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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G01C 1/02, 1/08

A1

(11) International Publication Number: WO 87/07366

(43) International Publication Date: 3 December 1987 (03.12.87)

(21) International Application Number: PCT/AU87/00150

(22) International Filing Date: 22 May 1987 (22.05.87)

(31) Priority Application Number: PH 6031

(32) Priority Date: 22 May 1986 (22.05.86)

(33) Priority Country: AU

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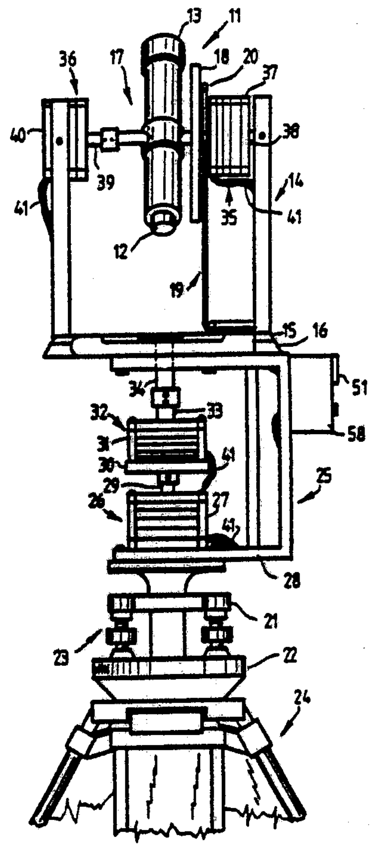
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE, DE (European patent), FR (European patent), GB, GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.

(54) Title: ANGLE MEASURING INSTRUMENTS

(57) Abstract

An angle measuring instrument, in particular a sextant or theodolite, having contrarotating stepping motors for fine positioning of the viewing means. A theodolite (10) having a telescope (11) mounted for pivotal movement about a horizontal and vertical axis and including coupled pairs of stepping motors (26 and 32) and (35 and 36) which may be actuated to drive the telescope (11) in the vertical and horizontal planes. Pulses are applied to the stepping motors to cause the motors to contrarotate for accurate adjustment of the telescope (11) and the pulses applied to the stepping motors are monitored and converted into an angular reading on a display (51).



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ANGLE MEASURING INSTRUMENTS

TECHNICAL FIELD

This invention relates to improvements to angle measuring instruments and in particular to instruments of the type including a sighting telescope or eye piece.

BACKGROUND ART

Angle measuring instruments are employed in many applications usually to measure an angle in a vertical plane or an angle in a horizontal plane or both. Such instruments include theodolites for measuring vertical and horizontal angles in surveying applications and sextants normally used for measuring the angle of a celestial body above the horizon for navigational purposes. In the above known types of instruments, bodies or objects from which angle measurements are to be taken are sighted through an eye piece or telescope, part of the instrument is moved manually and angle readings are taken from a scale. Generallly, such instruments are time consuming to use and require skilled personnel to operate same accurately. Whilst more sophisticted instruments have been proposed for angle measurement purposes for example instruments employing laser beam technology, these instruments are usually relatively expensive. In my International Application No. PCT/AU86/00011, I disclose a sextant which employs a stepping motor to move the index arm and index mirror through a range of angles with the pulses applied to the stepping motor being indicative of the angle of movement of the index mirror. This arrangements however is primarily applicable to conventional sextants.

DISCLOSURE OF INVENTION

The present invention aims to provide improved angle measuring instruments such as theodolites, sextants, levels or other like instruments which employ the princple of moving part of the instrument through an angle equal to the angle between objects, bodies or images being sighted and which enables such angle measurements to be made in a rapid, accurate, and efficient manner.

With the above and other objects in view, the present invention provides an angle measurements instrument of the type including first and second parts pivotally movable relative to each other through a range of angles to be measured, said first part including viewing means for viewing an object, drive means for causing pivotal movement of said first part relative to said second part, said drive means including first and second stepping motor means, means for applying a plurality of pulses to said first and second stepping motor means, and means for coupling said stepping motor means together such that in a first driving attitude, the effective angular movement of said first stepping motor opposes the angular movement of said second stepping motor.

In a first preferred aspect, the angle measuring instrument comprises a theodolite and pairs of coupled stepping motors are arranged to drive the theodolite telescope through a range of vertical angles and/or a range of horizontal angles.

In a second preferred aspect, the angle measuring instrument comprises a sextant and a pair of coupled stepping motors are coupled to the sextant index mirror to pivot th mirror through a range of angles.

The stepping motors may be coupled together in a number of different configurations for example with their bodies or stators secured together and free for pivotal movement and the respective rotor shafts of the motors connected to the first and second parts of the instrument. Alternatively, the shaft of one stepping motor may be coupled to the body of the other stepping motor with the opposite shaft and body being secured to the respective parts. In yet an alternative configuration, the motor shafts are coupled together and the respective bodies secured to the first and second parts respectively of the instrument. In the above configurations, the stepping motors have differing step angles so that in a first driving attitude, the angular movement of the respective shafts or bodies are subtracted resulting in a proportional incremental angular movement of the first part relative to the second part.

In a further configuration for use with stepping motors having the same step angle, the shafts of the respective stepping motors may be provided with pulleys of slightly differing diameters which are linked together via an endless belt, cable or wire. In this configuration, the respective stepping motor bodies are linked to the first and second parts of the instrument so that the effective movement of the first part relative to the second part is proportionally reduced in accordance with the proportion of the diameters of the respective pulleys.

Preferably, the actuation of the stepping motors is controlled by a microprocessor which generates the desired control pulses for operation of the motors in accordance with actuation of manually operable control switches and means are associated with the microprocessor to monitor the pulses applied to the stepping motors and convert the pulses to a proportional angle reading which may be displayed on a visual readout device. Suitably, the microprocessor is software controlled. The microprocessor may also be programmed to cause the stepping motors to be actuated in the same effective direction for rapid traversing movement of the first part relative to the second part, such movement being a sum of the angular movements of each of the stepping motors.

