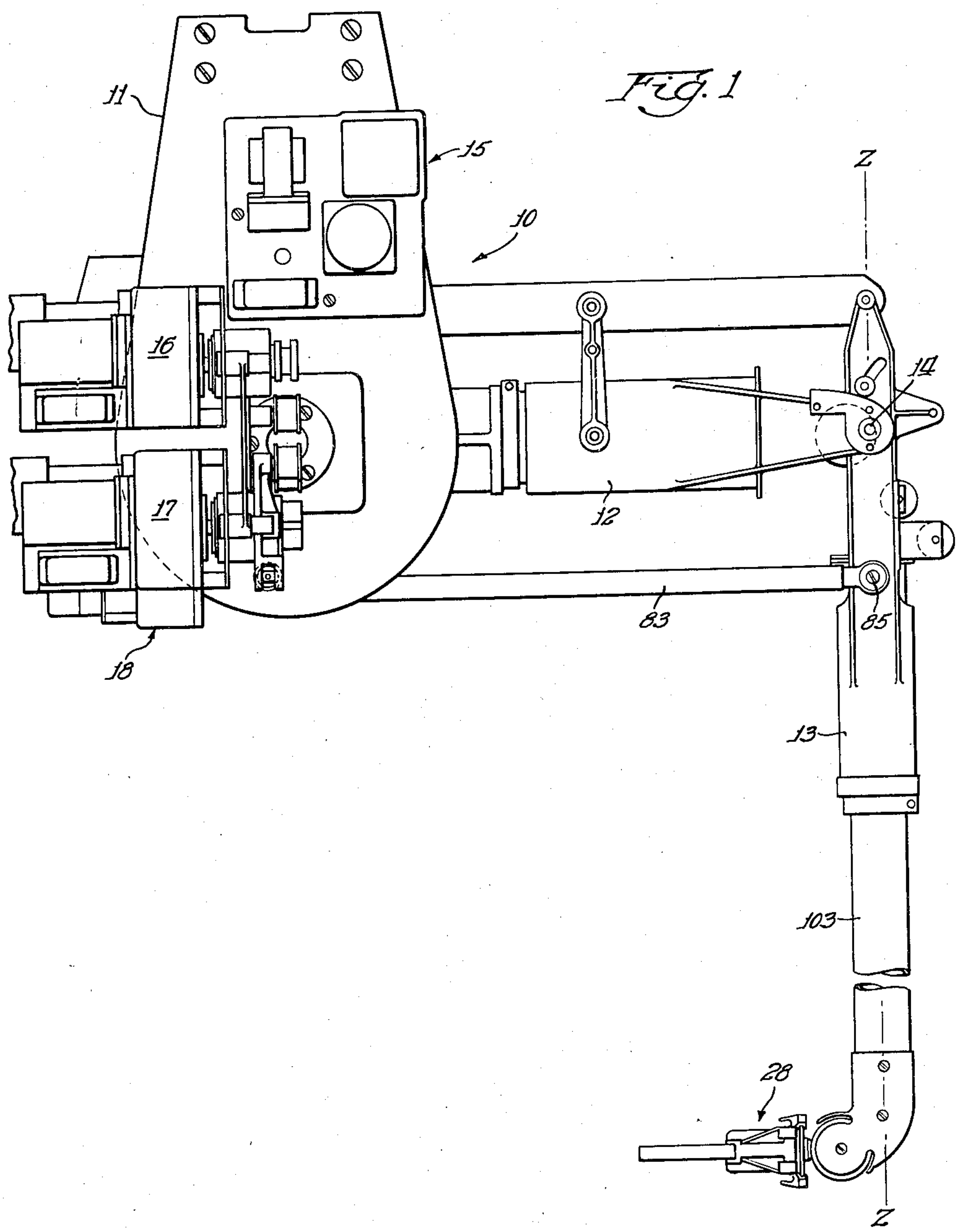
Fig. 1



INVENTOR.
Otis J. Olson
BY: Ray E. Snyder
Atty.

