Jan. 5, 1943. J. H. HAMMOND, JR 2,307,039

VARIABLE PITCH PROPELLER CONTROLLED BY WAKE

Filed April 17, 1941 4 Sheets-Sheet 1

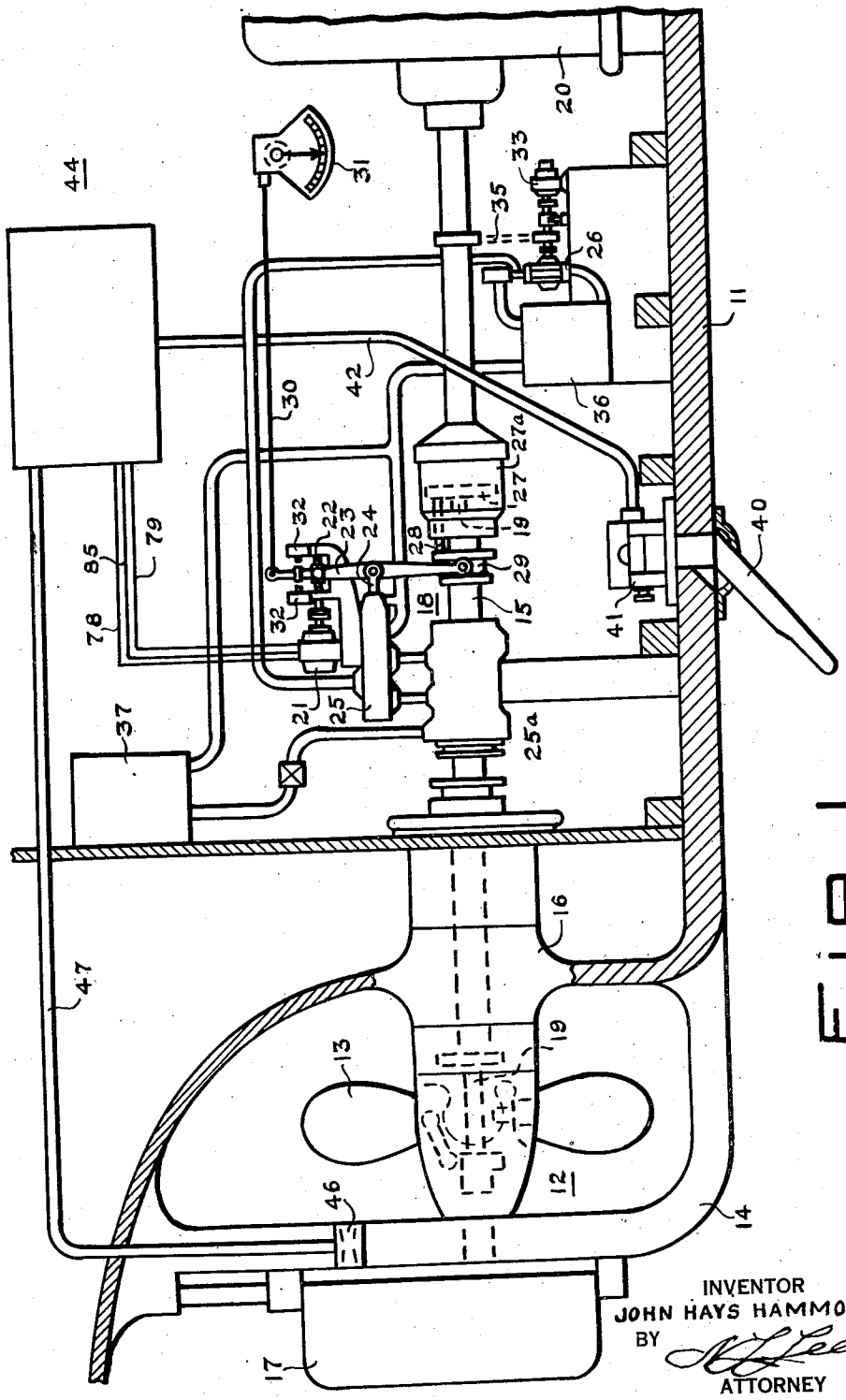


Fig. 1.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY
ATTORNEY

Jan. 5, 1943. J. H. HAMMOND, JR 2,307,039

VARIABLE PITCH PROPELLER CONTROLLED BY WAKE

Filed April 17, 1941 4 Sheets-Sheet 2

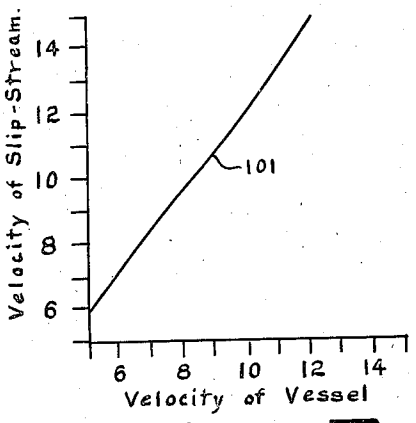


Fig. 2.

