United States Patent [19]

Bullard, III

[11] **3,714,714**

[45] **Feb. 6, 1973**

[54] **DRAFTING MACHINE**

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[22] Filed: **Feb. 12, 1971**

[21] Appl. No.: **114,832**

[52] **U.S. Cl.** **33/80**

[51] **Int. Cl.** **B43l 13/02**

[58] **Field of Search** .....33/76, 79, 80, 23 C, 18 R, 33/1 M, 189

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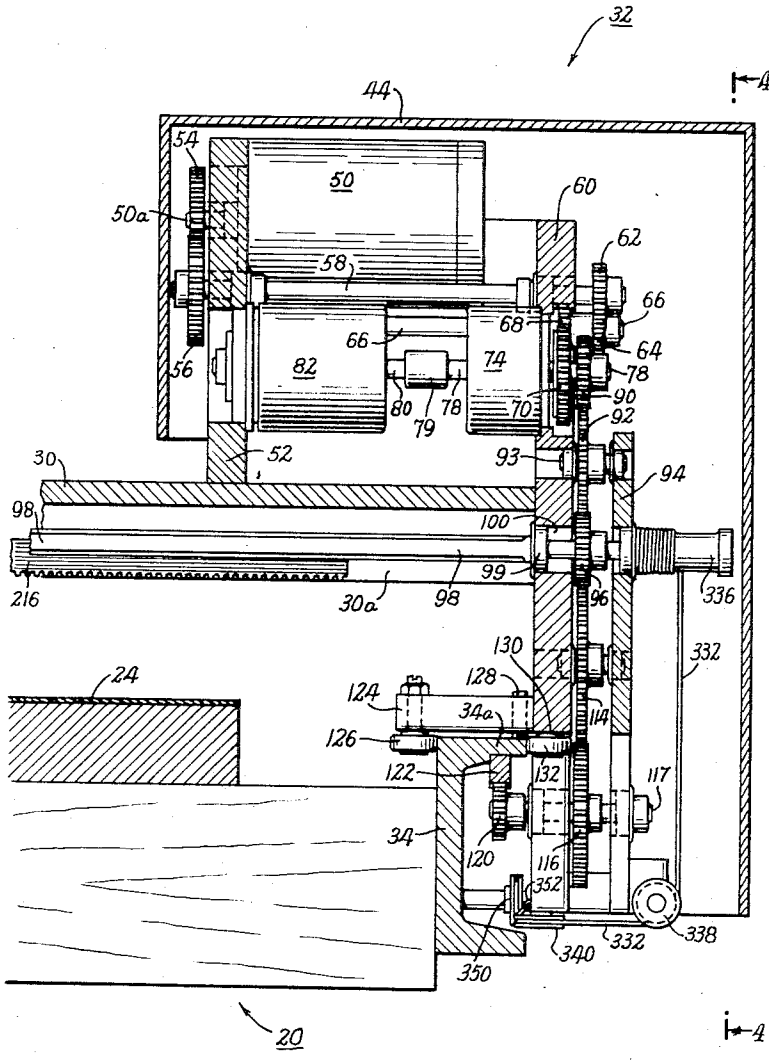
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Primary Examiner—Harry N. Haroian
Attorney—St. Onge Mayers & Reens

[57] **ABSTRACT**

The disclosed drafting machine comprises a drafting head coupled to a main carriage supported on a main rail for movement parallel to a transverse axis. Parallel top and bottom rails support main rail carriages for movement parallel to a longitudinal axis of the main rail pursuant to positioning the drafting head to any point on the drafting surface. A drive train is incorporated for precise point to point positioning of the drafting head either under manual positioning control or automatic positioning control on the basis of numerical positioning data inputs.

12 Claims, 14 Drawing Figures



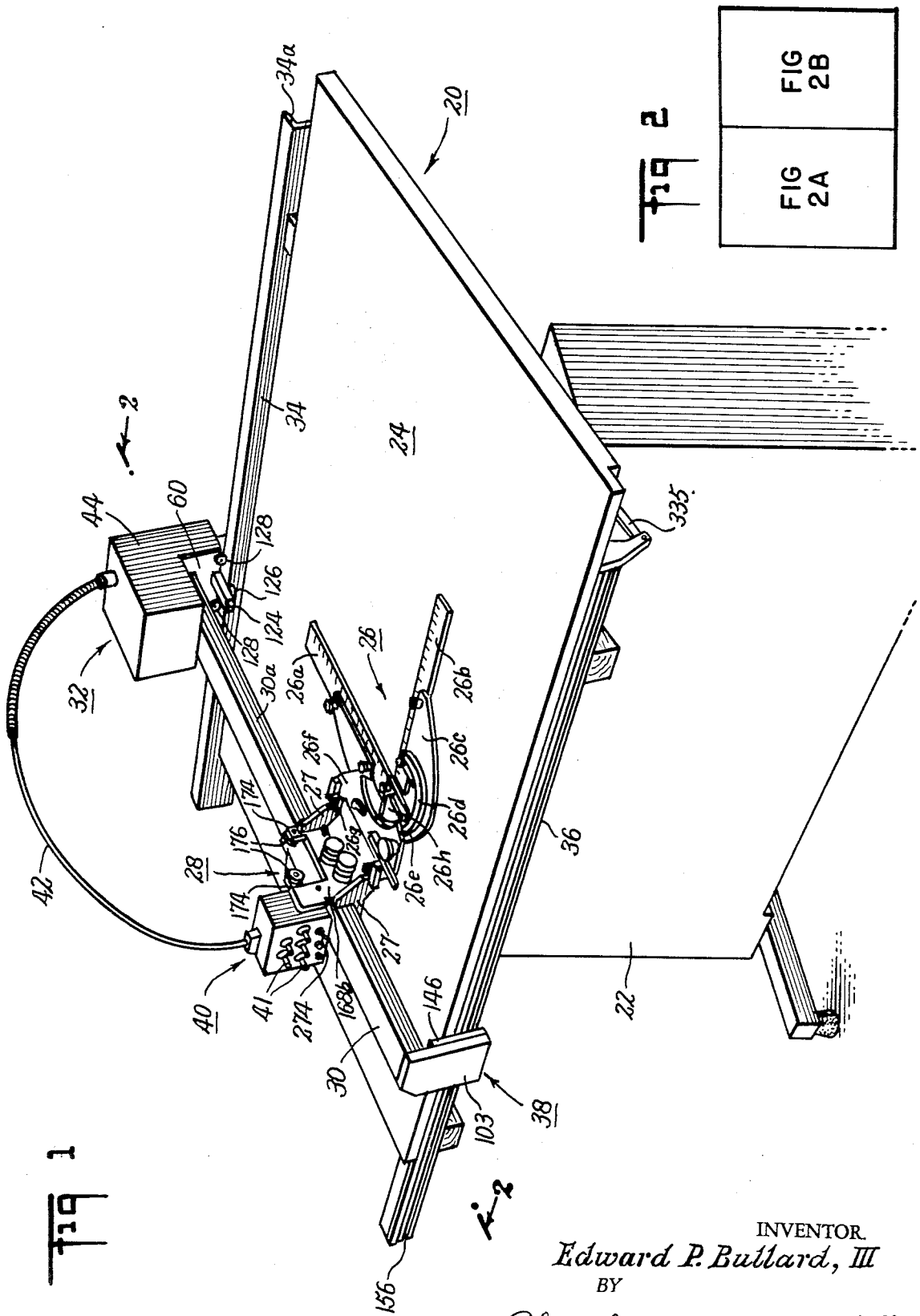


Fig 2

Fig 1

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ATTORNEYS

FIG 2A

FIG 3

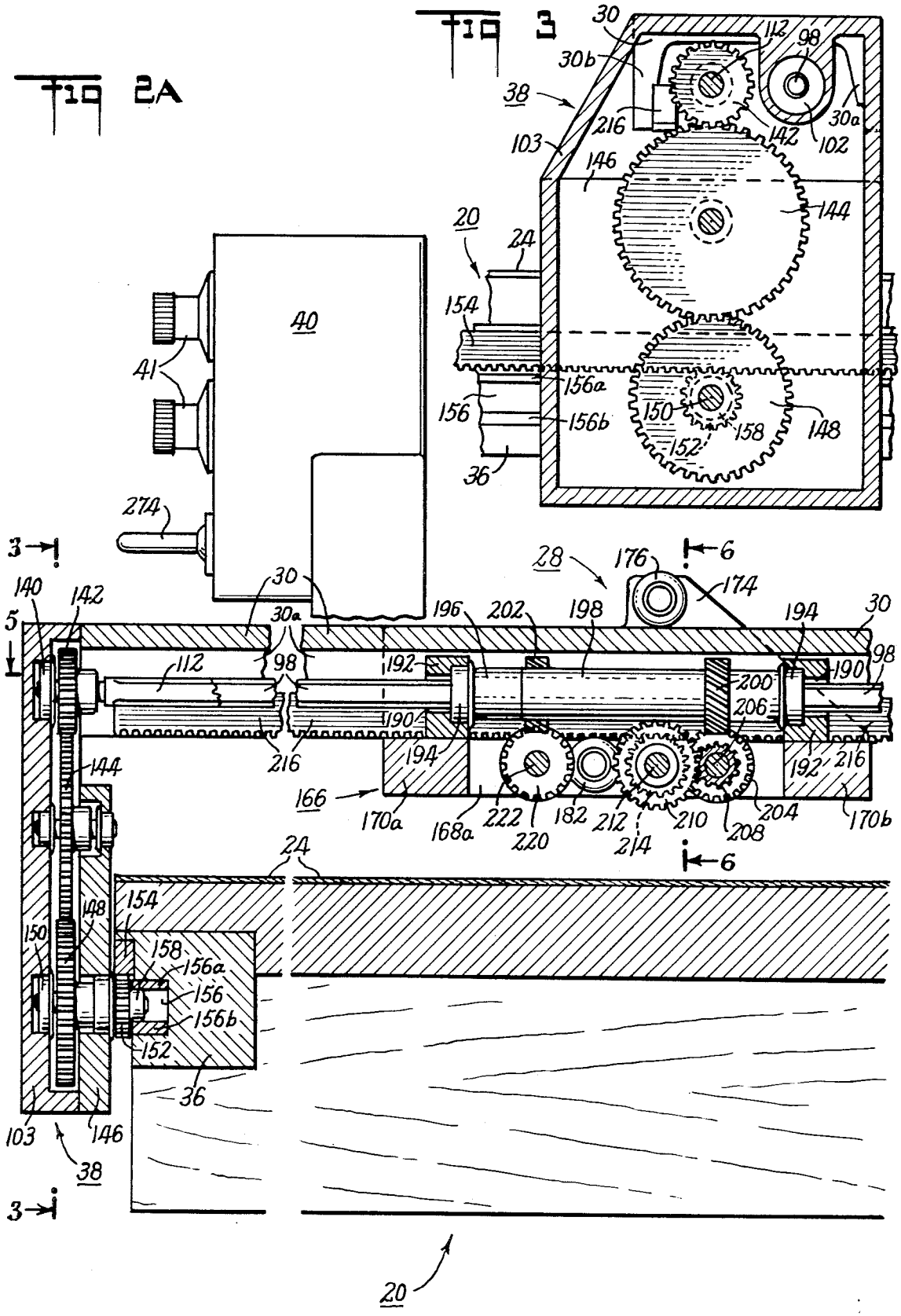

30
30b
38
103
216
112
98
30a
142
102
146
144
20
24
154
156a
156
156b
150
158
152
148
36
40
41
274
3
5
140
142
28
176
174
6
196
202
198
194
192
200
206
190
166
170a
168a
222
220
182
212
214
210
208
204
170b
148
150
158
156a
156
156b
152
36
103
146
38
3
20

Fig 2B

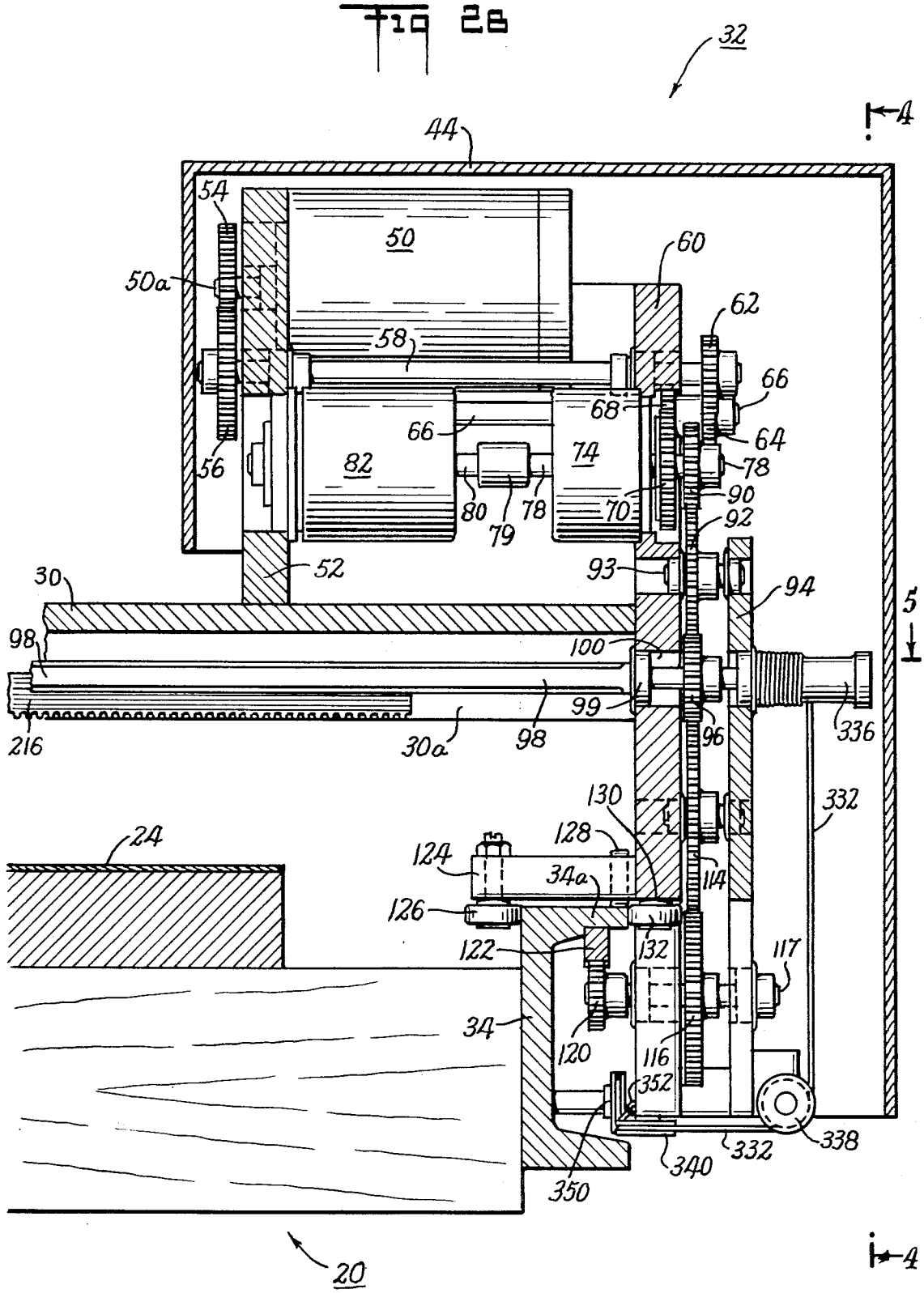

32
4
44
54
50
60
50a
62
58
66
68
66
64
82
74
78
56
80
79
78
70
90
92
52
93
94
30
5
98
100
99
216
30a
98
96
336
130
332
24
128
124
34a
114
126
122
132
117
34
120
116
352
338
340
332
350
4
20

FIG 4

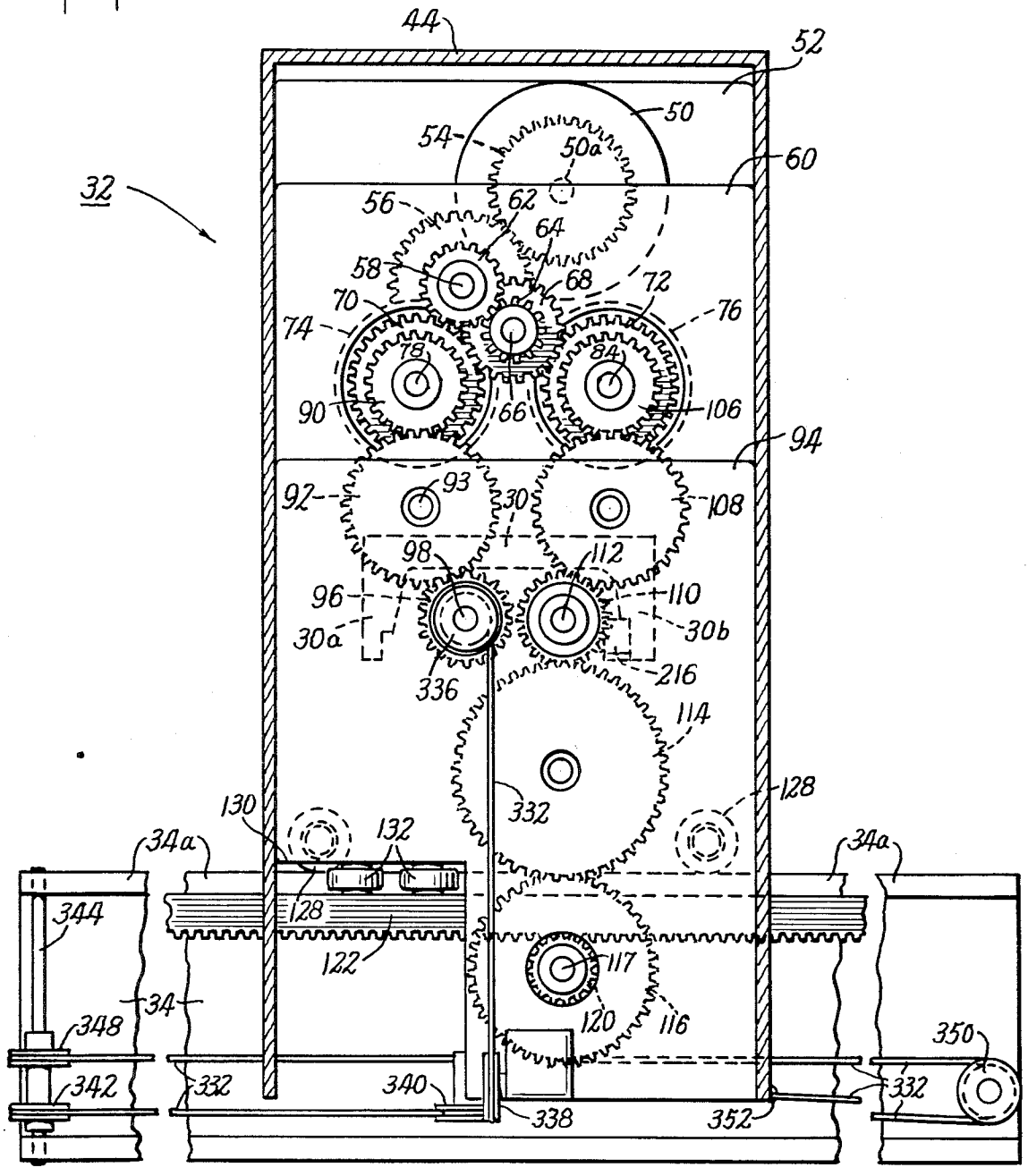

44
52
50
54
50a
60
32
56
62
64
58
68
72
70
74
76
78
84
90
66
106
94
92
93
30
108
98
112
96
110
30a
30b
216
336
114
332
130
128
132
34a
344
128
122
117
34
348
120
116
350
342
332
340
338
352
332

Fig 5

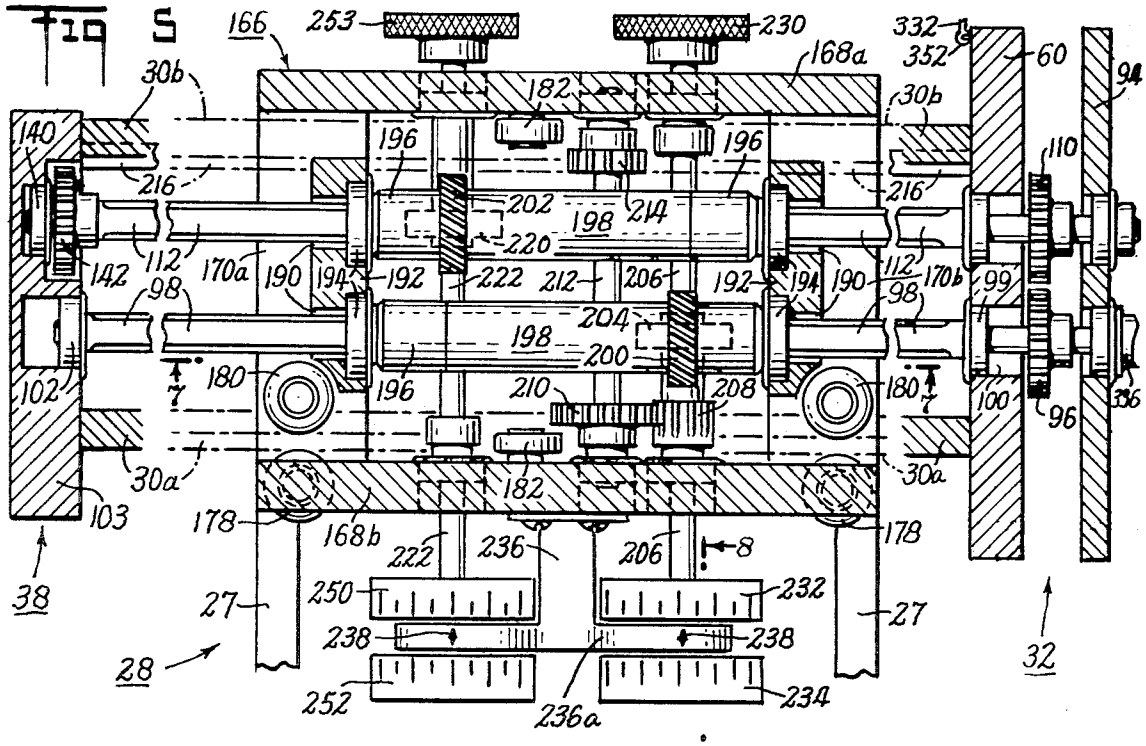


Fig 6

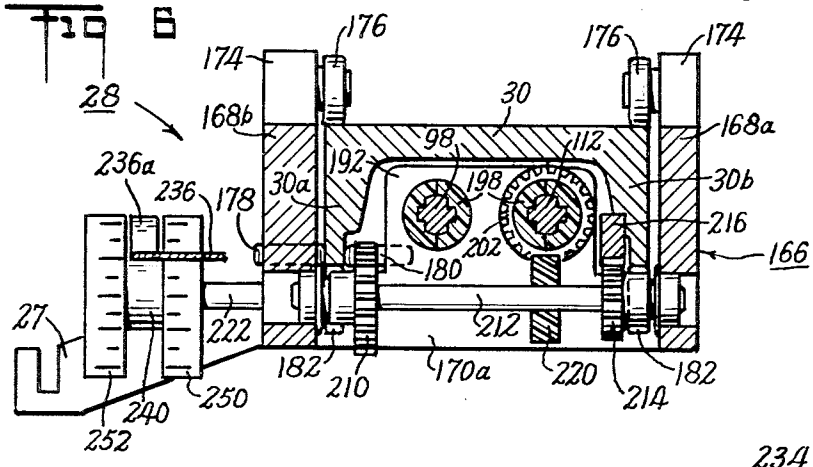


Fig 7

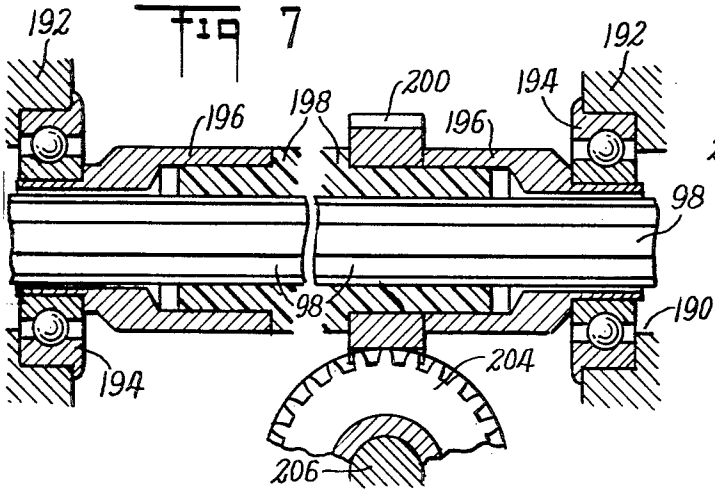
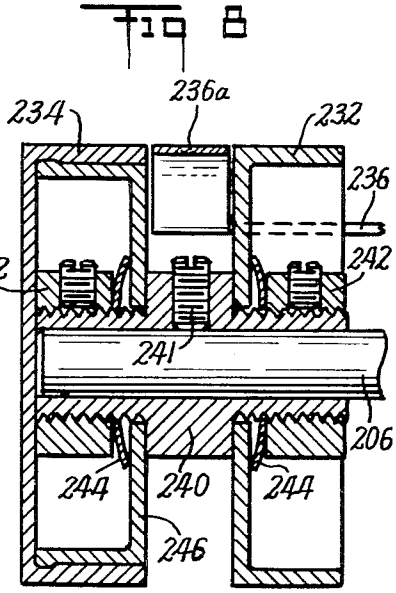
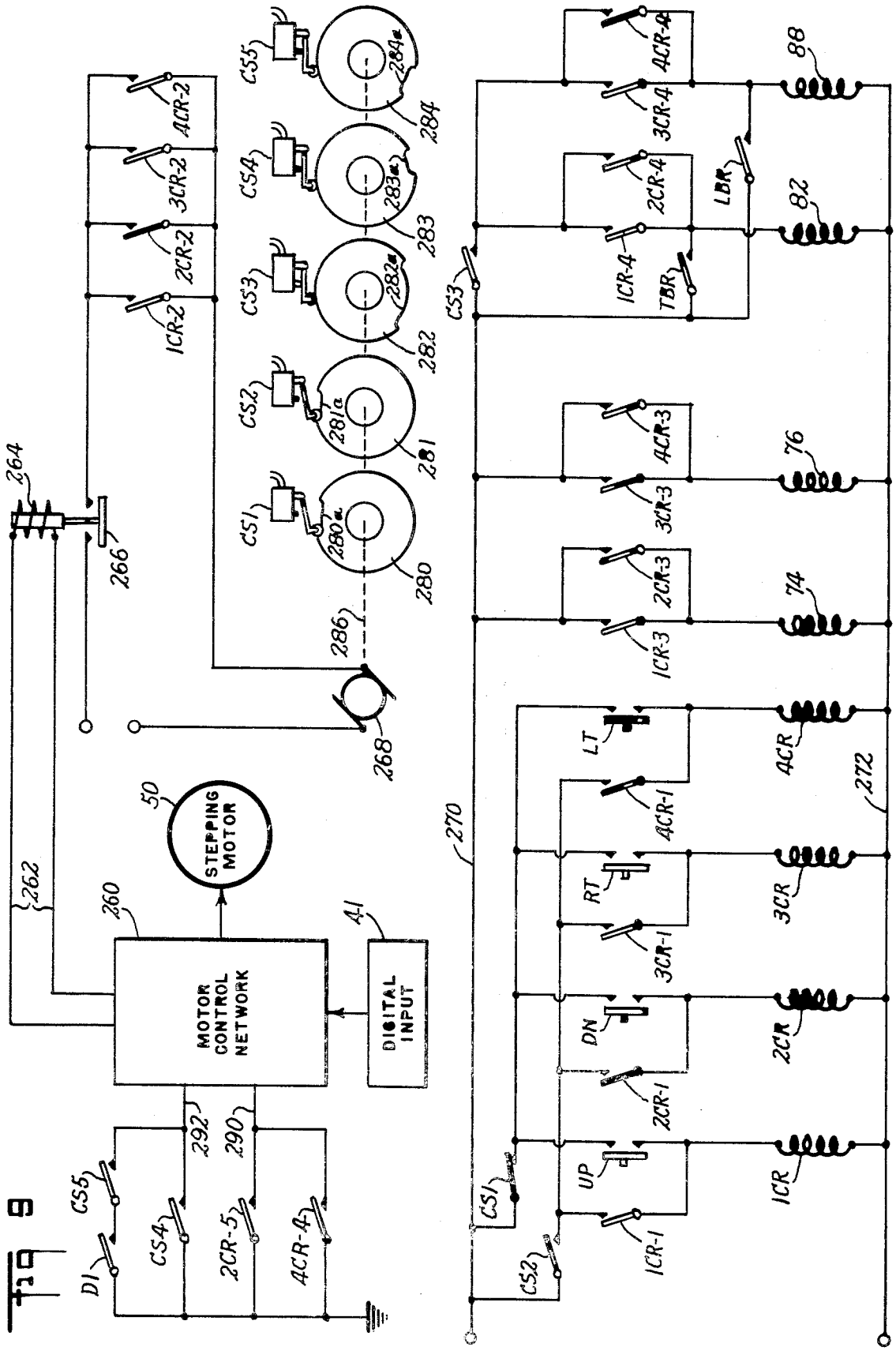


Fig 8




Fig 9
D1
CS5
CS4
2CR-5
4CR-4
292
290
262
260
MOTOR CONTROL NETWORK
41
DIGITAL INPUT
50
STEPPING MOTOR
264
266
268
286
280
281
282
283
284
CS1
CS2
CS3
CS4
CS5
ICR-2
2CR-2
3CR-2
4CR-2
270
272
CS1
CS2
UP
ICR-1
2CR-1
DN
3CR-1
RT
4CR-1
LT
ICR
2CR
3CR
4CR
ICR-3
2CR-3
3CR-3
4CR-3
74
76
ICR-4
2CR-4
3CR-4
4CR-4
TBR
LBR
82
88

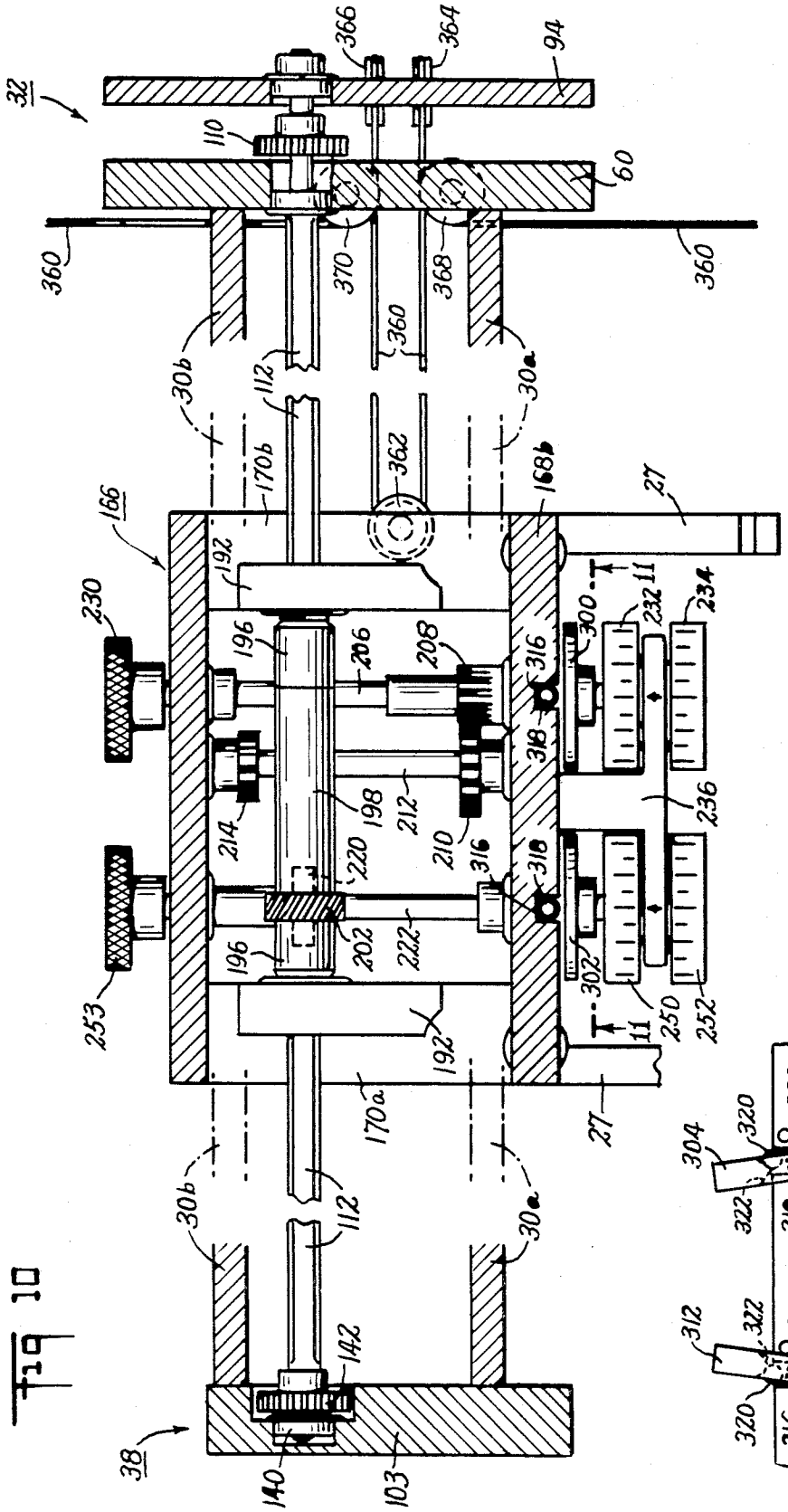

32
366
364
94
110
60
360
370
368
360
30b
112
30a
362
170b
168b
27
166
192
230
196
206
208
316
300
232
234
11
214
198
212
220
210
318
236
253
202
222
302
250
252
192
170a
27
142
38
140
103

Fig 10

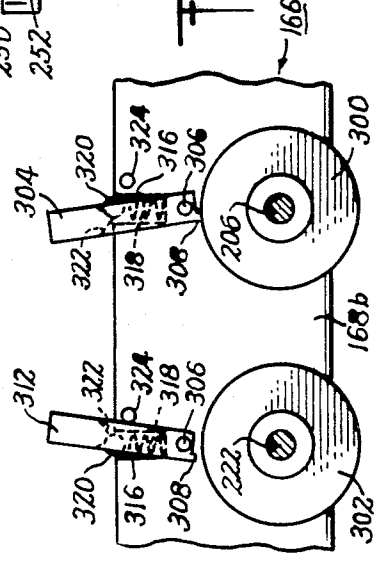

166
304
320
324
316
306
300
322
318
308
206
168b
312
222
320
316
308
302

Fig 11

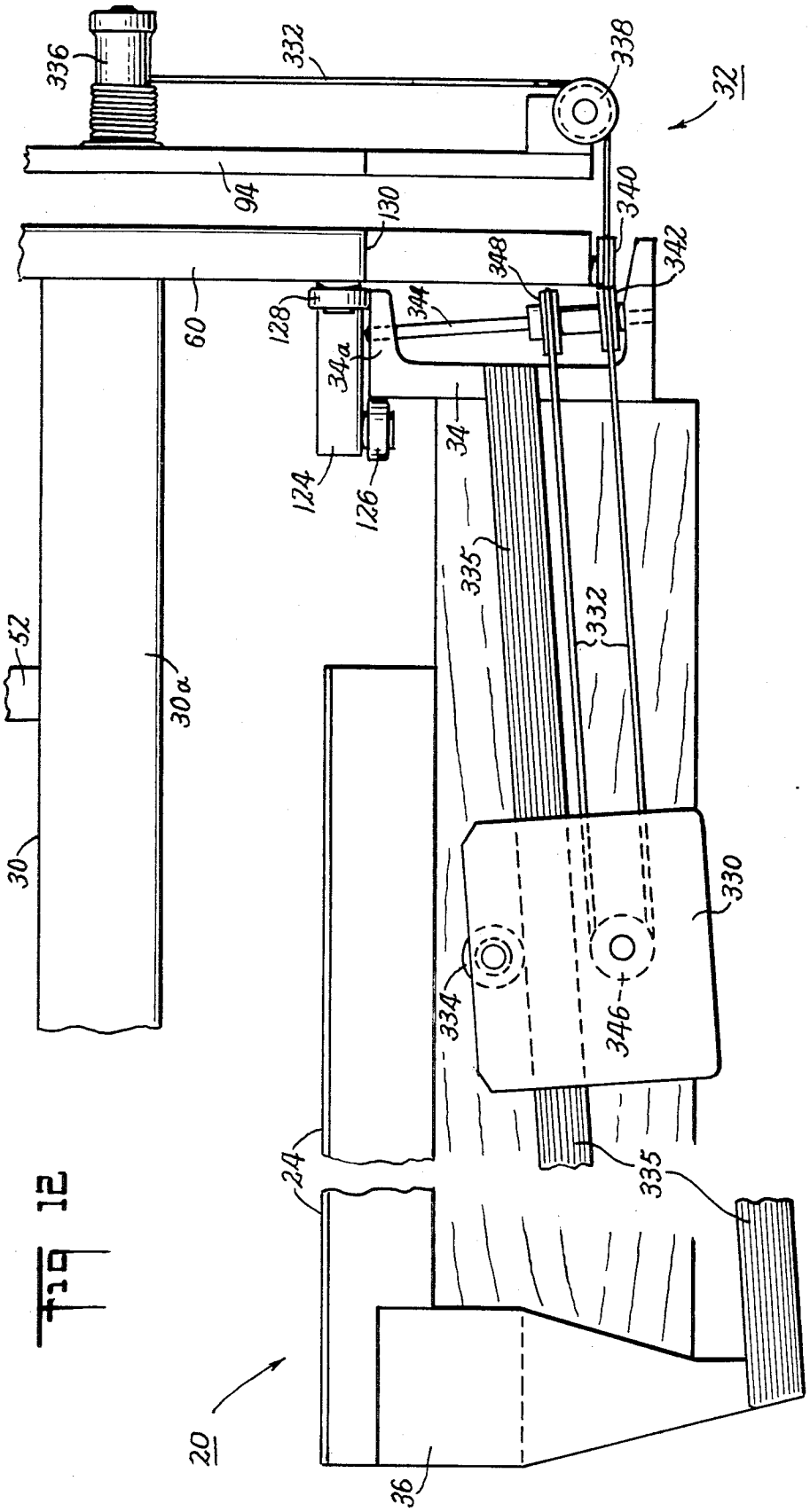

336
332
338
32
94
130
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342
348
344
60
128
34a
34
124
126
335
332
52
30a
30
330
334
346
24
335
20
36

Fig 12

DRAFTING MACHINE

BACKGROUND OF THE INVENTION

Drafting machines have been used for many years by draftsmen to assist them in making technical drawings more rapidly. The typical drafting machine comprises a drafting head having orthogonal straightedges. In one type of drafting machine the drafting head is connected to an articulated, pivotal arm consisting of a series of parallel links, which attempt to maintain the spatial orientation of the straightedges reasonably constant regardless of the position of the drafting head on the drawing surface. Unfortunately, the articulated and elongated nature of the pivotal arm readily accommodates a certain degree of flexure, and thus skewing of the spatial orientation of the straightedges is common as the drafting head is moved about. Even if parallelism of the drafting head is relatively precise, it can readily be distorted by inadvertent pressures exerted by the draftsman. Thus intended parallel lines may not be precisely so. In many situations such deviations may be intolerable.

In another common type of drafting machine, a longitudinal top rail supports and guides a transverse main rail for longitudinal movement. The main rail, in turn, supports and guides the drafting head for transverse movement. Since the bottom end of the main rail is supported on a flat track, the perpendicularity of the main rail to the top rail is dependent solely on the mounting of the top end of the main rail to the top rail. The requisite elongation of the main rail renders precise perpendicularity virtually impossible to maintain.

Moreover, when using drafting machines of this type, all dimensions must be scaled off by the draftsman. Consequently, there are always the problems of inconsistency in scaling, difficulty in reading the scale, and outright erroneous scaling. Thus, drafting machines currently available to draftsmen relieve little of the tedium involved in making technical drawings and do not prevent or even materially reduce the possibility of error.

It is accordingly a general object of the present invention to provide a drafting machine which, in the hands of a draftsman, provides for the production of more accurate drawings and in considerably less time than has been possible with currently available drafting machines. The drafting machine of the present invention greatly minimizes the major areas of human error, eliminates many sources of fatigue, and permits the draftsman to concentrate on the important aspects of drafting by relieving him of many of the routine functions normally associated with the drafting art.

Other more specific objects of the invention will in part be obvious and will in part appear hereinafter.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a drafting machine which is capable of enabling designers, architects, surveyors, detailers, etc., to produce drawings more accurately and in less time than has heretofore been possible. The instant drafting machine includes a drafting head which is coupled to a main carriage mounted on a main rail for movement in a transverse direction over a drafting surface. The main rail is adapted with a carriage at each

end which are in turn mounted on top and bottom rails to accommodate longitudinal movement of the main carriage.

Precision circular pitch rack gears are mounted by the top and bottom rails, and each is engaged by an identical pinion gear carried by the main rail carriages. The pinion gears are maintained in a constant angular relation by identical gearing and a cross shaft journalled by the main rail carriages. The ends of the main rail must therefore move in concert and all bending moments and stresses on the main rail are canceled with the result that perpendicularity of the main rail to the top and bottom rails is always assured.

A precision circular pitch rack gear also mounted by the main rail is meshingly engaged by a pinion carried by the main carriage. A pair of handwheels are mounted by the main carriage. One handwheel is coupled by the cross shaft to the pinions of the main rail carriages meshing with the top and bottom rail racks, such that rotation thereof moves the main rail and drafting head longitudinally. A graduated dial carried on the longitudinal handwheel shaft provides a readout of the increment of longitudinal movement of the drafting head induced by rotation of the longitudinal handwheel.

Similarly, the other handwheel is coupled to the main carriage pinion meshing with the main rail rack to produce transverse movement of the main carriage and drafting head. A graduated dial on the transverse handwheel shaft gives a readout of the increment of transverse drafting head movement induced by rotation of the transverse handwheel. Manual brakes are provided to prevent movement of the drafting head upon achievement of the desired positions in each direction.

This arrangement completely eliminates the necessity of scaling off dimensions. Instead the desired dimensions are read off the dials as the handwheels are rotated pursuant to positioning the drafting head accordingly. Drafting head positioning to within five thousandths of an inch is readily achieved.

The present invention also contemplates automatic positioning of the drafting head on the basis of numerical control positioning data inputs. Instead of positioning the drafting head by rotation of the handwheels, the desired increments of drafting head movement in the longitudinal and transverse directions are entered through digital switches. The digital inputs are supplied to a control network for a stepping motor. The motor is drivingly coupled through a first clutch, brake and cross shaft to the pair of main rail carriage pinions meshing with the top and bottom rail racks. The motor is also drivingly coupled through a second clutch, brake and cross shaft to the main carriage pinion meshing with the main rail rack. The clutches are engaged, the brakes released, and the motor is energized to successively step off the increments in the longitudinal and transverse directions entered by the digital switches. Upon ultimate positioning of the drafting head in each direction, the brakes are engaged prior to releasing the clutches to prevent inadvertent movement of the drafting head. Different drawing scales are achieved by changing the motor drive ratio. Depending on the scale being used, discreet resolution under automatic control varies from 0.003 inch to 0.00025 inch.

In either the manual or automatic drafting machine embodiments of the invention, the longitudinal and transverse brakes may be released, and the drafting head directly manipulated with minimum effort to various positions. Movement of the drafting head is with such mechanical ease that it is preferred to include a counterweight system for counterbalancing the weight of the main carriage and drafting head when the drafting surface is inclined.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of an automatic drafting machine constructed according to one embodiment of the invention;

FIG. 2 is a sectional view consisting of FIGS. 2A and 2B in juxtaposition, as taken along line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along line 3—3 of FIG. 2A;

FIG. 4 is a sectional view taken along line 4—4 of FIG. 2B;

FIG. 5 is a sectional view, partially broken away, taken along line 5—5 of FIGS. 2A and 2B;

FIG. 6 is a sectional view taken along line 6—6 of FIG. 2A;

FIG. 7 is a sectional view taken along line 7—7 of FIG. 5;

FIG. 8 is a sectional view taken along line 8—8 of FIG. 5;

FIG. 9 is a wiring and schematic block diagram of the electrical controls for the automatic drafting machine of FIG. 1;

FIG. 10 is a sectional view comparable to FIG. 5 illustrating a strictly manual drafting machine constructed according to an alternative embodiment of the invention;

FIG. 11 is a sectional view taken along line 11—11 of FIG. 10; and

FIG. 12 is a side elevational view of the drafting machine illustrating the essential features of a counterweight system usable with both the automatic and manual embodiments of the invention.

Similar reference characters refer to similar parts throughout the several views of the drawings.

DETAILED DESCRIPTION

In accordance with one embodiment of the invention, a drafting machine, as seen generally in FIG. 1, includes a drafting board **20** tiltably mounted on a base **22** to establish a desired inclination of the drafting surface **24**. A drafting head, generally indicated at **26**, rests on the drafting surface and is pivotally connected to a main carriage, generally indicated at **28**, which, in turn, is supported on a main rail **30** for transverse movement over the drafting board **20**.

Drafting head **26**, fully disclosed and claimed in my copending application entitled "Drafting Head Assembly" and filed concurrently herewith, generally includes a pair of straightedges **26*a*** and **26*b*** secured to support member **26*c*** in orthogonal relationship to each other. The support member is formed having an annular protractor rail **26*d*** which is accommodated in an annular track **26*e*** included in a frame **26*f***. Frame **26*f***, in turn, is pivotally connected to spaced brackets **27** extending laterally from main carriage **28** through the provision of a frame mounted pin **26*g*** received in a notch formed in each main carriage bracket. Thus the drafting head may pivot upwardly away from the drafting surface or disconnected altogether from the main carriage **28**, but is otherwise rigidly connected thereto.

The centers of curvature of protractor rail **26*d*** and track **26*e*** coincide and are precisely located at the intersection or vertex of straightedges **26*a*** and **26*b***. The straightedges terminate short of their vertex leaving a gap which is occupied by a transition rule **26*h*** pivotally connected to support member **26*c***. Transition rule **26*h*** has two positions; one position with one of its straight side edges aligned with the ruling edge of straightedge **26*a*** and another position with the other of its straight side edges aligned with the ruling edge of straightedge **26*b***. Thus transition rule **26*h*** serves to effectively extend the ruling edges of straightedges **26*a*** and **26*b*** through the gap area therebetween, thereby facilitating the drawing of lines up to and through their vertex.

Moreover, the protractor rail **26*d*** carried by support member **26*c*** is movable in track **26*e*** in frame **26*f*** to revolve the support member and thus straightedges **26*a*** and **26*b*** about their vertex to accommodate the drawing of radial lines therethrough.

The foregoing brief description of drafting head **26** is believed adequate for a complete understanding of the construction and operation of the drafting machine to be considered. Further details of the drafting head may be obtained by reference to the above-noted copending application, whose disclosure is specifically incorporated herein by reference. However, it will be appreciated that the drafting machine of the present invention may incorporate a variety of drafting heads to advantage.

Still referring to FIG. 1, the upper end of main rail **30** is mounted by an upper carriage **32** in turn supported by a top rail **34** attached to the drafting board along its upper side. A bottom rail **36** attached to drafting board **20** along its lower side supports a lower carriage **38** mounting the lower end of main rail **30**. Main rail carriages **32** and **38** are movable along top rail **34** and bottom rail **36**, respectively, in order to position the drafting head **26** and main carriage **28** longitudinally over the drafting surface **24**.

It is thus seen that main rail **30** moves longitudinally on the top and bottom rails, and the main carriage **28** moves transversely on the main rail to position the drafting head **26**, and specifically the vertex of its straightedges to any point on the drafting surface **24**.

The main carriage **28** mounts a numerical control input unit, generally indicated at **40**, which includes an array of digital input switches and various control switches for initiating and controlling positioning movements of the drafting head **26** in the longitudinal and transverse directions. The numerical control unit input **40** is electrically linked over a cable **42** to a motor control network housed in base **22**. The motor control

network controls a stepping motor mounted by upper main rail carriage **32**; the motor being hidden in FIG. **1** by a protective housing **44**. As will be seen in the description to follow, the stepping motor is drivingly connected to main rail carriages **32** and **38** and main carriage **28** so as to translate drafting head **26** in the longitudinal and transverse directions; the magnitudes of these movements being determined by the settings of the digital switches of the numerical control input unit **40**.

A suitable stepping motor for use in the present invention is a model **HS25** SLO-SYN Precision Stepping Motor manufactured by the Superior Electric Company of Bristol, Connecticut. This company also makes suitable stepping motor control networks for use in the automated drafting machine embodiment of the present invention. It will be appreciated that there are numerous makes and types of stepping motors and stepping motor control networks applicable to the present invention. Also, the automatic drafting machine of the invention may be adapted with analog positioning techniques using a servo motor network.

Referring now to FIGS. **2A** and **2B**, which are juxtaposed in the manner shown in FIG. **2**, the stepping motor, indicated at **50** in FIG. **2B**, is mounted by an upright plate **52** supported by the main rail adjacent its upper end. The output shaft **50***a* of the stepping motor carries a gear **54** which engages a gear **56** secured on the left end of a shaft **58** journalled by plate **52** and a mounting plate **60** of upper main rail carriage **32**, also attached to the upper end of main rail **30**. The right end of shaft **58** extending through and beyond mounting plate **60** carries a gear **62** adapted for meshing engagement with gear **64** (also FIG. **4**) secured on the right end of a shaft **66** also journalled by mounting plates **52** and **60**. It is contemplated that gears **54** and **56**, as well as gears **62** and **64**, may be replaced with gear sets of various drive ratios to thus establish different drawing scales automatically without having to scale the numerical inputs entered at numerical control input unit **40** up or down.

As best seen in FIG. **4**, shaft **66** mounts a second gear **68** adapted for meshing engagement with a pair of ring gears **70** and **72**, which are in turn mounted by the input drive members of a pair of electromechanical clutches **74** and **76**, respectively. Returning to FIG. **2B**, the output shaft **78** for clutch **74** extends coaxially through the clutch body and ring gear **70** carried on its input drive member. The left end of clutch output shaft **78** is connected by a coupling **79** to the brake shaft **80** of an electromechanical brake **82** supported by mounting plate **52**. In identical fashion, the output shaft **84** of clutch **76** extends coaxially through the clutch body and ring gear **72** on its input drive member as seen in FIG. **4**. The other end of clutch output shaft **84** from that shown in FIG. **4** is coupled to the brake shaft of an electromechanical brake which occupies the same position relative to clutch **76** as does brake **82** relative to clutch **74**. This brake is indicated schematically at **88** in FIG. **9**, together with the schematic representations of clutches **74**, **76** and brake **82**.

As best seen in FIG. **4**, output shaft **78** of clutch **74** carries a pinion gear **90** on its right end, as seen in FIG. **2B**, which is adapted for meshing engagement with an idler gear **92**. In FIG. **2B** it is seen that the idler gear **92** is mounted on a stub shaft **93** journalled at its ends in mounting plate **60** and a secondary mounting plate **94**. Idler gear **92**, in turn, meshes with a pinion gear **96** mounted on an elongated cross shaft **98** which extends the length of main rail **30**, as seen in FIGS. **2A** and **2B**. The right end of cross shaft **98** is journalled in a bearing **99** fitted in a through bore **100** formed in mounting plate **60**. The left end of cross shaft **98** is journalled in a bearing **102** mounted by a plate **103** (FIG. **5**), included as part of the lower carriage **38** for main rail **30**. As will be seen, cross shaft **98** is the transverse cross shaft which, upon rotation by motor **50**, produces transverse movement of the main carriage **28** on main rail **30**.

Returning to FIG. **4**, output shaft **84** of clutch **76** also carries a pinion gear **106** which engages an idler gear **108** journalled between mounting plates **60** and **94** (FIG. **2B**). Idler gear **108** engages a pinion gear **110** mounted on a second cross shaft **112**, also extending through main rail **30** in side by side relation with cross shaft **98**, as best seen in FIG. **5**.

Referring to FIGS. **2B** and **4**, pinion gear **110** on cross shaft **112** engages an idler gear **114** journalled between mounting plates **60** and **94**. Idler gear **114** engages a gear **116** mounted on a shaft **117** journalled by bearings fitted in through bores formed in mounting plates **60** and **94**. The left end of shaft **117** beyond mounting plate **60** carries a pinion gear **120** adapted for meshing engagement with an elongated, circular pitch rack gear **122** secured to the underside of the upper laterally extending portion **34**a of the channel-shaped top rail **34**. As seen in FIG. **4**, rack gear **122** is substantially coextensive with the length of top rail **34**.

The upper main rail carriage **32**, seen in FIG. **2B**, includes a laterally extending bracket **124** secured to mounting plate **60** for the purpose of mounting a pair of longitudinally spaced rollers **126** (one seen in FIG. **2B**) which roll along the upper front surface of top rail **34**. In addition, mounting plate **60** carries a pair of longitudinally spaced rollers **128** which ride on the upper surface of the laterally extending top rail portion **34**a (see also FIG. **4**). Mounting plate **60** is further notched, as indicated at **130** in FIG. **4**, to facilitate mounting a pair of rollers **132** adapted to roll along the edge of laterally extending top rail portion **34**a.

It is thus seen that upper carriage **32** for main rail **30** is supported by the top rail **34** for longitudinal movement therealong. The various carriage rollers **126**, **128** and **132** insure that the carriage movement is smooth and substantially effortless, and is accurately guided by top rail **34** without any possibility of binding or skewing. Longitudinal movement of upper carriage **32** is induced by rotation of pinion **120** in meshing engagement with the elongated rack gear **122**; pinion rotation being motivated either from motor **50** during automatic operation of the drafting machine, by rotation of a longitudinal handwheel at the main carriage **28**, or by longitudinal positioning forces exerted on the main rail, main carriage and drafting head.

As seen in FIGS. **2A** and **3**, the left hand end of cross shaft **112**, seen also in FIG. **5**, is journalled at its left end in a bearing **140** fitted in mounting plate **103** of lower carriage **38**. Just inwardly from its left end, cross shaft **112** carries a pinion gear **142** which engages an idler gear **144** journalled between mounting plate **103** and a secondary mounting plate **146**, also attached to

the lower end of main rail **30**. Idler gear **144**, in turn, engages a gear **148** mounted on a shaft **150** also journalled by mounting plates **103** and **146**. Shaft **150** carries a pinion gear **152** which engages an elongated, circular pitch rack gear **154** mounted by and coextensive with elongated bottom rail **36**.

Bottom rail **36** is formed having a longitudinally extending recess **156** in which are fitted coextensive upper and lower inserts **156***a* and **156***b* to provide a precise longitudinal guideway for a roller **158** carried on pinion gear shaft **150**. It is thus seen that upon rotation of cross shaft **112**, either by motor **50** or the main carriage handwheel, pinion gear **152** of the lower carriage **38** is rotated, and its meshing engagement with rack gear **154** induces longitudinal movement of the lower carriage **38**; this longitudinal movement being supported by roller **158** operating in notch **156** of bottom rail **36**. Since the gearing in the upper and lower main rail carriages from cross shaft pinions **110** and **142** on down to rack gears **122** and **154** is identical in each case, the ends of the main rail are constrained to always move equal amounts and therefore, the transverse relationship of the main rail **30** relative to the drafting board **20** is precisely maintained throughout the entire range of its longitudinal movement.

Main carriage **28**, as seen in FIGS. **2A**, **5** and **6**, comprises an open rectangular frame, generally indicated at **166**, having a pair of sidewalls **168***a* and **168***b* (FIG. **5**) straddling the main rail **30** and interconnecting end walls **170***a* and **170***b* extending under the main rail. Extensions of the end walls of mounting frame **166** provide the brackets **27** for pivotally connecting the drafting head **26** to the main carriage **28**.

Each main carriage frame sidewall is formed with an upstanding boss **174**, each mounting a roller **176**, as best seen in FIG. **6**. These rollers roll on the top surface of the channel-shaped main rail **30** to support and guide the main carriage **28** for movement therealong. To further guide the main carriage during its transverse movement, frame sidewall **168***b* mounts a pair of rollers **178** which ride against the outer surface of depending side portion **30***a* of main rail **30**, as seen in FIGS. **5** and **6**. Each main carriage frame end wall mounts a roller **180** which rides against the inner surface of main rail side portion **30***a*. In addition, each carriage frame sidewall mounts a roller **182** which rides against the bottom edge surface of depending main rail side portions **30***a* and **30***b*.

It is thus seen that the various rollers of the main carriage **28** working against the surfaces of the main rail **30** serve to mount and precisely guide the main carriage during its transverse movement. Preferably, the various carriage rollers, including the upper and lower carriage rollers previously described, are mounted in eccentric bearings which are adjustable so as to precisely position the roller axes and thereby remove any play in the mountings of the various carriages to their respective rails.

As best seen in FIGS. **2A** and **5**, cross shafts **98** and **112** pass freely through clearance holes **190** in a block **192** carried by each main carriage frame end wall **170***a* and **170***b*. Blocks **192** serve to mount separate bearings **194**, with the cross shafts **98** and **112** passing freely therethrough. It is seen in FIG. **7** that these bearings are adapted to journal end caps **196** which engage and maintain the halves of a split sleeve **198** in circumferential relation to each cross shaft, extending coaxially therethrough. Split sleeves **198** are preferably formed of a phenolic bearing material and have their bores appropriately keyed to engage elongated splines formed in the cross shafts (FIG. **6**).

It is thus seen that upon rotation of either cross shaft, driving rotation is imparted to its associate split sleeve **198** and yet the split sleeve is capable of sliding longitudinally on its cross shaft.

Again as seen in FIGS. **5–7**, split sleeve **198** about transverse cross shaft **98** mounts and rotates a helical ring gear **200**. Similarly, split sleeve **198** about longitudinal cross shaft **112** mounts and rotates a second helical ring gear **202**. Helical ring gear **200** is adapted for meshing engagement with a helical gear **204** carried by a shaft **206** journalled at each end in main carriage frame sidewalls **168***a* and **168***b*. Inwardly of frame sidewall **168***b*, shaft **206** carries a pinion gear **208**, which is adapted for meshing engagement with a gear **210** carried on a shaft **212** journalled in frame sidewalls **168***a* and **168***b*. Inwardly of frame sidewall member **168***a*, shaft **212** also mounts a pinion gear **214** adapted for meshing engagement with an elongated circular pitch rack gear **216** mounted by and coextensive with main rail depending side portion **30***b*, as best seen in FIGS. **2A** and **6**.

It is thus seen that rotation of the transverse cross shaft **98** is coupled through gears **200**, **204**, **208**, **210** and **214** to rack gear **216** to thereby produce transverse movement of the main carriage **28** on main rail **30**.

Again referring to FIGS. **2A**, **5** and **6**, helical ring gear **202** mounted on and rotated by the split sleeve **198** about longitudinal cross shaft **112** is adapted for meshing engagement with a helical gear **220** carried on a shaft **222** journalled in main carriage frame sidewalls **168***a* and **168***b*. Thus, rotation of the longitudinal cross shaft **112** is coupled to shaft **222** at a right angle thereto by the helical gears **202** and **220**. It is important to note however that the gear trains between the cross shafts **98** and **112** and the main carriage **28** are bi-directional in nature, and thus rotation of shaft **206** in the main carriage imparts rotation to the transverse cross shaft **98**, while rotation of shaft **222** in the main carriage imparts rotation to longitudinal cross shaft **112**.

It is seen in FIG. **5** that shaft **206** extends beyond the main carriage frame sidewall **168***a* and is fitted with a handwheel **230** facilitating manual rotation of shaft **206** which, in addition to rotating transverse cross shaft **98**, rotates pinion gear **214** meshing with rack **216**. As a result, transverse movement of the main carriage **28** on main rail **30** may be manually motivated by rotation of transverse handwheel **230**. The other end of shaft **206** extends through and beyond main carriage frame sidewall **168b** and mounts a pair of graduated readout dials **232** and **234**. Dial **232** is preferably graduated in 0.010 inch increments around its periphery, while dial **234** is graduated in the scale to which the draftsman is working. Thus, dial **234** is preferably readily removable, so that different dials graduated in various drawing scales may be substituted. A bracket **236** secured to carriage frame sidewall **168***b* is formed having a laterally extending arm **236***a* which projects between dials **232** and **234**. A bench mark **238** inscribed on bracket arm **236a** facilitates reading of the scale graduations on dials **232** and **234**.

Referring to FIG. 8, dial 232 is a cup shaped member carried on a hub 240 locked to shaft 206 by a set screw 241. The right end portion of hub 240 is threaded to receive a nut 242. A thrust washer 244 is introduced between nut 242 and the radial end wall of dial 232 to press the dial end wall against the raised central body portion of hub 240. By virtue of this construction, dial 232 rotates with shaft 206 to provide a readout in inches of the distance of transverse movement of the main carriage 28, and yet may be readily angularly re-oriented on shaft 206 without disturbing the shaft angular orientation. This arrangement is desirable so as to facilitate resetting dial 232 to align the zero of its scale with bench mark 238 and thereby simplify the reading of the scale pursuant to achieving a desired increment of transverse movement of drafting head 26 by rotation of transverse handwheel 230 or stepping motor 50. Thus, the draftsman need not scale off a desired increment of transverse movement but merely, in effect, dial in the desired increment by rotation of handwheel 230 while observing the scale on dial 232.

Dial 234 is, like dial 232, cup-shaped and is removably mounted on a second cup-shaped member 246 carried by hub 240. The left end portion of hub 240 is threaded to receive a nut 242 which lightly frictionally clamps the end wall of mounting cup member 246 between another thrust washer 244 and the raised central body portion of hub 240. Thus, dial 234 is rotated by shaft 206 and may also be readily angularly re-oriented to zero the scale carried thereby with reference to bench mark 238 without altering the angularly orientation of shaft 206. As previously noted, the scale on dial 234 is preferably graduated in accordance with the scale size to which the draftsman is working. Consequently, dials 232 and 234 respectively provide a readout of the actual distance of transverse movement of the drafting head and the distance of transverse movement translated to the prevailing drawing scale. Alternatively, either or both dials 232 and 234 may be graduated in fractional inch increments.

Returning to FIG. 5, main carriage shaft 222 extends through and beyond frame side member 168b and mounts a pair of dials 250 and 252 in the identical manner as dials 232 and 234 are mounted on shaft 206. Dial 250 provides a readout of the actual distance of longitudinal movement of the main rail 30 and main carriage 28 motivated by a longitudinal handwheel 253 secured on the other end of shaft 222 or motor 50, while dial 252 is graduated to provide an instant conversion of the longitudinal movement of the drafting head to the prevailing drawing scale.

The operation of the automatic drafting machine, wherein longitudinal and transverse movements of the drafting head 26 are motivated by stepping motor 50 in accordance with numerical inputs imposed on a decade array of digital input switches 41 included in the numerical control input unit 40, will now be described in connection with FIG. 9. The input switches 41 may take various forms, including that of a keyboard. These digital inputs indicating the desired distances the drafting head 26 is to be moved in the longitudinal and transverse directions are supplied to a stepping motor control network 260 which operates to translate the digital inputs into appropriate numbers of pulses; each pulse being effective to step the stepping motor 50 through a discreet increment of output shaft rotation.

In typical numerical control stepping motor control networks there is provided for the convenience of the user switched external terminals to which connection may be made for external control components in order to facilitate synchronizing the operations of the external components to the operation of the motor control network 260. Thus, as shown in FIG. 9, external leads 262 are shown connected to a relay 264 whose contacts, indicated at 266, are connected in the energization circuit for a timing motor 268. In accordance with the operating convention adopted in the illustrated embodiment, relay 264 is energized to close its contacts 266 at all times except during an execution of an indexing function, during which stepping pulses are supplied to stepping motor 50. Thus, during an indexing function, relay 264 is de-energized by the motor control network 260.

In one type of motor control network supplied by the Superior Electric Company, relay 264 and its contacts 266 are supplied internally, and thus the energization circuit for the timing motor 268 is simply connected directly to the appropriate output terminals of the motor control network 260.

Still referring to FIG. 9, the numerical control input unit 40 includes four directional control switches, indicated at UP, DN, RT and LT. Up switch UP is closed to initiate indexing movement of the drafting head upwardly along the transverse axis toward the top of the drafting board 20. Depression of down switch DN initiates indexing movement of the drafting head along the transverse axis toward the bottom of the drafting board. Similarly, switch RT initiates indexing movement of the drafting head along the longitudinal axis to the right over a distance represented by the digital input switches 41, while depression of switch LT initiates indexing movement along the longitudinal axis toward the left over the same distance. The four directional control switches are electrically connected in parallel with each other and in common across busses 270 and 272 through a normally closed cam actuated switch CS1. Each directional control switch controls the energization of a separate control relay 1CR, 2CR, 3CR and 4CR. Each control relay has a first set of relay contacts 1CR-1, 2CR-1, 3CR-1 and 4CR-1, respectively, which close upon relay energization initiated by enclosure of its associated directional control switch to establish a holding circuit through a normally open cam actuated switch CS2 to bus 270. These holding circuits sustain energization of their associated control relays and thus sustain an indexing function despite momentary closure of the associated one of the directional control switches.

In practice, the various directional control switches preferably take the form of a four position switch, indicated at 274 in FIG. 2A. The actuating lever of this switch is pushed up to close the UP switch contacts and down to close the DN switch contacts. Movement to the left closes the LT switch contacts and to the right closes the RT switch contacts seen in FIG. 9. There is thus provided in a sense directional correlation between the manipulation of the four position directional control switch 274 at the numerical control input unit 40 and the desired direction of movement of drafting head 26.

Still referring to FIG. 9, a second set of relay contacts for each control relay, indicated at 1CR-2, 2CR-2, 3CR-2, 4CR-2, are mutually connected in parallel in the energization circuit for timing motor 268. These second sets of control relay contacts are normally open, but upon energization of any one of the various control relays, the associated one set closes to complete the energization circuit for timing motor 268 which rotates a bank of five switch cams 280–284 jointly mounted on the timing motor output shaft, schematically indicated at 286. Switch cam 280 controls the actuation of cam switch CS1 which, as already noted, is connected in series with each of the directional control switches. Switch cam 281 controls the actuation of CS2 which, as already described, is connected in series with each of the control relays and their respective holding circuit contacts 1CR-1, 2CR-1, 3CR-1 and 4CR-1.

The relative angular orientations of the switch cams 280–284 at the beginning of an indexing function are essentially as shown in FIG. 9. Cam switch CS1 is normally closed when its cam follower actuating arm rides in recess 280*a* of switch cam 280. Thus, prior to an indexing function, the various directional control switches are activated by the closed condition of cam switch CS1. Upon closure of one of the directional control switches, the associated control relay is energized and closure of its second set of relay contacts completes the energization circuit for timing motor 268. At the conclusion of the initial 10° of rotation of switch cam 281 the cam follower actuating arm for cam switch CS2 rides out of cam recess 281*a*, effecting closure of its contacts and completion of the holding circuit for the energized control relay through its now closed first relay contact set. At the conclusion of 20° of rotation of the switch cam bank, the cam follower arm of cam switch CS1 rides out of recess 280*a*, opening its contacts and disabling all of the directional control switches.

As yet, the motor control network 260 has not initiated an indexing function, and thus relay contacts 266 remain closed for continued energization of timing motor 268. Each control relay is provided with a third set of relay contacts, indicated at 1CR-3, 2CR-3, 3CR-3 and 4CR-3, which are connected in series with the two clutches 74 and 76 across the busses 270 an 272. Specifically, control relay contacts 1CR-3 and 2CR-3 are connected in parallel to control the energization of transverse clutch 74, while control relay contacts 3CR-3 and 4CR-3 are connected in parallel to control the energization of longitudinal clutch 76. Thus, upon closure of either of the directional control switches UP or DN, either control relay 1CR or 2CR is energized, and its associated contacts 1CR-3 or 2CR-3 immediately close to energize and thus engage clutch 74 preparatory to transverse movement up or down of the drafting head 26, as the case may be. By the same token, closure of either of the switches RT or LT initiates energization of the associated control relay and immediate energization and engagement of the longitudinal clutch 76 preparatory to right or left longitudinal movement of the drafting head 26.

It is seen from FIG. 9 that switch cam 282 controls the actuation of a cam switch CS3 whose contacts control the energization of the transverse and longitudinal brakes 82 and 84, respectively, through a fourth set of control relay contacts 1CR-4, 2CR-4, 3CR-4 and 4CR-4. Specifically, control relay contacts 1CR-4 and 2CR-4 are connected in parallel to permit energization and thus disengagement of transverse brake 82 upon closure of cam switch CS3. Similarly, control relay contacts 3CR-4 and 4CR-4 are connected in parallel to permit energization and thus disengagement of longitudinal brake 88 upon closure of cam switch contacts CS3. After completion of approximately the initial 150° of rotation of switch cam 282, the cam follower actuating arm of cam switch CS3 falls into recess 282*a*, permitting energization and disengagement of the appropriate brake in accordance with which one of the various directional control switches has been closed. As yet, the motor control network 260 has not been signaled to execute an indexing function, thus relay contacts 266 remain closed for continued energization of timing motor 268.

Directional control inputs to the motor control network 260 are developed on input lead 290 under the control of a fifth set of relay contacts 2CR-5 and 4CR-5 included with control relays 2CR and 4CR, respectively. If either the down switch DN is closed to call for movement of the drafting head 26 downward in the transdirection or the left switch LT is closed to call for longitudinal movement of the drafting head to the left, one of control relay contacts 2CR-5 and 4CR-5 closes to connect the directional control input lead 290 for motor control network 260 to ground. This is interpreted by the motor control network as a command to rotate the stepping motor in a first direction which, by virtue of the gear trains employed, produces either downward transverse movement or leftward longitudinal movement of the drafting head. On the other hand, if either the up switch UP or the right switch RT is closed, the directional control input lead 290 for the motor control network 260 is left floating, and this is interpreted as a command to rotate the stepping motor in the opposite direction which, as is now apparent, produces either upward transverse movement or rightward longitudinal movement of the drafting head 26.

Reflecting briefly on the operation of the control circuit of FIG. 9 considered thusfar, closure of one of the directional control switches initiates energization of its associated control relay, which, in turn, operates to complete an energization circuit for timing motor 268 thereby initiating rotation of the switch cam bank. Depending upon which of the control relays is energized, the appropriate directional control input signal is developed on input lead 290 to the motor control network 260. Cam switch CS2 closes to complete the holding circuit for the energized control relay through one of its own relay contacts and then cam switch CS1 opens to deactivate the directional control switches. The energized control relay also selects the appropriate one of clutches 74 and 76 for energization and engagement to couple the stepping motor output shaft to the appropriate gear train for either longitudinal or transverse movement of the drafting head. Cam switch CS3 then closes under the control of switch cam 282 and the energized control relay determines which of brakes 82 and 88 is to be energized and thus released.

