Feb. 9, 1954 H. J. NICHOLS 2,668,514

MARINE PROPELLER STEERING SYSTEM

Filed July 30, 1948 3 Sheets-Sheet 1

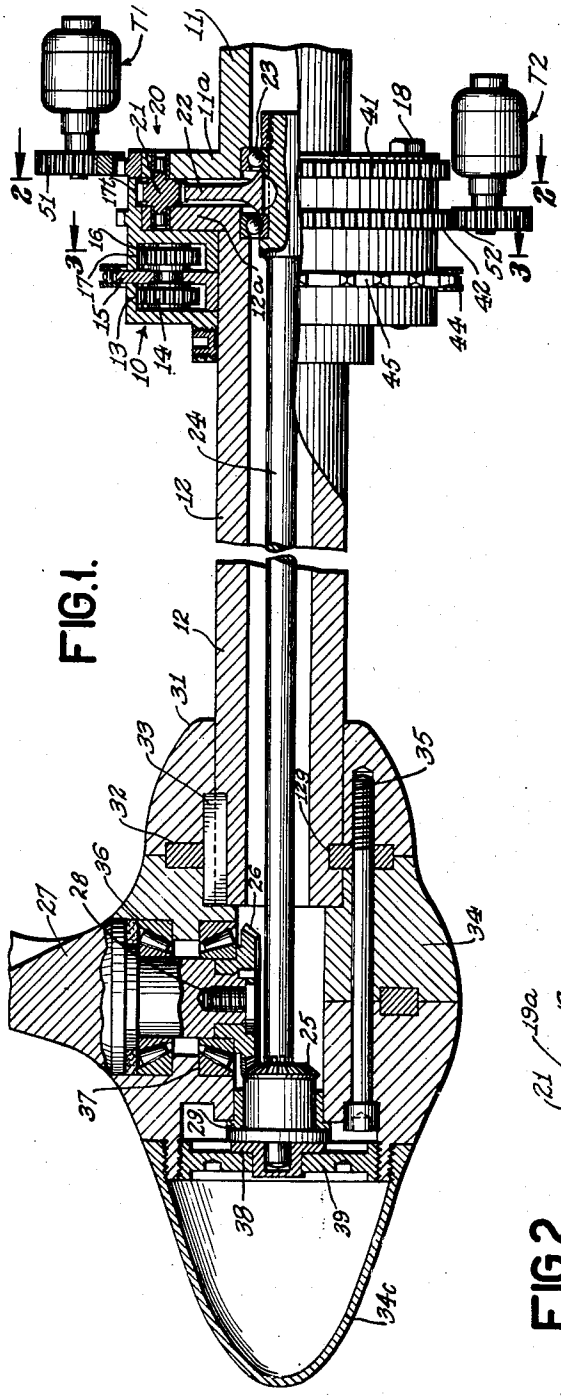


FIG. 1.

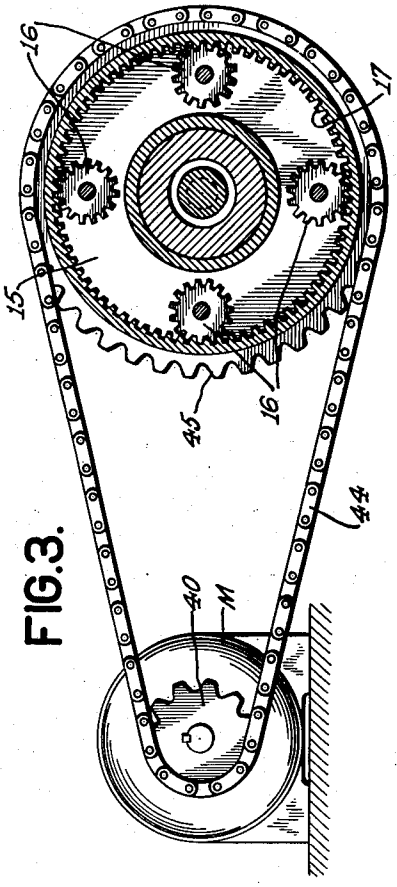


FIG. 3.

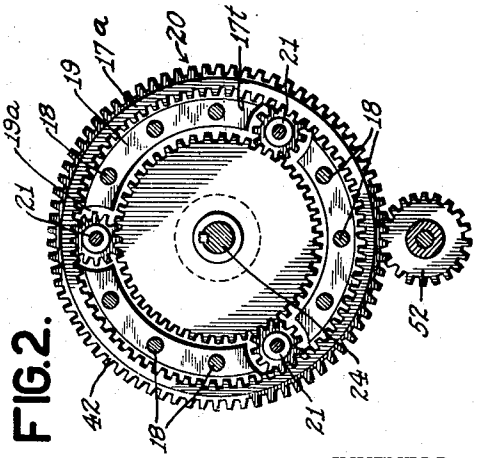


FIG. 2.

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MARINE PROPELLER STEERING SYSTEM

