Dec. 29, 1931. D. W. TAYLOR 1,838,335

TUNNEL BOAT

Filed May 20, 1929 3 Sheets-Sheet 1

Fig. 1.

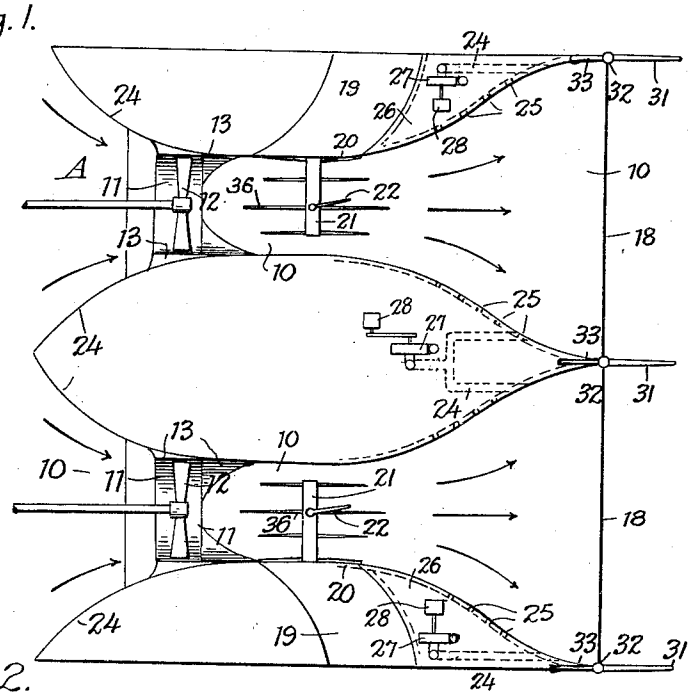
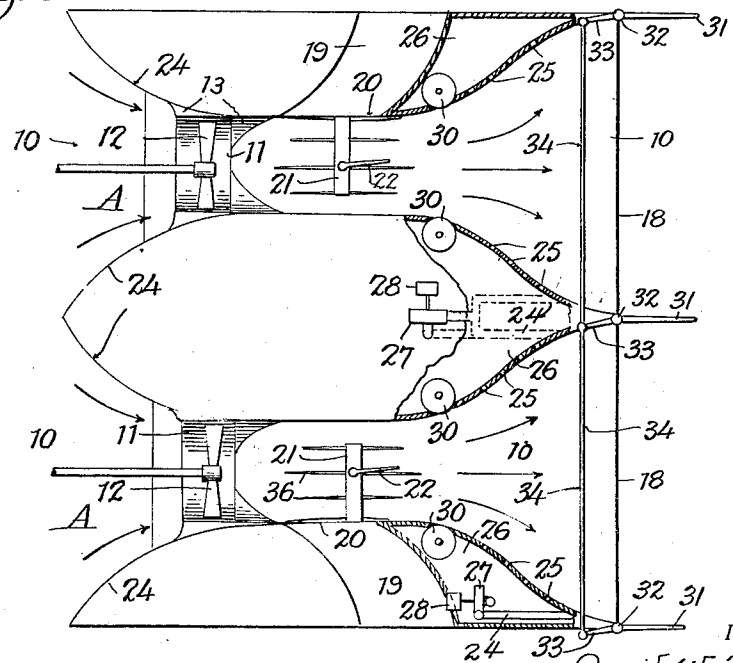


Fig. 2.



INVENTOR.

David W. Taylor

BY

Henry Orth Jr.

ATTORNEY.

Dec. 29, 1931. D. W. TAYLOR 1,838,335

TUNNEL BOAT

Filed May 20, 1929 3 Sheets-Sheet 2

Fig. 3.

