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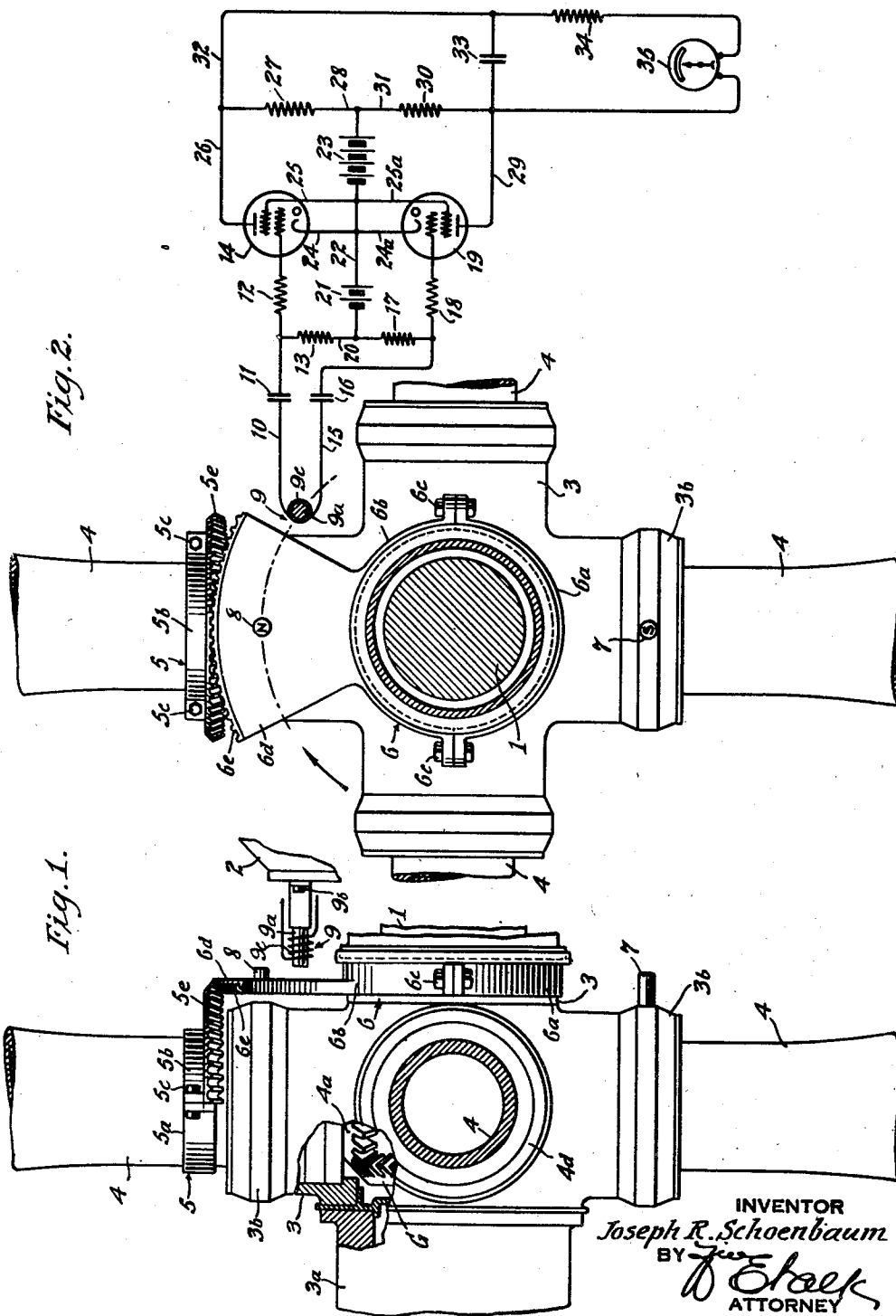
J. R. SCHOENBAUM