BRIEF DESCRIPTION OF DRAWINGS

In order that the invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate preferred embodiments of the invention and wherein :-

Fig. 1 is an elevational view of a theodolite incorporating the improvements according to the present invention;

Fig. 2 illustrates in block diagram form the control circuit for the instrument of Fig. 1;

Figs. 3 to 7 illustrate details of the control circuit of Fig. 2;

Figs. 8 to 10 illustrate alternative combinations of the stepping motors for driving the instruments; and

Figs. 11 and 12 illustrate in side and end elevational views a sextant according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to the drawings and firstly to Fig.1, there is illustrted a theodolite 10 incorporating the improvements according to the present invention. As is conventional, the theodolite 10 includes a telescope 11 including an eye piece 12 and object glass 13 which is mounted for pivotal movement about a horizontal axis on an upstanding A-frame assembly 14 secured to a vernier plate 15 mounted for rotational movement about a vertical axis on a lower fixed scale plate 16. The scale plate is provided with a graduated arc and the vernier plate 15 provided with a vernier scale so that the angular movement of the vernier plate 15 and thus the telescope 11 about a vertical axis can be visually observed and measured.

The telescope 11 is mounted on an arm assembly 17 which also includes a coaxial vertical scaled circle 18 and a T-frame 19 carrying vernier scales is mounted rotatably relative to the arm assembly 17 and connected non-rotatably to the A-frame assembly 14 so that the angle of movement of the telescope in a vertical plane can be read from the respective scales on the circle 18 and T-frame 19. Suitably, the T-frame 19 is provided with an altitude or bubble level20 to ensure that the T-frame is in a level attitude.

The instrument is supported by two support members or plates 21 and 22 separated by levelling or foot screws 23 provided for ensuring that the vertical axis of the instrument is truly vertical. The lower member 22 is fitted to the head of a supporting tripod 24 which supports the instrument on a ground surface.

In this embodiment, a bracket 25 which in this embodiment is generally U-shaped but which may simply comprise a cylinder extends between the scale plate 16 and the upper support member 21. A first stepping motor 26 is mounted with its stator body 27 fixed to the lower flange 28 of the bracket 25 and its rotor shaft 29 releasably coupled to a cup shaped housing 30. The body 31 of a second stepping motor 32 is partially received by the housing 30 and secured thereto whilst the shaft 33 of the motor 32 is coupled to the vernier plate 15 via a shaft extension 34 thereof.

A further pair of stepping motors 35 and 36 are coupled to the telescope 11 to cause rotation thereof in a vertical plane. The stator body 37 of the stepping motor 35 is fixed for movement with the telescope 11 by being mounted on a flange of the shaft assembly 17 and the rotor shaft 38 of the motor 35 is clamped to the A-frame assembly 17. The other stepping motor 36 is disposed on the opposite side of the telescope 11 with its shaft 39 coaxial with the arm assembly 17 and secured thereto whilst the motor body 40 is mounted on the opposite arm of the frame assembly 17. In both of the stepping motor configurations described above, the stepping motors of each pair have slightly differing step angles for a reason which will hereinafter become apparent.

The supply cables 41 of the respective motors 26, 32, 35 and 36 are connected to the control circuit 42 shown in Fig.2. This circuit 42 as shown in Figs. 3 to 7 includes a central processing unit 43 which includes a microprocessor 44 and associated ROM 45 and RAM 46, decoders 47 and 48 and parallel input/ output interfaces 49 and 50, the former of which is connected to respective actuating switches for the control circuit and to transistor drivers for driving the stepping motors whilst the latter is connected to a liquid crystal display which displays angular movement in both a horizontal and vertical plane.

The operating switches for the circuit comprise a zero switch 52 which when depressed zeros the reading on the L.C.D. display 51 to provide a datum against which a subsequent angle reading may be taken. A vertica/horizontal switch 53 allows the selection of the plane through which the telescope 11 is to be pivoted that is either a vertical or horizontal plane by bringing into the circuit either the stepping motor pairs 35 and 36 or 26 and 32. The switches 54 and 55 are provided for actuating the selected stepping motors to cause the telescope 11 to traverse in the required direction. In a preferred arrangement, the switches 54 and 55 comprise pairs of "course" adjustment and "fine" adjustment switches 54' and 54" and 55' and 55" as described below.

The control circuit 42 may be powered from any suitable source such as a battery 56 under the control of an ON-OFF switch 57 and the whole circuit 42 may if desired be mounted on the theodolite for example in a housing 58 on the bracket 25 with the L.C.D. display 51 mounted to be visible by the user.

In this embodiment, the microprocessor 44 comprises a type Z80A running at 4MHz as defined by the clock circuit 59 and includes a conventional reset circuit 60. The operating program for control of the microprocessor 44 is stored in the ROM 45 (see Fig. 4) being in this instance a 32K ROM comprising two type 27128 16K ROMs. The RAM 46 for carrying out various memory functions required comprises a 32K static ROM comprisingfour type 6264 8K RAMs.

The ROM 45 is software programmed to cause the generation of stepping motor control pulses in response to actuation of selected control switches 52 to 55 for application to the stepping motors through the interface 49 to thereby cause the telescope to traverse in the required direction.

The direction and extent of movement of a stepping motor shaft normally depends upon the sequence of pulses applied to the respective windings of the motors. In the present instance and for horizontal movement of the theodolite telescope shown in FIg. 1, "course" traversing movement of the telescope is achieved by depression of the switch 54', actuation of this switch causing a series of pulses to be applied to the stepping motor 31 whilst at the same time a holding current is applied to the stepping motor 26 to prevent its rotor shaft 29 and consequently the body 31 of the stepping motor 32 from rotating. Thus the vernier plate 15 and telescope 11 will be pivoted or rotated in a horizontal plane in steps equal to the step angle of the stepping motor 32. For "fine" adjustment of the telescope 11 when the telescope 11 is approaching an object or datum to be sighted, the "course" switch 54' is released and the "fine" switch 54" depressed. This will cause a series of pulses to be applied to the stepping motor 27 as well as the motor 32 however the pulses applied to the motor 26 are such as to cause the shaft

29 thereof to rotate in a direction opposite to that of the shaft 33. Thus the resultant stepping motion of the telescope 11 will be determined by the difference between the step angles of the stepping motors 26 and 32 and result in fine adjustment motion of the telescope towards its desired position.For this fine adjusment, the pulses applied to the motors are such as to cause the motor shaft to move in steps through their minimum step angles.

More rapid traversing of the telescope 11 may be achieved by applying pulses to both motors simultaneously to cause the shafts 29 and 33 to rotate in the same direction so that the horizontal motion of the telescope 11 is in steps equal to a summation of the step angles of each stepping motor.

A similar principle is employed to drive the telescope 11 in a vertical plane with the stepping motors 35 and 36 being actuated again singlely or so that the shaft 39 of the stepping motor 36 rotates in the same direction as the body 37 of the stepping motor 35 so that the telescope 11 pivots in steps equal to the summation of the step angles of the motors 35 and 36. Again for fine adjusment, the switch 55" may be actuated to apply pulses to the motors 35 and 36 simultaneously but so that the shaft 39 rotates in a direction opposite to the direction of rotation of the body 37 so that the step angular movements of the telescoope 11 comprise a subtraction of the step angles of the respective stepping motors 35 and 36.

