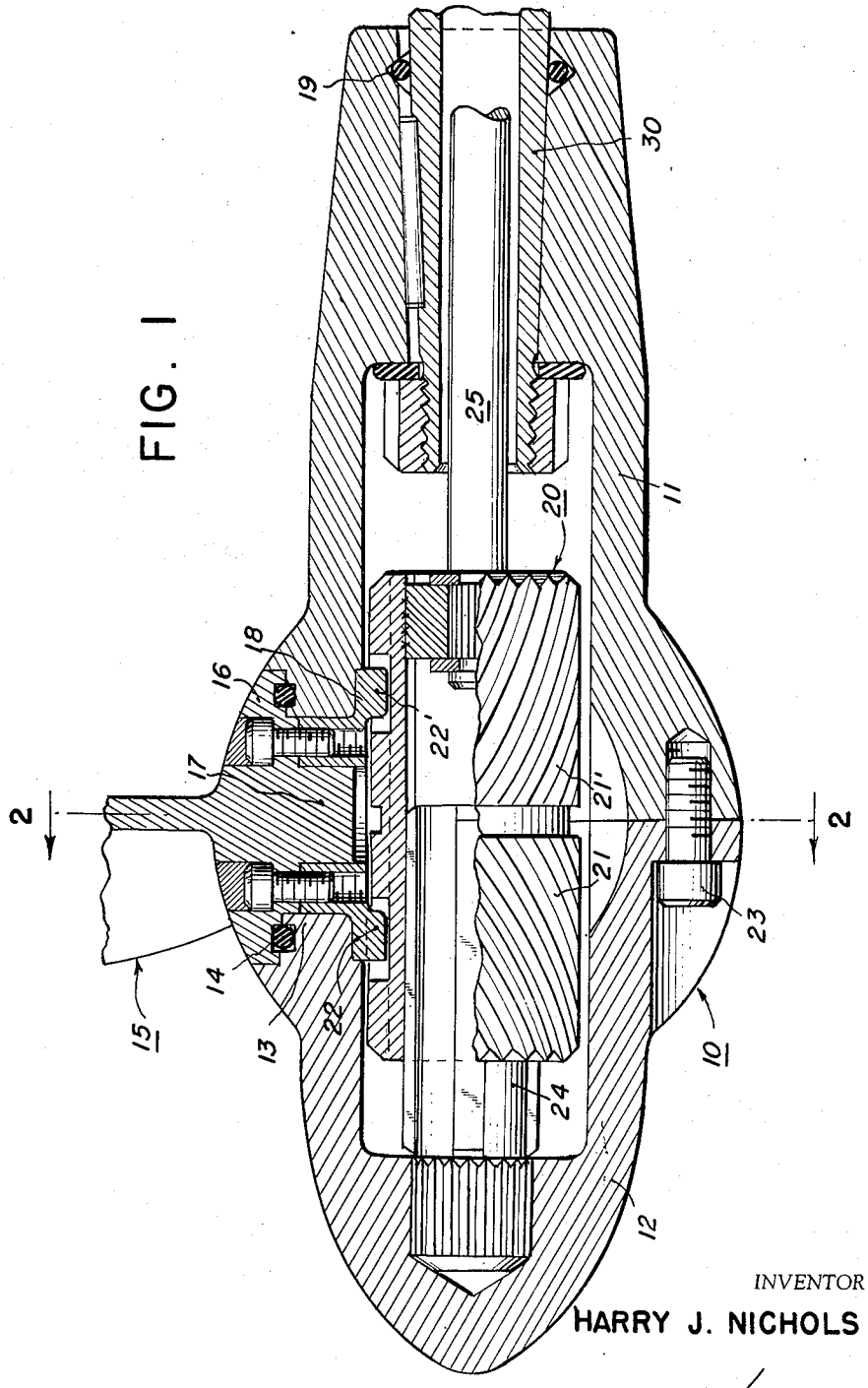
March 2, 1954 H. J. NICHOLS 2,670,805

CONTROLLABLE REVERSIBLE PITCH PROPELLER

Filed March 20, 1947 5 Sheets-Sheet 1

FIG. 1



INVENTOR
HARRY J. NICHOLS,

BY J. Harold Nicholson

ATTORNEY

March 2, 1954 H. J. NICHOLS 2,670,805

CONTROLLABLE REVERSIBLE PITCH PROPELLER

Filed March 20, 1947

5 Sheets-Sheet 2

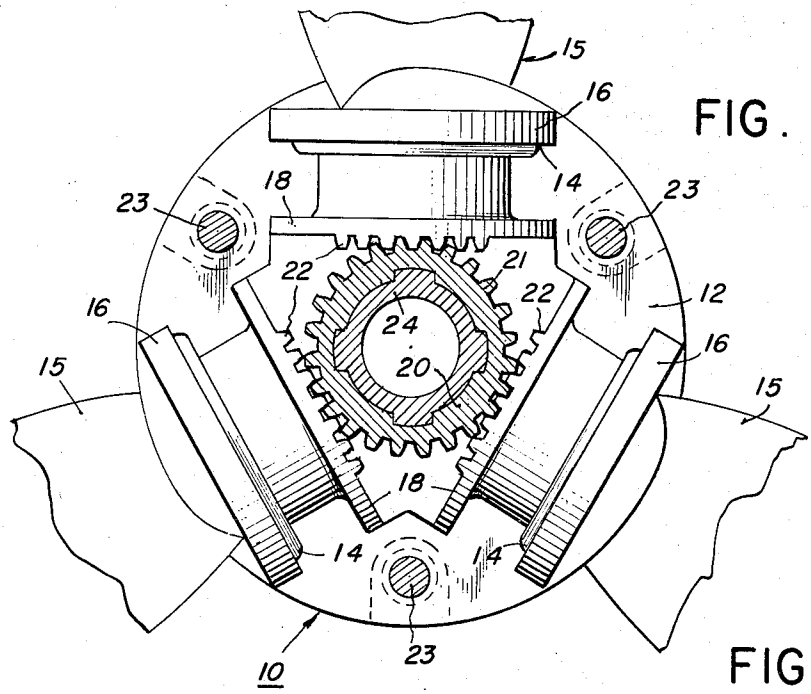


FIG. 2

FIG. 3

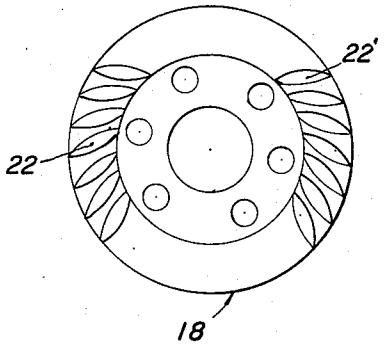
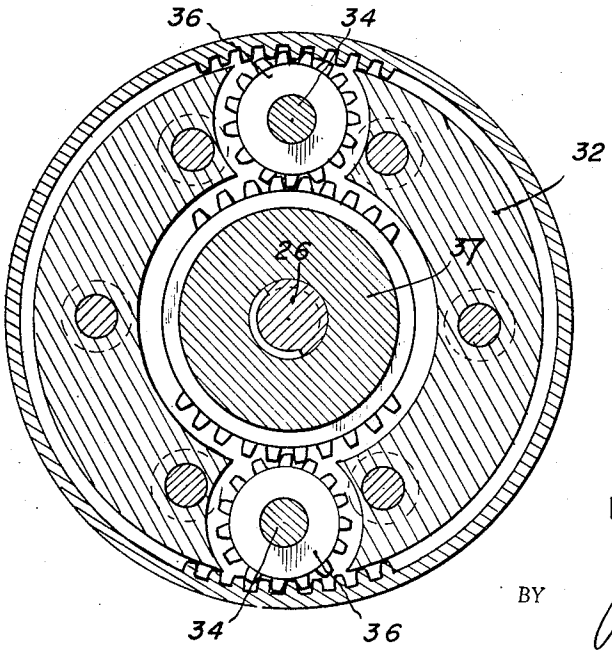


