(12) UK Patent Application (19) GB (11) 2 097 360 A

(21) Application No **8211500**
(22) Date of filing **21 Apr 1982**
(30) Priority data
(31) **8113115**
(32) **28 Apr 1981**
(33) **United Kingdom (GB)**
(43) Application published
3 Nov 1982
(51) **INT CL³**
B25J 13/00
(52) Domestic classification
B8H DV
(56) Documents cited
GB 1324400
GB 1136585
GB 0934775
US 3587872
US 4275986
(58) Field of search
B8H
(71) Applicants
United Kingdom Atomic Energy Authority, 11 Charles II Street, London SW1Y 4QP
(72) Inventors
Sinclair Matthew Third, Edward Abel, Geoffrey Clifford Wall
(74) Agents
United Kingdom Atomic Energy Authority, (John Edward Alderman), Patents Branch, 11 Charles II Street, London SW1Y 4QP

(54) **A manipulator**

(57) A manipulator has at least one pivotal joint 104 controlled by a rotary flexible shaft 121. A worm gear 114 connected to the flexible shaft 121 and meshed with a worm gear wheel 102 at the pivotal joint 104 effects pivotal movement of the joint 104, the rotary flexible shaft 121 being driven by an electric stepping motor.

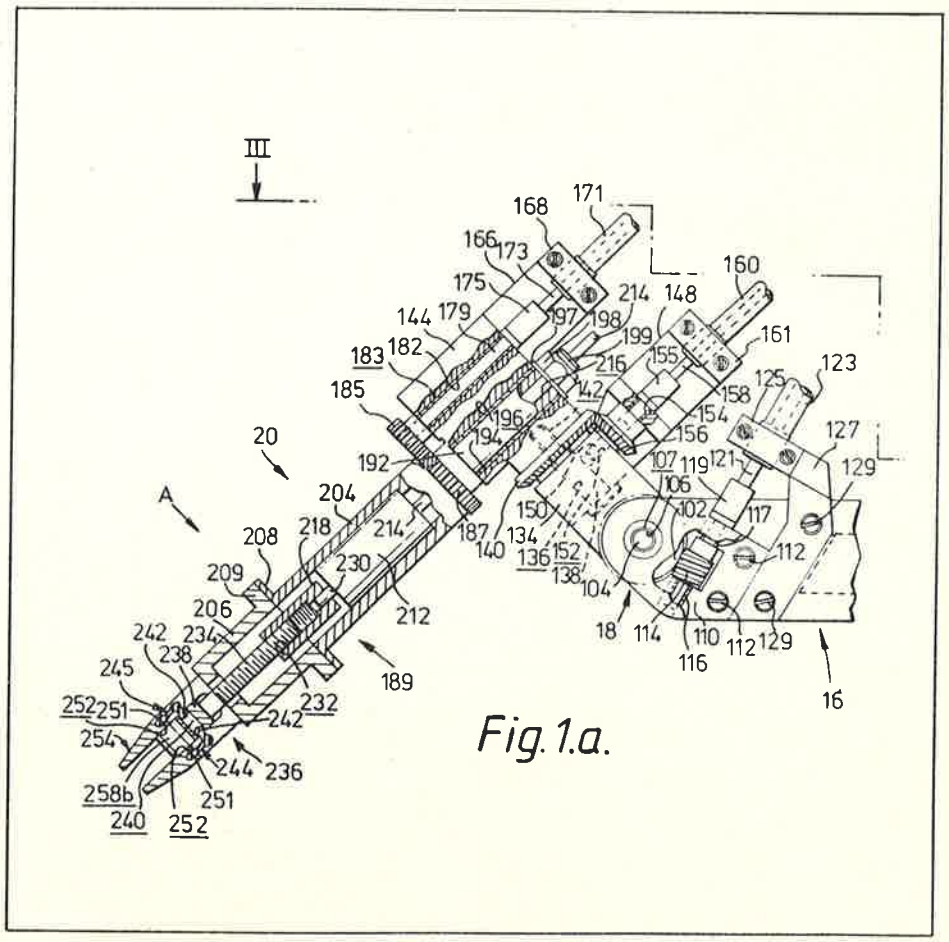


Fig. 1.a.