Sept. 20, 1960 O. J. OLSON 2,953,261

REMOTE-CONTROL MANIPULATOR

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Fig. 2

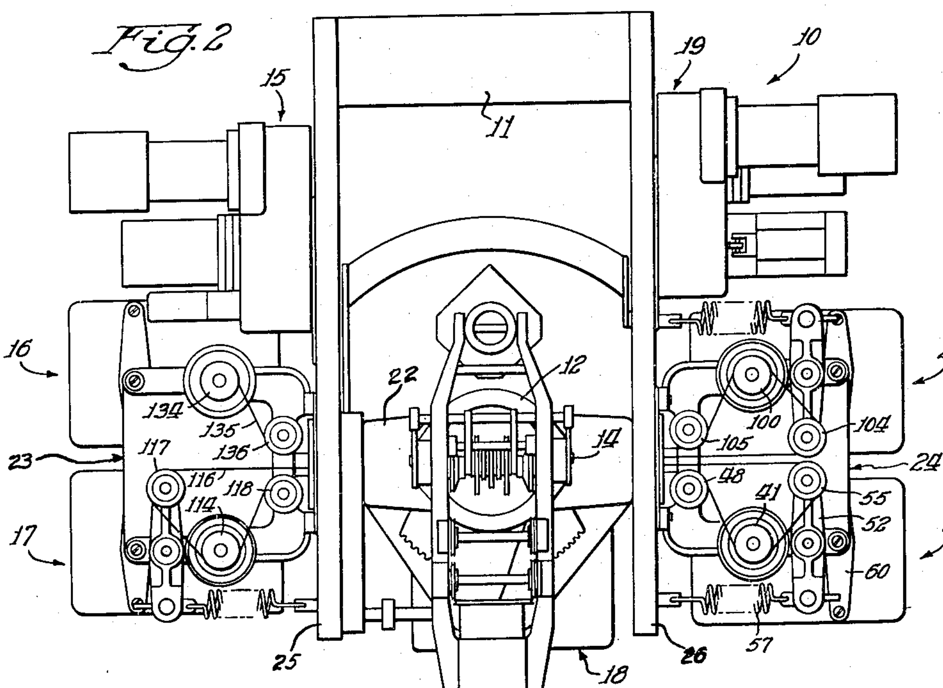
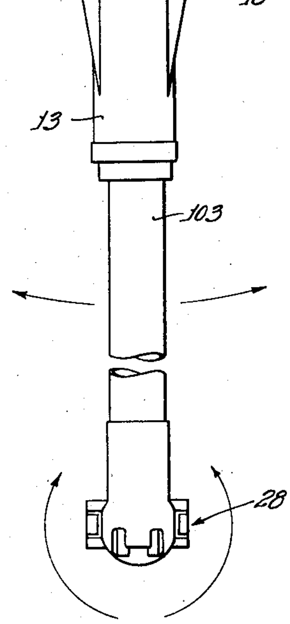
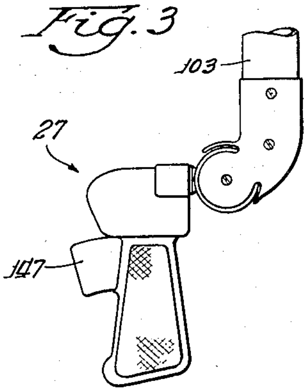



Fig. 3



INVENTOR.
Olis J. Olson
BY:
Ray E. Snyder
Atty.

