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HELICOPTER LIFTING ROTOR MECHANISM

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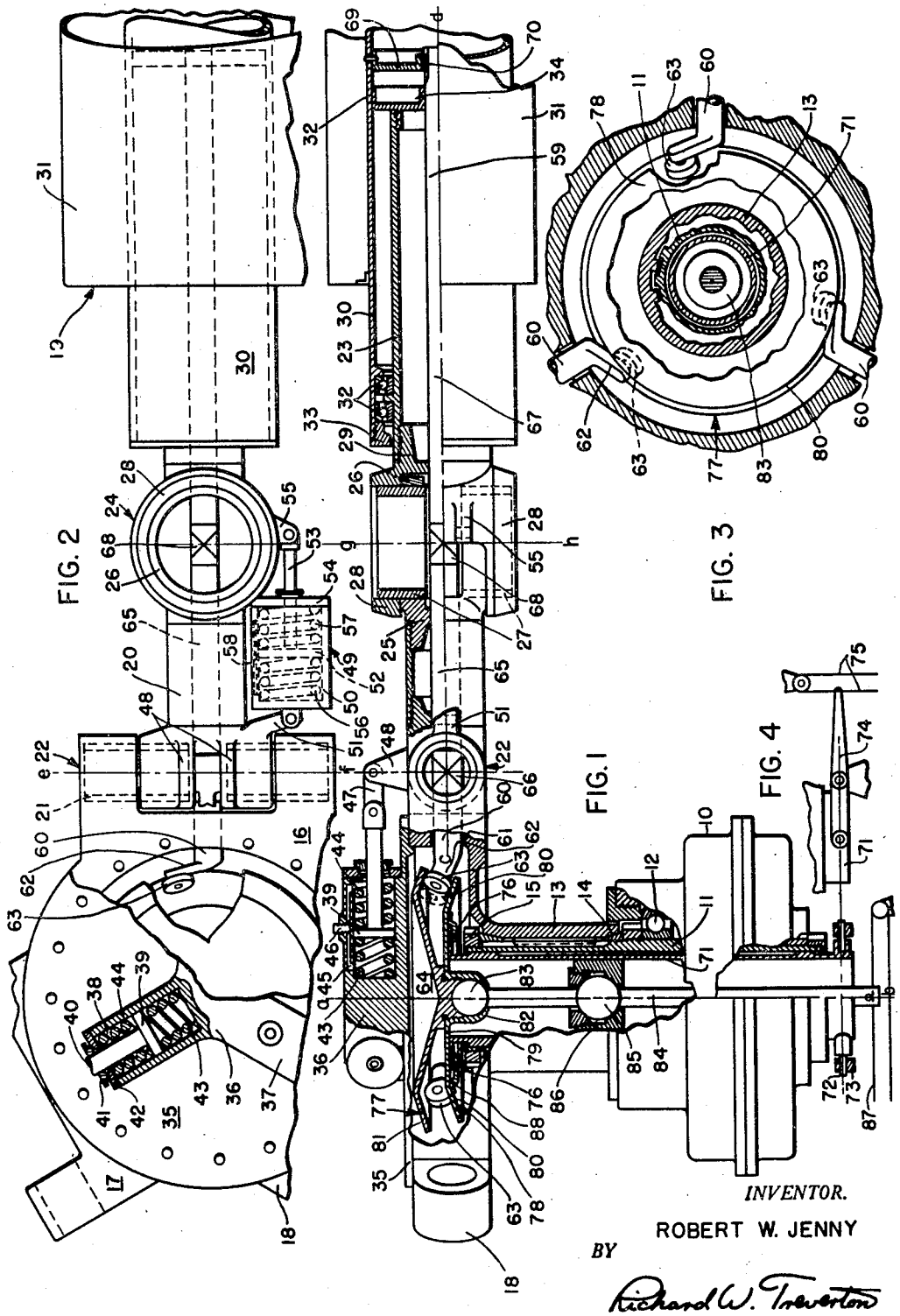


FIG. 1

FIG. 2

FIG. 3

FIG. 4

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HELICOPTER LIFTING ROTOR MECHANISM

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The invention relates in general to the lifting rotor mechanism of helicopters, particularly of the type which includes flapping and lag lead features in their rotor blades, and the invention particularly relates to the control mechanism for varying the angle of attack of the blades.

