# United States Patent [19]

**French**

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[54] **MULTI-AXIS HAND CONTROLLER**


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[52] **U.S. Cl.** ..... **74/471 XY**

[51] **Int. Cl.** ..... **G05g 9/04**

[58] **Field of Search** ..... 74/471 XY, 471; 200/6 A



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*Primary Examiner*—Milton Kaufman

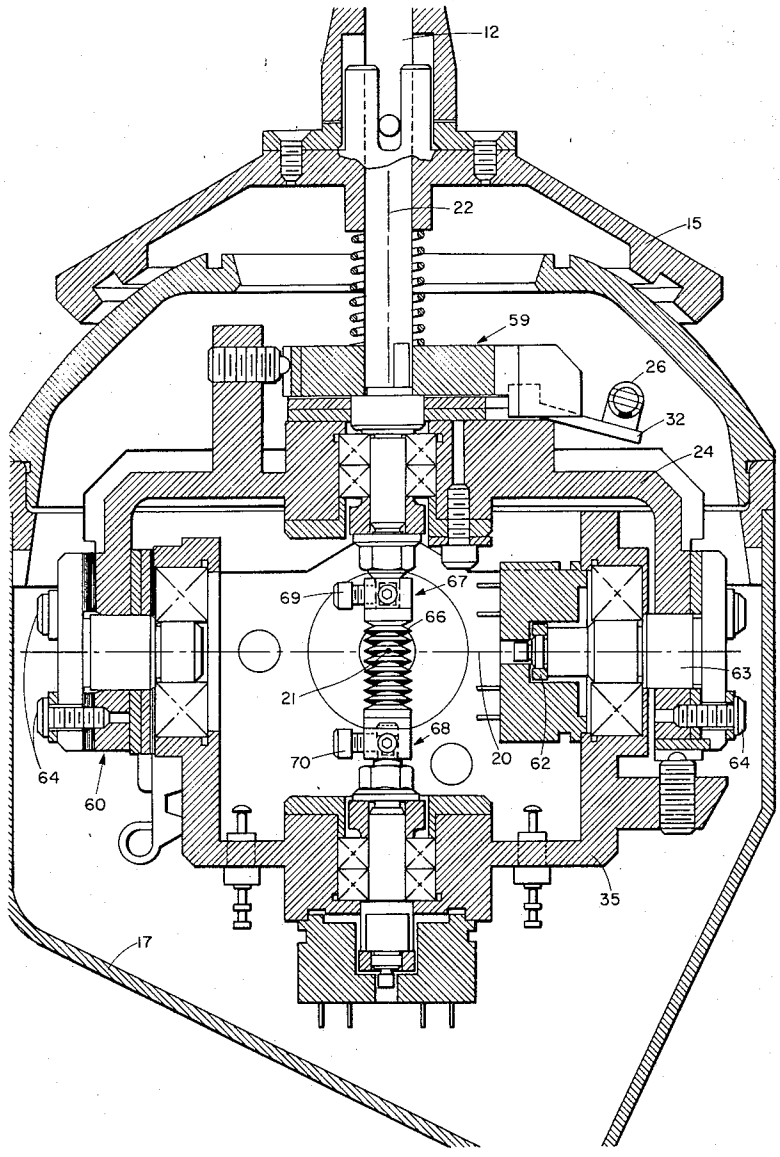
*Attorney*—R. S. Sciascia et al.

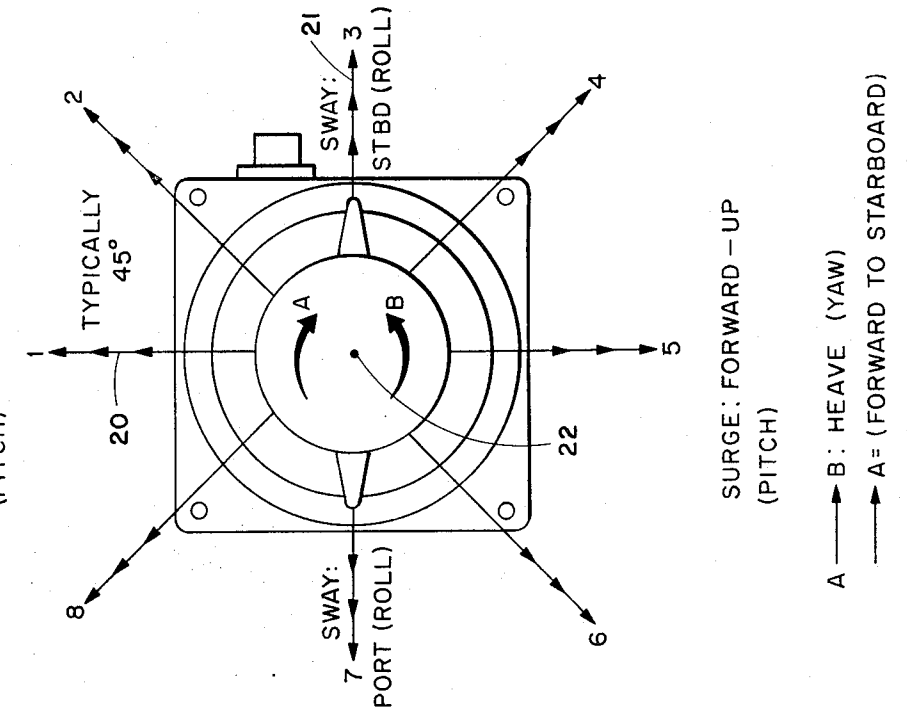


[57] **ABSTRACT**

A precision mechanical centering device is provided in which a single spring controls the return of two oppositely formed spring plates to a positive stop in each of the three axes of motion. Null adjustment is made by separating the tines of a tuning fork mounted on the same axis as each pair of spring plates until the tines contact the end surface of the spring plates. These end surfaces are positioned apart and prevented from closing by a tab of appreciable thickness which is either securely attached to or an integral part of a centrally located ground block.