GB 2 097 360 A

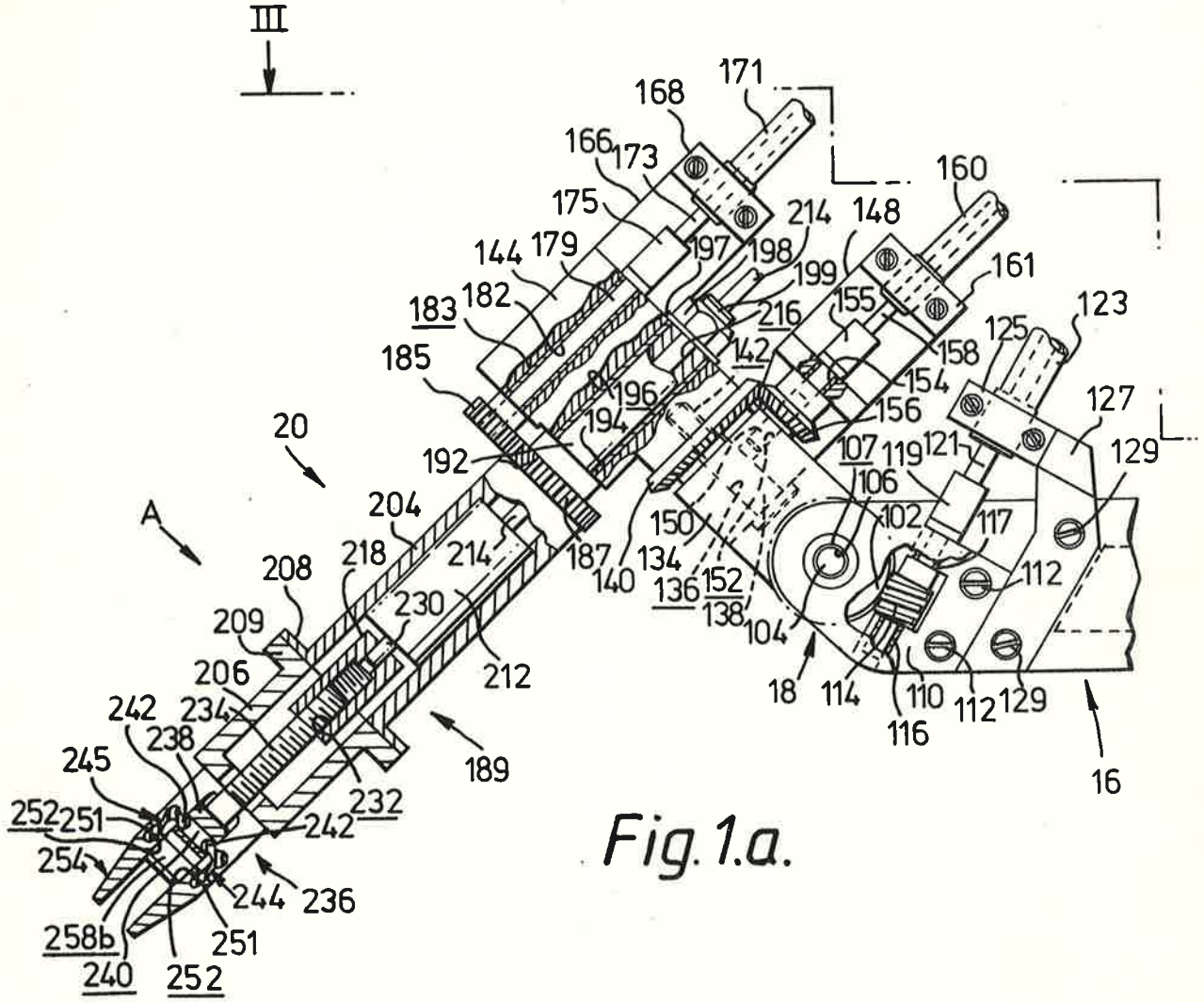

III
171
168
166
173
175
144
179
197
198
199
214
148
160
161
155
183
182
216
142
185
158
154
125
123
127
196
194
156
121
129
107
119
20
192
106
A
204
102
117
150
218
214
187
134
140
112
208
136
152
230
138
104
209
212
206
18
114
110
112
129
242
234
238
116
245
189
232
16
252
251
242
254
244
236
258b
251
240
252

Fig. 1.a.

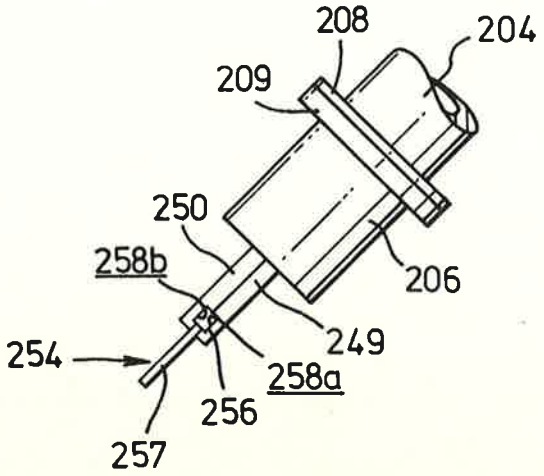

208
204
209
250
258b
206
249
254
258a
256
257

Fig. 1c.