The invention has for a general object the providing of an improved and simplified structure of the type above outlined which, while providing for the desired flexibility in the parts which make up the rotor, will at the same time restrain and dampen out sudden relative changes in location of the rotor parts imposed thereon by outside forces.

Another object of the invention is to provide a control for tilting of the airfoil sections of the rotor blades which will be positive, easy of manipulation and by means of which the blades may be varied to modify the lift effect or modified to provide a cyclic effect as may be desired, and which control is for the most part housed within the outlines of the rotor thus to avoid such control parts interposing deleterious aerodynamic effects on the apparatus.

Various other objects and advantages of the invention will be in part obvious from a consideration of the accompanying drawings and in part will be more fully set forth in the following particular description of the form of lifting rotor mechanism of helicopters embodying the invention, and the invention also consists in certain new and novel features of construction and combination of parts hereinafter set forth and claimed.

In the drawings:

Figure 1 is a view partly in vertical section axially of the rotor shaft and axially of one of the rotor blades, partly in side elevation and with parts omitted, disclosing a helicopter rotor assembly constituting a preferred embodiment of the invention;

Figure 2 is a plan view looking down upon the device as disclosed in Figure 1, with parts of the rotor hub broken away and with some of the dampening devices shown in section;

Figure 3 is a transverse sectional view taken on the line 3—3 of Figure 1 looking upwardly as indicated by the arrows; and

Figure 4 is a detail of the all-over lift mechanism at the bottom of Figure 1 looking at the same at right angles to the showing thereof at the bottom of Figure 1.

In the drawings there is shown a fixed structural part 10 of the helicopter, in which some of the upstanding parts of the helicopter rotor are

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mounted and for this reason hereinafter sometimes referred to as a support. Mounted in the support 10 and extending axially therethrough is a vertically extending rotor shaft 11 supported in journals, one of which is shown at 12, for rotation about a vertical axis *a*—*b*. Secured to the upper end of the rotor shaft is an open top hollow rotor hub 13 fixedly secured to the rotor shaft 11 by bushings 14 and a nut 15 in threaded engagement with the upper end of the rotor shaft. As viewed in plan in Figure 2, the hub is provided with three lateral extensions constituting flapping hinge yokes 16, 17, and 18, each designed to have hinged thereto one of three blades, of which only one marked 19 is illustrated. It is understood that the detailed description of this one blade and its associated parts will be sufficient for the other two blades herein omitted to economize in space.

Each blade is formed of two major parts normally extending in alignment and non-rotating about their long axis, of which the axis of blade 19 is indicated at *c*—*d*. These two component parts of the blade include a blade shank 20 fitted between the arms of the yoke 16 and pivoted thereto by pin 21. This arrangement of yoke 16, inner end of the blade shank 20 and pin 21 form a flapping hinge 22 turning about its axis *e*—*f* between the blade and the rotor hub. The other non-rotating and outer part of the blade forms a blade shaft 23 hingedly connected to the outer end of the blade shank for rotation about a vertical axis *g*—*h* to form a lag lead hinge 24. The lag lead hinge includes a pair of hollow elements arranged to turn relative to each other about the axis *g*—*h*. One of these elements 25 is screwed into the outer end of the blade shank and provides a rugged upstanding ring 26. Positioned in the upper and lower parts of the ring 26 are the two parts of a hollow hinge pin 27. Rotatably mounted on the outer portions of the hinge pin is the coacting barrel-like element 28 of the hinge. The barrel-like element includes a boss 29 screwed into the inner end of the blade shaft so that the blade shaft includes the barrel-like hinge element.