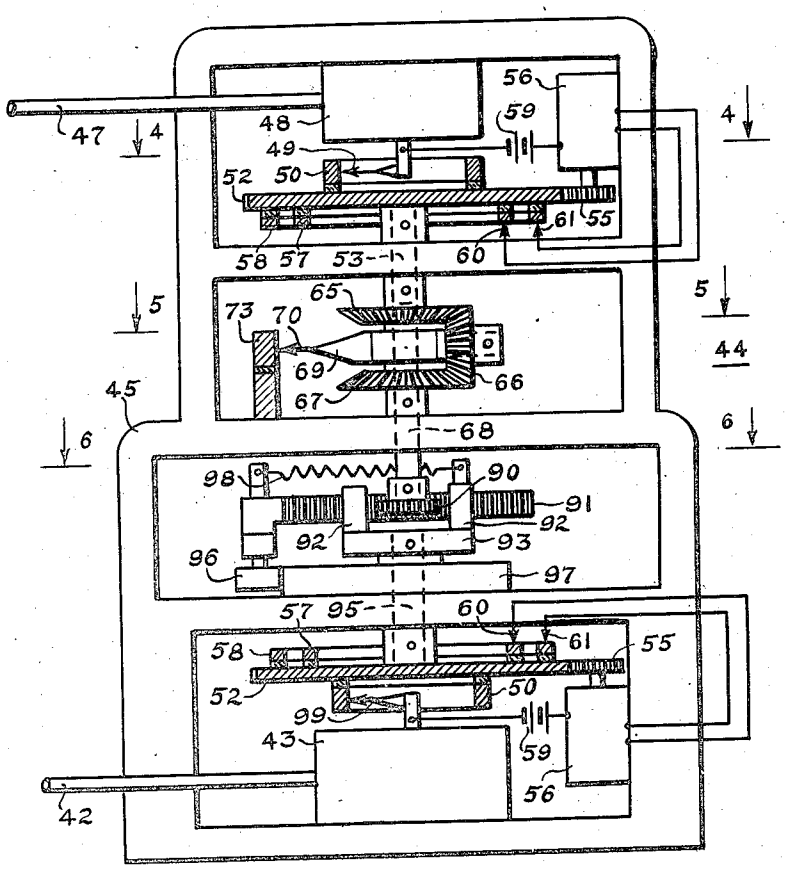


Fig. 3.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY
ATTORNEY

Jan. 5, 1943. J. H. HAMMOND, JR 2,307,039

VARIABLE PITCH PROPELLER CONTROLLED BY WAKE

Filed April 17, 1941 4 Sheets-Sheet 3

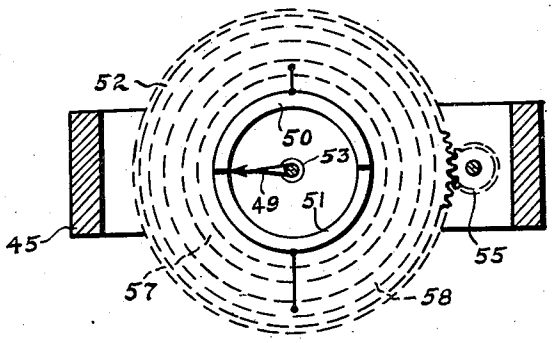


Fig. 4.

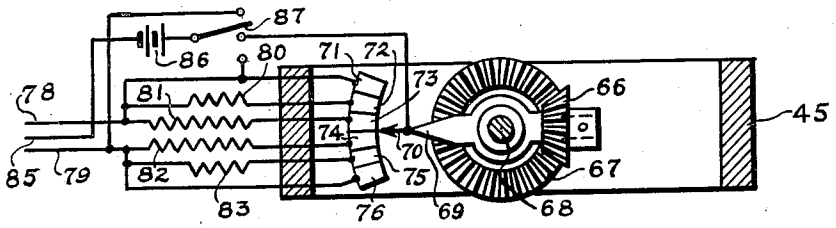


Fig. 5.

