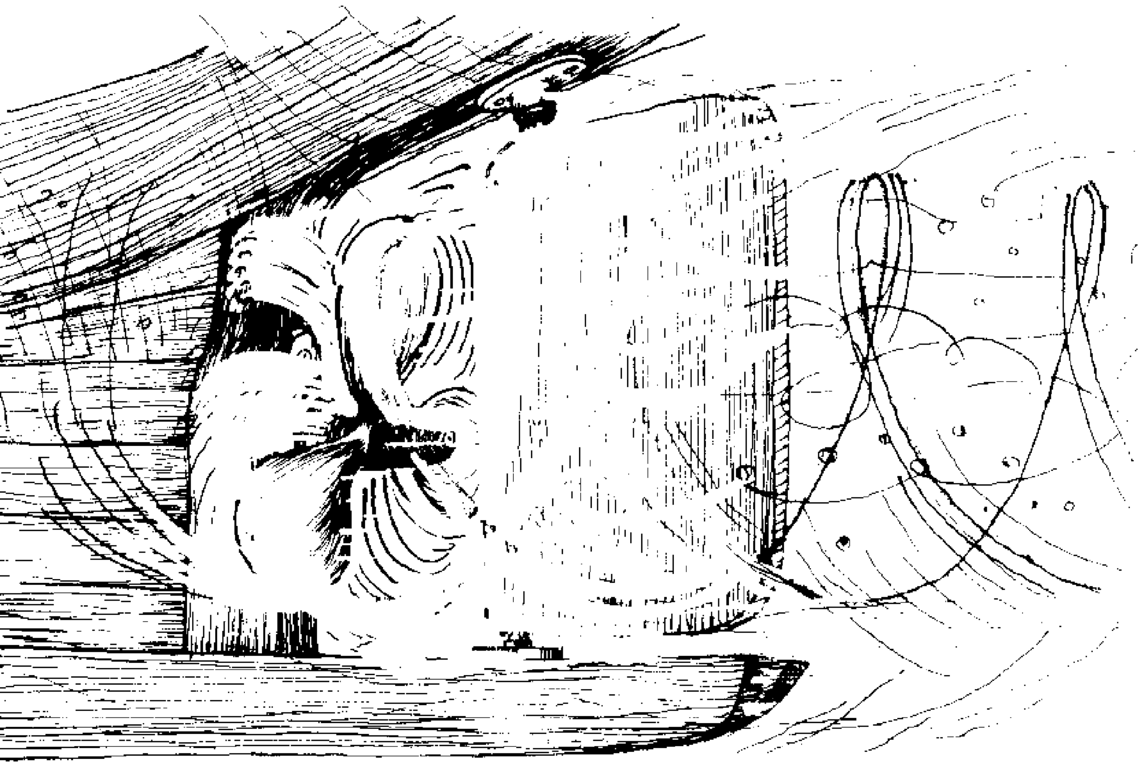
RIU-TL-71-001 C2

P 14

COMPUTING HORSEPOWER USED IN TRAWLING

by Robert E. Taber



SEA GRANT

UNIVERSITY OF RHODE ISLAND

Marine Leaflet Series
Number 2

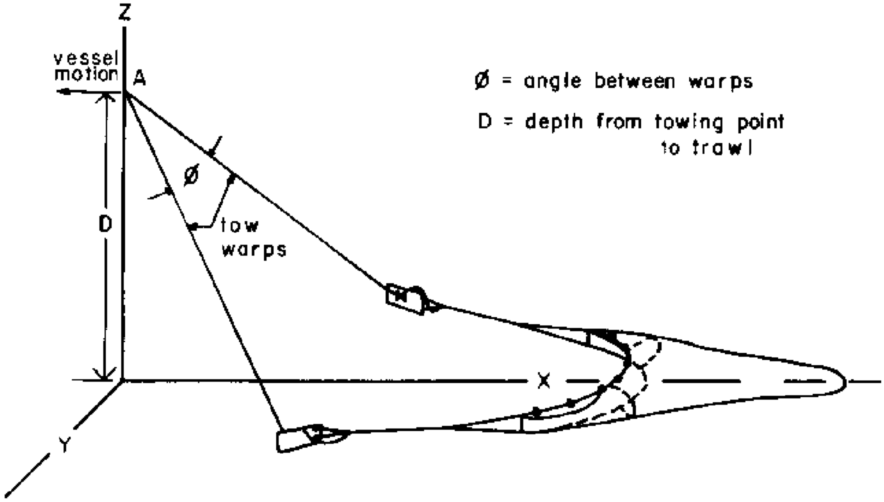


FIGURE 1. *Typical measurement configuration.*

$\vec{T} = \vec{T}_x + \vec{T}_y + \vec{T}_z$ where $\vec{T}_x$, $\vec{T}_y$, $\vec{T}_z$, are the components of the tension $\vec{T}$ in the x, y, z, directions respectively