Mounted for tilting movement about the blade shaft is a blade assembly including a blade main spar 30 to the outer portion of which is fixed the airfoil section 31 of blade 19. The inner end of the blade main spar is journaled on the inner portion of the blade shaft by means of ball and plain bearings 32. A ring 33 threaded into the inner end of the blade main spar encircles the blade shaft and acts to restrain the

blade against the action of centrifugal force. The outer end of the blade shaft is maintained in spaced relation to the torque rod hereinafter described by a fixed bearing diaphragm 34. From this construction it is appreciated that the blade is of somewhat conventional design in that it includes a flapping hinge connection with the rotor hub permitting the blade as a whole to move in a vertical plane about a horizontal axis *e—f* defined by the pin 21 and the blade is also permitted a lag lead action turning about the vertical axis *g—h* provided by the lag lead hinge 24.

Also following somewhat conventional design, the present disclosure shows the use of dampening devices for restraining what would otherwise be a freedom of flapping action between the rotor hub and the blade shank and also between the blade shank and the blade shaft. Referring first to the device which restrains the freedom of flapping action, reference is made to the upper portion of the hollow rotor hub which is provided with a cover plate 35. Positioned on the cover plate and formed integral therewith is a trifurcate box 36 each arm 37 of which forms a dampening device for its associated blade.

Referring in detail to any one of these devices, it will be noted that it includes an oil containing cylinder 38 in which is slidably mounted a piston 39, the piston rod 40 of which extends outwardly therefrom through stuffing box 41 in an end plate 42. The piston is engaged on opposite sides by a pair of balancing springs 43 and 44 which tend normally to maintain the piston centered in its cylinder. Opposite ends of the cylinder are at all times in fluid communication by means of a by-pass 45. The flow through this by-pass is controlled by an adjustable plug 46.

The outer end of the piston rod 40 is connected by link 47 to a pair of upstanding arms 48 formed integral with the blade shank 20. From this construction it will be understood that any tendency of the blade shank to move upwardly from its normal horizontal position as shown in Figure 1 will cause the piston to move to the left of its showing in this figure, and which movement is, of course, resisted both by the compressing of the left hand spring 43 and by the oil or other fluid contained in the end of the cylinder to the left of its piston. The resistance imposed by the fluid is slowly released by reason of fluid moving slowly through the by-pass from the left end of the cylinder, where the fluid is under compression for the time being, into the right end of the cylinder where the fluid is under a reduced pressure at this time by reason of the tendency of the piston to move towards the left. By a suitable adjustment of the opening through the by-pass provided by the controlling plug 46 the rate at which the fluid is so by-passed may be regulated, and in this way the degree of dampening action provided by the device may be conveniently regulated. As each cylinder is provided with its own bleeding control plug 46, it is possible so to adjust the several plugs to attain the desired accumulative effect on all of the dampening devices.

A similar form of dampening device is provided across the lag lead hinge 24, that is, between the blade shank 20 and the blade shaft 23 of each blade. For this purpose there is disclosed as part of the dampening device 49 for each lag lead hinge a cylinder 50 (Figure 2), pivotally connected at one end to arm 51 extending angularly from the hub portion of the blade shank 20. Slidably mounted in the cylinder is a

piston 52, the piston rod 53 of which extends through end plate 54 and is pivotally connected at its outer end to an arm 55 extending outwardly from the outer annular element 28 of the lag lead hinge 24. The piston 52 is provided on opposite sides with balancing springs 56 and 57 and with a plug controlled by-pass 58, all similar to the parts previously described in connection with the flapping hinge dampening device 37.

The present disclosure particularly features means for controlling the angle of attack of the several blades 31. As the control mechanism is similar for all of the blades, the brief description of one will be sufficient for the others. In general, each blade is controlled by a torque rod 59 which extends from the rotor hub radially outward therefrom and through its associated blade. Each torque rod comprises three universally connected parts normally in axial alignment as shown in the drawings. Considered from left to right of the showing in Figure 2 the torque rod includes a torque rod hub piece 60 which is mounted in the blade shank in bearings 61 provided therefor. Hub piece 60 is provided at its inner end with a crank arm 62 loosely turning on which is a small roller 63 for engaging between the face plates of a conical cam 64 hereinafter described.

