WEIGHT ESTIMATES

The total ship weight is composed of light weight + dead weight.

The lightship weight ($W_L$) is composed of:

- steel weight + outfit weight + machinery weight + margin

The following parts deal with methods of estimating these from the information available so far.

**Steel weight**

1). Cubic Number Method

Steel weight = cubic number coeff $\times \frac{L \times B \times D}{100} \times$ correction factors

where $\frac{L \times B \times D}{100}$ is cubic number.

Thus $W_s^* = W_s \times \frac{L^* B^* D^*}{L \times B \times D}$

The use of such method implies accurate knowledge from past similar ships as no account is taken of erections no. of bulkheads etc., unless a separate cubic no. such as $C \times \frac{L \times B \times D}{100}$ is used for erections etc.

Usual corrections applied to the weight are:

a) form corrections $= \left( \frac{1 + 0.5C_{B_{old}}}{1 + 0.5C_{B_{new}}} \right)$ with $C_B$ at load draught

b) L/D correction $= \left( \frac{L_D^{new}}{L_D^{old}} \right)^{\frac{1}{2}}$

2). E PARAMETER (WATSON)

Steel weight for various ship types can be appromental using the formula below:
\[ W_s = W_s \left[ 1 + 0.5 \left( C_b^1 - 0.70 \right) \right] \]

\[ W_s = \text{steel weight for actual} \ C_b^1 \text{ at 0.8 D} \]

\[ W_{s7} = \text{steel weight at 0.8D from the known value of the load drought may be using the empirical formula} :\]

\[ C_b^1 = C_b + (1 - C_b) \frac{(0.85D - T)}{3T} \]

\[ W_{s7} = KE^{1.36} \]

\( K \) and \( E \) values can be obtained from table (Ref.: Watson)

<table>
<thead>
<tr>
<th>Type</th>
<th>K</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tankers</td>
<td>0.079 - 0.035</td>
<td>1500 &lt; E &lt; 40000</td>
</tr>
<tr>
<td>Bulk Carriers</td>
<td>0.029 - 0.032</td>
<td>3000 &lt; E &lt; 15000</td>
</tr>
<tr>
<td>Cargo Vessels</td>
<td>0.029 - 0.037</td>
<td>2000 &lt; E &lt; 7000</td>
</tr>
<tr>
<td>Ferries</td>
<td>0.024 - 0.037</td>
<td>2000 &lt; E &lt; 5000</td>
</tr>
<tr>
<td>Trawiers</td>
<td>0.041 - 0.042</td>
<td>250 &lt; E &lt; 1300</td>
</tr>
</tbody>
</table>

The value of \( E \) can also be denied from a basis ship :-

\[ E = L(B+T) + 0.85L(D-T) + 0.85\sum l_i h_i + 0.75\sum l_2 h_2 \left( m^2 \right) \]

\( l_1, h_1 = \text{length and weight of full with erections.} \)
\( l_2, h_2 = \text{length and weight of houses.} \)

An allowance of 200 - 300 can be used for erections whose extent not yet known.

3). \textbf{RATE PER METRE METHOD}

This is a more refined system then cubic no. taking account of the differing effects of changes in the principal dimensions. Dimensional changes up to about 10% can be allowed for on the assumption that the relative effect on the whole steel weight per 1 m change in \( L, B, D \) is respectively

\[ 1.45, 0.95, 0.65 \]
i.e. the rate of change of steel weight per 1 m change in length is $\frac{1.45W_s}{L}$; in breadth $\frac{0.95W_s}{B}$, in depth $\frac{0.65W_s}{D}$.

a correction is again required for $C_B$.

APPLICATION OF THE RATE/METRE METHOD

If a ship dimension (metres) $L$, $B$, $D$ has steel weight $W_s$ tonnes the rates/metre are $a W_s/L$, $b W_s/B$, $c W_s/D$ for a new ship, dimensions $L^*$, $B^*$, $D^*$ the dimensional changes are

$$
\delta L = L^* - L; \delta B = B^* - B; \delta D = D^* - D
$$

Then $\delta W_s = aW_s \frac{\delta L}{L} + bW_s \frac{\delta B}{B} + cW_s \frac{\delta D}{D}

= W_s \left[ a \left( \frac{L^* - L}{L} \right) + b \left( \frac{B^* - B}{B} \right) + c \left( \frac{D^* - D}{D} \right) \right]

= W_s \left[ a \left( \frac{L^*}{L} - 1 \right) + b \left( \frac{B^*}{B} - 1 \right) + c \left( \frac{D^*}{D} - 1 \right) \right]

