

Lecture 9 : Ship weight Calculations

1. Ship Classification systems

Ship systems and their components provide detailed technical information needed for weight assessment, price estimation and production planning. Ship classification systems have been developed to provide to the yards and to the companies involved in the management and operation of ships tools to support ship specifications, estimates of light ship weight, ship building (or repair) costs and systematically sort listed information on the procurement of materials, equipment and services. In brief, there are three basic ship classification systems namely : (a) **MARAD** (MARitime Administration) used by the U.S.A. administration; (b) **SWBS**- Ship Work Breakdown Structure, used by the USA Navy and (c) **.SFI**- developed by the Norge Skips Forsknings Institutt (NSFI) of Norway, and is now property of XANTIC (www.xantic.net).

SFI is the most widely used classification system for the maritime and offshore industry. It consists of a technical account structure covering all aspects of ship/rig specification, and it can be used as a basic standard for all systems in the shipping/offshore industry. In shipbuilding, the grouping system can help shipyards to estimate the weight of system components hence the ship's lightweight and deadweight, and for price estimation purposes. In operations, it helps shipping companies to control purchasing, accounting, maintenance, technical records, etc., by tying them together.

The SFI group system introduces of 3-digit decimal classification. Accordingly, the ship is divided into 10 main groups (ranging from 0 to 9). Of those only main groups 1-8 are in use. Group 0 and 9 are used for classifying other main components that are not covered under the SFI standard. Each of the main groups (1digit) is composed of 10 sub - groups

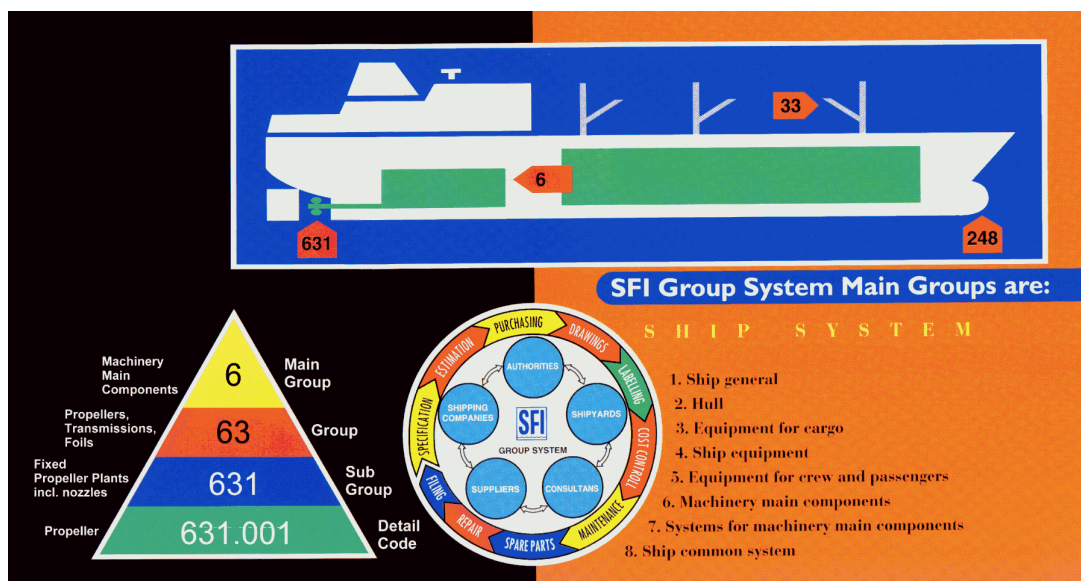


Fig 9.1 The SFI classification system (image credit : <https://en.wikipedia.org>)

The main groups are as the follows:

- Group 1 : general costs and details that cannot be assigned to any of the following groups such as general arrangement, launching, and drydocking.
- Group 2 : hull, superstructure and material protection of the vessel.
- Group 3 : cargo equipment and machinery including the loading and unloading equipment.

- Group 4 : ship specific equipment and machinery (navigational equipment, maneuvering machinery, anchoring equipment and communication equipment).
- Group 5 : equipment serving crew and passengers such as the lifesaving appliances, furniture, catering equipment, and sanitary systems.
- Group 6 : machinery main components including main engines, auxiliary systems, propellers, boilers, and generators.
- Group 7 : equipment serving main machinery such as fuel and oil lubrication systems, starting air systems, exhaust systems, and automation systems.
- Group 8 : ship Common Systems such as ballast and bilge systems, firefighting and electrical distribution systems.

2. Classification of weights

It is necessary to allocate ship weights in order to facilitate data gathering, reporting and analysis of ship weights. The traditional way of weight classification is to divide the ship's total displacement into lightship weight (W_{LS}) and total deadweight (DWT). The lightship weight is defined as:

$$W_{LS} = W_S + W_M + W_O + W_{margin} \quad (9.1)$$

where : W_S is the structural weight; W_M is the propulsion machinery weight; W_O represents the outfitting weight and W_{margin} is the Margin or reserve.