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3 Sheets-Sheet 2

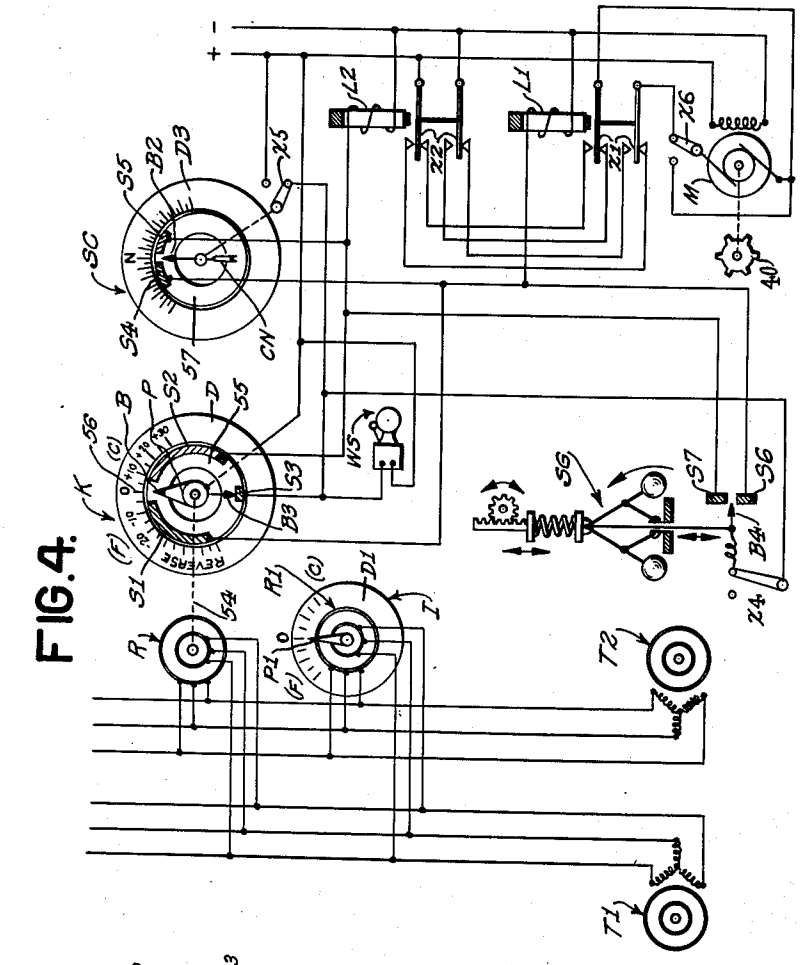


FIG. 4.

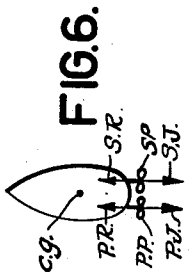


FIG. 6.

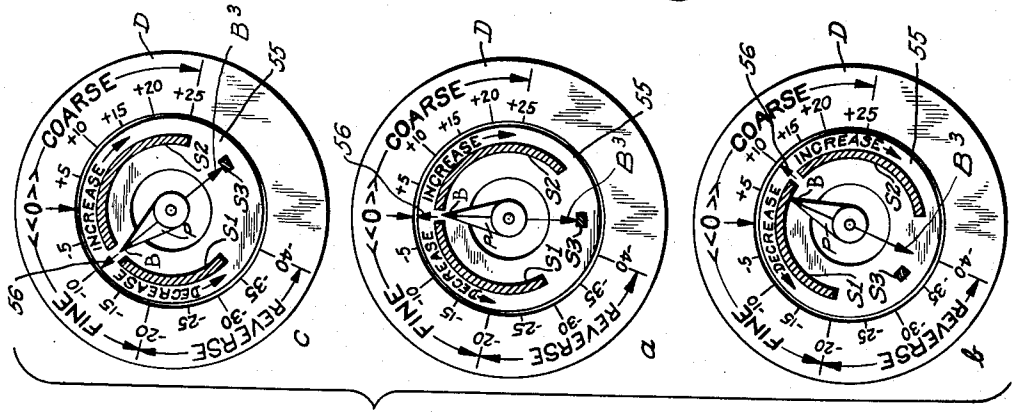


FIG. 5.

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MARINE PROPELLER STEERING SYSTEM

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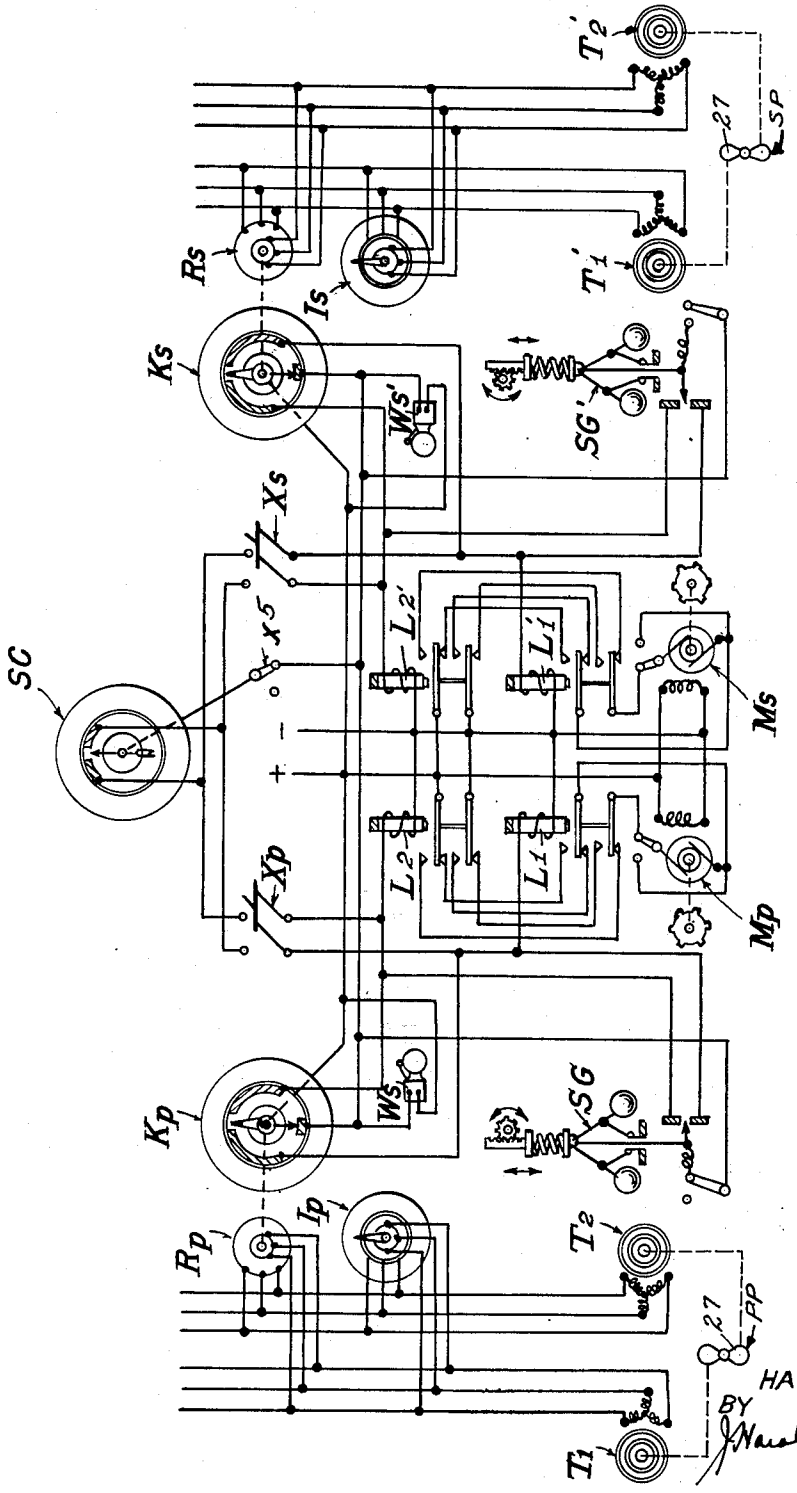