In each case, of course, the step angles of the motors are proportional to the pulsed control signals applied to the motors and in the motor combinations, the effective angular movement of the telescope is proportional to a summation or subtraction of the pulse signals. To obtain a visual display of the angle through which the telescope 11 moves, the pulses applied to the motors are monitored and converted into a proportional angular signal which is displayed in conventional form on the L.C.D. 51. Suitably, the L.C.D. 51 continuously displays angle of movement of the telescope during its traversing motion however if desired, a switch may be associted with the L.C.D. 51 to enable the angle reading to be displayed only after the traversing operation.

Figs. 8 to 10 illustrate alternative combinations of stepping motors for driving the theodolite telescope 11 through a range of horizontal angles. In Fig. 8, the body 61' of one stepping motor 61 is mounted to the vernier plate shaft extension 34 via a housing whilst the body 62'of a further stepping motor 62 is mounted on a bracket 63 mounted on a fixed part of the theodolite in this embodiment to the bracket 25. In this embodiment, the stepping motors 61 and 62 have the same step angles and the stepping motor shafts are provided with respective pulleys 64 and 65, the pulleys 64 and 65 being linked by an endless non-slip belt or alternatively and as shown, a non-stretch multi-strand wire 66 which is secured at one end to the pulley 65 and which passes about the other pulley 64 and back to be secured to the pulley 65. Preferably the wire 66 is wound a number of times about each pulley and located in helical grooves in the surface theref and the effective diameters of the pulleys are slightly different. Thus when pulses are applied to the respective motors 61 and 62 to cause them to contra-rotate through the same step angles, the angular motion transferred to the stepping motor body 61'will be proport-ional to the difference in effective diameters of the pulleys. This thereby enables a fine adjustment movement of the vernier plate 15 and telescope 11 to be achieved.

In a particularly preferred arrangement, one pulley may have a diameter of 5.08 cms. and the other pulley a diameter of 5.08cms. less 0.025 mms. With stepping motors having in a 1/5 th. step mode having 1/1000 of a revolution per step, this difference in pulley diameter will result in a reduction of 1/2000 so that for each step of the motors, 1/2,000,000 of a revolution of the motor body 59 will result; that is approximately ½ second/per step accuracy.

In the embodiment shown in Fig. 9, the stepping motors 67 and 68 are secured together with their stator bodies 69 and 70 in a back to back relationship and free to rotate whilst the stepper motor shafts 71 and 72 are secured to the vernier plate shaft 34 and the bracket 25 respectively. This embodiment will function in a similar manner to the Fig. 1 embodiment with the stepped motion applied to the vernier plate 15 being as a result of step movements of one or other of the motors 67 and 68 whilst fine stepping movement can be achieved by pulsing the motors 67 and 68 so that movement of the vernier plate 15 comprises a subtraction of the respective step angles of the motors 67 and 68. Alternatively, the motors 67 and 68 may be pulsed to drive the vernier plate 15 and thus the telescope 11 in steps comprising a summation of the step angles of the motors.

Fig. 10 show an alternative configuration of stepping motors for driving the theodolite vernier plate 15 with the stepping motor shafts being coupled together and the stepping motor bodies attached to the vernier plate shaft 34 and bracket 25 respectively and again the motors can be driven in the alternative manners described above. Similar combinations of motors as to those described above may be applied for driving the telescope 11 in a vertical plane.

Referring now to Figs. 11 and 12, there is illustrated a sextant 73 incorporating the principles of the present invention. The sextant 73 in this embodiment includes a main body 74 which incorporates a gripping handle 75 and a telescope 76 which is aligned with a split horizon mirror 77 which is mounted in a fixed position on the main body 74. An index mirror 78 for reflecting the image of a celestial body being observed into the horizon mirror 77 and thence into the telescope 76 is mounted rotatably on the body 74 and arranged to be pivotally driven by means of a pair of stepping motors 79 and 80. As shown, the stepping motor body 81 is fixed to one side of the index mirror and the shaft 82 of that motor clamped to the main body 74. The other stepping motor 80 is arranged coaxially on the opposite side of the index mirror 78 and has its shaft 83 fixed to that side of the index mirror 78. The body 84 of the motor 80 is mounted in a fixed attitude on the main body 74 of the sextant.

As with the theodolite embodiments described above, both of the stepping motors may be driven simultaneously by applied pulses so that their shafts are urged to move in the same direction. The resultant step motion of the index mirror 78will comprise a subtraction of the step angles of the motors 79 and 80. Alternatively, the motors may be pulsed so that the step motion of the index mirror comprise a summation of the step angles of the motors.

The direction of movement of the index mirror 78 is controlled by a toggle switch 85 on the handle 75, the switch being connected in a circuit similar to the circit described with reference with Figs. 2 to 7 with the switch 85 comprising the switchs 54 and 55 in this circuit and when operated initites operation of the programmed microprocessor to apply pulses to the respective motors.

As applied to the sextant, the L.C.D. 51 is required to display only vertical angle and from the displayed angle representitive of the altitude angle of a celestial body being observed and being brought down to the horizon, position can be calculated by using known navigational formula. Alternatively, the handle 75 of the sextant may also carry a "shot" switch 86 which may be actuated to initiate calculation of position from the altitude angle, chronometer reading at the time the shot is taken and stored navigational equations in the same manner as that described in my aforesaid International application.

The principles of the present invention may be applied to may different angle measuring instruments where a telescope is moved or a reflective element moved relative to a telescope through a range of angles to be measured. Whilst for maximum adaptability of the instruments, it is preferred that they be microprocessor controlled, they may if desired be controlled by hardware systems. Such angle measuring instruments employing the principles of the present invention may be of many differing forms and it will be realised that the forms of apparatus shown and described above may be considerably varied without departing from the broad scope and spirit of the invention.

CLAIMS

1. An angle measuring instrument of the type including first and second parts pivotally movable relative to each other through a range of angles to be measured, said first part including viewing means for viewing an object, drive means for causing pivotal movement of said first part relative to said second part, said drive means including first and second stepping motor means, means for applying a plurality of pulses to said first and second stepping motor means and means for coupling said stepping motor means together such that in a first driving attitude,the effective angular movement of said first stepping motor means opposes the angular movement of said second stepping motor means.