**16 Claims, 7 Drawing Figures**

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(PITCH)
TYPICALLY
45°
SWAY:
STBD (ROLL)
SWAY:
PORT (ROLL)
SURGE: FORWARD – UP
(PITCH)
A → B: HEAVE (YAW)
A = (FORWARD TO STARBOARD)
B = (FORWARD TO PORT)
1
2
3
4
5
6
7
8
20
21
22
A
B

Fig. 2

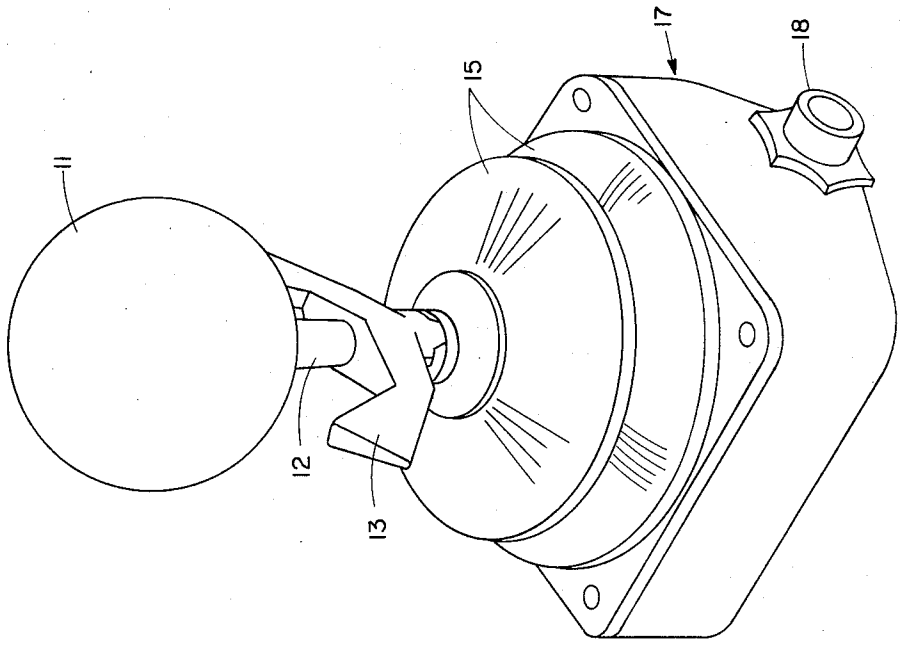
11
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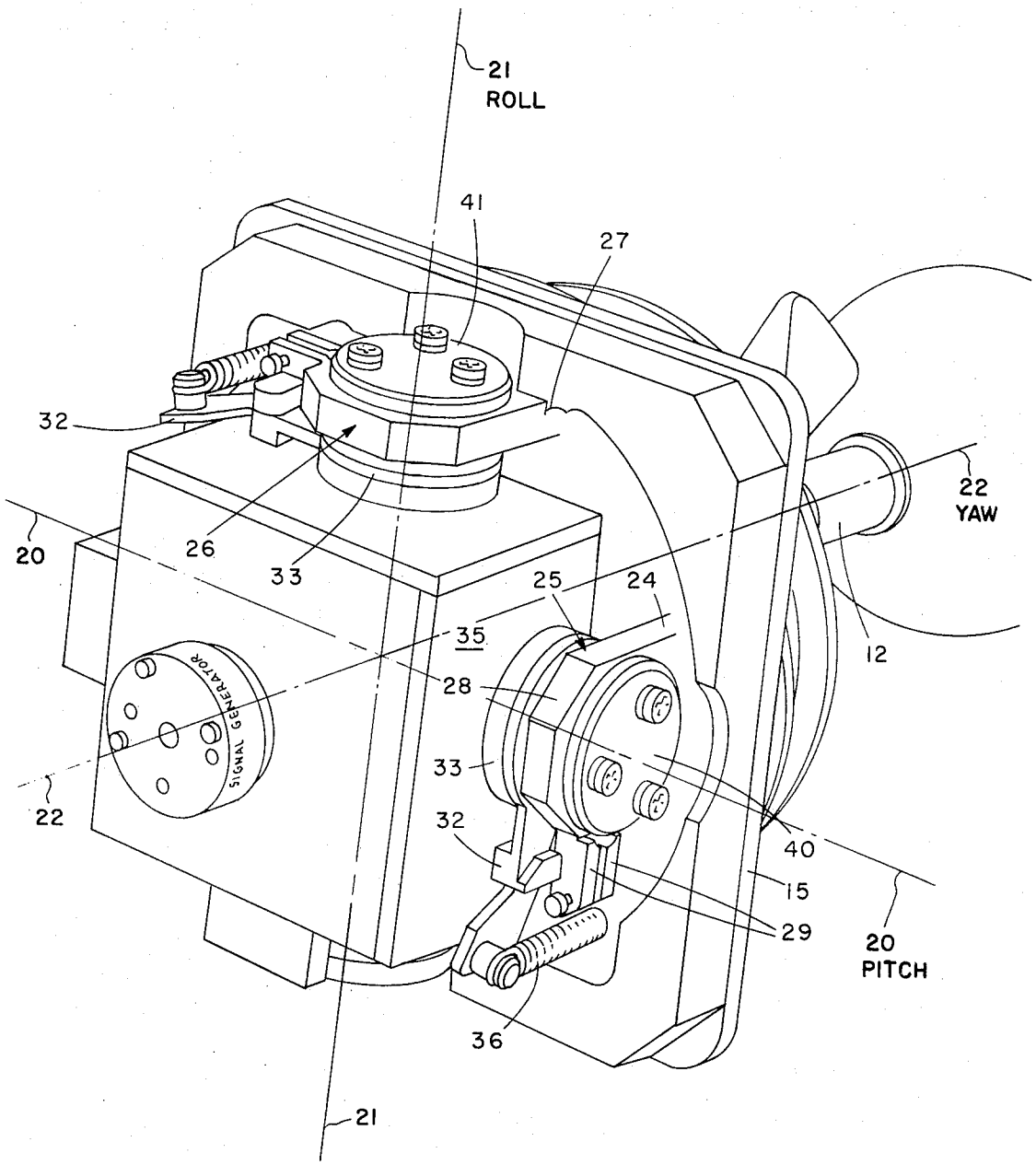
Fig. 1