Fig. 4

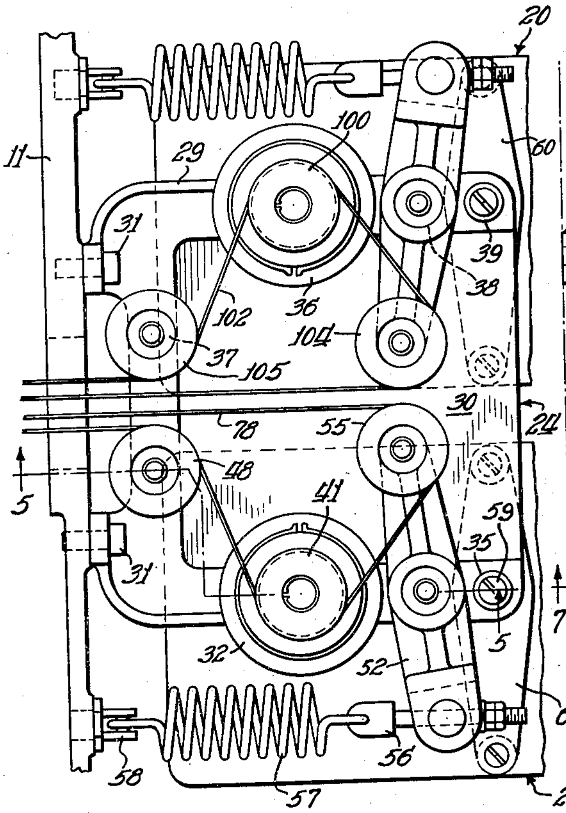


Fig. 6

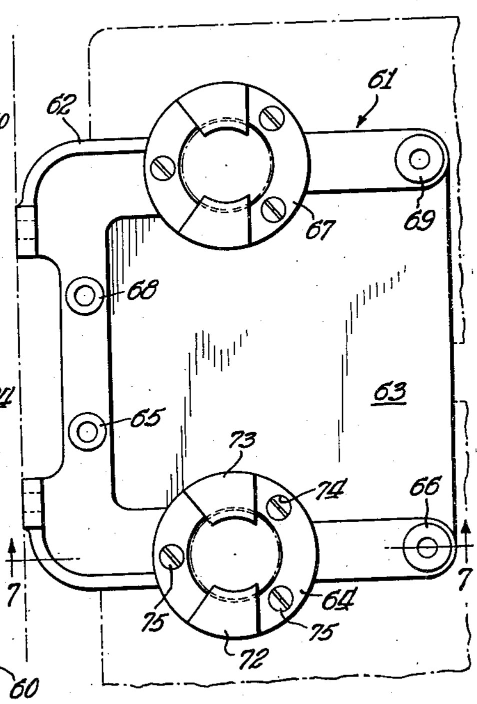


Fig. 5

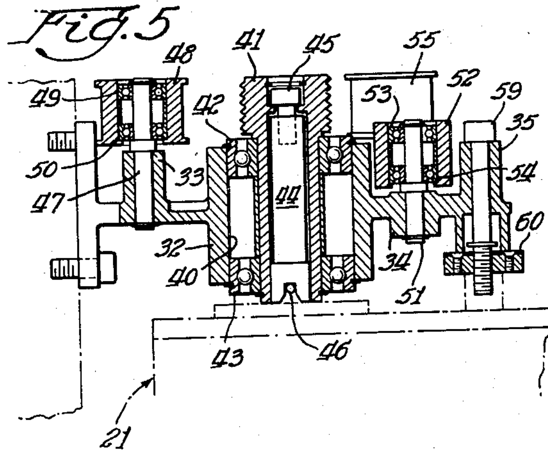
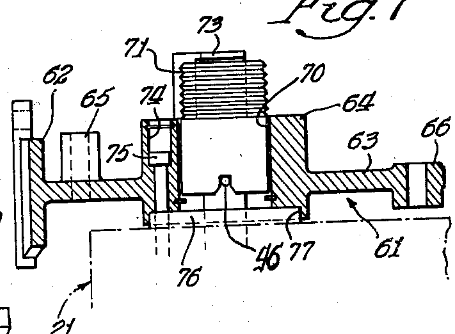


Fig. 7



Inventor:
Otis J. Olson
By: Roy E. Snyder
Atty.

Sept. 20, 1960 O. J. OLSON 2,953,261

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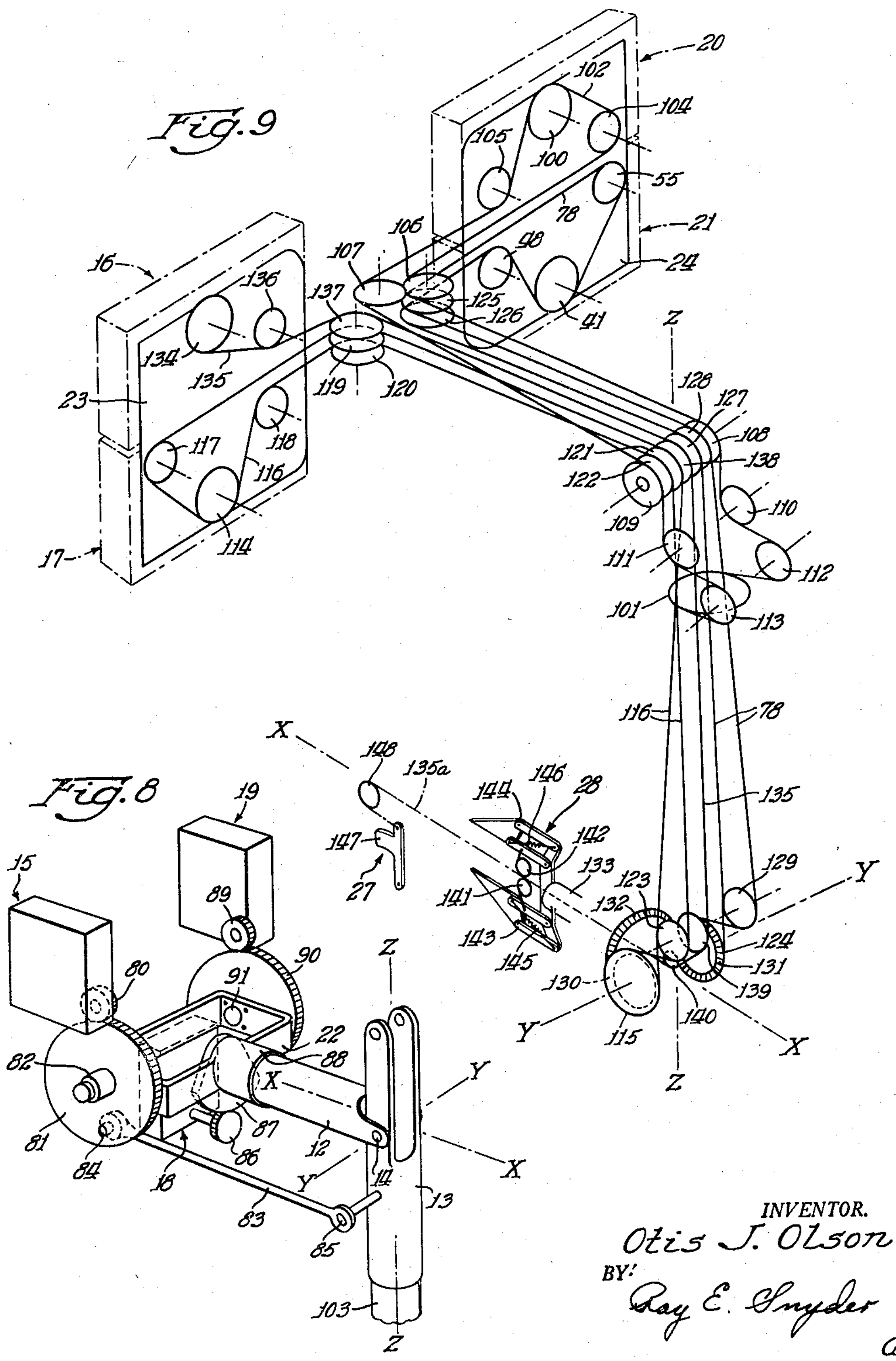
Fig. 9