The ship's deadweight is defined as :

$$DWT = DWT_c + DWT_{FO} + DWT_{FW} + DWT_{C\&E} + DWT_{PR} \quad (9.2)$$

where DWT_c is the cargo deadweight ; DWT_{FO} is the fuel oil weight ; DWT_{FW} is the lube oil weight; $DWT_{C\&E}$ represents the weight of crew and their effects and DWT_{PR} is the weight of provisions.

3. Preliminary Weight Calculations

Estimation of weight at early design stages requires the use of parametric models based on information of similar vessels either from literature or using a shipyard's database. An important part of this estimation is to decide on the relevant independent variables that are correlated with weights and their centers.

The **structural weight** consists of the weight of the basic hull to its depth amidships, the weight of the superstructures, extensions of the hull above the basic depth amidships (e.g. forecastle and the poop deck) and the weight of deckhouses. Because superstructures and deckhouses have an important effect on the estimation of the ship's vertical and longitudinal centers of gravity it is important to capture the designer's intent in relation to the existence and location of superstructures and deckhouses as early as possible in the design process. An approach to this has been traditionally proposed by Watson and Gilfillan using the so called modified Lloyd's equipment number E .

$$E = E_{hull} + E_{SS} + E_{dh} = L(B + T) + 0.85L(D - T) + 0.85 \sum_i h_i + 0.75 \sum_j h_j \quad (9.4)$$

This number is an area type independent variable. The first term represents the area of the bottom and the two sides of the hull below the waterline. The second term represents the area of the two sides above the waterline which are 15% lighter since they do not experience hydrostatic loading. The third term is the sum of the profile areas (*length x height*) of the superstructure elements. The fourth term represents

the sum of the profile areas of the deckhouse elements which are relatively lighter because they are not influenced by wave loads and have a width less than the ship's beam.

Watson and Gilfillan also introduced the following regression-based equation as a function of the equipment number:

$$W_S = KE^{1.36}[1 + 0.5(C_B - 0.7)] \quad (9.5)$$

where C_B is the block coefficient at 80% of the depth. The factor K varies with the ship type as shown on Table 7. It is noted that this estimation corresponds to the case of a vessel made 100% from steel.

<i>Ship type</i>	<i>K mean</i>	<i>K range</i>	<i>Range of E</i>
Tankers	0.032	±0.003	1500 < E < 40 000
Chemical tankers	0.036	±0.001	1900 < E < 2500
Bulk carriers	0.031	±0.002	3000 < E < 15 000
Container ships	0.036	±0.003	6000 < E < 13 000
Cargo	0.033	±0.004	2000 < E < 7000
Refrigerator ships	0.034	±0.002	4000 < E < 6000
Coasters	0.030	±0.002	1000 < E < 2000
Offshore supply	0.045	±0.005	800 < E < 1300
Tugs	0.044	±0.002	350 < E < 450
Fishing trawlers	0.041	±0.001	250 < E < 1300
Research vessels	0.045	±0.002	1350 < E < 1500
RO-RO ferries	0.031	±0.006	2000 < E < 5000
Passenger ships	0.038	±0.001	5000 < E < 15 000
Frigates/corvettes	0.023		

Table 7 K factor. Credits: (Thomas, 2003)

In commercial classification **machinery weight** includes only propulsion machinery; the prime mover, reduction gear, shafting and propeller. Watson and Gilfillan suggested a division of machinery weight into main engines and the remaining items. This approach is advantageous because it is usually possible to select the main engine early in the design process.

$$W_M = W_{ME} + W_{rem} \quad (9.6)$$

If the engine weight is unknown, the following regression equations should be used to deduce both the main engine and the rest of the machinery components according to the equation :

$$W_{ME} = \sum_i 12(MCR_i / N_{ei})^{0.84} \quad (9.7)$$

In the above, i subscript represents the index of multiple engines respectively running at a maximum continuous rate MCR_i in the order of N_{ei} rpm. The overall weight of the remaining items varies with the total plant MCR as follows:

$$W_{rem} = c_m (MCR)^{0.7} \quad (9.8)$$

where MCR is in KW and $C_m=0.69$ bulk carriers, cargo vessels and container ships; 0.72 for tankers; 0.83 for passenger vessels and ferries, and 0.19 for frigates and corvettes. It is noted that for modern diesel electric engines Watson proposed the following equation for the total machinery weight

$$W_M = 0.72(MCR)^{0.78} \quad (9.9)$$

Outfitting weight includes the weight of the electrical plants, auxiliary systems – such as HVAC, joiner work, furniture, electronics, paint, etc., and hull engineering– such as bits, chocks, hatch covers, cranes, windlasses, winches, etc. Watson and Gilfillan introduced the following equation to estimate outfitting weight :

$$W_o = C_o LB \quad (9.10)$$

where C_o is the outfitting weight coefficient is a function of the ship type and length and its values can be obtained from Figure 9.2.

