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How To Read Shipbuilding Drawings (Part 2)

by

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As stated in Part 1 of "How To Read Shipbuilding Drawings", ship design generally proceeds in three phases: Preliminary Design, Contract Design, and Construction Detail Design. Part 1 dealt with the Preliminary drawings; these show a minimum of detail, but enough to show the feasibility of the ship to meet the client's requirements as a concept.

The Contract phase of design is a combination of refinement of the Preliminary drawings, compromise in many areas to make everything work together, and addition of further details. It is an extensive set of plans and calculation when compared to the Preliminary stage of design. Naval Architecture has been called "The World's Greatest Compromise" because of the myriad of things in a ship that compete for space, function, accessibility, cost, and efficiency of operation. In fact, successful Naval Architecture is a bit like conducting a symphony-the experienced Conductor makes beautiful music out of the many competing instruments; the inexperienced Conductor gets noise rather than music and often blows his or her budget when half-way through the project. The author has been called in to make music out of the owner's self-led noisy project many times, usually with success. It is just amazing how many successful business owners that are inexperienced in marine design think that making a successful ship is simpler than designing a house or creating the unrelated business that made them wealthy.

The purpose of the Contract design phase is threefold: to produce a set of drawings for the ship that harmoniously work together, to make a suitable information package for a shipyard to develop an accurate price quote from, and to produce the drawings that show that the design meets Classification Society and/or Coast Guard or Flag State requirements if the vessel is to be regulated as such. In the case of the latter, each of these entities publish books of regulations and/or design guides that must be followed in order to meet a minimum standard of design and construction that they will put their stamp of approval on. For the Classification Societies, they certify the insurable risk that is undertaken by the insurance companies; The Coast Guard or Flag State requirements (which a Coast Guard may be the enforcer of) are mostly concerned with the inspection, safety and manning aspects of the vessel, and quite often defer the inspection of structure and systems to the Classification Societies on newly constructed vessels.

Glossary-more extensive than Part 1:

- 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.
- Azipod-a propulsion thruster, often in a nozzle, that can rotate 360 degrees, thus precluding the need for a rudder. They are either electrically or mechanically powered.
- 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.
- 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 similar to a short wall along the middle of each side of the ship on the outboard bilges 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-A room at or near the top of the ship containing the controls to drive the ship. Also called the Pilothouse or Wheelhouse.
- Bulbous Bow-A bulbous appendage on the bow of he ship that lowers hull resistance and increases fuel efficiency.
- 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
- Camber-the transverse curvature of a deck surface, particularly outside of deckhouses, which allow water on deck to drain outboard. Camber is often something like a 4-5” higher center than outboard.
- 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.
- Class-the general name for an organization that published design guides and prodides technical plan review and surveys during construction that established a minimum standard for design and construction.

- 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. Classification Societies publish many of these standards for various types and functions of ships and other marine equipment. Most ships are designed and built to Classification 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.
- Classification Society-organizations such as American Bureau of Shipping, Bureau Veritas (French), Class NK (Japanese), DNV (Norwegian/German), Lloyd's Register of Shipping (British), and others.
- Coast Guard-A marine police force that also enforces marine safety and environmental regulations. These regulations are often based on those of the International Maritime Organization (IMO), but often have regional differences. Similar entities are U.S. Coast Guard, Affaires Maritimes (France), Marine Coastguard Authority (MCA-British), Transport Canada, and others.
- 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 required to be 1.5 times the strength of the other watertight bulkheads.
- Deck-a horizontal floor (in building terms) in or on the hull.
- Deckhouse-an inhabitable structure on or above the weather deck, that may not be as wide as the edge of the weather deck.
- 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)
- Elevation View-a view on a drawing showing vertically-oriented parts.
- Flag State-the industry term for any country that regulates its shipping through a published set of rules or regulations. Some Flag States have a Coast Guard that is their enforcement arm; other smaller States utilize authorized marine surveyors to inspect and issue documentation of conditions that must be rectified so that the Flag State can issue their approval documents when conditions are met.
- 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.
- Free Surface Effect-the effect of shifting fluids due to rolling and pitching that is detrimental to the stability of the ship
- Freeing Port-an opening in the bulwarks to allow seawater to drain off of the deck in large amounts. These often have hinged doors on them that swing out but not in so they act as a check valve for water flow.
- Girder-a major longitudinal and/or transverse load-bearing structural member that supports the hull bottom, bulkheads, and decks over a locally wide and long area. They have a deeper web depth than longitudinal stringers or stiffeners.
- 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, with shallower depth longitudinal stringers and transverse frames in between.
- Longitudinal Stringer or Stiffener-a longitudinal structural member that stiffens shell and deck plate locally.
- Particulars-the important overall dimensions, capacities, design speed, and Classification notations of the ship.
- Pipe Fitting symbols-a series of graphic symbols showing the types of fittings to be used in the piping plans.
- 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 figure 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.
- Power Takeoff-a meachanical means of powering an auxiliary device, such as a shaft coming from an engine that drives a pump.
- 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 1, 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 most 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.
- Shell-the outer plating of the hull and superstructure/deckhouse
- 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.
- Swash Bulkhead-a bulkhead within a tank that has holes in it so that sloshing fluids are slowed down in their movement.
- Superstructure-deckhouse structure on the weather deck that is as wide as the hull. This is often forward and/or aft on the hull.
- Tangent Line-the intersection point 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 or non-integral 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.
- Welding Symbol-one of many graphic symbols that indicate specific types of welds to make to join metal parts. Properly following these on the plans has a large effect on the strength of the ship.

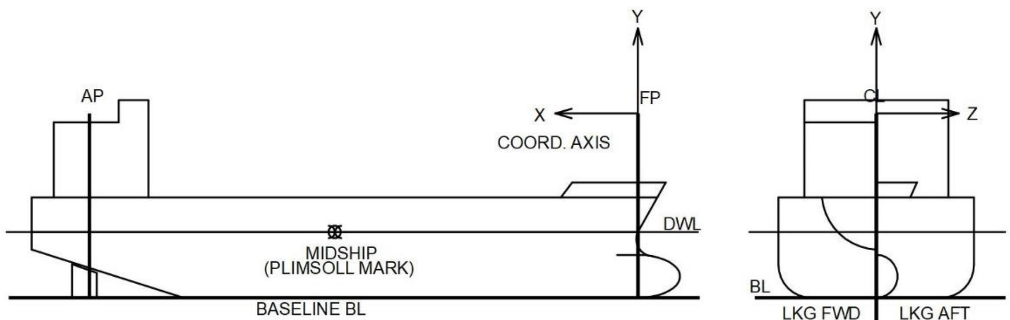

FIGURE 1

The list of drawings done in the Contract stage (depending on applicability) in this part are as follows:

- Outboard Profile and Arrangement revision
- Inboard Profile and Arrangement revision
- Tank and Ballast Plan revision
- Machinery Arrangement revision
- Interior and Exterior Rendering revisions
- Weight Estimate revision
- Speed/Power/Range/Fuel Consumption Report revision
- Hull Lines Plan revision
- Table of Offsets revision
- Specifications
- Construction Profile
- Typical Bulkheads and Frames
- Hull and Deckhouse Layup Plan (if fiberglass/composite structure)
- Engine Foundations
- Scantling Plan
- Weld Symbol List

- Welding Schedule
- Loadline Drawing
- Propulsion Shaftline and Rudder Details
- Fills, Vents, and Sounds
- Pipe Symbol List
- Bilge System Schematic
- Black Water System Schematic
- Compressed Air System Schematic
- Deck Drains Arrangement
- Oily Bilge Water Schematic
- Exhaust System Schematics
- Fixed Gas Fire Extinguishing System
- HI-FOG and Water Sprinkler Fire Extinguishing System
- Fresh Water System Schematic
- Fuel Service and Transfer System Schematic
- Liquid Cargo Transfer System Schematics
- Gray Water Drains Schematic
- Hydraulic Power System Schematic if centralized
- Hydraulic Power System Schematics for individual systems if not centralized
- Lube Oil and Dirty Oil System Schematic
- Seawater Cooling System Schematic
- Seawater Ballast System Schematic
- Seawater Fire Extinguishing System Schematic
- Steering Arrangement

Covered in Part 3:

- Machinery Space Ventilation Systems Schematics
- HVAC Arrangements for manned and cargo spaces
- A.C. Electrical Power Calculations
- A.C. One-Line Diagram
- D.C. Electrical Power Calculations
- D.C. One-Line Diagram
- Emergency Lighting Arrangement
- Lighting and Receptical Plan
- Navigation Electronics Arrangement

- Navigation Lighting Details
- Anchoring Details Plan
- Doors, Windows, and Hatch Details
- Joinery Plan
- Furniture Plan
- Fire Zone Drawing
- Fire and Thermal Insulation Arrangement
- Fire Plan
- Outfitting Plan
- Safety Plan
- Mooring Arrangement Plan
- Dangerous Cargo Marking Plan
- Painting and Coatings Plan

Preliminary Plans and Calculations Requiring Revision:

Outboard Profile and Arrangement

The Outboard Profile and Arrangement drawing is updated at this stage to include more details of the windows, doors, painting, masts, the draft marks, boarding gates, anchoring gear, manhole-sized hatches into hull compartments, tank vent pipes and fill containments, and much more. A port side profile view may also be added to show differences from the starboard side in window and portlight arrangements due to in the interior, asymmetries in the deckhouse, and other reasons. The draft may have to be increase slightly if the weight estimate shows that the design waterline is too low. It is best to do this at this stage, because having to do so later in the Detail stage may require some structural revisions to the hull framing depth. This is a major reason why weight margins are built into the weight estimate-you can always repaint the top of the waterline, but if you have to raise the overboard pipe discharges as well because you were more than 3-6" off, it's a serious problem requiring a lot of welding, reworking the interior, and possibly repainting the hull later on. The minimum allowed freeboard is generally about 15% of the hull depth as well, so if the hull has to be made deeper to maintain the allowed freeboard, this also becomes a serious design issue that is best corrected in the Contract design stage before construction begins!

Inboard Profile and Arrangement

The Inboard Profile and Arrangement drawing is also updated at this stage to show realistic and Class-required thicknesses of bulkheads, hull side, decks, and overhead sheathing, sheathing drops from the overhead decks due to pipe, wireway, ducting, insulation and structure, realistically dimensioned furniture, passageway width including handrails, other ergonomic dimensions, and spaces reserved for machinery, equipment, ducts, exhaust pipes, wire runs, piping runs, etc. The details of the latter systems in the spaces are not shown, but they are labeled as reserved spaces. The development of the interior arrangements starts getting to be "a battle for an inch" at this stage, as the actual thicknesses of everything start to come into being and some things may need to be shifted to make everything else fit and function well. This is also the point where a hull design may need to have some length added, or the draft increased for the same reasons. Many inexperienced "designers" fail to reserve enough space for these things because they are most concerned with maximizing the living space in order to sell the project. This is particularly true in yachts, where these designers are taught the "art" of yacht design and not much of the engineering. I taught yacht design at one of these schools for a few years and was the only faculty member who had actually engineered yachts that were built. These oversights often come home to roost later during the Detail design stage, which causes a lot of rework after interior furnishings have been ordered.

In the commercial ships I was involved in, we never saw what the finished interior design was going to look like until much later in the building of the ship, and the interior design drawings were developed from mostly commercially-available marine furniture catalogs. In most cases, there was minimal rework compared to yachts when installing the interiors.

Yachts, on the other hand, are furnished mostly with custom made furniture, artwork, and built-in cabinetry, so the details of this is an important early-stage component that not only helps sell the yacht project but defines much of what goes inside the walls.

Tank and Ballast Plan revision

If the Preliminary weight estimate and stability showed that the hull would trim poorly, lean to one side, or sit too deep in the water when fully loaded, a revision of the Tank and Ballast Plan will be in order. The author once started a new job overseeing the design of a 300' car ferry, and the first thing noticed in the Contract Design by an outside design firm was that 150 tons of seawater ballast was in the forepeak but the hull still trimmed down by the stern by 4 feet(!). There was an obvious error in the hull shape such that the center of buoyancy was too far forward of the center of gravity. Fortunately, steel cutting for the hull had not started yet. Once the hull shape in the design was corrected to eliminate this ballast and to get level trim at full load, everything proceeded well until near the end, when it was discovered from the inclining (stability) test that their weight estimate had the center of gravity too low by almost 3 feet compared to actual! We had to add 200 tons of permanent solid and seawater ballast in the middle bottom of the ship to meet the stability requirements, but it was finished with perfect trim, right at the maximum load waterline. This saved the company a $3 million contract penalty that would have resulted had the hull shape error not been found and corrected.

The Naval Architect should always strive to design a ship that needs a minimum of ballast to trim, heel, and meet stability properly in all loading conditions. Strict weight estimation and control is a great help to achieve this goal. Meeting the stability properly can often be done using a minimum of solid ballast in most ships but the reality is that there are few ships or yachts, say over 100' long, that can operate properly without ballast of some sort. There are different reasons for the use of the two types of ballast used in a ship. Liquid water ballast, whether it is fuel, seawater or fresh water, is used to control the heel, trim, and center of gravity that effects stability, primarily over the variable load range of the ship from full to empty, and secondly to lower the center of gravity to improve stability in ships that are weight sensitive to carrying solid ballast, such as aluminum high speed vessels. Solid ballast is used to bring the arrival load condition into proper trim and stability as an addition to what the liquid ballast can affect. For instance, a yacht with shallow fuel tanks and small fresh water tanks may have limited space and volume for additional seawater ballast tanks, and thus may need to ballast with a combination of reserved fuel that is not to be used at sea, such as a 30% reserve limit, and the rest may favor dense, solid ballast such as lead ingots to meet stability requirements. The need to carry reserve fuel that cannot be used at sea is actually a design mistake, for yachts have a very limited draft range between light and full load compared to cargo ships. In such cases solid ballast would be preferable if there is enough toom low enough and in the right location to locate it. Alternatively, a double-skin tanker has sufficient volume outside of the cargo fuel tanks to carry a large load of seawater ballast when empty, and smaller loads of ballast when at lesser loads. Solid ballast in this case is probably not needed at all.

As mentioned in Part 1, an alternative that the U.S. Navy and some foreign navies using former U.S. Navy ships, is seawater-compensating fuel and gasoline tanks. These are used in submarines, destroyers, cruisers, and LPD 4 amphibious assault ships, all of which have long, slim hulls with round bilges, that tend to roll to angles as high as 45 degrees in a storm when on the surface. The way this works is that there is an opening at the bottom at the far end of a pair of connected fuel tanks from the suction pipe in the "receiving" tank, and seawater is allowed to flood the bottom end of the "overflow" tank as the fuel is used. Because seawater is heavier than fossil fuels, the weight of fluid in the tanks increases slightly as fuel is used, causing the ship to sink a little deeper in the water, This weight increase, along with the minimal free surface effect at the interface between the fluids, tends to improve the transverse stability as the ship burns off fuel. This is a somewhat rare method, however; at the time of this writing there are 106 surface ships and about 68 submarines that use this method, and possibly no commercial ships.