Fig. 8



INVENTOR.
Otis J. Olson
BY: Ray E. Snyder
Atty.

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REMOTE-CONTROL MANIPULATOR

Otis J. Olson, Decatur, Ill., assignor to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Filed Aug. 2, 1957, Ser. No. 676,031

8 Claims. (Cl. 214—1)

This invention relates to remote control electromechanical master-slave manipulators. More particularly, the present invention relates to an improved mounting design for the gear boxes of such manipulators.

A remote control electromechanical master-slave manipulator of the type involved is disclosed in pending application of Goertz et al. S.N. 517,105, filed June 21, 1955, now Patent No. 2,846,084 and assigned to the United States of America as represented by the Atomic Energy Commission.

Manipulators of this type in general comprise a master assembly and a slave assembly which are electrically interconnected and are substantially identical in construction. The master assembly is operated by a hand control mechanism, motions of which are transmitted to a plurality of separate gear boxes by a plurality of cables and gears. The motions transmitted to the individual gear boxes are transmuted therein into electrical impulses which are transmitted to the individual respective gear boxes of the slave assembly. The electrical impulses are there transmuted back into mechanical motions which are transmitted by a plurality of cables and gears to a grasping tool carried by the slave assembly. The master-slave manipulator is so designed that the motion of the grasping tool accurately reproduces the motion of the hand control tool as it is moved by the operator. In addition, the master-slave manipulator is designed to reflect forces exerted by the slave assembly back to the master assembly so as to give the operator a sense of feeling of the operation of the slave assembly.

The electromechanical master-slave manipulator described in pending application S.N. 517,105, now Patent No. 2,846,044, has a plurality of gear boxes to which cables are attached for transmitting motions to and from a hand control tool or a grasping tool. Each of the gear boxes is mounted upon a frame by means of a spring loaded stud which functions to maintain tension in the cables at all times. Each of the gear boxes must be of a separate design to accommodate this spring loaded stud. The cables are strung around a complicated pulley arrangement disposed between the gear boxes and the hand control tool or grasping tool. In the event that one of the gear boxes must be removed for repairs, the tension on the cables is released and the cables spring off from the pulleys. Restringing of the cables upon replacement of the gear box is an extremely tedious and arduous process.

Wherefore, it is an object of the present invention to provide an improved mounting bracket for mounting the gear boxes of an electromechanical master-slave mnipulator.

It is another object to provide an improved cable tensioning device independent from the gear boxes of an electromechanical manipulator.

It is an additional object to provide an improved gear box mounting bracket and cable tensioning device which allows standardization of many of the gear boxes to be used with an electromechanical manipulator.

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It is still another object of the present invention to provide an improved gear box mounting bracket and cable tensioning device which allows removal of the gear boxes without releasing tension on the cables.

The invention consists of the novel constructions, arrangements, and devices to be hereinafter described and claimed for carrying out the above stated objects and such other objects as will be apparent from the following description of preferred forms of the invention, illustrated with reference to the accompanying drawings, wherein:

Figure 1 is an elevational side view of a slave assembly of the remote control manipulator of the present invention carrying a grasping tool;

Figure 2 is an elevational end view of the slave assembly;

Figure 3 is an elevational side view of a hand control tool for a master assembly of the manipulator illustrated in position corresponding to the position of the grasping tool in Fig. 1;

Figure 4 is an enlarged elevational view of a mounting bracket and cable tensioning device of the present invention;

Figure 5 is a view taken along line 5—5 of Figure 4;

Figure 6 is a modification of the moving bracket illustrated in Figure 4;

Figure 7 is a view taken along line 7—7 of Figure 6;

Figure 8 is a schematic illustration of the gearing by which translational motions of the grasping tool are transmitted from the respective gear boxes of the slave assembly; and

Figure 9 is a schematic illustration of the cables and pulleys by which rotational motions of the grasping tool are transmitted from the respective gear boxes of the slave assembly.

Like characters of reference designate like parts in the several views.

