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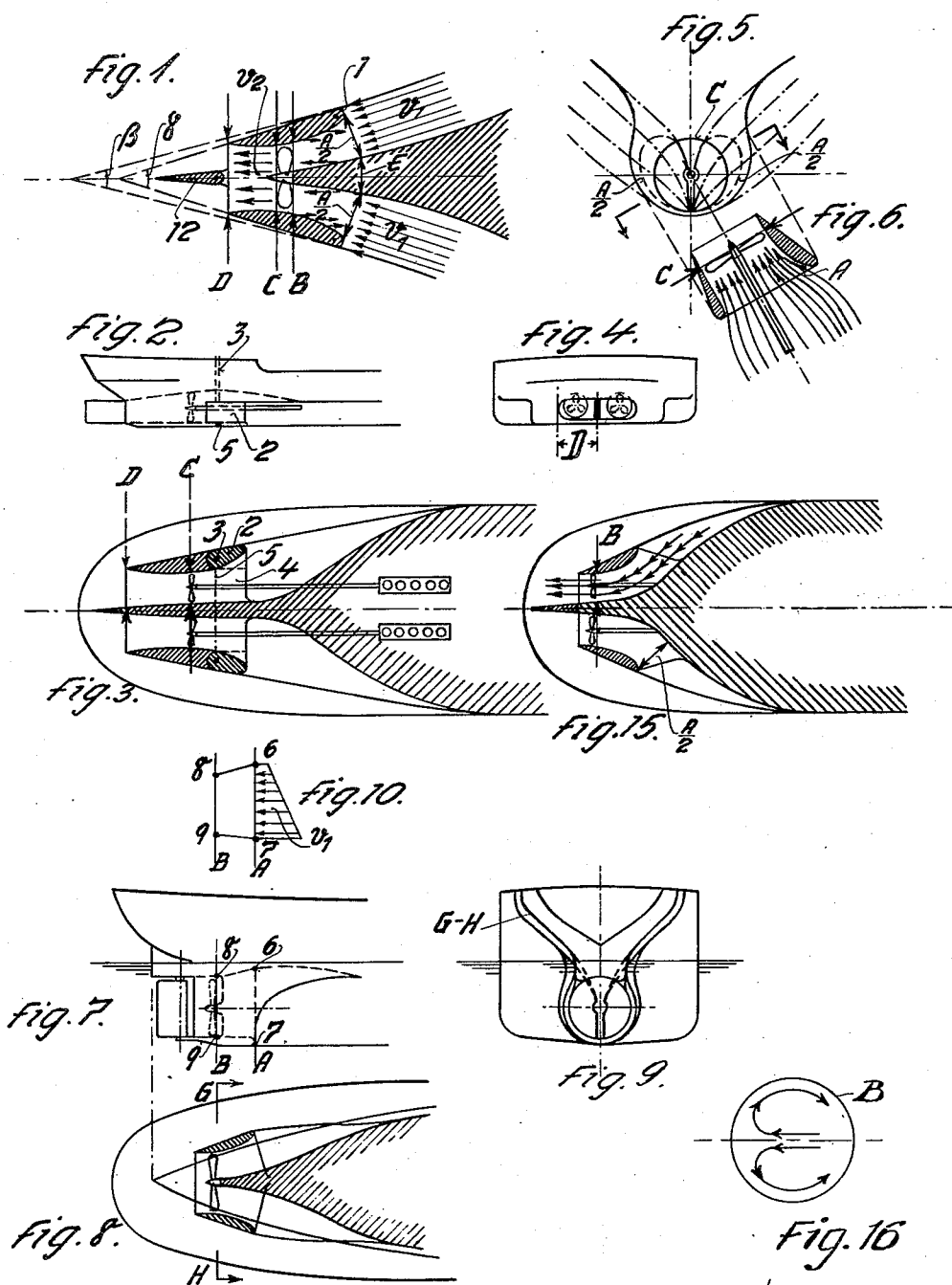
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2,030,375