The middle portion of the torque rod forms a torque rod shank piece 65. The pieces 60 and 65 are connected by a universal joint 66 the center of which is located at the horizontal axis *e—f* of the flapping hinge 22. The outer portion of the torque rod constitutes a torque rod blade piece 67 which extends slightly beyond the outer end of the blade shaft and its diaphragm 34. The pieces 65 and 67 of the torque rod are connected by a universal joint 68 the center of which is in the horizontal axis *g—h* of the lag lead hinge 24. The outer end of the torque rod blade piece 67 is secured to the blade main spar 30 by a spacing diaphragm 69 which is secured to the torque rod by key 70.

Referring to the control for the three crank arms corresponding to the crank arm 62 and their associated torque rod in each blade, reference is made to the parts within the rotor shaft and rotor hub. Slidably mounted within the rotor shaft is an all-over lift control including a hollow sleeve 71 slidably mounted for vertical movement in the rotor shaft. Sleeve 71 projects downwardly below the rotor shaft and has opposite sides thereof fulcrumed as shown at 72 to the bifurcated arm 73 of a lever 74 controlled by an upstanding cable 75. At its upper end the sleeve 71 is provided with an outstanding flange 76 on which the non-rotating cam 64 rests. The cam is of a conical type and includes a pair of superposed and connected plates 77 and 78. The lower plate 78 has a flat inner portion 79 supported by the lift flange 76 and a downwardly inclined marginal edge portion 80 which provides a roller track and forms a portion of a conical surface concentric with its own axis and when in the position illustrated, concentric with the axis *a—b*. The several crank arm rollers engage this cam surface and rotate on the same about a circular path. The upper plate 77 is of dished form at its center and has its outer marginal portion 81 downwardly inclined to form a roller restraining guide. The underside of the guide 81 is inclined in a plane parallel to the roller track 80 and acts to restrain accidental upward movements of the crank arms and to rotate the crank arms downwardly when the cam as a

whole is lowered by the all-over lift control. The two plates coact at their centers to form a downwardly facing socket 82 containing a ball 83 forming a universal joint between the cam at its center and the upper end of a ball jointed lever 84 extending axially of the sleeve 71 and of the rotor shaft 11. The lever 84 includes a ball shaped fulcrum 85 spaced below the joint 83 and mounted for universal articulation in a slide box 86 slidably mounted in the sleeve 71 for vertically adjusted movement. The lever is controlled in its tilting movement by a cable 87 engaging its lower end. It is understood that the cam, together with its ball jointed lever 84, together with the all-over lift mechanism, form an assembly, including sleeve 71 and form relatively fixed parts and do not rotate with the rotor shaft in parts driven thereby.

Means are provided at the lower end of the sleeve 71 to maintain a supply of lubricant therethrough to all of the movable parts contained within the outlines of the rotor shaft and its rotor hub.

In operation, and assuming that the rotor shaft, the rotor hub and the several blades are turning about the axis *a*—*b* through conventional driving mechanism forming no part of this disclosure, it will be understood that normally the blades are turning in a horizontal plane with the airfoil sections disposed to give the requisite lift or autogiro effect as may be desired. It is also understood that the blades are free to assume their flapping positions and their lag lead positions as is at present known, except that the dampening devices herein disclosed interpose some restraint to the normal freedom of change of positions in the several parts of the blades as above indicated.