Referring now to Figures 1–3, there is illustrated a slave assembly **10** which generally comprises a frame **11**, a horizontal arm **12**, a vertical arm **13**, pivotally mounted on the horizontal arm **12** by a pin **14**, and gear box assemblies **15**, **16**, **17**, **18**, **19**, **20**, and **21**. The gear boxes **15** and **19** are mounted directly upon the frame **11** on opposite sides thereof; the gear box **18** is mounted upon a generally rectangular-shaped member **22** which supports the horizontal arm **12**; the gear boxes **16** and **17** are mounted upon a bracket **23**; and the gear boxes **20** and **21** are mounted upon a bracket **24**. The mounting brackets **23** and **24** in turn are mounted upon depending members **25** and **26**, respectively, of the frame **11**.

The assembly **10** can function either as a master assembly or a slave assembly, the two assemblies being substantially identical. The assembly **10** can function as a master unit when a hand control tool **27** is mounted on the lower end of the vertical arm **13**, and the assembly **10** functions as a slave unit when a grasping tool **28** is mounted on the lower end of the vertical arm **13**.

Referring now to Figures 4 and 5, the mounting bracket **24** is seen to comprise a generally U-shaped frame **29** and a web portion **30** formed between the arms of the frame **29**. The frame **29** is mounted upon the frame **11** by means of a plurality of machine screws **31**. The bracket **24** is preferably cast from an alloy of aluminum so as to obviate radioactive contamination. The bracket **24** is formed with a plurality of cylindrical bosses **32**, **33**, **34**, **35**, **36**, **37**, **38**, and **39**. The boss **32** is formed with a cylindrical aperture **40** in which is journalled a cable drum **41** by means of bearings **42** and **43**. The cable drum **41** is attached to a shaft **44** by means of a machine screw **45**. The shaft **44** extends into the interior of the gear box **21** and functions to either drive or be driven by the gearing within the gear box **21**. The drum **41** is locked for unitary rotation with the shaft 44 by means of a pin 46 which extends radially through the shaft 44 and through wedge-shaped openings formed on the end of the drum 41 adjacent to the gear box 21.

The boss 33 is adapted to receive a stub shaft 47 upon which is rotatably mounted an idler pulley 48 by means of bearings 49 and 50.

The boss 34 is adapted to receive a stub shaft 51 upon which is mounted a lever arm 52 by means of bearings 53 and 54. The lever arm 52 has an idler pulley 55 rotatably mounted upon one end and has a connecting shank 56 mounted on the other end thereof. A spring 57 is attached at one end to the shank 56 and is anchored at its other end by means of a pin 58 to the frame 11.

The boss 35 is adapted to receive a machine screw 59 which extends through and is attached to a leaf spring member 60. The spring member 60 is attached to the gear box 21 and allows for any slight eccentricity in mounting the cable drum 41 upon the shaft 44.

The upper half of the mounting bracket 24 as shown in Figure 5 is substantially a mirror image of the lower half just described, and the bosses 36, 37, 38, and 39 serve to mount a pulley arrangement and the gear box 20 in the same manner as just described for the gear box 21. This portion of the mounting bracket 24, therefore, will not be further described in detail.

Referring now to Figures 6 and 7, there is illustrated a mounting bracket 61 which is a modified design of the mounting bracket 24. The bracket 61 comprises a generally U-shaped frame 62 and a web portion 63 of substantially the same dimensions as the bracket 24. The frame 62 is formed with bosses 64, 65, 66, 67, 68, and 69.

The boss 64 has a cylindrical aperture 70 formed therein in which is mounted a cable drum 71. The cable drum 71 is attached to the shaft 44 of the gear box 21 by a pin 46 as previously described. The boss 64 is also formed with cable guards 72 and 73 which extend around in close proximity to the cable drum 71.

The boss 64 is also formed with a plurality of holes 74 through which the gear box 21 is attached to the bracket 61 by means of bolts 75. The bolts 75 are threaded into a cylindrical shoulder 76 mounted upon the gear box 21 and concentric with the shaft 44. The boss 64 is also formed with a cylindrical aperture 77 which fits closely over the shoulder 76 and which functions to center the gear box 21 with respect to the bracket 61.

The boss 65 is adapted to receive the stub shaft 47 upon which is mounted the idler pulley 48 as previously described.

The boss 66 is adapted to receive the stub shaft 51 upon which is mounted the lever arm 52 as previously described.

The bracket 61, as is apparent, is substantially simpler in construction than the bracket 24 but retains all of the advantages thereof. The bracket 61 has the additional advantage of eliminating the bearings 42 and 43, the boss 34, and the leaf mounting spring 60. The bracket 61 also has the cable guards 72 and 73 formed integrally with the boss 64 which are in close proximity to the cable drum 71. The cable guards 72 and 73 function to keep the cables disposed in grooves on the drum 71 during the stringing process. The cable drum 71 is also of simpler construction than the drum 41 and is reduced in axial length.