At this point, all of the appropriate conditions are met for initiating an indexing function. After approxi-

mately 160° of rotation of the switch cam bank, the cam follower switch actuating arm for cam switch CS4 rides into recess **283***a* in the periphery of switch cam **283**. The contacts of cam switch CS4 are connected to an index command input lead **292** for the stepping motor control network **260**. Upon closure of the normally open cam switch contact CS4, a ground signal is impressed on index command input lead **292**, signaling the motor control network to initiate an indexing function. As the indexing function is initiated, relay **264** is de-energized, and its contacts **266** drop out to de-energize the timing motor **268**. to

Upon completion of the indexing function, relay **264** is again energized, its contacts **266** close and timing motor **268** is re-energized. After approximately 220° of rotation of the switch cam bank, the cam follower switch actuating arm for cam switch CS3 rides out of recess **282***a*, and its contacts open to break the energization circuit to the brakes **82** and **88**. thus, immediately before and after execution of an indexing function, the brake which was disengaged to permit the indexing function is engaged to prevent spurious movement of the drafting head. It is observed that while the drafting head is being moved in the longitudinal direction, for example, the transverse brake **82** is engaged to prevent inadvertent transverse movement of the drafting head while it is being indexed in the longitudinal direction, and vice versa. After approximately 350° of rotation of the switch cam bank, the cam follower arms for cam switches CS1 and CS2 ride into their associated switch cam recesses. Cam switch CS2 opens to break the energization circuit to the particular control relay which had been energized and incidentally the energization circuit for timing motor **268**, while cam switch CS1 closes to again activate the directional control switches in preparation for the next indexing function.

In many cases it may be desirable to manually override the automatic operation of the drafting machine of the present invention and move the drafting head **26** manually, either by rotation of handwheels **230** and **253** or simply by grasping the drafting head **26** and directly positioning it. To this end, there is provided a transverse brake release switch TBR which shunts both the cam switch CS3 and the parallel control relay contacts 1CR-4 and 2CR-4 to permit direct energization and release of the transverse brake **82**. Similarly, a longitudinal brake release switch LBR shunts the cam switch CS3 and control relay contacts 3CR-4 and 4CR-4 to permit direct energization and release of the longitudinal brake **88**.

As an additional feature of the invention, a fifth switch cam **284** is included in the switch cam bank rotated by timing motor **268**. This switch cam controls the actuation of a cam switch CS5 whose contacts are connected in series with a double index switch DI across the contacts of cam switch CS4. It will be recalled that closure of cam switch contacts CS4 generated the index command input signal on lead **292** to the stepping motor control network **260**. As will be seen, if the double index switch DI is closed, it arms cam switch CS5 to generate a second index command input signal on lead **292** and the stepping motor **50** is indexed again by the amount set into the digital input switches **41**. More specifically, it will be recalled that after rotation of switch cam **283** through approximately 160° of rotation, cam switch CS4 closes to generate the index command input signal on lead **292**. Energization to the timing motor **268** is broken by relay contacts **266** until this first indexing function is concluded. Relay **264** is then again energized, and the energization circuit to the timing motor **268** is re-established. With an additional 10° of rotation of switch cam **293**, the cam follower actuating arm for cam switch CS4 rides out of recess **283***a* causing its contacts to open. After approximately 200° of rotation of the switch cam bank, the cam follower actuating arm for cam switch CS5 rides into the recess **284***a* in switch cam **284** and its contacts close to connect the lead **292** through the closed double index switch DI to ground. There is thus generated a second index command input signal to the stepping motor network **260** which responds by controlling the stepping motor **268** to execute a second indexing movement in the same direction and through the same distance as the first indexing movement initiated by closure of cam switch CR4.

It is thus seen that upon closure of the double index switch, the draftsman immediately doubles the drawing scale he is working to. Similarly, he can maintain the double index switch DI closed and instantaneously reduce the drawing scale he is working to by one-half merely by opening the double index switch.

This feature is particularly advantageous in mechanical drafting of round parts with the double index switch DI closed. Then, when the draftsman has located the center line of the round part, he merely enters its diameter on the digital switches **41** and opens the double index switch DI. Upon closure of the appropriate directional control switch, the drafting head automatically moves a distance equal to the radius of the part. By the same token, if the draftsman locates the peripheral surface of the round part, he can initiate a single index function after entry of the diameter of the part to precisely locate the center line or axis thereof.

It will be recalled from the foregoing description that the automatic numerical control drafting machine of FIG. 1 can be readily operated in a manual mode. This is achieved simply by closure of the brake release switches TBR and LBR shown schematically in FIG. **9** and located at the numerical control input unit **40**. Specifically, if the draftsman wishes to manually index the drafting head in the transverse direction, he closes the switch TBR to release the transverse brake **82**. The draftsman then simply dials in the distance he wishes to move the drafting head **26** in the transverse direction by rotation in the appropriate direction of handwheel **230** while obtaining a continuous readout of the transverse movement from dials **232** and **234**. It will be noted from FIG. **9** that since none of the directional control switches have been depressed, the transverse clutch **74** is not engaged, and thus the transverse driving power introduced via handwheel **230** is not coupled to the stepping motor **50**. Preferably while manually moving the drafting head in the transverse direction, the longitudinal brake release switch LBR is left open to maintain the longitudinal brake **88** engaged, thus preventing inadvertent movement of the drafting head in the longitudinal direction while it is being positioned in the transverse direction.

Similarly, if manually motivated longitudinal movement of the drafting head **26** is desired, the longitudinal brake release switch LBR is closed while leaving the transverse brake release switch TBR opened. This releases the longitudinal brake **88** while maintaining the transverse brake **82** engaged. The desired increment of longitudinal movement is then dialed in by rotation of the longitudinal handwheel **253** while observing the scales of either of dials **250** and **252** (FIG. **5**). Also as previously noted, one or both of the brake release switches TBR and LBR may be closed and the drafting head **26** positioned merely by manual pressure on the drafting head itself.

This suggests that many of the features of the drafting machine of the present invention may be achieved in a strictly mechanical version of the invention. Obviously, a manually actuated embodiment would permit the elimination of stepping motor **50**, clutches **74** and **76**, brakes **82** and **88**, stepping motor control network **260** and the numerical control input unit **40**. In addition, the longitudinal and transverse drive gear train between the stepping motor and the cross shafts **98** and **112** are unnecessary. Moreover, since the longitudinal and transverse drive inputs are introduced at the main carriage **28**, the transverse cross shaft **98** can also be eliminated. It will be appreciated that the elimination of all of these components will amount to a considerable cost savings to the purchaser.

The essential differences between the automatic numerical control drafting machine and the purely mechanical version are reflected in the sectional view of FIG. **10** which corresponds to the sectional view of FIG. **5**. Like parts are given corresponding reference numerals in FIG. **10**. To translate the drafting head **26** in the longitudinal direction, longitudinal handwheel **253** is rotated and this rotational input is coupled through the helical gear **220** on the handwheel shaft **222** and the helical ring gear **202** fitted on split sleeve **198** to the longitudinal cross shaft **112**, and thence through the gearing at each end of the longitudinal cross shaft in the upper and lower carriages **32** and **38** to the rack gears **122** and **154** carried by top and bottom rails **34** and **36**, which gearing is identical to that previously described in connection with the automatic numerical control drafting machine embodiment of the invention.

For transverse movement of the drafting head, rotation of handwheel **230** is coupled through gears **208**, **210**, shaft **212** and gear **214** to rack gear **216** carried by main rail **30**. Since transverse driving power is not brought in externally of the main carriage **28**, but originates either by rotation of handwheel **230** or through pressure exerted on the drafting head which is connected to the main carriage, transverse cross shaft **98** in unnecessary and thus is eliminated from FIG. **10**.

Since the manual drafting machine embodiment of the present invention preferably does not include electrically actuated braking, it is preferred to provide mechanically actuating braking to hold the drafting head in a desired position. Accordingly, as seen in FIG. **11**, the transverse handwheel shaft **206** is adapted to mount a brake drum **300** adjacent the outer surface of sidewall **168***b* of the main carriage mounting frame **166**. Similarly, a brake drum **302** is mounted on the longitudinal handwheel shaft **222**. A brake operator lever **304** is pivotally mounted on a pivot post **306** carried by frame sidewall **168***b* and is formed with a brake shoe tip **308** adapted for frictional engagement with the periphery of brake drum **300**. Similarly, brake drum **302** is engaged by a brake shoe tip **308** carried by a brake operator lever **312** mounted on a second pivot post **306** carried by frame sidewall **168***b*. As best seen in FIG. **10**, the frame sidewall **168***b* is formed with a groove **316** vertically aligned with each pivot post **306**. A spring **318** is accommodated in each groove **316** and urges a ball **320** secured to its upper end upwardly against the under surface of a lateral extension of each brake operator lever **304** and **312** overlying the upper edge of the main carriage frame sidewall **168***b*. The bottom edge of each of these lateral extensions engaged by the upwardly spring biased balls **320** is V-shaped, as indicated at **322** in FIG. **11**, to thus provide a toggling characteristic to the operation of the brake operator levers **304** and **312**.

As best seen from FIG. **11**, lever **304** has been pivoted in the counterclockwise direction to engage its brake shoe tip **308** against the periphery of brake drum **300**. Ball **320** engages the right side of the V-shaped edge **322** to retain the lever **304** in its operative, brake engaging position. When lever **304** is pivoted in the clockwise direction about pivot post **306**, ball **320** depresses and rides over the apex of the V-shaped edge surface **322**, whereupon it is effective to position the lever against a stop post **324** carried by the main carriage frame sidewall **168***b*. The brake operator lever **304** is thus retained in its inoperative, brake disengaging position.

Still referring to FIG. **11**, the longitudinal brake operator lever **312** is shown toggled to its inoperative position with its brake shoe tip **308** disengaged from the periphery of its brake drum **302** and its right side edge bearing against a second stop post **324**. It is thus seen that the brake operator levers **304** and **312** are readily toggled by simple finger pressure to selectively brake and release the main carriage **28** for longitudinal and/or transverse movement.

It has been found that due to the freely movable character of the mounting of the main carriage on the main rail, as well as the main rail carriages on the top and bottom rail, it is desirable to provide a system for counterbalancing the weight of the main carriage **28** and drafting head **26** when the drafting table **20** is tilted, such as illustrated in FIG. **1**. Otherwise, when the transverse electrical brake **82** in the automated embodiment or the transverse mechanical brake, consisting of brake drum **300** and brake operator lever **304**, in the manual embodiment is released to permit transverse positioning of the drafting head, the main carriage will move toward bottom rail **36** under gravity unless restrained by the draftsman. To overcome this problem there is provided, as seen in FIG. **12**, a counterweight **330** which is effectively coupled to the main carriage **28** by a cable **332**. The counterweight **330** mounts a roller **334** which rides on a side rail **335** extending along the right end of the drafting board **20**, as seen in FIG. **1**, between top rail **34** and bottom rail **36**.

In the automated embodiment of the invention, as seen in FIGS. **2B**, **4** and **12**, a spool **336** is secured on the end of transverse cross shaft **98** extending beyond the secondary mounting plate **94** of the upper main rail

tion, and with care to within 0.002 inch, using the readout dials. In the automatic embodiment, depending on the prevailing drawing scale, discreet resolution varies from 0.003 inch to 0.00025 inch. Drafting head positioning speed motivated by the stepping motor varies from 60 inches per minute to 300 inches per minute, again depending on the drawing scale and the resolution desired. Generally, lower travel speeds give higher positioning resolution.

The extreme rigidity of the drafting head connection to the main rail and the top and bottom rails guarantees line parallelism over the entire drafting surface, even to the point of withstanding inadvertent pressures exerted by the draftsman. The braking feature prevents inadvertent movement of the drafting head.

It is contemplated that the principles of the present invention may be adapted to a point coordinate locator with a cross-hair viewer substituted for the drafting head. From a zero coordinate position, the viewer is moved to align its cross-hair with the point whose coordinates are to be determined. The extent of movement in the transverse (Y) and longitudinal (X) directions to the point may be read from the readout dials or from a suitable distance readout device geared to the viewer in the manner that the stepping motor **50** is geared to the drafting head in the disclosed automatic drafting machine embodiment.