COMBINED DEVICE OF A SHIP'S PROPELLER ENCLOSED BY A NOZZLE

Filed Sept. 7, 1933

3 Sheets-Sheet 1



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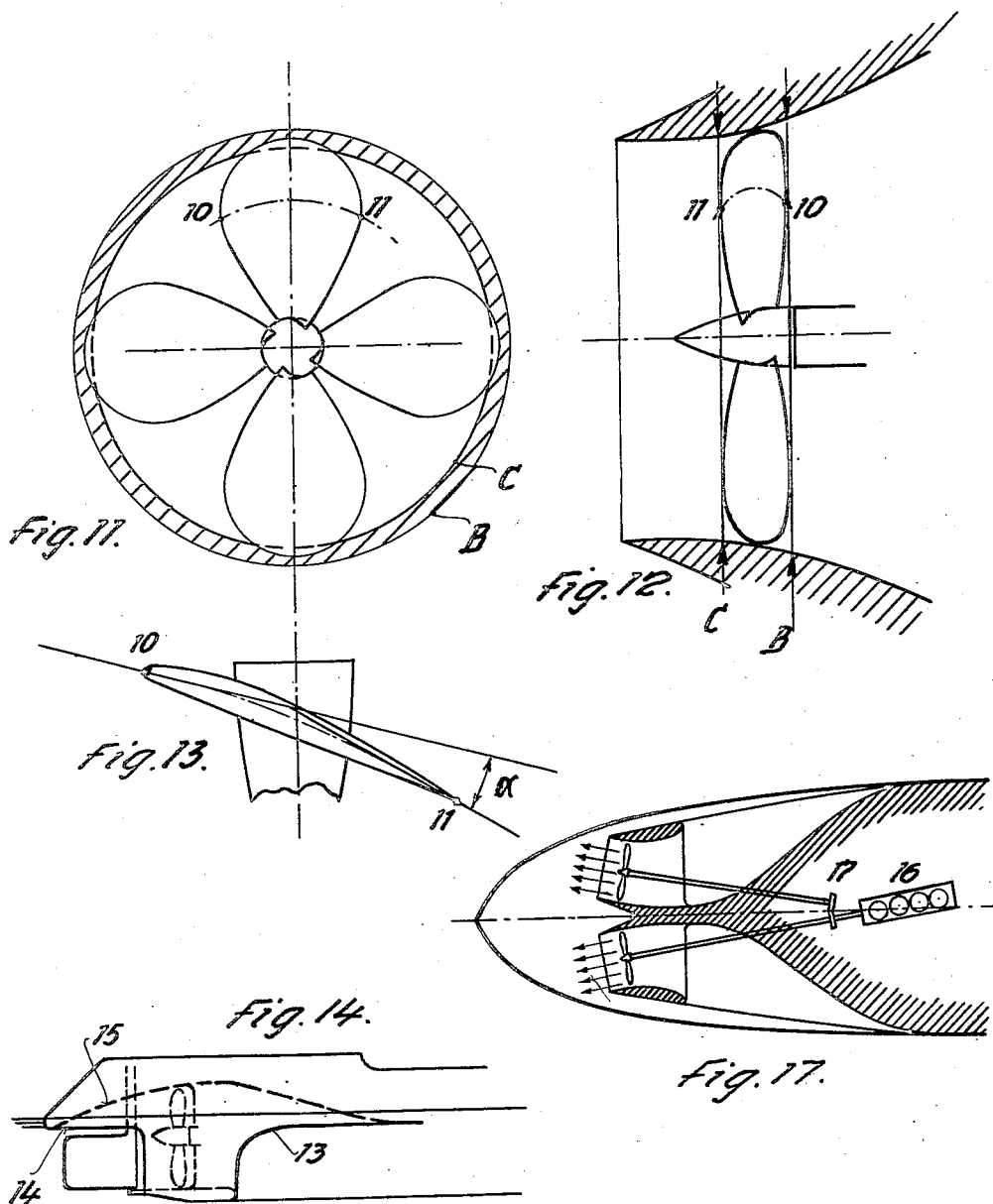
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3 Sheets-Sheet 3