A cable 78 extends around the idler pulley 48, the drum 41 and the idler pulley 55 and is connected to the hand control tool 27 or to the grasping tool 28 as will be described subsequently. Tension in the cable 78 is maintained by means of the spring 57 which acts upon the lever arm 52 and the pulley 55 so as to tend to stretch the cable 78.

The gear box 21 can be removed from the mounting bracket 24 by the simple process of removing the machine screws 45 and 59. It is to be noted that the drum 41 remains in place, as do the idler pulleys 48 and 55, and the spring 57 continues to maintain tension in the cable 78 as just described. Removal of the gear box 21 therefore has no effect upon the tension in the cable 78 and hence cannot result in the cable 78 becoming unstrung during the process or removal. It is to be noted that this advantage also is retained by the mounting bracket 61.

The mounting bracket 23 is substantially identical to the bracket 24 except that one boss for mounting a lever arm corresponding to the lever arm 52 is eliminated. The bracket 23 otherwise functions in the same manner as the bracket 24.

Referring now to Figs. 8 and 9, there is illustrated a cable and gearing arrangement by which motions of the hand control tool 27 are transmitted to the separate gear boxes of a master assembly and by which rotational and translational motions are imparted by the gear boxes 15—21 to the grasping tool 28. The grasping tool 28 is capable of seven distinct motions under the influence of the hand control tool 27. These motions comprise three translation motions, three rotational motions, and the grasping action of the tool 28. The three translational motions, sometimes referred to as gross motions, are described in terms of the X, Y, and Z axes shown on the figures. The three rotational motions are also described in the reference system defined by the X, Y, and Z axes.

The three translational motions of the grasping tool 28 are generated by the gear boxes 15, 18, and 19. A gear 80 is rotatably mounted on and driven by the gear box 15 and is in mesh with and drives a relatively large gear 81. The gear 81 is journalled on a hub 82, forming a part of the mounting frame 11. A connecting shaft 83 is attached at one end to the gear 81 by means of a pin 84 at a point near the periphery of the gear 81, and the connecting shaft 83 is attached at its other end to the vertical arm 13 by means of a pin 85.

A gear 86 is rotatably mounted on and driven by the gear box 18 and is in mesh with a sector gear 87 formed integrally with the horizontal arm 12. The horizontal arm 12 is journalled within a cylindrical portion 88 formed integrally with a rectangular-shaped member 22.

A gear 89 is rotatably mounted on and driven by the gear box 19 and is in mesh with and drives a relatively large gear 90 which is journalled on a hub 91 forming a part of the frame 11. The rectangular shaped member 22 is attached at one side to the gear 90 and is journalled at its other side on the hub 82.

Translational motion of the grasping tool 28 along the X axis is produced primarily by the gear box 15 and the gear 80 mounted thereon. The gear 80 drives the gear 81 and tangential motion of the gear 81 is transmitted through the connecting shaft 83 to the vertical arm 13. The vertical arm 13 and the grasping tool 28 are caused to swing pendulously in the XZ plane about the pin 14. For large displacements along the X axis, it is apparent that the horizontal arm 12 must be depressed below its horizontal position in order that the grasping tool 28 may move in a straight line. In order to depress the horizontal arm 12 below its normal horizontal position the gear box 19 drives the gear 89 which in turn drives the gear 90 causing it to turn about the axis defined by the hubs 82 and 91. The gear 90 carries the rectangular member 22 with it and causes the horizontal arm 12 to swing through an angular displacement sufficient to maintain the grasping tool in motion in a straight line along the X axis. Pure translational motion of the grasping tool 28 along the X axis is thus produced by the combined actions of the gears 80 and 89 of the gear boxes 15 and 19, respectively.

Translational motion of the grasping tool 28 along the horizontal Y axis is produced primarily by the gear box 18 and the gear 86 mounted thereon. The gear 86 drives the sector gear 87 causing it to rotate about the axis defined by the horizontal arm 12. The vertical arm 13 and grasping tool 28 are thus also caused to swing pendulously about the axis of the horizontal arm 12. For large displacements along the Y axis, the horizontal arm 12 must be depressed below the horizontal position as described above for the motion along the X axis. This depression of the horizontal arm 12 is produced by the gear box 19 and the gear 89 as described above. Pure translational motion along the horizontal Y axis is thus produced by the combined action of the gear boxes 18 and 19.

Translational motion of the grasping tool 28 along the vertical Z axis is produced primarily by the gear box 19 and the gear 89 mounted thereon. The gear 89 drives the gear 90 which carries with it rectangular frame 22, the horizontal arm 12, and the vertical arm 13. The vertical arm 13 and grasping tool 28 are caused to swing pendulously in the XZ plane by the gear box 19 acting alone, and for large displacements the gear box 15 and the gear 80 must also act upon the vertical arm 13 to maintain the grasping tool 28 in motion along the Z axis. Pure translational motion along the Z axis is thus produced by the combined action of the gear boxes 15 and 19 as described above for motion along the X axis; the amount of rotation of the gears 80 and 89 respectively being interchanged to produce the two translation motions.

