds, trims, and wave effects. There are various equations and methods that have also been developed in the past to estimate resistance, especially in smaller vessels. Several computer programs are available which can estimate hull resistance based on data from similar vessels, and this is where coefficients of form can be helpful. The latest method is Computer Fluid Dynamics, which utilizes a computer program to develop a mesh of the resistance types surrounding a hull, and the method has been compared against model testing and full scale results over enough years to become an accurate way to optimize hull efficiency.

Ship hull resistance can be broken down into 5 types, namely, skin friction, wave making, wave breaking, viscous eddy resistance, and separation resistance. Skin friction is, of course, a function of the wetted surface area of the immersed hull. On a microscopic scale, the layer of water molecules closest to the shell plating is held to the moving hull by the roughness of the surface. Adjacent layers outboard of the contact layer have less and less friction between the layers, to a point a few inches thick where the water outside of the outer moving layer has zero velocity. This moving layer constitutes an "added mass" and contributes to the drag and a virtual weight addition to the hull. There is, in effect, a velocity gradient in the water molecular layers going from ship speed at the hull surface, and eventually decreasing to 0 at the outer layer of the added mass layer. Over the months after repainting the bottom, sea growth fouls the hull, adding weight and drag to the added mass layer as it gets thicker, increasing the friction of the next adjacent layers of water molecules.

Wave making resistance is the tendency for the bow, plowing through the water, to make the bow wave and stern wave as the ship disturbs the otherwise stationary water. The bulbous bow is a device which is used to create a hydrodynamic disturbance of the water ahead of the hull, which effectively smoothes out the bow lines and moves the bow wave a few feet ahead of the stem of the ship. Doing so increases fuel efficiency by lowering the resistance at the bow due to wave making and wave breaking.

Wave breaking resistance is a small component of hull drag, which is evidenced by the water that climbs the stem as the ship goes through the water. The sharper the stem, the less of this there is, but current trends on yacht design using vertical stems because of "the look" tend to create enough breaking resistance that small "eyebrows" of plat must be added around the stem to knock the water down.

Viscous eddy resistance is the resistance caused by swirls of water that occur at the stern as the ship moves forward. The port side swirls rotate clockwise and the starboard side swirls move counterclockwise to fill in the void behind the ship hull. The imparted motion of the swirls also contributes to added mass, and much study has gone into determining the best ways to separate these from dragging along behind the hull.

Separation resistance is the resistance caused by the added mass layer separating from the hull aft of amidships, where the hull starts to narrow going toward the stern. This forms a vacuum-like drag on the hull along with the viscous eddy resistance shown below.