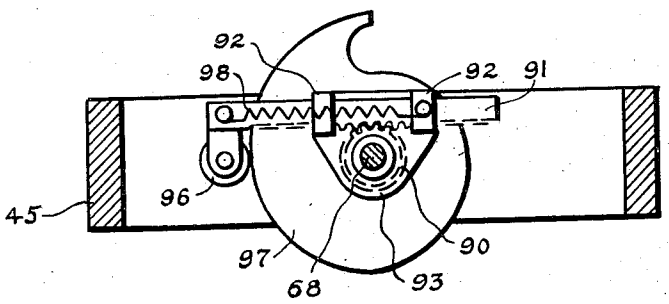


Fig. 6.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY
ATTORNEY

Jan. 5, 1943. J. H. HAMMOND, JR 2,307,039

VARIABLE PITCH PROPELLER CONTROLLED BY WAKE

Filed April 17, 1941 4 Sheets-Sheet 4

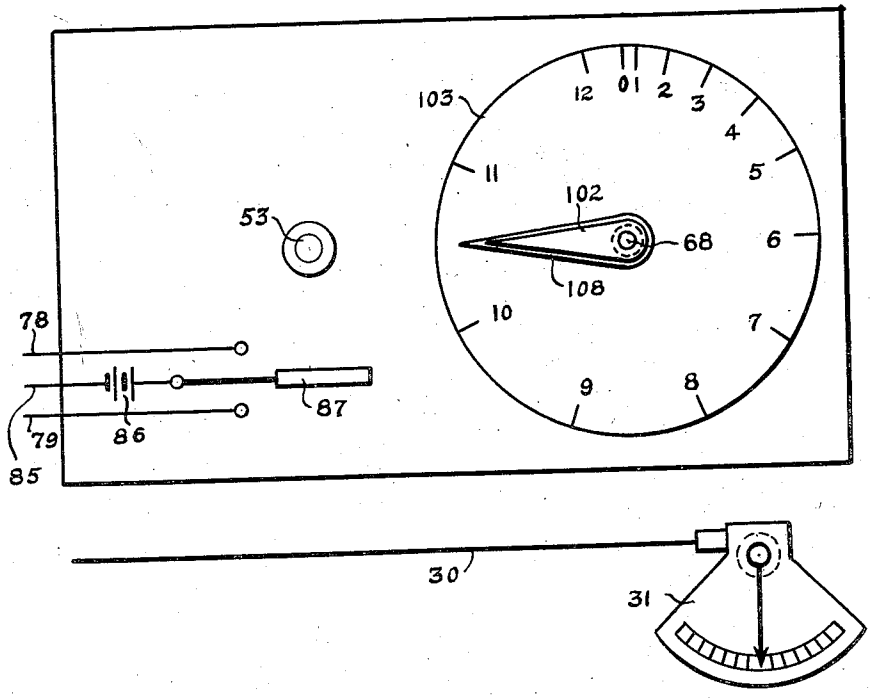


Fig. 7.