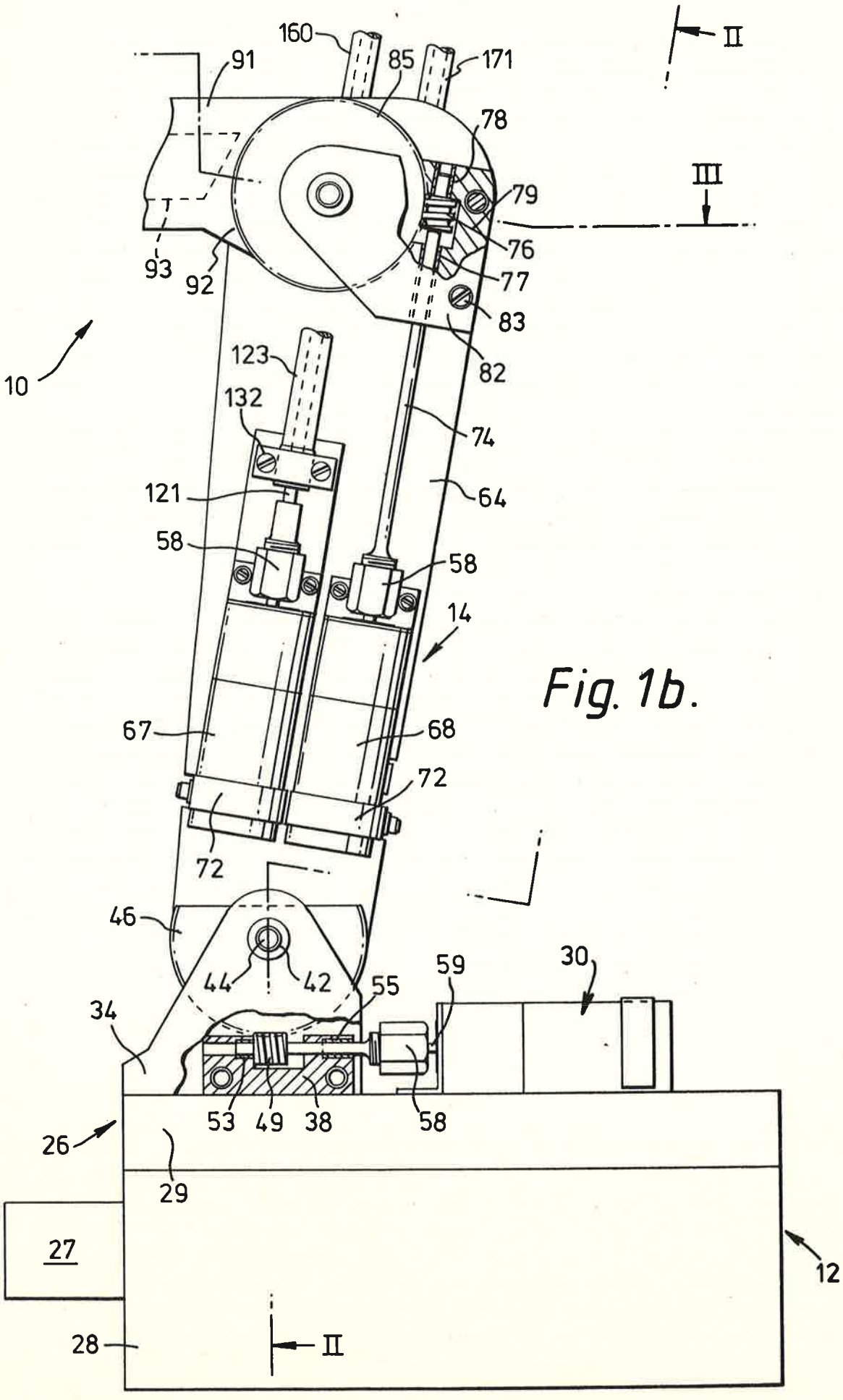
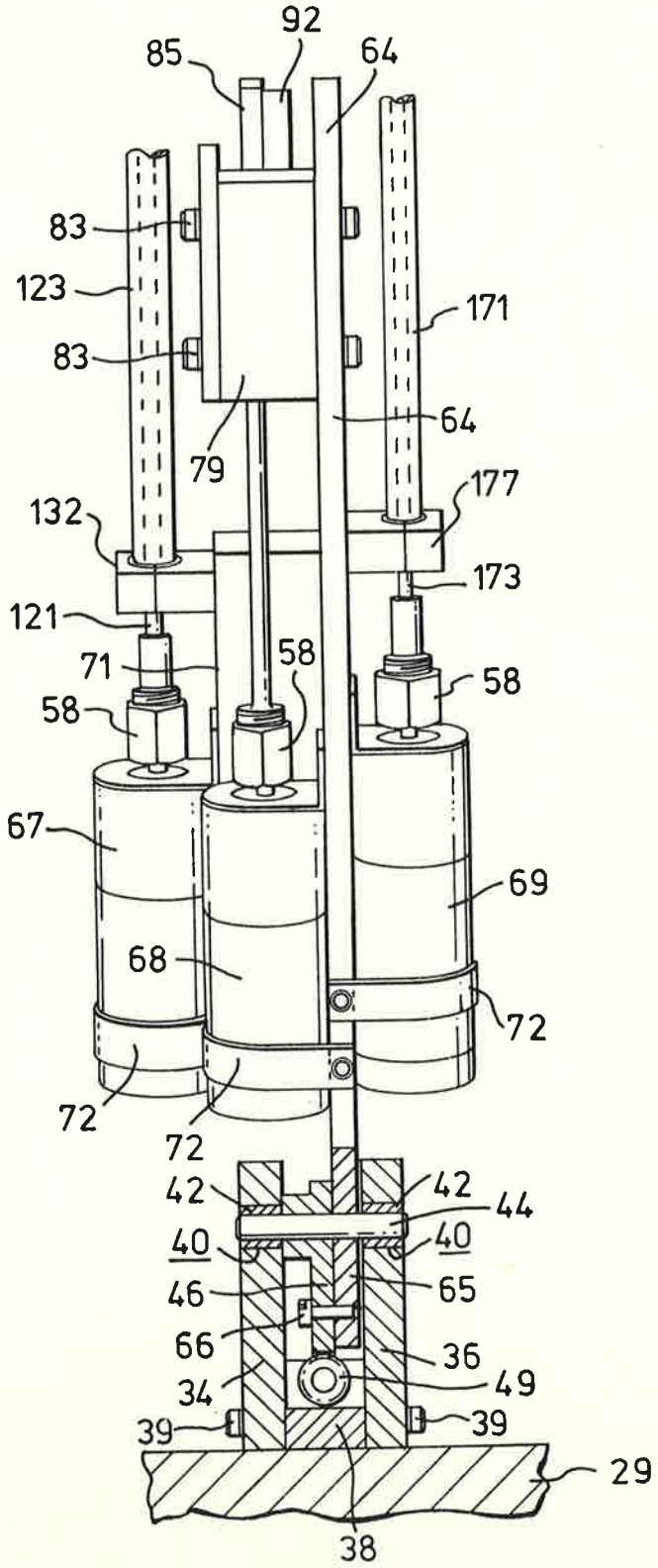