2. An angle measuring instrument according to Claim 1 wherein each said stepping motor means includes a stator body and a rotor shaft, said stepping motor means being directly coupled and wherein the step angle of one said motor means is different from the step angle of the other said motor means.

3. An angle measuring instrument according to Claim 2 wherein said rotor shaft of said first motor means is coupled to the body of said second motor means and wherein said body of said first motor means and said shaft of said second motor means are secured to said first and second parts respectively.

4. An angle measuring instrument according to Claim 3 and including means for selectively applying pulses to said motors to cause the angular movements of said motors to be in the same direction.

5. An angle measuring instrument according to Claim 1 wherein each said motor drives a pulley, the pulleys of said motors being interconnected via a flexible link and wherein the diameter of one said pulley is smaller or greater than the diameter of the other said pulley.

6. A theodolite of the type including a telescope, support means for said telescope, and mounting means for mounting said telescope for pivotal movement relative to said support means through a range of angles, drive means selectively actuable for causing pivotal movement of said telescope, said drive means including first and second stepping motor means, means for selectively applying drive pulses to said stepping motor means and means for coupling said stepping motor means together such that in a first driving attitude, the angular movement of one stepping motor means opposes the angular movement of the other stepping motor means.

7. A theodolite according to Claim 6 wherein said stepping motor means have different step angles and wherein the rotor shaft of one said motor is coupled to the stator body of the other said motor, with the stator body of said one motor and the rotor shaft of the other said motor being coupled to said support means and said telescope respectively.

8. A sextant of the type including a supporting body, an eye piece mounted on said supporting body, a horizon mirror on said body aligned with said eye piece, and an index mirror mounted pivotally on said supporting body, drive means for pivoting said index mirror through a range of angles, said drive means including first and second coupled stepping motor means, and means for actuating said stepping motor means to cause the angular movements of said stepping motor means in a first driving attitude to oppose each other.

9. Apparatus according to any one of the preceding claims and including means for monitoring the pulses applied to said stepping motor means and visual display means for displaying an angular reading in accordance with the pulses applied to said stepping motor means.

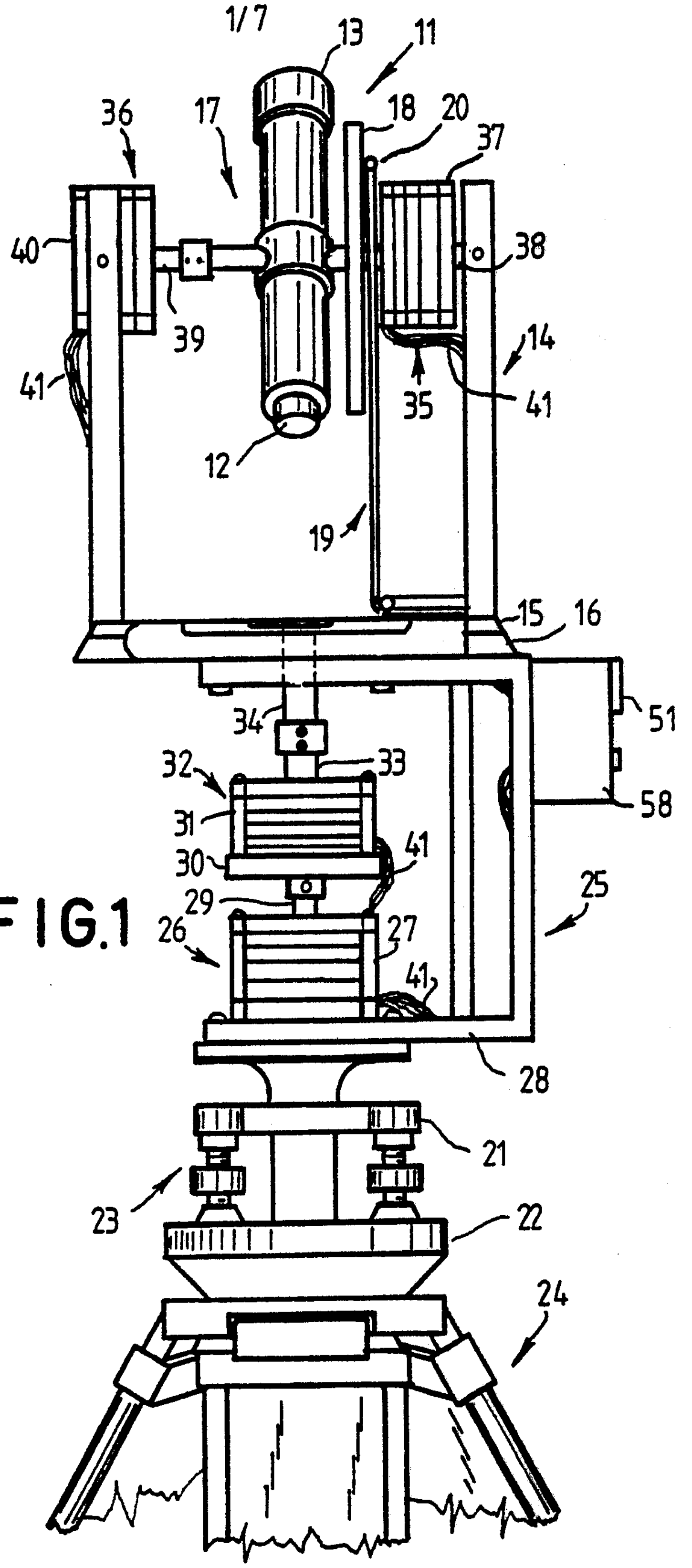
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FIG.1