FIG. 5



INVENTOR

HARRY J. NICHOLS,

BY J. Harold Kiesau & Co

ATTORNEY

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CONTROLLABLE REVERSIBLE PITCH PROPELLER

Filed March 20, 1947 5 Sheets-Sheet 3

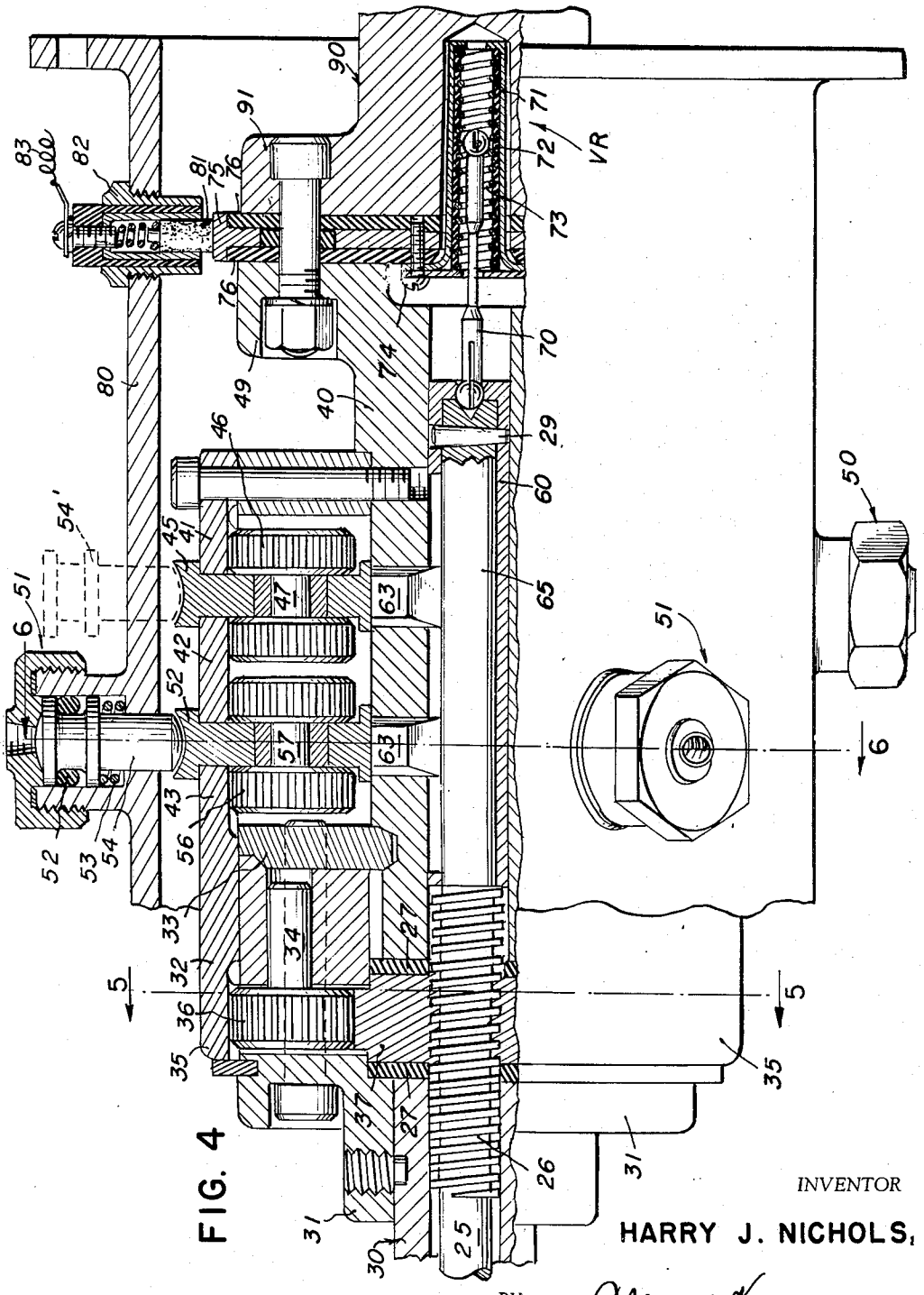


FIG. 4

INVENTOR

HARRY J. NICHOLS,

BY

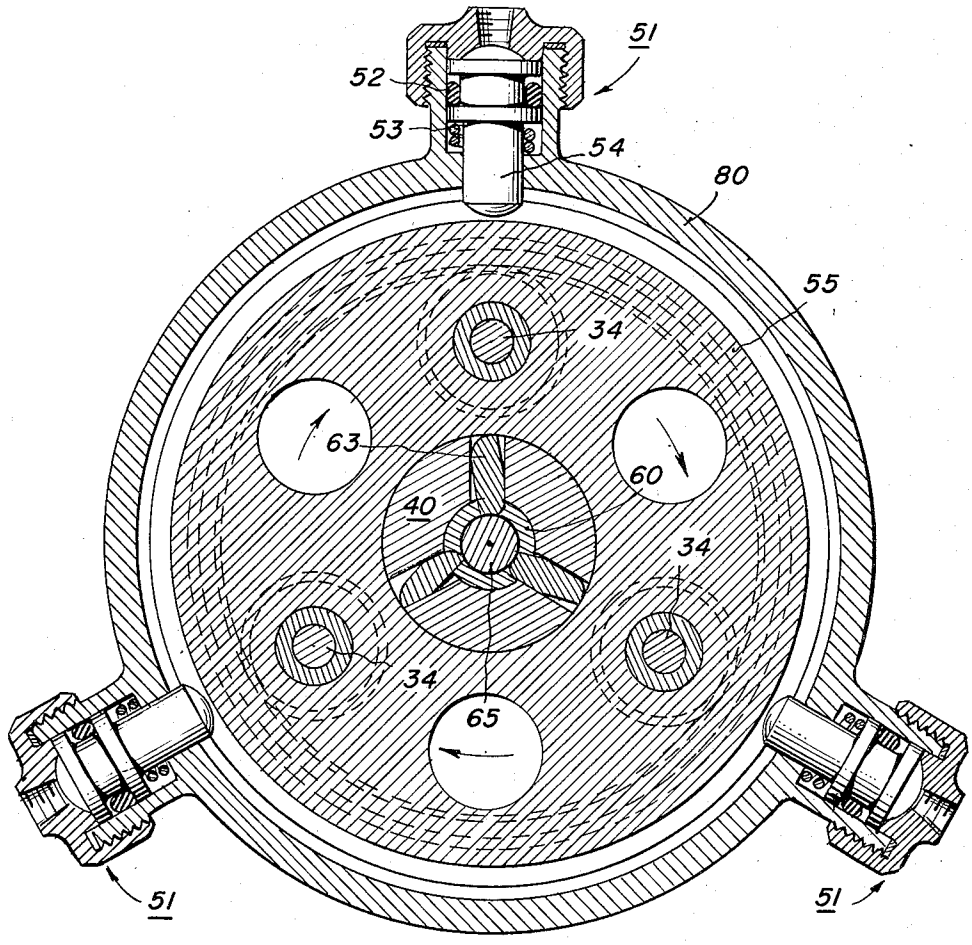
ATTORNEY

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CONTROLLABLE REVERSIBLE PITCH PROPELLER

Filed March 20, 1947 5 Sheets-Sheet 4

FIG. 6



INVENTOR
HARRY J. NICHOLS,

BY J. Harold Kilcoyne

ATTORNEY

March 2, 1954 H. J. NICHOLS 2,670,805

CONTROLLABLE REVERSIBLE PITCH PROPELLER

Filed March 20, 1947

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FIG. 7

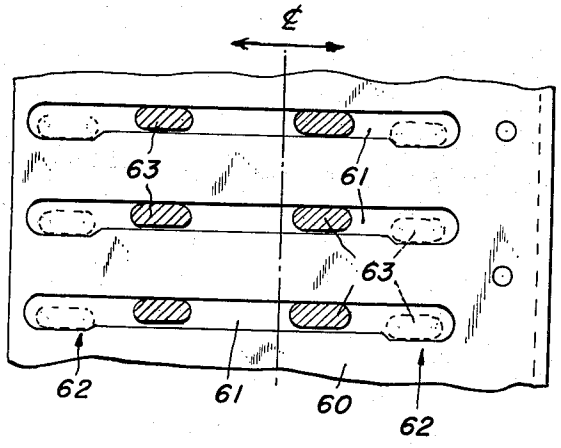
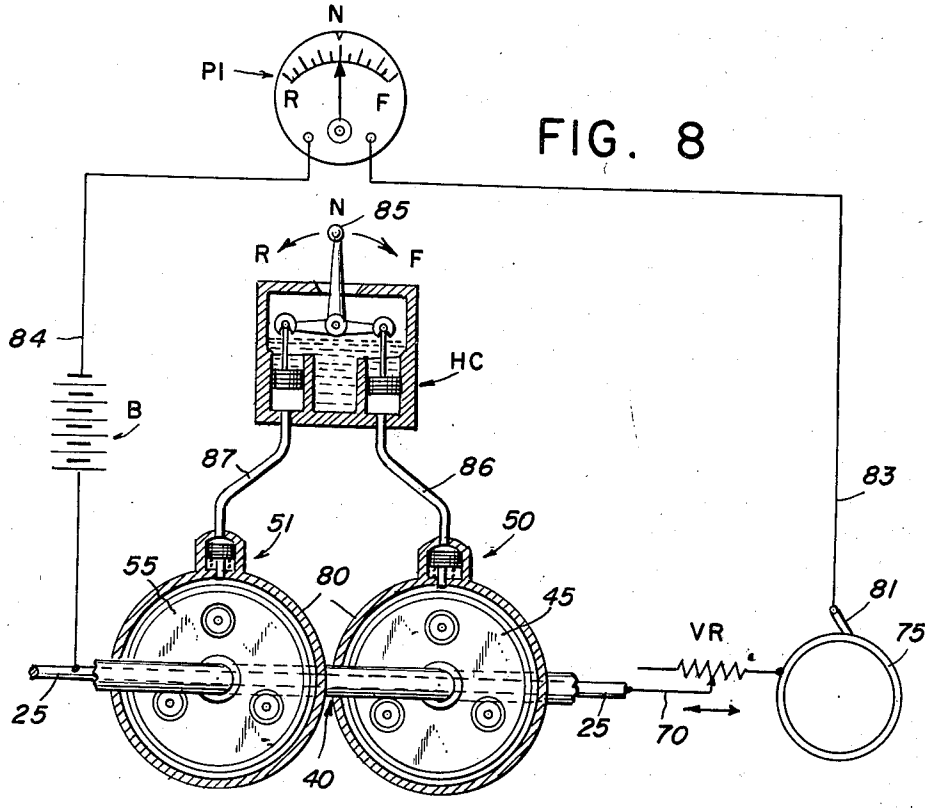


FIG. 8



INVENTOR

HARRY J. NICHOLS,

BY J. Harold Kearney

ATTORNEY

Patented Mar. 2, 1954

2,670,805

UNITED STATES PATENT OFFICE

2,670,805

CONTROLLABLE REVERSIBLE PITCH PROPELLER

Harry J. Nichols, Point Pleasant, N. J.

Application March 20, 1947, Serial No. 735,980

16 Claims. (Cl. 170—160.22)

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This invention relates to controllable reversible pitch propeller systems and more especially to such propellers for use on marine vessels, and has for its main object the provision of a propeller of the character described in which the pitch of the blades can be readily and accurately varied, and also reversed, while the propeller is in rotation under load.

Another object is to provide an exceptionally simple, compact, and durable pitch changing mechanism which is economical to manufacture, easy to install and service, and which embodies pitch limiting and pitch indicating devices, and other practical features to facilitate operation by unskilled and non-technical operators.