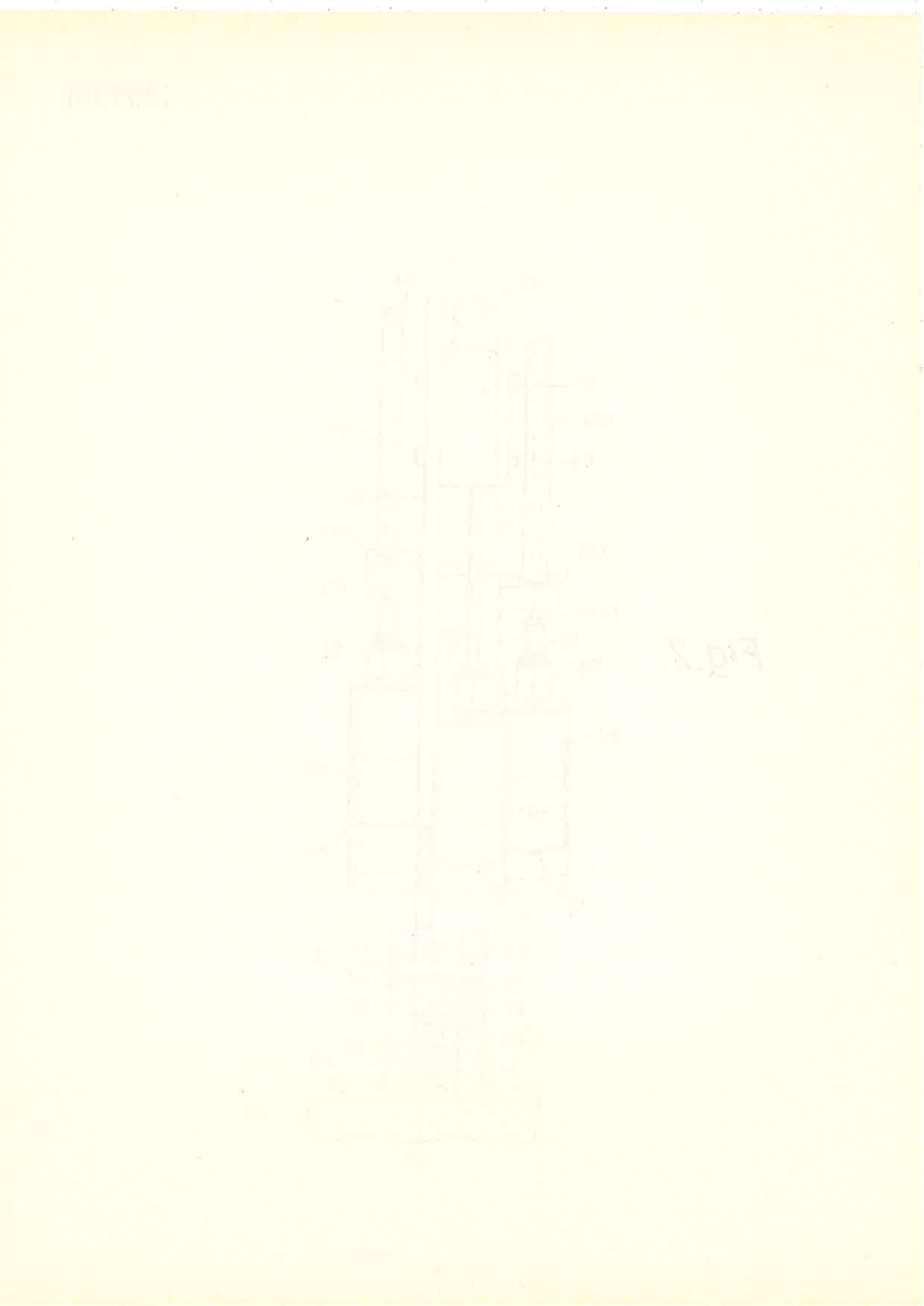