It will thus be seen that the objects set froth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A drafting machine comprising, in combination:

A. a carriage having means for attaching it to a drafting head;

B. an elongated main rail mounting the carriage for linear movement in either direction parallel to a first orthogonal axis over a drafting surface, said main rail having a first rack gear carried by and substantially coextensive with the rail;

C. a pair of guide rails respectively supporting said main rail at its opposite extremities for lateral movement in either direction parallel to a second orthogonal axis perpendicular to the first, at least one of said guide rails having a second rack gear substantially coextensive with that guide rail;

D. a first drive train for effecting movement of said carriage along said first axis, said first drive train comprising a first pinion gear secured to said carriage and engaging said first rack gear;

E. a second drive train for effecting concurrent movement of the extremities of said main rail along said guide rails and comprising a second pinion gear secured to said main rail and engaging said second rack gear;

F. a single motive means for driving both the first and second drive trains; and

G. coupling means operable selectively to drive either said first or said second drive train from said motive means, said coupling means comprising

1. a first clutch energizable to couple the driving output of said motive means to said first pinion gear, and

2. a second clutch energizable to couple the driving output of said motive means to said second pinion gear alternatively to but not concurrently with its coupling to the first pinion gear.

2. The drafting machine defined in claim **1**, which further comprises:

A. a first handwheel supported by said carriage and drivingly coupled to said first pinion, said first handwheel being operable, when said first clutch is deenergized, to move said carriage in a direction parallel to said first axis, and a second handwheel supported by said carriage and drivingly coupled to said second pinion by way of an elongated shaft aligned with said main rail and fixedly supported thereon, said second handwheel being operable, when said second clutch is deenergized, to move said main rail laterally in a direction parallel to said second axis.

3. A drafting machine comprising, in combination:

A. a carriage having means for attaching it to a drafting head capable of being moved by the carriage;

B. an elongated structure mounting said carriage for linear movement thereon in either direction parallel to a first orthogonal axis over a drafting surface;

C. means supporting said elongated structure at its opposite ends for linear movement on said supporting means in either direction parallel to a second orthogonal axis perpendicular to the first;

D. a first drive train for effecting movement of said carriage along said first axis and a second drive train for effecting movement of said elongated structure along said second axis, whereby to position a drafting head attached to the carriage at any desired point over the drafting surface;

E. a single motive means for driving both the first and second drive trains, and

F. coupling means operable selectively to connect said motive means to drive either said first or said second drive train, said coupling means comprising

1 a first clutch energizable to couple the driving output of said motive means to said first drive train, and

2. a second clutch energizable to couple the driving output of said motive means to said second drive train alternatively to but not concurrently with its coupling to the first drive train means.

4. A drafting machine according to claim **3** in which said motive means is a stepping motor and in which there is provided

A. a numerical input unit for expressing alternatively the distance said carriage is to move in either direction on said elongated structure or the distance said elongated structure is to move on said supporting means in either direction along said second axis; and

B. a motor control network for translating the distance expressed at said numerical input unit into corresponding numbers of energizing pulses for application to said stepping motor to index said stepping motor accordingly.

5. The drafting machine defined in claim **4**, which further includes:

carriage 32. This spool serves as a take-up and play-out spool for the cable 332, depending on the direction of rotation of cross shaft 98. As best seen in FIGS. 2B and 4, cable 332 extends downwardly and around a vertically oriented pulley 338 mounted at the lower end of secondary mounting plate 94. From pulley 338, the cable 332 extends horizontally and around a horizontally oriented pulley 340 mounted at the lower end of mounting plate 60. Then as seen in FIG. 4, the cable runs to the left along top rail 34 and around a pulley 342 journalled on a shaft 344 mounted at its ends in the upper and lower lateral extensions of top rail 34 (also seen in FIG. 12). From pulley 342, the cable 332 extends around a pulley 346 mounted by the counterweight 330 and back around a second pulley 348 journalled on pulley shaft 344. Then, as seen in FIG. 4, the cable extends along the entire length of top rail 34 and around a pulley 350 mounted at the other end thereof, returning to the upper main rail carriage 32 where its end is secured to mounting plate 60, as indicated at 352.

From the foregoing description it is seen that when main carriage 28 moves transversely downward on main rail 30, spool 336 is rotated by transverse cross shaft 98 in a direction to take up the cable 332, and the counterweight 330 moves upwardly on side rail 335 toward top rail 34. Conversely, when the main carriage moves transversely upward, spool 336 is rotated by transverse cross shaft 98 to play out the cable and the counterweight 330 moves downwardly on side rail 335 toward bottom rail 36. Thus the weight of the main carriage and drafting head acting in the transverse direction is effectively counterbalanced by counterweight 330, and the transverse position of the drafting head is maintained when the transverse brake is removed.

On the other hand, when the main rail 30 moves longitudinally, it is seen that each end of cable 332 is fixed to the upper main rail carriage 32, and thus the cable is effectively played out from the side of the upper carriage in the direction of its movement and simultaneously taken up at the opposite side of the upper main rail carriage. Thus, during longitudinal movement of main rail 30 the counterweight 330 does not move on side rail 335 and offers no counterforce to longitudinal positioning of the drafting head 26.

It will be observed that by virtue of mounting the counterweight 330 on side rail 335, its counterbalancing effect to the forces of gravity on the main carriage and drafting head is automatically adjusted in accordance with the degree of tilt of drafting board 20. Specifically, if the drafting board is perfectly horizontal, there is no force of gravity due to the weight of main carriage 28 and drafting head 26 aligned with main rail 30, and thus there is no necessity for counterbalancing. Preferably, as seen in FIG. 12, side rail 335 is provided with a slight inclination by virtue of its mounting between the top and bottom rails such that counterweight 330 does exert a slight counterbalancing force in the absence of drafting board tilt to somewhat compensate for the slight frictional losses in the transverse drive train and the slight drag of the drafting head 26 on the drafting surface 24. When the drafting board is tilted, the side rail 335 is inclined a corresponding amount to automatically increase the counterbalancing effect of counterweight 330 to the increased gravity force component acting on the main carriage and drafting head which is aligned with main rail 30 in the transverse downward direction. The weight of the drafting head and main carriage can thus be substantially perfectly counterbalanced such that when the transverse brake 82 is released, the main carriage and drafting head do not move transversely downward under the influence of gravity.

In the manual embodiment of the invention, as best seen in FIG. 10, there is no transverse cross shaft and thus a different technique for coupling the counterweight 330 to the main carriage 28 must be employed. Specifically, the cable, indicated at 360, is in the form of a continuous loop, which is wrapped around a pulley 362 mounted by the main carriage 28. Both reaches of cable 360 from pulley 362 extend toward the upper main rail carriage 32 and around a pair of upper and lower vertically aligned pulleys 364 and 366 carried by the secondary mounting plate 94. The lower pulley of each pulley pair 364 and 366 directs the cable around pulleys 368 and 370, respectively. From pulley 368 in FIG. 10, the cable extends along main rail 34 and around a pulley corresponding to pulley 342 in FIG. 12. From this pulley the cable extends around pulley 346 carried by counterweight 330 and back around a second pulley corresponding to pulley 348 in FIG. 12, and then along the length of top rail 34 to a pulley at the other end corresponding to pulley 350 in FIG. 4. From pulley 350, the cable returns to pulley 370 in FIG. 10, completing its loop path.

The counterweight system for the manual drafting machine operates in the same manner as the counterweight system already described for the automatic drafting machine. Specifically, when the main rail 30 moves longitudinally, the position of counterweight 330 on side rail 335 is unchanged. On the other hand, when the main carriage 28 moves transversely of the drafting surface 24 on main rail 30, the length of the cable loop between the main carriage and the main rail upper carriage 32 either increases, drawing the counterweight 330 toward top rail 34, or decreases, allowing the counterweight to move toward bottom rail 36 on side rail 335.

From the foregoing description, it is seen that there is provided a drafting machine which, in either its manual or automatic numerical controlled embodiments, enables a draftsman to produce technical drawings more accurately and in less time than has been possible with currently available drafting machines. The draftsman need not point off dimensions using a separate scale, but instead merely enters the dimensions via digital switches 41 or dials in the desired dimensions using handwheels 230 and 253 and their associated readout dials to accurately prepare a drawing. Thus accuracy is not dependent on eyesight, steadiness of hand, and the ability to read fine scales. With appropriate setup, drawing scale enlargements or reductions can be obtained automatically with the draftsman having to resort to conversion tables and scales or to mathematical calculations. Thus errors are avoided and much of the tedium, as well as instrument manipulation and positioning, is avoided.

In the manual embodiment, the drafting head can be readily positioned to within 0.005 inch of the true posi-

A. a control circuit including directional control switch means for selecting one of said first and second clutches for engagement, deriving a directional control input signal to said control network to indicate the appropriate rotational direction for said stepping motor output shaft, and initiating the application of an index command signal to said motor control network to execute an indexing function along one of said axes.

6. The drafting machine defined in claim 5, wherein said control circuit further includes:

1. timing sequence control means actuated by said directional control switch means to delay the application of said index command signal to said control network until after said selected one clutch has been engaged and said motor control network has received said directional control input signal.

7. The drafting machine defined in claim 6, wherein said first drive input means includes a first brake and said second drive input means includes a second brake, and

1. said directional control switch means selects one of said brakes for disengagement, and
2. said timing sequence control means delays the release of said one brake until immediately prior to the application of said index command signal.

8. The drafting machine defined in claim 7, wherein said timing sequence control means further operates to re-engage said one brake upon conclusion of an indexing function and then to disengage said one clutch in preparation for the initiation of the next indexing function.

9. The drafting machine defined in claim 8, wherein said control circuit further includes a double index switch operating in conjunction with said timing sequence control means, immediately upon the conclusion of a first indexing function, to apply a second index command signal to said control network and thereby produce a second indexing function moving said drafting head in the same direction and over the same distance as was achieved during said first indexing function.

10. The drafting machine defined in claim 7, wherein said control circuit further includes a brake release switch for each said first and second brakes, thereby permitting individual and selective releases of said brakes independently of said directional control switch means and said timing sequence control means.

11. The drafting machine defined in claim 4, wherein each of said drive trains further includes at least one interchangeable gear set for establishing a predetermined relationship between the distance expressed by said numerical input unit and the lengths of movements of said drafting head parallel to said axes, whereby to automatically convert to a predetermined drawing scale.

12. A drafting machine comprising, in combination:

A. a main carriage having means for attaching it to a drafting head capable of being moved by the carriage;

B. an elongated main rail mounting said carriage for linear movement thereon in either direction parallel to a first orthogonal axis over a drafting surface;

C. a pair of spaced parallel side rails for said machine arranged perpendicular to the main rail at its opposite extremities;

D. secondary carriage means positioned at each end of the main rail and mounting the main rail on the side rails for lateral movement in either direction parallel to a second orthogonal axis which is perpendicular to the first;

E. a single electric motor having an output shaft for providing motion-producing power to said main carriage and to said main rail;

F. first input drive train means for producing movement of said main carriage along said first axis and comprising

1 a first elongated rack gear carried by, and substantially coextensive with, said main rail,

2 a first pinion gear rotatably secured to said carriage and adapted for meshing engagement with said first rack gear, and

3 a first shaft rotatably supported on said main rail and extending from end to end of that rail,

4 a first clutch selectively coupling the output shaft of said motor to said first shaft, and

5 a first drive coupling slidably mounted with respect to said first shaft for coupling the rotation of said first shaft to said first pinion gear as said carriage moves along said main rail; and

G. second input drive train means for producing lateral movement of said main rail along said second axis and comprising

1. a second rack gear mounted by, and substantially coextensive with one of said side rails,
2. a second pinion gear rotatably secured to one of said secondary carriage means and adapted for meshing engagement with said second rack gear,
3. a second shaft rotatably supported on said main rail and extending lengthwise of that rail, said second shaft being drivingly coupled to said second pinion, and
4 a second clutch for selectively coupling said motor output shaft to said second shaft.

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