Another object is to provide a strong and rugged blade turning mechanism adapted to be housed within a propeller hub of relatively small diameter which will have a minimum of working parts and will hold the blades rigidly, thereby avoiding any possibility of flutter or vibration of the blade in operation due to excessive back-lash or elasticity; and which will also automatically lock the blades against being turned by external forces at any position of pitch adjustment.

Another object is to provide a torque-amplifying actuating mechanism for driving the blade turning mechanism which is self-energizing, that is, it derives its operating torque from the propeller shaft; and which is adapted for remote control.

Another object is to provide a pitch varying mechanism of adequate angular range, including reversing, which is capable of changing the pitch in micrometric increments when desired, yet also is capable of changing the pitch at a rapid rate for maneuvering and meeting emergencies.

Yet another object is to provide a pitch changing mechanism in which the actuating mechanism is relieved of any strain except when the pitch is being changed, thus reducing wear and enabling relatively light mechanical parts to be employed.

A further object is to provide a mechanical pitch limiting device to prevent the pitch being varied beyond the proper operating range, and an electrical pitch indicating device to indicate visually at all times the pitch of the blades.

With these and other objects in view, as well as other advantages incident to the improved construction, the invention consists in various novel features and combinations thereof set forth in the claims with the understanding that the several necessary elements constituting the same may be varied in proportion and arrangement

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without departing from the nature and scope of the invention as defined in the appended claims.

To enable others skilled in the art to comprehend the underlying features of this invention that they may embody the same by suitable modifications in structure and relation to meet the various practical applications contemplated by the invention, drawings showing a preferred embodiment of the invention form part of this disclosure, and in such drawings like characters of reference denote corresponding parts in 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 transverse sectional view taken substantially on lines 2—2 of Fig. 1.

Fig. 3 is a detail view of the inner end of a blade root showing the novel crown gear of the invention.

Fig. 4 is a side elevation in partial cut away section of the propeller shaft coupling and power mechanism forming part of the invention.

Figs. 5 and 6 are transverse sectional views taken substantially on lines 5—5 and 6—6 respectively, of Fig. 4.

Fig. 7 shows the pitch limit cam sleeve in flat development to illustrate the principle of the control of the pitch block device of the invention.

Fig. 8 is a schematic diagram illustrating the features and mode of operation of the control apparatus.

Description

Considered as a whole, and referring generally to the drawings, the construction of the invention constitutes a complete machine comprising two main units; namely a propeller hub assembly including mechanism housed within the propeller hub for turning the propeller blades axially in unison, as shown in Fig. 1; and a shaft coupling assembly including torque-amplifying power mechanism for actuating the blade turning mechanism located within the vessel, as shown in Fig. 4. A tubular propeller shaft and a connecting rod, slidably mounted coaxially in the propeller shaft and moved by the power mechanism, operatively connect these two main units. The invention also includes control apparatus for controlling the pitch of the propeller blades from a remote station, including means for indicating the pitch visually.

Referring now to the drawings in detail and particularly to Figs. 1 and 2, the hub assembly of

the invention is shown as including a two-piece hollow hub 10 having a forward driving portion 11 which is tightly fixed to the tubular propeller shaft 30 by a tapered, keyed connection and retainer nut in conventional manner as shown, or by other suitable construction. A gasket 19 is provided to prevent leakage at the hub and shaft connection. The after part or cap 12 of the hub is tightly fixed to the forward part 11 by a plurality of longitudinally extending cap screws 23 located intermediate the blades as shown in Fig. 2. This hub structure mounts the blades and houses the blade turning mechanism.

The hub as a whole is formed with a plurality of radially extending bores comprising inner and outer circular seats and an intermediate annular shoulder 13. Blades 15, each having a circular boss 16 and cylindrical root 17, are rotatably secured in the radial bores; each blade having a flanged blade gear 18 mounted concentrically on its root portion and fixed thereto by means of cap screws extending through the boss as shown. A packing or seal 14 of any preferred type is assembled between the blade boss 16 and shoulder 13 to prevent leakage of lubricant and entrance of water into the hub. Obviously, the gear 18 could be made integral with the blade root. The two-piece construction shown, however, permits of the gear being made of a harder and stronger metal than that of the blades, and facilitates manufacture.

The blades 15 can be rotated about their axes in the hub to vary their pitch in unison by means of novel mechanism now to be described. A combined gear and wedge 20 of hollow cylindrical form and having external herringbone gear teeth 21, 21' as shown, is mounted for reciprocation axially in a closed axial bore formed in the two parts of the hub. Wedge 20 is demountably fixed on the outboard end of connecting rod 25 by means of a tight splined connection and retainer rings, as shown, or in any other desired manner provided the connecting rod is not permitted to rotate. Wedge 20 has a splined internal bore adapted to slide without turning on a mating externally splined guide stud 24 fixed axially in the hub cap 12, preferably by pressing the knurled end of the stud into an internal axial hole drilled in the hub cap from inside as shown. This construction enables the wedge 20 to be reciprocated by the connecting rod 25, but neither the wedge nor the connecting rod can turn relative to the hub.

Referring to Figs. 2 and 3 in connection with Fig. 1, each of the blade gears 18 is provided with two sets of skewed crown teeth 22, 22', which teeth are adapted to engage successively with the herringbone teeth 21, 21' of wedge 20 in the usual manner of gear teeth. These two sets of teeth are located in opposite arcs of a common concentric circle and diametrically opposite teeth are inclined oppositely at the same angle of inclination as the herringbone teeth. (See Fig. 3.) As is well understood, the contour of the crown teeth must be conjugate to that of the herringbone teeth in order to provide proper meshing. The faces of the crown teeth are somewhat rounded, so as to avoid interference in action between the meshing teeth due to the perpendicular axes of the herringbone and crown gears.

It will be evident from the drawings that with the construction shown, the blades 15 will be turned axially in unison when wedge 20 is translated axially by connecting rod 25. The wedge acts directly on the blade gears, hence intermediate gears as in the prior art are unnecessary, thus promoting simplicity and compactness while minimizing back-lash. It is also to be noticed that the novel mechanism described enables the wedge to act simultaneously in the same rotary direction on teeth of the blade gears located diametrically opposite, thereby applying a torque couple to turn each blade, rather than merely a single torque force. This feature is highly advantageous, since it tends to reduce greatly the load on the blade bearings incident to pitch change. It also provides a double operating connection between the wedge and the blades, doubling the strength of this connection and reducing wear. It is further to be noticed that although the wedge can turn the blades axially, the blades cannot rotate the wedge about its axis, because one set of crown teeth tends to rotate the wedge in the opposite direction from the other. The rotary action between the herringbone and crown gears is therefore irreversible and the only effective motion that the blades can impart to the wedge is that of axial translation. Moreover, the wedge turns the blades at a mechanical advantage due to the inclined plane effect provided by the sloping teeth, while the axial reaction of the blades is correspondingly reduced.