Machinery Arrangement revision

The Machinery Arrangement in the Contract stage of design gets more complicated as more machinery supporting or operated by the major machinery is added to the plan. Auxiliary equipment such as fuel water separators, oil and fuel filters, pumps, power takeoffs, electric motors, switchboards, galvanic isolators, transformers and battery chargers get added to this drawing on the arrangement and equipment list. This drawing probably reaches a 90-95% complete stage so that everything can be priced. Figure 2 shows a revised version of the Machinery Arrangement shown in Part 1; the equipment list would be included but is not shown here.

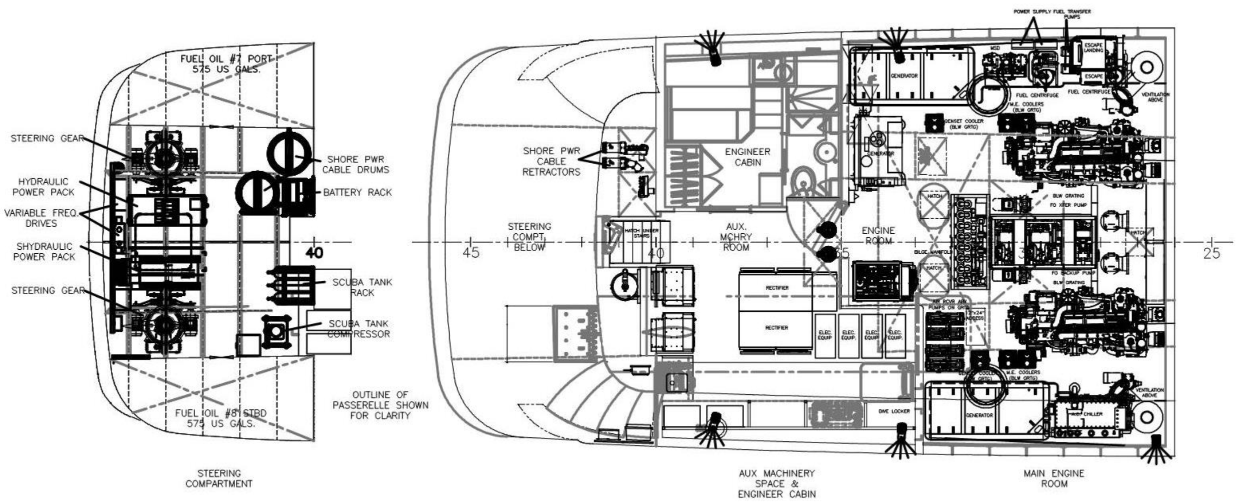

Figure 2: Revised Machinery Plan

Interior and Exterior Rendering revisions

Important in yachts in the Contract stage, these drawings often go through a series of design reviews in the beginning, with many changes made before the client makes final decisions. The clients also tend to make changes all along, depending on what custom furniture, fixtures, materials, textures, and colors they find along the way to completion. When designing yachts for a large volume custom builder, the author had to add a special owners' weight margin to hold onto until the end, because they would show up in the final weeks with all sorts of furnishings we had never seen! Fortunately, the total sum was not huge, and I was able to stay within my tight 3% margins in the final weight estimate and still get it exact enough. The tendency of yacht owners to do this may be why so many shipyards new to yacht building go broke within a few contracts; the owners tend to generate a lot of Change Orders during construction, and unless they and the owners are well managed by the builder, the builders can lose a lot of money by overlooking the domino effect these changes have on work already in progress or completed. Commercial builders tend to have a more consistent experience during building, with possibly fewer Change Orders and less effect on work already completed since the spaces of cargo ships are not as tightly packed and the interior furnishings are much more catalog-based.

Weight Estimate revision

As explained in course 436 Marine Weight Estimation and Control, it is important to update the weight estimate several times during design and construction as more and more accurate information becomes available from design evolution, vendor equipment selection, and lifting weights of assemblies. During the evolution of the weight estimate, the included margins in each section can be reduced as design commences from Preliminary, to Contract, then to Detailed stages of design. The building yard should take over the weight estimate by the commencement of the Detail stage, through the completion. Ideally the displacement at the time of the stability test will be within 3% or less of the originally designed weight and draft. It is wise for the preliminary design firm to keep up with the developing weight estimate and inclining (stability) test results to confirm their original design assumptions, and to modify them for the future if necessary. It is not uncommon for building yards to build the ship a bit heavier than designed in the end, and particularly so for lightweight, high speed vessels unless they have previous experience building them. There have been instances where the builder ended up with a rejected vessel because their heavier-than-designed end product would not make contract speed or the draft was deeper than allowed by the structural design.

Speed/Power/Range/Fuel Consumption Report revision

If the Preliminary weight estimate differs on the heavy side from the full load design draft by more than 6 inches to a foot, it may be necessary to recalculate the required power, and thus the resulting speed, range, and fuel consumption. The difference in wetted surface area, particularly on the larger ships, can make a big difference in fuel efficiency and speed. A difference of fractions of a knot can make for a large expense increase over the life of the vessel. Several remedies are available for this: lightening the design by changing to lighter materials and equipment, increasing the length/beam ratio by lengthening the hull, and/or deleting some features that may be unnecessary. It is important to meet the contractually required speed, range, and fuel economy targets, as these often include large monetary penalties for not doing so (as above). It is also important to note that lengthening a ship can actually make it slightly faster, as long as the beam and draft do not change. I have seen a yacht that was unnecessarily repowered with higher horsepower engines because the head engineer, who was not educated in ship model testing, scaled the length, beam, and draft to determine the new displacement and wetted surface area of a yacht that was lengthened 10 feet with no other changes. The cost of two new main engines and their supporting systems was hundreds of thousands more than the originals, when the originals would have actually made the yacht faster by a half knot if left alone.

Hull Lines Plan revision

The hull lines may be required to be revised as noted above if speed targets are not met or the trim was off. A notorious example of this was the “Queen Mary 2”. The design contract had been signed with a 2-year limit on design and construction before the hull hydrodynamics had been tested, and once the testing was done, the results showed the ship to be 4 knots slower than required by the contract. This is quite significant, and it would have been ruinous to the builder had it been delivered this way. The solution was to lengthen the ship, add an optimized bulb to the bow, make the bow lines finer and make some tweaks to the stern, thereby increasing the length/beam ratio and lowering hull resistance. The end results were satisfactory, but it must have been hair-raising for the project NA! Similarly, the RO-RO car ferry I worked on (mentioned above) met speed, but had poor trim, and changes had to be made in a rush to fix it since the delivery date would not change. Such issues can be stressful, but they often can be overcome by another round of hull design.

Table of Offsets revision

The Table of Offsets must be correct and complete before the cutting of hull plating or the mold for a composite hull can be made, so revision of this item follows any revision of the hull or deckhouse shaping that must be done.

Once any required revisions to the design have been made, the remaining tasks of Contract Design can proceed.

Specifications

The Specifications (specs, for short) are a written description of the parts, processes, materials, paints, colors, equipment, etcetera, that make up the ship. These are sometimes delivered in the Preliminary stage, but are always delivered in the Contract stage of design. The Specs are often spelled out in the contract to build as superseding the drawings, so they must be thorough. They point out in writing many details that the plans might not show, so they are used to settle disagreements of intent, quality, and equipage of the project. A Contract Spec may run to 100 pages or more depending on the size and complexity of the ship. The U.S. Navy issues multiple sets of General Specifications, called the GenSpecs, that apply to specific types and classes of Navy ships, and in the interest of cost savings, they have shifted to allowing more commercial-type specs on auxiliary ships.

New Structural Plans

Construction Profile (sometimes incorporated with the Inboard Profile and Arrangement)

The Contract Construction Profile drawing is similar to the Inboard Profile drawing, but it does not show non-structural details. The Preliminary Inboard Profile and Arrangement showed primary structural components such as girders, bulkheads, tanks, and decks, but only in simplified ways. Additional details shown on the Construction Profile are profile views of bulkheads with stiffener, girder, and opening details, stairs, ladders, hatches, watertight and weathertight door cutouts, tanks and tanktops (plating on top of a tank built integral to the hull structure), elevator shafts, portlights, windows, bow thruster tunnels, engine foundations, and any other structural details necessary to further develop the ship. This drawing has details derived from the structural calculations done to show Class or the builder's minimum standards, and may call out extra strength requirements as well. Like the previous drawings, it is a descendant of the Hull Lines drawing and shows the same views, but with more and different information inside the hull profile and plan views.

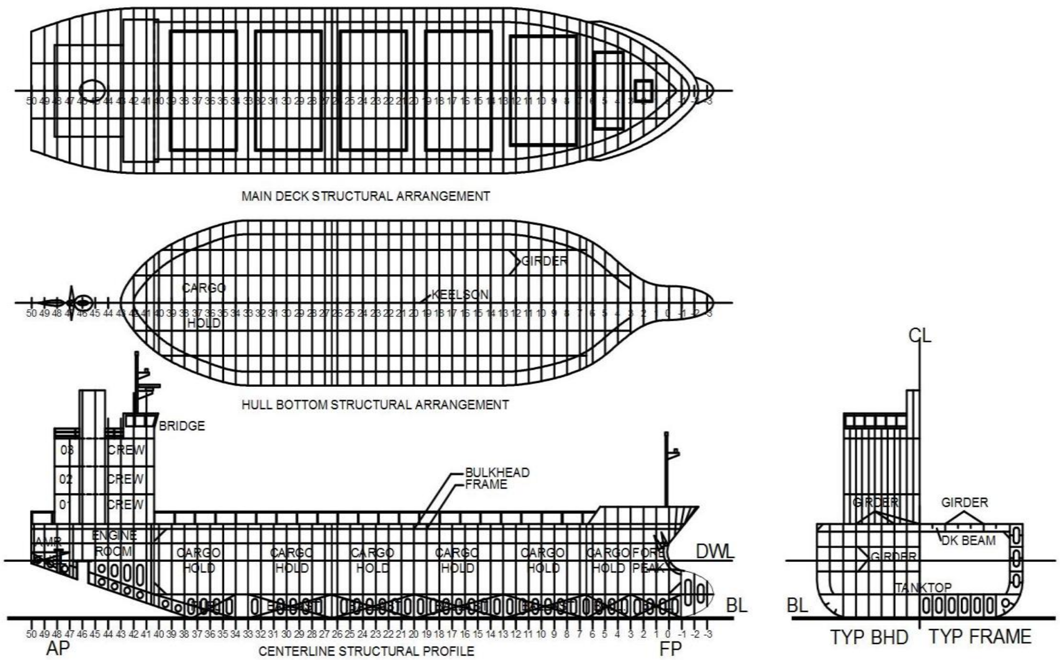

Figure 3: Contract Construction Profile

Typical Bulkheads and Frames

The Typical Bulkheads and Frames drawing shows elevation views of these structural members. Only the typical types of these are shown, rather than every one of them in the ship. The Contract drawings will include important dimensions and metal plate thicknesses as calculated to the required standards, but not every one. The individual bulkheads and frames, complete with all details, welding symbols, production notes, and all dimensions, are left for the shipyard to draw in the Detail design phase. Note that metal bulkhead construction is generally of two types: plate stiffened with welded-on angles, tees, and/or flat bars, and corrugated plate that is bent in a zigzag pattern that creates structural depth from one side to the other, precluding the need for vertical stiffeners. Depending on the height of the corrugated bulkheads and the hydrostatic or cargo loads they may see, they may have additional horizontal girders to carry the horizontal loads while shortening the unsupported vertical spans. These are common in tankers and bulk carriers, where smooth bulkhead surfaces that do not catch cargo are desirable. The two types of bulkheads are shown in the figure below.

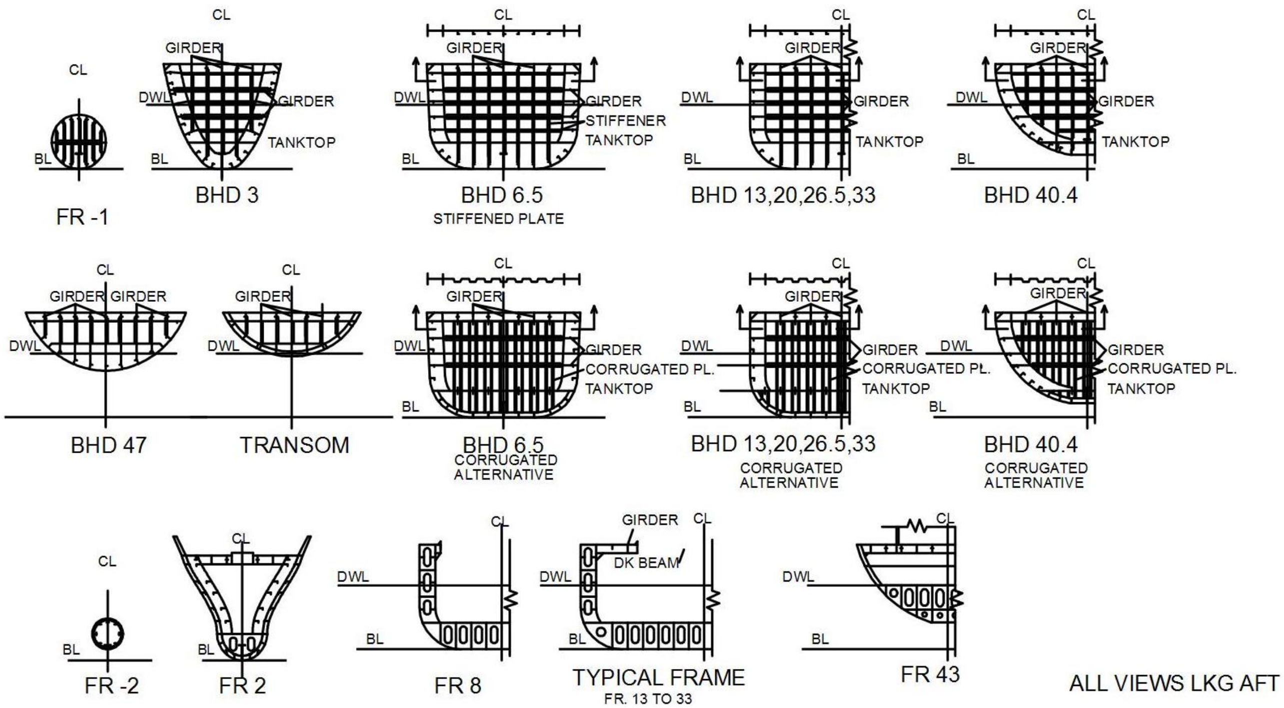

Figure 4: Typical Bulkheads and Frames

Hull and Deckhouse Layup Plan (if fiberglass/composite structure)

Fiberglass and composite structures are similar in layout to Figures 3 and 4, but the details of the structural components are vastly different from the metal ones shown above. The reason for this is that fiberglass and some composites have a significantly lower stiffness than steel or aluminum (about 1/30th and 1/14th , respectively), so the structural details must be thicker to provide the strength needed. This is primarily done using a "sandwich" of core material and skins of fiberglass and other composites. The term "fiberglass" pertains specifically to those structures made of the various types of resins and woven and mat glass fiber materials without core materials, whereas "composites" covers all of the plastic type constructions including fiberglass, carbon fiber, Kevlar, Spectra, and other sheet materials, and various core materials made of plastic foam, honeycomb aramid fiber and carbon fiber, marine plywood, and balsa wood. The design and use of these materials is a broad subject in itself, and it is too much to cover here (see class on Fiberglass and Composites As A Marine Material). But, the structural methods of design are somewhat the same as those of metals, in that many fiberglass and composite vessels are built in a somewhat similar outside shell/inside primary ribs and girders, but often the stiffeners that would be there between the girders and main frames are stiffeners by thick cores as a sandwich construction. The skins themselves are made up of alternating layers of "mat" and "roving", with the number of each determined by the structural needs. Mat is a cloth made by pressing chopped strands of fine fiberglass together with a chemical binder, which acts as a binding layer between the layers of roving. Roving is a woven cloth, coarser in texture and with thicker strands, which provides the strength in the matrix. Roving is oriented either 0-90 degrees (in line with the hull), or 45-45 degrees (diagonal to the hull) depending on the local load direction. Hull and bulkhead layups often use both directions in alternating layers to provide longitudinal, transverse, and twisting resistance altogether as metals normally do due to their homogeneous material properties. The glass and other composite materials are bound together with either polyester, vinylester, or epoxy resins. Epoxy composites are about 20% stronger than the others. So, composite hulls and deckhouses are somewhat like stiffened eggshells, with the shell taking up a larger share of the load resistance.