160
91
85
171
II
78
III
79
76
77
83
93
92
82
10
123
132
74
121
64
58
58
14
67
68
72
72
46
44
42
55
59
30
34
53
49
38
58
26
29
27
12
28
II

Fig. 1b.

Fig.2.


92
85
64
83
123
171
83
64
79
177
132
173
121
71
58
58
58
67
69
68
72
72
72
42
42
44
40
40
46
65
66
36
34
49
39
39
29
38



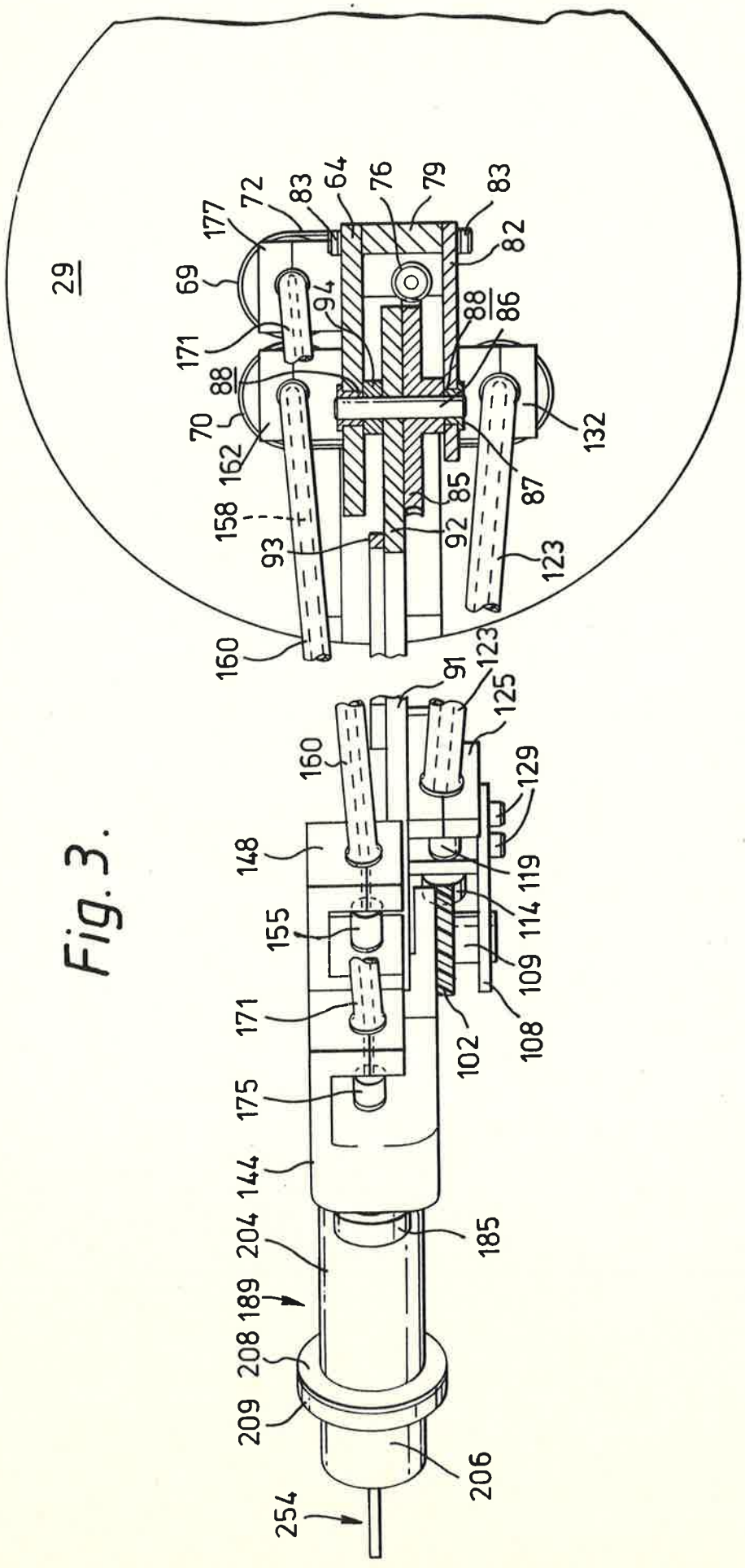

29
177
72
83
64
76
79
83
82
69
94
88
86
171
88
70
162
158
93
85
92
87
132
123
160
91
123
125
129
160
148
155
171
175
144
204
189
208
209
206
254
185
119
114
109
108
102

Fig. 3.

Fig.4.

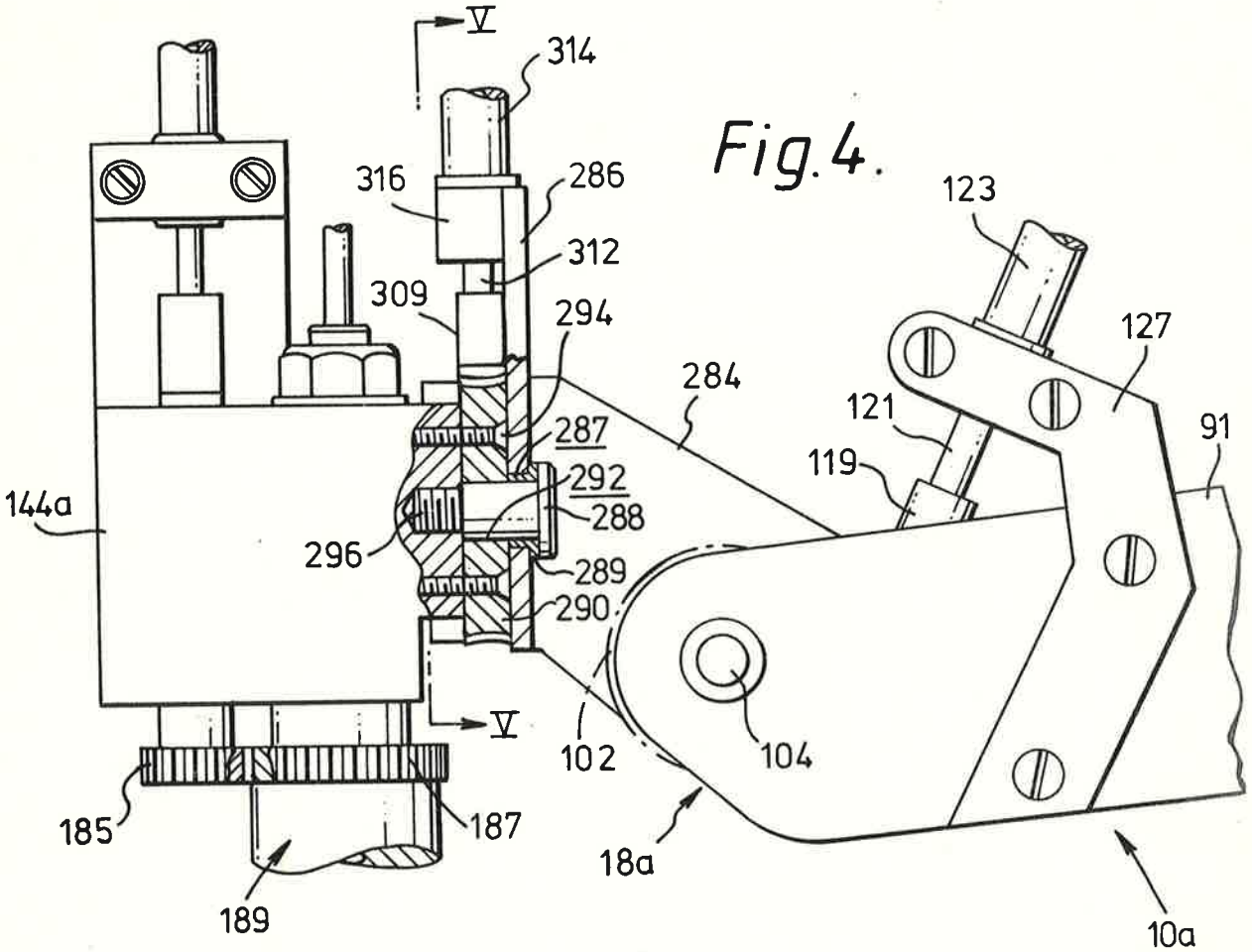
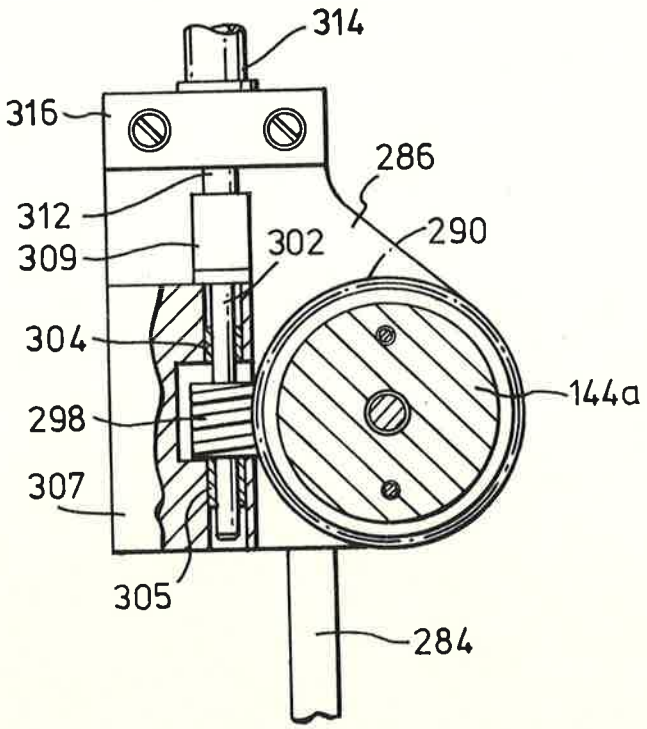