2,485,245

CONTROL SYSTEM

Filed July 7, 1944

3 Sheets-Sheet 1



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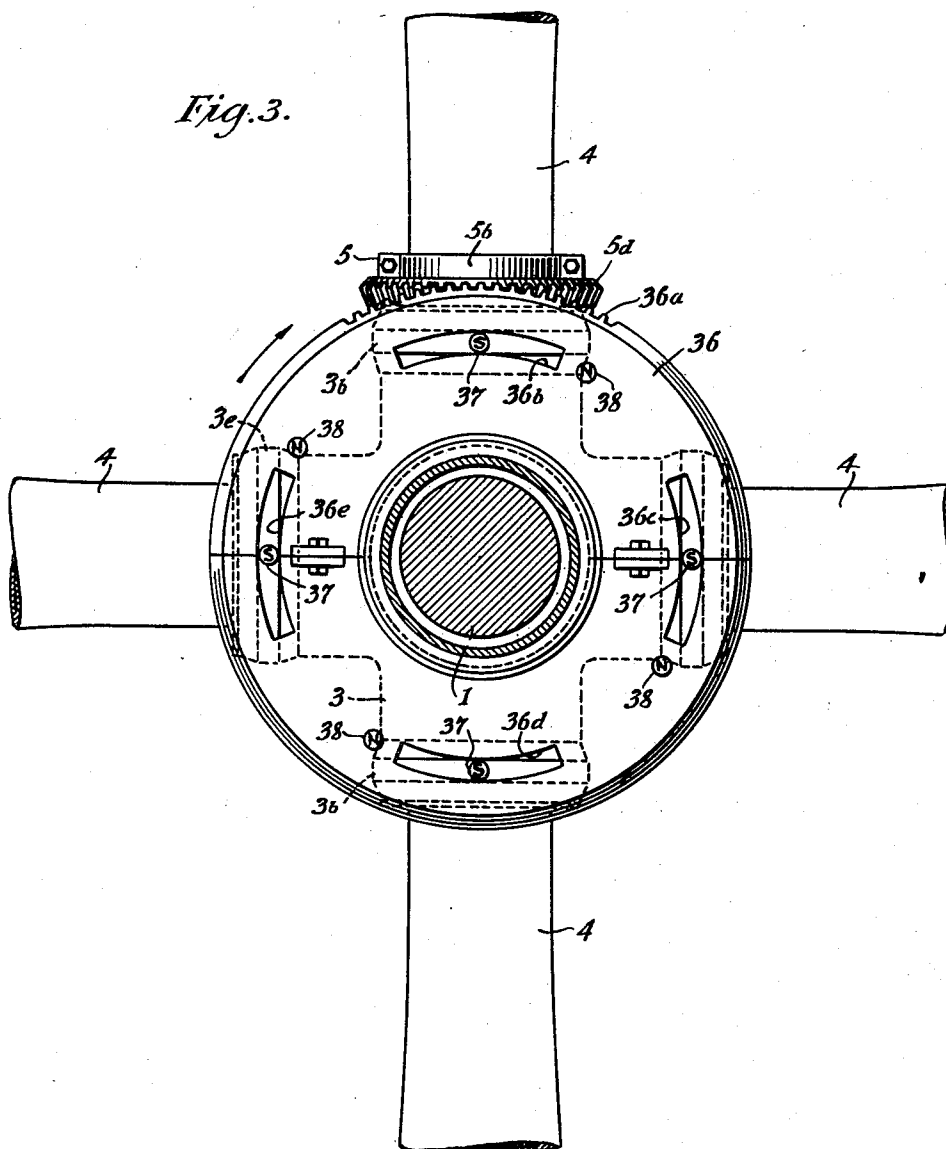
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CONTROL SYSTEM