The current upper limit (2021) of composite boat and ship construction is about 175 feet for yachts and 203 feet for a minesweeper. Fiberglass and composites are desirable hull and deckhouse materials in these types of vessels because of their low susceptibility to corrosion and thereby lower maintenance, and in the case of minesweepers, they are non-magnetic. A disadvantage to growth, however, is that fiberglass and composite materials have a lower tensile strength and interlayer shear strength than metal ships, so they tend to get much thicker and eventually heavier than aluminum and steel ships depending on how large they are. The figure below shows the basic structural types of composite construction; where a metal bulkhead may be the same thickness as the two skin layers of fiberglass sandwich, the thickness of the core provides a separation distance that increases the section modulus and moment of inertia of the construction to a similar value that would be required for metal. In fact, one method of calculating the required composite thickness is to first find the required solid fiberglass values as one would calculated for metals, then using fewer fiberglass skin thicknesses, increase the core thickness to where the two are equal in strength and stiffness. The stiffeners are designed similarly. Note that composite stiffeners look a lot different than the angles and tees used in metal ships. Rather than being shaped like an “L” , “T”, or flatbar as in metal ships, these are called “hat sections” because of their resemblance to a hat. The sides may be angled as shown, or vertical. The wide tabs at the panel skin are necessary to develop the shear strength necessary to keep the stiffeners glued on, since they cannot develop the strength of a weld without significantly more contact area. Unidirectional roving is a series of long strands of fiber all laid up in the direction of the load path, similar to adding a thicker flat bar on a tee or angle to increase section modulus. Carbon fiber is an exception to this, in that it has a stiffness similar to steel.

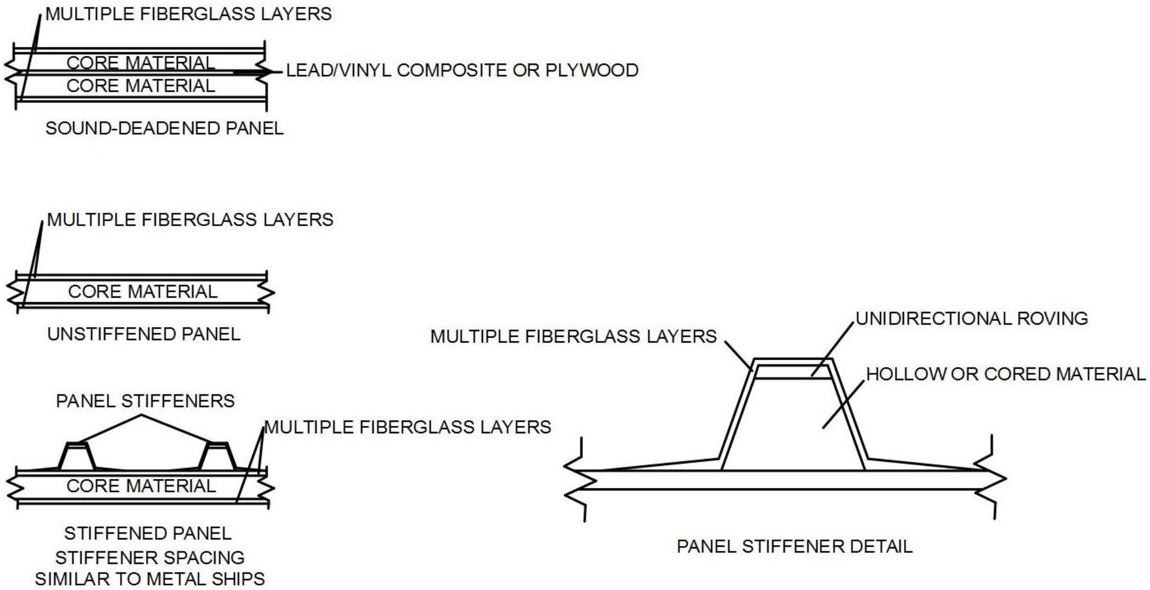

Figure 5: Fiberglass Structural Details

Engine Foundations

The engines and transmissions are often the heaviest items in the ship, so they require strong longitudinal girder foundations with adequate transverse support members to be mounted on. These girders not only support the vertical weight of the engines, but also resist the propeller thrust driving the ship, the twisting of the hull as the passing waves alternately support the ship, the longitudinal bending due to varying buoyancy due to varying wave support and variable cargo loads, and often act as the sides of tanks. They must be designed to be heavy enough to be out of phase with engine vibrations, but still must have openings for pipes, wireways, and sometimes crew members to go through. One of the reasons for the early adoption of iron in steamship hulls was because the wooden-hulled steamships had short structural lives due to the hammering of the pistons in the engines that were hard-mounted to the foundations. The adoption of iron, and then steel hulls cured much of this problem except for vibrations, which took until the 20th century to figure out. The flanges of engine foundations are usually wider than the flanges of the extended girders further forward, because the engine and transmission mounts must be bolted through them. These flanges also vary in height as suits the mounting feet of the engines and transmissions, unlike the flanges further forward, which are generally level with tank tops.

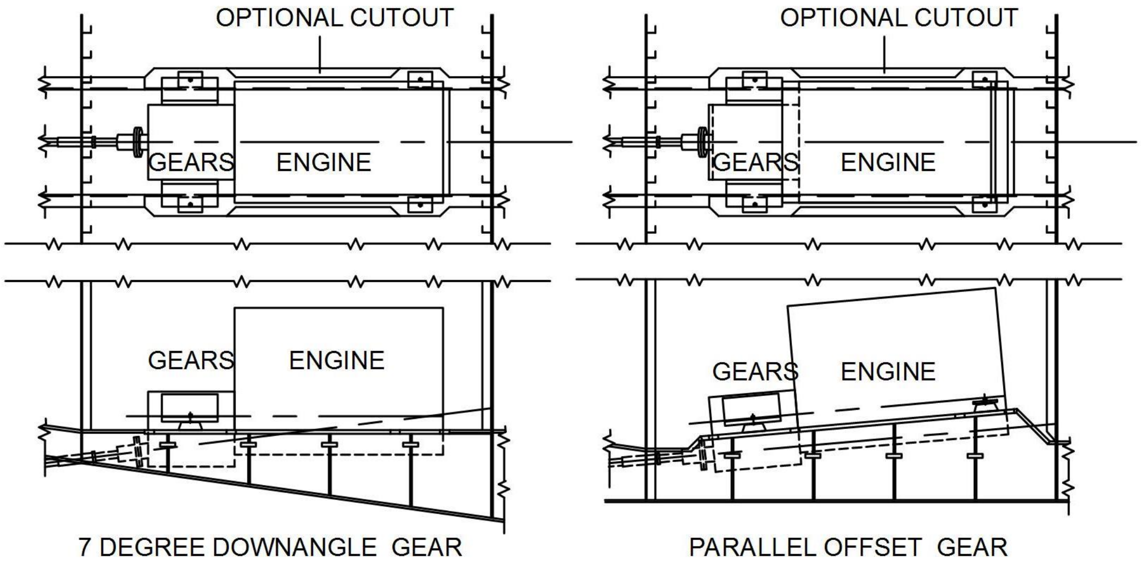

Figure 6: Engine Foundations

Scantling Plan

The Scantling Plan shows the thickness of all the shell, decks, and superstructure plating in the ship. The Contract level plan only shows the seams where the thickness changes, whereas the Detail level plan shows all seams regardless of thickness. The plate thicknesses are calculated per Class or other design minimum requirements, with some local areas made thicker than minimum to resist abrasion and higher-than-normal expected corrosion. Steel requires a corrosion allowance addition of 25% of the original required thickness, since these parts rust over time, and usually from the inside if in the hull bottom. It is quite common for a steel ship of 20-30 years of age to need the entire bottom plating up to the waterline replaced, plus many more localized structure where water tends to accumulate. Aluminum is much less susceptible to seawater corrosion, as it forms a much slower corrosion layer. Aluminum is also half the weight of steel for the same strength, so high-speed ships are almost always made from it. Composite metal ships with steel hulls and aluminum superstructures and deckhouses are also common, as they gain the advantages of the strength of the steel hull and the lightness and lower maintenance requirements of the aluminum topsides. There are two ways of joining these otherwise unweldable materials: the aluminum and steel parts can be bolted together with a rubber gasket in between to insulate against galvanic corrosion, or one can use explosive-bonded materials such as TriClad® or NobelClad®.

A composite hull scantling plan is called a Layup Schedule. This shows the number of layers and material types to be used all over the ship. The process of rolling the layers of glass or other cloth into the mold necessary to make its shape is called laying up the hull or deckhouse.

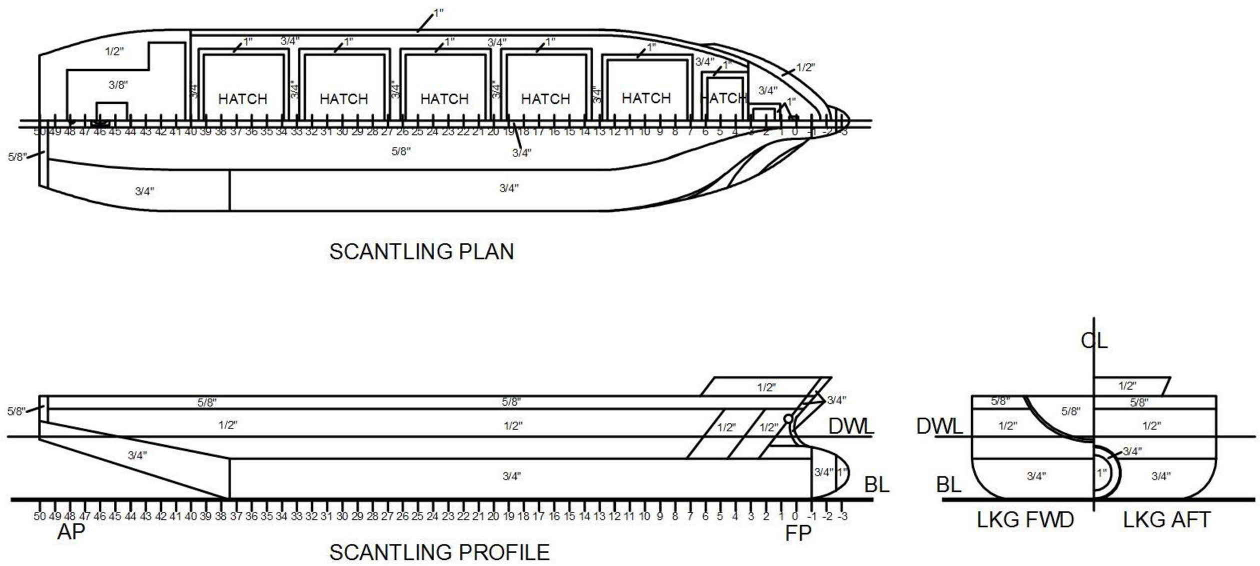

Figure 7: Scantling Plan

Weld Symbol List

The Weld Symbol List is a list of standard symbols that indicate what type of welding is to be used on specific parts. These often are the same as the requirements for Classification. The Contract phase of design shows a minimum of weld symbols, mostly critical welds, and generalizes most others.

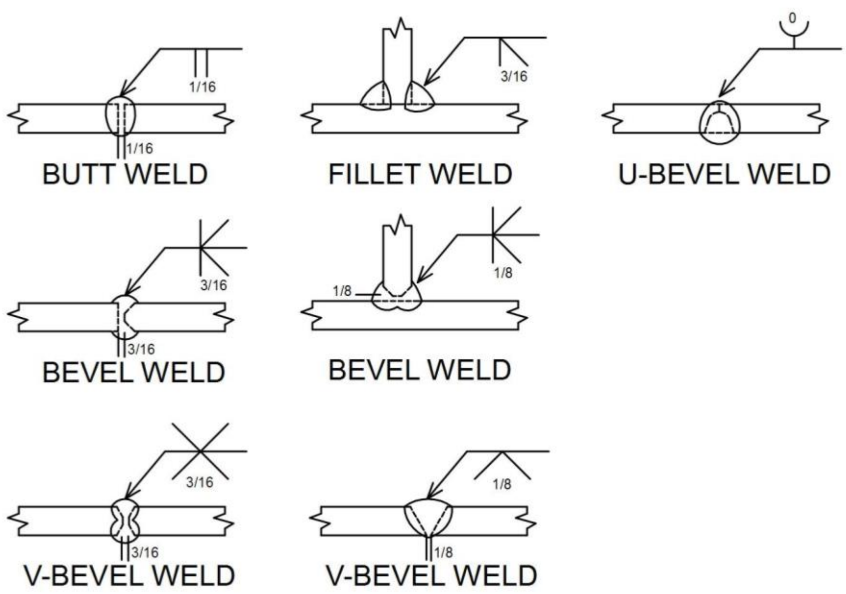

Figure 8: Weld Symbols

Welding Schedule

The Welding Schedule is the generalized list of weld types and thicknesses to be used on various types of plate and assemblies. Rather than show symbols all over each drawing, these are to be referred to for the majority of weld types.