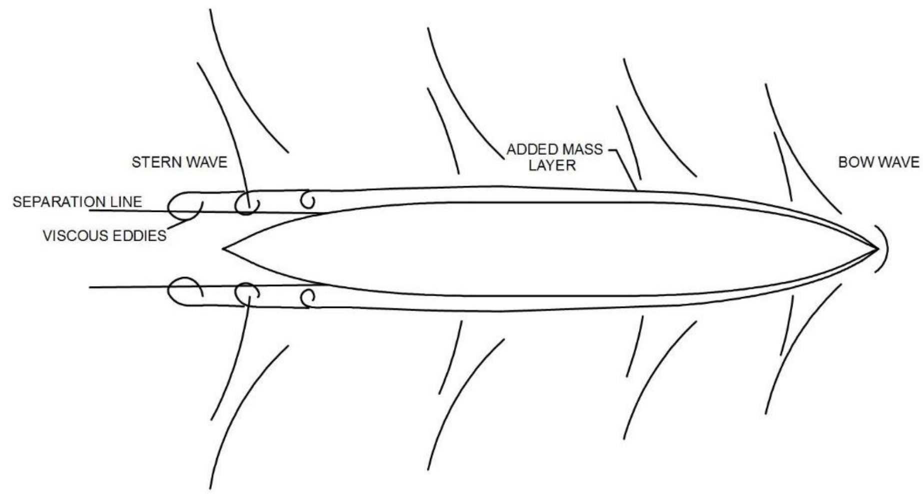

Figure 10: Typical Ship Wake Pattern

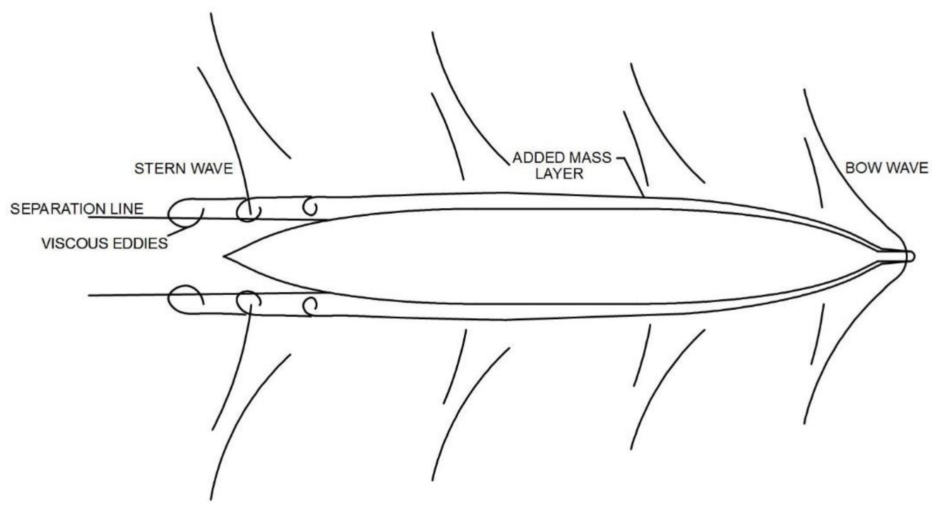

Figure 11: Wave pattern of ship with a bulbous bow

Once the hull resistance is estimated, the amount of horsepower or kilowatts needed to go various speeds can be determined mathematically. See my course in Powering, Resistance, and Propulsion for how this is done. Given the knowledge of how much power is needed to go the desired speed, one can specify what propulsion equipment will be desired to do the job. For comparative purposes, it is best to figure power in kilowatts, since this unit covers both electrical and mechanical methods of propulsion.

Propulsion Selection

Propulsion is limited to variations on propeller drive systems. Choices are the conventional open propeller of anywhere between 2 and 7 blades, surface-piercing propellers, propellers surrounded by nozzles which concentrate the water flow through a wing foil cross-section circular duct, waterjets, and pump jets.

The conventional propeller was first used back in the 1830s and has been constantly updated and developed since then. Conventional propellers are produced in a large number of sizes, blade designs, blade numbers, and hub designs depending on the desired application. Companies like Michigan Wheel, Lips B.V, and Teignbridge produce catalogs that one can choose the prop from, or they can have the company’s application engineers do the selection given the parameters of the vessel. Conventional fully immersed propellers are good for a speed range up to about 35 knots, above which they tend to cavitate, and lose blade lift and thrust.