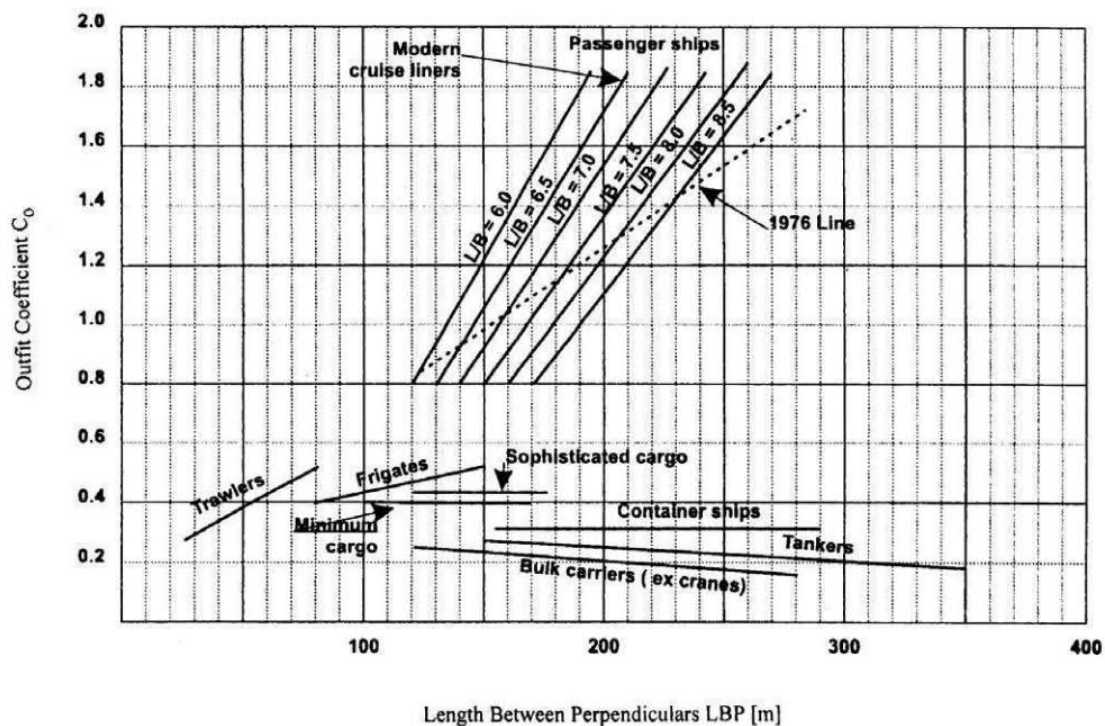


Figure 9.2 Outfit coefficients (Thomas, 2003)

Cargo deadweight is usually an owner requirement, or it can be estimated from analysis of the hull capacity. The remaining deadweight items can be estimated in the same way as the lightship weight. Based on the selection of the main machinery and the prime mover of a vessel, the specific fuel consumption rate (SFR) for propulsion plant is provided. Accordingly, fuel weight can be estimated as:

$$W_{FO} = SFR \times MCR \times range/speed \times margin \quad (9.11)$$

For diesel engines, SFR is 0.00019 t/KWhr and 10% addition is allowed to account for shipboard operations. For gas turbines SFR is 0.000215 t / KWhr . Overall, the SFR design margin might be between 5-10%. In practice a ship would not reach her maximum continuous rate except for worst service conditions. Thus, this estimation may be seen as overconservative

The **lube oil weight** depends on the type of machinery used and is usually derived based on existing vessel records. On the other hand, the **weight of fresh water** depends upon the designer's intents

relative to onboard distillation and storage. For example, modern commercial vessels often carry the water that would be needed over the entire voyage. Naval vessels and cruise vessels because they have much higher capacity demands they can distill water onboard. On the basis of using 45 gallons per person per day, the total water tankage weight would need to be:

$$W_{FW} = 0.17t / (\text{Person} \times \text{day}) \quad (9.12)$$

the above would be satisfactory for 10 days storage with distillation and 45 days storage without distillation onboard. The **weight of the crew and their effects** can then be estimated as:

$$W_{C\&E} = 0.17t / \text{person} \quad (9.13)$$

And finally, the **weight of provisions** can be estimated using:

$$W_{PR} = 0.01 t / (\text{person} \times \text{day}) \quad (9.14)$$

Alike weight estimation, **centers estimation** in the early stages of design can use parametric models. For example, the vertical / longitudinal centers of gravity (VCG/LCG) of the basic hull can be estimated using equations proposed by Kupras:

$$\begin{aligned} VCG_{hull} &= 0.01D[46.6 + 0.135(0.81 - C_B)(L/D)^2] + 0.008D(L/B - 6.5) \text{ for } L \leq 120m \\ &= 0.01D[46.6 + 0.135(0.81 - C_B)(L/D)^2] \text{ for } L > 120m \end{aligned} \quad (9.15)$$

$$LCG_{hull} = -0.15 + LCB \quad (9.16)$$

where both LCG and LCB are expressed in percentage of the ship's length with positive results demonstrating the positioning of centers forward of amidships.

The VCG of machinery is given as a function of the inner bottom height h_{db} and the height of the over-head of the engine room D' by Kupras:

$$VCG_M = h_{db} + 0.35(D' - h_{db}) \quad (9.17)$$

The longitudinal center of the machinery weight depends upon the overall layout of the vessel. For machinery aft vessels, the LCG can be taken near the after end of the main engines. The vertical center of the outfit weight is typically above the main deck and can be estimated using an equation proposed by Kupras:

$$VCG_o = D + 1.25 \text{ for } L \leq 125 \text{ m} = D + 1.25 + 0.01(L - 125) \quad 125 < L \leq 250 \text{ m} = D + 2.5 \quad 250 \text{ m} < L \quad (9.18)$$

The longitudinal center of the outfit weight depends upon the location of machinery and deckhouse. The remainder of the outfit weight is distributed along the entire hull. A percentage of distributing the outfit weight and the longitudinal center of gravity is proposed by Lamb as follows:

$$LCG_o = (25\%W_o \text{ at } LCG_M, 37.5\% \text{ at } LCG_{dh}, \text{ and } 37.5\% \text{ at amidships}) \quad (9.19)$$

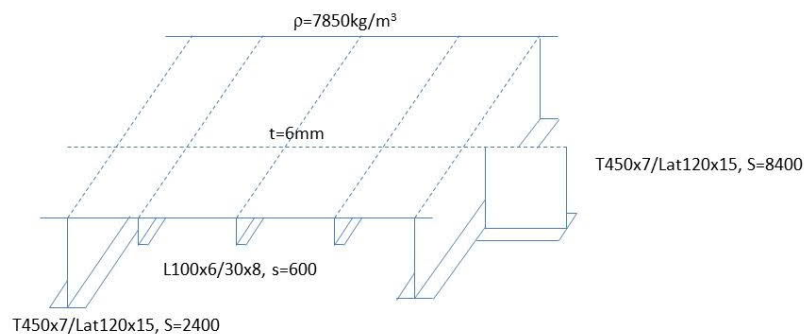
It appears necessary to have margins on power, weights, water, space and other quantities. Small margins may lead to a situation where the design fails to meet its requirements. On the other hand, if the margin is too large, the vessel will be over-designed resulting in waste and potentially the designer's failure to be awarded the contract. Most current contracts include penalties if the vessel does not make design speed or some other requirements such as the deadweight. For lightship weight at early design the margin may be 3-5%.

Weight estimation and calculations, at the intermediate and the final stages of design, are carried out using weight coefficients based on final drawings and general arrangement and the measured weights

of the systems components. Another way to measure lightship weight and center of gravity is the inclining experiment (see Lecture 5, Section 2.5).

4. Questions

1. A mass of 6 tonne is moved transversely through a distance of 14 m on a ship of 4300 tonne displacement, when the deflection of an 11 m pendulum is found to be 120 mm. The transverse metacenter is 7.25 m above the keel. Determine the height of the center of gravity above the keel.
2. Estimate the outfitting weight of a cruise ship of 150 m length, 25 m breadth, and 9 m draught using Watson and Gilfillan parametric model.
3. A ship has the following characteristics: $L=100$ m, $B=20$ m, $T=7$ m, $D=10$ m, and displacement of 11480 tonne. Estimate (a) the center of gravity of the hull ; (b) the center of gravity of the machinery (given that double bottom height=0.7 m and height of the engine room= 5m) ; (c) the center of gravity of the outfitting.
4. You are required to estimate the main machinery weight for a preliminary design of a bulk carrier. The self-propulsion performance has been estimated and result in the maximum continuous rate=3 MW and an estimated rpm of 300.
5. What is the purpose of weight calculations when designing and building a ship? Describe different stages of weight calculations, the aim of those and discuss their limitations in terms of accuracy.
6. Calculate the weight of deck with area 10000 m² manufactured from the panel presented below.



7. Explain for what purpose the SFI Coding and Classification System and how it can be applied in the context of ship weight calculations.