WELDING SCHEDULE							
MEMBER NAME	SCANTLING	TO	MEMBER NAME	SCANTLING	SIZE	LENGTH	NOTES
DECK BEAMS	6X4X5/16L		MAIN DECK	3/8", 1/2"	1/4"	3"	12" CHAIN
DECK TRANSV.	10X5X3/8 FL PL		MAIN DECK	3/8", 1/2"	1/4"	3"	8" CHAIN
DECK GIRDER	12X4X3/8 FL PL		MAIN DECK	3/8", 1/2"	1/4"	3"	8" CHAIN
DEEP FLOOR	1/4" PLATE		MAIN DECK	3/8", 1/2"	3/16"	2 1/2"	9" CHAIN
W.T. BHD	5/16" PLATE		MAIN DECK	3/8", 1/2"	3/16"	CONT.	BOTH SIDES
SWASH BHD	5/16" PLATE		MAIN DECK	3/8", 1/2"	1/4"	3"	9" CHAIN
SEWAGE TANK	3/8" PLATE		MAIN DECK	3/8"	7/32"	CONT.	BOTH SIDES
DECK PLATE	3/8" PLATE		SIDE SHELL	5/16" PLATE	1/4"	CONT.	BOTH SIDES
DECK PLATE	3/8" PLATE		SIDE SHELL	1/2"+3/4" PL	1/4"	CONT.	BOTH SIDES
DECK PLATE	1/2" PLATE		SIDE SHELL	1/2" PLATE	5/16"	CONT.	BOTH SIDES
LONGL DK BMS	3X2X1/4L		EXT. UPR DKS	1/4" PLATE	3/16"	CONT.	BOTH SIDES-NOTE 3
LONGL DK BMS	3X2X1/4L		INT. UPR DKS	1/4" PLATE	3/16"	2 1/2"	12" STAGGERED
TRANS DK WEBS	9X4X3/8 FL PL		EXT. UPR DKS	1/4" PLATE	3/16"	CONT.	BOTH SIDES-NOTE 3
TRANS DK WEBS	9X4X3/8 FL PL		INT. UPR DKS	1/4" PLATE	3/16"	2 1/2"	9" CHAIN
DKHOUSE BHDS	3/16" & 1/4"		UPR DKS	1/4" PLATE	3/16"	CONT. 1 SIDE	3/16" 2 1/2-9 OTHER SIDE

NOTES:
1. ALL WELDING PROCEDURES, MATERIALS, AND PREPARATION SHALL BE AS REQUIRED BY THE AMERICAN BUREAU OF SHIPPING.
2. DECK BEAMS, TRANSV WEBS, AND GIRDERS SHALL HAVE DOUBLE CONTINUOUS WELD AT EACH END FOR LENGTH EQUAL TO DEPTH OF STIFFENER.
3. UPPER DECK STRUCTURES (PLATING SND STIFFENERS) IN EXTERIOR AREAS TO BE DOUBLE CONTINUOUS WELD.
4. ALL BRACKETS TO BE WELDED DOUBLE CONTINUOUS ALL AROUND.

Figure 9: Welding Schedule

Loadline Drawing

A Loadline Drawing is required if the vessel is to receive an International Loadline for seagoing commerce. This is a drawing that shows the window and hatch openings in the deckhouse and weather deck, deck curvature (sheer), door sill heights to the outside, bulwark heights, well deck depths if any, freeing port sizes and locations, and ventilation opening sizes, locations, and sill heights. The purpose of the drawing is to show that all possible openings in the ship comply with dimensional and closure standards set forth in the International Loadline Convention, which is concerned with seagoing safety. The height of the Plimsoll Mark (the allowable maximum draft) is determined from the calculations done that incorporate the information above. The maximum height of a cargo ship load waterline is usually about 85% of the hull depth. If the allowed maximum draft differs from the design waterline, then some further redesign will be necessary to bring the two into near compliance.

Propulsion Shaftline and Rudder Details

This drawing shows the propulsion system as a shaft centerline elevation from main engine through the transmission, thrust bearing, shafting details, shaft seals, shaft supports, propeller struts, propeller, and rudder mounting and blade details from the outside. The rudder structure itself is shown on a separate drawing. The engine maker, model number, rated horsepower and maximum rpm, transmission make, model, and ratio, dimensions of shafting, including shaft angle and sighting target point on the forward engine room bulkhead, as well as bearing separation distances are shown. Propeller design specifications are also listed in a table similar to a Table of Particulars. For Azipod-powered vessels, this drawing shows only the azipod, its maker, power and rpm rating, transmission ratio if it has one, foundation, location, propeller specs, and powering concept with some important dimensions.

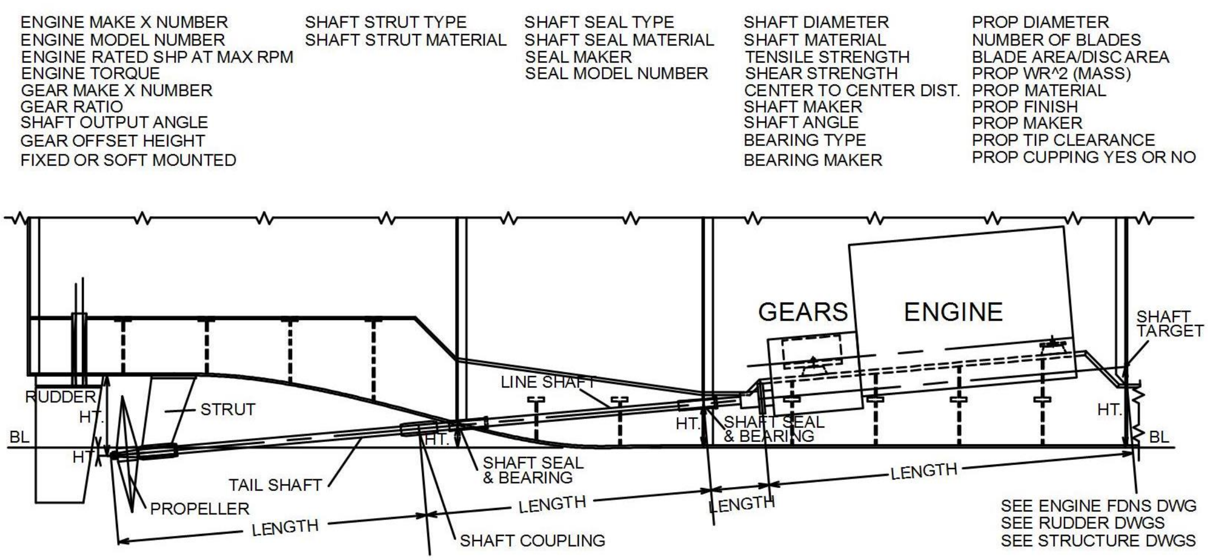

Figure 10: Propulsion Shafting Drawing

An Azipod is a propulsion device similar to an outboard motor, but they usually have a higher power rating, and they are mechanically or electrically powered. They find widespread use in tugs, towboats, cruise ships, and offshore platform supply vessels because the azipod can be rotated 360 degrees, so a rudder is not needed and therefore they have 100% thrust available in any direction. Azipods also require less maintenance than conventional shaft layouts like the one shown above.

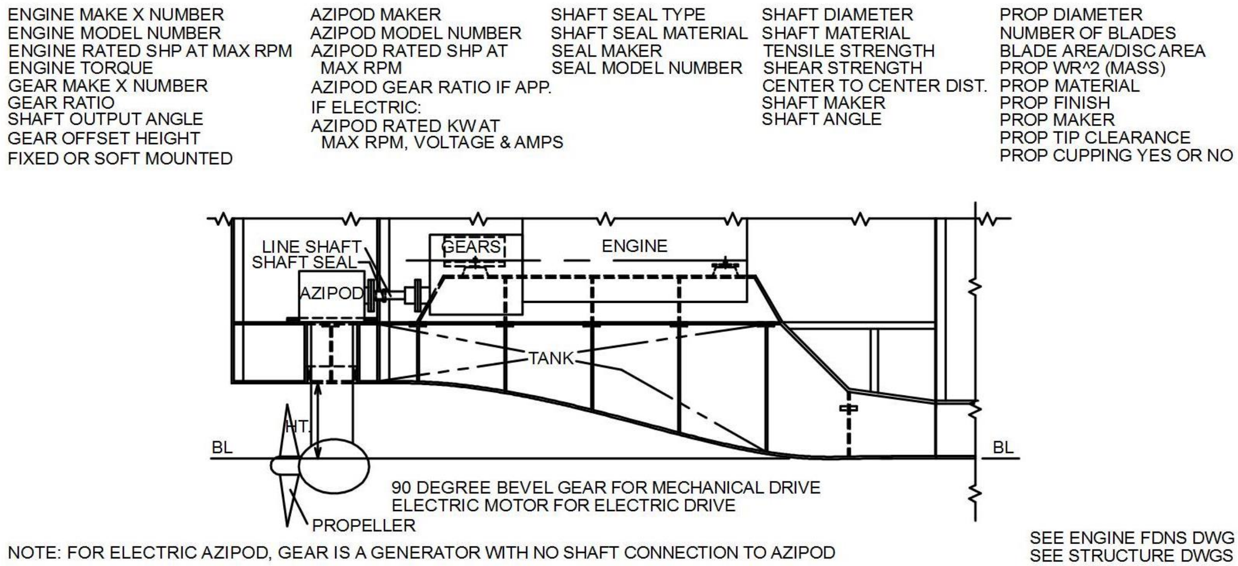

Figure 11: Azipod Propulsion Drawing

Fills, Vents, and Sounds Schematic

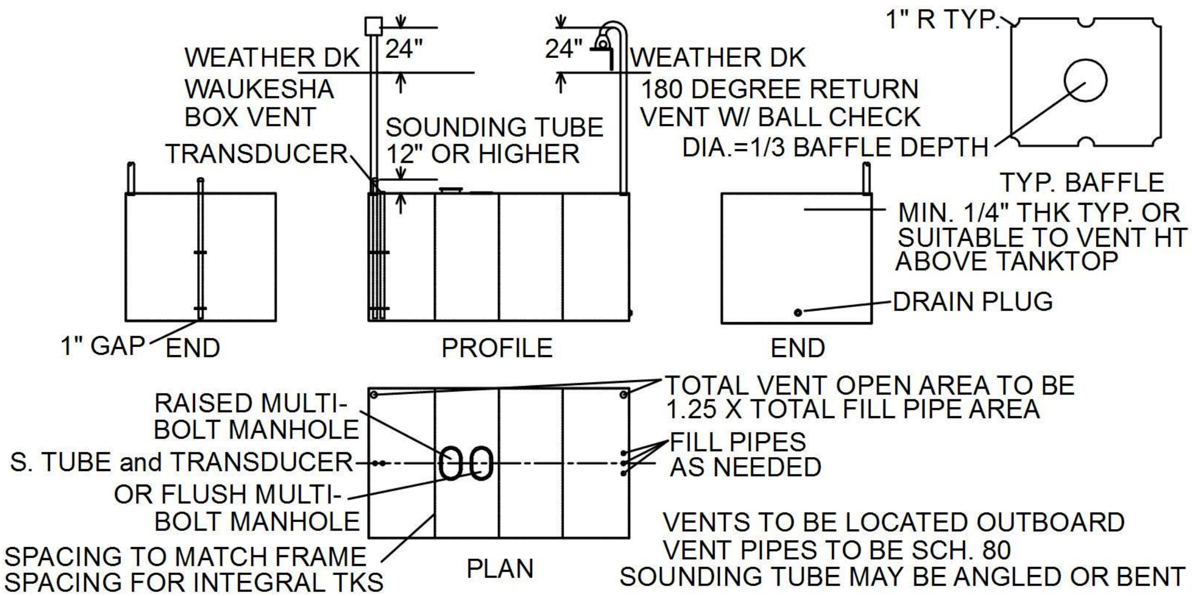

Figure 12: Fills, Vents, and Sounds Drawing

The Fills, Vents, and Sounds schematic shows conceptual details of how the tanks are to be filled, vented, and fluid levels are to be determined, and where on the ship these are located. All tanks require a way to fill them and to utilize the contents. All tanks also require air vents to allow the air above the fluids to shift with the fluid surface and to escape or replace increasing air volume as tanks are filled or emptied. Restricted vents can be hazardous, as a tank being filled with a plugged vent will often pop the deck or tanktop off of the interior structure, damaging the tank. The opposite is true if a tank is being emptied over time with a plugged vent; the tank may collapse from the vacuum created inside. All tanks except for small tanks such as lube oil and dirty oil, dirty bilge water, and hydraulic fluids vent to the atmosphere outside of the ship through check valves above the deck. These are set up so that waves on deck over two feet deep with lift the float in the check valve, temporarily closing the tank vent so that water cannot get in. Once the water level subsides, the float drops and reopens the air vent. Tank level sounding systems are comprised of the fool-proof old standby of a vertical or angled pipe that goes from somewhere above the tanktop to the bottom of the tank. A sounding tape consisting of a tape measure with a weight like a plumb bob on the end is dropped into the tank, and once the bob hits bottom, the tape can be withdrawn and the fluid level can be seen as measured on the tape level. There are also many types of electronic, manual float-type, and clear tube fluid level (sightglass) devices available, and almost all vessels now have these other means of determining fluid levels.

Different tank systems may have different system usage methods. Fuel systems, for instance, are usually high in capacity, between tens of thousands to hundreds of thousands of gallons. Consequently, there are often at least three or more tanks to fill. Filling the tanks of such a system could take days if there was only one, small diameter fuel fill. Therefore, it is a good idea to do some research as to the size of fuel tanker or facility delivery hoses, flow rates, and pressures available to the ship, so that a reasonable fuel fill time in under a day or two can be achieved. This may take more than one fuel fill pipe, and it’s always good to have at least one on each side of the ship. Fuel fill pipes are housed in a structural containment that is open at the top so the crew member can reach in and unscrew or unsnap the closing cap. Any spillage drains back into the fuel fill pipe. There may be multiple tank fill pipes in one containment, and a crossover pipe with valves under the deck to allow filling of wing tanks on the other side of the ship. Small vessels are refueled using nozzles with hoses similar in size to what you fill your car or truck with at the gas station, and the fill fittings for them are similar in size to the tank pipe in a car but with screw-on lids. Larger ships use quick-connect hose fittings on larger diameter hoses for fuel fill pipes, particularly those fueling directly from a truck or commercial facility. The tanker trucks that fill the gas stations use commercial-size hoses with quick-disconnect fittings. Piping materials are to be schedule 40 black steel no matter what the hull material is, for fire resistance.

