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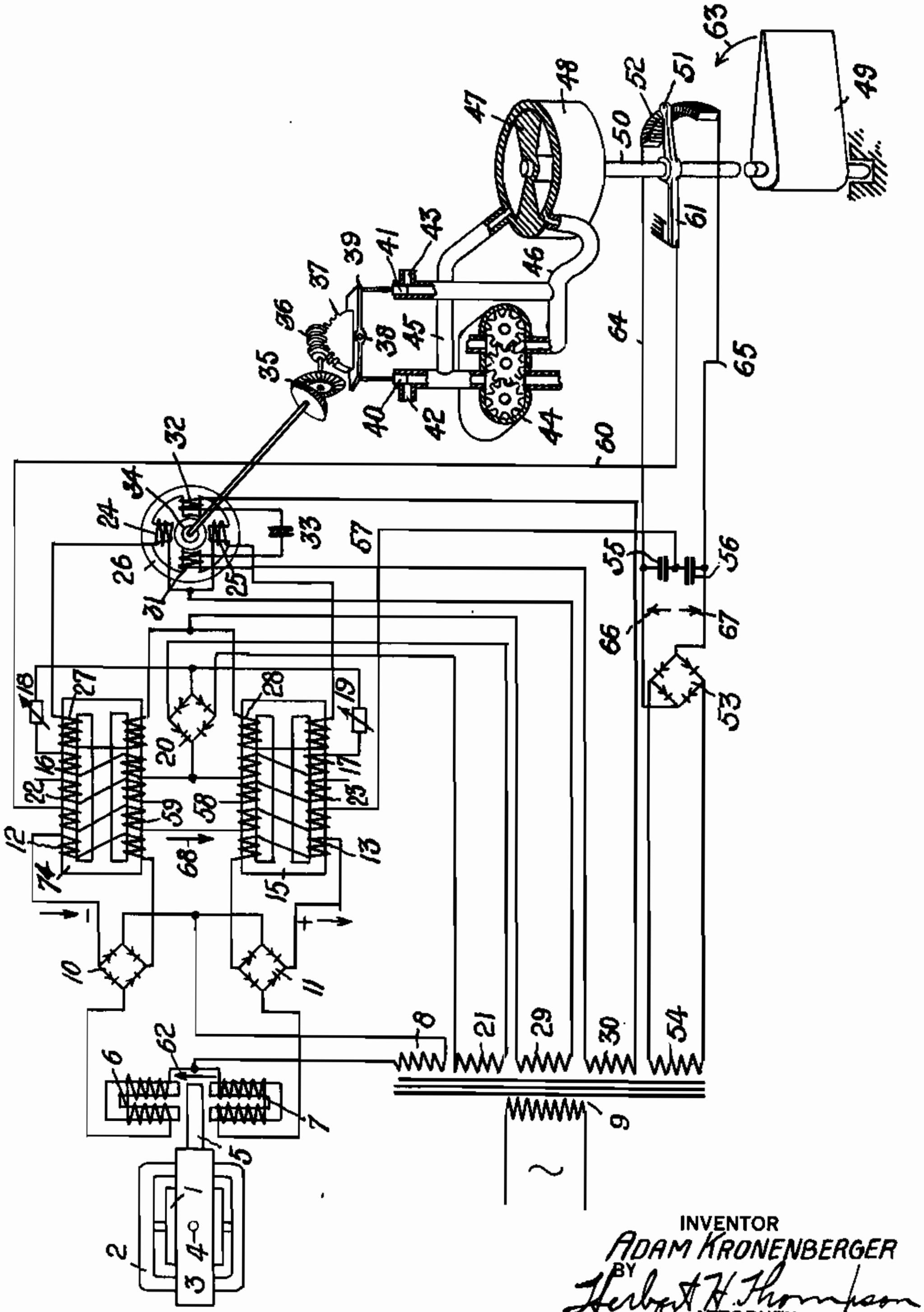

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# ALIEN PROPERTY CUSTODIAN

## AUTOMATIC STEERING DEVICE FOR AIRCRAFT

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The invention relates to automatic steering devices for aircraft in which a directional transmitter controls a servo-motor through a relay. In systems of this kind the directional transmitter usually consists in a gyro instrument (as for instance a directional gyro or a gyro vertical) and in order to adequately dampen the movements of the craft, there are added to the basic control value according to the respective requirements further impulses dependent on the rotary speed or the rotary acceleration of the craft.

In order to obtain an effective control free from hunting it is essential that no material delay occurs between the disturbing influence on the craft and the counteracting deflection of the control surfaces. Furthermore the control surface should be restored to its normal position as quickly as possible after the disturbance has been compensated for. It is therefore necessary in the first place to avoid any difference in phase in the control apparatus causing the deflections of the control surfaces, for which reason it is advantageous to use a hydraulic servo-motor having comparatively small mass and operating substantially without delay.