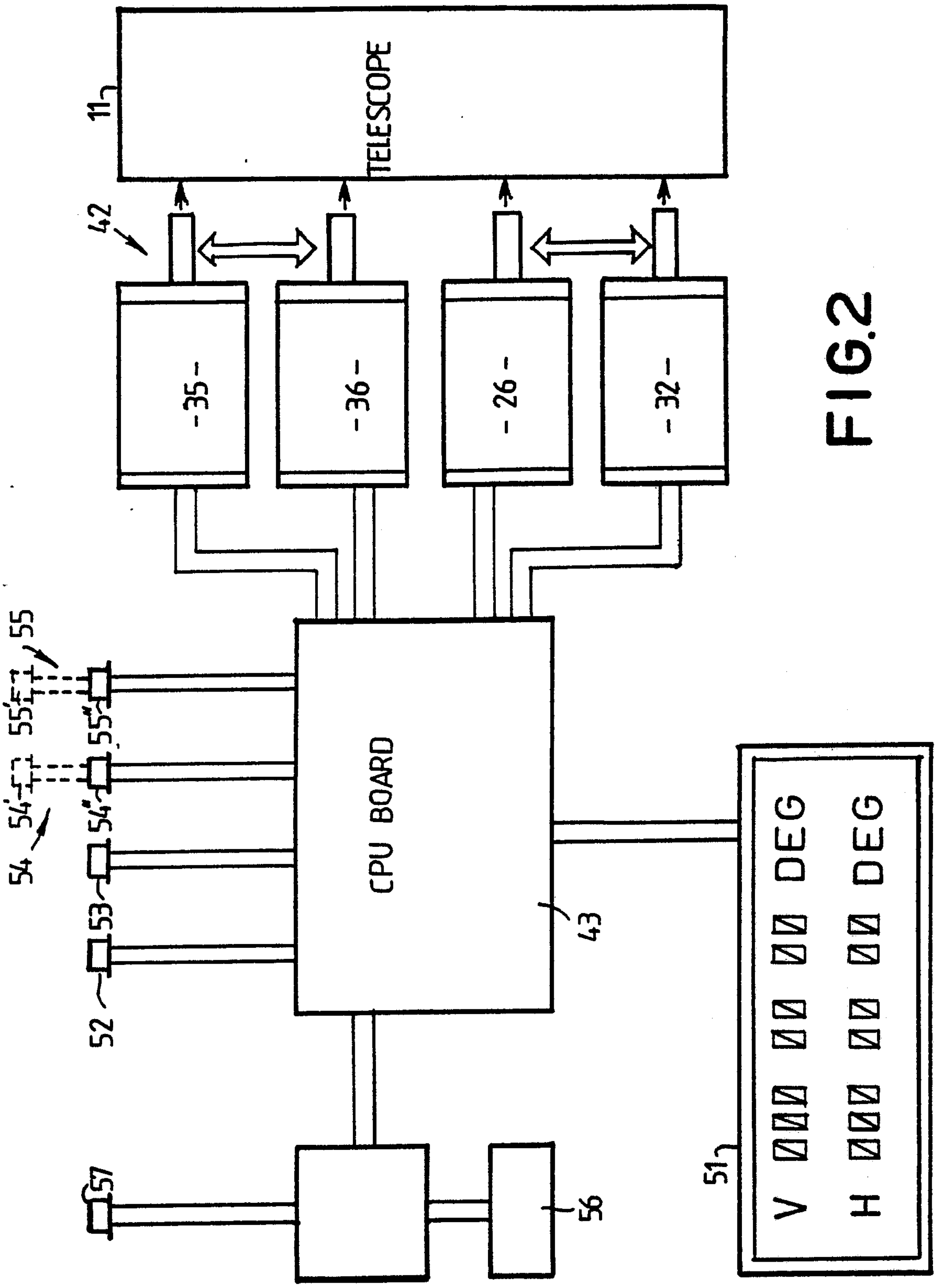
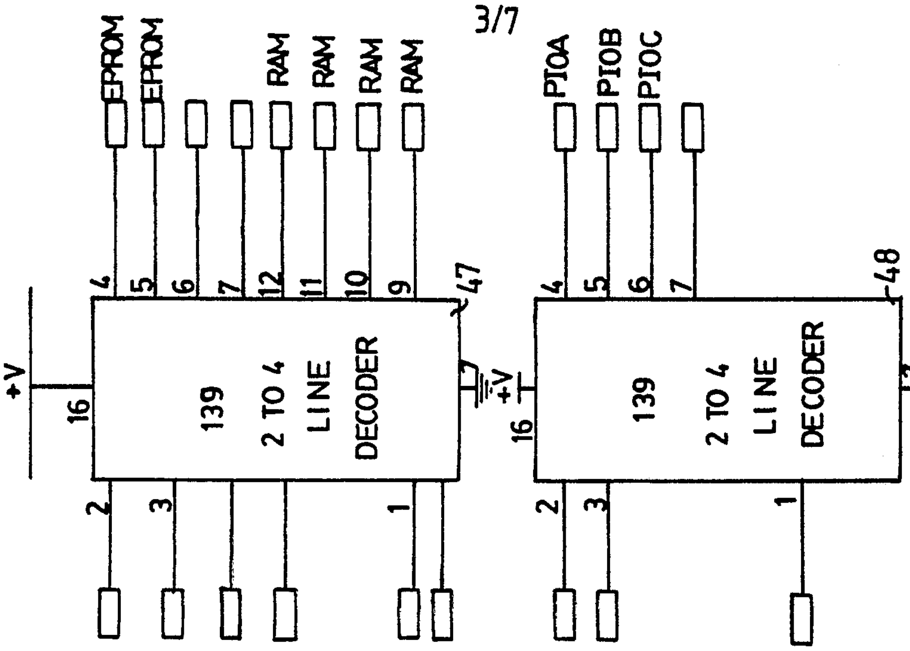
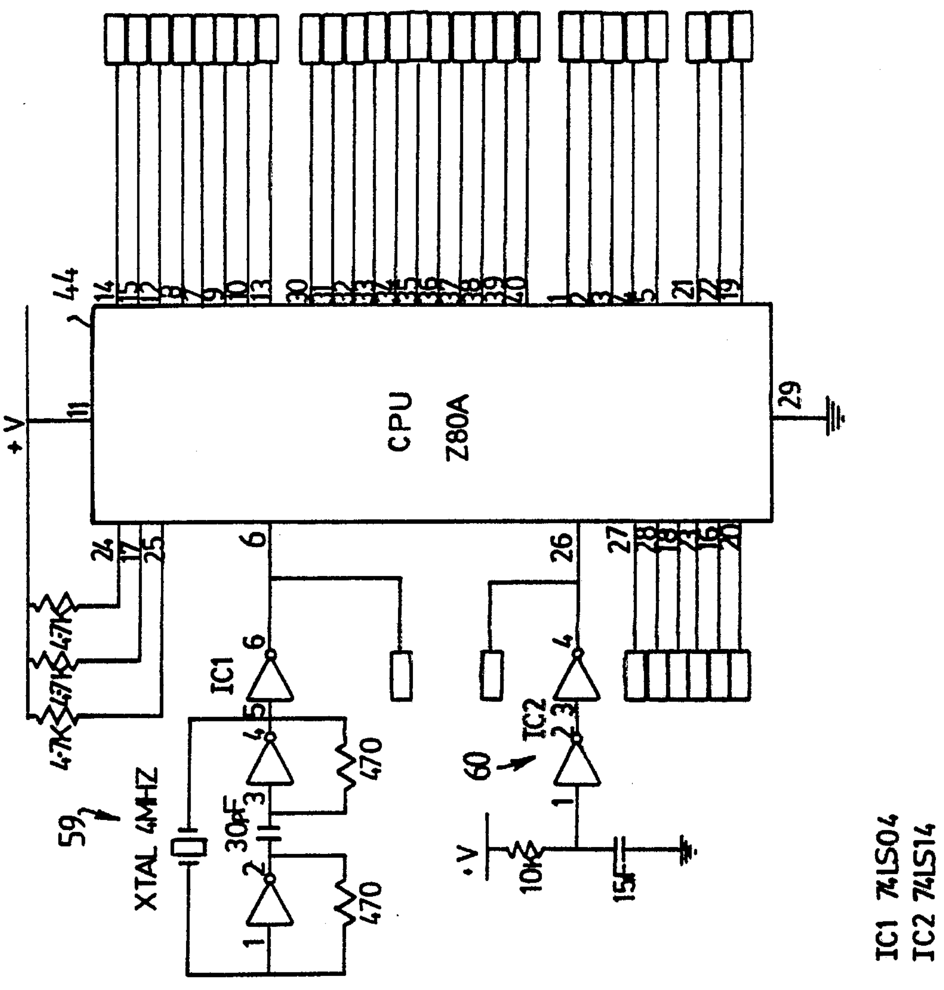