FIG. 7

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UNITED STATES PATENT OFFICE

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MARINE PROPELLER STEERING SYSTEM

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Application July 30, 1948, Serial No. 41,656

9 Claims. (Cl. 115—35)

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This application is a continuation-in-part application of my application Serial No. 433,991, filed March 9, 1942.

This invention relates to controllable and reversible pitch propeller systems for marine and naval vessels.

More particularly, it relates to mechanism for varying the pitch of the propeller blades while the propeller is stationary or in rotation under load, and a system for controlling the pitch-varying mechanism whereby the pitch can be varied manually or regulated automatically to adapt the propeller action to various operating conditions such as light or heavy loads, towing, maneuvering, stopping, backing, and constant speed operation or automatic rudderless steering by pitch regulation.

An electric master controller is provided for the remote control of the propeller pitch, as for example from the navigating bridge and other locations. Another feature of the invention is the provision of control means whereby the pitch-varying mechanism can be placed under the joint or optional control of a plurality of agencies such as an automatic speed governor, a helmsman, and an automatic pilot. Further control features are means for remotely indicating the pitch of the propeller, automatic follow-up means whereby the pitch is automatically brought to a preselected angular position and stopped there, and automatic warning signal means.

It is known of course that various types of variable-pitch and reversible-pitch marine propellers have been devised and used. These devices have met with considerable success in practice, but have been characterized by complicated construction, or by elaborate, costly, and heavy machinery, such as pressure pumps, hydraulic rams, and the like. It is a general object of the present invention to provide a controllable pitch marine propeller organization characterized by relative simplicity, reliability, durability, flexibility, high efficiency, and low cost.

Another object is to provide a practical pitch-varying mechanism whereby a relatively feeble control-torque is greatly amplified and utilized to produce a change of pitch. As a direct consequence, the amount of power required for control purposes, and the size, weight, and cost of the pitch-varying mechanism is greatly reduced, while the versatility and efficiency of the apparatus as a whole is greatly increased.

A further object is to provide a pitch-varying mechanism of unlimited angular range, including reversing the pitch, which is capable of gradually

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changing the pitch in minute increments, yet also is capable of changing the pitch at a rapid rate at will.

A further object is to provide pitch-varying mechanism which can be applied without extensive modification of the normal marine propeller and propeller shaft arrangements; which involves a minimum of change in the normal propeller design; which permits the actuating and control apparatus to be mounted conveniently inside the vessel; which is readily installed and serviced; and in general meets the rigid requirements for marine use.

Other objects will be in part obvious from the annexed drawings and in part hereinafter indicated in connection therewith by the following analysis of this invention.

This invention accordingly consists in the features of construction, combination of parts, and in the unique relation of the members and in the relative proportioning and disposition thereof, all as more completely outlined herein.

To enable others skilled in the art fully to comprehend the underlying features of this invention, that they may embody the same by the numerous modifications in structure and relation contemplated by the invention, drawings depicting a preferred embodiment of the invention form a part of this disclosure, and in such drawings like characters of reference denote corresponding parts throughout the several views, in which—

Fig. 1 is a side elevation in partial axial section of a marine variable pitch propeller and drive shaft therefor embodying certain features of the invention;

Fig. 2 is a cross-section of line 2—2 of Fig. 1;

Fig. 3 is a cross-section on line 3—3 of Fig. 1;

Fig. 4 is a schematic diagram showing the elements of the pitch control system;

Fig. 5 is a series of diagrams illustrating typical positions of the master controller dial;

Fig. 6 is an elementary diagram to illustrate the principles of rudderless steering; and

Fig. 7 is a schematic diagram illustrating the application of the invention to either or both of the propellers of a twin-screw installation.

General description

Considering the invention as a whole, and referring to Fig. 1 generally, the compound epicyclic-gear torque-amplifier 10 is mounted bodily as a unit on the propeller shaft 12, preferably inside the vessel as for example at the coupling with a drive shaft 11. The entire pitch-changing mechanism rotates bodily with the shaft at shaft

speed, the gears normally being at rest relative to each other. A radial spur-gear transmission assembly 20 (see Fig. 2), mounted in a special flange-coupling, transmits pitch-changing torque from the torque-amplifier 10 to a torsion shaft 24 mounted inside propeller shaft 12, and thence, via ring bevel gear 25 and individual blade gears 26, to the individual propeller blades 27 (of which only one is shown in Fig. 1 in order to simplify the drawings), of the twin propellers PP and SP, as in Fig. 7.

By applying a directional control torque to the planetary wheel 15 of the torque-amplifier 10, as for example by a reversible motor M and a chain drive 44, the torsion shaft 24 is caused to turn gradually in one direction or the other, whereupon the pitch is increased or decreased as the case may be. The torque-amplifier gears are self-locking, that is the torque-amplifier gear train cannot be driven backwards by the blade reaction.

The entire gear mechanism is inherently statically and dynamically balanced, a plurality of balanced pinions being employed to distribute the load reactions and to secure good teeth action. The gear mechanism as a whole is exceptionally efficient and smooth running.