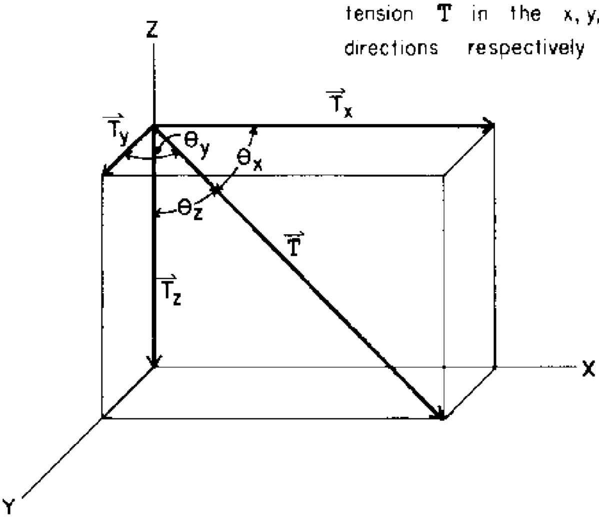


FIGURE 2. *Port warp tension components.*

Determination of component of tension in direction of motion (for calculation of horsepower required to move the trawl forward). The horsepower actually used in towing the trawl through the water is calculated from the component of the warp tension in the direction of motion (Figure 1). The tension component ($\vec{T}_x$) can be readily obtained by looking at one of the tow warps in a rectangular Cartesian coordinate system (Figure 2).

A towing efficiency of only 20 percent is not uncommon for trawlers. The towing efficiency is defined as the ratio of the horsepower used for moving the trawl through the water to the horsepower delivered to the propeller shaft. Hence, an engine capable of delivering 200 shaft horsepower may have a towing power as low as 40 horsepower.

The horsepower is calculated from the component of the warp tension in the direction of vessel motion and the velocity of the trawl. For bottom trawling the velocity of the trawl over the ground is used, and for mid-water the velocity of the trawl through the water is used. In order to cancel the effects of tide and wind, it is desirable to obtain an average velocity from the results of tows in opposite directions through a known distance. Hence, the average velocities of the trawl over the ground and through the water would be equivalent.

Horsepower is work per unit time [T], with work defined as a force [F] moved through some length [L], or distance. Hence the units of work are [F] [L] and the units of horsepower are [F] [L]/[T]. Horsepower may also be expressed in units of force times velocity as the units of velocity [V] are [L]/[T]. It is important to note in determining work or horsepower that only the force in the direction of motion is used. Therefore, in order to determine the actual horsepower used in towing the trawl, only the component of the warp tension in the direction of motion may be used. One should note that no work is being done to spread the trawl or to keep it on bottom or at a set level as there is no motion of the trawl laterally or vertically. Figure 1 illustrates the trawl under tow with point A on the z-axis being the towing point on the vessel and the x-y plane the level at which the trawl is acting. For a bottom trawl, the x-y plane is the seabed.

The tension component ($\vec{T}_x$) of the trawl warp can be readily obtained by looking at one of the trawl warps in a rectangular Cartesian coordinate system (Figure 2). $\vec{T}$ is the force exerted on the towing point of the vessel by the port warp. The force $\vec{T}$ can be replaced by the three perpendicular forces $\vec{T}_x$, $\vec{T}_y$ and $\vec{T}_z$, so that the vector sum of $\vec{T}_x$, $\vec{T}_y$ and $\vec{T}_z$ equals $\vec{T}$. The arrows over the letters simply indicate the quantities are vectors; i.e., they have both a magnitude and a direction and must be handled vectorily.

The derivation of a formula for determining the actual horsepower used and an example of the formula's use can now be shown.