Fig. 1^a

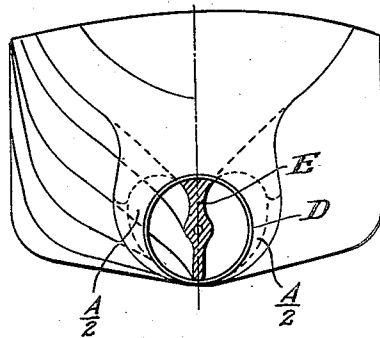


Fig. 19.

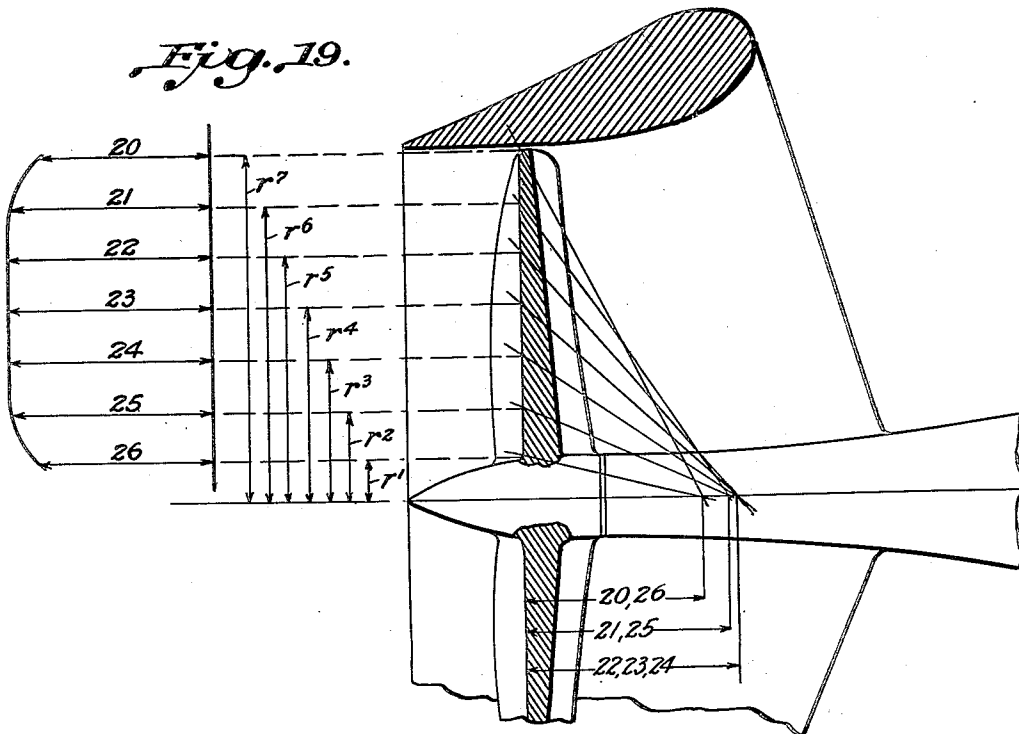


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UNITED STATES PATENT OFFICE

2,030,375

COMBINED DEVICE OF A SHIP'S PROPELLER
ENCLOSED BY A NOZZLE

Ludwig Kort, Hanover, Germany

Application September 7, 1933, Serial No. 688,505
In Germany July 25, 1933

13 Claims. (Cl. 115—42)

Nozzle-shaped appendages to a ship's hull around screw propellers which are open on both ends longitudinally and entirely closed transversally are known.—These nozzles are in some cases so shaped and arranged that the propeller works about at their narrowest cross section which surrounds its disc area with but little play. Aft of the propeller the area of the cross sections does not increase at all or only slightly while in front of it these areas increase constantly and materially.