The cavity of hub 10 is preferably provided with a supply of lubricant, such as light grease or solidified oil, to provide lubrication for the working parts of the mechanism in the hub.

Referring now to Fig. 4 which shows the power mechanism for reciprocating connecting rod 25, this mechanism is carried by an assemblage of parts serving as a coupling for connecting propeller shaft 30 to drive shaft 90, as for example an engine shaft. Drive shaft 90 is shown as being provided with a conventional upset flange 91, while propeller shaft 30 is preferably provided with a separable flange 31 of any desired construction. The coupling members comprise a short hollow coupling shaft 40 having an integral flange 49 at the driving end, and at the propeller shaft end a demountable coupling ring 32 keyed to the coupling shaft and held against axial movement by a split lock-plate 33 whose inner perimeter is let into an annular groove in the coupling shaft. The flange 31 and the coupling ring 32 and lock-plate 33 are strongly clamped together by plural bolts in well known manner.

The inboard end of connecting rod 25, which extends into the coupling section, is formed with strong screw threads located some distance from the end to provide a screw 26 and is mounted so as to be slidable coaxially within the bore of the coupling shaft. A rotatable round nut 37, having external gear teeth, is mounted to turn freely on screw 26 and is held against axial movement by thrust washers 27 supported in circular recesses as shown, thus providing a thrust bearing for connecting rod 25. This part of the mechanism constitutes a screw jack.

Rotary nut 37 is provided with external gear teeth, thus constituting a sun gear as a whole as well as a nut. Sun gear 37 is driven by torque transmission gearing comprising a plurality of pinions 36 mounted in circular recesses in the coupling ring 32 and free to rotate on stud shafts 34 fit therein, and an annular gear 35 rotatably mounted on coupling ring 32. By referring to Fig. 5, it will be seen that when annular gear 35 rotates, the pinions 36 drive the sun gear 37, thereby turning it on screw 26 and forcing axial

movement of the connecting rod by screw jack action.

Annular gear **35** is rotated for pitch changing purposes by torque-amplifying epicyclic gearing capable of deriving energizing torque from the drive shaft, and applying bi-directional torque to gear **35** responsively to the selective application of one or the other of two control brakes **54, 54'**. This gearing eliminates the need of any external source of power, such as a motor or pump, for driving the pitch changing mechanism. The torque amplifying gearing comprises differential gearing, of spur gear type, mounted on coupling shaft **40** and consisting of two differential gear trains of opposite rotational effect connected in tandem. External or internal orbit gears can be used in the differential trains, the latter being shown for illustrative purposes. Beginning at the drive shaft end of the coupling, the initial member of the differential gearing is the first orbit gear **41**, fast on coupling shaft **40**, which gear is in effect the primary driving member of the gear trains. The next member of the gearing is the first planet carrier **45**, equivalent to an epicyclic train arm, mounted loose on shaft **40** and having a rim brake-drum. Planet carrier **45** carries a plurality of double planet pinions **46** mounted to mesh properly with the neighboring orbit gears as the carrier revolves. Each planet pinion is tight on its shaft **47**, the latter being journaled in bearings in the web of planet carrier **45**. The driven member of the first differential gear train is the second or intermediate orbit gear **42**, in the form of a floating ring gear having double-width teeth, operatively connected to the first orbit gear **41** by planet pinions **46** and also serving as the driving member of the second differential gear train. The next member of the gearing is the second planet carrier **55**, identical in construction with the first planet carrier **45**, likewise mounted loose on coupling shaft **40**, and likewise having a rim brake-drum. Planet carrier **55** carries a plurality of double planet pinions **56** whose shafts **57** are journaled in bearings in the web thereof, as before. The final and driven member of the second differential gear train is the third orbit gear **43**, operatively connected to the intermediate gear by planet pinions **56** and integral with or fast to annular gear **35**.

Preferably, all the planet pinions have the same number of teeth, and the first driving and final driven orbit gears have an equal number of teeth, but the intermediate orbit gear has a slightly different number of teeth than the other orbit gears. It follows according to well known formulae that the two differential gear trains would then have equal train values or speed ratios, but of opposite algebraic signs, sometimes termed equal but contrary ratios. In the present case, it is essential that rotation of planet carriers **45** and **55** in one direction produce rotation of driven orbit gear **43** in opposite directions; whereby a certain relative rotation of planet carrier **45** will cause a change of pitch in one direction, while like rotation of planet carrier **55** will cause a change of pitch in the other direction. Moreover, it is highly desirable that the gearing have a large speed reduction ratio, which is characteristic of the gearing described.

Brakes are provided to apply retarding braking action independently to the two planet carriers. While either mechanical or hydraulic brakes can be used, the preferred form of brakes is of hydraulic type and comprises two sets of closed hydraulic brake cylinders **50, 51**, disposed radially with equal spacing on a housing **80**. (See Fig. 6.) Brake pistons **54** are mounted to work within the closed brake cylinders and are provided with means to prevent leakage past them, such as an O-ring seal **52** as shown. The pistons are normally held in the inoperative position by compression springs **53**. The arrangement is such that when hydraulic fluid under sufficient pressure is applied to the top space in either set of cylinders, the brake pistons therein are thrust inwardly into frictional engagement with the associated brake drum, thereby applying braking force to the associated planet carrier. Each set of brake cylinders is preferably located on the housing in staggered relation, as indicated in Fig. 4.

Operation

The operating principle of the pitch changing mechanism is as follows: Normally, the gears and the planet carriers all rotate bodily as a unit with the coupling shaft, being stationary with respect to that shaft and to each other. Assume now that with the coupling shaft in rotation, brake fluid pressure is applied to the brake cylinders **50** operatively associated with the first planetary carrier **45**, and the brake pistons thereof bear on the brake drum of the carrier with sufficient pressure to retard its rotation. As soon as the planet carrier starts to slow down due to braking action, the planet pinions **46** carried thereby are caused to roll around and planetate in the two adjacent orbit gears. Due to the slight difference in the number of teeth of the successive orbit gears, a differential angular displacement of intermediate orbit gear **42** relative to first orbit gear **41** occurs as the pinions planetate, in well known manner, the torque producing such displacement being derived from the drive shaft. The second set of planet pinions **56** meanwhile act to lock the intermediate orbit gear **42** to final orbit gear **43**. This locking action becomes apparent when it is considered that the teeth of the double pinions mesh with the teeth of the adjacent orbit gears at nearly the same pitch circle, and accordingly when not in rotation about their axes they act to key the said gears together, thus positively preventing their relative rotation. Planet carrier **55** in the absence of braking force will therefore be compelled by the locking action of its planet pinions to revolve along with the adjacent orbit gears. Orbit gear **43** will accordingly be rotated along with the intermediate orbit gear and will transmit operating torque therefrom to annular gear **35**. The torque transmission gear train will be thus driven to rotate nut **37** on screw **26**, thereby forcing connecting rod **25** to move in an axial direction to turn the blades to change their pitch, as previously described.