\text{Eg.} \quad \begin{array}{cccccc}
\text{Rate} & \text{per} & \text{Metre} & \text{Method} \\
\text{L(m)} & \text{B} & \text{D(m)} & \text{C_B} & \text{W_s (tonnes)} \\
\text{Basis} & 104.0 & 15.71 & 9.26 & 0.7250 & 1521 \\
\text{New Design} & 114.5 & 16.86 & 10.08 & 0.7350 & \\
\text{Ratio factor} & 1.101 & 1.073 & 1.088 & \\
\text{Subtract 1} & 0.101 & 0.073 & 0.088 & \\
\text{Weighting factor} & 1.45 & 0.95 & 0.65 & 0.146 + 0.069 + 0.057 \\
\end{array}

\therefore \delta W_s = W_s \times 0.27_s

\therefore W_s = 1.272 \times W_s

Block coeff. correction factor

$$(1 + 0.5 \times 0.7350)/(1 + 0.5 \times 0.7250) = 1.0037$$
\[ W_s^* = 1.272 \times 1521 \times 1.0037 \]
\[ = 1942 \text{ Tonnes} \]

For comparison:

Cubic No. Method

\[
W_s^* = W_s \times \frac{L^* \times B^* \times D^*}{L \times B \times D}
\]
\[ = 1956 \text{ tonnes} \]

\( C_b \) correction number before, 1.0037

\[
\frac{L}{D}_{correction} = \sqrt{\frac{114.5 \times 9.26}{104.5 \times 10.08}}
\]
\[ = 1.0066 \]

\[
W_{s^k} = W_s^* \times 1.0037 \times 1.0066
\]
\[ = 1956 \times 1.0037 \times 1.0066 \]
\[ = 1976 \text{ tonnes} \]
OUTFIT WEIGHT

The outfit weight is usually varied according to the square number i.e. L X B. However, the constant will depend on ship type

\[ i.e. \ W_o^* = W_o \times \frac{L^* x B^*}{LxB} \]

variation, \[ W_e^* = s W_e \times \frac{L^* x B^*}{LxB} + \left(1 - s\right) x W_e \ where \ 0 \leq s \leq 1 \]

For ships with special items of outfit, e.g. refrigerated cargo ships it is advisable to take-off weight for the special item and calculate the remainder using the square number.

\[ Watson \ plots, \ \frac{outfit \ wt.}{LxB} \ against \ ship \ length \]

which shows the dependency of capacity carriers such as passenger ships on length whereas other types retain an almost constant square number ratio.

Some values which could be used are:

- General cargo ship = 0.39
- Tanker = 0.22
- Bulk carrier = 0.2

MACHINERY WEIGHT

One of the most important factors in machinery weight is the choice of type of machinery. The most common types are

i) direct drive slow speed diesels
ii) geared medium speed diesels
iii) geared steam turbines.

However, other types are

iv) diesel - electric installations
v) turbo - electric installations
vi) geared gas turbines - aero or industrial
vii) gas turbo-electric
viii) nuclear
Other factors which are of importance are:

a) type of ship and cargo carried - this determines to a large extent the auxiliaries fitted, e.g. oil tanker have boilers to provide steam for oil heating and tank cleaning.

b) number of propellers

c) position of engine room.

For diesel engines, Watson divides the weight into dry main engine weight and remainder weight and produces the following equations:

\[
W_m = 9.38 \left( \frac{MCR}{N} \right)^{0.84} + K(MCR)^{0.70}
\]

\(MCR\) = maximum continuous rating of engine which is power, produce continuously over considerable periods. In practice this may be greater than calculated power to ease maintenance costs.

\(K\) = 0.56 for bulkers, general cargo

= 0.57 for tankers

= 0.65 for passenger / ferry

or a figure derived from a basis ship

These equations have an allowance to cater for the step functions of weight. The main machinery weight could also be chosen directly from manufacturer's literature. For steam turbines Watson provides only a single relationship

\[W_m = 0.16(\text{SP})^{0.59}\]

horse powers and ratings are provided in metric form.