Fresh water tanks are usually fewer in number and less in capacity, since most vessels over about 50 feet now have a reverse-osmosis watermaker on board. These are devices that filter the salt and other impurities out of seawater to make drinkable water. The fresh water fills are usually about 1 ½” diameter pipes, with a minimum of one fill point on deck. These are located separately from the sewage pumpout fitting to avoid confusion. Like the fuel fill pipes, smaller vessels have screw-down plates on the deck and larger ones have quick-connect hose fittings. Piping materials are usually copper, PVC, CPVC for high temperature areas, or ABS plastic. In USCG-regulated vessels, plastic pipes must have a shutoff valve on each side of each watertight bulkhead that the pipes pass through.

Ballast tanks are used for trimming the ship and improving stability, and up until recently, their fills were underwater and seawater was primarily used. However, with environmental regulations changing to limit the transfer of foreign animal species from one side of the world to another, the use of seawater for ballast is shifting to using fresh water where possible, which has been renamed "technical water" and this requires deck fills and/or connections to the watermaker system and perhaps the elimination of overboard discharges of ballast water. Piping materials are usually schedule 40 or 80 black steel, MONEL, or copper-nickel (CuNi).

Small tanks such as those noted above under venting, are filled directly into their tanks from drums stowed aboard or sometimes on deck in the fuel containment in separate fills.

Pipe Symbol List

The Pipe Symbol List is not necessarily included separately in Contract drawings because each piping drawing often has a symbol legend on the first page, which includes this. However, the symbols used are pretty standardized as shown below.

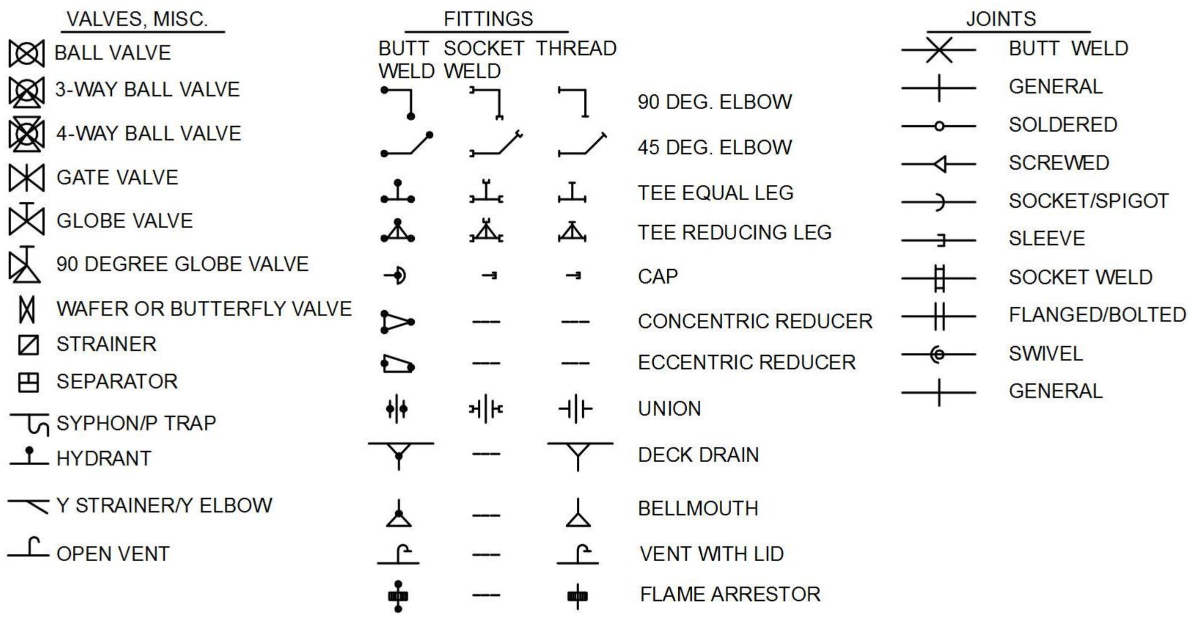

Figure 13: Pipe Symbol List

Bilge System Schematic

The Bilge system Schematic is a system logic drawing that consists of single line representing pipes, symbols representing the pumps and fittings, a Bill of Materials showing desired parts, types, manufacturers, quantities, system dimensions, materials, system pressure notes, and any remarks deemed necessary. These may be 2-dimensional or oblique, 3-dimensional in orientation, but are usually not shown on the ship background. This drawing is provided as guidance for how the client desires the system to operate, and also indicates all of the features required by Class or Flag State (Coast Guard or equivalent) to meet regulations. The Bilge System Schematic shows how all of the bilges in all watertight compartments can be emptied of accumulated water from leaks and condensation. The pipe sizes listed are for illustration purposes only; larger ships will have larger pipes and fittings. This drawing is usually cross-connected to the seawater firemain system so the two systems may be shown on one drawing. Piping materials are usually schedule 40 or 80 black steel, but may be MONEL or CuNi for those pipes with foot valves that continually hold residual water. Aluminum and plastics are not recommended for this vital system due to low melting points in a fire. Stainless steel is only recommended if the system has check valves at the manifold instead of foot valves at the suction ends since stagnant seawater causes crevice corrosion in stainless steel.

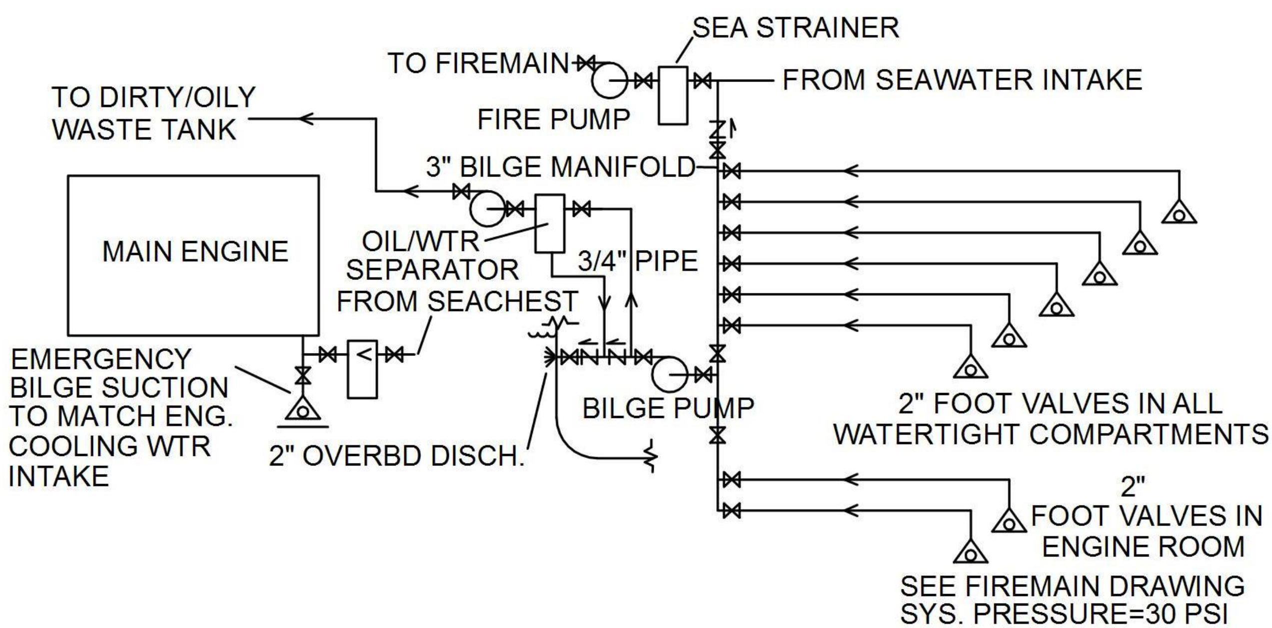

Figure 14: Bilge System Schematic

Black Water System Schematic

Like the Bilge System Schematic, the Black Water System Schematic shows the system logic and material recommendations of the sanitary system. Black Water systems are run by various methods-compressed air, fresh or salt water gravity flush, vacuum, and direct incineration. Included in this drawing are any holding tanks, Marine Sanitation Device (MSD) treatment plants, toilets, piping as single lines, toilet vents, a reference to the Fills, Vents, and Sounds drawing for the holding tanks and MSD vents, pumps, and overboard and deck discharges, and a Bill of Materials and system pressure notes. Piping materials are usually schedule 40 aluminum or steel, with schedule 80 connections at the hull for corrosion allowance on steel hulls.

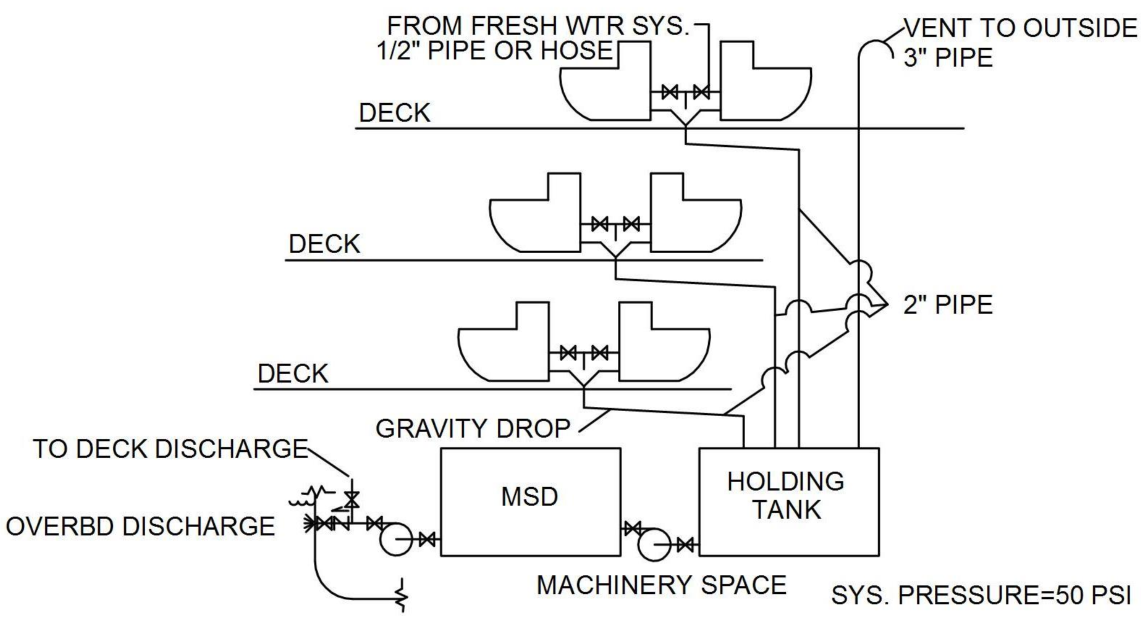

Figure 15: Gravity Drain Black Water System Schematic

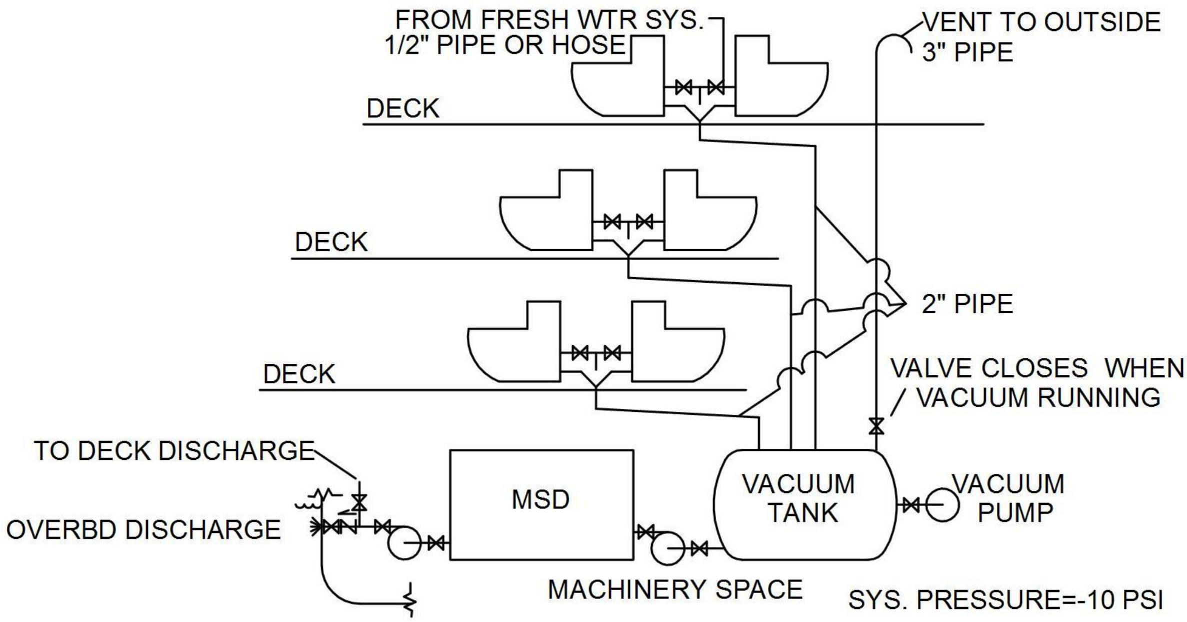

Figure 16: Vacuum Black Water System Schematic

Compressed Air System Schematic

The Compressed Air System Schematic is another one-line drawing showing the logic of this system. Shown on this drawing are the air compressors, piping, fittings, air dryers, storage tanks, horns, tool connection fittings, and connections to any other pneumatic systems such as engine controls, air springs and rams, etc. Ships using compressed air for engine starting will have a split high and low pressure system, where the engines are started with the high pressure air, and the rest of the users are run on lower pressure air through a pressure reducer. Class and Flag requirements for compressed air engine starting are a minimum of 6 starts possible for each engine, stored in the air receiver(s). They also often require a minimum of one generator to be capable of some other means of starting, like electric motors or hydraulic pumps with manual handles. Like the systems above, a Bill of Materials, system pressure notes, pressure vessel certification information, and references to connected systems are included. Piping materials are usually schedule 40 aluminum or steel.