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3 Sheets-Sheet 2



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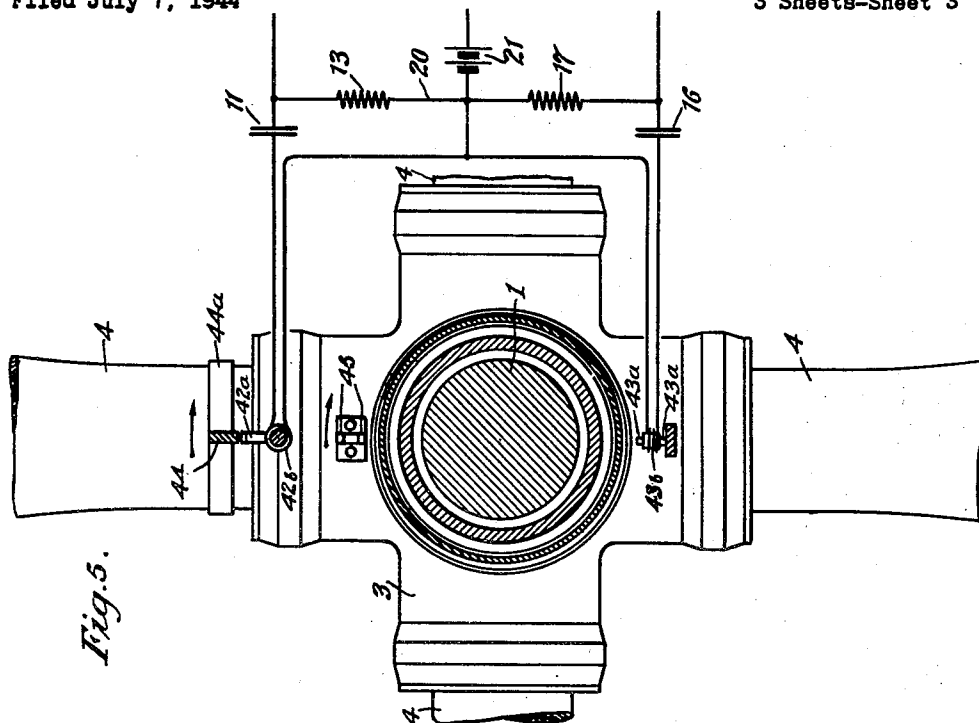
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CONTROL SYSTEM

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3 Sheets-Sheet 3



## UNITED STATES PATENT OFFICE

2,485,245

## CONTROL SYSTEM

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10 Claims. (Cl. 170-160.22)

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My invention relates to a system for producing a control effect which is dependent upon the relative position of relatively movable control members. More particularly, the aforesaid system is one which partakes of cyclic movement.

My invention relates to a system comprising a pair of control members which move cyclically with respect to a controlled member, a control effect being imparted to the controlled member and this control effect varying in response to movement or displacement of one of the control members with respect to the other; more particularly, the aforesaid control effect is imparted to the controlled member without interposing any physical or mechanical coupling between the controlled member on the one hand and the control members on the other hand.

In a more specific aspect, the aforesaid control effect varies as change is effected in the pitch angle of an airplane propeller blade, said control effect operating a suitably calibrated pitch-indicating meter.

Various other objects, advantages and features of my invention will become apparent from the following detailed description.

My invention resides in the control system, arrangements and combinations of the character hereinafter described and claimed.

For an understanding of my invention and for an illustration of some of the forms thereof, reference is to be had to the accompanying drawings, in which:

Figure 1 is an elevational view, partly in section, showing an airplane propeller and associated control mechanism of the invention.

Fig. 2 is a rear elevational view, partly in section, of the propeller shown in Fig. 1, this view schematically illustrating a control circuit of the invention;

Fig. 3 is a rear elevational view, partly in section, showing a modification of the invention;

Fig. 4 is an elevational view, partly in section, showing an airplane propeller and a modified form of control mechanism; and

Fig. 5 is a sectional view, partly in elevation, taken on the line 5-5 of Fig. 4 looking in the direction of the arrows.

Referring to Figs. 1 and 2, a propeller shaft 1 is indicated as extending from the nose 2 of an airplane engine. Splined to the shaft 1 is a propeller hub 3 comprising a forwardly extending housing 3a and any suitable number of blade sockets 3b in which are mounted the respective propeller blades 4, these being rotatably journaled so that the pitch thereof may be changed

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in any suitable manner. It will be understood that the propeller blades are interconnected by gearing in such fashion that the pitch angle of all of the blades is the same for any selected pitch setting of the propeller. Therefore, the act of measuring or ascertaining the pitch angle of one blade determines the pitch angle of each blade in the propeller system.

As shown, this interconnection comprises a ring gear G which is driven by an electric pitch-changing motor, not shown, through suitable reduction gearing. Each blade root has an integral bevel gear, one of which is indicated at 4a, meshing with said ring gear G, the latter rotating the respective propeller blades to thereby change the pitch thereof in response to energization of the pitch-changing motor.

Although an electrical pitch-changing system has been described, it will be understood that the invention is applicable to any type of pitch-changing system.

In accordance with the invention, one propeller blade 4 has secured thereto a two-piece ring 5, the two segments 5a, 5b of which are held in positive engagement with said propeller blade in any suitable manner, for example, by bolts 5c. The ring 5 is positioned upon the upper blade 4 as close as practical to the hub socket 3b. The ring segment 5b comprises a gear segment 5e utilizable as described below.