So long as the cam 64 is disposed in its normal position illustrated with its axis coinciding with the axis of rotation *a*—*b*, the several rollers will turn about the cam track 80 and move over a closed path set by the track in a horizontal plane. The torque rods will be locked against rotation so long as the circular line of contact between rollers and the cam remains in a fixed horizontal plane. So long as this condition persists the torque rods will be held fixed against rotation and thus the angle of attack of the several blades will likewise be fixed at whatever angle may be initially set. Should it be desired to change the angle of attack of all the blades simultaneously and thus lift the leading edges of all of the airfoil sections in one direction as when an all-over lifting control effect on the device is desired, the lever 74 controlling the all-over lift control device is operated to elevate sleeve 71 and therethrough to elevate the cam as a whole while still maintaining it concentric with the axis *a*—*b* but in another and elevated horizontal plane. This shifting axially from one horizontal plane to another has the effect of rotating all of the crank arms in the same clockwise direction over the same angle of turn and thus similarly changing the angle of all of the associated blades. In the showing in Figure 1 an attempt was made to show one of the rollers by dotted outline in its new position elevated above its former position riding higher on the cam, but the change in position is quite small and the change from the full line to the dotted line positions had to be exaggerated to disclose any change at all.

In the event that it is desired to restore the blades to their original pitch angle, the lever 74 is moved in the opposite direction, lowering sleeve 71 and flange 76, thus lowering the cam. This lowering of the cam causes its upper plate 81 to bear on the crank arms to rotate them in the opposite direction and thus effect a restoration of the blades towards or even beyond their previously pre-set position. In this way the blades may be set to Autogiro position or may be disposed to lower the machine by power effect as a whole.

The device also provides means for lateral control of the machine by cyclic action of the rotor blades. To attain this object, the lever 84 is tilted about its fulcrum 85 in the desired direction. Tilting the lever 84 acts through the joint 82 to shift the cam bodily away from its position centered at the axis *a*—*b* while maintaining its normal horizontal position.

It will be appreciated that rocking the shaft 84 about its fulcrum 85 over the small angle permitted by the construction will tend to effect a slight lowering of the ball 83 but any such tendency is resisted by the flange 76. As the cam is held by flange 76 from any such lowering effect the bearing 86 as a whole will rise in the guideway provided therefor by the sleeve 71. There is thus provided an automatic adjustment of the fulcrum and in this way any tendency of the shifted cam to bind itself on flange 76 is avoided. In order to prevent possibility of the cam 64 tilting or rising from the flange 76 any suitable restraining means may be provided. Such means may comprise, for example, a ring 88 secured to lower plate 78 and provided with portions underlying the flange 76.

The horizontal shifting of the vertical axis of the cam will, of course, cause the cam to approach the crank arm or arms towards which it is moved, and correspondingly will cause the cam to recede from the crank arm or arms away from which it is moved. Assuming for the moment that the rotor and associated blades are not turning, then it will be seen that any shifting of the cam, say to the right of the showing in Figures 1 and 2, will cause the right crank arm to be rotated upwardly and thus locate its roller higher on the inclined cam surface 80 than before, as indicated in dotted lines in Figure 1. Any such shifting of the cam to the right will correspondingly act on crank arms on its opposite or left side to rock any such crank arms on the retreating side of the cam downwardly and thus locate its roller lower on the inclined cam surface 80 than before. Now assume the rotor hub and with it the several blades and associated parts to be rotating about the axis *a*—*b* and the cam turning about a new axis offset therefrom. The right roller which was riding high when on the right side of the cam now rides low when on the opposite or left side of the cam. In other words, the point of contact of the rollers in their engagement with the cam track 80 move about a closed path elliptical in this case and in a plane which is inclined to the axis *a*—*b*. It therefore follows that as each crank arm describes a path or rotation about the cam, it is rocked upwardly for one half of the rotation and is then rocked downwardly for the other half rotation. This provides a cyclic effect of the blades, the blades similarly tilting more or less upward during one half of the rotor rotation and tipping more or less downwardly during the other half of the rotor rotation. Should it be desired to change the direction of movement of the machine, it is simply necessary to tilt the control lever from its previously tilted position into such other tilted position as will modify the

period in the rotation of the blades at which they change their oscillatory motion to attain the new direction of travel.

It is obviously possible to restore the control lever to the normal upright position illustrated in the drawings and thus to restore all of the blades to that pitch angle at which they were originally set for normal sustaining flight. While the present disclosure employs a cam of the conical type by reason of cheapness in the construction, it is suggested that the cam be of a hemispherical type. Irrespective of whether a conical or spherical type of cam is used, the operation will be the same.