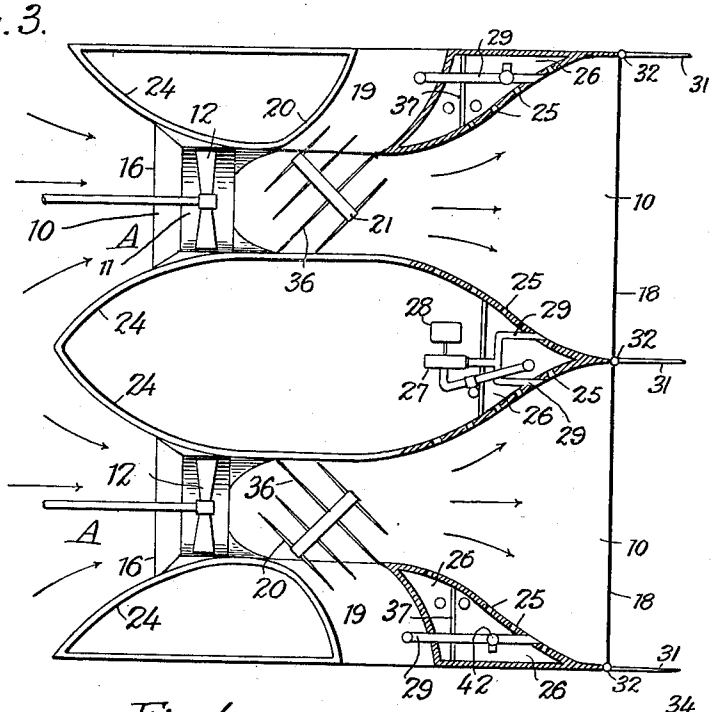


Fig. 4.

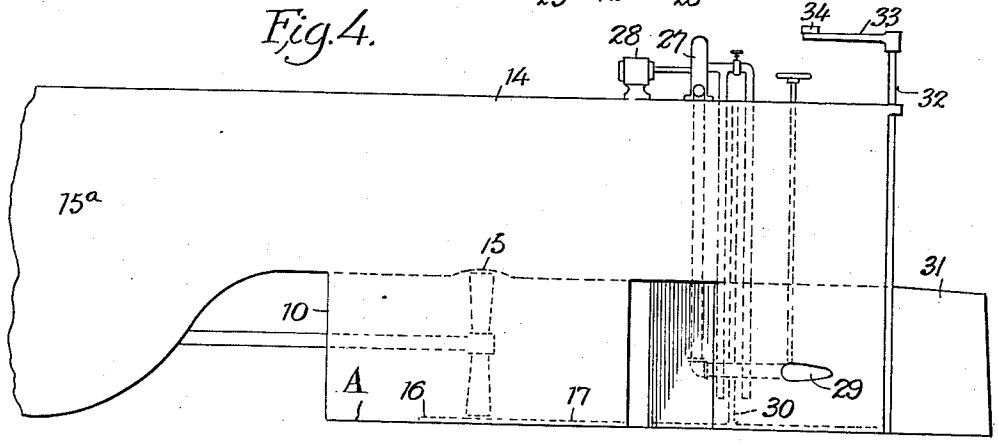
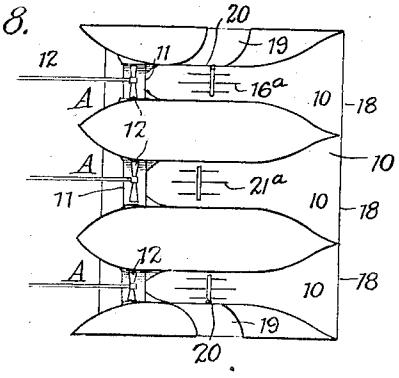


Fig. 8.



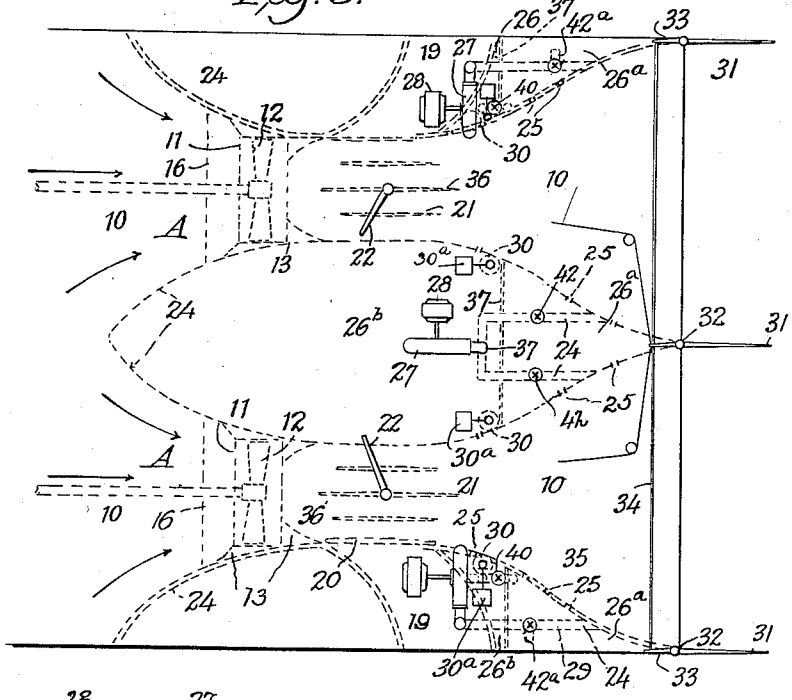
INVENTOR.
David W Taylor
BY
Henry Orth Jr
ATTORNEY.