V
314
316
286
312
309
294
284
123
127
121
91
119
287
292
288
144a
296
289
290
V
102
104
185
187
18a
189
10a

Fig.5.


314
316
286
312
290
309
302
304
144a
298
307
305
284

SPECIFICATION

A manipulator

This invention relates to a manipulator for the remote handling of an object, for example an object in a radioactive environment. Although numerous manipulator designs have been developed over the years, many of them are relatively complex and expensive, and there is still a need for a relatively simple design of manipulator which is comparatively, inexpensive for performing relatively light remote handling operations.

The invention therefore provides a manipulator for remote handling of an object, the manipulator being capable of pivotal movements and having at least one of the pivotal movements thereof controlled by rotary flexible shaft means.

Preferably, the flexible shaft means is controlled by electric motor means, for example servo or stepping motor means.

Desirably, at least one of the flexible shaft means is connected to a worm gear meshed with a worm gear wheel, the worm gear wheel being arranged to turn on the pivotal axis of the respective pivotal movement so as to effect the pivotal movement.

The manipulator of the invention may incorporate a jaw assembly comprising, opposing jaw members each locating, at one end thereof, one end of a respective bell crank lever, each lever having the other end thereof located in a grooved member arranged to be displaced by screw thread means so as to pivot the levers. Preferably, the jaw members locate in a common groove extending transverse to the displacement of the grooved member so that pivotal movement of the levers displaces the jaw members along the groove.

The invention will now be further described by way of example only with reference to the accompanying drawings in which:—

Figures 1*a* and 1*b* shop complementary partly broken away side views of a manipulator;

Figure 1*c* shows a fragmentary view in the direction of arrow "A" of Figure 1*a*;

Figure 2 shows a view on the line II—II of Figure 1*b*;

Figure 3 shows a view on the line III—III of Figures 1*a* and 1*b*;

Figure 4 shows a fragmentary partly broken away view of a modified form of the manipulator of Figures 1*a* and 1*b*; and

Figure 5 shows a view on the line V—V of Figure 4.

Referring now to Figures 1*a* to 3, a manipulator 10 for relatively light operations is shown and comprises, a base unit 12, an upper arm 14, a forearm 16, and a wrist assembly 18 on which is mounted a head assembly 20.

The base unit 12 comprises a proprietary rotary table unit 26 actuated by an electric motor 27 and which comprises a stationary base 28 and a rotary table 29 on which is secured a motor in the form of a combined electric stepping motor/gearbox assembly 30. Two side plates 34, 36 respectively mounted on the rotary table 29 are spaced apart by a block 38 secured to the rotary table 29 and joined together by screws 39, and provide respective housings 40 for bearings 42 which locate a respective end of a shaft 44 to which a truncated worm gear wheel 46 is secured. A worm gear 49 in engagement with the worm gear wheel 46 is located in bearings 53, 55 in the block 38, and at one end is joined to a coupling 58 mounted on a shaft 59 of the stepping motor/gearbox assembly 30.

A flat upper arm member 64 of the upper arm 14 has a rounded end 65 secured to the worm gear wheel 46 by screws 66, and supports four motors in the form of electric stepping motor/gearbox assemblies 67, 68, 69, 70 respectively each secured to the upper arm member 64 by a respective clamp fitting 72 with the exception of the stepping motor 67 which is secured to a spacer 71 itself secured to the upper arm member 64, the stepping motor/gearbox assemblies 67, 68 being mounted on one side of the upper arm member 64 and the stepping motor/gearbox assemblies 69, 70 being mounted on the other side thereof. The stepping motor gearbox assembly 68 is arranged to drive a shaft 74 through a coupling 58, the shaft 74 extending to a worm gear 76 mounted in bearings 77, 78 in a block 79 in a similar manner to that described in relation to the worm gear 49. The block 79 is sandwiched between the upper arm member 64 and a side plate 82 and secured thereto by screws 83. A worm gear wheel 85 meshed with the worm gear 76 is secured to a shaft 86 mounted at each end in a flanged bearing 87 located in a housing 88 in the side plate 82 and in the upper arm member 64 respectively, and a flat forearm member 91 stiffened by a web 93 has an enlarged and rounded end 92 secured to the worm gear wheel 85 by screws (not shown), and annular spacer 94 being mounted on the shaft 86 between the upper arm member 64 and the flat forearm member 91.