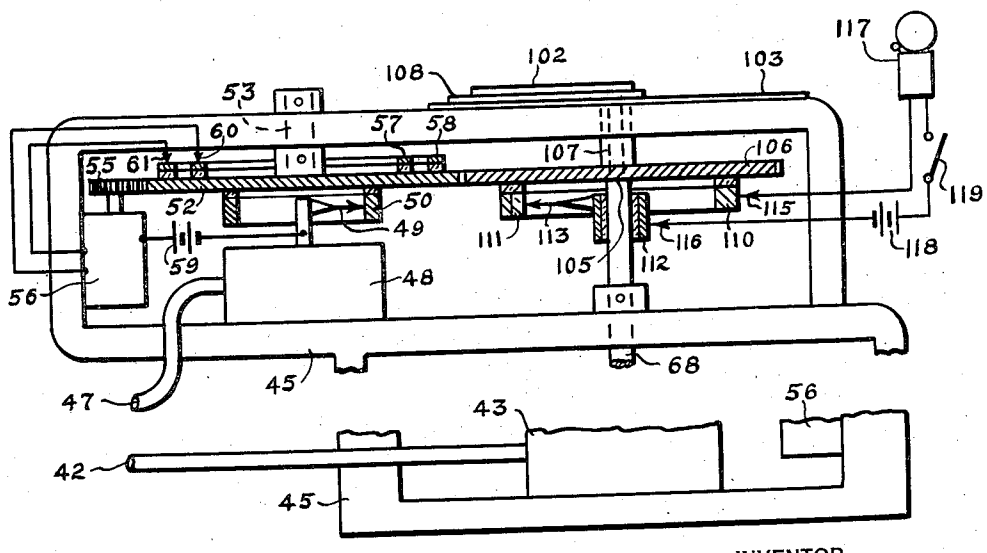


Fig. 8.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY
ATTORNEY

Patented Jan. 5, 1943 2,307,039

UNITED STATES PATENT OFFICE

2,307,039

VARIABLE PITCH PROPELLER CONTROLLED BY WAKE

John Hays Hammond, Jr., Gloucester, Mass.

Application April 17, 1941, Serial No. 388,943

6 Claims. (Cl. 170—163)

This invention relates to variable pitch propellers and more specifically to means for automatically varying the pitch of a propeller so as to maintain the most efficient propulsion conditions with a fixed power output under varying conditions of wind and weather.

The invention further relates to means for indicating the speed of the vessel thru the water and the speed of the slip stream of the propeller and provides means responsive to the relationship between these two indications to vary the pitch of the propeller blades in such a manner that the efficiency of propulsion will be maintained at a maximum.

The invention provides means for automatically designating the theoretical slip stream speed for various propeller and ship speeds and comparing the same with the actual slip stream speed.

The invention also provides control mechanism for automatically varying the pitch of the propeller blades so as to bring the theoretical and actual slip stream speeds into agreement.

The invention further provides means for indicating the theoretical and actual slip stream speeds and manual means for controlling the pitch of the propeller blades so as to bring these two speeds into agreement.

The invention also provides means for varying the rate of change of pitch of the propeller blades in accordance with the amount of change of the deviation between the theoretical and actual slip stream speed.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Figure 1 illustrates diagrammatically the system as applied to the driving mechanism of a marine vessel.

Figure 2 shows the curve of relationship between the speed of the vessel and the speed of the slip stream of the propeller.

Figure 3 is an elevation partly in section of an integrating mechanism for controlling the pitch of the propeller blades.

Figure 4 is a sectional view taken on line 4—4 of Figure 3.

Figure 5 is a sectional view taken on line 5—5 of Figure 3.

Figure 6 is a sectional view taken on line 6—6 of Figure 3.

Figure 7 is a top plan view of a modified form of the invention, and

Figure 8 is an elevation, partly in section, of the mechanism shown in Figure 7.

Like reference characters denote like parts in the several figures of the drawings.

In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the accompanying drawings and more particularly to Figure 1, the hull of a marine vessel is indicated at 11. The vessel is driven by means of a propeller 12, which is provided with adjustable blades 13, and which has an outboard bearing in the rudder post 14. The propeller 12 is attached to the end of a hollow shaft 15 which passes thru a bearing 16. A rudder 17 is mounted on the rudder post 14. The shaft 15 is driven by a prime mover 20 which may be of any desired type such as a Diesel engine and is preferably provided with a governor, not shown, for maintaining a constant speed of rotation.

The blades 13 are connected to a variable pitch mechanism 18 which may be of any well known and standard construction such as that manufactured by the Escher Wyss Company of Zurich, Switzerland, the details of which form no part of the present invention and are accordingly not specifically set forth herein. This mechanism, in general, comprises a rod 19 slidable longitudinally within the shaft 15 and connected to control the pitch of the blades 13. The rod 19 is actuated by a piston 27 in a fluid pressure cylinder 27a. Fluid for actuating the piston 27 is supplied by a pump 26 through a control valve 25 and a distribution valve 25a which communicates with the cylinder 27a through ducts, not shown, in the shaft 15. A motor 21 rotates a worm 22 which operates to move the upper end of a floating lever 23, which, in turn, is pivoted to the end of a valve rod 24 which controls the valve 25. The piston 27 is connected by a rod 28 to a collar 29 which is slidably mounted on the shaft 15 and engages the lower end of the lever 23 so that the position of this end of the lever corresponds to the pitch of the blades 13.