The action of restoring the control surface to its normal position when the control value dies down to zero can be accelerated by replacing the aircraft steering devices as in common use by a steering gear which is yielding against the exterior forces acting upon the control surface. Such an arrangement may be obtained for instance by alternate throttling of two pressure fluid streams which are carried to either side of the servo-motor prior to passing through the throttling orifices. In such a controlling gear a state of balance is established between the relative wind acting upon the control surface and the liquid pressure supplied to the servo-motor in response to the steering values derived from the controlling instruments. When the steering value becomes zero the deflection of the control surface becomes zero likewise without the necessity of reversing the servo-motor as would be the case in self-locking steering gears. In order to maintain such deflection of the control surface as is necessary for overcoming the disturbance, a constant liquid pressure will, however, be required in such yielding control gear in the case of a constant disturbance of the balance of the craft due for instance to failure of one lateral motor. Therefore according to the invention I use a servo-motor yielding against external forces acting on the control surfaces in combination with an unrestrained relay, the speed of movement of which is dependent upon the amount of the control values. When a disturbance occurs, the relay is brought in the position necessary for the elimination of such disturbance, whereby a certain liquid pressure and a corresponding deflection of the control surface are produced. This deflection is maintained even after the craft has attained the desired position and the initial control value has become zero with the result that a torque balancing the disturbing moment is constantly exerted on the craft. This deflection of the control surfaces is maintained until the constant disturbance has been eliminated and is then nullified by means of a countercontrol value restoring the relay to its middle position. The returning of the control surfact is caused by the relative wind while the servo-motor is only being relieved of the control pressure. In a self-locking steering gear, on the other hand, a countercontrol is required for the returning of the control surface to its middle position, as in this case the restoring force of the relative wind is not utilized. Now the reversal of a rudder motor inclusive the rudder takes considerably longer than the reversal of a relay, which is of light construction and thus controllable at a corresponding high velocity. Another advantage in the use of a resilient servo-motor is that it requires but little driving power whilst the control surface is in its middle position, while the self-locking hydraulic gears commonly used run constantly under full load.

A Ferraris motor may advantageously be used as relay as it is readily reversible due to the small mass of its armature. In order to avoid overcontrol, the motor revolutions may be limited by an impulse derived from the velocity of the control surface. This can be achieved in such a way that a contact brush sliding over a voltage divider is connected to the rod system of the servo-motor. The two branches of the voltage divided are connected with the two condensers to a Wheatstone bridge. By this means the compensating voltage resulting from the displacement of the sliding brush becomes an index of the velocity of the control surface. By transmitting this impulse after appropriate amplification to the relay, a force is opposed to the other control values, and the deflection of the control surface is restricted.

The impulse may be amplified by means of a choking coil amplifier. A simple way of mixing the control values is that of providing the amplifier with several magnetizing windings, each winding being connected with one transmitter. Further details concerning the invention are apparent from the following description of an embodiment of the invention.

The drawing represents schematically an automatic steering gear in which the control impulses act through the choking coil amplifier upon a Ferraris motor serving to set a hydraulic servo system.

A gyroscope with two degrees of freedom acts as the controlling element to determine the rotary velocity and rotary acceleration of the craft about its vertical axis. The horizontal rotary axis of the gyro rotor 1 is supported in a frame 2, which is in turn rotatable in a gimbal ring 3 about a likewise horizontal axis which is vertical to the first axis. The gimbal ring is adapted to turn slightly about a vertical axis 4. In a manner not shown the gimbal ring 3 and the rotor carrier 2 are restrained in their middle position relative to the casing, the restrainment being strong for the gimbal ring while it is comparatively slight for the rotor carrier. Thus the gyroscope may precess a fair amount about its horizontal axis at turns performed by the craft about its vertical axis, the movements being proportional to the turning speed, while a moment corresponding to the turn acceleration acts upon the gimbal ring to turn about its vertical axis 4. An armature 5 playing between two coils 6 and 7 is secured on the gimbal ring. According to the position of the armature relative to the coils 6 and 7 the reluctance of the coils and hence their mutual induction is varied. Consequently the voltage supply through the winding 8 of a transformer 9 meets with corresponding differences in resistance with the result that different currents are produced in the windings 12, 13 of two amplifier chokes 14, 15 connected via a rectifier 10, 11. Premagnetizing windings 16, 17 connected via variable resistors 18, 19 and a full-way rectifier 20 with a winding 21 of the transformer 9 serve to adjust the most favorable working point on the magnetizing curve of the amplifier.

Two further magnetizing windings 22, 23 are mounted on the amplifier chokes 14, 15 for transmitting the course deviation, said magnetizing windings being controlled, in a manner which need not be described, by means of a directional gyroscope not shown. The control values are mixed, amplified and supplied to a Ferraris motor 26 through control windings 24, 25. Windings 27, 28 communicating with the motor windings 24, 25 connect the exciting voltage supplied by the winding 29 of the transformer 9 to the amplifier chokes. The exciting voltage for the Ferraris motor is supplied by a further transformer winding 30 connected to the corresponding motor windings 31 and 32. In order to obtain the necessary phase displacement, a condenser 33 is inserted in this circuit.