Loosely mounted upon the propeller hub 3 is a two-piece ring 6, the two segments 6a, 6b of which are suitably connected to each other, as by the bolts 6c. The ring segment 6a comprises a sector 6d terminating in a gear segment 6e which meshes with the aforesaid gear segment 5e.

Mounted, in the example shown in Figs. 1 and 2, upon that blade socket 3b opposite the ring 5 is a magnet 7, the axis of which is parallel with respect to the axis of the shaft 1. A magnet 8 is mounted upon the ring sector 6d and, preferably, said magnet 8 is centered with respect to the radial edges of said sector 6d. The magnet 7 and the magnet 8 are at equal radial distances from the axis of the engine shaft, the south pole of magnet 7 and the north pole of magnet 8 being at their respective right-hand ends, Fig. 1. It is to be understood that the magnet 7 could be mounted in any other suitable manner upon the hub 3 so long as there is a substantial circular distance between magnet 7 and magnet 8, it being important, however, that said magnets are at equal radial distances from the axis of the engine shaft 1.

As further shown by Fig. 1, a pick-up coil,

indicated generally at 9, has a cylindrical core 9a of magnetic material which is secured to the engine nose 2 by screws 9b and carries a suitable pick-up winding 9c. The axis of the cylindrical core 9a is parallel to the axis of the engine shaft 1 and at the same radial distance therefrom as the magnets 7 and 8, the left-hand end of the pick-up coil 9 being closely spaced with respect to the plane of rotation of the right-hand end of the magnets 7 and 8.

Referring now to Fig. 2, one terminal of the pick-up coil 9 is connected by a conductor 10, which includes a condenser 11, to terminals of the resistors 12 and 13, the other terminal of the resistor 12 being connected to the grid of a thyatron 14, or equivalent. The other terminal of the pick-up coil 9 is connected by a conductor 15, which includes a condenser 16, to terminals of the resistors 17 and 18, the other terminal of the resistor 18 being connected to the grid of a second thyatron 19, or equivalent. The lower terminal of resistor 13 and the upper terminal of resistor 17 are interconnected by conductor 20 which also extends to the negative terminal of a grid bias battery 21, the positive terminal of which is connected by a conductor 22 to the negative terminal of a plate battery 23. Branching from the conductor 22 are conductors 24, 24a which are connected to the respective cathodes of the thyatrons 14 and 19. Also branching from the conductor 22 are conductors 25, 25a which are connected to the respective screen grids of the thyatrons 14 and 19.

Extending from the plate of the thyatron 14 is a conductor 26 which leads to one terminal of a resistance 27, the other terminal of which is connected by a conductor 28 to the positive terminal of the plate battery 23. The plate of the thyatron 19 is connected by a conductor 29 to one terminal of a resistance 30, the other terminal of which is connected by a conductor 31 to the aforesaid conductor 28 which leads to the positive terminal of the plate battery 23. Branching from the conductor 26 is a conductor 32 which includes a condenser 33 and extends to the conductor 29. Shunted across the condenser 33 is a resistor 34 in series with a suitable indicating device 35 which may be a conventional D. C. milliammeter, having its pointer adjusted to rest at the center of the scale when no current is passing therethrough. With this type of meter, a deflection is obtained which is proportional to the average amount of current passing therethrough.

The operation of the above described pitch-indicating system is as follows: Rotation of the propeller blades 4 in its socket 3b in response to operation of the pitch-changing mechanism causes circular motion of the gear segment 5e with resultant rotation of the gear segment 6e which, in turn, changes the length of the arc between magnet 7 and magnet 8. Thus, the circular distance between magnet 7 and magnet 8 is dependent upon and proportional to the pitch angle of the propeller blade 4.

As the propeller rotates about the axis of the shaft 1, the north pole of the magnet 8 and the south pole of magnet 7 alternately pass the pick-up coil 9 and induce pulses of electrical energy of opposite polarity in a circuit which includes one terminal of the pick-up coil 9, conductor 10 including condenser 11, resistor 13, conductor 20, resistor 17, conductor 15 including condenser 16, and thence to the other terminal of said pick-up coil 9.