The characteristics of the pitch-changing mechanism make the invention adaptable to any power, speed, or other probable propeller design requirement. The construction is such that the blade can turn indefinitely in either direction, hence the range of pitch-change is unlimited.

The power required to cause a change of pitch varies over a considerable range, depending on rate of change and operating conditions, but the external control-torque is always small compared to the augmented torque utilized for pitch-changing, say a few percent thereof. Consequently, the control motor is quite small compared to the driving equipment of other systems. Suitable remote control apparatus is provided to regulate the pitch to various operating conditions, including quick reversing and rudderless steering. The system as a whole, including the three primary control devices described, constitutes a true servo-system.

The variable pitch propeller

Referring to the drawings more in detail, and particularly to Fig. 1 in which a typical variable pitch propeller construction suitable to the invention is shown, the propeller shaft 12, mounted in bearings supported by the vessel's structure (not shown), is provided with an annular groove 12*g* adapted to receive a split ring 32 and key ways, adapted to receive keys 33 (one being shown), by which means the propeller hub 34 is secured to shaft 12. A sleeve 31, also fitted with key ways, and recessed to receive ring 32, and adapted for attachment to hub 34 by through bolts 35 (one being shown) also forms part of the hub assembly.

Propeller blades 27 (only one being shown) are rotatably mounted in hub 34 by any suitable means, such as anti-friction bearings 36 and 37, in such manner that they can be rotated axially without limit in either direction. Each blade is provided with a bevel gear 26 mounted fast on the shank thereof by suitable means such as bolt 28. A ring bevel gear 25, slidably but non-rotatably mounted on torsion shaft 24 and journalled in a bearing 29 mounted in hub 34, is held tightly in mesh with the blade gears by a thrust bearing 38 mounted on cover disc 39. The hub 34 is made in two transverse sections to facilitate assembly of the blades and their bearings therein, and is fitted with a hub cap 34*c* in the usual manner. The hub assembly is water tight and is self-lubricated by contained grease in well known manner.

The pitch-changing mechanism

Referring now to Figs. 1 to 3, the pitch-changing mechanism comprises generally the torque-amplifier 10, the transmission gear assembly 20, the torsion shaft 24, and the bevel gears 25 and 26 in the propeller hub. The drive shaft 11 is provided with a flange 11*a* spaced from a flange 12*a* on the propeller shaft 12 by a ring 19, Fig. 2, the assembly being tightly held together by through bolts 18 to form a combined shaft, coupling and gear housing. The torque-amplifier 10 comprises planetary or epicyclic differential gearing consisting of stationary internal gears 13 mounted fixedly on propeller shaft 12, driver planetary carrier 15 (herein called the planetary carrier), mounted rotatably and concentrically on shaft 12 and carrying compound planetary pinions 14—16, and driven internal gears 17 rotatably mounted on shaft 12. Gear 13 is in mesh with pinions 14 and gear 17 is in mesh with pinions 16. Gear 17 is also provided with an extension rim passing over flange 12*a* and formed with internal teeth 17*t* which mesh with pinions 21 of the transmission gear assembly. The pinions 21 are mounted in recesses 19*a* (Fig. 2), formed in ring 19 and are journalled in flanges 11*a* and 12*a* and mesh with sun gear 22 mounted fixedly on torsion shaft 24, the latter being rotatably mounted concentrically within the hollow of shaft 12 by anti-friction bearings 23 and extending therethrough to the propeller assembly. Flange 11*a* is provided with external gear 41 and gear 17 is provided with an equal external gear 42, these gears meshing with equal pinions 51 and 52 driving the rotors of rotary transmitters T1 and T2 respectively. Planetary carrier 15 is equipped with external sprocket teeth 45 adapted to cooperate with drive chain 44, driven by electric motor M by means of sprocket 40, as shown clearly in Fig. 3.

In operation, the whole gear system normally rotates bodily with the shaft, the planet pinion teeth locking the internal gears of the differential gearing in stationary relation, the chain drive and motor M turning over idly. If it is desired to change the pitch, electric current is applied directionally to motor M to cause the chain drive to drive planetary carrier 15 in one direction or the other. For example, assuming that it is desired to decrease the pitch, reverse current is applied to energize the motor M to cause planetary carrier 15 to rotate counter-clockwise relative to the propeller shaft, assumed to be rotating clockwise, the effect being to slow down planetary carrier 15. Thereupon, planet pinions 14—16 begin to roll in the adjacent internal gears 13—17 producing a slow counter-clockwise creep of gear 17 with respect to stationary gear 13. Internal gear 17*t* thereupon drives pinions 21 which in turn drive sun gear 22, whereby torque is transmitted via torsion shaft 24 to decrease the pitch of the blades. Naturally, the pitch change continues so long as planetary carrier 15 has relative rotation and at a rate proportional to such relative rotation. It should here be noted that applying braking action to cause backwards relative rotation of planetary carrier 15, as for example by connecting the motor so as to cause regenerative

braking as explained hereafter, the planetary action would be as explained above, and the pitch decreased accordingly.

To increase the pitch, motor M is energized to cause wheel 15 to speed up relative to its normal rotation. Thereupon, pinions 14—16 roll in the adjacent internal gears 13—17 to produce a with-rotation creep of gear 17 which is transmitted through the transmission as before described, but in reverse sense, to increase the pitch of the blades. As before, the pitch-change continues so long as there is relative rotation of planetary carrier 15 and at a rate proportional thereto. From the above, it is evident that the rate of pitch change can be varied over a wide range by regulating the duration of motor current and/or by varying the speed of motor M according to well-known practice. For small changes of pitch, motor M can be energized only momentarily and due to inertia of the motor and planetary drive, the relative change of speed would be small, and the pitch change micrometric. But for large changes of pitch and particularly for quick reversing during emergencies, full current can be applied to motor M for a substantial period, accelerating the motor to full speed in either direction to change the pitch at the maximum rate.

Pitch control system

Referring now to Fig. 4 which illustrates by means of a schematic diagram one application of the pitch control system of the invention, T1 and T2 represent the identical rotary electrical transmitters of Fig. 1. These rotary transmitters, similar in construction to small 3-phase induction alternators and preferably provided with permanent magnetic fields, and adapted to generate 3-phase alternating current whose frequency is proportional to speed of the rotating member of rotor. Rotary transmitters of this type being well known in the electrical art in connection with "synchro-tie" systems, detailed description of their construction here is unnecessary.

The transmitters are driven by pinions 51 and 52 meshing with spur gears 41 and 42 operatively associated with flange 11*a* of drive shaft 11 and with gear 17, respectively. These gears are cut to the same number of teeth and to the same pitch diameter. Likewise, pinions 51 and 52 of transmitters T1 and T2 are duplicates. Therefore, so long as gear 17 and flange 11*a* rotate together, transmitters T1 and T2 generate 3-phase alternating currents of the same frequency, but not necessarily in phase. These currents are distributed by 3-wire mains, as indicated, to as many rotary electrical receivers as desired, as for example R and R1. These receivers are similar in construction to small, wound-rotor, 3-phase induction motors, and being well known in the electrical art in connection with "synchro-tie" systems, detailed description here is unnecessary. It should be noted, however, that the current from one transmitter is connected to the stator windings of the receivers, while the current from the other transmitter is connected to the rotor windings of the receivers. The connections are in consistent order, following well known principles, so that the rotors of R and R1 assume an angular relation to their respective stators which represents the difference in phase between the currents produced by T1 and T2. It is to be understood that the rate of rotation of the rotors of T1 and T2 is immaterial, so far as receivers R and R1 are concerned, but that relative angular displacement of the rotors of T1 and T2 produce corresponding angular displacements of the rotors of both R and R1 with relation to their respective stators, thereby indicating angular relations between drive shaft 11 and the pitch-changing gear 17.

In ultimate analysis, the pointers of the indicating and controller devices reflect by angular position the degree of pitch change of the propeller blades relative to an arbitrary reference mark on the propeller hub. These indicating and controller devices can be provided in duplicate and located at convenient remote points, such as the bridge, pilot house, emergency station, etc. providing a control system of unusual flexibility, versatility, adaptability, and convenience.

The indicator device I, actuated by the shaft of receiver R1 and forming a part of that unit if desired, consists essentially of a rotary pointer P1 and stationary concentric dial D1 with arcuate scale graduated to indicate propeller pitch-angle relative to normal position, that is degrees fine (F) or coarse (C) with respect to an arbitrary origin. It is in effect a remote electrical pitch-angle indicator, and for brevity is hereafter referred to as the pitch indicator I.

The indicating controller device, referred to as the controller K, consists essentially of a rotary pointer P operated by the shaft 54 of receiver R, a stationary concentric dial D with arcuate scale graduated to indicate the relative pitch-angle of the propeller; and a rotatable commutator as shown in Fig. 5 comprising conducting segments S1, S2, S3, mounted on an insulated setting ring 55 rotatable concentrically with the dial. Segments S1 and S2 are positioned so as to be electrically contacted by contactor or brush B shown as integral with the dial pointer. Another brush B3 is mounted diametrically opposite P. One side of an electric current source is connected to these brushes. Segments S1 and S2 are electrically connected to relays L1 and L2, respectively, via the main control circuits. Between segments S1 and S2 is a short neutral gap bisected by index mark 56 at which point brush B is out of circuit as shown. Diametrally opposite, in a long gap between segments S1 and S2, is located segment S3, normally in contact with brush B3 and connected electrically with other automatic auxiliary control devices, such as the automatic steering compass SC and the speed governor SG. Hence the circuit from segment S3 is termed the auxiliary control circuit. The combination of brush B3 and segment S3 functions as an "off-normal" switch for the auxiliary control circuit.

Relay L1 is provided with double "break-make" contacts to form switch X1 and preferably with a slow-release device on the magnet core as indicated. The contacts of X1 when actuated carry current from the mains to the control motor M. Let it be assumed that relay L1 functions to increase the pitch as previously described, hence L1 may be termed the "coarse" relay. Relay L2, also preferably of slow-release type, is likewise provided with double "break-make" contacts to form switch X2 which when closed carries reversed current to motor M to cause the pitch to be decreased, hence L2 may be termed the "fine" relay. Furthermore, should relay L2 be energized for a prolonged period, the pitch will eventually be reversed from normal, reversing the propeller thrust. It should be noted that the contacts of relays L1 and L2 are so interconnected that in the event both relays operate, the power circuit is

opened. Hence, it is impossible for the two relays to produce a short circuit by simultaneous action.

As an emergency safety measure for marine installations, a safety switch X6 is provided which, when thrown to the alternate position, short circuits motor M, the effect of which is to apply regenerative braking thereto, which causes wheel 15 to slow down and thereby decrease the pitch. Thus in the event control were lost under circumstances requiring emergency reversing, the propeller could nevertheless be reversed by actuating switch X6. For marine installations, the emergency regenerative braking could be arranged so that should the speed increase unduly in fine pitch, the blades would be brought back quickly to a safe, coarse pitch, and operated at a suitable fixed pitch for the duration of the emergency. Other emergency measures, such as boosting the motor voltage to increase the rate of pitch change, are readily applied, due to the versatility of the pitch control system.

Manual operation

The normal manual operation of the pitch control system is as follows: Assuming that the pitch is to be increased from normal setting as at "A" in Fig. 5, that is made coarser, the rotatable setting ring 55 of controller K is turned clockwise as at "b" in Fig. 5 until the index mark 56 stands at say +10. Thereby, the auxiliary circuit is broken as brush B3 leaves segment S3 and current is applied to segment S1 by brush B (symbolized by pointer *p*), which energizes relay L1 which by actuation of the blades of switch X1 applies current to motor M to cause clockwise rotation of wheel 15 as previously described. As gear 17 is turned differentially clockwise in response to the rotation of carrier 15, the pitch is increased and transmitter T1 gains phase proportionally over transmitter T2, so that the phase change between these transmitters energizes receiver R to turn pointer P of controller K in the clockwise direction. Likewise, pointer P1 of indicator I is actuated through the system which functions as a follow-up means therefor to show the pitch change. As the pitch increases and pointer P approaches the index mark 56, brush B loses contact with segment S1, cutting off the current from relay L1. When current is thus cut off, after a brief delay relay L1 drops out, whereupon contacts X1 transfer to remove current from motor M, thereby terminating the pitch-change. (The main purpose of the brief delay in the drop-out of relays L1 and L2 is to ensure that the brushes definitely clear the segments, avoiding the possibility of destructive burning of the contact members.) As the pointer P returns to neutral position between segments S1 and S2, brush B3 returns to normal position on segment S3.

In similar manner, to decrease the pitch, the setting ring 55 is turned the desired amount counter-clockwise in the dial as at "c" in Fig. 5. Thereupon, relay L2 is energized from segment S2 actuating contacts X2 to put reverse current on motor M which drives wheel 15 in the reverse direction. This results in easing or reversing the pitch as previously described. As the pitch change progresses, the pointers P and P1 are turned counter-clockwise accordingly by the receivers R and R1, and eventually the circuit relay L2 is broken at neutral gap G. Thereupon, relay L2 drops out, and switch X2 cuts current off motor M, terminating the pitch change. Obviously, the pitch can be altered in either direction at will regardless of the prior change. It is evident that merely by manipulation of controller K the propeller pitch can be varied effectively to maneuver a vessel in docking, as well as for stopping and backing.

Thus it is to be noted that merely by moving the setting ring 55 to the selected pitch indication, the proper devices are selectively energized and actuated to cause the propeller pitch to be changed a corresponding amount in the proper direction, whereupon the pitch changing operation is automatically terminated. This constitutes the pitch responsive automatic follow-up and cut-off feature, as essential to a true servo-system.

Constant speed operation

Referring again to Fig. 4, the primary control element for constant speed operation is preferably a centrifugal governor SG of flyweight type driven by the propeller engine at a speed proportional to the engine speed. The principles and construction of flyweight governors being well known, extensive description here is deemed unnecessary. In this case, the governor actuates a contactor or brush B4 connected in the auxiliary control circuit and adapted to make electrical contact alternately with segment S6 or segment S7. A suitable speed adjusting mechanism is provided to adjust the tension of the governor speed-spring, so that at the desired speed level brush B4 rests in the neutral gap between the segments S6 and S7 as shown.

The operation to establish and maintain a constant speed is as follows: Assuming that the engine throttle has been set at the approximate speed, the governor SG is set at the desired speed, and the governor slides brush B4 up or down, according to the existing speed. Assuming that the speed is too low, brush B4 will rest on segment S7 which being electrically connected with the "fine" relay L2 will energize the same and cause the pitch to be decreased as before described. Decreasing the pitch enables the engine to run faster at the same throttle setting, hence the engine speed increases and brush B4 moves toward the neutral gap. At substantially calibrated speed, the various factors come into balance with brush B4 in the neutral gap and the propeller operating at fixed pitch. But should the speed change, the governor reciprocates brush B4 to selectively energize relay L1 or L2 as required to regulate the blade pitch to maintain constant engine speed.

It is to be noted, however, that should the pitch be changed beyond a minor amount, brush B3 will lose contact with segment S3, opening the auxiliary control circuit so that the current supply to brush B4 will be cut off, terminating the control of governor SG. It is also to be noted that the reaction of the pitch change on the governor causes the latter to terminate the control cycle. Thus, the system under the primary control of the governor constitutes a servo-system.

Automatic rudderless steering

The facility and precision with which the propeller pitch can be controlled by this invention makes possible and practical "automatic rudderless steering" of twin-screw vessels by pitch regulation of the propellers. For that purpose, only slight additions to the apparatus already described is required. Accordingly, the rudderless steering operation, which naturally requires two propellers, can be clearly explained

by describing the actuation of a single propeller of a twin-screw installation by the means of the invention.

The principle of automatic rudderless steering can be readily understood by referring to Fig. 6 which shows in elementary manner the normal forces acting on a twin-screw vessel due to the action of its propellers, the port propeller being indicated by PP and the starboard propeller by P. The essential fact is that in driving the vessel ahead each propeller accelerates a stream or jet of water astern, producing a forward thrust on the propeller which pushes the ship ahead. So long as the jets are in equal momentum, the thrusts are balanced, and the vessel tends to move ahead in a straight line. But if the jets become unequal, the unbalanced thrusts produce a turning movement of the vessel around its center of gravity C. G. which diverts the course into a curve, thus producing a steering effect. Unequal jets can be produced by unequal speeds and/or unequal pitches of the two propellers. But for present purposes, and preferably in practice, the speeds of the propellers are assumed to be equal, and steering to be effected by regulating the pitch of either or both propellers slightly, herein termed pitch regulation, according to steering conditions. However, it is to be understood that the speeds and pitches of the propellers can be varied greatly and the pitches reversed, for producing radical changes of course or for maneuvring.

For purposes of automatic steering by pitch control, termed "automatic rudderless steering," the primary regulation element of the "automatic pilot" control arrangement is a special steering compass indicated as SC in the diagram of Fig. 4. This compass is preferably equipped with a rotatable setting ring **57** carrying electrical contacts whereby control currents are transmitted to the electrical pitch control apparatus. The needle CN of the steering compass of course always tends to point to true north (N), while the settable compass ring **57** turns around the needle as the vessel turns. The needle CN is equipped with a contact brush B2, symbolized by the arrowhead, adapted to make electrical contact with two short segments S4 and S5 mounted on setting ring **57** and separated by a neutral gap. Needle CN is normally connected to the auxiliary control circuit leading from segment S3 of controller K, while segments S4 and S5 connect with the windings of relays L1 and L2 respectively. Ring **57** is set so that the needle CN centers in the neutral gap when the vessel is on the desired course. Hence, as the vessel turns away from the course to which the ring **57** is set, one or the other of the relays is energized by the control circuits leading from the segments.

Illustrative of the operation of the pitch control apparatus for automatic rudderless steering, let it be assumed that the vessel is steady on its set course heading true north, that the speeds and the pitches of the twin propellers have been equalized, and that the needle CN is steady in the neutral gap between segments S4 and S5. The automatic pilot apparatus is therefore inactive. Should the vessel veer to the right, segment S4 would be brought into contact with brush B2, thereby applying energizing current to relay L1 which applies operating current to motor M to increase the pitch of the blades of the starboard propeller. The momentary effect of this increase of pitch will be to cause the starboard propeller SP in Fig. 6 to propel a stronger jet rearwardly, and hence the starboard thrust on the vessel will be increased, tending to turn the vessel to the left, that is, back to its original course. Should over-correction occur, the compass needle CN will contact segment L to energize relay L2, thereby to decrease the pitch and reduce the starboard thrust, resulting in a counter correction. The steering compass SC thus function to keep the vessel on the set course by initiating minor regulations of the propeller pitch. It is to be noted that the response of the controlled element, in this case the vessel, reacts on the primary control element, the compass, to terminate the control cycle. Therefore, in this case as in the prior cases, the system functions as a true servo-system.

The automatic warning signal

During the automatic steering process (and during constant speed operation), the pointer P of the master controller K will perform short excursions to either side of the zero "0," but brush B3 will normally retain contact with segment S3, enabling SC to regulate the pitch. But should the pitch variations tend to accumulate in one direction or the other, or a major departure from the set course occur, brush B3 will lose contact with segment S3, breaking the auxiliary control circuit and SC will therefore lose control. In that event, a special warning signal circuit will be energized from either segment S4 or S5, as the case may be, and the warning signal WS will be actuated. It will be noted that the warning signal WS, preferably a relatively high impedance device such as a telephone bell, is connected in series with a circuit from the (+) power main to the auxiliary control circuit from segment S3. Thus when the auxiliary control circuit is broken at S3, but the main control circuit is closed at S4 or S5, current will flow from (+) power through WS via S4 and L1, or S5 and L2, to (−) power. If desired, it can be so arranged that the operating current for WS is less than the required operating current for L1 and L2 so that the latter are not affected by the warning signal current.

In this connection, it should be noted that in any case where the vessel is not brought back to the set course by a small change of pitch, the warning signal WS will give notice of the fact. Thus attendants will be apprised of the manual circumstances and proper corrective measures can be taken, as for example by promptly returning the vessel to the set course by manipulation of the master controller. This constitutes the automatic "off-course" warning signal feature.

During constant speed operation under the control of governor SG, should the circuit be broken at segments S3 by a marked change of pitch, but closed at segment **6** or segment **7**, the warning signal WS will be energized to give warning of loss of governor control. This constitutes the automatic "off-speed" warning signal feature.

Cut-out switches X4 and X5 are provided to put the speed governor SG and the steering compass SC out of action if desired. However, it is deemed preferable to have master controller K ready to function at all times, so that the propeller pitch is automatically maintained at or near the desired value. Thus, for example, should the steering compass SC tend to produce an abnormal degree of pitch change, master control K will automatically take charge to limit the pitch change, thus providing a safeguard

against wild steering. Hence no cut-out switch is shown for the master controller, although such a switch could obviously be provided if desired.

Twin screw control

Referring now to Fig. 7 which illustrates the application of the pitch control system of the invention to either or both of the two controllable reversible pitch propellers of a twin screw installation, the schematic diagram there shown comprises substantially the diagram of Fig. 4 and a mirror (horizontally reversed) copy of that diagram placed to the right thereof. The circuits on the left of the power mains marked (+) and (−) respectively represent the controls for the port propeller and those on the right represent the controls for the starboard propeller. It follows of course from the foregoing description that one steering compass SC can be utilized to control either one or both of the propellers of a twin screw installation for purposes of automatic rudderless steering.

Referring to Fig. 7 in detail, double pole switches Xp and Xs are provided for putting the single steering compass SC alternatively in control of either one or both of the propeller pitch changing systems for purposes of automatic rudderless steering. The circuits associated with switch Xp connect SC operatively to relays L1 and L2, which in turn control port pitch changing motor Mp; and the circuits associated with switch Xs connect SC operatively with identical relays L1′ and L2′ which in turn control starboard pitch changing motor Ms. These relays function as described in connection with the diagram shown in Fig. 4, and all the additional elements of apparatus are mere duplicates of those shown in Fig. 4, hence detailed description of the apparatus is not required.

In automatic rudderless steering of a twin screw vessel, the steering effects of the two propellers are relatively reversed, that is, an increase of thrust of one propeller produces substantially the same steering effect as a decrease of thrust of the other propeller and vice versa. Hence it should be noted that in Fig. 7 the steering compass SC is connected to the control relays L of the port controls inversely with respect to the control relays L of the starboard controls. The control arrangements illustrated provide three optional conditions for automatic rudderless steering. If only switch Xs is closed, the starboard propeller is controlled by steering compass SC to effect automatic rudderless steering as described in connection with Fig. 4. If only switch Xp is closed, the port propeller is controlled by steering compass SC to effect automatic rudderless steering; control relays L1 and L2, however, being actuated inversely. If both switches Xs and Sp are closed, both propellers are controlled as before by compass SC to effect automatic rudderless steering. In the last instance, however, more steering action would as a rule be exercised in bringing the vessel back to the preset compass course. Hence, in practice, the choice between the three optional control set-ups will as a rule be governed by the sea and weather conditions, and the tendency of the vessel to be set off its course in one direction or the other.

It will be obvious to those skilled in the art that substantial increased average vessel speed and savings in propulsion power, as well as saving wear-and-tear on the steering engine, will result from the application of automatic rudderless steering. This follows mainly from the fact that a rudder produces considerable drag when acting to steer a vessel, or when a certain rudder angle is required to hold the vessel on its course, while controlling the pitch for steering does not introduce any additional drag.

It will be evident to those skilled in the art that the pitch control apparatus described provides exceptional flexibility and versatility of control, and that various control functions can be obtained by combining the control elements in various ways. Therefore it is unnecessary to describe the various switching arrangements by which these combinations can be effected.

Without further analysis the foregoing will so fully reveal the gist of this invention that others can, by applying current knowledge, readily adapt it for various applications without omitting certain features that, from the standpoint of the prior art, fairly constitute essential characteristics of the generic or specific aspects of the invention, and therefore such adaptations should and are intended to be comprehended within the meaning and range of equivalency of the following claims.

I claim:

1. In a propulsion system for a twin screw vessel, in combination, means for driving said vessel including a pair of controllable propellers, individual means for varying the pitch of each of said propellers including an electric motor drivingly connected to said pitch varying means, and automatic electrical control means operatively connected in control relation to one of said motors for controlling said one motor for purposes of steering said vessel automatically comprising a compass responsive to a change of course of said vessel having a fixed direction element and electrical contacting means operatively connected therewith, course setting means carrying electrical contacts adapted for alternate coaction with said contacting means of said compass in accordance with a change of course of said vessel, and means operatively connected to and being under joint control of said course setting means and said compass element for controlling said motor whereby the pitch is varied to steer said vessel on a preset course.

2. In a propulsion system for a twin screw craft having a pair of variable pitch marine propellers, power means connected to drive each propeller, and individual power means operatively connected to vary the pitch of each of said propellers, the combination comprising pitch control means operatively connected to actuate independently each of said individual power means, and automatic pilot steering means operatively associated with either or both of said pitch control means for purposes of steering said craft automatically on a set course, said automatic pilot steering means including compass means for detecting deviations of said craft from a set course, course setting means operatively associated with said compass means, and means operable to connect said compass means and said course setting means so as to actuate either or both of said pitch control means to correct said deviations, whereby the relative pitch of said propellers can be automatically regulated to maintain said craft on a set course.

3. In a propulsion system for a twin screw craft of the kind including motive means for driving said craft, a pair of controllable pitch marine propellers driven thereby, power means individual to each propeller operatively connected to vary the pitch thereof, and pitch con-

trol means operatively connected to actuate independently each of said individual power means; automatic pilot steering means adapted to actuate either or both of said pitch control means for purposes of steering said craft automatically on a set course, including compass means for detecting deviations of said craft from a set course, course setting means operatively associated with said compass means, and means for connecting said compass means and said course setting means to actuate either or both of said pitch control means so as to correct said deviations, whereby the pitch of either or both of said propellers can be automatically regulated to maintain said craft on a set course.

4. In a propulsion system for driving a vessel including a pair of controllable pitch propellers having substantially parallel propeller shafts located on opposite sides of the center line of said vessel and each having blades rotatable about their own axes; the combination of power means individual to each propeller operatively connected to rotate axially the blades thereof; individual pitch control means operatively connected to each of said power means for controlling independently each of said power means and thereby to vary the pitch of the blades of the associated propeller; and automatic pilot apparatus operatively associated with said pitch control means, including compass means for indicating the course of said vessel and responsive to a change of course thereof, settable means operatively associated with said compass means for presetting a desired course of said vessel, and means jointly actuated by said compass means and said settable means for automatically regulating either or both of said power means and thus the relative pitch of said propellers, whereby the vessel can be automatically steered on a preset course by pitch regulation.

5. In a propulsion system for a vessel including a pair of controllable pitch propellers located on opposite sides of the center line of said vessel and individual pitch changing mechanisms operatively connected to each of said propellers for changing the pitch thereof, the combination of individual pitch control means operatively connected to each of said mechanisms thereby to vary independently the pitch of said propellers, and automatic pilot apparatus operatively associated in supervisory control relationship to said pitch control means for regulating either or both of said pitch control means and thus the relative pitch of said propellers as required to automatically steer said vessel on a preset course solely by pitch regulation.

6. In a propulsion system for a twin screw vessel including controllable pitch twin propellers and individual mechanisms for changing the pitch of each of said propellers, in combination, individual pitch control means operatively connected to each of said individual mechanisms for varying independently the pitch of said propellers, and automatic pilot apparatus operatively associated in supervisory control relationship to said pitch control means and being selectively connectable to said individual pitch control means singly or jointly, thereby to regulate the relative pitch of said propellers so as to steer said vessel on a set course.

7. In a propulsion system for a twin screw vessel including a pair of controllable pitch propellers for driving said vessel, the combination of individual power means having a driving connection to each propeller for changing the pitch thereof, individual pitch indicating and controller means including a master pitch controller operatively connected to each of said individual power means and adapted to vary independently the pitch of each propeller and follow-up pitch indicating means for continuously indicating the pitch of each associated propeller during maneuvering of said vessel, and auxiliary automatic pilot apparatus operatively associated with said pitch control means, and including means for presetting a selected vessel course and means for detecting deviations from said course, for regulating said individual pitch control means singly or jointly so as to counteract such deviations, thereby to steer said vessel on the selected course solely by pitch regulation.

8. In a propulsion system for a twin screw vessel including a pair of controllable pitch propellers and individual mechanism for changing the pitch thereof, the combination comprising pitch control means operatively connected to each said mechanism including for use during maneuvering of said vessel, a pitch setting means and a juxtaposed follow-up pitch-change indicating and pitch-change cut-off element for setting and indicating the pitch of each said propeller individually and for cutting off said pitch-changing means upon the pitch of said propeller having been changed in accordance with the setting of the pitch-setting means, and settable automatic pilot apparatus operatively associated in supervisory control relationship to said pitch control means for controlling selectively said pitch control means singly or jointly thereby to regulate the relative pitch of said propellers as required to steer said vessel on a preset course solely by pitch regulation.

9. In a propulsion system for a twin screw vessel including a pair of controllable pitch propellers, individual mechanism operatively connected to each of said propellers for changing the pitch thereof, individual power means having a driving connection to each said pitch changing mechanisms, individual pitch control means including a settable master pitch controller and an associated follow-up pitch indicating means operatively connected to each of said power means for varying and indicating the pitch of each propeller independently during maneuvering of said vessel, settable automatic pilot apparatus adapted to modify the action of said individual pitch control means as required to steer said vessel on a preset course, and means for connecting said automatic pilot apparatus with either or both of said master pitch controllers as required to maintain the vessel on said preset course.

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