The upper end of the lever 23 is connected by a wire 30 to an indicator 31 which shows the pitch at which the blades 13 are set. Stops 32 are provided for limiting the maximum and minimum pitch of the blades 13. The fluid pump 26 is driven either by a motor 33 or a belt 35 from the shaft 15. A reservoir 36 and a supply tank 37 are provided for the necessary fluid.

It is to be understood that other pitch control devices may be employed in place of that referred to above, for varying the pitch of the propeller blades 13 in response to actuation of the motor 21. A particular type is shown for purposes of illustration only.

Mounted on the hull 11 is a speed indicating device which may be of any well known and standard construction such as that made by the Kenyon Instrument Company of Boston and known as the Kenyon speedometer. This comprises a strut 40 which is attached to a metallic bellows 41 containing fluid under pressure. The bellows 41 is connected by a hydraulic tube 42 to a speedometer 43 which is mounted in an integrator 44 (Figure 3). It is to be understood that other types of speedometer devices may be used if desired. A Pitot tube 46 is mounted on the rudder post 14 and is connected by a tube 47 to a velocity indicator 48 which is mounted at the top of the integrator 44.

The shaft of the velocity indicator 48 carries a contact arm 49 which cooperates with two semi-circular segments 50 and 51 which are mounted on, but insulated from, a gear 52 (Figure 4) which is secured to a shaft 53 having a bearing in the frame 45 of the integrator 44. The gear 52 meshes with a pinion 55 which is mounted on the shaft of a motor 56. Two slip rings 57 and 58 are mounted on, but insulated from, the gear 52. The slip rings 57 and 58 are electrically connected to the segments 50 and 51 respectively. A battery 59 is provided for operating the motor 56 and is connected on one side to the contact 49 and on the other side to the motor 56. This motor is provided with two field windings for causing it to rotate in opposite directions. One of these windings is connected to a contact 60 which engages the slip ring 57 and the other winding is connected to a contact 61 which engages the slip ring 58.

The shaft 53 has secured to its lower end a bevel gear 65 which meshes with a bevel pinion 66 which in turn meshes with a second bevel gear 67 secured to a shaft 68 which has a bearing in the frame 45. The bevel pinion 66 is mounted for rotation on a member 69 which is rotatably mounted on the shaft 68. The member 69 carries a contact 70 which cooperates with a plurality of contact segments 71—76 which are mounted on but insulated from the frame 45.

The segments 71 and 76 are connected to two conductors 78 and 79 which are connected to the reversing windings of the motor 21. The segments 72 and 73 are connected to two resistors 80 and 81 the other ends of which are connected to the conductor 78. The segments 74 and 75 are connected to two resistors 82 and 83, the other ends of which are connected to the conductor 79. The common lead of the reversing windings of the motor 21 is connected by a conductor 85 to one side of a battery 86, the other side of which is connected to the blade of a three position switch 87. The center contact of this switch is connected to the contact 70, the upper contact to the conductor 79 and the lower contact to the conductor 78.

Secured to the lower end of the shaft 68 is a gear 90 which meshes with a rack 91 (Figure 6) mounted for longitudinal motion in two brackets 92 which form part of a member 93 which is secured to the upper end of a shaft 95 having a bearing in the frame 45. Rotatably mounted at the end of the rack 91 is a roller 96 which engages the periphery of a cam 97 which is secured to the frame 45. A spring 98 mounted between the rack 91 and the member 92 causes the roller 96 to be always held against the face of the cam 97.

Secured to the lower end of the shaft 95 is a follow-up system identical to that described in connection with the velocity indicator 48 and the corresponding parts of which bear the same numerals. The shaft of the speedometer 43 carries a contact arm 99 which cooperates with the segments 50 and 51 of this follow-up system.

While a Kenyon speedometer and a Pitot tube have been shown for measuring the velocities of the vessel and the propeller slip-stream respectively, it is to be understood that any other suitable types of velocity recorders may be used in their place if so desired.

Operation

In the operation of the form of the invention shown in Figures 1 to 6 the pitch of the blades 13 is set at the normal operating angle for the speed at which it is desired to operate the vessel. The setting of the blades 13 is accomplished by moving the blade of the switch 87 into the upper or lower position which will cause the motor 21 to move the upper end of the lever 23 to the left or right to increase or decrease the pitch in a well known manner, the angle of pitch being indicated by the pointer of the indicator 31.