Assuming that the thyatron 19 is not ionized,

passage of magnet 8 adjacent the pick-up coil 19 causes the grid of said thyatron 19 to become more negative. This merely strengthens the negative potential already existing thereon by reason of the grid-bias circuit of the tube, which includes the battery 21, cathode and grid of the thyatron 19, resistor 18 and resistor 17, and hence has no effect on the operation thereof.

Assuming that the thyatron 14 is not ionized, passage of the magnet 8 adjacent the pick-up coil 9, as above described, causes the grid of the thyatron 14 to become more positive to overcome the cut-off bias maintained by the grid-bias circuit for thyatron 14, which includes the battery 21, cathode and grid of thyatron 14, resistor 12 and resistor 13 and initiate flow of plate current through a circuit which includes the cathode and plate of thyatron 14, conductor 26, resistor 27, conductor 28 and battery 23. The plate current thus passing through thyatron 14 charges the condenser 33 over a circuit which includes battery 23, cathode and plate of thyatron 14, conductor 26, conductor 32, condenser 33, conductor 29, resistor 30 and conductor 31. Moreover, during operation of the thyatron 14, current is passed through the indicating device 35 by an indicating circuit which includes the battery 23, cathode and plate of thyatron 14, conductor 26, conductor 32, resistor 34, indicating device 35, resistor 30 and conductor 31, this current tending to move the pointer of the indicating device 35, for example, to the right.

After the magnet 8 passes beyond the pick-up coil 9, current will continue to flow through the described circuits due to the ionization of gas molecules within thyatron 14 by the current passing therethrough with resultant production of positive ions which are attracted to and form a screen around the normally negative grid, this screen of positive ions preventing the grid from exercising its usual function of stopping the flow of plate current. It will be understood that this screen of positive ions will be maintained around the grid until, as hereinafter described, the passage of plate current through the tube is stopped, at which time the gas molecules will be deionized and the tube will be restored to its original circuit condition, this deionization being facilitated by the negative potential of the screen grid.

As the south pole of magnet 7 passes adjacent the pick-up coil 9, the voltage impressed upon the grid of the thyatron 14 decreases which, due to the ionized condition of the tube, has no effect on the operation thereof.

However, passage of the magnet 7 adjacent the pick-up coil 9, as above described, causes the grid of the thyatron 19 to become more positive to overcome the cut-off bias maintained thereon by the grid-bias circuit and permit the flow of plate current therethrough over a circuit which includes the cathode and plate of thyatron 19, conductor 29, resistor 30, conductor 31 and battery 23. Upon closure of this circuit, a voltage is impressed upon the condenser 33 by a circuit similar to that described for thyatron 14, causing discharge thereof. This discharge causes a momentary interruption of the flow of plate current through thyatron 14 with resultant deionization of the gas molecules therein, this deionization permitting the grid to resume its normal function of preventing the flow of plate current through the tube by reason of the cut-off bias supplied by battery 21. As soon as the flow of plate current through thyatron 14 stops, no

current passes through the indicating device 35 over the described indicating circuit.

However, at this time, flow of current is initiated over a second indicating circuit which includes the cathode and plate of thyatron 19, conductor 29, indicating device 35, resistor 34, conductor 32, resistor 27, conductor 28 and battery 23. It will be noted that this flow of current through the indicating device 35 is in opposite direction with respect to the current flow produced by the first-described indicating circuit and tends to move the pointer of the indicating device 35 to the left. It will also be understood that the last-described indicating circuit will remain operative after the south pole of magnet 7 passes beyond the pick-up coil 9 due to the ionization of gas molecules within the thyatron 19.

As the propeller revolves and the north pole of magnet 8 again passes adjacent the pick-up coil 9, thyatron 14 is again energized with resultant deenergization of thyatron 19 by condenser 33. At this time, current flow through the last-described indicating circuit is stopped and current again passes through the first-described indicating circuit.