21
ROLL
41
27
32
22
YAW
20
26
33
25
24
35
12
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SIGNAL GENERATOR
33
22
32
40
15
29
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PITCH
36
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Fig. 3

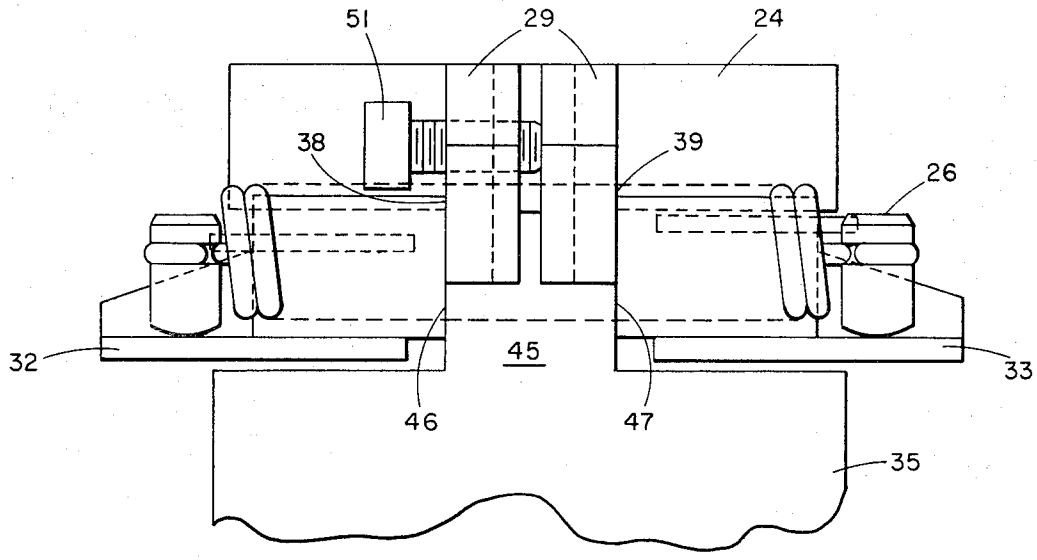


Fig. 4

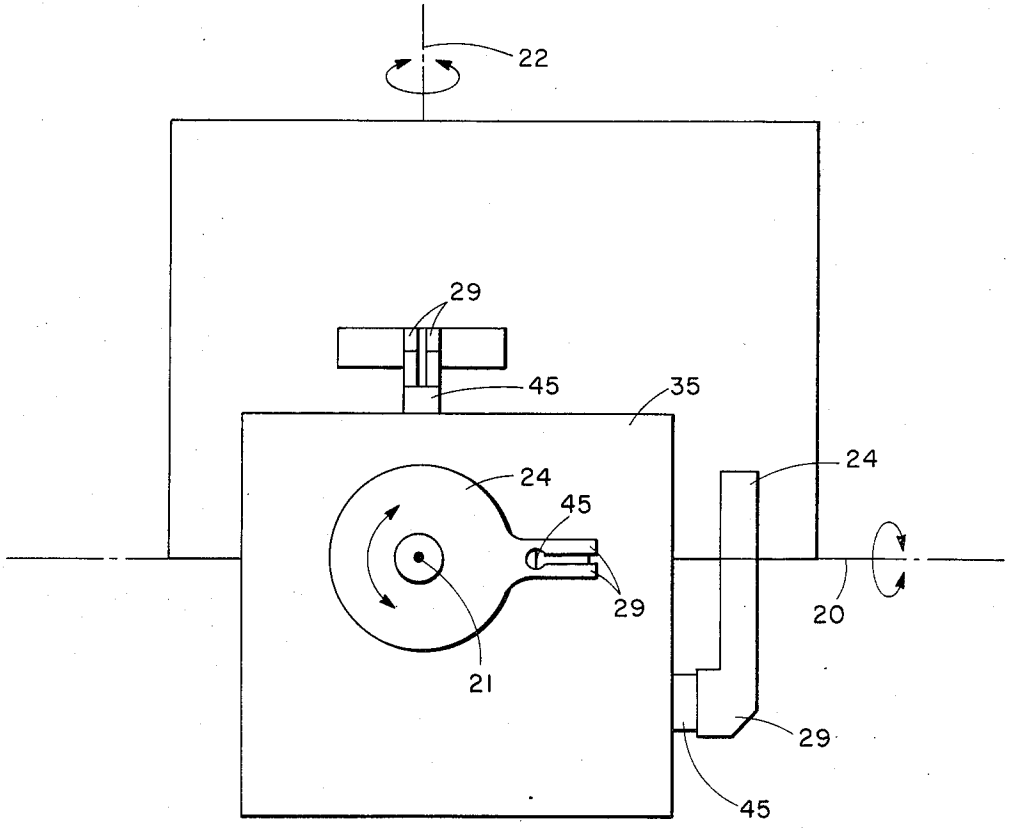


Fig. 6

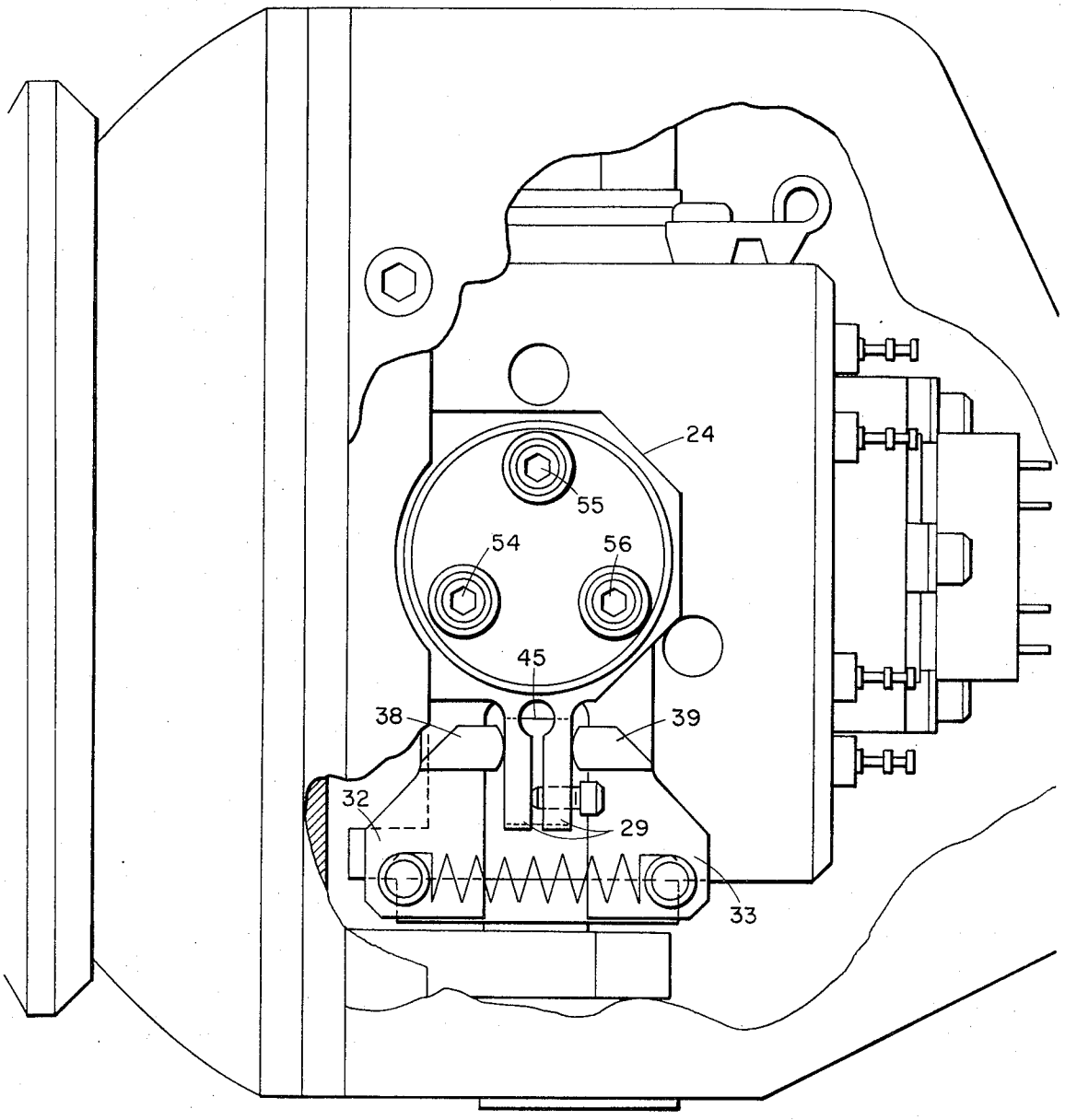


Fig. 5

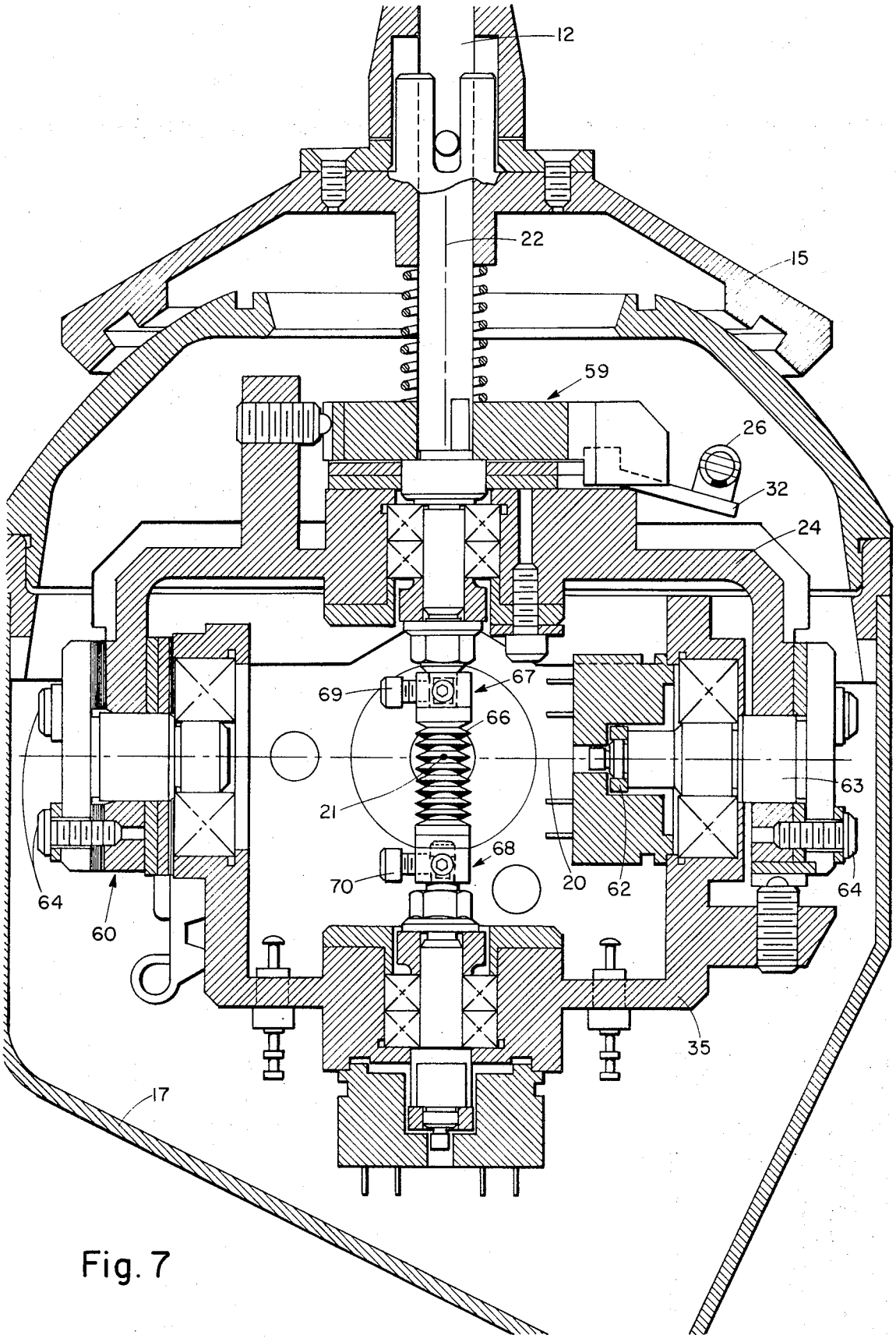


Fig. 7

# MULTI-AXIS HAND CONTROLLER

This invention concerns precision mechanical centering means, and more particularly, apparatus for achieving a substantially absolute null position about one or more axes in gimbaled or non-gimbaled systems.

In controlling moving objects such as land or water vehicles or even aircraft, it is desirable that control about two or more axes be concentrated in a single hand-gripped control element. In an aircraft, for example, such a control element would be a stick through which pitch, yaw and roll may be controlled in lieu of the present methods where both foot and hand-operated controls are utilized. Such a hand control unit, to provide the precise control necessary, must have a substantially absolute null position so that there is no play in the system which would cause a lag in transmitting controls from the operator to the various mechanisms connected to the hand controller. Since a single stick control is the optimum means for achieving a substantially absolute null, it is desirable that the mechanism be compact, simple in operation and yet not so costly as to preclude its use in low-cost vehicles. Present attempts at making such hand-controlled units are directed to controllers which achieve a center position by various combinations of opposed springs and interconnecting