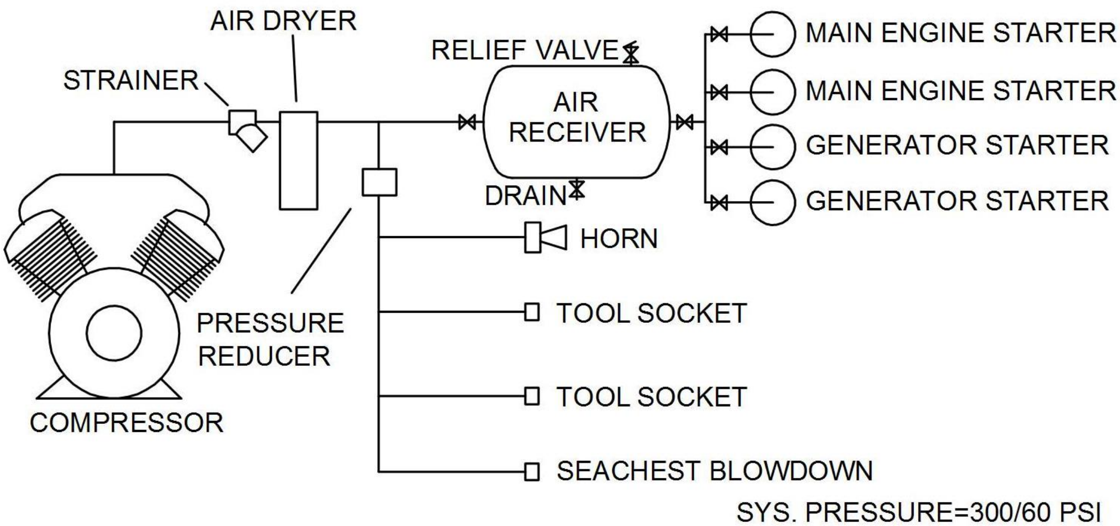

FIGURE 17: Compressed Air System Schematic

Deck Drains Arrangement

The Deck Drains Arrangement is optionally included as a separate drawing in the Contract drawings, as the locations of the drains are often shown on a deck arrangement drawing but the details of where the drain pipes go are left to the Detail stage of design. Yachts often have a specially-designed drain grating plate that includes the builder's symbol or logo, and this may be included to inform the bidder of the need to produce a number of these custom pieces. It is important to locate drains in all collection points regardless of forward or aft trim, and heel to either side, and particularly if the deck has no camber. Piping materials are usually schedule 40 aluminum, fiberglass, or black steel if that is what the hull is made from. For steel vessels, piping at the hull is usually schedule 80 as a corrosion allowance.

Oily Bilge Water and Dirty Oil System Schematic

The Dirty Bilge Water and Dirty Oil System Schematic is a logic drawing showing how the oily bilge water is separately collected in the machinery spaces from the bilge water elsewhere in the ship, and how the oil is separated from water in order to avoid oily waste discharges to the sea. The separated oil is pumped to the Dirty Oil tank and the water is often discharged at sea. See Figure 14 for this. The used Lube Oil is also emptied into this tank. Like the other tank system drawings, it shows the collection tank, pump(s), pipes, suction fittings and valves, a Bill of Materials, system pressure notes, Class and Flag State requirements, and references to other drawings such as the Fills, Vents, and Sounds drawing. Piping materials are usually schedule 40 black steel.

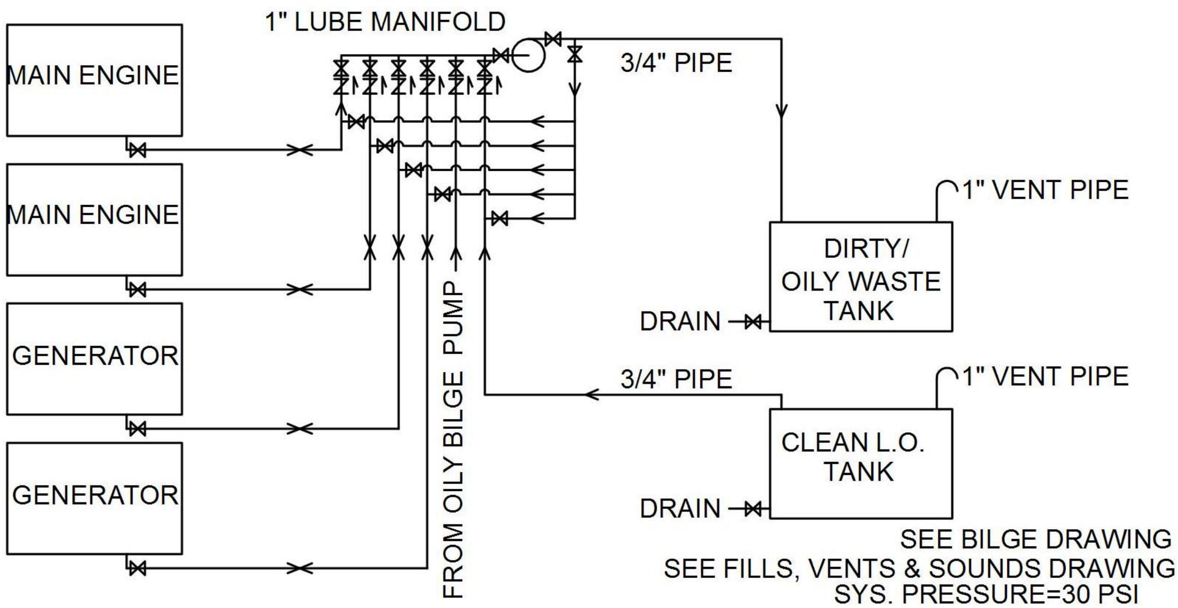

Figure 18: Lube Oil and Dirty Oil System Schematic

Exhaust System Schematic

Exhaust Systems consist of two major types-wet exhaust and dry exhaust. Wet exhaust systems (on the left in the figure below) are cooled using seawater that has already gone through the main engine and gears, or generator. This water is injected into the piping system just downstream of the highest point in the system. The location of the cooling water injection is critical so that cooling water cannot get back into the cylinder heads of the engine. Also, the exit point of the wet exhaust system is critical because it must be at a point underwater that does not build up too much hydrostatic backpressure due to water deoth, or if it exits above the waterline (the horizontal silencer arrangement), it must be sufficiently below the highest loop point in the system so that external waves cannot get up over the high point and into the cylinder heads. However, it is usually right at the waterline so that there is no hydrostatic pressure at the exit. As the cooling water/exhaust mixture enters the water lift muffler, the muffler contains about half of its depth in cooling water, which the quiets the bubbling exhaust noise. The exhaust gas separates from the cooling water in the upper half of the waterlift muffler and both gas above and water below exit out of the waterlift muffler. In boats with a water drop silence aft of the water lift silencer, the remaining cooling water is separated from the exhaust stream and it drains back to the sea under the boat so that no one can hear the dribbling of the exiting cooling water. The dry and cool exhaust then exits the boat either underwater or through the side or transom at the waterline. Underwater exhaust systems in my experience only work well above about 12-16 knots, where the exhaust eductor (like a clamshell) under the boat develops a vacuum behind it, which lowers the hydrostatic pressure that the exiting exhaust sees. The volume of cooling water being injected is controlled by a throttling valve as the water enters the exhaust pipe. An exhaust bypass is necessary in such a system for vessel speed conditions below 16 knots so that the lower volume of exhaust at the lower speeds can escape above the waterline, eliminating the hydrostatic pressure problem. Two stroke diesels are particularly sensitive to this issue, but 4 stroke diesels are not so sensitive. Allowable backpressure graphs showing critical pressures for various rpms are available from the engine manufacturers for use in designing these types of systems. These systems are common in yachts, high speed ferries, and patrol vessels and are suitable for aluminum, wood, and fiberglass/composite hulls. Sportfishing vessels and some ferries more commonly use the horizontal silencer layout.

Dry exhaust systems are common in all other types of vessels as well as some of the vessels mentioned above. In these systems there is no cooling water injection; the silencer and the pipes are insulated with fiberglass mat blankets and sometimes stainless steel sheet metal as a decorative touch as well. Since there is no cooling water injection, the silencer is a baffle type more like a large automotive muffler, and there are no water lift or water drop silencers in the system. However, due to recent IMO Tier III environmental regulations, several types of exhaust scrubbers and/or catalytic converters are being required to lower soot, carbon dioxide, methane (if any), nitrous oxide, and sulfur dioxide emissions. In these systems the silencer can be arranged horizontally or vertically depending on available space, and a scrubber device and/or economizer is installed above the silencer. Methods of cleaning exhaust are larger automotive-type catalytic converters and water/urea injector sections, where water and the chemical urea (derived from cattle urine) is injected into the hot exhaust, which sets off a chemical reaction that breaks the urea and carbon/oxygen bond from the exhaust into ammonia. This is then run through a catalytic converter, which breaks the ammonia down into nitrogen and water vapor, which exit out of the stack.

An economizer is a waste heat boiler, which is a series of tubes full of fresh water that absorb the heat from the cleaned exhaust for use throughout the ship as hot fresh water. These can recover about 30% of the otherwise wasted heat, saving energy that would otherwise be produced by burning more fuel or making more electricity. Piping materials are either Schedule 40 mild steel or schedule 10 316 stainless steel.

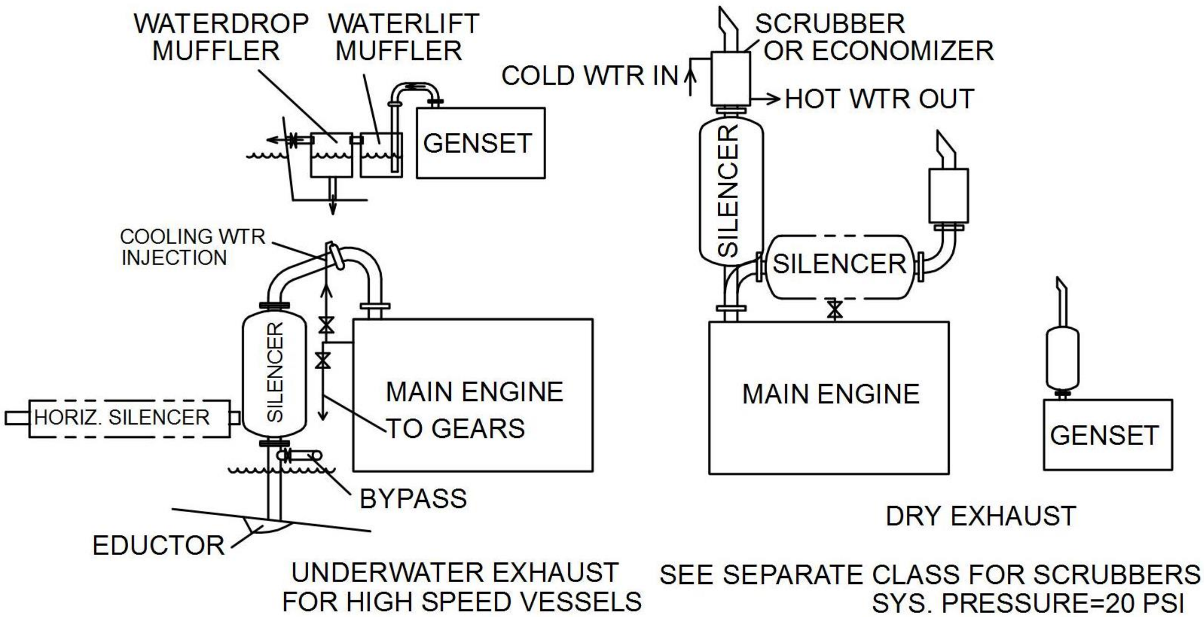

Figure 19: Exhaust System Schematics

Fixed Gas Fire Extinguishing System

The Fixed Gas Fire Extinguishing System is a schematic of the CO2 (carbon dioxide), HALON (no longer in production but still in use), or FM200 (hydrofluorocarbon gas) fire extinguishing system required for the Engine Room and machinery spaces that contain auxiliary engines. The storage bottles are required to be located separately from the protected space. The schematic drawing shows the storage bottles, discharge methods, piping as a one-line, discharge warning alarm lights and horns, fittings and valves, nozzles, a Bill of Materials, system pressure notes, Class and Flag State requirements, and references to other drawings such as Fire and Safety Plan and Alarm Systems drawings. Regulations require at least one discharge station outside of the space to be protected, an alarm light and audible horn, and a time-delayed release of the agent for 30 seconds to allow the crew in the space to escape. When the system discharges, gas is emitted through multiple nozzles in the overhead of the protected space at specifically spaced intervals to lower the oxygen ratio in the space.