FORMULA

From Figure 2 the magnitude of the components are:

$$T_x = T\cos\theta_x;\quad T_y = T\cos\theta_y;\quad T_z = T\cos\theta_z$$

T_x is the force to be calculated and, hence, θ_x must be found. One can find θ_x through the relation

$$1 = a_x^2 + a_y^2 + a_z^2$$

where:

$a_x = \cos\theta_x$; $a_y = \cos\theta_y$; $a_z = \cos\theta_z$, and

$\theta_y = 90 - \frac{\phi}{2}$ where ϕ is the angle between the tow warps measured, and

$\theta_z = \cos^{-1}\left(\frac{D}{L}\right)$ where D = depth of trawl plus height above surface to towing point and L = length of trawl warps used.

hence:

$$a_x = \sqrt{1 - a_y^2 - a_z^2}$$

or substituting in:

$$\cos\theta_x = \sqrt{1 - [\cos(90 - \frac{\phi}{2})]^2 - (\frac{D}{L})^2}$$

Since power for trawl = $(T_x)(V)$ for one warp and 1 hp = 33,000 ft.-lb./min. where T_x is in lbs. and V is in ft./min. and $T_x = T\cos\theta_x$ then:

$$\text{hp (trawl one warp)} = \frac{TV\cos\theta_x}{33{,}000} = \frac{TV}{33{,}000}\sqrt{1 - [\cos(90 - \frac{\phi}{2})]^2 - (\frac{D}{L})^2}$$

Looking at the term under the radical and in particular $[\cos(90 - \phi/2)]^2$ and noting that for small angles of ϕ (with which we are concerned) we may drop this term without any significant effect. Horsepower will be figured in the example both ways in order to demonstrate how insignificant the term is.

Hence, for both trawl warps (The derivation considered only one warp and, hence, must be doubled for both warps.):

$$\text{hp (trawl)} = \frac{2TV}{33{,}000}\sqrt{1 - (\frac{D}{L})^2}$$

where:

T = warp tension in lbs.
V = velocity in ft./min.
D = depth of trawl to towing point in ft.
L = trawl warp length in ft.

EXAMPLE

Given:

Tension in each warp = 2,100 lbs.
ϕ = angle between warps = 13°
D = depth from towing point to trawl = 120 ft.
L = warp length = 75 fath = 450 ft.
V = 3 knots = 100 ft/min.

A) Neglecting the term with ϕ:

$$hp = \frac{2TV}{33{,}000}\sqrt{1 - (\frac{D}{L})^2}$$

substituting in:

$$hp = \frac{(2)(2100)(100)}{33{,}000}\sqrt{1 - (\frac{120}{450})^2}$$

$$hp = \frac{14}{1.1}\sqrt{1 - (.267)^2} = \frac{14}{1.1}\sqrt{.928}$$

$$\underline{hp = 12.26}$$

B) Keeping the ϕ term:

$$hp = \frac{14}{1.1}\sqrt{1 - (.267)^2 - [\cos(90 - \frac{13}{2})]^2}$$

$(\cos 83.5^o)^2 = (.113)^2 = .0128$

$$hp = \frac{14}{1.1}\sqrt{1 - .072 - .0128} = \frac{14}{1.1}\sqrt{.915}$$

$hp = 12.18$

Hence, the error induced by deleting the angle between warps ϕ (in percent)

$$= \frac{12.26 - 12.18}{12.18} \times 100$$

$$= \frac{.08}{12.18} \times 100 = \frac{8}{12.18}$$

$= .66\%$

CONCLUSION

The actual horsepower used to tow a trawl may be readily determined according to the relation

$$hp = \frac{2TV}{33,000}\sqrt{1 - (\frac{D}{L})^2}$$

where:

T = average warp tension in lbs.
V = velocity of vessel in ft./min. (averaged for opposite directions)
D = depth from towing point on vessel to the trawl in ft.
L = length of tow warp used in ft.

Approximation may be made by also deleting the radical term. However, this term increases in importance as the warp length-to-depth ratio decreases and becomes quite significant when the ratio decreases to less than four to one. Again, a towing efficiency of only 20 to 25 percent is not uncommon, and one should not be dismayed if this, in fact, proves true in his case.

COMPUTING HORSEPOWER USED IN TRAWLING

by Robert E. Taber, commercial fisheries specialist, University of Rhode Island Marine Advisory Service

For further copies write to Marine Advisory Service, University of Rhode Island, Kingston, Rhode Island 02881.