The vessel is then brought up to the desired speed at which time the strut 40 will receive a certain amount of pressure due to the motion of the vessel thru the water. This pressure will be transmitted by the hydraulic cylinder 41 and tube 42 to the speedometer 43, the contact arm 99 of which will rotate in a clockwise direction, as seen from above, an amount proportional to the speed of the vessel.

As the contact arm 99 rotates it will engage the segment 50 causing an electrical circuit to be closed from the battery 59, contact 99, segment 50, slip ring 57, contact 60 and winding of motor 56 back to battery 59. This will cause the motor 56 to be rotated in such a direction that the gear 52 will be rotated clockwise. This rotation will continue until the insulation between the segments 50 and 51 is under the contact 99, at which time the motor 56 will stop. If the contact 99 should move in a counter-clockwise direction a circuit would be closed thru segment 51, slip-ring 58, contact 61 and the other winding of the motor 56 to cause it to rotate the gear 52 in the opposite direction. In this way a follow-up system is provided in which the gear 52 accurately and quickly follows the motion of the contact 99, so that the position of the gear 52 is proportional to the speed of the vessel.

The motion of the gear 52 will be transmitted by the shaft 95 to the member 93, which in turn will rotate the rack 91 and roller 96. As the latter rolls over the face of the cam 97, it will be moved away from the axis of the shaft 95 thus causing the rack 91 to rotate the gear 90 relative to the member 93 an amount proportional to the radial motion of the roller 96. It is thus seen that the relative motion of the gear 90 and shaft 68

with respect to the member 93 and shaft 95 is dependent on the shape of the cam 97.

If the cam 97 were circular in shape the shaft 68 would move exactly in synchronism with the shaft 95, as there would be no relative motion between the rack 91 and the member 93. The shape of the cam 97 is determined by the relative velocity of the vessel thru the water and the velocity of the slip-stream of the propeller for the most efficient propulsion with a given horsepower output under varying conditions of wind and weather. An example of this relationship is depicted in Figure 2 in which the curve 101 is plotted with speed of vessel as abscissa and velocity of slip-stream as ordinates. This curve may be obtained either from theoretical data or from actual test runs of the vessel and will be different for each vessel and therefore the cam 97 will be different for each vessel and may vary for different conditions of the same vessel such as loading, horsepower out-put to be maintained on run, etc. It may, therefore, be necessary to have a set of cams for each vessel which can be put in place of cam 97 to suit the conditions of the various runs.

As already stated the motion of the shaft 95 is proportional to the speed of the vessel thru the water as determined by the speedometer 43. The motion of the shaft 68, however, as determined by the shape of the cam 97 will give the theoretical speed that the propeller slip stream should have under the prevailing conditions of wind and weather. In other words, the position of the shaft 68 indicates the velocity that the propeller slip stream should have for the most efficient propulsion of the vessel with the predetermined horsepower out-put and under the prevailing conditions of wind and weather.

In order to determine whether the actual slip-stream of the propeller has this theoretically efficient velocity the speed of the slip-stream is determined by the Pitot tube 46 and is measured by the velocity indicator 48. The contact arm 49 operates a follow-up system similar to that described in connection with the speedometer 43, similar parts being designated by the same numerals. The gear 52 and therefore the shaft 53 will rotate an amount proportional to the speed of the propeller slip-stream, only in this case the rotation with increase of velocity will be counter-clockwise, as seen from above.

As the gear 65 is attached to the shaft 53, it will rotate an amount proportional to the actual slip-stream velocity in a counter-clockwise direction and as the gear 67 is attached to the shaft 68 it will rotate an amount proportional to the theoretical slip-stream velocity in a clockwise direction. If the actual slip-stream velocity is equal to the theoretical slip-stream velocity, the two gears 65 and 67 will rotate thru equal angles in opposite directions, thus rotating the pinion 66 but not turning the member 69 about the shaft 68. As long as the actual and theoretical velocities are the same, the member 69 will remain stationary and the contact 70 will remain on the insulation between the segments 73 and 74 (Figure 4).