Other proposals show propellers surrounded by rings, straight or conical tubes or the like.

All of these combinations having as their aim to increase the propulsive efficiency of the propeller, and yet they all failed in practical use, as none of them were uniting the proper shape of the nozzle with the proper relation between the propeller, its revolutions, the areas at the narrowest cross section and at the mouth of the nozzle and the form, speed and resistance of the ship. And this combination is principally decisive for the effect or failure of the device.

It is therefore the object of my invention to show up out of the known forms the correct basic form of the nozzle and to improve on it by changing its shape according to the necessary relation between the area at the mouth and the narrowest cross section with regard to the given speed of the ship and the work to be done by the propeller.

It is further the object of my invention to bring the shape of the hull adjacent to the nozzle in the proper form so as to get the best combined results between the ship and the nozzle which is attached to it.

My invention further relates to means for adapting the nozzle to varying speeds of the ship at varying loads on the propeller.

My invention further relates to the adaption of such nozzles and propellers to various types of ships and the given conditions of the navigation for which these ships are to be used.

Reference is to be had to the accompanying drawings forming part of this specification and described hereafter. In these drawings similar characters of reference indicate corresponding parts in all the figures.

Fig. 1 is a diagrammatic horizontal section taken about the height of the propeller shaft through the stern of the ship showing the improved propelling device.

Figure 1a is a diagrammatic view at the stern of a ship fitted to the nozzle according to Fig. 1 showing the areas A₂ and E denoted in Fig. 1 and also a circular exit opening D.

Fig. 2 is a side elevational detail of the arrangement shown in Fig. 3.

Fig. 3 is a sectional plan view of the stern of a twin screw shallow draught vessel with the nozzle surrounding the propelling screws,

Fig. 4 is a rear elevation of the vessels shown in Figs. 2 and 3,

Figs. 5 and 6 show an end elevational and longitudinal section respectively of a modified form of the arrangement,

Fig. 7 is a side elevational detail of a further form of the invention,

Fig. 8 is a horizontal sectional view of the arrangement shown in Fig. 7,

Fig. 9 is an end elevational view of the arrangement shown in Fig. 7.

Fig. 10 is a diagrammatic view showing how the speed v_1 of the water entering the mouth of the nozzle shown in Fig. 7 varies due to the wake of the hull between the parts of said opening near the ship's hull and those further away from the hull,

Fig. 11 is a rear view looking towards the inside of the nozzle of a slightly modified form,

Fig. 12 is a horizontal sectional detail of the nozzle in Fig. 11 showing how the propelling screw operates between the circular cross sections B and C,

Fig. 13 is the enlarged and developed vertical area of the cylindrical cross section 10—11 through one of the propeller blades shown in Figs. 11 and 12,

Fig. 14 is a side elevational view of a further modified form showing the stern of a shallow draught, single screw vessel with a nozzle surrounding the propeller,

Fig. 15 is a sectional plan view of the stern of a twin screw ship with nozzles surrounding the propellers modified from Figure 2,

Fig. 16 is a diagrammatic view of the whirling motion of the water just before it enters the propeller when encountered by the arrangement shown in Fig. 15,

Fig. 17 shows a sectional plan view of the stern of a twin screw boat with nozzles surrounding the propellers, the center lines of the aft end of the nozzles and the center lines of the propeller shafts being set at an angle to each other diverging towards the rear of the boat,

Fig. 18 shows in horizontal section the hub and blade of a screw propeller and one side of the surrounding nozzle, and

Fig. 19 is a pitch diagram of the propeller blades, shown in Fig. 18.