At the other end of the forearm member 91, a worm gear wheel 102 is secured to a shaft 104 mounted in respective bearings 106 (only one is shown) located in a housing 107 in a side plate 108 and (not shown) in the forearm member 91, an annular spacer 109 being between the worm gear wheel 102 and the side plate 108. A block 110 is sandwiched between the side plate 108 and the forearm member 91 and secured thereto by screws 112. A worm gear 114 meshed with the worm gear wheel 102 locates in respective bearings 116, 117 in the block 110, and extends to a coupling 119 connecting the worm gear 114 to one end of a flexible shaft 121 in a flexible conduit 123, the conduit 123 being held by a clamp unit 125 against a support arm 127 secured to the forearm member 91 by screws 129. The other end of the flexible shaft 121 is connected by a coupling 58 to the stepping motor 67, the other end of the conduit 123 being held by a clamp unit 132 against the spacer 71.

A shaped mounting 134 secured to the worm

gear wheel 102 is shown partially cut away and has a cylindrical hole 136 to locate as a clearance fit a shouldered screw 138 which extends through a bevel gear wheel 140 to locate in a threaded hole 142 in a mounting block 144 of the head assembly 20 to which the bevel gear wheel 140 is secured. A support 148 is secured to one side of the shaped mounting 134, and a shaft 150 has one end located as a clearance fit in a cylindrical hole 152 in the shaped mounting 134 and has the other end thereof extending through a bearing 154 in the support 148 to a coupling 155. A bevel gear 156 meshed with the bevel gear wheel 140 is secured to the shaft 150, and the coupling 155 is connected to one end of a flexible shaft 158 located in a flexible conduit 160 held by a clamp unit 161 to the support 148. The other end of the flexible shaft 158 is connected by a coupling 58 to the stepping motor/gearbox assembly 70, the other end of the conduit 160 being held by a clamp unit 162 attached to the upper arm member 64.

A bracket 166 extending from the mounting block 144 incorporates a clamp unit 168 for holding one end of a flexible conduit 171 through which a flexible shaft 173 extends to coupling 175, the other end of the flexible shaft 173 being connected to the stepping motor/gearbox assembly 69 and the other end of the conduit 171 being held by a clamp unit 177. A rod 179 extends through a bearing 182 in a housing 183 in the mounting block 144, and has one end connected to the coupling 175. A spur gear pinion 185 is mounted on the other end of the rod 179 and meshes with a spur gear wheel 187 integral with a rotatable beak assembly 189 of the head assembly 20, the beak assembly 189 having a hollow shaft portion 192 which extends through a bearing 194 in a housing 196 in the mounting block 144 and is retained therein by a washer 197 and a nut 198 which is engaged with a threaded spigot 199 at the end of the hollow shaft portion 192. An upper housing portion 204 and a lower housing portion 206 of the beak assembly 189 are secured together at respective flanges 208, 209. Inside the upper housing portion 204 a direct current electric motor 212 is located and is arranged to be energised through an electric cable 214 extending through an axial aperture 216 which extends through the upper housing portion 204, the hollow shaft portion 192, and the threaded spigot 199. A coupling 218 is mounted on a drive shaft 230 of the electric motor 212, and is internally threaded at one end 232 to engage a threaded rod 234 extending from a jaw assembly 236, a flat head 238 of the rod 234 having a transverse slot 240 at one side thereof in which locate rounded ends 242 of left hand and right hand bell crank levers 244, 245 respectively. Rounded ends 251 at the other ends of the bell crank levers 244, 245 locate in a groove 252 in a respective jaw member 254, the jaw member 254 having as shown in Figure 1*c* a rectangular section slider portion 256 at one end of a finger portion 257 thereof and locating in opposing transverse grooves 258*a*, 258*b* in flat body members 249, 250 respectively in which the bell crank levers 244, 245 pivotally locate.

In operation, on the stepping motor/gearbox assembly 30 being energised, the action of the worm gear 49 turns the worm gear wheel 46 and causes pivotal movement of the upper arm member 64. Energisation of the stepping motor/gearbox assembly 68 rotates the shaft 74 and thus rotates the worm gear 76 which turns the worm gear wheel 85 causing pivotal movement of the forearm member 91. When the stepping motor/gearbox assembly 67 is energised, it rotates the flexible shaft 121 and thus rotates the worm gear 114 which turns the worm gear wheel 102 causing pivotal movement of the shaped mounting 134. Energisation of the stepping motor/gearbox assembly 70 rotates the flexible shaft 158 and thus the bevel gear 156 which turns the bevel gear wheel 140 and with it the mounting block 144. On the stepping motor/gearbox assembly 69 being energised, it rotates the flexible shaft 173 and thus the pinion 185 which turns the gear wheel 187 and causes corresponding rotation of the beak assembly 189. Energisation of the electric motor 212 rotates the coupling 218 about the threaded rod 234 causing linear displacement of the threaded rod 234 and thus pivotal movement of the bell crank levers 244, 245 with corresponding transverse linear displacement of the jaw members 254.

The stepping motor/gearbox assemblies 67, 68, 69 and 70, and the electric motor 212 may be controlled in a conventional manner, or may be incorporated in a master switching arrangement operated by movements corresponding to the required movements of the manipulator 10, an example of such a switching arrangement being shown in co-pending patent application No. 8029136.