Therefore, during rotation of the propeller, the thyatrons 14 and 19 are alternately energized, thyatron 14 being energized from the time magnet 7 passes adjacent the pick-up coil 9 until deenergized by the discharge of condenser 33, this discharge occurring at the time magnet 8 passes the pick-up coil 9, at which time current flows through thyatron 19 which remains energized until magnet 7 again passes the pick-up coil 9. Thus, the length of time thyatron 14 is energized during each rotation of the propeller depends on the length of arc or circular distance between magnet 7 and magnet 8 which, in turn, is dependent upon and proportional to the pitch angle of the propeller blades. Furthermore, during each revolution of the propeller, thyatron 19 is conductive throughout the period when thyatron 14 is non-conductive. During operation of the propeller by the aircraft engine, any change in the pitch angle of the propeller blades causes movement or displacement of the control magnets 7 and 8 with respect to each other and this produces a corresponding change in the average length of time that thyatron 14 is energized in comparison with the average length of time that thyatron 19 is energized with resultant proportional change in the average amount of current supplied to the indicating device 35 by the respective indicating circuits of said thyatrons. By suitable initial calibration of the indicating device 35, a reading directly in degrees of pitch angle is obtained.

In order to gain a greater degree of sensitivity to the change in pitch of the propeller blades, I may utilize the modification of my invention shown in Fig. 3, in which the propeller is of generally the same construction as shown in Figs. 1 and 2 and in which similar parts are indicated by the same reference characters used in said Figs. 1 and 2. In Fig. 3, a circular disk 36 is shown as mounted on and rotatable with respect to the hub 3. A peripheral segment of the circular section 36 is provided with gear teeth 36a which mesh with the gear segment 5e of the split ring 5. Each blade socket 3b carries a magnet 37, the axis of which is parallel to the axis of the engine shaft 1, and the south pole of which faces the airplane engine. The magnets 37 extend through the respective arcuate slots 36b of the

circular section 36, said slots being of sufficient length to permit rotation of the circular section 36 by gear 5e through the entire pitch-changing range of the propeller blades. Each magnet 37 has associated therewith a magnet 38, the north pole of which faces the airplane engine. The magnets 37 and 38 are all at an equal radial distance from the axis of the engine shaft 1 and are so arranged that, in any position of the circular section 36, the circular distance between each magnet 38 and its adjacent magnet 37 is the same.

As the propeller rotates, the magnets 37 and 38 pass a stationary pick-up coil, not shown, which is connected to the same thyatron circuit and pitch-indicating meter shown in Fig. 2. The operation of this modification of my invention is essentially the same as the form of Fig. 2 except that, in this case, the pick-up coil receives eight impulses per revolution of the propeller instead of two, this feature causing increased sensitivity and accuracy of the pitch-indicating meter.

It is to be understood that the foregoing description is not intended to limit the spirit and scope of invention but is merely illustrative thereof. It is apparent that a propeller blade 4 and the hub 3, respectively, constitute relatively movable zones or areas of a system in which measurements are to be made. With the form of the invention shown in Figs. 1 and 2, the magnets 7 and 8 are mounted, respectively, on separate parts which are movable relative to each other, these separate parts being, respectively, the hub 3 and the sector 6d; the magnet 8, in effect, is on the propeller blade by reason of the fact that the sector 6d is geared thereto. Accordingly, the hub 3 and sector 6d constitute zones which are movable relative to each other within the purview of the broader claims. In a broader application of the invention, the magnets 7, 8 may be mounted on a single part or structure and in zones or areas thereof which are movable relative to each other, such movement being caused, for example, by deformation produced on said single part or structure.

The magnets 7 and 8 are, broadly speaking, control members and they move relative to each other in accordance with the relative motion between the aforesaid zones or areas. Equivalently, suitable fingers may replace the magnets 7 and 8, these fingers operating a tripping mechanism outside the movable system. Alternatively, the magnets 7 and 8 can be replaced by suitable light sources and the pick-up coil 9 can be replaced by one or more photo-electric cells.

Referring to Figs. 4 and 5, I have shown a form of the invention which, to some extent, differs from the forms thereof hereinbefore described. Thus, as illustrated, the engine nose 2 has secured thereto a pair of supporting members 40 and 41 which extend toward the propeller and have suitably secured thereto the respective magnetic structures 42 and 43. The magnetic structure 42 comprises the non-magnetized iron pole pieces 42a connected together by an iron core which supports a winding 42b and is magnetized in any suitable manner. Similarly, the magnetic structure 43 comprises non-magnetized iron pole pieces 43a connected together by an iron core on which a winding 43b is disposed, the core last named being magnetized in any suitable manner.

As illustrated in Fig. 5, the magnetic structures 42 and 43 are positioned on the extended diameter of the propeller shaft 1; that is, the magnetic

structures 42 and 43 are separated by angles of 180°.