If, however, the vessel should encounter strong head winds and be slowed down the actual slip-stream velocity as measured by the Pitot tube 46 might not decrease as the theoretical velocity as determined by the speed of the vessel. In this event, the gear 67 would rotate thru a greater angle in a counter-clockwise direction than the gear 65 would rotate in a clockwise direction. This would cause a rotation of the member 69 and therefore of the contact 70 in a counter-clockwise direction causing this contact to engage the segment 74 which will close a circuit from the battery 86 thru the resistance 82 to the motor 21 causing it to rotate slowly in a direction to move the upper end of the lever to the right, for example. This will move the valve to the right, which will allow fluid under pressure to pass from the pump 26 to the cylinder 27a by means of the ducts in the shaft 15. This will actuate the piston 27 which, by means of the rod 19 and the link mechanism, will cause the propeller blades 13 to slowly decrease their pitch. This will decrease the actual slip-stream velocity thus causing the gear 65 to rotate in a clockwise direction. This in turn will rotate the member 69 in a clockwise direction until the contact 70 rests again on the insulation between the segments 73 and 74 thus stopping the motor 21.

If the vessel should increase its speed due to a following wind or other favorable conditions the actual speed of the slip-stream would be less than the theoretical and the reverse action would take place, thus causing a gradual increase in the pitch of the propellers until the actual and theoretical slip-stream speeds became identical at which time the contact 70 would again rest on the insulation between the segments 73 and 74 at which time the motor 21 would stop.

If the changed conditions cause a rapid change of speed so that the contact 70 engages either segment 72 or 75, then the resistor 80 or the resistor 83 will be thrown in circuit with the motor 21. As resistors 80 and 83 have less resistance than resistors 81 and 82, the motor 21 will be caused to rotate faster, thus changing the propeller pitch more rapidly to take care of the more rapidly changing conditions.

If the conditions change so quickly that the contact 70 engages either segment 71 or 76 then no resistance will be thrown in the circuit of the motor 21 and it will rotate at its maximum speed, thus changing the propeller pitch at a maximum rate. The stops 32 are provided so that the propeller pitch is prevented from exceeding certain limits beyond which it could not operate efficiently under any conditions.

In this way the pitch of the propeller blades 13 is varied to cause the propeller to operate at the maximum possible efficiency for the existing conditions of wind and weather utilizing the rated horsepower of the prime mover. The rate of change of pitch will vary in accordance with the rate of change of speed of the vessel so that with a gradual change of speed there will be a slow change of propeller pitch, thus preventing violent changes of pitch which would cause undue strain on the driving mechanism, disagreeable vibrations and inefficiency of the propeller.

On both of the recording instruments 43 and 48, the motion of the contact arms 99 and 49 indicate the respective velocities in accordance with the square law. In this way the two contact arms will have identical angular positions for equal velocities. If, however, different types of recording instruments are used which have different types of scale readings, it will be necessary to insert a compensating mechanism between the upper gear 52 and the gear 65 which would correct this inequality and bring the motions of the two gears 65 and 67 to a common scale.

This may be accomplished by the use of a cam mechanism similar to that already described in connection with parts 90—97 and which would be

located between the upper gear 52 and the bevel gear 65. The cam of this mechanism would be so shaped that the angular motion of the gear 65 for various velocities would be the same as the angular motion of the gear 67 for similar velocities.

The follow-up mechanism may be varied in form, a specific embodiment having been disclosed for purposes of illustration only, and may be applied to other central systems.

Referring to the modified form of the invention shown in Figures 7 and 8, the mechanism up to and including the shaft 68 is identical to that already described and corresponding parts have been given the same numerals. In this form of the invention the shaft 68 has been extended so that it protrudes above the top of the frame 45 and has secured thereto a pointer 102 which registers with a scale 103 secured to the top of the frame 45. Rotatably mounted on the shaft 68 and resting against a shoulder 105 provided thereon is a gear 106. Secured to this gear is a sleeve 107 which surrounds the shaft 68 and which protrudes above the top of the frame 45. Secured to the sleeve 107 is a second pointer 108 which also registers with the scale 103.

Mounted on, but insulated from, the gear 106 is a circular contact segment 110 in which is inserted a small block of insulation 111. Mounted on, but insulated from the shaft 68 is a sleeve of conducting material 112 to which is attached a contact 113 which engages the segment 110. Two brushes 115 and 116 engage the segment 110 and the sleeve 112 respectively and are in the circuit of a bell 117, a battery 118 and a switch 119.

Mounted on the frame 45 is the velocity indicator 48 together with the follow-up system as already described the parts of which bear the same numerals as the corresponding parts in the previous figures. The gear 52 of this follow-up system meshes with the gear 106. The battery 86 and switch 87 are mounted on the top of the frame 45 and are connected by the conductors 78, 79 and 85 to the motor 21. The blade pitch indicator 31 is located adjacent to the apparatus so that it can be readily viewed by the man operating the switch 87.