arms or plates. While the opposed spring type of centering does return to a center position, the position is variable beyond allowable tolerances where a 1/10° dead zone is required. Wandering, which is inherent in existing systems, increases with the age and use of the device. Another disadvantage of opposed springs is that to achieve identical response in opposite directions it is necessary that springs with identical characteristics be used. Such springs are virtually impossible to manufacture and this, combined with the normal changes in spring characteristics due to use and the wearing of mechanical parts has resulted in a failure to date to produce a precision, hand-controlled mechanical centering device.

The foregoing disadvantages and limitations of present hand-controlled systems using opposed springs have prevented the production of a hand control suitable for navigating a three-dimensional vehicle such as a submarine. Such a unit is virtually essential for maneuvering, for example, a deep submergence search and rescue vehicle to align on a sunken vehicle's escape hatch or hover in a current over some desired point on the bottom. A similar application in two-axis control would be that of yaw for steering and pitch for forward and reverse control of automobiles either on wide expressways or, with more precision, through congested traffic. The invention provides the extremely precise hand control which is necessary in the control of these and other vehicles. Its cost is low so that it may be produced for general use and its construction is relatively simple so that replacement is economically feasible in lieu of attempting on site repairs.

The present invention achieves its high degree of precision centering to a null position by means of a null centering assembly which includes a ground block for providing a firm base or anchor, protruding appendages on the block against which are positioned and which restrain a pair of spring plates having a common rotary axis and which are connected by a single spring, and an adjusting plate mounted on the same axis as the spring plates and having adjustable tines which are integral therewith and which extended between the spring plates. Control about a given axis is precise to within a dead zone of less than 1/10° and is effected through the shaft upon which the spring plates and adjusting plate are mounted. Shaft movement transverse to the direction in which the tines extend forces the adjacent spring plate on the appropriate axis away from its protruding appendage under restraint of the spring so that upon release of the shaft force the spring will return the spring plate to a stop position against the protruding appendage and the tines of the adjusting plate. The tines are adjusted by a set screw which extends through a threaded hole in one tine and abuts at its end against the other tine. The spring plates are provided with enlarged ends which extend a sufficient distance to, at their lower extremity, abut against the block appendage and, at their upper extremity, accommodate therebetween the tines of the adjusting plate. The ground block, therefore, is the restraining member to which either spring plate is returned upon the release of pressure exerted through the shaft. The adjusting plate, being mounted on top of the spring plates, prevents any but rotary motion about the shaft while the tines center the adjusting plate with respect to the spring plates and provide a reference for translating mechanical movement into electrical impulses.