Dec. 29, 1931. D. W. TAYLOR 1,838,335

TUNNEL BOAT

Filed May 20, 1929 3 Sheets-Sheet 3

Fig. 5.



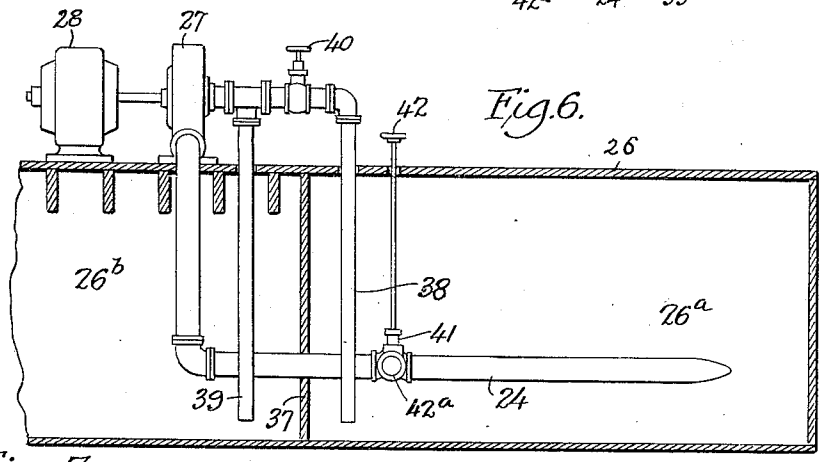
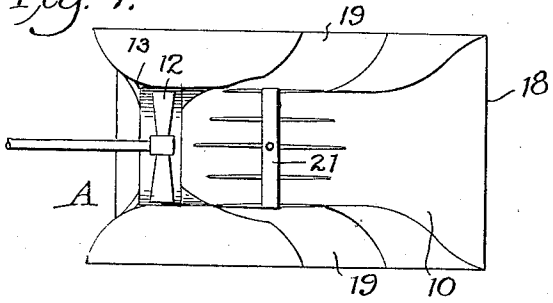


Fig. 6.

Fig. 7.



INVENTOR.
David W. Taylor
BY
Henry Orth Jr
ATTORNEY.

Patented Dec. 29, 1931 1,838,335

UNITED STATES PATENT OFFICE

DAVID W. TAYLOR, OF WASHINGTON, DISTRICT OF COLUMBIA

TUNNEL BOAT

Application filed May 20, 1929. Serial No. 364,494.

My invention relates to the propulsion of shallow water crafts and especially to that type of boat known as tunnel boats, and has for its object to increase the propelling efficiency of this type of vessel as well as to facilitate their handling and obtain these results when using preferably screw propellers.

In the propulsion of vessels by means of screw propellers, paddle wheels, or the like, which produce thrust forward by impelling water astern, the efficiency of the propelling instrument as usually installed is intimately associated with the sectional area of the column of water impelled astern by the propeller or paddle wheel, the race, as it is usually designated.

If the race is too small the sternward velocity given the water, its slip velocity, is high and the lost energy which the race carries away results in low efficiency. If the race is too large and there is little loss through slip, however, the friction of the large propelling instrument associated with the large race becomes disproportionately large and this large frictional loss results in low efficiency.

For shallow draft river craft, especially tugs, which push or pull large tows at low speed, it is not possible to provide a race large enough for a good efficiency. For such vessels, it is theoretically desirable to have the maximum possible race equal in sectional area to the width at the stern multiplied by the draft.

This result is approximately attainable in extremely shallow draft craft fitted with stern wheels, but when the draft is measured in feet instead of inches such extreme stern wheels become impracticable. Nevertheless, the stern wheel for shallow draft craft has in practice a larger race than the screw propeller or propellers, even when the latter are fitted to project above the normal water level, and so gain area of race, because in action the water in the partial tunnel in which the screw propeller operates rises to immerse the propeller.

crew propulsion has many practical advantages and it is my idea to combine with the screw propeller certain arrangements of stern such that the combination enables us virtually to reach the efficiency associated with an area of race equal to the width of stern multiplied by the draft of the vessel.