Figure 12: Conventional Ship Propeller

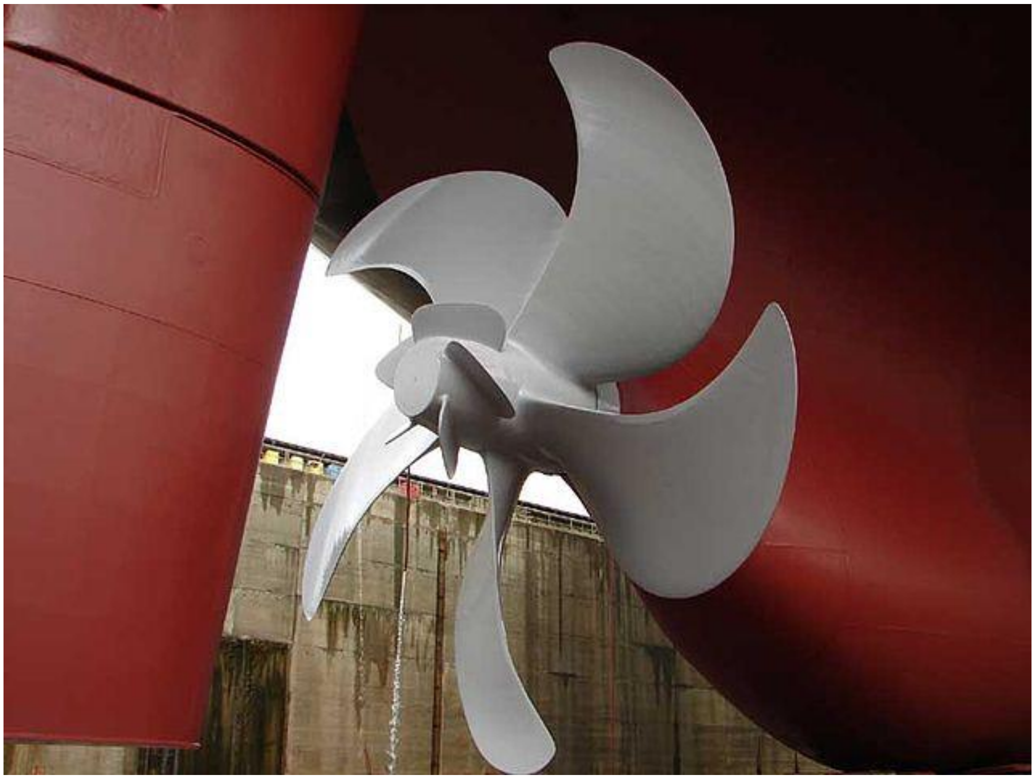

Figure 13: Conventional Ship Propeller with Hub Vortex Reducer Cap

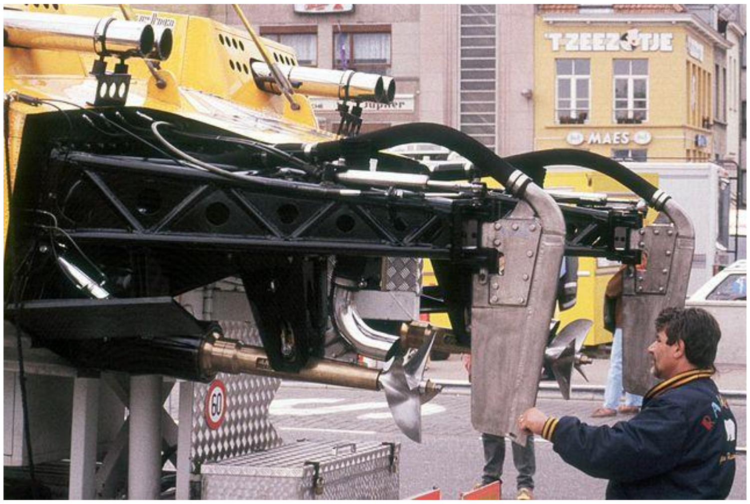

Figure 14: Surface-Piercing Propellers

Surface-piercing propellers are used on high-speed yachts, racing powerboats, and patrol boats. They were invented by Howard Arneson in 1980 for use on racing powerboats, and they became the standard for these types of boats. They evolved from earlier supercavitating propellers that were mounted on straight shafts. Arneson drives, however, are adjustable for angle of immersion up and down, and for steering sideways. The drives in the picture are another make that are not steerable, so they need rudders for steering. Only the lower half of the propeller runs immersed in the water, and the back half of the blade shape is missing compared to normal fully immersed propellers, The cavitation bubble that forms behind the blade while running fills in the shape needed to provide thrust. These are good for speeds up to over 200 miles per hour.

A new type, called a Sharrow propeller (https://www.sharrowmarine.com) after its inventor, is only being manufactured as yet in small boat diameters, but it shows remarkable efficiency compared to conventional props. The Sharrow prop has a blade that looks like a loop, open in the center, and the loop itself has an elliptical cross-section.