Coactable with the magnetic structure 42 is a bar 44 formed from soft iron and comprising a ring section 44a which is clamped around a propeller blade 4 and hence is movable therewith at all times. As the propeller rotates, the bar 44, once for each rotation, momentarily is opposite the pole pieces 42a of the magnetic structure 42 and functions as an armature therefor whereby a pulse of current is induced in the winding 42b. The surface 44b of the bar 44 is so shaped that, for any pitch position of said blade 4 and, when the bar 44 is in its armature-forming position, there is substantially no change in the length of the air gap between said surface 44b and the ends of the pole pieces 42. To this end, the curve defining the surface 44b should be a sine function.

Secured to the propeller hub 3 is a U-shaped structure 45 which is so positioned radially on said hub that, once for each rotation thereof, the structure 45, momentarily, is opposite the pole pieces 43a and hence closes the magnetic circuit of the magnet 43 whereby a pulse of current is induced in the winding 42b.

Referring to Fig. 5, the winding 43b is shown as connected across the resistor 13 whereas the winding 43b is shown as connected across the resistor 17. In other respects, the circuit of Fig. 5 is a duplicate of the circuit of Fig. 2.

Assuming that the propeller shown in Figs. 4 and 5 is rotating, the following action occurs:

When the bar 44 sweeps past the magnet 42, a pulse of current is induced in the winding 42b. As a result, a flow of plate current is established in the thyatron 14 and the previously established flow of plate current in the thyatron 19 is discontinued. When the structure 45 sweeps past the magnet 43, an action the reverse of that described above is performed; that is, a flow of plate current in the thyatron 19 is established and this is accompanied by discontinuation of the previously established flow of plate current in the thyatron 14. Thus, the thyatrons 14 and 19 alternately actuate the meter 35 in the proportional manner hereinbefore described.

With the arrangement shown in Figs. 4 and 5, the bar 44 and structure 45 are control members which move relative to each other when the pitch of the propeller blades is changed. This relative movement results in changes in the durational control of the magnet 42 on the thyatrons 14 and 19.

From the foregoing, it is apparent that my invention has utility for measuring or indicating purposes in many fields other than the aircraft propeller art. It is further apparent that the described embodiments of the invention are not restricted to the measurement of pitch angles but that any measurable characteristic or interest in a system can be measured so long as the distance between magnets 7 and 8, or equivalent, is proportional to said measurable characteristic. Furthermore, the movable system need not rotate about its axis. It is sufficient that cyclical movement be imparted to said movable system whereby the magnets 7 and 8, or equivalent, pass adjacent the pick-up coil, or equivalent, at regular spaced intervals.

Further, the operation of the thyatrons 14 and 19 is similar to the operation of extremely sensitive holding relays and the use of such relays, or equivalents, is within the purview of the invention. In some of its broader applications, the thyatrons, or equivalent, may control record-

ing or other mechanism in lieu of an indicating device as illustrated. Thus, the breadth and scope of my invention is to be determined by reference to the sub-joined claims rather than by the preceding description.

While the invention has been described with respect to certain particular preferred examples which give satisfactory results, it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended therefore in the appended claims to cover all such changes and modifications.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a propeller pitch-indicating system, the combination with an aircraft housing, a propeller shaft extending therethrough, a hub mounted on said shaft, and variable-pitch propeller blades journaled in said hub, of control members rotatable with the propeller and movable relative to each other in correspondence with change in pitch angle of said propeller blades, means energized by one of said control members for a part of each revolution of said propeller, means energized by another of said control members for the remaining part of each revolution of said propeller, and means proportionally responsive to the difference in average energization of said first named means and said second named means.

2. In a propeller pitch-indicating system, the combination with an aircraft housing, a propeller shaft extending therethrough, a hub mounted on said shaft, and variable-pitch propeller blades journaled in said hub, of groups of control members rotatable with the propeller and movable relative to each other in correspondence with change in pitch angle of said propeller blades, means energized by one of said groups of control members for a part of each revolution of said propeller, means energized by another of said groups of control members for the remainder part of each revolution of said propeller, and means proportionally responsive to the difference in average energization of said first named means and said second named means.