It is thus seen that by means of the device illustrated, there is attained a control of the blades from a point within the fuselage body of the machine and thus convenient to the pilot. The disclosure particularly features the omission of any blade control parts in the air streams outside of the mechanism which includes the rotor. While the dampening devices are positioned external to the blades and the rotor hub, these parts have been made as small as possible and are so disposed as to cause the least possible amount of air stream interference. The parts are made rugged particularly at the articulated joints and elsewhere to compensate for severe localized strains at these points.

All of the movable parts within the outlines of the rotor shaft and hub are housed within the pool of lubricant supplied to the system from means contained in the fuselage and forming no part of this disclosure.

I claim:

1. Mechanism for controlling the angular tilting of an airfoil section of a helicopter as the section revolves, the combination of guide means including an upper and a lower plate having opposing vertical spaced apart parallel surfaces coacting to provide an annular channel therebetween extending downwardly and outwardly in fixed relation to the vertically extending axis of the guide means, an airfoil controlling torque rod provided with a crank guided for bodily movement about a circle of revolution in a horizontal plane and encircling said guide means, said crank provided with a roller operating in said annular channel and controlled in its rocking capacity by the engagement therewith of one or the other of said plates, said crank being held from rocking when the axis of the guide means contains the center of said circle of revolution and rocked by whichever of said plates happens to be in engagement therewith when said axis and center are relatively displaced from each other, and means for shifting the guide means horizontally in any direction to relocate the circles therein at which said surfaces engage the roller as it revolves about the guide means.

2. In a helicopter rotor assembly, the combination of a rotating hub, a rotor pitch control element pivoted to the hub upon a pitch axis disposed approximately in a plane of rotation of the hub and having a cam follower eccentric of said pitch axis, a non-rotating cam having opposed surfaces engaged by said cam follower, said surfaces being substantially parallel and substantially conical, a member movable axially of the hub and supporting the cam for axial movement therewith and also for lateral movement relative thereto in any direction in a plane of rotation of the hub to bring the axis of revolution of the cam surfaces into coincidence or eccentricity with the hub axis, axial and lateral movements of the cam respectively effecting mean and cyclic rotor pitch changes, a lever extending substantially axially within the hub, said lever being fulcrumed for universal pivot movement upon a pivot movable axially of the hub and the upper end of the lever having a universal connection with the cam whereby the lever may be operated to effect lateral movements of the cam in any selected direction.

3. In a helicopter rotor assembly, the combination of a rotating hub, a rotor pitch control element pivoted to the hub upon a pitch axis disposed approximately in a plane of rotation of the hub and having a cam follower eccentric of said pitch axis, a non-rotating cam having surfaces engaged by said cam follower, said surfaces being substantially parallel and substantially conical, a member supporting the cam for lateral movement relative thereto in any direction in a plane of rotation of the hub to bring the axis of revolution of the cam surfaces into coincidence or eccentricity with the hub axis, such lateral movements of the cam effecting cyclic rotor pitch changes by varying the path of the cam follower upon the cam surfaces, a lever extending substantially axially within the hub, said lever being fulcrumed for universal pivot movement upon a pivot that is movable axially of the hub and the upper end of the lever having a universal connection with the cam whereby the lever may be operated to effect lateral movements of the cam in any selected direction.

4. In a helicopter rotor assembly, the combination of a rotating hub, a rotor pitch control element pivoted to the hub on a pitch axis disposed approximately in a plane of rotation of the hub and having a cam follower eccentric of said pitch axis, a non-rotating cam having vertically spaced opposed surfaces engaged by said cam follower, said surfaces being substantially parallel and substantially conical, a member movable axially of the hub and supporting the cam for axial movement therewith and also for lateral movement relative thereto in any direction in the plane of rotation of the hub to bring the axis of revolution of the cam surface into coincidence or eccentricity with the hub axis, and means for moving said member axially and said cam laterally for thereby effecting, respectively, mean and cyclic rotor pitch changes.

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