Operation of Figures 7 and 8

In the operation of the modified form of the invention shown in Figures 7 and 8 the shaft 68 and therefore the pointer 102 will indicate on the scale 103 the theoretically most efficient propeller slip-stream speed for the speed at which the vessel is running under the prevailing conditions of wind and weather with the rated horse power of the prime mover 20. This is accomplished in a manner similar to that already described in connection with the previous figures. The actual speed of the propeller slip-stream will be measured by the Pitot tube 46 and will be indicated by the position of the contact arm 49. The motion of this arm will be transmitted by the follow-up system and gears 52 and 106 to the pointer 108 which will indicate on the scale 103 the actual slip-stream speed.

If these two pointers do not coincide it will indicate that the actual slip-stream speed is not what it should be for maximum efficiency and therefore the pitch of the blades 13 should be changed. If, for example, the pointer 108 indicates a higher slip-stream speed than the pointer 102, it will show that the actual slip-stream speed is greater than the theoretical and therefore the pitch of the propellers should be decreased. This is accomplished, as already described, by moving the switch 87 into the lower position where it is held until the pitch has been decreased sufficiently to reduce the actual slip-stream speed to the theoretical speed as indicated by the pointer 108 moving into line with the pointer 102, as shown in Figure 7. The pitch of the blades under this condition is indicated by the pointer of the indicator 31. If the actual slip-stream speed is less than the theoretical, the pitch of the blades 13 is increased by moving the switch 87 to its upper position until the two pointers 102 and 108 are in line.

When these two pointers 102 and 108 are in line indicating that the pitch of the blades 13 is correct for the prevailing conditions of wind and weather, the switch 119 is closed. As under these conditions the contact 113 is resting on the insulation 111 the circuit to the bell 117 will be open. If conditions change, however, so that the actual slip-stream speed is not the same as the theoretical, the contact 113 will move off the insulation 111 and engage the contact segment 110, thus closing the circuit to the bell 117 which will be sounded thus apprising the navigator of the condition who will then change the propeller pitch accordingly.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but might be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. In a system for driving a vessel, a variable pitch propeller having blades, means directly responsive to the speed of the propeller slip stream with respect to the vessel, means responsive to the speed of the vessel through the water to designate the proper theoretical slip stream speed at said vessel speed, and means comparing the actual and theoretical slip stream speeds.

2. In a system for driving a vessel, a variable pitch propeller having blades, means directly responsive to the speed of the propeller slip stream with respect to the vessel, means responsive to the speed of the vessel through the water to designate the proper theoretical slip stream speed at said vessel speed, means comparing the actual and theoretical slip stream speeds, and means actuated by said comparing means to control the pitch of said blades in a sense to maintain a predetermined relationship between said actual and theoretical slip stream speeds.

3. In a system for driving a vessel, a variable pitch propeller having blades, means directly responsive to the speed of the propeller slip stream with respect to the vessel, means responsive to the speed of the vessel through the water to designate the proper theoretical slip stream speed at said vessel speed, means comparing the actual and theoretical slip stream speeds, and means actuated by said comparing means to control the pitch of said blades in a sense to maintain a predetermined relationship between said actual and theoretical slip stream speeds and at a speed proportional to the amount of change of speed of said slip stream from said predetermined relationship, the speed of control being greater when the change in slip stream speed from said relationship is greater and vice versa, regardless of the direction of said change.

4. In a vessel having a propeller producing a slip stream, means responsive to the speed of

travel of said vessel, indicating means actuated by and as a function of the response of said last means, means responsive to the slip stream speed and indicating means actuated by said last means, said indicating means being arranged for simultaneous reading for comparing the indicated speeds.

5. In a vessel having a propeller producing a slip stream, means responsive to a function of the speed of travel of said vessel, means responsive to the slip stream speed, and means actuated by the combined effect of said first two means to indicate the relationship thereof.

6. In a vessel having a variable pitch propeller producing a slip stream, means responsive to a function of the speed of travel of said vessel, means responsive to the slip stream speed, and means actuated by the combined effect of said first two means to vary the pitch of said propeller in a sense to maintain a predetermined relationship therebetween.

JOHN HAYS HAMMOND, JR.