3. In a propeller pitch-indicating system, the combination with an aircraft housing, a propeller shaft extending therethrough, a hub mounted on said shaft, and variable-pitch propeller blades journaled in said hub, of magnetic members rotatable with said hub and movable relative to each other in response to pitch-change of said propeller blades, a pick-up coil actuated by said magnetic members, a pair of grid-glow tubes alternately energized and de-energized by said pick-up coil to provide a differential current dwell of one direction as a function of the angle between said members, and an angle indicator connected to said tubes and responsive in its indication to a succession of said differential current dwells.

4. In a propeller pitch indicating system, the combination with an aircraft housing, a propeller shaft extending there through, a hub mounted on said shaft, and variable pitch propeller blades journaled in said hub, of control members rotatable with the propeller and moveable relative to each other in correspondence with change in pitch angle of said propeller blades, means energized by one of said control members and de-energized by the other and means energized by the other of said control members and de-energized by the one, and means responsive to the difference in energization time over a plurality

of successive energizations of both of said means for indicating blade pitch.

5. In a propeller pitch indicating system, the combination with an aircraft housing, a propeller shaft extending therethrough, a hub mounted on said shaft and variable pitch propeller blades journaled in said hub, of magnetic control members rotatable with the propeller and moveable relative to each other in correspondence with change in pitch angle of said propeller blades, thermionic means energized by one of said control members and de-energized by the other to establish a current flow for a corresponding period and thermionic means energized by the other of said control members and de-energized by the one to establish a current flow for a corresponding second period, and means responsive to the average difference of the total current flow between the first and second named periods to indicate propeller blade pitch.

6. In a propeller pitch indicating system, the combination with an aircraft housing, a propeller shaft extending therethrough, a hub mounted on said shaft, and variable pitch propeller blades journaled in said hub, of control members rotatable with the propeller and moveable relative to each other in correspondence with change in pitch angle of said propeller blades, each of said members having a magnetic polarity opposed to the other, stationary magnetic field influenced means energized oppositely by said members, grid-glow discharge means responsive to one sequence of opposed energizations of said means to establish a flow of current for the intervening period, grid-glow discharge means responsive to the opposite sequence of opposed energizations of said means to establish a flow of current for a second intervening period, and means responsive to the flows of current for indicating the current difference in terms of blade pitch over a plurality of energization periods.

7. In a pitch indicating system for a propeller having a hub and blades journaled therein for pitch change, an element rotatable with the hub, a second element rotatable with and with respect to the hub and movable with respect thereto in accordance with the pitch positions of said blades in said hub, a pickup device fixedly disposed adjacent the path of said elements as they rotate with the hub and including means to produce an electrical pulse upon the passage of each element thereby, means operated by said electrical pulses to produce successive current surges of opposite polarity, each surge being initiated by the passage of one of the elements by said pickup and each terminated by the passage of the other element by said pickup, and means operated by said current surges and operative to indicate the difference between the time integrated currents of one polarity and the time integrated currents of the other polarity.

8. In a pitch indicating system for a propeller having a hub and blades journaled therein for pitch change, an element rotatable with the hub, a second element rotatable with and with respect to the hub and movable with respect thereto in accordance with the pitch positions of said blades in said hub, a pickup device fixedly dis-

posed adjacent the path of said elements as they rotate with the hub and including means to produce an electrical pulse upon the passage of each element thereby, means operated by said electrical pulses to produce successive current surges of opposite polarity, each surge being initiated by the passage of one of the elements by said pickup and each terminated by the passage of the other element by said pickup, means to average the current of one polarity, means to average the current of the other polarity, and means to indicate the difference between said averaged currents.

9. In a propeller pitch indicating system, a propeller shaft extending from a housing, a hub on the shaft, variable pitch propeller blades journaled in said hub for pitch change, control members rotatable with the propeller and moveable relative to each other on the propeller hub in accordance with pitch angle changes in the propeller blades, means energized by one of said control members for a part of each revolution of the propeller, means energized by another of said control members for the remaining part of each revolution of the propeller, and means to indicate the difference in average energization of said first and second means.

10. In a propeller pitch indicating system, a propeller shaft extending from a housing, a hub mounted on the shaft, variable pitch propeller blades journaled in said hub for pitch change, groups of control members rotatable with the propeller and moveable relative to each other in accordance with pitch angle changes in the propeller blades, means energized by one of said groups of control members for a part of each revolution of the propeller, means energized by another of said groups of control members for the remaining part of each revolution of said propeller, and means to indicate the difference in average energization of said first and second means.

JOSEPH R. SCHOENBAUM.

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