The armature 34 of the Ferraris motor 26 drives a worm 36 through a reduction gear 35, the worm engaging with a worm wheel 37. The latter is adjustable about its axle 38 and serves to control a seesaw 39 of a hydraulic setting gear. Two small valve pistons 40, 41 are provided for alternate throttling of outlet orifices 42, 43. The pressure fluid is circulated by means of an electrically driven three-gear pump. When at an inclination of the seesaw one of the outlets is throttled, pressure is created in the corresponding control line 45, 46, respectively, whereby the vane 47 of a rotary piston 48 is set in motion causing a deflection of the rudder 49.

On a shaft 50 connecting the piston 48 with the control surface, a sliding brush 51 is mounted so as to be insulated. This brush slides over *a* voltage divider which is mounted rigidly relative, to the craft and both ends of which communicate with the output end of a full-way rectifier 53 fed from a winding 54 of the transformer 9. Two condensers 55, 56 are connected with the two branches of the voltage divider 52 so as to form a bridge circuit. A conduit 57 branches off between the two condensers, leading to a control winding 58 of the amplifier choke 15. A corresponding control winding 59 secured on the choke 14 is connected in series with the winding 58 and communicates via a line 60 and a spring contact 61 with the tap 51 of the voltage divider 52.

With a view to explaining the mode of operation of the directional steering gear let it be assumed that the craft is thrown out of its course by a gust of wind. To compensate for the disturbance it is necessary that the control surface be deflected to the right which is effected in the following manner: At a standstill of the steering gear the resistors 16, 19 are set so as to produce a certain premagnetization resulting in the two amplifier chokes 14, 15 being each about half saturated so that the currents passing through the two control windings 24, 25 of the Ferraris motor 26 are equal and therefore balance one another. On account of the assumed turning of the craft to the left, the armature 5 executes a relative movement upwardly in the direction of the arrow 62, as the gyroscope as a mass of great inertia tends to maintain its position in space. Thereby the resistance of the choke 7 declines and the current in the control winding 13 of the lower choke 15 gains in strength while on the other hand the current in the winding 12 of the choke 14 declines. The directional gyroscope (not shown) acts in the same sense on the windings 22 and 23. Due to the enhanced magnetization of the choke 15, the current in the output winding 28 increases likewise so that it preponderates over the declining current in the winding 29 of the other amplifier choke. Consequently the field of the control winding 25 of the Ferraris motor is stronger than that produced by the winding 24, and the armature 34 commences to turn with corresponding speed in a sense so as to cause an over-pressure to be produced in the foremost chamber fed by the line 46 of the servo-motor 48, with the result that the control surface deflects to the right as shown by the arrow 63. In this connection it is requisite that the seesaw be turned clockwise, whereby the cross section of the discharge orifice 43 is reduced and a pressure increase in the conduit 46 is produced.

The restoring system 51—61 provided for restricting the speed of the control surface restricts the control impulse in the following manner:

While the control surface is moving in the direction indicated by the arrow 63, the voltage at the condenser 55 is reduced and that at the condenser 56 increased. Be it assumed that the line 64 possesses a positive potential and the line 65 a negative potential corresponding to the direction of the arrows near the rectifier 53. Then a compensating current is created upon the displacement of the brush 51 in the direction of the arrow 63, said current being in the direction of the arrows 66, 67. Thereby in turn a current is produced in the windings 58, 59 in the direction of the arrow 68. This current flows in a direction opposite to that of the current passing through the windings 12, 13 (as well as that in 22, 23) balancing same at a correspondingly high rotary speed of the control surface 63 causing the armature 34 of the motor 26 to come to rest.

The compensating current should be proportional to the rotary speed of the control surface. This is achieved by keeping the time constant of the compensating process sufficiently small by corresponding dimensioning of the condensers 55, 56 and of the respective resistors. Under these conditions the electric combination represents a differential gear electrically reproducing the speed of the control surface. The compensating current flows only until the charges of the two capacities 55, 56 balance the voltages existing at the potentiometer 51, 52. (The charges of the condensers are of course given by the proportion voltage to capacity). When the control surface comes to a standstill the compensating process is practically terminated, so that there is then no current in the lines 57, 60.

In case the seesaw has not been fully deflected, the control surface comes to a standstill as soon as the control presure and the relative wind acting on the control surface balance. In a servo-motor system which is non-yielding relative to exterior forces it would be necessary for the motor 26 to reverse in order to cause the control surface to come to rest, as in this case the engine working pressure is constantly effective as long as the relay is deflected from its middle position.

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