Referring now, more particularly to the draw-

ings, in which similar reference numerals designate corresponding parts throughout the several views:

The water enters the nozzle in Fig. 1 at the opening A with the speed v_1 multiplied by the wake factor, enters the propeller at the cross section B and leaves the propeller at the cross section C with the increased speed v_2 , which speed is somewhat reduced at the widened cross section D of the exit opening. At the mouth A of the nozzle the transverse section of the hull has the area E.

It is of great importance that this area E should be as small as possible. By fining out the lines of the hull at, and in front of the mouth of the nozzle, the water enters said mouth parallel to the propeller shaft.

The best efficiency of the nozzle with the given propeller characteristics will be reached, if the mouth A, measured transversely to the flow of the water, is made about so large that for the desired service speed of the ship the amount of water required to leave the propeller at the increased speed v_2 can enter without being accelerated in front of the nozzle by the suctional effect of the propeller, or in other words that v_1 is made to be about equal to the service speed, v , of the ship diminished by the wake speed running in front of the nozzle and in the direction of the ship's track.

Expressed by a simple formula the following relation must be about adhered to:

$$C.v_2 = A.v_1 \text{ or } C.P.r.\alpha = A.v.\beta$$

Therein means:

C=the narrowest cross section of the nozzle (being about equal to the disc area of the propeller) in square feet.

A=the opening at the front of the nozzle measured transversely to the flow of the water in square feet.

P=the pitch of the propeller in feet.

v =the service speed of the ship at service conditions of resistance, in feet per second.

v_1 =the speed of the water entering the mouth of the nozzle without acceleration by the action of the propeller in feet per second.

v_2 =the speed of the water leaving the propeller at C in feet per second.

r =the revolutions of the propeller per second.

α =the slip coefficient of the propeller for the given service speed v and the resistance of the ship at service conditions.

β =the wake coefficient for the speed of the water in front of the nozzle in relation to the service speed of the ship.

The following serves for the calculation:

The value (C) represents the narrowest part of the nozzle and results from the usual manner of the ship's construction by taking into consideration the draught of the ship and also the diameter of the propeller because the narrowest part of the nozzle must closely surround the propeller. The diameter of the propeller results according to known shipbuilding principles from the available type and size of the engine and its given revolutions per minute. It results furthermore from the draught of the ship and the type of stern i. e. the place and space which is available for the propeller. One chooses a large propeller if possible and one is only limited by the aforesaid general conditions in the known manner.

The value (P) indicates the pitch of the propeller. This pitch results according to the estab-

lished practice from the given revolutions per second (r), the given diameter of the propeller (about equal to C) and the service speed which the ship will make with the given engine power.

The revolutions per second (r) of the propeller are constant with an already existing ship because they depend on the already existing machine installation. In a new construction, it results from the given diameter of the propeller and the fixed product value $P.r.$ for the required service speed.

The slip factor α is an empirical value which is taken from empirical tables.

The right side of the equation begins with the value "A" which is to be found.

The further two values on the right side of the equation are: v , the service speed of the ship per second which is fixed and β , the wake factor, a coefficient which is dependent on the given form of the ship and can also be ascertained from tables.

If the relation between the entrance opening and the smallest cross section as stated above is not adhered to or in other words the mouth A is made for instance too large there will be a braking back current in front of the nozzle.— If on the other hand the mouth A is made too narrow part of the water-mass required for the propulsion will have to be accelerated in front of the nozzle and the decreased hydrostatic pressure will have a braking-effect on the ship and in addition the propulsive-effect of the nozzle will decrease.

Fig. 1 also shows a bulky edge at the mouth of the nozzle, well rounded off inside and outside—similar in shape and purpose to the front edge of the wings of airplanes.—This bulged edge allows that—within certain limits—the entering opening at A or the quantity of water entering the nozzle adapts itself automatically and with a minimum loss to variations of speed and of resistance of the ship.