Accordingly, it is an object of the present invention to provide a means for achieving a precise null position in a control unit operated by hand through movement of a single shaft.

Another object of the invention is to provide a mechanical null achieving means which can be incorporated by identical units into a multi-axis system.

A further object of the invention is to provide a null centering means which does not require matched springs for control in opposed directions and in which the null is achieved about several axes through appendages on a single anchor assembly.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description thereof when considered in conjunction with the accompanying drawings in which like numerals represent like parts throughout and wherein:

FIG. 1 is a perspective view of the hand controller assembly;

FIG. 2 is a plan view of the embodiment of FIG. 1 showing the axes of motion about which control is effected;

FIG. 3 is a perspective view of the ground block and gimbal housing and assembly of the embodiment of FIG. 1;

FIG. 4 is a front view of the null centering components shown in FIG. 3;

FIG. 5 is a side elevation of the null centering components at a single axis;

FIG. 6 is a schematic diagram showing the disposition of null centering components about each of three axes of motion; and

FIG. 7 is a sectional view of an assembled embodiment taken along the pitch axis thereof.

Referring to FIG. 1, the hand controller is shown to include a ball or hand knob 11 for gripping and operating by hand, a shaft 12 which extends to the interior control elements, a brake lever 13 by means of which a particular setting of the components is locked in place, a cover plate 15 and a control element housing 17 which includes a receptacle 18 for receiving electri-

cal connections. In FIG. 2, the hand controller is seen in a plan view with the axes of motion indicated as a pitch axis 20, a roll axis 21 and a yaw axis 22. Hand knob 11 is movable in any direction about a pivot, shown in FIG. 7, at the base of shaft 12 and since it is connected to gimbaled elements, positioning the knob in a direction intermediate of the various axes distributes in the proper proportion the degrees of motion about each axis which are represented by a single selected position. In FIG. 3, the device is seen with the housing, except for the bottom cover, removed. Shaft 12 is rotatably received in a gimbal yoke 24 with sets of control elements 25 and 26 deployed either on yoke 24 or on the housing as indicated at 27, respectively. The control elements include an adjusting plate 28 having a pair of tuning fork tines 29 extending therefrom a selected distance. Tightly positioned for rotation about a common shaft, not shown, beneath adjusting plate 28 are a pair of spring plates 32 and 33 which are spaced apart by a protruding appendage or boss, not shown, on a base block 35 which anchors the assembly. The spring plates are maintained in contact against the boss by a spring 36. In FIG. 3, the control elements for motion about the pitch axis are indicated at 40 while those for motion about the roll axis are indicated at 41. A similar set of control elements, not shown, for rotation about the yaw axis is positioned within the cover 15 of the housing and disposed about shaft 12 with the spring plates spaced apart by a boss or stop, not shown, on the upper surface of yoke 24.

FIGS. 4 and 5 show the control elements in more detail, with FIG. 4 showing a front elevation of these elements and with base block 35 indicated schematically at the base of the figure. The boss on block 35 is indicated at 45 while a pair of abutting members 46 and 47 of spring plates 32 and 33 are shown contacting boss 45. Abutting members 46 and 47 extend above boss 45 as indicated at 38 and 39 and between these upper extensions the tines 29 of adjusting plate 24 extend. Tines 29 are spaced apart by a set screw 51 which extends through one tine and abuts against the other tine as shown. Centering adjustments are made by positioning adjusting plate 24 so that tines 29 are substantially centered between spring plates 32 and 33 and thereafter set screw 51 is turned until the tines contact the adjacent sides of the spring plates. In FIG. 5, a top view of one set of control elements is shown in the secured or null position. This view illustrates spring plates 32 and 33 in the zero position as determined by spreading tines 29 between the upwardly extending portions 38 and 39 of the respective spring plates. Adjusting plate 24 is secured in a centered position by a plurality of bolts 54, 55 and 56.

In FIG. 6, the disposition of respective adjusting plates 24 only is shown to depict the arrangement of these plates in a three-axis system. About roll axis 21, for example, the adjacent adjusting plate depicted is positioned so that movement in either direction from center will cause one plate to be held against the appendage stop 45 on block 35 while the other plate is rotated apart therefrom under spring tension.

In FIG. 7, the assembled device is shown in a section taken through the pitch and yaw axes. In this view, the subassembly indicated at 59 for controlling motion about the yaw axis is shown mounted on yoke 24 under brake cover 15 while the subassembly indicated at 60 for controlling motion about the pitch axis is shown as partially integrated with yoke 24. That is, the adjusting plate is made integral with the leg of the yoke as shown in FIG. 3 while on the side of the housing not shown, the adjusting plate for controlling motion about the roll axis is made integral with the housing itself. Each of the control assemblies is coupled to the armature of a microsyn or other rotation sensing electrical device as indicated at 62 which is adjusted so that its zero output position is precisely aligned with the mechanical center of its respective assembly. Thus, in FIG. 7, the zero output of the microsyn or other device associated with armature 62 is aligned with the mechanical assembly indicated on the same axis by means of an adjustable pivot pin 63 and a plurality of pivot pin bolts 64. The bolts are loosened, the mechanical center of the device is adjusted, the pivot pin is then aligned with the zero output position of the microsyn or other device and thereafter the pivot pin bolts are tightened to secure the assembly in this position. It will be appreciated that a similar process is followed in each of the other assemblies so that any mechanical motion is immediately converted into electrical signals by the movement of each microsyn or device. FIG. 7 also illustrates the manner in which motion is transferred from shaft 12 to the various axes through the center of housing 17 which center is positioned at the intersection of the roll, pitch and yaw axes. In this embodiment, housing 17 is made sufficiently large to accommodate therein the microsyns, bearings, and other accessories associated with each axis of motion. Shaft 12 is coupled to a flexible bellows coupling 66 at the center of the housing which, in turn, is coupled to an extension of shaft 12 on the opposite side of block 35 by, respectively, collars 67 and 68 and set screws 69 and 70.