If desired, a pivotal movement of the manipulator 10 may be effected by an alternative arrangement, for example as shown in Figures 4 and 5, and referring to Figure 4, a wrist assembly 18*a* is shown of a manipulator 10*a* similar in most respects to the manipulator 10 of Figures 1*a* to 3 but having an alternative arrangement for pivoting a mounting block 144*a* which is identical to the mounting block 144 of Figure 1*a* except for the manner in which it is pivotally attached to the wrist assembly 18*a*. At the wrist assembly 18*a*, an inclined T-shaped mounting 284 replaces the shaped mounting 134 of Figure 1*a*, and has a mounting face 286 defining an aperture 287 in which a flanged bearing 289 locates. A shouldered screw 288 extends through the bearing 289 and a worm gear wheel 290 with a central hole 292 is mounted on the screw 288 and secured by several screws 294 (only two are shown) to the mounting block 144*a*, the mounting block 144*a* having a threaded hole 296 in engagement with the screw 288. As shown more clearly in Figure 5, a worm gear 298 engages the worm gear wheel 290 and has a shaft 302 located in respective bearings 304, 305 in a mounting

block 307 secured to the mounting face 286. One end of the shaft 302 is connected to a coupling 309 joined to one end of a flexible shaft 312 extending from a flexible conduit 314 which is secured by a clamp unit 316 to the mounting face 286. The other end of the flexible shaft 312 is secured to the stepping motor/gearbox assembly 70 (not shown in Figures 4 and 5) in the same manner as that described in relation to the flexible shaft 160 of Figures 1*a* to 3.

In use of the manipulator 10*a*, rotation of the flexible shaft 312 rotates the worm gear 298 and thereby the worm gear wheel 290 causing corresponding rotation of the mounting block 144*a*, and rotation of the worm gear wheel 102 at the wrist assembly 18*a* caused by rotation of the flexible shaft 121 results in pivotal movement of the mounting 284.

One advantage of the use of a worm gear and worm gear wheel to provide a pivotal movement of the manipulator, results from the self locking capability of such a gear combination.

The stlructural components of the manipulators 10 and 10*a* are conveniently fabricated from materials suited to the application for which the manipulator is to be used. These materials include stainless steel, aluminium, or plastics materials for light duties and subsequent ease of disposal, such plastics materials including glass fibre reinforced plastics materials, or synthetic resin bonded fabric, for example that sold under the Registered Trade Mark "TUFNOL".

It will be understood that other pivotal movements may be incorporated in the manipulators of Figures 1*a* to 5 in the manner of the invention. The invention has been described in relation to the use of electric stepping motors to give a brushless drive that can easily be controlled using a small computer, since the drive electronics are essentially digital, but as such the manipulators of Figures 1*a* to 5 operate on open loop control, there being no feedback of position information. In more complex schemes, however, position, velocity or acceleration transducers may be used to monitor the position and the dynamics of the arms and their pivotal joints of the manipulator of the invention, and the derived information used to enhance the control of the manipulator. The use of alternative motors or drive mechanisms, which may be electric, hydraulic, or pneumatic, may be more appropriate in some of these applications than the aforesaid electric stepping motors. For example, direct current torque motors to provide relatively high power to weight ratios, disc motors to provide relatively high torque to inertia ratios with low armature inductance, or induction motors although an inverter would be required for adequate control. For relatively heavy duty applications, an inverter fed permanent magnet synchronous machine has advantages, since it has a relatively high power to weight ratio and is able to be accurately and repeatedly repositioned.

CLAIMS

1. A manipulator for remote handling of an object, the manipulator being capable of pivotal movements and having at least one of the pivotal movements thereof controlled by rotary flexible shaft means.

2. A manipulator as claimed in Claim 1, wherein the flexible shaft means is controlled by an electric motor means.

3. A manipulator as claimed in Claim 2, wherein the electric motor means comprises a servo motor means.

4. A manipulator as claimed in Claim 2, wherein the electric motor means comprises a stepping motor means.

5. A manipulator as claimed in any one of the preceding Claims, wherein at least one of the flexible shaft means is connected to a worm gear meshed with a worm gear wheel, the worm gear wheel being arranged to turn on the pivotal axis of the respective pivotal movement so as to effect the pivotal movement.

6. A manipulator as claimed in any one of the preceding Claims, incorporating a jaw assembly comprising, opposing jaw members each locating, at one end thereof, one end of a respective bell crank lever, each lever having the other end thereof located in a grooved member arranged to be displaced by screw thread means so as to pivot the levers.

7. A manipulator as claimed in Claim 6, wherein the jaw members locate in a common groove extending transverse to the displacement of the grooved member so that pivotal movement of the levers displaces the jaw members along the groove.

8. A manipulator as claimed in Claim 6 or Claim 7 wherein the jaw assembly includes an electric motor means arranged to rotate the screw thread means.

9. A manipulator as claimed in any one of the preceding Claims, further comprising an upper arm, a forearm pivotally mounted on the upper arm, a first mounting member pivotally mounted on the forearm, a second mounting member extending from the first mounting member and rotatable with respect thereto, and a jaw assembly extending from the second mounting member and rotatable with respect thereto.

10. A manipulator as claimed in any one of the preceding Claims, including a turntable for turning the manipulator about the rotary axis of the turntable.

11. A manipulator as claimed in any one of the preceding Claims, wherein structural portions of the manipulator comprise a plastics material.

12. A manipulator substantially as hereinbefore described and with reference to Figures 1*a* to 3 of

the accompanying drawings.

13. A manipulator as claimed in Claim 12, modified substantially as hereinbefore described and with reference to Figures 4 and 5 of the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained