Oct. 25, 1949. H. T. PENTECOST 2,486,059

CONTROL MECHANISM FOR HELICOPTERS WITH COAXIAL ROTORS

Filed Oct. 9, 1945 3 Sheets-Sheet 1

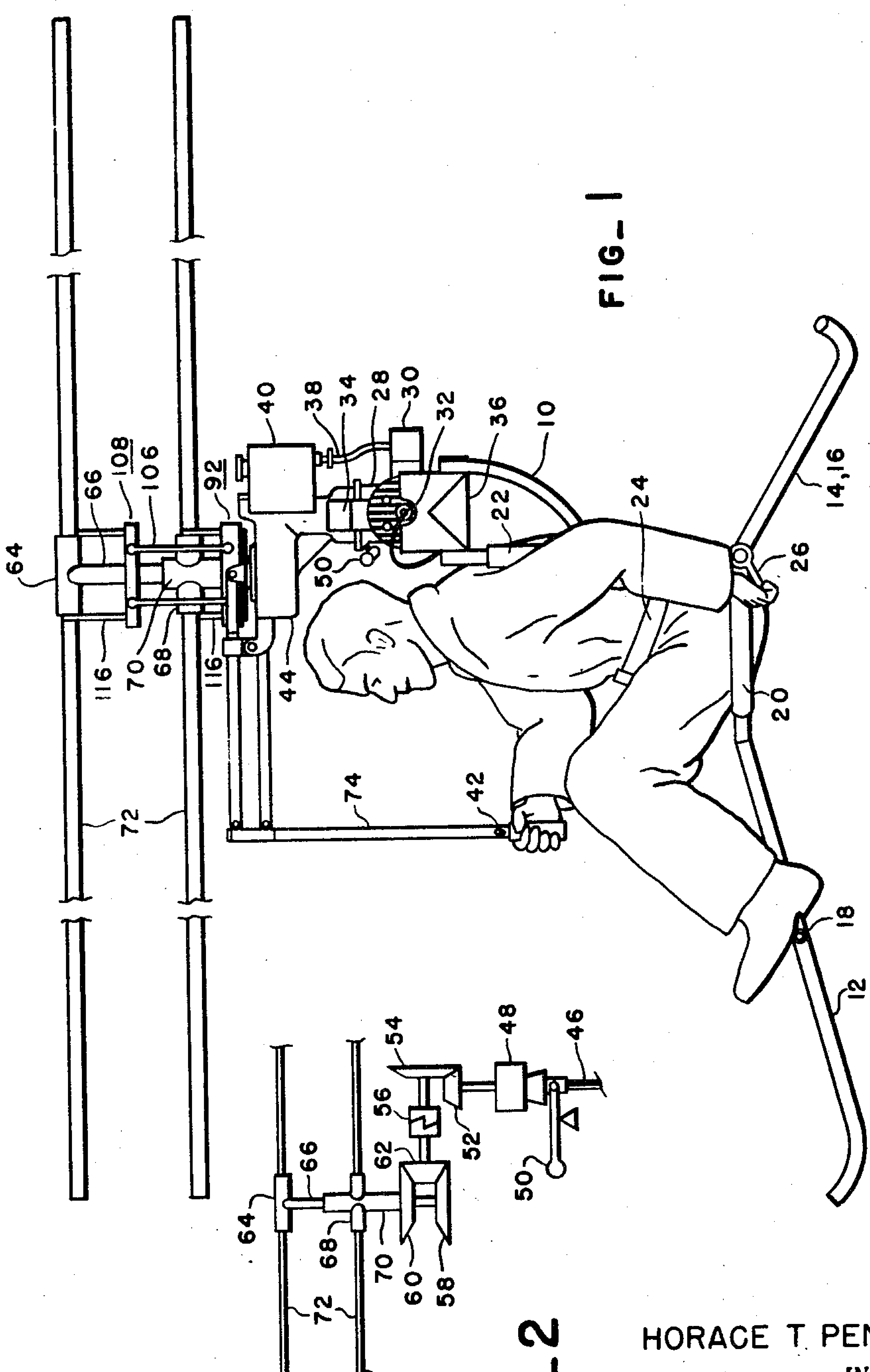

FIG_1

FIG_2

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Oct. 25, 1949.

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3 Sheets-Sheet 2

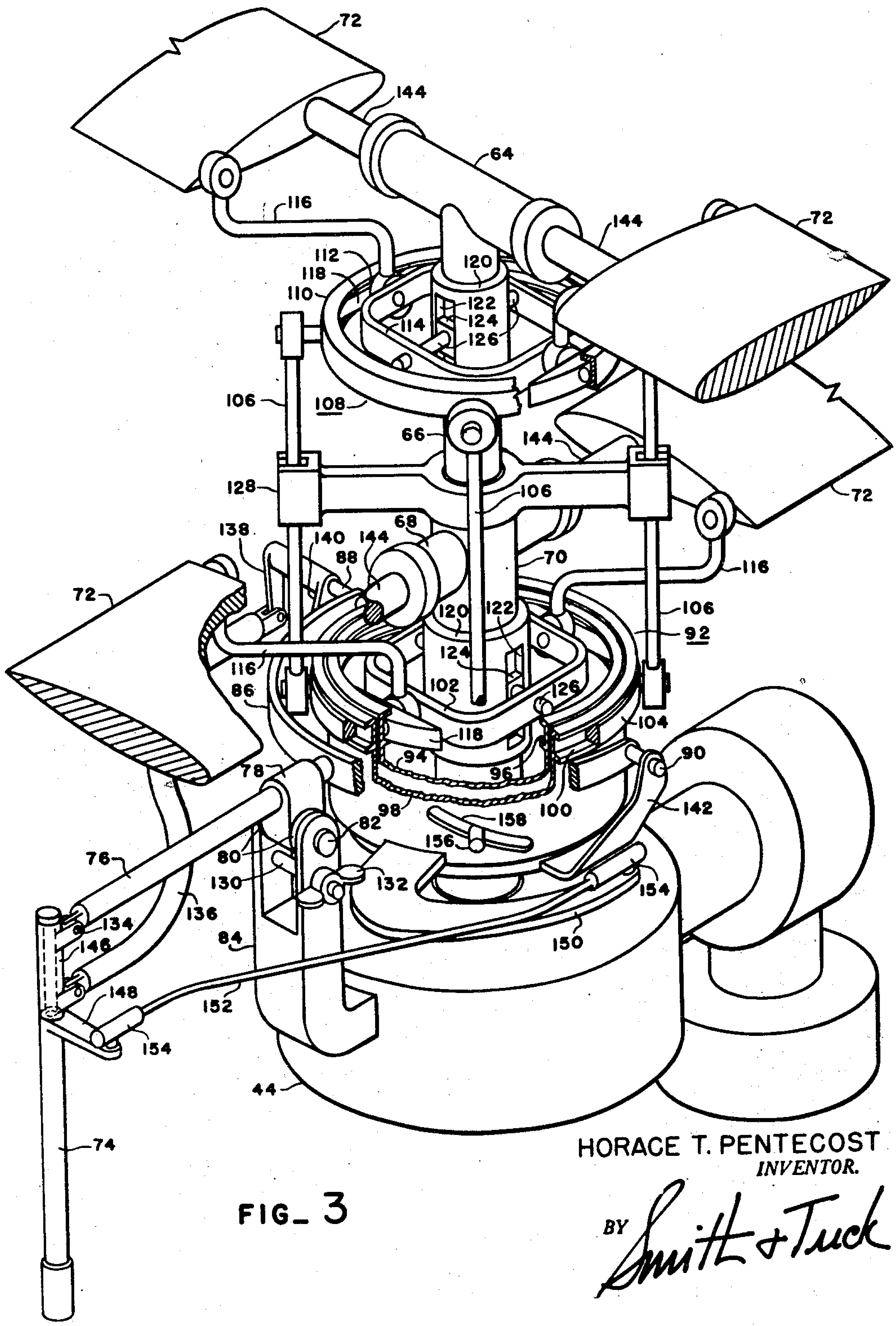

FIG_ 3

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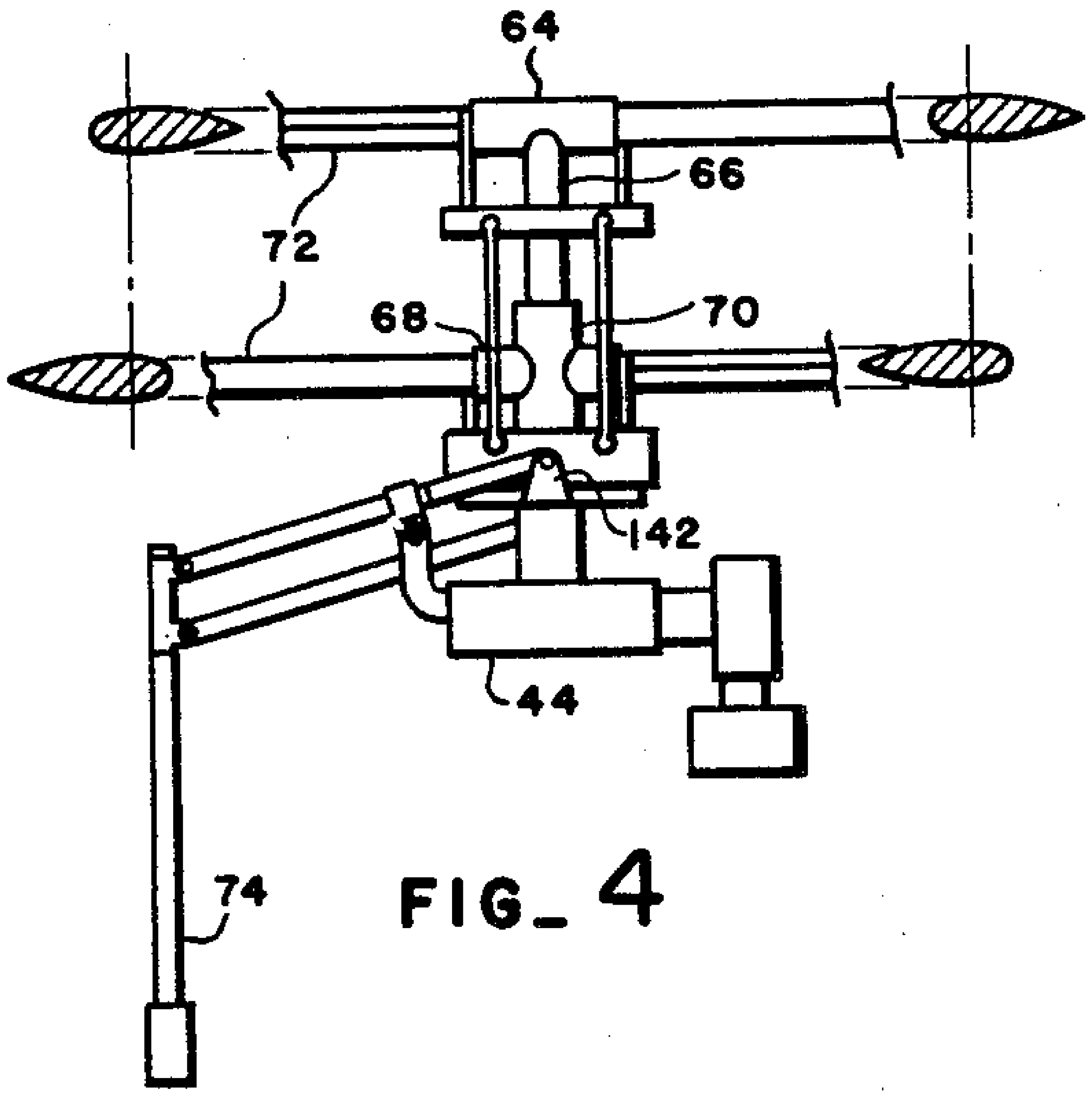

FIG_4

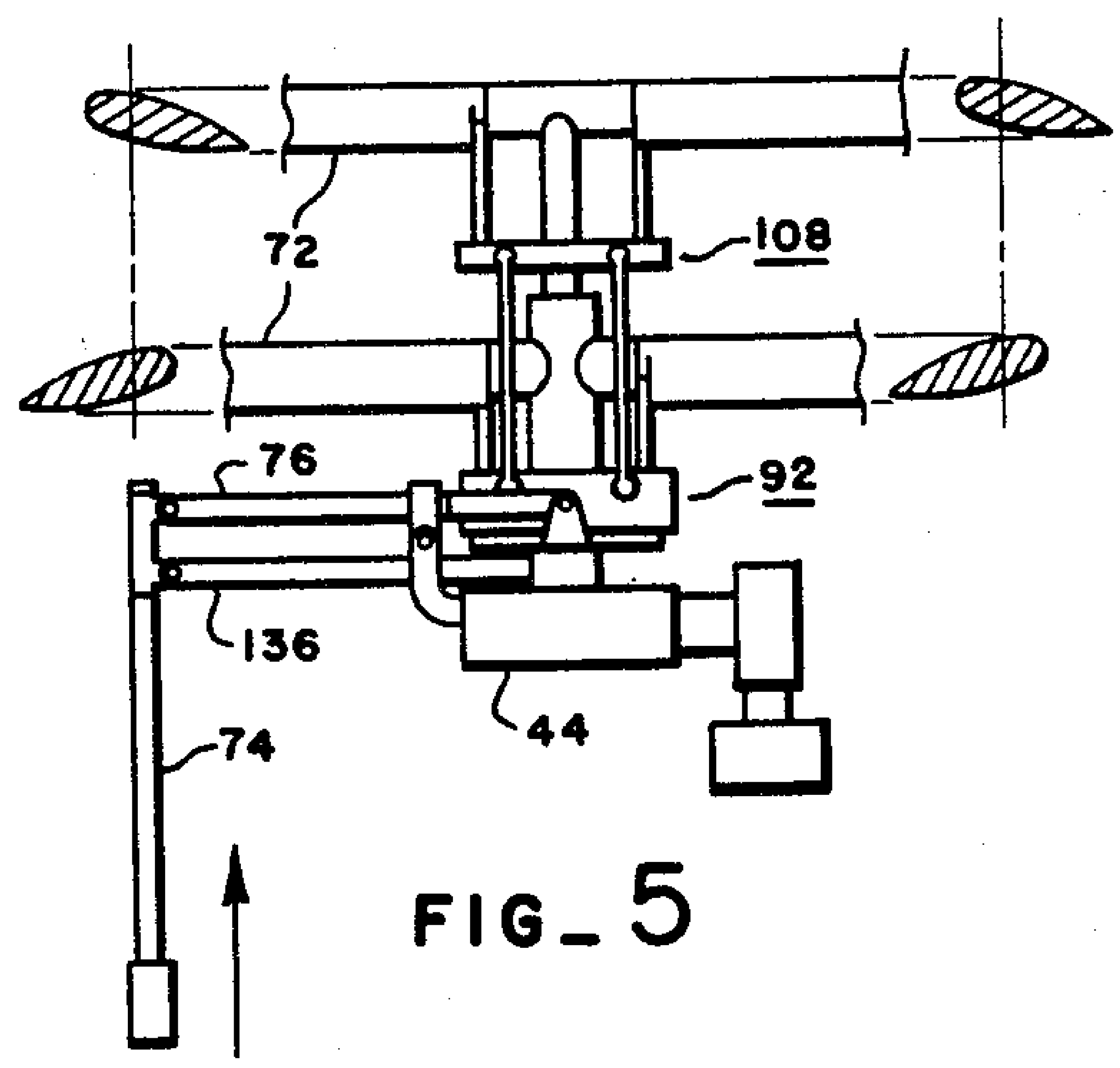

FIG_5

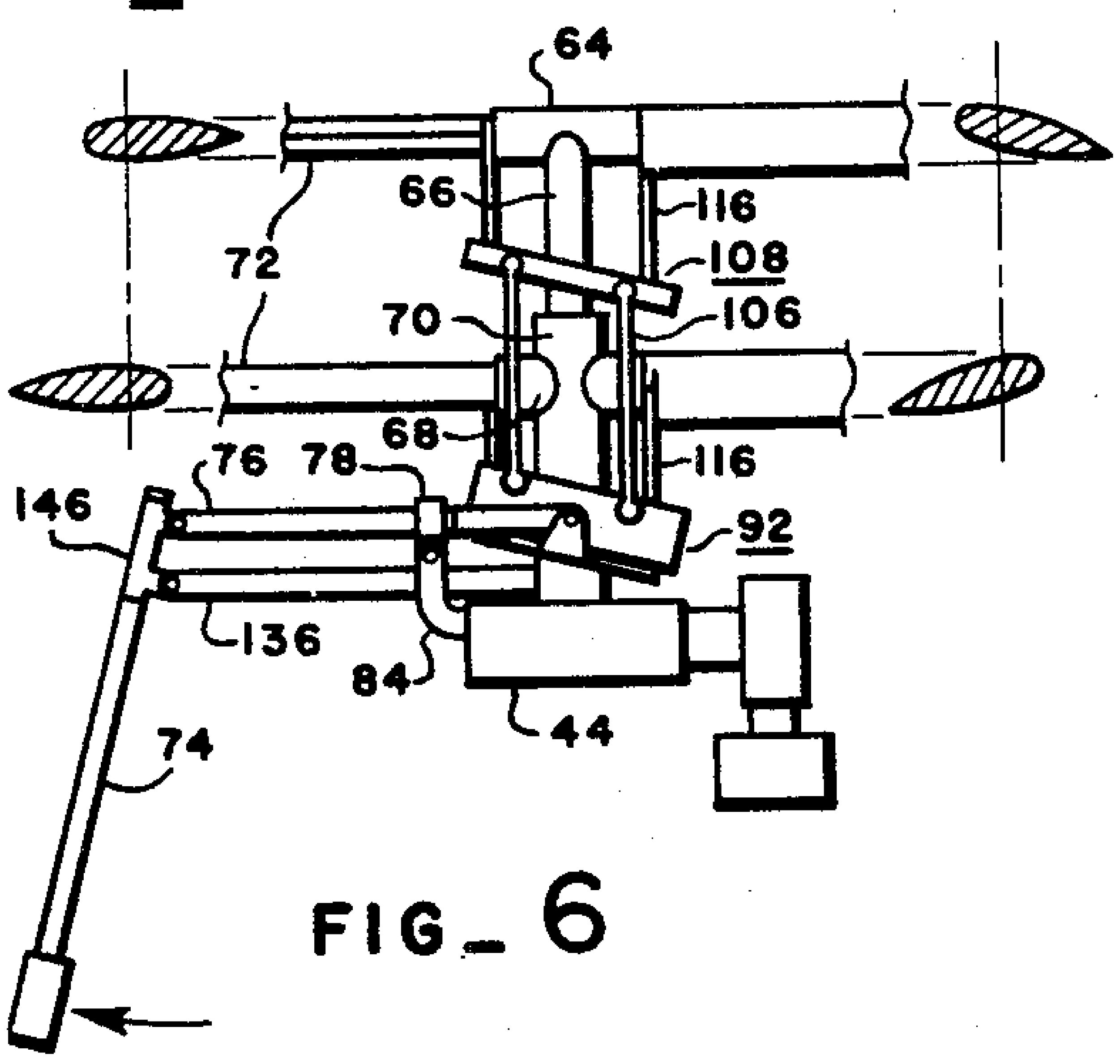

FIG_6

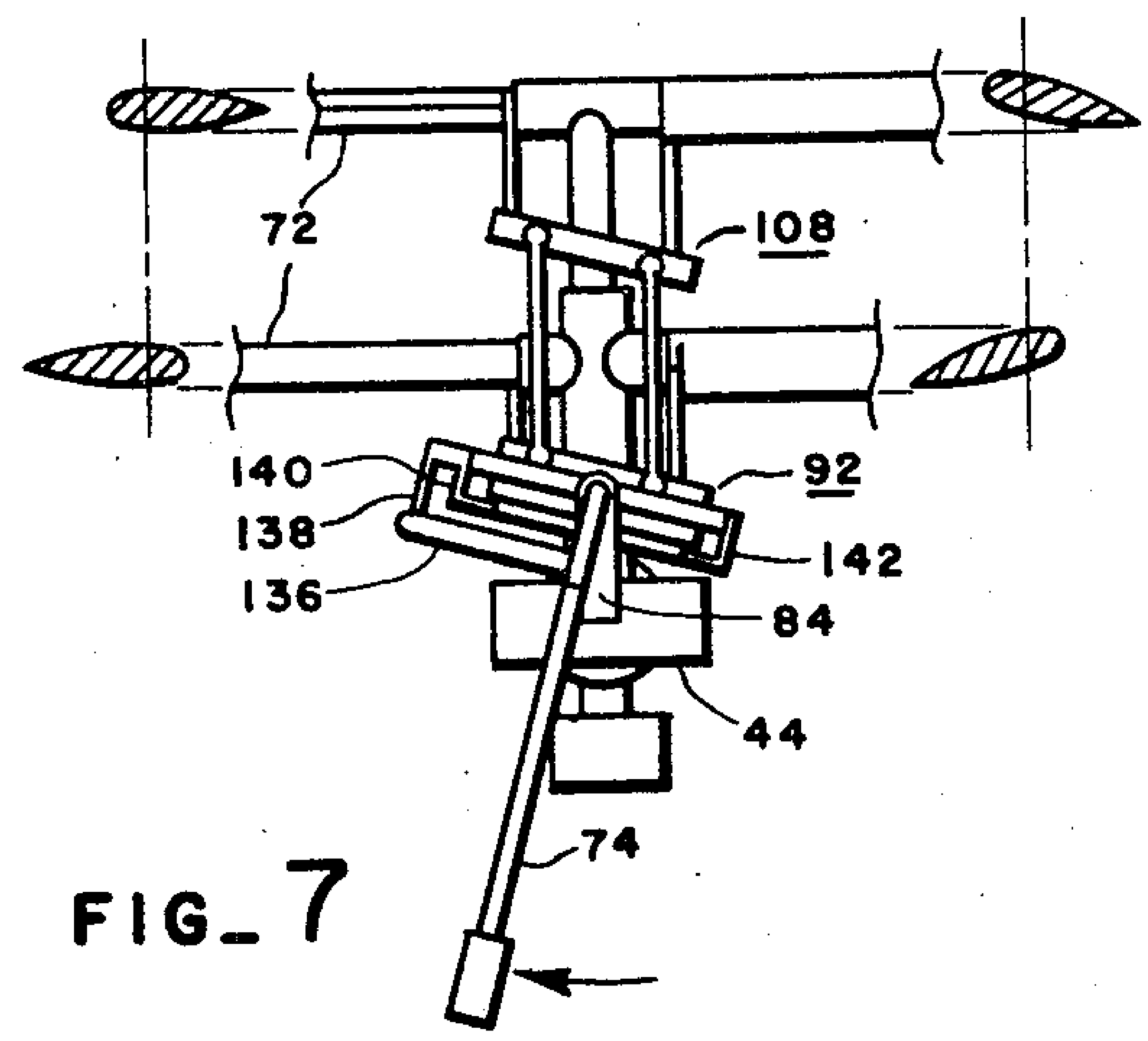

FIG_7

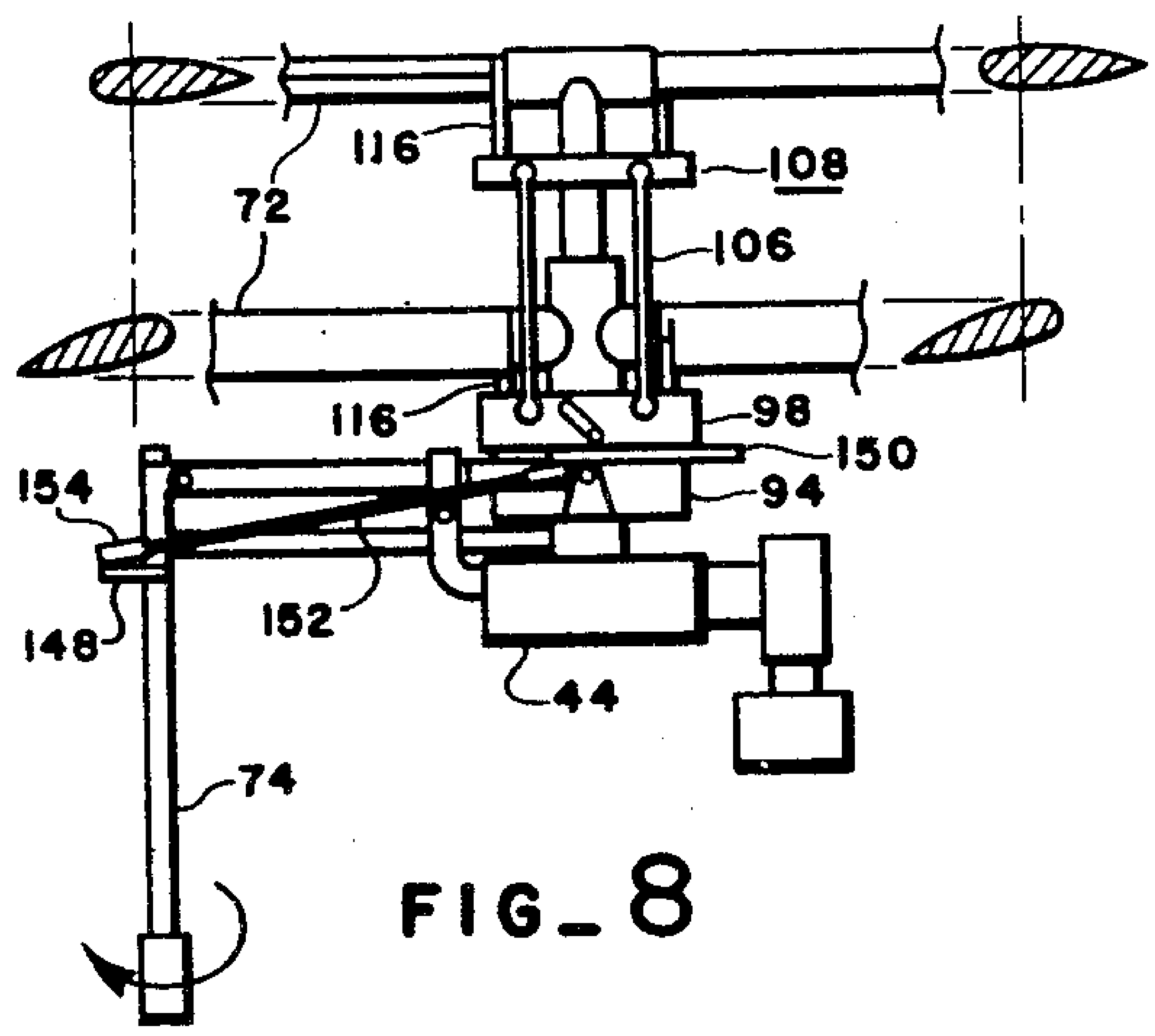

FIG_8

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UNITED STATES PATENT OFFICE

2,486,059

CONTROL MECHANISM FOR HELICOPTERS WITH COAXIAL ROTORS

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Application October 9, 1945, Serial No. 621,254

4 Claims. (Cl. 170—135.24)

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This invention relates to a control mechanism for helicopters with co-axial rotors and, more particularly, to an operating and control means for counter-rotary, co-axially bladed helicopters.

It is a prime object of the invention to provide improved and simplified control of helicopter operation and flight.

Existing helicopters, including those of the co-axial counter-rotary type, are now flown by trained operators who have learned to coordinate their movements of several different control elements to produce the proper collective adjustments which result in desired flight maneuvers. These individual control elements usually consist of: First, means for positioning the angle of pitch of all blades collectively in order to change the total lift of the rotors; second, means for obtaining cyclical blade angle pitching in order to create or change the horizontal thrust necessary for lateral flight of the craft in any direction; and, third, means for maintaining or rotating the draft in any desired direction about its upright axis while in flight.

A lever operable by hand is usually provided to adjust the pitch angle of all blades collectively, and by means of a twisting handgrip throttle mounted thereon engine power is also controlled. A second lever operated by the pilot's other hand and free to be positioned in the direction of desired travel usually controls the cyclic pitching of the rotor blades. The usual method to control the direction of the craft about its upright axis includes right and left foot pedal elements which are selectively depressed by the operator depending upon the direction in which he desires the craft to rotate.

It is evident from the above that the pilot thus engaged to maintain satisfactory flight is physically fully occupied, since both his hands and both his feet are continually required to effect control adjustments. Such other adjustments as may be necessary to engine or auxiliary equipment controls must then be made with difficulty and at the expense of continuous safe flying control.

Other objects of the invention, therefore, are to impress collective pitch and cyclic pitch upon the blades of a counter-rotary co-axial blade type helicopter by means of a single operator controlled element; to impress collective pitch variably upon the blades; to impress cyclic pitch upon the blades while at the same time and by the same means varying the collective pitch between the blades; and to impress both cyclic and

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collective pitch by a single manually operable means that is also capable of varying the collective pitch of the blades.

Still other and important objects of the invention include the provision of novel means for collectively pitching a pair of blades in helicopters of the type mentioned above, and novel means for cyclically pitching such blades, which means may or may not be associated with a single control element.

Other objects and advantages of the invention will be apparent from the following descriptions, the accompanying drawings and the appended claims.

In the drawings:

Figure 1 is a side elevation of a small helicopter embodying my improvements;

Figure 2 is a schematic diagram of the transmission thereof;

Figure 3 is a perspective view of the rotor blade control means thereof, with various small sections broken away for convenience of illustration;

Figure 4 is a schematic view of the mechanism in the zero pitch position;

Figure 5 is a schematic view of the mechanism in the full collective pitch position;

Figure 6 is a schematic view of the mechanism in the forward cyclic pitch position;

Figure 7 is a schematic view of the mechanism in the transverse cyclic pitch position;

Figure 8 is a schematic view of the mechanism in the variable collective pitch position.

Referring in detail to the drawing in which one form of the invention is illustrated, the aircraft comprises a frame of tubular members 10, adapted to support the pilot in suitable flying position. Three radially spaced members 12, 14, 16 form the ground engaging elements of frame 10 and serve to maintain lateral stability of the craft when at rest. A tube 18 is attached to the forward engaging element 12 and furnishes a foot rest for the pilot. Two canvas pieces 20 and 22 are attached to, and suspended between the tubular members of frame 10, furnishing a seat and back support for the pilot. A safety belt 24 and a manual throttle control 26 are also mounted on frame 10 at convenient locations.

Also comprising the aircraft and rigidly attached to frame 10 is an engine 28, including a carburetor 30, spark plugs 32, exhaust stacks 34, air-cooling baffle 36, fuel line 38, and a fuel tank 40. One form of engine which may be used to furnish power for sustaining flight of the craft is of the internal combustion two stroke, two cylinder opposed type. It is forced air-cooled by means of paddles attached to the flywheel which also houses the magneto. Starting may be by means of a rope, knotted at one end and wrapped around the flywheel in the same manner as is customary with outboard-type marine motors. The flywheel is preferably mounted on the underside of the engine with the crankshaft axis upright and the power end of the shaft at the top of the engine. Throttle 26 may be attached directly to carburetor 30 for manual control or an inertia type throttle governing device may be used to maintain constant engine speed with manual throttle 26 serving as an over-ride control for use only when emergency power is required or when unusual operating requirements dictate its use. A switch button 42 shorts the primary circuit of the engine magneto system and may be conveniently located on the flight control element where the operator may quickly stop the engine by depressing the button with his thumb.

Also comprising the aircraft and fitted to the upper end of the engine 28 is a transmission 44. The function of the transmission, more fully described in my co-pending application, Serial No. 622,727, filed October 17, 1945, now Patent No. 2,261,348, is to furnish means for converting and dividing engine torque between two coaxial counter-rotating rotors, as well as furnishing (*a*) means for manually disengaging all engine power and rotation from being transmitted to the rotors and (*b*) means for automatically limiting the transmission of torque through the system to the single or one way route from the engine power end to the rotor shafts 66 and 70.

Figure 2 illustrates a method for obtaining the foregoing desired condition. A splined engine power-shaft 46 is fitted into a cone clutch 48 controlled manually by a clutch lever 50. A pinion 52, receiving power through the clutch 48, and a gear 54 reduce engine speed and angularly change the axis of rotation. A ratchet type overrun clutch 56, between gear 54 and pinion 62, allows the rotors to become automatically free to rotate in their normal directions upon engine stoppage while still being interconnected by differential gears 58 and 60 through pinion 62. The upper rotor hub 64 is connected, by means of the upper rotor shaft 66, to gear 58 and the lower rotor hub 68 is connected to gear 60 by means of the lower rotor shaft 70, these shafts being coaxial.

Attached to each rotor hub 64 and 68, and also comprising the aircraft, are pairs of rotor blades 72. These may be of the size and configuration most advantageous in obtaining maximum performance and greatest economy for the craft as determined by aerodynamic and power calculations. A blade may be selected with a symmetrical airfoil section and a center of pressure which falls approximately at the quarter chord point. A blade is hinged to its rotor hub so that it may rotate about a longitudinal axis coinciding with its center of pressure axis or at a point quarter distant between leading and trailing edge. Very little force then is required to change its relative angle of attack throughout a sufficiently wide range to encompass both the maximum and minimum angles normal to helicopter rotor blade operation in flight. For this reason, the pilot may be able to directly and manually control the blade angles during flight without undue effort.

The mechanism required to position and maintain the blade angles necessary for controlled flight maneuvers then comprises and completes the aircraft selected to illustrate my invention. In Figure 3, a control handle 74 may be moved by the pilot in any direction he wishes the craft to fly. It may be moved up or down as shown in Figures 4 and 5, the result being a simultaneous increase or decrease in the angle of attack or pitch of all rotor blades. With an upward push of the control handle and an increase of blade angle, together with an increase in engine power either by manual or automatic adjustment of the throttle control, the craft will climb. The upward force on the control handle 74 is transmitted by rod 76 through slide bushing 78 radially movable about pin 82. The latter pin is pivotally mounted stationary with the case of transmission 44 by bifurcated arm 84. The fork yoke 86, rigidly attached to rod 76, then forces two pins 88 and 90 down, which are connected to and in turn carry downward the lower gimbals assembly 92, composed of an inner ring 94 and track 96 and an outer ring 98 and track 100, a lower gimbals spacer yoke 102, and parts attached thereto. An outer ring shoe 104, engaged in the outer ring track 100, has rods 106 universally attached thereto. Rods 106 are also universally connected to the upper gimbals assembly 108, composed of the upper ring 110 and track 112 and the upper gimbals spacer yoke 114, and parts attached thereto. The latter is also forced downward upon an upward movement of control handle 74.

A blade pitch rod 116 is universally attached at one end to the trailing portion of a blade 72 and at the other end to a rotary track shoe 118, which in turn rides in a ring track 96, 112. When the control handle 74 moves upward the trailing edge of all blades will be forced down, and the result will be a simultaneous increase in all the angles of attack of the blades. This will be true for any rotational speed of the counter-rotating hubs 64, 68. The lower ends of rods 116 and the shoes 118 connected therewith are held in a proper radial position in each gimbals assembly by gimbals spacer yokes 102, 114. These yokes are radially fixedly, slidably and pivotally related to their adjacent hubs and rotor shafts. This relation is accomplished in each case by providing the shafts 66 and 70 with collar 120 secured thereto, and having diametrically opposed slots 122 in which move shoes 124 that carry the pins 126, on eah pair of which is pivotally mounted a gimbals spacer yoke 102, 114. The upper and lower gimbals spacer yokes, shoes, and blade rods of the upper and lower gimbals assembly rotate in opposite directions since they are attached to the counter-rotary shafts. The upper ring 110 and track 112 of the upper ring gimbals assembly, however, are rotated with the lower rotor by means of the four rods 106, which are held vertically aligned and are rotated with guide crosshead 128, which is attached to, and rotated with, the lower rotor shaft 70. This arrangement permits the like adjustment of the angle of attack of each rotor throughout their cycles of rotation as illustrated in the schematic Figures 4 and 5.

Collective pitch adjustment is a function which is normally made only occasionally during flight, and since the control handle will be used chiefly to effect other functions to be explained hereafter, it is advisable to include means for easily maintaining a collective pitch position once it is set into the system. One method is the use of a friction device at the fulcrum pin 82, such as fiber washers 80 compressed between the matching surfaces of the support arm 84 and slide bushing 78. The pressure may be adjusted to give the proper degree of resistance to motion between these parts and thus leave the pilot free to make other and more frequent adjustments on the control handle. For this purpose the bifurcations of arm 84 may be drawn together by bolt 130 and wing nut 132.

In order to control the horizontal movement of helicopters through the air while they are being sustained at the same time by the lift developed by rapidly rotating blades, it has been found that cyclic pitching, or cyclically changing the angle of attack of each blade during its travel around the hub center, is necessary. For coaxial counter-rotary machines it may be advisable to arrange the control mechanism so that cyclic pitching can be impressed upon the blades of both rotors simultaneously. The phasing, or the positioning of the point at which counter-rotating blades should reach their maximum or minimum angle of attack in their travel about the hub center to give the maximum or most efficient total lateral thrust, is a debatable question but one which does not essentially affect this invention since, by properly positioning the shoe ends of rods 116 and the diametrically opposed slots 122 radially about the hubs 64 and 68, any phasing can be obtained with mechanisms described herein.

Figure 6 shows that by pushing the control handle 74 forward the blades of both rotors are cyclically pitched in such a manner as to create an unbalanced total lift and, therefore, thrust in a forward direction. Figure 7 shows a similar condition in which a motion of the control handle 74 to the left results in a thrust to the left. The mechanics of the control, in fact, allow the control handle 74 to be displaced in any direction away from vertical with a resulting motion of the craft in that direction.

In Figure 3, assuming that the slide bushing 78 is stationary with the support arm 84 and with the case of transmission 44 because of the friction of the washers 80, the control handle 74 may pivot fore and aft on pin 134, and from side to side about the center line of rod 76 journalled in the slide bushing 78. By swinging on the pin 134 handle 74 carries rod 136 connected thereto fore and aft, which action in turn swings crank arm 138 on yoke pin 88. Since the arm 138 is connected by strap 140 to the inner ring 94 of the lower gimbals assembly 92, any motion of the control handle 74 in a forward or aft direction results in a tipping of the gimbals assembly 92 fore or aft. Since the rod 76 is attached to yoke 86 which, in turn, supports the lower gimbals assembly 92 by straps 140 and 142, any right or left motion of the control handle 74 will tip the lower gimbals assembly 92 to the right or left. Any motion of the control handle 74 away from the vertical then results in the lower gimbals assembly 92 tipping in the same direction, as will, also, the upper gimbals assembly 108, since all tipping motions of the lower assembly are transmitted to it by rods 106. Both gimbals assemblies 92, 108, since they are universally attached to their respective rotor shafts 70, 66, will likewise function at any rotor speeds and maintain any tilted position so determined by the control handle 74. It is evident, then, that as the paired blades 72 are rotated by their hubs 64 or 68, and since their roots 144 are turning in a fixed plane perpendicular to the axis of the coaxial shafts 66, 70, the blades will changes their angles of attack about their pitching axis exactly as determined by the tilt or tipping of the ring tracks 100 and

112, in which the rotary track shoes 118 are traveling, and to which the ends of the blade pitch control rods 116 are attached. Therefore, the positioning of control handle 74 in any direction other than parallel to the axis of the coaxial rotor shafts 66, 70, will impress a cyclic changing of attack angles of all rotating blades 72 in a manner creating greater lift in portions of their rotational sweep. Such induces a transverse thrust in the same direction as the handle has been moved and a subsequent motion of the craft in that direction.

The control handle 74, rods 76 and 136, and arm 138 constitute a parallelogram hinged at each corner, the motions of which are limited by the slide bushing 78, through which the upper rods 76 may slide fore and aft slightly. Thus, cyclic pitching is not affected by any vertical displacement of the control handle 74 in adjusting collective pitch, and the opposite is equally true because at any collective pitch position of control handle 74, cyclic pitch may be impressed as desired upon the system by appropriate movement of the same control handle 74.

In order for the pilot to perform all the useful flight maneuvers inherent in machines of the helicopter type, one additional control provision is necessary. While in flight, particularly so in the hovering condition, it is desirable that he be furnished means for facing the craft in any direction by rotating it about its upright axis. In fact, since the craft is attached to, and suspended under, rotating elements which have been arranged in such a way as to transmit both the torque and counter-torque of the engine to the surrounding air, it is necessary to furnish means for easily adjusting or balancing these torques so that the craft itself will not constantly rotate in one direction or the other. The fact that a greater resistance to rotation of one rotor as compared with the resistance to rotate in the opposite direction of the other rotor will result in the craft itself rotating in this same opposite direction is utilized in this invention to furnish directional control. The resistance to the rotation of either upper or lower rotor is accomplished by increasing the angle of attack, and thus, the aerodynamic drag of the blades of that rotor.

Referring to Figure 3, control handle 74 is shown free to rotate about its longitudinal axis in sleeve fitting 146 which also holds it in proper operating position. The rotary motion of handle 74 is translated into rotary motion of the outer ring 98 by means of the linkage system comprising arm 148 on the handle 74, arm 150 on the ring 98, and the push-pull link 152 connected between said arms by ball and socket fittings 154. This system constitutes a second flexible parallelogram between the handle 74 and the lower gimbals assembly 92, and operates the directional control system regardless of the position of the control handle as it is employed for its other control functions.

As has been noted above, the lower gimbals assembly 92 is composed of the inner ring 94 and track 96 which determine the blade angles of the lower rotor, and the outer ring 98 and track 100 which, by means of rods 106, control the position of the upper gimbals assembly 108 and, thus, the blade angles of the upper rotor. The inner ring 94 and track 96 are held motionless radially by straps 140 and 142 and pins 88 and 90, which are attached to the yoke 86. The outer ring and track 98, 100 are free to both rotate around and to slide up and down relative to the outside of the inner ring 94 and track 96, restricted only by three or more pins 156 which are rigidly attached to the inner ring 94, and which protrude through cam slots 158 cut in the outer ring 98. These cam slots 158 are cut in a helical pattern so that any rotation of the outer ring 98 will result in its being raised or lowered relative to the inner ring 94. Since these rings respectively determine the pitch angles of the upper and lower rotor blades, a twisting of the control handle 74 will thus introduce a differential adjustment between blade angles of the two rotors.

As illustrated in Figure 8, the twisting of the control handle 74 about its longitudinal axis clockwise as viewed from above will effect the increase in pitch of the blades of the lower rotor as compared with that of the blades in the upper rotor. Since the lower rotor is rotating counter-clockwise, an increase in its blade pitch, and subsequent increase in its resistance to rotation, will result in a reaction at the transmission and, thus, within the suspended craft a reaction of a similar magnitude and in the opposite direction. Such reaction in this example will be in a clockwise direction, and the craft then will rotate in the same direction that the control handle is twisted. Rotating the control handle counter-clockwise will increase the pitch of the blades of the upper rotor, as compared with that of the blades of the lower rotor, and the craft will then rotate counter-clockwise.

For purposes of illustrating my invention more clearly, the following mythical flight may be considered typical. Assume that the craft shown in Figure 1 is standing idle in a small cleared area, surrounded by buildings or trees similar to those found in most urban areas, and that the pilot wishes to be transported to some other similar spot several miles distant. The machine has been checked for mechanical worthiness, and the fuel tank has been filled with the proper mixture of fuel and lubricant. The pilot may seat himself in the machine and fasten the safety belt 24 and check the manual clutch control handle 50 to make sure that the clutch is disengaged. He or an assistant may then start the engine, and when it is warmed sufficiently to insure trouble free continuous operation, the pilot may position control handle 74 in the manner shown in Figure 4. This will set all the blades at zero angle of attack and thereby reduce their frontal area and, hence, their aerodynamic drag to the minimum while the rotors are being brought up to flying speed. The pilot may next engage the manually operable clutch slowly while increasing his throttle setting as the engine power is being absorbed through the transmission and by the rotors. The clutch will be fully engaged at some speed considerably under that of flying, and the pilot may then concentrate on only the control handle 74 and his throttle setting. When the rotors have reached full flying speed as determined by either the pilot's skill or by a governing device set to maintain the engine at optimum speed, the pilot will gradually force the control handle upward to a position similar to that shown in Figure 5.

The craft will then rise vertically at a rate of speed determined by the speed with which the control handle has been moved, and by the amount of power being delivered by the engine to the rotors. As the craft leaves the ground it may be apparent that the rotor torque may not be balanced, and the craft may begin rotating about its upright axis until the pilot corrects it directionally by twisting the control handle about its longitudinal axis as described.

He may wish to continue in vertical flight until he has risen above the surrounding obstructions, in which case he will allow the control handle to remain as in Figure 5 and maintain direction by holding the handle at the point where he has twisted it to balance out uneven rotor torques.

When the craft has reached the height of a few feet, the pilot may lower the control handle and at the same time reduce throttle until the craft has ceased rising and the engine is supplying just enough power, and the rotors are producing just enough lift, to sustain the craft. It will be necessary in laterally moving air to make adjustments from time to time in his cyclic pitching to keep the machine from moving laterally with respect to the ground. The pilot will counteract these lateral tendencies by moving the control handle as in Figures 6 and 7, or, more precisely, in the direction opposite from that in which the machine has begun to move. While thus hovering, he may wish to face the machine in a new direction, in which case he twists the control handle in that direction, returning it again to the balance position when the machine has made the maneuver.

To continue the rise, he will again push the control handle upward and increase engine power. To execute a forward turning climb, he will push the control handle forward, twist it in the direction of turn, and probably reduce throttle somewhat as he gains forward speed. This is due to the fact that it requires less power for the craft to climb laterally than it does to climb at the same rate vertically. When the turn is complete, he will twist the handle to its neutral position. When the climb is complete, he will reduce collective pitch and engine power slightly and continue forward flight. As his forward velocity increases he may return the control handle from its forward position, Figure 6, to nearly that shown in Figure 5. When he has reached his destination he will pull the control handle back toward himself, whereupon the craft will reduce its forward speed and will begin to lose altitude. When all forward motion has ceased, the handle is returned to normal as shown in Figure 5, and moved down slightly as the throttle is reduced. The craft will then settle vertically at a rate determined by the collective pitch and throttle setting. As it nears the ground, the pilot will increase this setting by again moving the handle upward and making ground contact lightly with the same maneuver as described above for hovering.

If, during the course of the trip and at some considerable altitude, the engine should fail, or for some other mechanical reason power should cease being transmitted through the over-run clutch 56 in Figure 2, the rotors will continue revolving, due to their inertia, for a short time, which will give the pilot sufficient opportunity to adjust the control handle from that of full power as in Figure 5, to a position at which the rotor blades are at a small angle of attack, and which will allow auto-rotation. In this instance the rotors of the craft will continue to revolve due to the aerodynamic forces acting upon them as the craft loses altitude, and at the same time furnishing lift which reduces the craft's rate of descent in much the same manner as a falling and rotating maple seed. With skill, the operator may control the craft in such a way as to glide to the nearest relatively open spot for his power-off landing. By maintaining the control handle at its auto-rotation setting, he is free to displace it laterally and to twist it, and thereby determine the lateral speed and direction of the craft. A landing of this kind may be severe, and possibly even destructive to parts of the craft, but it is unlikely to be fatal to the operator. With sufficient skill, however, it may be possible for the pilot to allow the craft to fall at a greater rate of speed during its early descent, thereby building up rotor speed and inertia which, just prior to ground contact, he may utilize for furnishing the craft with enough vertical lift to reduce its fall to zero. This maneuver, termed "flare-out," will then allow the machine and pilot to drop the remaining few feet to a very light landing.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims, as follows.

I claim:

1. In a helicopter, a pair of co-axial shafts, a blade adapted for variable lift and associated with each said shaft, means for moving said shafts in counter-rotation, between the paths of said blades and movable with one of said blades a first annular track, outside the paths of said blades a second annular track, a third annular track normally coplanar with and concentric of said second annular track, all of said tracks being longitudinally movable of said shaft axes, a spacer yoke between each the first and second said tracks and the inner and outer of said co-axial shafts respectively, each yoke having a pivotal coupling with the adjacent track and, at ninety degrees therefrom, a second pivotal coupling with the adjacent shaft, said last mentioned coupling being movable longitudinally of the shaft, a pitch control link revolubly coupled to each the first and second annular tracks and pivotally coupled to an adjacent blade to vary the lift of the blade upon longitudinal movement of the said tracks, said second and third tracks having therebetween co-operable screw elements operable upon rotary motion of one track relative the other track to produce relative longitudinal movement of each other along a common axis, link means coupled between said first and second annual tracks, a guide crosshead secured for rotation to the outer of said co-axial shafts and slidably engaged with the links between said first and second tracks, means for simultaneously moving said second and third tracks longitudinally of said shaft axes whereby said blades have variable lift impressed thereon, means for tilting one of said tracks relative said shaft axes, and a single manually operable element associated with said means for effecting longitudinal movement of said tracks and said means for tilting said tracks and operatively associated with said second and third tracks to impart a torque to one to produce relative rotary motion therebetween.

2. In a helicopter, a pair of coaxial shafts, a pair of blades adapted for variable lift and associated with each said shaft, means for moving said shafts in counter-rotation, between the paths of said blades and movable with one of said blades a first annular track, outside the paths of said blades a second annular track, a third annular track concentric of said second track, all of said tracks being longitudinally movable of said shaft axes, pitch control link means revolubly coupled to each the first and second annular tracks and pivotally coupled to an adjacent blade to vary the lift of said blade upon longitudinal movement of said tracks, a guide cross head secured for rotation to the outer of said co-axial shafts and slidably engaged with the links between said first and second tracks, said second and third tracks being relatively movable of each other along a common axis, means for effecting said relative movement between said second and third tracks, link means coupled between said first and third tracks, means for simultaneously moving said second and third tracks longitudinally of said shaft axes whereby said blades have variable lift impressed thereon, means for tilting one of said tracks relative said shaft axes, and a single manually operable element associated with said means for effecting longitudinal movement of said tracks and said tilting means and said means for relatively moving said second and third tracks.

3. In a helicopter, a pair of coaxial shafts, a blade adapted for variable lift and associated with each said shaft, means for moving said shafts in counter-rotation, between the paths of said blades and movable with one of said blades a first annular track, outside the paths of said blades a second annular track, a third annular track concentric of said second track, all of said tracks being longitudinally movable of said shaft axes, a pitch control link revolubly coupled to each the first and second annular tracks and pivotally coupled to an adjacent blade to vary the lift of said blade upon longitudinal movement of said tracks, said second and third tracks being relatively movable of each other along a common axis, co-operable screw elements between said second and third tracks for effecting said relative movement, and operable upon rotary motion of one screw element with respect to the other, link means coupled between said first and third tracks, means for simultaneously moving said second and third tracks longitudinally of said shaft axes whereby said blades have variable lift impressed thereon, means for tilting one of said tracks relative said shaft axes, and a single manually operable element associated with said means for effecting longitudinal movement of said tracks and said tilting means and said means for relatively moving said second and third tracks.

4. In a helicopter, a pair of coaxial shafts, a blade adapted for variable lift and associated with each said shaft, means for moving said shafts in counter-rotation, between the paths of said blades and movable with one of said blades a first annular track, outside the paths of said blade a second annular track, a third annular track concentric of said second track, all of said tracks being longitudinally movable of said shaft axes, a pitch control link revolubly coupled to each the first and second annular tracks and pivotally coupled to an adjacent blade to vary the lift of said blade upon longitudinal movement of said tracks, said second and third tracks being relatively movable of each other along a common axis, means for effecting said relative movement between said second and third tracks, link means coupled between said first and third tracks, means for simultaneously moving said second and third tracks longitudinally of said shaft axes whereby said blades have variable lift impressed thereon, between the first track and the inner of said coaxial shafts and between said second track and

the outer of said coaxial shaft, a spacer yoke coupled for rotation with each shaft and mounted for slidable movement therealong, said yokes each having a pivotal couple with its respective track at ninety degrees from its couple with the shaft, means for tilting one of said tracks relative said shaft axes, and a single manually operable element associated with said means for effecting longitudinal movement of said tracks and said tilting means and said means for relatively moving said second and third tracks.

HORACE T. PENTECOST.

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