In cases where there are larger variations of speed or resistance the mouth at A may be enlarged or diminished by using a more or less rectangular-shaped mouth of the nozzle, the vertical edges of said mouth being formed by streamline-shaped flaps (2) shown in Figures 2 and 3, which may be turned and governed from the inside of the ship by a vertical shaft (3). The flaps (2) on their lower and upper sides are turning on smooth horizontal surfaces which keep the nozzle tight from the side, up to the extreme positions of the flaps. As an alternative the widening out of the mouth of the nozzle may be done by a horizontal flap (4) being governed by a horizontal shaft (5). The tightness at the sides of this flap is to be effected in a similar way as described for flap (2).

Figs. 5 and 6 show the possibility of using the nozzle as an instrument to equalize the speed of the water which reaches the various points of the propeller area. Parts of the water entering the mouth of the nozzle at A at a low speed on account of the wake,—e. g. near the counter of the stern—will undergo a material increase of speed by contracting the streamlines within the nozzle especially at these points or in other words the given area of the mouth at A is distributed in such a way with regard to the area B at the entrance of the propeller that the widest opening is in way of the wake.

Figs. 7 and 10 show another way for the equalization of the speed of the water at B. Fig. 10 shows by way of a scheme how the speed v_1 of the water may be distributed between the points 6 75

and 7. The corresponding points at B are 8 and 9. As the suction of the propeller is largely depending on its pitch it may be assumed that the hydrostatic pressure is about equal at 8 and 9 and smaller than at 6 and 7, while again the pressure at 6 is larger than at 7. Thus there is a great difference of pressure between points 6 and 8 and a smaller one between 7 and 9. Hence follows that the tendency for the acceleration of the water is especially large between 6 and 8 and if the nozzle between sections A and B is made long enough the equalization of the speed of the water will result automatically.

As the length of the nozzle on the other hand will increase the friction of the water on its walls there is of course an economical limit to this elongation.

The aforementioned friction as well on the walls of the nozzle as on those parts of the hull which are around the propeller shaft has the tendency that the speed of the water will be diminished within these zones which may be looked at as running chiefly cylindrical around the propeller shaft. This differentiation of the speed of the water entering the disc area of the propeller may be offset economically by giving the propeller a radially increasing and at the blade tips again decreasing pitch.

This is indicated by Figs. 18 and 19. In Figure 18 there is illustrated the hub and blades of a screw propeller closely surrounded by the nozzle. The blades of this propeller having radially varying pitch, that is for the different radii r_1 to r_7 ; the pitch is larger in the middle part of the blade and smaller at the wing tips and at the hub. The length of the lines 20 to 26 in the pitch-diagram Fig. 19, indicating the pitch, show how the pitch should be varied between the radii r_1 to r_7 inclusive with respect to the difference of the speed of the entering water. The actual pitch angles for the radii r_1 to r_7 are shown in Fig. 18.

The usual way in designing a propeller is to make the cylindrical sections through the blades straight on the pressure side and rounded on the fore-side.—A propeller of this kind is shown by Figs. 11, 12, and 13.—From Fig. 13 it will be seen that the middle line of the blade section is not straight but curved. The tangents on this curve through the points 10 and 11 are crossing each other at an angle α .

It is about this angle α measured on the periphery of the cylindrical section by which the effective pitch increases from the entrance side to the exit side of the propeller. That means the water will undergo an additional increase of acceleration while passing through the blades and the jet of water leaving the propeller will be contracted accordingly in diameter.

It will be well to differentiate the area B and C accordingly, i. e. to make C smaller than B. Should this be omitted there will be the danger that the jet of the water separates itself from the walls of the nozzle or the entering edge of the blades will have to work so much harder and less economically. On the other hand with C smaller than B there will be a gain of propulsive action expressed by the difference of areas between B and C multiplied with the decrease of hydrostatic pressure within this ring-zone.