Referring now to Fig. 9, the three rotational motions of the grasping tool 28 are generated by the gear boxes 17, 20, and 21. A drum 100 is rotatably mounted on and driven by the gear box 20. The drum 100 is connected to a drum 101 by means of a cable 102. The drum 101 is fixedly mounted in a horizontal plane on top of a vertical shaft 103 rotatably disposed within the vertical arm 13. The cable 102 extends from the drum 100 to the drum 101 over a plurality of pulleys 104, 105, 106, 107, 108, 109, 110, 111, 112, and 113. The pulley 104 functions to maintain tension in the cable 102 and the pulleys 105—113 are idler pulleys which function to change the direction of the cable between the drums 100 and 101.

The gear box 17 has a drum 114 rotatably mounted thereon and driven thereby which is connected to a drum 115 adjacent to the grasping tool 28 by means of a cable 116. The cable 116 extends over a plurality of pulleys 117, 118, 119, 120, 121, 122, and 123. The pulley 117 functions to maintain tension in the cable 116, and the pulleys 118—123 are idler pulleys which function to change the direction of the cable 116 between the drums 117, 114, and 115. The gear box 21 has the drum 41 rotatably mounted thereon and driven thereby which is connected to a drum 124 adjacent to the grasping tool 28 by means of the cable 78. The cable 78 extends around a plurality of pulleys 55, 48, 125, 126, 127, 128, and 129. The pulley 55 functions to maintain tension in the cable 78 as previously described, and the pulleys 48, 125—129 are idler pulleys which function to change the direction of the cable 78 between the drums 41 and 124.

The drums 115 and 124 are axially displaced with respect to each other and are connected to the grasping tool 28 by means of a gearing arrangement which comprises a beveled gear 130 and a beveled gear 131 attached to the axially facing sides of the drums 115 and 124, respectively. A third beveled gear 132 is disposed at right angles to and in mesh with both of the gears 130 and 131. The gear 132 is formed integrally with a shaft 133 to which is attached the grasping tool 28.

In operation, the manner in which the rotation of the grasping tool 28 about the X, Y, and Z axes is produced will now be described.

To produce rotation about the vertical Z axis, the gear box 20 drives the drum 100 in one direction or the other and tangential motion of the drum 100 is transmitted through the cable 102 around the several pulleys 104—113 to the drum 101. The drum 101 and the vertical shaft 103 upon which the grasping tool 28 is mounted are caused to rotate either clockwise or counterclockwise about the vertical Z axis in accordance with the direction of rotation of the drum 100.

To produce rotation of the grasping tool 28 about the horizontal Y axis, the gear boxes 17 and 21 drive the drums 114 and 41, respectively. The tangential motions of the drums 114 and 41 are transmitted by means of the cables 116 and 78, respectively, to the drums 115 and 124. The drums 115 and 124 rotate simultaneously in the same direction and cause the gear 132 and the shaft 133 and grasping tool 28 to move arcuately in the XZ plane about the Y axis. The beveled gear 132 in mesh with the gears 130 and 131 does not rotate about its own axis for this particular motion.

To produce rotation of the grasping tool 28 about the X axis, the drums 114 and 41 drives the cables 116 and 78, respectively, which in turn drive the drums 115 and 124. For this motion, the drums 115 and 124 are driven in opposite directions of rotation with respect to each other. The relatively opposite direction of rotation of the gears 130 and 131 causes the gear 132 to rotate either clockwise or counterclockwise about its own axis carrying the grasping tool 28 with it.

To produce rotation about the axis other than the three given axes requires the co-action of two or all three of the gear boxes 17, 20, and 21.

The grasping action of the tool 28 is produced by the gear box 16. The gear box 16 has a drum 134 rotatably mounted thereon and connected to the grasping tool 28 by means of a cable 135. The cable 135 extends around pulleys 136, 137, 138, 139, 140, 141, and 142. The cable 135 is a single strand and is anchored at one end to the drum 134 and is spliced at its other end with each of the spliced ends extending around the pulleys 141 and 142 and being anchored to tongs 143 and 144 of the grasping tool 28. The pulleys 136—142 are all idler pulleys which function to change the direction of the cable 135 between the drum 134 and the grasping tool 28. The tongs 143 and 144 are biased into a normally open position by means of springs 145 and 146. The springs 145 and 146 also function to maintain tension in the cable 135.

In operation, the grasping action of the tool 28 is produced by squeezing a trigger bar 147 pivotally mounted within the hand control tool 27 of the related master assembly. The trigger bar 147 is attached to a cable 135*a* which extends around an idler pulley 148 rotatably mounted within the hand control tool 27. The motion of the trigger bar 147 is transmitted through the cable 135*a* to a gear box on the related master assembly corresponding to the gear box 16.