Next assume that retarding braking force is similarly applied to the second planetary carrier **55** by means of the associated brake system. Since intermediate orbit gear **42** is locked by planet pinions **46** to drive gear **41**, the intermediate orbit gear now becomes the driving member of the second differential gear train. As planet carrier **55** slows down, planet pinions **56** planetate in the adjacent orbit gears and the final orbit gear **43** is driven relative to the shaft, but in the opposite direction due to the opposite ratio of the second differential gear train.

The differential gear trains described are therefore self-locking, that is, they can be operated as gear trains only by relative rotation of the

planet carriers. Another important aspect of these differential gear trains is that they act as drive couplings when not functioning as gear trains.

By reason of the mechanical advantage provided by the hub mechanism, the screw jack combination, and the differential gearing, the braking torque required to actuate the pitch changing mechanism is very small, amounting to only a small fraction of the delivered torque. The brakes can therefore be of relatively light construction. And since the gears are used only during pitch change and then at light loading, comparatively light gears can be used without risk of undue wear.

For effecting a small or gradual change of pitch, braking action should be applied only sufficiently to retard but not to stop the proper one of the planet carriers. The rate of pitch change, which is proportional to the rate of rotation of the planet carriers relative to the shaft, will be correspondingly slow. For a fast change of pitch, as for example for an emergency stop of the vessel, the braking action can be increased so as to stop the proper planet carrier and then the pitch would be changed at the maximum rate, depending on the shaft speed and the over-all reduction ratio of the pitch changing mechanism. Thus it is apparent that the rate of pitch change can be regulated according to the application of the braking force. This feature contributes importantly to the flexibility and practicality of the pitch changing system of the invention, providing a smoothness of control comparable to that of hydraulic brakes on an automobile.

It is also to be noticed that pitch changes in both directions are effected by relative rotation of the carriers in the same direction. Should such rotation occur without brake action, as for example when accelerating or stopping the engine rapidly, both carriers would be similarly retarded or advanced relative to the drive shaft, and the rotation of one would offset the rotation of the other. This feature eliminates the need for brakes or locking devices to prevent unwanted changes in the pitch by reason of abrupt change in the engine speed, as has been the practice in the prior art.

Pitch block feature

Referring now to Figs. 4, 6, and 7, the pitch changing mechanism of the invention is provided with a novel device for limiting the range of pitch change, usually called a pitch block device. The purpose of the pitch block device is to limit the pitch variation to a predetermined working range, in this case from full-forward to full-reverse pitch. Because of the large speed reduction ratio, and consequent high mechanical advantage of the gearing and screw jack mechanism, to merely limit the travel of wedge **20** in its bore would risk breakage of some part of the kinematic chain when the motion of the wedge was blocked. Accordingly, in the embodiment now to be described, the pitch block device is made effective to block the relative rotation of one or the other of the planet carriers depending on the pitch limit reached. When the relative rotation of a planet carrier is thus blocked, the associated brakes will merely slip, limiting the consequences to some negligible amount of wear of the braking surfaces.

For purposes just explained, the connecting rod **25** is provided with an unthreaded cylindrical extension or mandrel **65** which extends into the bore of coupling shaft **40**. A cam sleeve **60**, provided with a plurality of equally spaced longitudinal slots **61** (see Fig. 7), herein termed cam slots, is fixed on the end of mandrel **65** by a taper pin **29**. Two sets of radially disposed tilting wedges or sprags **63** are loosely positioned to work in radial slots cut in coupling shaft **40** and located in the median planes of planet carriers **45** and **55** respectively. The cam slots are of course indexed with the shaft slots. Referring now particularly to Fig. 6, each sprag **63** is double tapered from the middle of its length, thereby providing fulcrums on the opposite flanks. The inner tapered ends of the sprags fit into the cam slots; and the outer end surfaces are slightly rounded, as shown.

The operating principle of the pitch block device is as follows: When in normal or inoperative position as shown in Fig. 6, the sprags are held by the cam slots in untilted position wherein the radial dimension of the sprags is only slightly less than the space between the periphery of mandrel **65** and the inner bore of the carrier **45**, **55**. In this position, the carriers can rotate freely on coupling shaft **40**. When, however, the connecting rod **25** is translated by the screw jack device away from the median position a certain predetermined distance, indentations **62** notched in the sprag-controlling edge of cam slots **61** near the ends thereof are brought into registry with one set of sprags operatively associated with one of the carriers. When the sprags are free of the restraint of the cam slots, the friction on their outer ends due to the rotation of the carrier will tilt the sprags about one of their fulcrums to wedging position; or alternatively, the cam slots can be formed thus to tilt the sprags, if so desired. When so tilted, the sprags wedge between the mandrel **65** and the inner bore of the carrier, thus positively preventing further rotation of the said carrier. Since the pitch of the blades is directly related to the position of connecting rod **25** and hence of cam sleeve **60**, it is evident that the pitch limits at which the carriers are prevented from further rotation can be determined by the position of the indentations **62**.

It is to be noticed that when one of the carriers is blocked from further relative rotation by the brakes, the other carrier remains free. Hence the pitch block device prevents varying the pitch beyond predetermined limits, while leaving freedom to change the pitch within those limits. And when the pitch is changed away from a limiting position, the cam is moved towards the median position and thereupon tilts the sprags out of wedging position to non-operative position. The release of the pitch block is thus effected in a positive manner.

Pitch indicating system

Referring now to Figs. 4 and 8, for purposes of providing remote visual indication of the pitch angle an electric indicating system is provided as follows: A tubular variable resistor VR is mounted by suitable means in an axial hole in drive shaft **90**, but is insulated from electrical contact therewith. The variable resistor consists of a helical coil **71** of resistance wire of high specific resistivity contained within an insulator sleeve **72**, which sleeve in turn is contained within a metal flanged thimble **73**. One end of the coil is electrically connected to thimble **73**. A conducting metal connecting link **70**, having ball ends split longitudinally to provide spring action, has one end

secured in a socket provided in the outward end of cam sleeve 60 in the manner of a ball and socket joint. The other end is slidable within the bore of the coil of resistance wire, being frictionally engaged in conductive contact therewith. This assembly constitutes a linear variable resistor VR of sliding contact type which is capable of functioning when submerged in oil or grease.