TELESCOPE
11
42
-35-
-36-
-26-
-32-
CPU BOARD
43
52
53
54
54'
54"
55
55'
55"
57
56
51
V ØØØ ØØ ØØ DEG
H ØØØ ØØ ØØ DEG

FIG.2



EPROM
EPROM
RAM
RAM
RAM
RAM
PIOA
PIOB
PIOC
+V
139
2 TO 4
LINE
DECODER
47
48

FIG.5



+V
CPU
Z80A
44
IC1
IC2
XTAL 4MHZ
59
60
470
470
10K
IC1 74LS04
IC2 74LS14

FIG.3

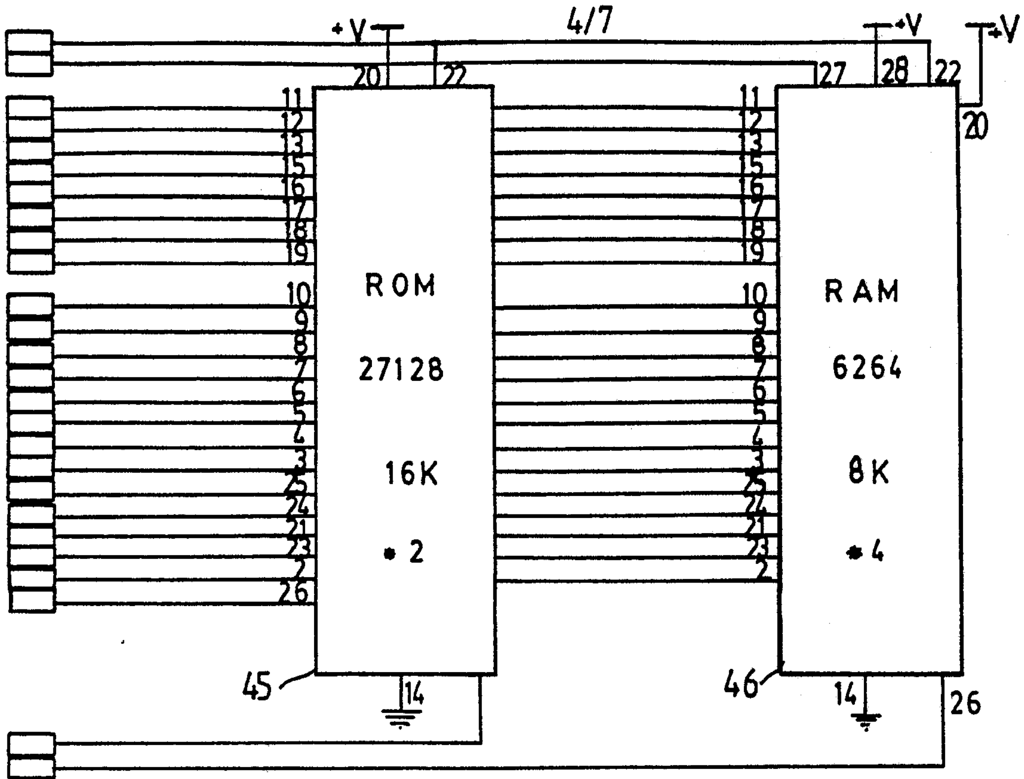

ROM
27128
16K
* 2
RAM
6264
8K
* 4
+V
45
46

FIG.4

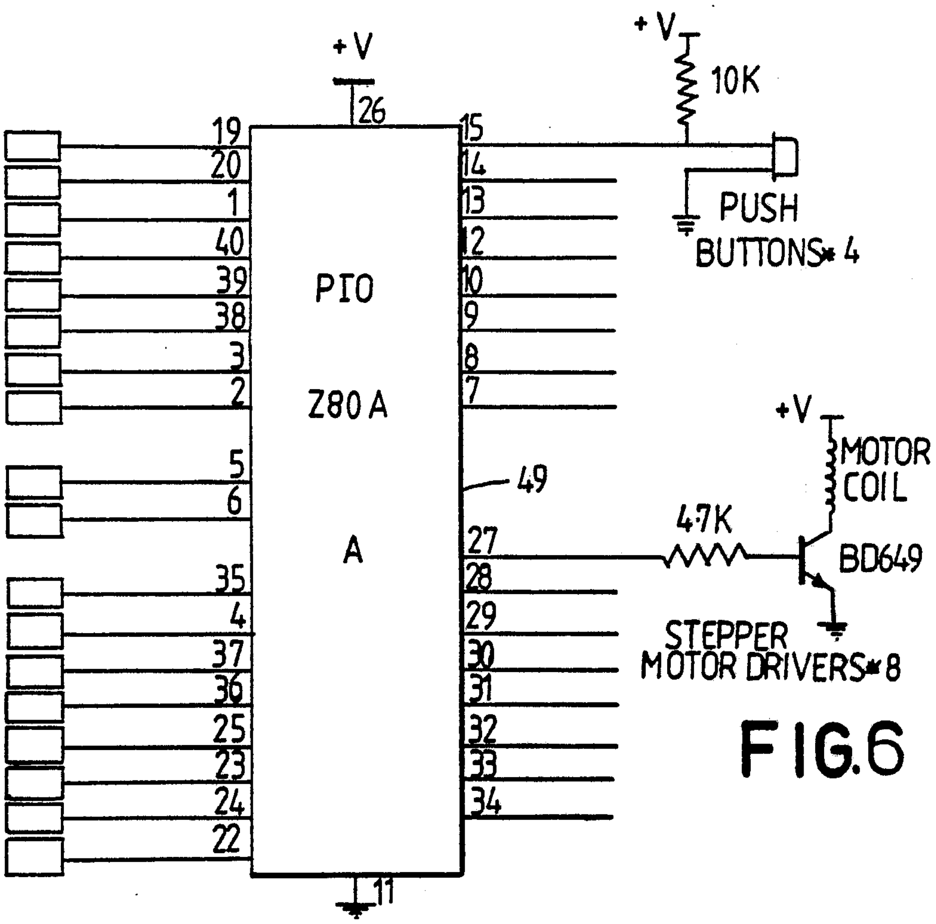

PIO
Z80 A
A
+V
10K
PUSH BUTTONS* 4
MOTOR COIL
47K
BD649
STEPPER MOTOR DRIVERS*8
49

FIG.6

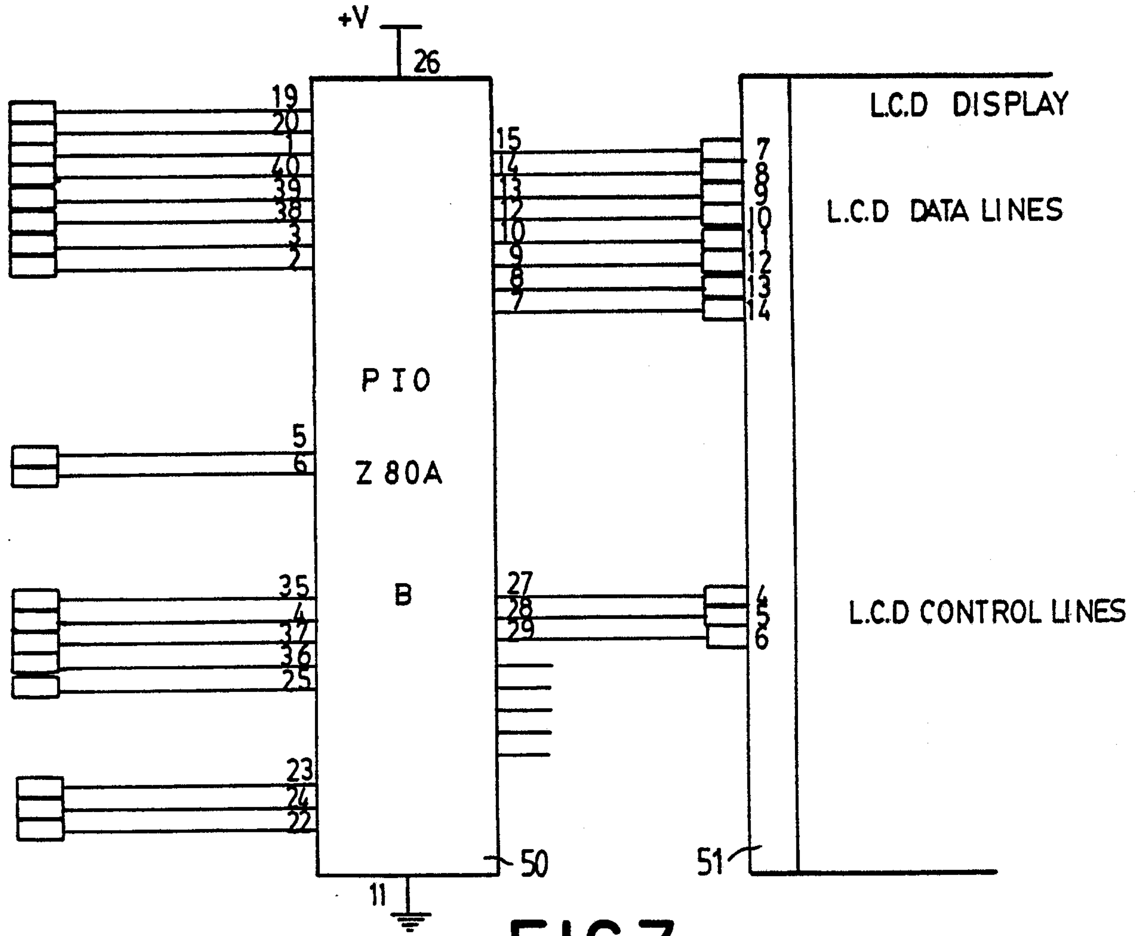

+V
26
19
20
1
40
39
38
3
2
15
14
13
12
10
9
8
7
L.C.D DISPLAY
L.C.D DATA LINES
7
8
9
10
11
12
13
14
P I O
Z 80A
B
5
6
35
4
37
36
25
27
28
29
4
5
6
L.C.D CONTROL LINES
23
24
22
50
51
11

FIG.7

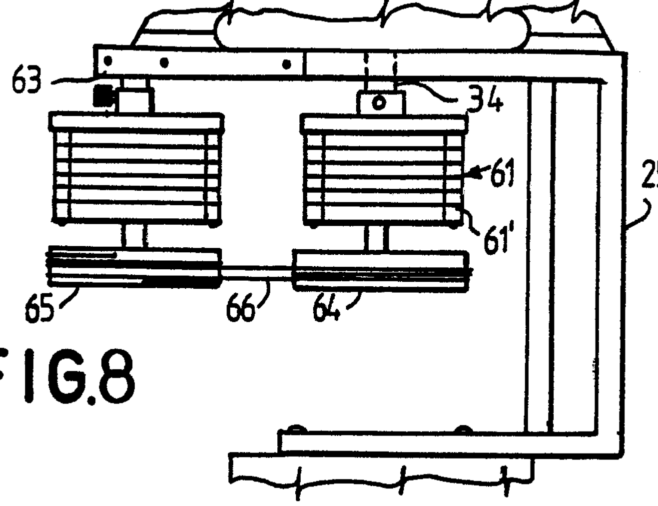


FIG.8

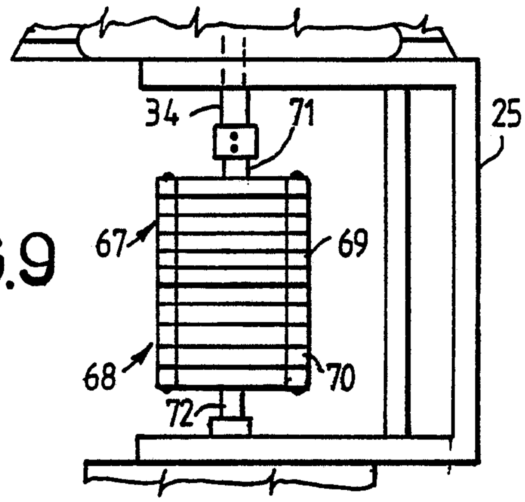


FIG.9

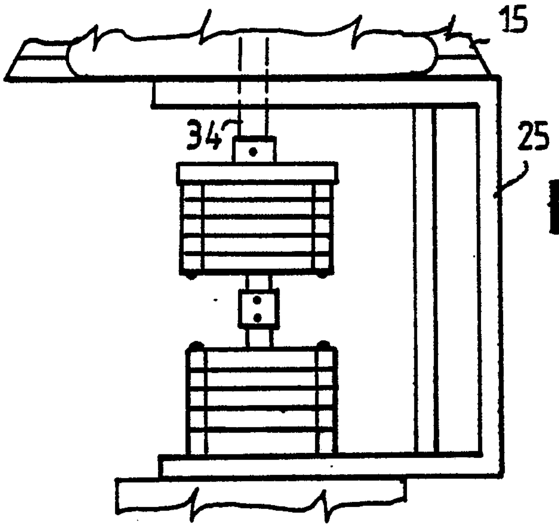


FIG.10

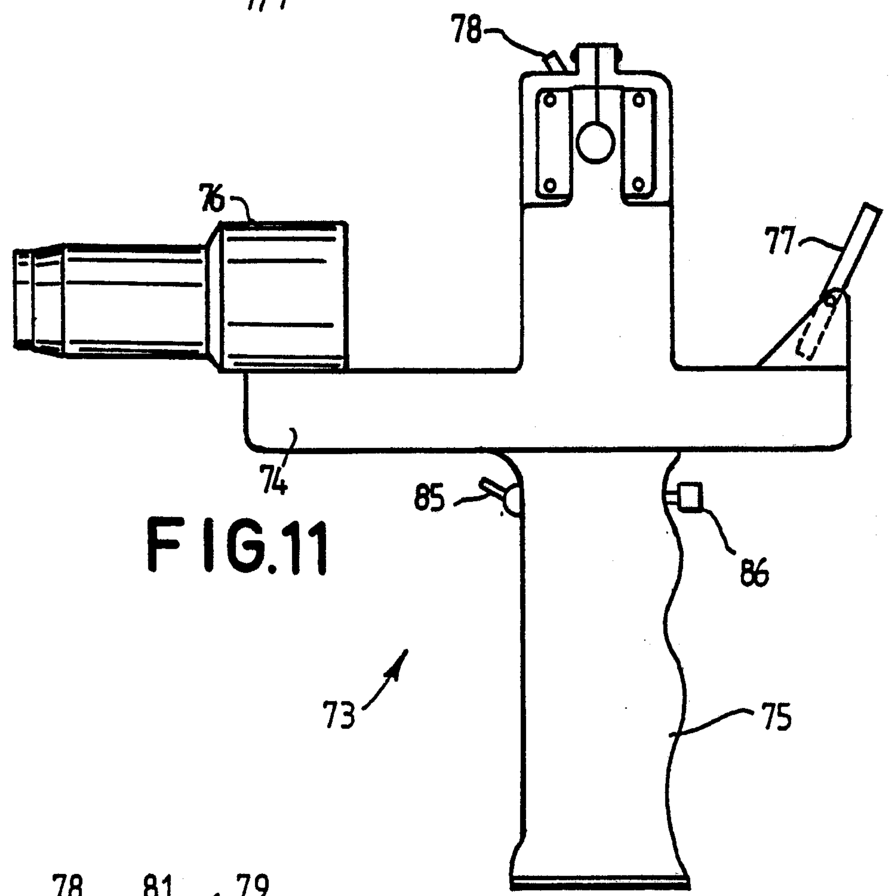


FIG.11

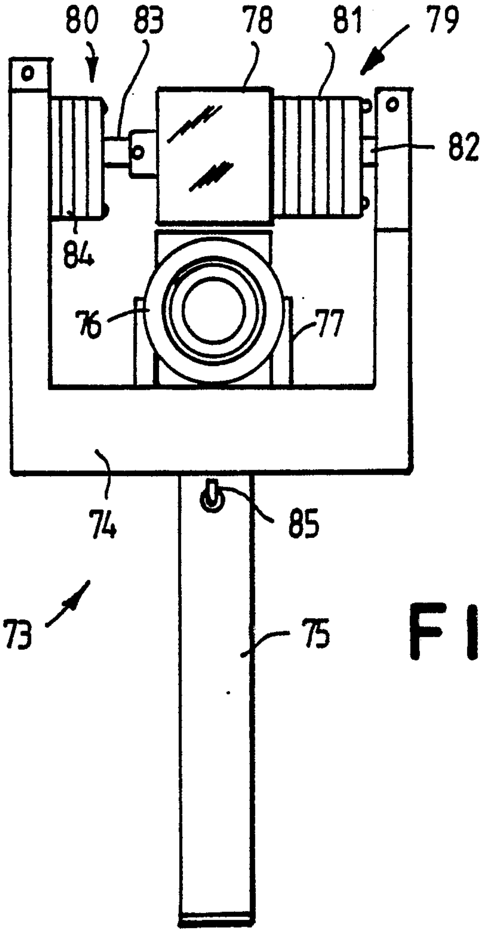


FIG.12

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 87/00150

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int Cl G01C 1/02, G01C 1/08

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	G01C 1/00, 1/02, 1/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU: IPC as above; Australian Classification 00.43

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X,Y	AU,B, 59184/60 (245415) (NORTH AMERICAN AVIATION, INC) 6 October 1960 (06.10.60) See page 5, lines 32-41.	1,2,4,6,8,9
Y	GB,B, 1177158 (BRITISH AIRCRAFT CORPORATION LIMITED) 7 January 1970 (07.01.70)	1,6,8,9
Y	FR,B, 594563 (BAULE) 15 September 1925 (15.09.25) See page 2, lines 68-75.	4
Y	US,B, 3854037 (FELDMAN et al) 10 December 1974 (10.12.74)	8
A	US,B, 3230377 (SMITH) 18 January 1966 (18.01.66)	1,6

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
15 September 1987 (15.09.87)	(17.09.87) 17 SEPTEMBER 1987
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	W J MAJOR

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 87/00150

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
GB 1177158	BE 722184 FR 1596606	CH 470652 US 3596363	DE 1801927

END OF ANNEX