In operation, the controller assembly of the present invention provides electrical signals proportional to heave (yaw), surge (pitch) and sway (roll) to appropriate vehicle propulsion components. The control stick and hand grip knob are moved about a central axis to achieve the foregoing modes of control. The hand grip and control stick or shaft 12 are mechanically coupled to microsyns 62 so that movement of the control stick from the neutral position displaces the microsyns from their electrical null position, producing proportional electrical outputs. Excitation for the microsyns is 3.2 volts rms at 400 $H_z$. Although the microsyn has been described as the electrical unit which is coupled to the mechanical control assemblies, it will be appreciated that such coupling could also be accomplished with small servos, potentiometers, or synchro resolvers within the concept of the invention. The microsyns or other electrical components control the rate entered into the main propulsion system in an angular manner similar to control through a rheostat connected to the various axis controls.

The control assemblies can be adjusted mechanically to a desired resistance by simply changing the springs to ones having a desired tension. That is, for certain persons or applications a better feel of the motion of the device is obtained by adjusting the opposing force, such as in power brakes in an automobile, to an amount to which the operator is most sensitive. The device is exceedingly simple in both construction and operation when considered in relation to the complex devices in use for providing three-axis control none of which are known to approach the limit of a 1/10° dead zone.

In construction, the tines of the adjusting plate are made narrower by a few thousands of an inch than the width of the ground boss on the ground block. This feature permits the tines to be inserted between the spring plate leaves while allowing a sufficient clearance for adjusting the tines to the precise width of the ground boss.

There is thus provided a hand controller which may be panel mounted and provides three degrees-of-freedom movement. The controller converts torques applied to the hand grip or knob into annular displacements about the torque axes which, in turn, generate electrical signals proportional to the displacements in roll/surge, pitch/sway and yaw/heave. Angular displacement about each axis is restricted to plus or minus 15° from the neutral position which position is perpendicular to the panel mounting surface. The spring restraint which is provided for each axis will return the hand controller to its neutral position when torque is removed. The lock mechanism will lock the hand controller in any position within its operating limits. The degrees of control provided by the hand controller of the present invention are the same as those required by a helicopter operator using both hands and feet, and the accuracy of the controller far exceeds that of any existing hand controller. This accuracy is provided about three axes whereas most hand controllers are designed to provide control about only two axes.

A pair of controls has been constructed and has operated with extreme accuracy in a laboratory mockup of a nuclear submarine control system. This accuracy is reflected in a dead zone about each axis of less than 1/10° being achieved. The controls have been installed in the copilot and pilot stations of the Navy's DSRV System. Similar units could be used for control of a space capsule, control of heavy aircraft, and automobile control with the automobile control especially eliminating the dangerous steering post and providing throttle control forward and reverse control aft, steering control left and right and braking control about the third axis. The device also could be used to control heavy construction engines and electrical cars and steam cars using fluidics.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. For example, as indicated above, the assemblies may be individually or collectively coupled with other electrical rate devices than the microsyns described and the spring plates may be varied in shape and in their relation to the tines within the inventive concept so long as the device may be adjusted to the width of the ground boss and each spring plate will be returned to the ground boss when pressure or torque is removed therefrom.

What is claimed is:

**1.** A panel mounted hand controller for providing three-axis control of a free-moving object through selective movement of a control stick which is restricted to angular displacements of ± 15° and a dead zone of 1/10° comprising:

a housing and means rotatably supported therein for mounting said control stick and permitting omnidirectional movement and rotation thereof relative to the three axes of motion,

said housing and said means having openings about said control stick to accommodate the desired limit of movement thereof,

said means rotatable about one axis of motion with respect to said housing;

a yoke rotatably mounted on said means and orthogonally disposed with respect to said one axis of motion for providing rotation about a second axis of motion;

said control stick rotatably received in and extending through said yoke for rotation about the third axis of motion;

a pair of matched plates of opposite hand mounted for rotation about each of said axes of motion;

said plates each having parallel-disposed extensions;

a mechanical stop interposed between respective pairs of said extensions for establishing a neutral position thereof and a resilient means connecting said respective pairs of extensions for urging each extension against its respective stop; and

signal generating means coupled about each of said axes of motion for generating signals representative of relative motion of said control stick, said yoke, and said rotatably supported means about said axes with respect to, respectively, said yoke, said rotatably supported means, and said housing,

whereby desired movement of said object may be caused by selected movement of said control stick about one, two or all three of the axes of motion.

**2.** The device as defined in claim **1** wherein said rotatably supported means is a receptacle within which the three axes of motion intersect,

said control stick rotatably mounted in said receptacle opposite the opening for accommodating movement of said control stick; and

a flexible section in said control stick encompassing the intersection of the three axes of motion to permit flexing of said control stick during rotation of said yoke about the pitch axis.

**3.** The device as defined in claim **2** wherein the surface of said housing adjacent the opening therein has a spherical curvature;

a spherical cover plate adjustably mounted on said control stick and adapted to mate with said spherical surface of said housing; and

means on said control stick for forcing said cover plate against said housing at any position of said control stick so that said control stick may be locked in any position against the forces of said resilient means.