I do this by taking advantage of the variations of pressure forward and aft of the propeller to obtain useful pressure re-actions in the fore and aft direction in addition to the usual propeller thrust. It is well known for example, that screw propellers as ordinarily fitted exert in action a suction upon the part of the vessel forward of them. With usual installations this suction is opposed to the thrust of the propeller and hence prejudicial to efficiency. I shape the portion of the vessel forward of the propeller in such manner that this suction develops a forward thrust and hence is helpful, not harmful.

Referring to the drawings, in which like parts are similarly designated:

Figure 1 is a plan view of one form of my invention;

Fig. 2 shows the addition to Fig. 1 of driven rollers for assisting in reducing the skin friction on the aft portions of the tunnels and facilitating divergence of the water of the race.

Fig. 3 is a modification of Fig. 1, using two compartments in each;

Fig. 4 is an elevation of stern overhang with the pump arrangement, showing one of the grids in steering position.

Fig. 5 shows the embodiment of all the aforesaid improvements combined.

Fig. 6 is an enlarged view of the pumping outfit.

Fig. 7 is a diagram showing a single tunnel;

Fig. 8 is a like view showing more than two tunnels.

The tunnels 10 are rectangular in cross-section except in region 11 of the propeller or propellers 12 which is circular and gradually merges into the rectangular section as both ends of this region as indicated at 13.

The tunnels are carried by a rather long stern overhang 14, Fig. 4, on the hull 15ª, and their number depends on the width of the boat and the number of screw propellers used The tunnel top is preferably submerged just below the water line and is flat except that it

may be slightly arched at 15 in the region of the propellers.

Each tunnel has a widened or flaring entrance at its forward intake end and gradually widens or flares at its rear discharge end with a substantially straight portion of uniform section immediately to the rear of the propeller.

The tunnels are open at the bottom at their entrance ends at A in the vicinity of the forward end 16 of the bottom 17 near the propellers to facilitate the entrance of water to the propellers and from there on to about the point 18 the bottom of the tunnel is closed and flat. The sides of the tunnel are preferably straight between their flaring ends.

This straight portion, preferably but not necessarily, has a lateral exit 19 normally closed by one of the blades 20 of a grid 21 pivoted in the tunnel to the rear of the propeller and preferably just before the discharge end of the tunnel begins to widen.

This grid is operated by a tiller 22 or wheel on the deck of the boat. One function of the grid, which consists of several vertical blades, is to decrease and break up the swirl or rotary movement of the column of water leaving the propeller.

When the vessel is under way the water enters the tunnel at the section A, flows aft, as indicated by the arrows, is acted upon by the propeller 12 at the minimum section, passes aft through the frame of vertical plates 21, which takes out the rotation set up in the passage through the propeller, then diverges again to the rear and leaves the tunnel at the widened section 18.

The action is as follows—

The water entering the tunnel at the open bottom portion A and from the bottom, is accelerated to the rear or sucked aft by the propeller 23. This results in a velocity aft and corresponding reduction of pressure, according to the well known Bernouilli's law.

The reduction of pressure in the converging portion of the tunnel forward of the propeller results in a forward force upon the flaring parts 24 of the tunnel sides. In passing through the propeller 12, the water is given a motion of rotation resulting in thrust. Its sternward velocity is not increased as it fills the tunnel before reaching and after leaving the propeller. It then passes through the frame 21 which stops the rotation. In the rear flaring portion of the tunnel it spreads out, loses velocity and increases pressure. The increasing pressure upon the diverging portion of the tunnel again produces a forward resultant thrust, so that inefficient action of the small propeller is reinforced and made efficient by the reactions upon the tunnel sides resulting from the propeller action. Now in order to have a tunnel as above function as described, we must understand and provide against certain practical difficulties that must be taken care of.

The principal difficulty is that behind the propeller without special arrangements the water will not diverge and develop the pressure against the sides of the tunnel that is essential to efficient functioning. When water is flowing through a converging tunnel the high pressure near the entrance portion of large section is converted into high velocity through the small sections with corresponding reduction of pressure, all according to Bernouilli's law. But this process, though reversible in theory for a perfect or frictionless fluid, is not readily reversible for water, which is not a perfect fluid and cannot flow over a surface without friction. What happens with water is that it breaks away from the surface of an ordinary tunnel and streams aft from the propeller in a jet of practically the same diameter as the propeller with no increase of pressure. Between this jet and the sides of the tunnel is a belt of broken turbulent water whose pressure is but little, if any, above that of the jet it encases and hence the pressure on the sides of the tunnel is far below that necessary to produce efficient propulsion.