For a basis ship calculation if ships are similar then a simple variation with \(\text{SP}^{0.67}\) will be adequate i.e.

\[
\frac{W_m^*}{W_m} = \left( \frac{\text{SP}^*}{\text{SP}} \right)^{0.67}
\]
DEADWEIGHT DEDUCTIONS

Fuel Weight

Fuel weight is simply determined from the fuel consumption of the engine chosen and the required range of the vessel.

\[
\text{Fuel weight} = \text{consumption rate} \times \text{SP} \times \text{steaming time}
\]

\[
= \text{CR} \times \text{SP} \times \frac{\text{range}}{\text{speed}}
\]

CR may be given or can be taken to be:

\[
0.216 \text{ kg/kwh for diesel engine}
\]

Weight of Remainder

Can be used as proportions of full displacement. These include items such as stores, fresh water, etc.
TUTORIAL 4

1. In power estimation state the meaning of the following terms:
   Frictional resistance, residuary resistance, quasi-propulsive coefficient, shaft power, effective power and standard series.

2. Write down the power estimating relationship for two geometrically similar ships running at corresponding speeds.

3. Define the terms “geometrically similar” and “corresponding speed”.

4. Given a machinery power and a fuel consumption rate, write down an expression for fuel weight estimates.

5. What are the four major categories of weight used in weight estimates of marine vehicles?

6. What are “dead weight deductions”? State the main items.

7. Using the cubic number method, estimate the steel weights of the following new designs from the basis ships.

   **BASIS**
<table>
<thead>
<tr>
<th>L (m)</th>
<th>B (m)</th>
<th>T (m)</th>
<th>C_B</th>
<th>D (m)</th>
<th>Ws (tones)</th>
<th>L (m)</th>
<th>B (m)</th>
<th>T (m)</th>
<th>C_B</th>
<th>D (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>120.0</td>
<td>20.0</td>
<td>8.6</td>
<td>0.69</td>
<td>14.0</td>
<td>2900</td>
<td>105.0</td>
<td>18.0</td>
<td>8.2</td>
<td>0.72</td>
</tr>
<tr>
<td>ii)</td>
<td>92.5</td>
<td>13.6</td>
<td>8.6</td>
<td>0.7021</td>
<td>10.8</td>
<td>1075</td>
<td>105.0</td>
<td>18.0</td>
<td>8.2</td>
<td>0.72</td>
</tr>
</tbody>
</table>

8. Repeat Q7 using the rate per metre method. Comment on any differences between the results of the two methods.

9. Using the square number method, estimate the outfit weight of the following designs from the basic ships.

   **BASIS**
<table>
<thead>
<tr>
<th>L (m)</th>
<th>B (m)</th>
<th>C_B</th>
<th>W (tones)</th>
<th>New Design</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>92.5</td>
<td>13.6</td>
<td>0.7021</td>
<td>546</td>
</tr>
<tr>
<td>ii)</td>
<td>114.4</td>
<td>15.9</td>
<td>0.6636</td>
<td>714</td>
</tr>
</tbody>
</table>

10. Repeat Q9 with (a) 20% of outfit weight remaining constant and (b) 50 tonnes of cargo handling equipment on the basis being replaced by 135 tonnes on the new design.
11. Estimate the machinery weights of the following design from the basic ship.

<table>
<thead>
<tr>
<th>BASIS</th>
<th>New Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP (kw)</td>
<td>Wm (tones)</td>
</tr>
<tr>
<td>i) 1660</td>
<td>458</td>
</tr>
<tr>
<td>ii) 2989</td>
<td>549</td>
</tr>
</tbody>
</table>

12. Calculate the full deadweight of the following designs:

<table>
<thead>
<tr>
<th>( \Delta_f ) (tones)</th>
<th>( W_s ) (tonnes)</th>
<th>( W_o ) (tones)</th>
<th>( W_m ) (tones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) 7978</td>
<td>1912</td>
<td>350</td>
<td>516</td>
</tr>
<tr>
<td>ii) 74112</td>
<td>5934</td>
<td>791</td>
<td>1063</td>
</tr>
</tbody>
</table>

And for the following, assuming shell and appendages displacement is 0.5% of moulded displacement:

<table>
<thead>
<tr>
<th>L (m)</th>
<th>B (m)</th>
<th>T (m)</th>
<th>CB</th>
<th>( W_s ) (tones)</th>
<th>( W_o ) (tones)</th>
<th>( W_m ) (tones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iii) 120.5</td>
<td>20.0</td>
<td>8.62</td>
<td>0.6910</td>
<td>2910</td>
<td>590</td>
<td>549</td>
</tr>
<tr>
<td>iv)   90.5</td>
<td>13.43</td>
<td>7.45</td>
<td>0.7021</td>
<td>1000</td>
<td>483</td>
<td>402</td>
</tr>
</tbody>
</table>

Calculate also the ratios of full deadweight to full displacement.