Thimble 73 is suitably mounted in the central hole of an insulated flanged metal disc 75, sandwiched between two insulator rings 76; as for example by screws 74, which screws also serve to make electrical contact between thimble 73 and ring 75. Disc 75 and the insulator rings 76 are firmly clamped in position between flange 91 of drive shaft 90 and flange 49 of coupling shaft 40. The periphery of disc 75 serves electrically as a collector ring with which a brush 81, mounted in a conventional insulated brush holder 82 supported by housing 80, makes electrical contact in well known manner. A conductor 83 connects brush 81 to an external electrical circuit including pitch indicating instrument PI of Fig. 8.

Control system

Referring now to Fig. 8 which shows schematically the control system for controlling the pitch changing mechanism already described from a remote station, selective control of the hydraulic brakes is provided by a double-cylinder hydraulic controller HC of conventional type, having a three-way, neutral biased control handle 85 adapted to actuate the hydraulic brakes selectively. The cylinders of the controller are hydraulically connected to the hydraulic brakes by fluid transmitted by small tubing 86, 87 in the usual manner. The control handle has a neutral position "N," and the direction of pitch change responsive to operation of the handle is indicated by "F" for forward or increase of pitch, and "R" for reverse or reduction of pitch.

An electrical pitch indicator instrument PI, of known ohmmeter type, is provided at the control station, this indicator being connected in series circuit with variable resistor VR and a battery B, as indicated in the diagram or as desired, provided link 70 is included in the circuit. The pitch indicator instrument, whose response should be proportional to the change of resistance of variable resistor VR, is preferably of voltage-compensated type, in which case the battery B may be the engine battery. The dial of the pitch indicator has a scale calibrated to indicate the blade pitch, the relative pitch also being indicated, as by the letter "F" for forward and the letter "R" for reverse, as indicated. The position of "neutral" or zero effective pitch, that is the pitch at which the residual forward and reverse thrusts are in balance, is also indicated, as by the letter "N."

The operation of the controls may be illustrated by the following example: Assume that a vessel equipped with the propeller system of the invention is stationary alongside a dock, with the engine running and lines cast off; further that the propeller is in neutral pitch and the control handle free. In that condition, the control handle would be in the neutral or "N" position, the indicator would indicate neutral pitch "N" as shown in the diagram, and no effective pressure would exist in the hydraulic brake cylinders. Then to go ahead, the control handle would be moved slowly towards the "F" position, thereby applying increasing pressure to the proper hydraulic brake. Braking force being thereby applied to retard the proper planet carrier, the pitch changing mechanism will be actuated to increase the pitch of the blades as previously described. As the pitch is increased, the propeller becomes effective to drive the vessel ahead. Assuming the engine to run at constant speed, after acceleration the speed of the vessel would be related to the blade pitch, up to the power limit of the engine. When the desired pitch is reached, as indicated by the pitch indicator whose pointer follows the blade pitch, the control handle is released and thereupon returns itself to neutral "N" position.

To stop the vessel when underway, the control handle is moved towards the reverse or "R" position, thereby applying hydraulic pressure to the other hydraulic brake and retarding the planetary carrier to actuate the pitch changing mechanism to reduce the pitch. As soon as the pitch becomes negative with respect to the angle of attack of the water entering the propeller blades, the propeller produces a reverse thrust to oppose the forward motion of the vessel. The vessel can accordingly be brought to rest by slowly reducing the pitch to neutral in correlation with the loss of speed. Meanwhile, as before, the pointer of the pitch indicator follows the pitch of the blades, visually indicating same.

For more rapid stopping or for reversing the motion of the vessel, the control handle should be moved gradually further towards the reverse "R" position. The pitch reducing mechanism would accordingly be actuated at maximum speed and full reverse thrust obtained. In this case the control handle should be held in reverse until the pitch of the blades is reduced to a negative pitch, wherein reverse thrust only is produced. The reverse speed of the vessel will be related to the degree of negative pitch, but in general less negative than positive pitch will be used.

From the above, it will be evident that the control handle can be manipulated to control the direction and rate of pitch change, and the vessel speed accordingly, while the pitch indicator indicates the existing pitch of the blades, thus serving as a guide to the operator in manipulating the control handle. When the vessel is driven by an engine under the control of a constant speed governor, the direction of motion and the speed of the vessel can be controlled merely by finger tip manipulation of the pitch control lever. The need for a clutch and reversing gear; and of manipulating the throttle, throwing out the clutch, and operating the reverse gear lever in coordination during maneuvering, according to present practice, can all be eliminated by the system provided by the present invention. Moreover, the controllable reversible pitch propeller provides superior and smoother maneuvering ability, and improved performance and economy in operation. It will be evident to those skilled in the art that the pitch control system described provides exceptional flexibility and versatility of control, and other substantial operating advantages.

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 as my invention:

1. A variable pitch propeller system of the type having a tubular propeller shaft, a drive shaft, and a mechanical drive coupling therebetween for drivingly connecting said shafts, and having, in combination; a hub assembly fixed to said propeller shaft including a hollow hub having radial blades rotatable about their axes mounted thereon, and a mechanical movement mounted in said hub for turning said blades axially in unison; means for operating the aforesaid mechanical movement including a connecting rod slidable axially in the bore of said tubular propeller shaft to operate the said mechanical movement, and a screw-jack mechanism for translating said connecting rod axially; power mechanism carried bodily by said coupling for operating said screw-jack mechanism including torque-amplifying differential gearing characterized by a large speed reduction ratio for deriving, upon individual application of two minor control braking actions, driving torque from said drive shaft and applying operating torque in one or the other rotational direction to said screw-jack mechanism at a slow speed relative to the shaft speed; a pair of brakes for applying control braking action selectively to said differential gearing to operate said screw-jack mechanism in one or the other direction; and control means for actuating said brakes at will from a remote station, thereby to vary the pitch as desired.

2. The combination of the propeller system of claim 1 and an automatic safety device carried bodily by said coupling and operative to block said gearing against improper actuation by said brakes at predetermined limits, thereby limiting the pitch variation to a predetermined working range.

3. In combination with the propeller system of claim 1, of electrical means actuated by the axial translation of said connecting rod for indicating the pitch visually at a remote station.