It is true that if the divergence is very gradual the jet does not break away from the boundary layer of turbulent water next the walls of the tunnel. This, however, is not a suitable type of tunnel for two reasons. The angle of divergence must be so small that the length of the tunnel for the necessary area of divergence is too great to carry behind a boat and if it could be carried, the friction of the water upon the excessive surface would be so great that the arrangement would be hydraulically inefficient.

I construct a diverging tunnel short enough to be practicable and yet such that the stream will diverge and hug it. This result is attained by one or both of two devices.

When water flows over a surface, unlike a perfect fluid, which slips over the surface without adherence or friction, the layer of water of infinitesimal thickness in contact with the surface clings to it and through its viscosity sets up a shearing action upon the water flowing past it, (skin friction). The result is that as we pass along the stream there develops a "boundary layer" of turbulent vortices which thickens steadily and after it reaches a certain thickness the smooth stream inside breaks away as already stated.

However, if we fit in the surface over which the water is flowing, a slot or slots at right angles or thereabouts to the direction of flow so that the boundary layer is peeled off, as it were, before the stream breaks away from it, the stream expands nearly as would a perfect fluid and its velocity is converted into pressure which can be utilized to drive the vessel ahead. It is necessary to remove the small

fraction of the water acted upon which passes through the narrow slots 25, into chambers 26 whose sides form the side walls of the tunnel. This is readily done with some convenient form of pump 27 driven for example by an electric motor 28. The water pumped is discharged in a sternward direction through a pipe or pipes 29 in order to increase the thrust which propels the vessel, or restored to the stream as described later.

In cases where the divergence of the propeller race required is greater than can be satisfactorily obtained by the suction slots 25 alone within the length available for the discharge tunnel, the initial divergence is facilitated by cylinders 30 in Fig. 2, whose axes are parallel to the tunnel side walls and so placed that a part of the tunnel wall is replaced by the surface of a rotating cylinder whose speed of rotation is such that this surface has very nearly the velocity of the stream, but preferably a little more velocity. Then as the water passes the cylinder, the relative velocity is very small so that the stream can expand with no material development of a boundary layer. The clearance between the rotating cylinder and the fixed diverging wall is naturally in the form of a narrow slot and the fixed diverging wall is initially virtually tangent to the revolving cylindrical surface. The cylinders 30 are driven by small motors 30^a.

The rear portions of the discharge tunnels preferably are parallel or nearly so to the fore and aft direction of the vessel. I prefer to accomplish this result by fitting fore and aft rudders 31, as tunnel side terminations and rotating about 32. The rudder tillers 33 are connected together by a bar 34 for simultaneous movement by any type of steering gear.

While rudders so fitted are adequate for a vessel running free and for a tow boat towing by a line ahead, for a "towboat" pushing a group of barges, as is so common on our rivers, it is very desirable to be able to develop sidewise or flanking forces greater than possible in practice with any form of rudder. I obtain this result as follows: Since in my case with my form of tunnel the propeller works at high slips, causing large rotary and sternward velocities of the water, it is advisable to fit immediately behind the propeller a series of preferably vertical plates 20, in longitudinal planes to take out the rotation of the water. These plates are fitted vertical and rotatable, one side plate 20 forming a part of the tunnel side and so disposed that when turned through an angle of 45 degrees or so, as indicated at Fig. 3, a center plate 36 of the grid 21 forms a deflecting diaphragm which directs all the water of the tunnel race into side channels 19 from which it is ultimately discharged athwartships. This arrangement produces a very large sidewise or flanking action, one or the other of frames being turned according to the desired direction of side or flanking force.

The water which is peeled off the race by the slots in the tunnel sides may be discharged sternward from the pumping appliances through pipes, but a preferable arrangement is to pump it through a watertight bulkhead, 37, Figs. 5 and 6, into a rear compartment of the chambers 26, fitted with discharge slot or slots 25 to direct the water again to the side of the race but with a higher velocity than the body of the race. This has much the same effect as peeling off the vortical surface through the earlier slots in the forward compartment of the chambers and causes the race to hug the tunnel side.

Fig. 6 shows a pumping arrangement in which 26^a and 26^b are two compartments of a chamber 26 separated by the water tight bulkhead 37. The motor 28 is connected to the pump 27 having two suction conduits 38 and 39 one for each compartment and a discharge conduit 24. Interposed between the suction conduits 38 and 39 is a cut-off valve 40 that disconnects compartment 26^a from the pump, and the discharge conduit has a two-way valve 41 that is operated by a hand wheel 42 from the deck. This valve has a discharge branch 42^a that allows the pipe 24 to discharge into compartment 26^a instead of through the end of the pipe into the water below the water line.