Fig. 1 and others show the nozzle-body to be double walled, i. e. with an inner part properly nozzle-shaped and an outer hull by which the nozzle is fastened to the ship. For ships with medium and large speeds the shape of the outer hull should be adapted to the natural flow of the

water which has to pass it. The natural tendency of this flow is that the water from both sides of the nozzle will unite aft of it at an angle β which is shown in Fig. 1. If this angle on the hull of the nozzle is made too small, the flow of the water will be contracted and an acceleration of the water will result with a decrease of hydrostatic pressure and accordingly a braking effect on the hull. If however the angle β is made a little larger than the natural direction of the stream lines would call for, the result will be a diminution of speed and an increase of the hydrostatic pressure. As this pressure works on the outer rear side of the nozzle, it will add to the propulsive powers of the hull.

This latter case is shown by Fig. 1, where β denominates the angle of the natural flow of the stream lines and β' the somewhat larger angle of the outer hull of the nozzle. It is a matter of course that β' should not be made so large that the water might separate from the nozzle as it passes by.

Fig. 1 further shows a stream lined rudder 12 placed immediately aft of the nozzle. As such a rudder will have a braking effect on the water leaving the nozzle, the area at D should be widened sufficiently to allow an unhampered flow of the water.

Fig. 14 shows a case where the highest part of the nozzle over-reaches the water surface on the outside of the nozzle. Line 13 indicates how in this case the mouth of the nozzle in its upper part is turned forward and running below the water surface until it meets with the hull body proper. If in a similar way the after opening of the nozzle is turned downward in its upper part, as indicated by line 14, the power for lifting the water in front of the propeller will be constantly regained without requiring any power from the ship's engine.

Line 15 in Fig. 14 indicates how the back end of the nozzle should be formed in this instance, i. e. such that the water-mass leaving the propeller may follow Newton's law of the free throw.

Figs. 2, 3, 4, and 17 show twin-screw ships with nozzles. In using this kind of arrangement it is desirable that the water flowing towards the nozzles should be turned into the direction of the propeller shafts before it enters into the mouth of the nozzle. If this rule is not followed there will be a poor propulsive effect. It will be noted at Fig. 15 that there is a sharp horizontal turn in the entering part of the nozzles, producing on the inner walls (towards the center line of the ship), due to the centrifugal force, a double-turn whirling effect, which is particularly shown in Fig. 16. This whirling effect prevents the water from entering the propeller area at B in the proper direction, that is about parallel to the propeller shaft. Fig. 3, aside of Fig. 15, shows how this whirling effect is avoided by properly shaping the hull in front of the nozzle in order to get results from the combination of ship, propellers and nozzles.

If a twin screw arrangement with nozzles is used for shallow water, it will be well—as shown by Figs. 2, 3 and 4—to change the cross sections of the rear part of the nozzle between C and D—while making this distance sufficiently long gradually in such a way that the two rear openings C may be united into a common area of oval or rectangular shape. By this method the danger is overcome that the space between the two water jets from the propellers might not be filled

out quickly enough and cause a braking back current.

Fig. 17 shows a twin screw arrangement with nozzles for a tugboat wherein the two propeller-shafts are set at an acute angle to each other, united by gear wheels 17 and driven by a common engine 18. This arrangement saves one engine and the water jet leaving the propellers will not meet with the bow of the barge, which may be towed on a short tow rope behind the tug. The resistance of the barge will thereby be diminished.

Figs. 5, 7, 8, and 9 show for single screw ships how the body of the nozzle may be rigidly and homogeneously united with the hull of the ship. The water lines in the upper part and above the nozzle are drawn out to unite as far as practicable behind the nozzle. The result of this method is not only a rigid connection between nozzle and ship but at the same time the resistance of the ship in combination with the nozzle will be materially improved by the long water lines.

All of the nozzles shown by the various figures are double walled bouyant bodies the displacement of which may—without a disturbing effect to the propulsive efficiency—be made large enough to carry not only the weight of the nozzle arrangement, but may also give some additional buoyancy to the after part of the hull. This is of importance especially in cases where lighters are later on changed into motorships and the original shape of the hull was not made to carry the additional weight of the machinery.

What I claim is:

1. Propelling device on screw-propelled ships comprising in combination a screw propeller, and a tubular shaped nozzle around the propeller arranged longitudinally of the propeller shaft, said nozzle being fitted to the hull, surrounding near its narrowest inner cross section closely the propeller circle, and widening out quickly in front of the propeller to an entrance opening, the size of which is substantially larger than that of the exit opening aft of the propeller, the body of the nozzle having a shape substantially such that the distance from the shaft to the exterior surface of the nozzle decreases from forward to aft and having a well rounded entering edge at the mouth of the nozzle forming the connection between the inside and outside surfaces of the nozzle body.

2. Propelling device for screw-propelled ships according to claim 1, characterized by the fact that the ship's hull in front of the nozzle is shaped so as to turn the stream-lines of the water before they enter the mouth of the nozzle about parallel to the propeller shaft.

3. A propelling device for ships, as claimed in claim 1, in which the cross sectional area of the entrance opening (A) has such a ratio to the given narrowest cross section (C) of the nozzle in the plane of the propeller taking into account the pitch (P) and revolutions per second (r) of the propelling screw as figured in connection with the proper slip factor (α) for the service speed per second (v) of the ship under service conditions, that the quantity of water passing through the cross section (C) per second ($C \times P \times r \times \alpha$) is not less than what is taken in through the entrance opening (A) with the ship's service

speed per second (v) multiplied by the ship's wake factor (β) according to the formula.

$$C \times P \times r \times \alpha = A \times v \times \beta$$

4. Propelling device for screw-propelled ships according to claim 1, characterized by the fact that the pressure sides of longitudinal profiles of the nozzle body form outside angles with the stream-lines of the water streaming toward the outer edge of the mouth of the nozzle which at their maximum are not substantially more than 180 degrees.

5. Propelling device for screw propelled ships according to claim 1, characterized by the fact that the cross sectional area of the nozzle inlet opening is distributed around the propeller shaft in such a way that the widest part of the mouth, and consequently the greatest reduction in area from the inlet to the propeller disk, is situated substantially near the ship's hull in the zones of the greatest wake.

6. Propelling device for screw propelled ships according to claim 1, characterized by the fact that the upper part of the edge of the mouth of the nozzle is bent down forwardly having a well rounded off bulky edge which extends about horizontally to the ship's hull, this edge being in all points lower than the highest point of the cross-section of the nozzle in the cross sectional plane of the propeller circle.

7. Propelling device for screw propelled ships according to claim 1, for a twin-screw arrangement, characterized by the fact that the inside ducts of the nozzle behind the propellers being of such gradual change-shape that they practically merge into each other towards the outlet opening with a common outline with a view to avoid the formation of eddies between the two water jets issuing the nozzle.

8. Propelling device for screw-propelled ships according to claim 1 wherein the upper inside of the nozzle is formed by the ship's wall characterized by the fact that the waterlines immediately above the nozzle converge aft of the nozzle.

9. Propelling device for screw propelled ships according to claim 1 characterized by the fact that adjustable flaps are arranged on the nozzle body forming part of the circumference of its said mouth and being adapted to vary the inlet area of the latter.

10. Propelling device for screw-propelled ships according to claim 1, for a twin-screw arrangement, wherein the direction of the two nozzles are diverging towards the rear.

11. Propelling device for screw-propelled ships according to claim 1, characterized by the combination with a propeller, the pitch of which is smaller at the wing tips than at the intermediate parts of the blades.

12. Propelling device for screw-propelled ships according to claim 1, characterized by the combination with a propeller, having increasing pitch from the inlet to the outlet edge of the blades the inside cross sectional area of the nozzle being smaller immediately aft of the propeller than immediately in front of it.

13. Propelling device for screw-propelled ships according to claim 1, in which the nozzle forms an integral part of the ship's hull.

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