Propellers surrounded by nozzles where developed in the 1960s and are widely used on tug and towboats to increase propeller thrust. These are sometimes called Kort nozzles, after the inventor, Ludwig Kort. These are so widely used that there are fabricating companies that specialize in only building nozzles. The nozzles increase the prop thrust by up to 30% depending on several factors.

Figure 15: Nozzle Propellers on a Tug

Waterjets employ a water inlet tunnel at the bottom of the ship just forward of the propeller, and they have an enclosed propeller (called an impeller) similar to a nozzle. However, waterjets run at a higher rpm than nozzle props and like the name says, shoot a jet of water out of a nozzle aft of the prop that is more constrained than in a nozzle prop. They are generally only used on high-speed vessels. To allow steering and stopping a waterjet is equipped with a "bucket" aft of the nozzle outlet that, when activated by hydraulic rams, can redirect the nozzle jet to port, starboard, or underneath for reverse and stop.

Figure 16: Waterjet with steerable nozzle but no bucket

Pumpjets are similar to a waterjet in that they use an enclosed impeller, but instead of a tunnel under the hull, they take in water all around. These are best used on submarines, remote and autonomous underwater vehiles, and other similar hulls like SWATHs (Small Waterplane Area Twin Hulled ships that have a two to four torpedo-like hull shapes underwater, with support legs to hold a platform above the water).

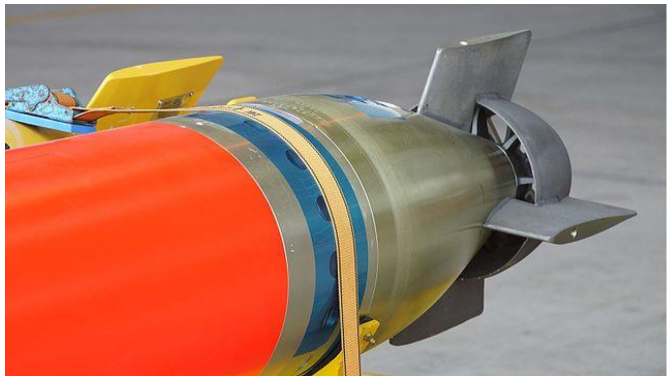

Figure 17: Pumpjet on a torpedo

Range and Fuel Capacity

Range is determined by the designed mission of the vessel, plus a reserve in case of delays or unavailability of fuel. The fuel consumption of the engines and generators is given on the power versus rpm graph, either in gallons per hour or grams per horsepower-hour (which requires a little calculation to get the answer). Since the fuel consumption varies with speed, it is wise to do mission speed studies to get more accurate total required capacity with reserve. A new twist on this is the new requirement to burn low sulphur fuel when the ship is near land in a territorial done requiring this, which requires not only separate fuel tanks, but means to drain the fuel supply piping of higher sulphur fuel before switching over to low sulphur. Once the results of the mission studies are done, it is possible to calculate the required volume of fuel tanks.

Weight Estimate

Starting the Weight Estimate comes next. See my class number 436, "Marine Weight Estimation and Control" for details on how this is done. The weight estimate is the foundation upon which the stability is built, so it needs to be accurate, and should often be revised as more details become available. If done well, by the time the Stability Test is done, there should be minimal difference (1-3%) between the weight estimate and the results of the test.

Hydrostatics and Stability

Hydrostatics are done by first creating a model of the hull in a suitable computer program, and entering the desired range of drafts, trim or LCG, heel or TCG, and tabulating the results. Calculation of the Preliminary Stability can proceed from there. See my class number

460, "Hydrostatics, Wetted Surface, and Bonjeans Curves" for more information on how this is done.

Once the above steps are done the first time, there are inevitably some changes that need to be made to refine the design. A second and sometimes third trip around the design spiral, or concurrent design effort, often needs to be done to refine the design to a presentable Preliminary stage. Drawings are made to document the results and for the presentation. As stated above, see my course number 441, "How To Read Shipbuilding Drawings, Part 1" for detailed information on what the Preliminary drawing and calculations should consist of.