The master and slave assemblies of the electromechanical manipulator are electrically interconnected. The motions of the hand control tool 27 are transmitted to the respective gear boxes of the master assembly through a cable and gearing arrangement substantially identical to that shown in Fig. 8 and Fig. 9. The rotation of the cable drum or gear mounted on each of the respective gear boxes is transmuted therein into an electrical signal which is directly proportional to the amount of rotation of the cable drum or gear mounted on the gear box. This electrical signal is transmitted to the respective gear boxes of the slave assembly 10. The signals are there transmuted back into rotational motions, and the rotational motions are transmitted through the cable and gearing arrangements shown in Figs. 8 and 9 to the hand control tool 28.

The electrical system by which rotational motions are converted into electrical signals and then reconverted into rotational motions may be any suitable synchro motor-generator system. An example of such a system is illustrated in the pending application of Goertz et al., Serial No. 517,105, now Patent No. 2,846,084.

There has been provided by this invention an improved gear box mounting bracket and cable tensioning device wherein the cable tensioning device is independent from the separate gear boxes and which permits the easy removal of the gear boxes without affecting the tension in any of the cables.

While I have described my invention in connection with one specific embodiment thereof, it is to be understood that this is by way of illustration and not by way of limitation and the scope of my invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

I claim:

1. In a remote-control manipulator, the combination of a frame, a control tool, means for movably mounting said control tool with respect to said frame, a gear box removably mounted with respect to said frame, a cable drive mechanism including a plurality of pulleys interconnecting said tool and said gear box so that parts in said gear box rotate with movement of said tool, and means for mounting said pulleys rigidly with respect to said frame so that said cable is maintained in tension when said gear box is removed from said frame.

2. In a remote-control manipulator, the combination of a frame, a control tool, means for movably mounting said control tool with respect to said frame, a gear box removably mounted with respect to said frame, a cable drive mechanism including a plurality of pulleys, interconnecting said tool and said gear box so that parts in said gear box rotate with movement of said tool, a bracket fixed to said frame and having said pulleys mounted thereon, an idler pulley movably mounted on said bracket and a spring acting on said idler pulley for tensioning said cable, and a shaft interconnecting said gear box with one of said pulleys for completing the drive therebetween and permitting the removal of said gear box with respect to said frame without releasing tension in said cable.

3. In a remote-control manipulator having a master assembly and a slave assembly, the combination of a frame for mounting one of the assemblies, a control tool movably carried by said frame, a gear box carried by said frame, a cable interconnecting said gear box with said tool so that parts of said gear box rotate with movement of said tool, a bracket for rigidly mounting said gear box on said frame, and a cable tensioning device mounted on said bracket adapted to allow said gear box to be removed without releasing tension in said cable.

4. In a remote-control manipulator having a master assembly, the combination of a frame for the assembly, a hand control tool pivotally mounted on said frame, a gear box carried by said frame, a cable interconnecting said hand control tool with said gear box for transmitting pivotal motion of said control tool to said gear box, a bracket for rigidly mounting said gear box on said frame, and a cable tensioning device mounted on said bracket adapted to allow said gear box to be removed from said frame without releasing tension in said cable.

5. In a remote-control manipulator having a master assembly, the combination of a mounting frame for the assembly, a hand control tool mounted for rotation about three mutually perpendicular axes and carried by said frame, a plurality of cables interconnecting said hand control tool with said gear boxes for transmitting rotational motions of said hand control tool to said gear boxes, a plurality of brackets for rigidly mounting said gear boxes on said frame, and cable tensioning means mounted on said bracket for maintaining said cables under tensions at all times.

6. In a remote-control manipulator having a slave assembly, the combination of a frame for the assembly, a grasping tool movably mounted on said frame, a gear box carried by said frame, a cable interconnecting said gear box with said grasping tool for transmitting motion from said gear box to said grasping tool, a bracket for rigidly mounting said gear box on said frame, and cable tensioning means mounted on said bracket for maintaining the cable under tension at all times.

7. In a remote-control manipulator having a slave assembly, the combination of a mounting frame for the assembly, a grasping tool mounted for rotation about three mutually perpendicular axes and carried by said frame, a plurality of gear boxes carried by said frame, a plurality of cables interconnecting each of said gear boxes with said grasping tool for transmitting rotational motions from said gear boxes to said grasping tool, a plurality of brackets for rigidly mounting said gear boxes on said frame, and cable tensioning devices mounted on said bracket for maintaining said cables in tension and adapted to allow removal of said gear boxes from said brackets without releasing tension in said cables.

8. In a remote-control manipulator having a slave assembly, the combination of a mounting frame for the assembly, a grasping tool movably carried by said frame, a gear box carried by said frame and having a rotatable drive shaft, a cable and pulley mechanism interconnecting said gear box with said grasping tool for transmitting motion from said gear box to said grasping tool, said mechanism including a cable drum mounted on the drive shaft of said gear box, a bracket for rigidly mounting said gear box on said frame and a cable tensioning device for mounting a portion of said pulley and cable arrangement including said drum, said cable drum adapted to be disconnected from said drive shaft for allowing said gear box to be removed from said bracket without releasing tension in said cable.

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