**4.** The device as defined in claim **3** wherein the axis of motion which is colinear with the longitudinal axis of said control stick is the yaw axis, the axis about which said yoke rotates is the pitch axis, and the axis about which said receptacle rotates is the roll axis;

cylindrical shaft sections supporting said receptacle in said housing and said yoke on said receptacle,

said shaft sections selectively positioned along said pitch and roll axes and respective pairs of said matched plates mounted thereon and on said control stick; and

strap means affixed to said housing for supporting said receptacle for rotation about said pitch axis;

said strap means and said yoke including pairs of tines positioned substantially in register with respective ones of said mechanical stops and means for adjusting said tines so as to be in register with said mechanical stops,

whereby movement of said control stick causing motion in either direction about any of said axes of motion will displace respective ones of said pairs of plates from its respective mechanical stop against the tensile force of the same respective resilient means thereby assuring the same corrective force for returning the displaced plates to the neutral or zero position in contact with the respective mechanical stop.

**5.** In a system for providing three-axis control of an object through a panel mounted hand control member restricted to angular displacements of ± 15° and a dead zone of 1/10° the combination of:

said control member aligned with and rotatable about one of the three axes of motion and means coupled to said control member and rotatable about each of the remaining axes of motion;

a pair of matched plates of opposite hand mounted for rotation about said axes in response to movement of said control member and said means coupled thereto;

a resilient member connecting and common to each pair of plates;

means for arresting said plates under tension of said resilient member at a null position when said control member is in the neutral position,

said plates spaced apart in the null position by said arresting means so that movement of said control member from the neutral position in either direction about any or all of said axes of motion causes rotary displacement of only one of said plates in each pair at a time against the tensile force of said common resilient member with said arresting means preventing movement of the other plate of the pair,

said control member returned to the neutral position upon removal of the disturbing torque by the said one displaced plate or plates.

**6.** The system as defined in claim **5** and further including signal generating means mounted in fixed relation to each of said axes for generating signals representative of relative motion of said ones of said pairs of plates about said axes,

whereby desired movement of said object may be caused by selected movement of said control member about one, two or all three of the axes of motion.

**7.** The system as defined in claim **6** and further including positioning means on said control member and on said coupled means,

said positioning means extending between respective pairs of said plates and in substantial alignment with and close proximity to said arresting means; and

means for precisely aligning said positioning means with said arresting means.

**8.** The system as defined in claim **7** and further including means for locking said control member in any position to which it may be moved.

**9.** A hand controller adapted to be panel mounted for providing three axis hand control of a freely movable object through selective movement of a control stick which is restricted to angular displacement of ± 15° and a dead zone of 1/10° comprising:

a housing, a ground block and means for rotatably suspending said ground block in said housing,

said block rotatable about one of the axes of motion with respect to said suspending means;

a yoke rotatably mounted on said block;

said yoke rotatable about a second axis of motion which is orthogonal to said one axis of motion;

a control stick extending through said housing, said yoke and said block and pivotally mounted in said block;

said housing and said block having openings about said control stick so as to permit movement thereof in any direction;

means mounted on said yoke and said suspending means for resiliently resisting and for arresting rotary movement of said control stick with respect to said yoke, said yoke with respect to said block, and said block with respect to said housing; and

motion detecting and relaying means mounted adjacent to said rotary movement resisting means to transmit signals generated by movement of said control stick to said movable object.

**10.** The device as defined in claim **9** wherein the surface of said housing adjacent the opening therein has a spherical curvature; and

a spherical cover plate adjustably mounted on said control stick and adapted to mate with said spherical surface of said housing; and

means on said control stick for forcing said cover plate against said housing at any position of said control stick so that said control stick may be locked in any position.

**11.** The device as defined in claim **10** wherein said rotary movement resisting means are disposed about each of the three axes of motion;

said rotary movement resisting means each including a pair of oppositely formed matched plates and a common resilient means connecting each pair of plates,

said pair of plates spaced apart in the neutral position by protruding portions of said ground block and said yoke,

said resilient means so positioned as to be elongated in the direction of movement of said control stick, the ones of said pairs of plates not rotated by motion of said control stick abutting said protruding portions and providing a precise reference with respect to the zero or neutral position of said control stick.

**12.** The device as defined in claim **11** wherein said means for arresting rotary movement are ground bosses positioned on said ground block and said yoke;

adjusting means secured to said means for suspending said ground block and said yoke opposite respective ones of said ground bosses,

said adjusting means narrower than the width of said ground bosses to permit insertion of the adjusting means between the rotary movement resisting means,

said adjusting means adjustable to the precise width of said ground bosses,

said precise adjustment, said gound bosses and said common resilient means providing a dead zone of 1/10° or less in the operation of said hand controller.

**13.** The method of controlling the omnidirectional movement of an object by a panel-mounted hand controller through selective movement of a control stick

which is restricted to angular displacements of ± 15° and a dead zone of 1/10° comprising:

rotating a reference component about one axis of motion with respect to the hand controller housing;

rotating a second component about a second axis of motion with respect to the reference component;

rotating the control stick about a third axis of motion with respect to the second component;

providing a stationary reference to rotation about the three axes of motion by ground components positioned adjacent to each axis of motion;

restraining both clockwise and counterclockwise rotation about each axis by a single resilient component common to oppositely configured motion transfer means;

anchoring the control stick in the reference component; and

providing a flexible section in the control stick in the region of the intersection of the three axes of motion to permit rotation of the second component about the axis which passes therethrough.

**14.** The method as defined in claim **13** wherein control about two of the axes of motion is effected by coupling together the control stick and the second component,

the flexible section in the control stick permitting rotary movement of the second component with respect to the reference component.

**15.** The method as defined in claim **14** and further including generating signals representative of relative motion of the control stick, second component and reference component with respect to the second component, reference component and housing for control of movement of said object.

**16.** The method as defined in claim **15** wherein motion in yaw of said object is obtained by rotating the control stick with respect to both the second component and the reference component, motion in pitch of said object is obtained by rotating the second component with respect to the reference component and motion in roll of said object is obtained by rotating the reference component with respect to the housing.

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