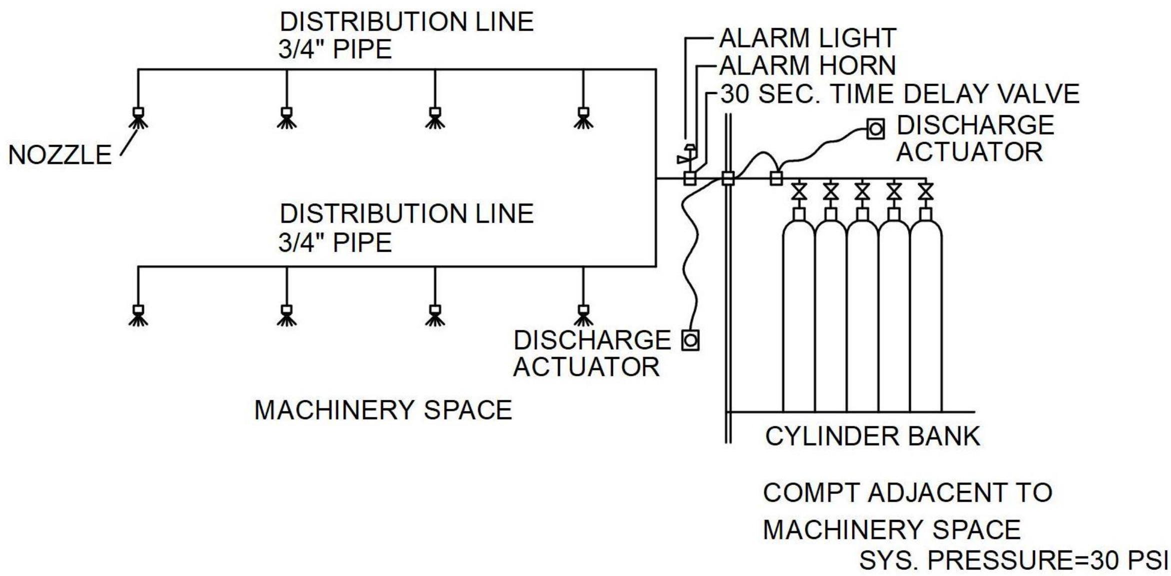

FIGURE 20: Fixed Gas Fire Extinguishing System Schematic

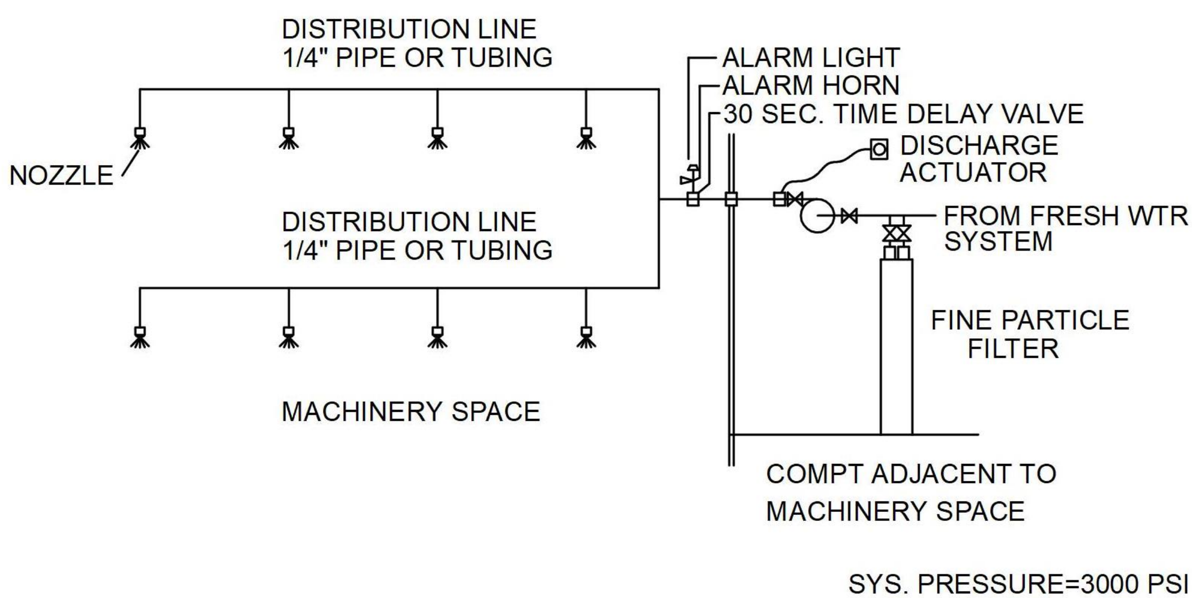

Figure 21: HI-FOG Fire Extinguishing System Schematic

HI-FOG and Water Sprinkler Misting Systems

The HI-FOG Misting System is an alternative to fixed gas systems in that highly filtered and atomized fresh water is misted into the space under extreme pressure with special nozzles to displace the oxygen ratio and thereby cool and smother an oil-fueled fire. It is similar to the Fixed Gas Fire Extinguishing System drawing except for the replacement of storage cylinders with high pressure pumps, and alarm lights and horn since it doesn't use a non-breathable gas. This system uses less water than a sprinkler system and wets down the space much less. A water sprinkler extinguishing system is similar to what you have seen in hotels and other public buildings. They are not suitable in machinery spaces because oil fires cannot be extinguished by water alone, but are required in seagoing passenger ships in non-machinery spaces.

Seawater Firemain System Schematic

A Seawater Firemain System is required by all Flag States and Class Societies on their regulated vessels. The schematic shows the calculated number of hose cabinets and hydrants that will be required, the specific fire pump with its flow capacity and pressure head, and its link to the bilge system to act as an emergency bilge system if needed. Depending on the size and type of vessel there may be a requirement for an additional independent fire pump or more located outside of the Engine Room. The fire pump must be capable of throwing specified capacity of water at a specified head pressure, and it will be tested on sea trials to prove that they meet the requirements. These requirements are based on the IMO International Firefighting Regulations, which require enough 50 foot (15.24 m) hoses to reach any place on the vessel, minimum hose sizes, spray and fog nozzles of approved types, and the specific pump requirements. Pumps are often powered by electric motors, or power takeoffs on the main engines, and requirements for multiple pumps require different power sources so that one type cannot render the system useless if one powering method is not working. Piping materials are often black steel, MONEL, Copper-Nickel (CuNi), and maybe bronze. Stainless steel is not recommended for this system unless the pipes are to be kept dry when not in use, due to stainless steel's sensitivity to anaerobic crevice corrosion when the fluid sits a long time. I would not recommend PVC, aluminum, or any other plastics in a firemain system even if the hull is fiberglass or composite-having flammable or low melting temperature firemain pipes is not a good idea..

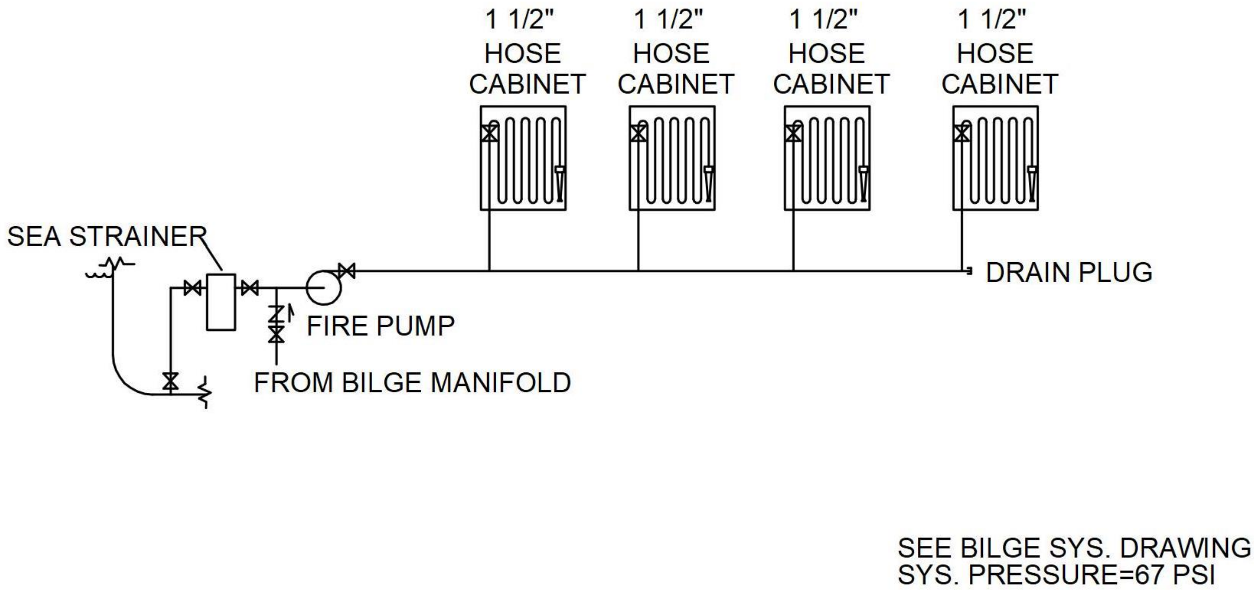

FIGURE 22: Seawater Firemain Schematic

Other firefighting devices required to be provided but not shown on a schematic are the ABC-type and water-type portable fire extinguishers, and Aqueous Film Forming Foam (AFFF) portable tank type for fighting fuel and grease fires.

Fresh Water System Schematic

The Fresh Water System schematic shows in logic form the fresh water storage tanks, filters, reverse-osmosis water maker system, water heaters, piping, circulation pumps, accumulators, and all of the devices being supplied fresh water for sinks, showers, bathtubs, toilets, deck washdown spigots, and other fresh water sources. All of the devices are connected to the piping through an isolation valve and a hose. The reverse-osmosis watermaker filters salt and other impurities from seawater to make drinkable fresh water. Not shown due to space are the galley appliances, and the thru-hull valve on the seawater inlet, the extra-salty leftover water (brine) pump, piping, and thru-hull valve for that system that is ejected back to the sea. The devices needing hot water are often piped in a loop from the water heaters through the devices and back to the water heaters so that instantaneous hot water is available. An accumulator, which attenuates pulses in the water flow from the pumps, is installed just downstream of the pumps along with the particulate and activated carbon filters. There is a manifold in the Engine Room or Auxiliary Engine Room to transfer fresh water from tank to tank to aid in control of the vessel heel and trim. In addition to the toilets, showers, and sinks, deck washdown spigots and low point drains are important for maintenance and if the ship will be operating in freezing temperatures. Piping can be constructed in copper, PVC and CPVC (for higher temperatures), and ABS plastics; stainless steel is used but not recommended if systems are going to be stagnant for lengths of time due to potential crevice corrosion. This is a complicated system even at the schematic stage.

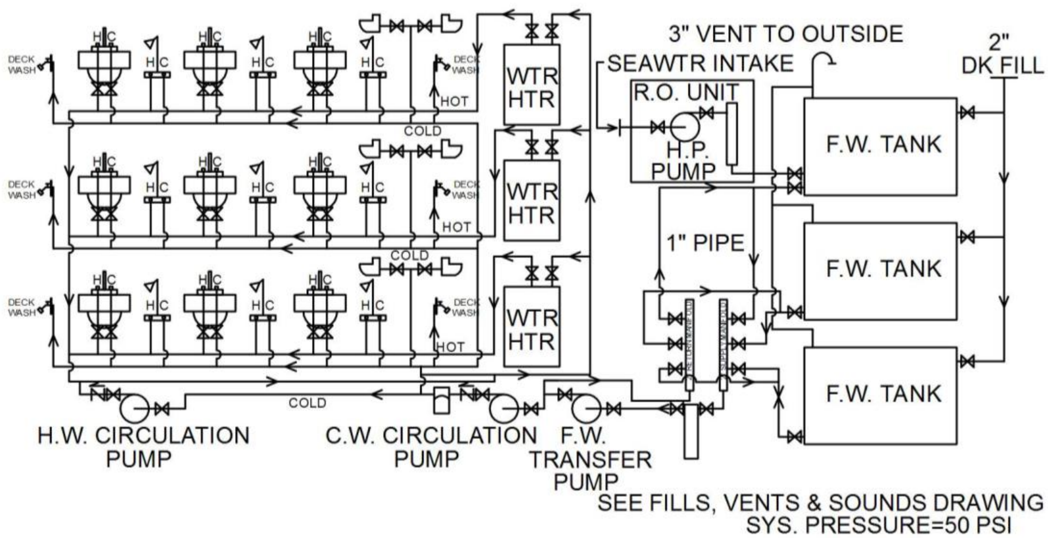

Figure 23: Fresh Water System Schematic

Fuel Service and Transfer System Schematic

The Fuel Service and Transfer System schematic shows the logic of this system for controlling heel and trim, filtering fuel for combustion, feeding the propulsion engines, generators, and sometimes heaters, and returning unused fuel back to the tanks. The figure shown is a simple one-fuel system; ships transferring between low sulphur and normal sulphur fuel zones must now have the ability to carry both types of fuel, to drain the pipes of the previous fuel type, and refill them with the next fuel type to be used. For international seagoing ships the capacity requirement for low sulphur fuel is much lower than regular fuel, so perhaps only one low sulphur fuel tank is needed, but it is important to avoid cross-contaminating the different fuel types as the levels are checked in port and subject to environmental fines if the requirements are not adhered to.

In the one-fuel system shown, fuel is loaded into the storage tanks, and fuel to be used that day is transferred though a fuel/water separator or centrifuge, and several sequentially finer mesh filters, to the Day Tank. The propulsion, generator, and any auxiliary engines such as for bow thrusters draw fuel from the Day Tank and return unused fuel back to it. As the fuel level drops, the engineer transfers more stored fuel to the Day Tank as above. Not shown is a fuel transfer meter, which shows the number of liters or gallons being transferred. Fuel tank levels are watched by the engineers, and if the vessel trim or heel needs adjustment to level, they transfer fuel and/or ballast as needed. The tank sludge that gets passed along to the oil/water separator gets filtered out and sent to the oily waste tank either for reinjection with the fuel in small concentrations to burn it, or it gets taken to the next port for disposal.

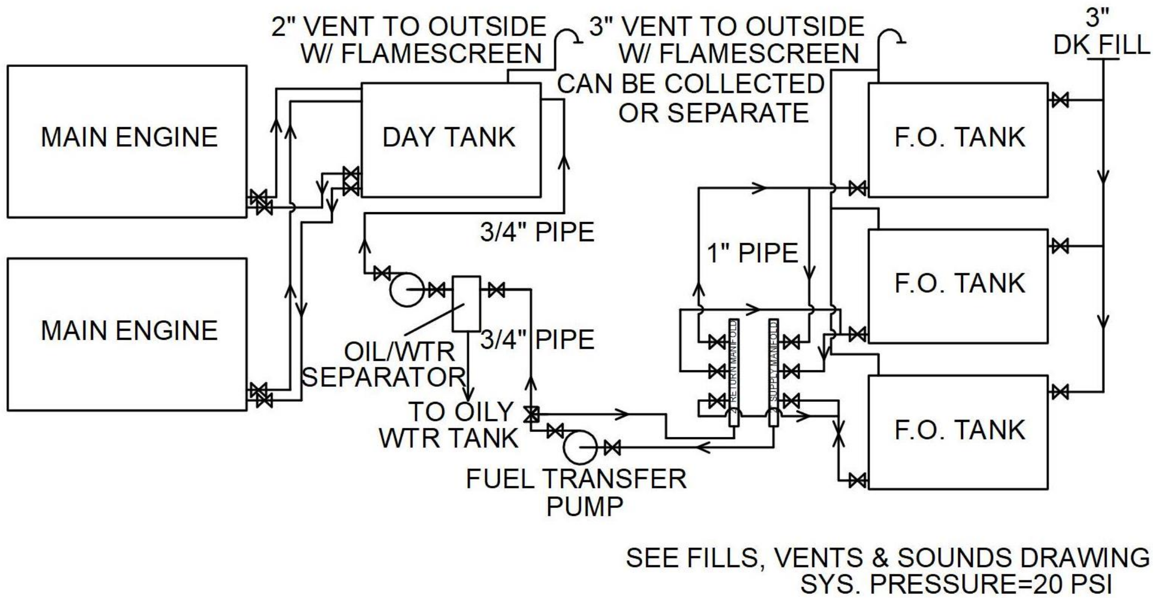

Figure 24: Fuel System Schematic

Liquid Cargo Transfer System Schematics

The Liquid Cargo Transfer System schematic for tankers and offshore supply vessels works similar to a ballast system, where the tanks are loaded either in port or from a lighter (a smaller, shallow draft liquid cargo vessel), taken to its destination, and offloaded in a similar way to how it was loaded. Unlike ballast systems, liquid cargos are not discharged into the sea. Liquid cargos can consist of raw petroleum, refined petrochemicals, alcohols, all sorts of other chemicals, fresh water, etc. Flammable liquid cargos such as alcohols and gasoline require special tank vents and vapor detection and alarm systems to alert the crew of the danger happening. Liquid cargos with higher flame points such as diesel fuel only require fine mesh flame screens on the vents in addition to closing plates in case of storms.

Gray Water Drains System Schematic

The Gray Water Drains schematic shows the logic of all of the freshwater drains in the ship. Gray water consists of sink and shower drains, ground food in disposalls, air conditioning condensate (if using direct expansion Freon systems), soapy water, and freshwater containing biodegradable liquids and solids. Most of these drain by gravity, but a pump and collection tank(s) are necessary to discharge what is collected. Some environmental areas do not allow the discharge of gray water at all; in such cases the gray water must be processed in the MSD along with black water. In areas that allow gray water dscharge, there is an underwater discharge pipe and isolation valves connected to the pump. The air conditioning condensate is to be kept separate from the other gray water discharges to avoid soapy smells getting back to the air handlers.

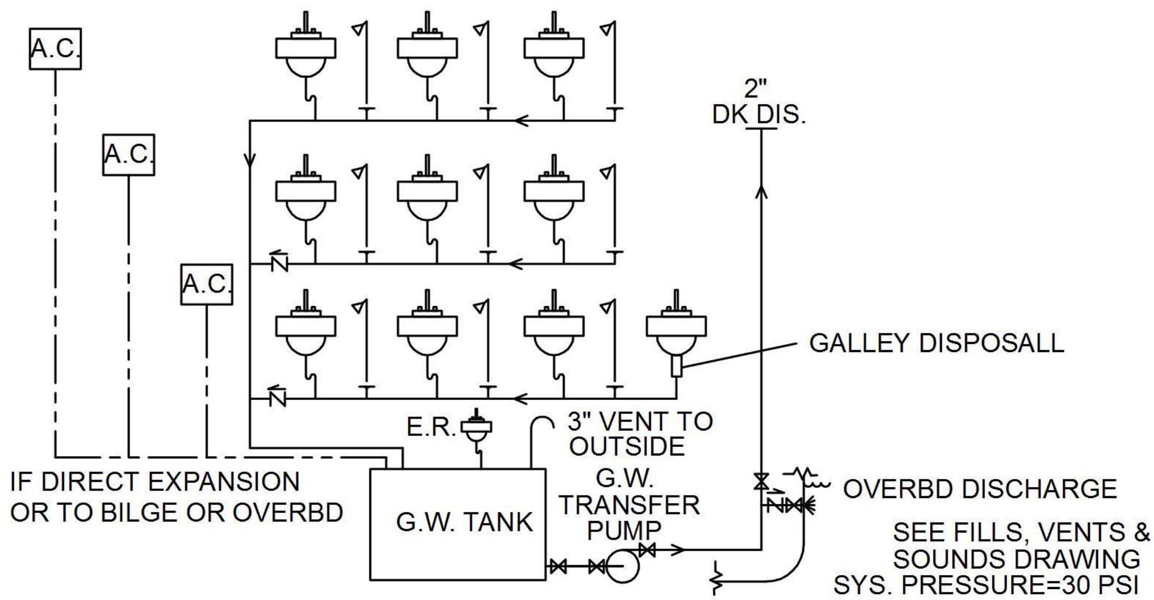

Figure 25: Gray Water System Schematic

Hydraulic Power System Schematic if centralized

A centralized Ship Service Hydraulic System schematic shows the system logic of a single power unit consisting of an electric or engine-driven pump, with filter, reservoir tank, oil cooler, and manifold, driving multiple local devices such as anchor windlasses or capstans, cargo and towing winches, mooring capstans (smaller than anchor capstans, used for docklines), mechanical cranes or davits for lifting heavy objects, bow thrusters, stabilizers, etc. Hydraulic steering is a vital system, and as such is required to be an independent system with backup fed power directly from the main switchboard. The oil cooler is a bypass type heat exchanger that feeds seawater through one side and out, and hydraulic oil through the other side and out, for greatest cooling efficiency. All devices are connected to the piping with valves and short approved-type hoses for isolating any component and for vibration resistance. Piping materials are schedule 120 black steel pipe or steel mechanical tubing specifically rated for the system pressure plus a safety factor.

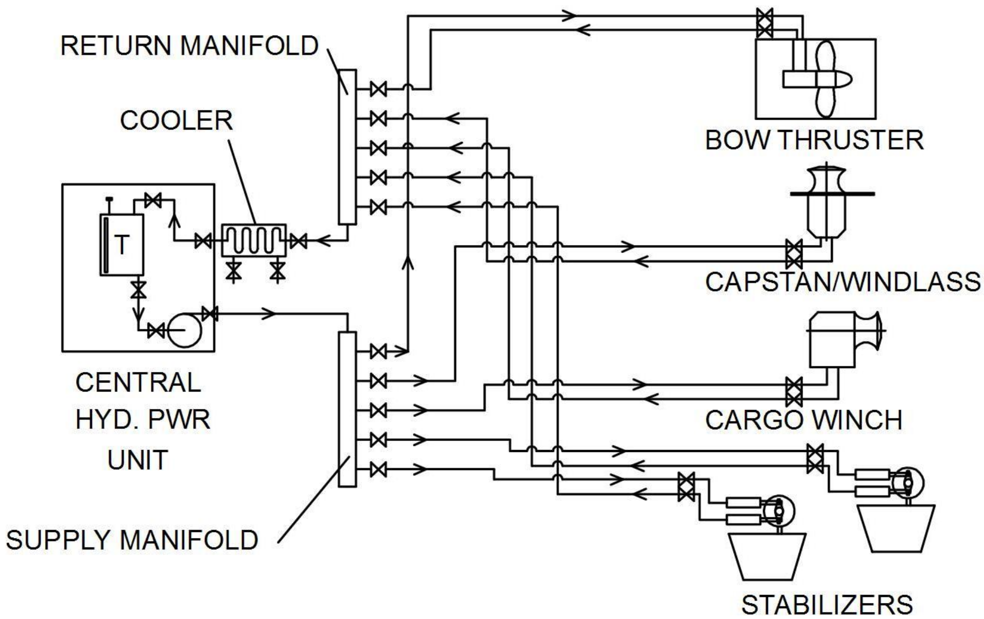

Figure 26: Centralized Hydraulic System

Hydraulic Power System Schematics for individual systems if not centralized

A non-centralized hydraulic system will have multiple independently-powered devices as above, each with their own power unit. This is a much more complicated system than a centralized one, but it is less susceptible to total system failure since each device has its own power unit. Steering systems, as noted above, are always required to be a non-centralized, independent system with backup power.

Steering Arrangement Schematic

The Hydraulic Steering System schematic shows the logic of the ship's steering system, which consists of a hydraulic power unit (pump, filter, and reservoir), two hydraulic rams, rudders with tiller and a jockey bar, a manifold supplying and returning oil to each steering station, an emergency steering arrangement by manual means, and a reference to the main electrical power One-Line Diagram. Larger ships may use a gear-driven steering system instead of hydraulic cylinders. Piping materials are steel mechanical tubing specifically sized for the system pressure with a safety factor.

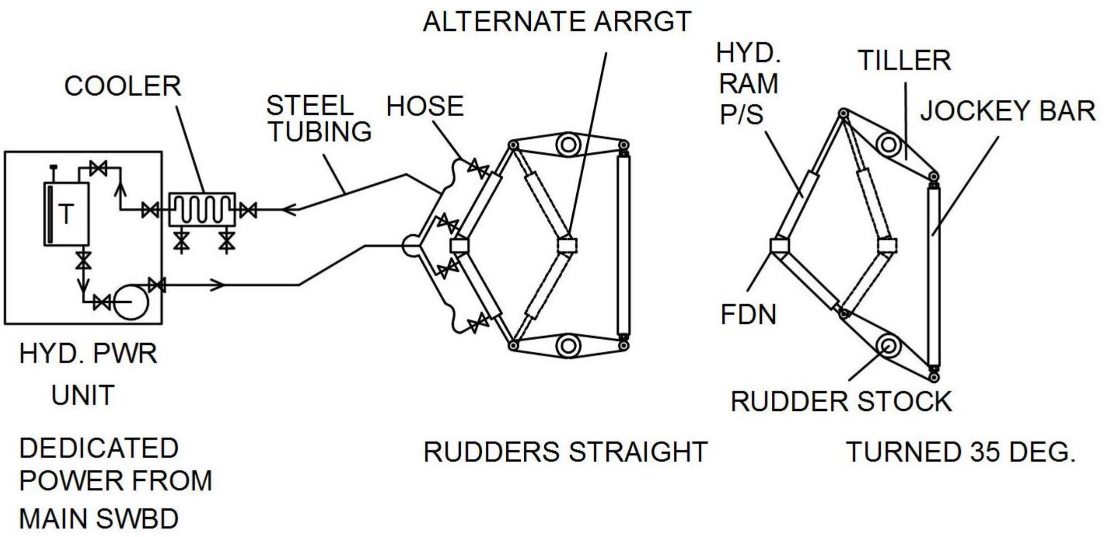

Figure 27: Hydraulic Steering System

Seawater Cooling System Schematic

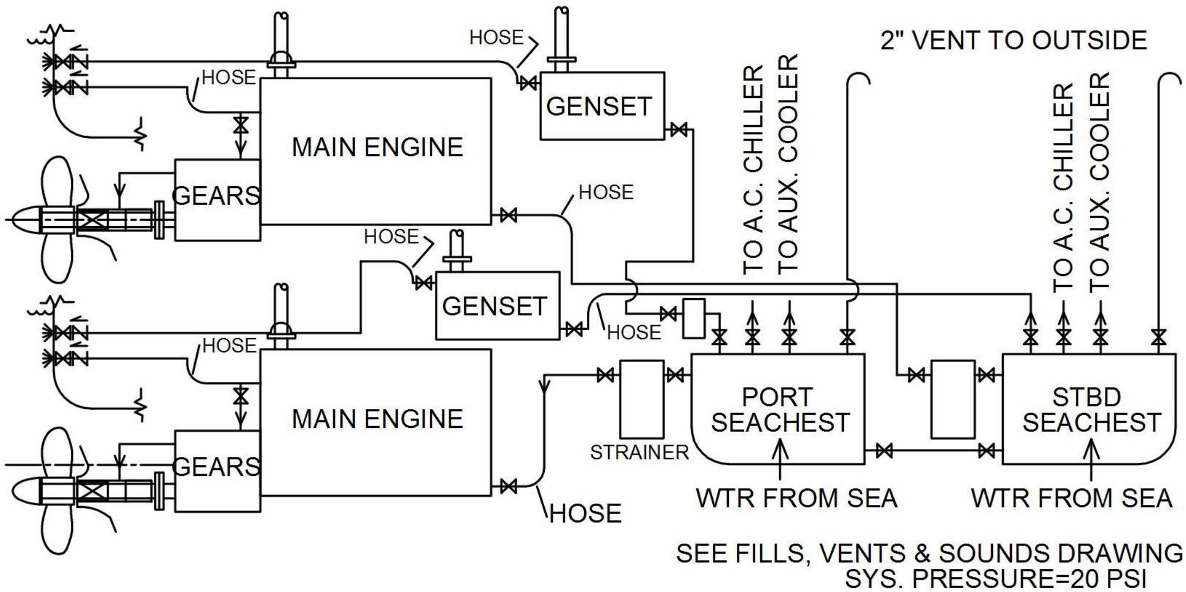

Figure 28: Seawater Cooling System Schematic-Seachest Type

The Seawater Cooling System schematic shows the logic of how all of the machinery requiring cooling gets serviced. In the type shown there are one or two sea chests, which are trunks open to the sea through strainer plates that filter out sea grass, plastic and other floating trash, logs, etc. In the double seachest type there is a cross-connection with valves that allow for isolating one side without stopping machinery so that compressed air can be used to blow out ice or other debris that gets inside and clear the air vent that keeps the seachest completely filled with water. There are several pipe connections to the seachest that feed the main engines, generators, and perhaps other auxiliary engines through strainers, as well as supplies to the air conditioning chilled water cooler, hydraulic oil coolers, steering oil cooler, and other auxiliary cooling needs. In the case of the main engines, their cooling water goes partially to the transmission oil coolers and partially overboard, or in the case of wet exhausts, also partially into the exhaust system. Generator cooling is similar except that they do not have transmissions to cool. In all cases the cooling water that has passed through the device it cools, exits to the sea through overboard discharge valves. Often these discharges are grouped together to minimize the number of hull penetrations.

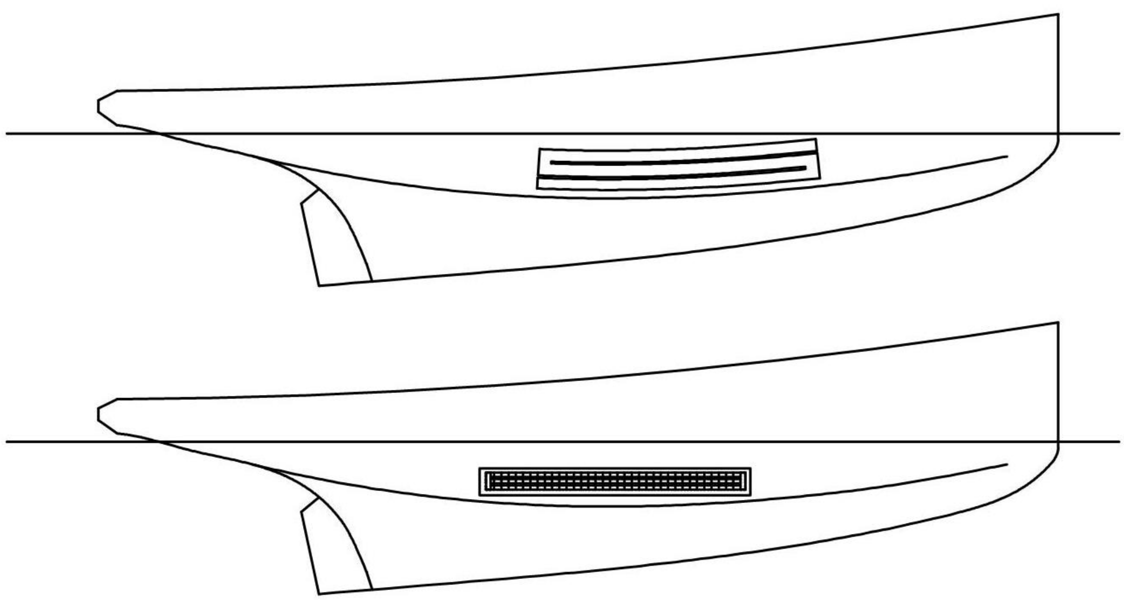

Figure 29: Seawater Cooling System Schematic-Channel or Fernstrum Cooler Type

The Channel (above) or Fernstrum Cooling System(below) types are similar to the seachest type inside the ship, but they differ outside the hull. Neither type utilizes a seachest arrangement; both have either structural steel channels welded to the outside of the hull in a fore-and-aft zig-zag pattern (channel cooler), or an external stainless steel pipe with heat sink plates set in a recessed box that the water to be cooled runs through. The advantage of these is that cooling water in the machinery is clean fresh water with anti-freeze instead of muddy, sandy, fresh or salt, lowering corrosion and maintenance of the entire cooling system especially by eliminating sea growth inside the piping. Both types of cooling systems are widely used on smaller workboats, as they are somewhat limited in their cooling capacity by the length of cooler that can be mounted outside the shell plate.

See "How To Read Shipbuilding Drawings, Part 3" for the rest of the Contract level design plans.

Bibliography

Marine Engineering, Society of Naval Architects and Marine Engineers, 1992.