When valve 40 is closed and valve 41 is set to discharge through branch 42^a into compartment 26^a water entering compartment 26^b through the slots will be pumped into compartment 26^a to be discharged through its slots as above described. When valve 40 is opened and valve 41 set to discharge water through the entire length of pipe 34 water will be pumped from both compartments 26^a and 26^b and discharged outside the chamber.

I have illustrated tunnel boats having one or more tunnels and where there are three or more tunnels, the grids as 21^a Fig. 8 in the intermediate tunnels are stationary as it is only the two tunnels at the two sides of the boat that are provided with steering passages 19.

I claim—

1. In a tunnel boat, a tunnel having flaring inlet and outlet ends, and a propeller in the tunnel; in combination with water chambers forming side walls of the discharge end of the tunnel, means to admit water from the tunnel into the chambers and means to pump water from the chambers.

2. In a tunnel boat, a tunnel and a propeller in the tunnel; in combination with water chambers forming side walls of the tunnel at its discharge end, narrow slots in said walls to admit water from the tunnel to

the chambers and means to pump water from the chambers.

3. In a tunnel boat, a tunnel, and a propeller in the tunnel; in combination with water chambers forming the side walls of the discharge end of the tunnel, and driven rollers set in slots in the walls of the chambers and means to pump water from the chambers, said rollers forming narrow passages into the chambers and between them and the edges of the slots.

4. In a tunnel boat, a tunnel and a propeller therein, in combination with water chambers forming the sides of the tunnel and having openings from the tunnel into the chambers, means to pump water from the chambers and discharge it to the rear of the boat beneath the water line.

5. In a tunnel boat, a tunnel and a propeller therein; in combination with water chambers forming the side walls of the tunnel, with openings for the passage of water from the tunnel into the chambers and driven rollers also in said walls, and means to pump water from the chambers and discharge it abaft below the water line.

6. In a tunnel boat, a tunnel and a propeller therein; in combination with lateral passages discharging substantially at right angles to the longitudinal axis of the boat from the tunnel between its ends, means to normally close said passages, said means positionable to close the tunnel and open said passages whereby a maximum flanking action is obtained.

7. In a tunnel boat, a tunnel and a propeller therein, in combination with lateral passages from the tunnel back of the propeller, anti-swirl devices in the tunnel and normally closing said passages and means to rotate said devices to close the tunnel and direct the water from the propeller through said passage.

8. In a tunnel boat, a tunnel, and a propeller therein, in combination with water chambers whose side walls form sides of the tunnel and are provided with slots for the entrance of water from the tunnel into the chambers, a partition in each chamber dividing it into compartments and means to withdraw water from one compartment and discharge it into another.

9. In a tunnel boat, a tunnel and a propeller therein; in combination with a water chamber on each side of the tunnel back of the propeller and having slotted side walls forming the side walls of the tunnel, a watertight partition subdividing each chamber into compartments, a pump, a suction pipe having a branch leading to each compartment, a valve between the branches, a discharge pipe, discharging abaft below the water line and a two way valve to cause the discharge pipe to deliver into the rearmost compartment of a chamber.

10. In a tunnel boat having a stern overhang, one or more tunnels and corresponding propellers therein, the tunnel or tunnels having a total discharge width substantially equal to the width of the boat at the stern, said tunnel or tunnels carried by the overhangs closed at the bottom from near the propeller position to substantially the rear end of the tunnels and the bottom of the overhang forming the top of the tunnel or tunnels.

11. In a tunnel boat having an overhang, a tunnel rectangular in section and having a closed bottom, lateral passages from the tunnel discharging substantially at right angles to the longitudinal axis of the boat, and movable anti-swirl devices normally closing the passages and movable to close the tunnel and simultaneously open the passages and also preventing swirling of the water passing to the passages.

12. In a tunnel boat, a stern overhang, water chambers carried by the overhang beneath the same, said chambers spaced to form a tunnel and lateral passages, said tunnel having laterally diverging ends, the ends of the tunnel being the width of the overhang, a single propeller in the tunnel and movable means back of the propeller to prevent swirling in any position thereof, said means controlling the tunnel and passages.

In testimony that I claim the foregoing as my invention, I have signed my name.

DAVID W. TAYLOR.