4. In a variable pitch marine propeller including a hollow hub and radial blades having their roots secured in said hub so as to be rotatable about their axes to vary their pitch, a mechanical movement housed within said hub for so rotating said blades in unison comprising; a slidable cylindrical wedge having external herringbone teeth mounted coaxially in said hub, means mounted in said hub coacting with said wedge so as to allow axial movement without rotation relative to the hub, and a crown gear fast to the root of each blade and having diametral oppositely inclined teeth operatively meshing in the manner of gear teeth with the herringbone teeth of said wedge.

5. A variable pitch marine propeller system, including a hollow propeller shaft and a driving shaft, a power unit for rotating said driving shaft, and a mechanical coupling for drivingly connecting said shafts, having, in combination; a hollow hub fast to said propeller shaft mounting radial blades rotatable about their axes to vary their pitch and housing a mechanical movement for so rotating said blades in unison; means for operating said mechanical movement including a connecting rod movable in the bore of said propeller shaft to operate said movement; power mechanism carried bodily by said coupling for actuating said connecting rod including speed-reducing differential gearing normally capable upon selective application of braking action thereto of deriving adequate power from said power unit to actuate said connecting rod so as to vary the pitch of said blades in a gradual but positive manner when said blades are in rotation under load; selective braking means for actuating said differential gearing; control means for controlling said braking means at will from a remote station; and a pitch block device for blocking said differential gearing against improper actuation by said brakes in a manner to exceed predetermined pitch limits.

6. In a variable pitch marine propeller having a tubular propeller shaft and a hollow hub fast to said shaft mounting axially rotatable blades, in combination, a mechanical movement housed within said hub adapted to rotate said blades axially in unison to vary their pitch, a mechanical drive coupling connected to drive said propeller shaft, power transmission means for driving said mechanical movement, differential gearing mounted bodily on said coupling in driven relation to said coupling and in driving relation to said power transmission means, brake means for actuating said differential gearing to increase or decrease the blade pitch, control means for actuating said brake means at will from a remote station, and mechanical means for blocking said differential gearing against improper actuation by said brake means at predetermined pitch limits.

7. In a variable-pitch marine propeller system, the combination of a hollow propeller shaft, a hollow hub fast thereto mounting axially rotatable radial blades, mechanism for rotating said blades axially in unison including an operating rod extending through the bore of said propeller shaft and movable therein to operate the aforesaid mechanism, a mechanical coupling for driving said propeller shaft, power transmission means operatively connected to move said operating rod when under load, differential speed-reducing gearing carried bodily by said coupling and operatively connected in driven relation to said coupling and in reversible rotary driving relation to said power transmission means, hydraulic braking means for selectively actuating said differential gearing to produce forward or reverse rotation of said power transmission means, control means for controlling said braking means to vary the pitch of said blades, and electrical means independent of said control means and actuated by the movement of said operating rod for indicating the pitch of said blades.

8. In combination with a propeller having a pitch varying mechanism, of means for limiting the variation in blade pitch to a certain working range comprising an operating member of the pitch varying mechanism having a movement proportional to the blade pitch, a rotary member for actuating the pitch varying mechanism, a plurality of wedges adapted to block under controlled conditions the relative rotation of said rotary actuating member, and automatic control means actuated by said operating member adapted to retain said wedges in non-blocking position normally, to free said wedges for movement into blocking position when a certain pitch limit is reached and to displace said wedges from blocking position when the said pitch limit is thereafter departed from in the direction of the working range.

9. In variable pitch propellers having radial blades with roots secured in bearings in a hub for

axial rotation thereby to change their pitch, a mechanical movement for so rotating said blades in unison, comprising, a crown gear fast to the root of each blade and having two sets of oppositely inclined skew teeth located diametrically opposite, and a cylindrical wedge having herringbone teeth oppositely inclined at the same angles as the said skew teeth and mounted with its axis concentric with said hub and in meshing engagement with said crown gears.

10. In a variable pitch propeller having axially rotatable blades with roots secured in bearings in a hub, means for rotating said blades axially in unison comprising a crown gear having two sets of diametral oppositely inclined skew teeth fast to each blade root, a cylindrical wedge having herringbone teeth adapted to mesh with the aforesaid skew teeth, and means for guiding the movement of said cylindrical wedge so that it can move only in axial translation.

11. In a variable pitch propeller system adapted for changing the pitch of its own blades responsively to the manipulation of control means located at a remote station, the combination of power means including spur-gear differential gearing for moving said blades for pitch variation, selective brake means for actuating said differential gearing, remote control means for operating said brake means under the control of said gearing, automatic pitch block means for blocking and unblocking the rotation of said differential gearing selectively and regardless of the action of said brake means thereby to limit the pitch variation to a predetermined working range, and means actuated by said gearing for indicating the pitch visually at said remote station.

12. In a variable pitch propeller system, the combination of power means for changing the propeller blade pitch, including spur-gear differential gearing having two independent planetary members, and automatic pitch-limit means for blocking the rotation of said planetary members selectively at predetermined limits thereby to limit the range of pitch variation, said pitch limit means also being adapted to unblock the rotation of a blocked planetary member responsively to the movement of said power means in the opposite direction.

13. A mechanical movement for adjusting the angle in unison of radial propeller blades so mounted as to be capable of angular adjustment each about its own axis thereby to vary their pitch comprising, a crown gear having two sets of oppositely inclined diametral teeth fast to the root of each blade, a cylindrical wedge member having external herringbone teeth mounted with its longitudinal axis concentric with respect to and meshing as a gear with said crown gears, and means for moving said wedge member axially.

14. Actuating mechanism for varying in unison the pitch of a plurality of radial propeller blades symmetrically mounted with respect to a common center so as to be each rotatable about a radial axis converging at said center including, a cylindrical wedge member having uniformly spaced external teeth mounted concentrically between said blades, and individual crown gears each mounted fast on the root of one of said blades and having teeth located in two diametrically opposite segments adapted to mesh operatively with the teeth of said wedge member.

15. The mechanism of claim 14 in which the said wedge member is provided with herringbone teeth and the said crown gears with diametral oppositely inclined skew teeth having the same helical angle as said herringbone teeth.

16. In a variable pitch marine propeller, the combination of a hollow driving shaft, a plurality of blades carried thereby and so mounted as to be capable of angular adjustment each about its own longitudinal axis for varying the blade pitch, an operating rod movable axially within said driving shaft for imparting angular movement to said blades, power means capable of deriving power from said driving shaft to drive said operating rod, control means for actuating said power means, and an automatic mechanical safety device carried bodily by said driving shaft and actuated by movement of said operating rod so as to block said power means against improper actuation by said control means at predetermined limits of movement of said operating rod thereby limiting the pitch variation to a predetermined working range.

HARRY J. NICHOLS.

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