But in arriving at this conclusion, we have taken only the case of smooth and still water. Here it is obvious that the slowest rate and smallest power will be most economical ; but it should be remembered that the great purposes of steam are generally of a different nature from the mere generation of motion through a quiescent fluid. The force of adverse winds and waves is to be opposed, stream-tides and currents are to be stemmed ; and it is the success of steam in conquering those obstacles, and obtaining regularity and speed in spite of them, which constitutes its superiority over wind or animal power in navigation.

Now, if we take a simple case of one of these, we shall soon find that a higher proportion of power to ton­nage may be essential, not only to speed, but even to economy. Suppose a steam-boat with a small propor­tion of power, capable of propelling the vessel at the ve­locity of three miles an hour through still water, to be applied to stem a current of three miles an hour, is it not plain that the vessel would make no head way, and thus a low proportion of power would burn an immense quantity of coal in doing nothing but standing still ?

Let ns again suppose that the same vessel, capable of steaming three miles an hour, meets with a moderately strong breeze opposed to her, such as prevents her from making any progress at all against it; then it is plain that by the continuation of this breeze, the vessel burning a continual supply of fuel would consume an indefinite quantity of coal in standing still. This extreme case of too little power, shows that there is at least one propor­tion of power, which is too small for economy of fuel ; viz , that proportion which, being very economical of fuel in fine weather, is brought up altogether by adverse winds. In this case, the consumption of fuel is rendered indefinite, and the useful effect of fuel completely anni­hilated by too small a proportion of power.

As, then, we have plainly established the existence of a limit to diminution of power, in the vicinity of which it must be followed by extravagant consumption of fuel, we may now proceed to investigate the question of best proportion, or the point where the attainment of high speed is accompanied by absolute saving of fuel as compared to lower velocity. For this purpose, we merely take it for granted that the speed through the water will be nearly as the square root of the power, according to the general law of the resistance of fluids ; that the resistance offered by bad weather or adverse winds has been ascertained and is de­termined on a particular station : that is, that it is known that on a given station a given vessel with a given power makes a voyage in adverse circumstances in, suppose, double the time of her most prosperous voyage; say her most prosperous voyage is in fourteen days, and her adverse voyage in twenty-four days, being a retard­ing power of ton days out of twenty-four ; we take this retardation of ten days as the measure of the retarding power of adverse weather in the given circumstances. And further, let the following quantities be thus re­presented :—

Let *h* be the power, *v* the velocity, *f* the fuel consumed, *t* the time in good weather,

Let *h'* be the power, *v'* the velocity, *f'* the fuel consumed, i' the time in bad weather, } In a given vessel, on a given situation.

Let *h"* be the power, *v''* the velocity, *f"* the fuel consumed, *t"* the time in good weather,

Let *h'"* be the power, *v"* the velocity, *f'''* the fuel consumed, *f'* the time in bad weather, } In another vessel of greater power on the same station.

Also, let *k* represent the consumption of fuel per horse­power per hour, and *s* the length of the voyage or dis­tance performed. Then

*f — k h* f. *v —* a given quantity,

*v*

*f' — kh s if —* a given quantity.

, and „ *h'∖*

*f"=w⅛ v-vW*

∕∙=\*\*⅛ ∙"=J(<-3)'-∙,+∙λ p

hence/1" = - *= kh's* ∣ ( y√) ~ *vi* + ν’ ∣~⅛

Putting *f*"' *= u, h' — x,* and differentiating, we get

t∙2 4. √Λ — 5

whence by reduction, in the case of a minimum, we ob­tain the value

.r (A.)

tΓ x z

Whence we obtain the very simple rule for finding the best proportion of power to tonnage : *From the square of the velocity of any given vessel in good weather, subtract the square of the velocity of the same vessel in the worst weather, divide the difference by the square of the velocity in good weather, and the quotient multiplied into double the horse-power of the said vessel will give the power which would propel the same vessel in the same circum­stances with the smallest quantity of fuel.*

We have also from (A) *h'* = 2 *h —*

c,

(B) √,= √2 (β\*-√≡)⅜

(C) *if" =* (»’ — υ's)⅜

(D) ∕\* = √2 ⅛∆i(c\* — v,2)\*

(E) ∕"' =s -g⅛(t>8 *-tf,)⅛*

*(F) t\* ≈ s-*

√ 2 (c> —

(G) *f' = c*

√ — tΛ

It appears from the comparison of (B) with (C), that a vessel has its power in the most economical proportion to its tonnage on a given station, when its worst voyage does not exceed the time of its best in a greater propor­tion than √2 to 1 ; that is, than 14 to 10, or 7 to 5.

From (D) and (E) it further appears that in a vessel, whose power is thus proportioned, the consumption of fuel in the worst voyage will not exceed that of the best voyage in a greater proportion than 10 to 7 ; that is to say, for 70 tons of fuel burned on a good voyage, it will not be necessary to carry more than 100 tons, in order to provide against the worst.

Let us take as an example a transatlantic steam-ship, which has a proportion of 1 horse power to 4 tons of capacity. Her unfavourable voyage being between England and America twenty-two days, and her favour­able voyage fourteen days, being a comparative velocity of 7 and 11, then

*If = 2h t'2 ~* r'\* = 2. 1~1-~∑-^!2 = 2. — *v,* 121. 121

12. 1

— nearly.

10. j

Hence, the power of such a vessel should be increased in the ratio of six to five ; that is to say, the engines at