April 5, 1960 J. K. STORY 2,931,573

TRIGONOMETRIC RESOLVING APPARATUS

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FIG. 1.

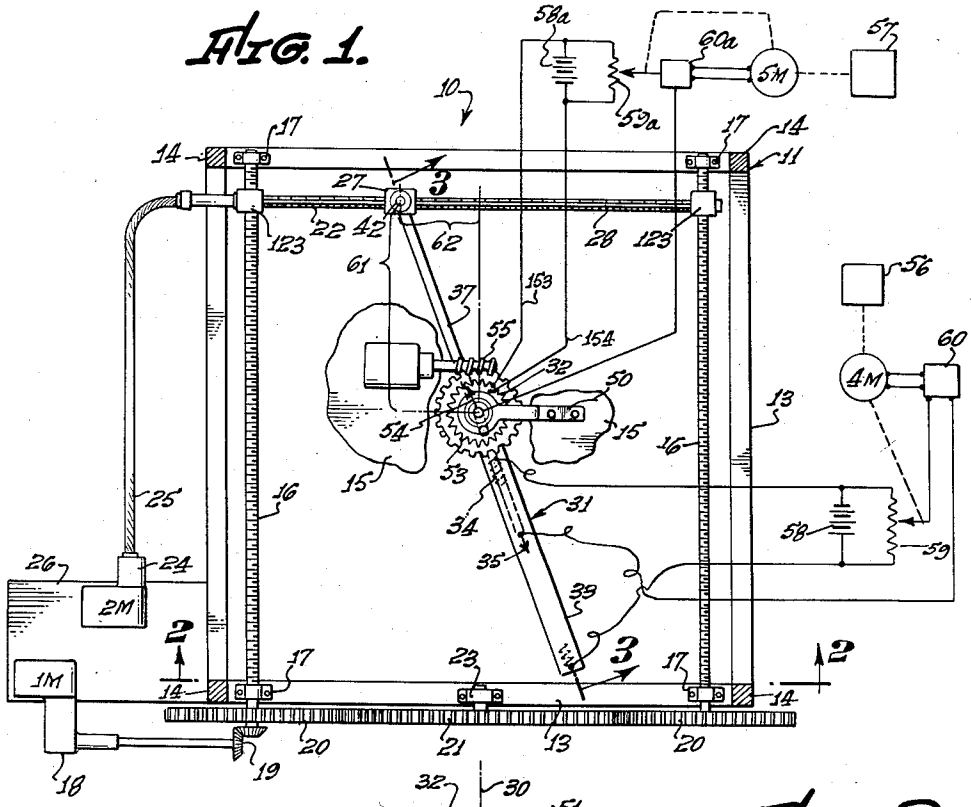


FIG. 2.

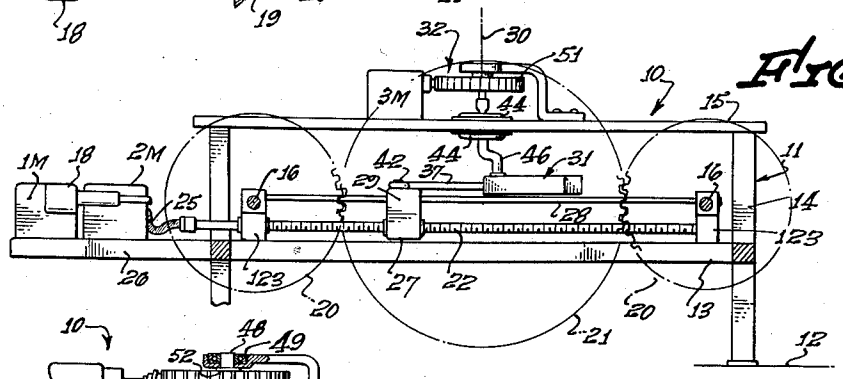
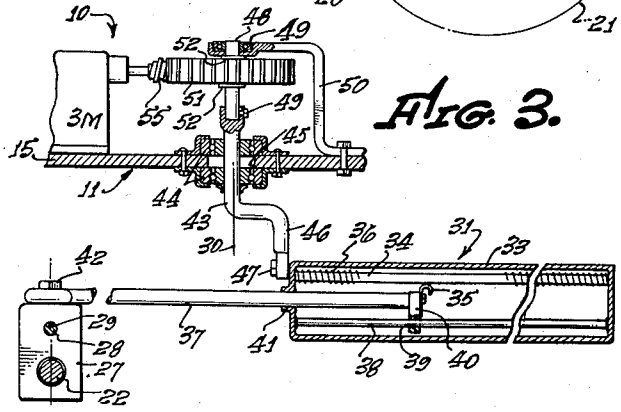


FIG. 3.



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TRIGONOMETRIC RESOLVING APPARATUS

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5 Claims. (Cl. 235—189)

This invention relates to improved trigonometric resolving apparatus for developing a representation of a point in polar coordinates. The present application constitutes a continuation-in-part of my copending application Serial No. 465,281, filed October 28, 1954, and now Patent No. 2,843,941, on "Well Surveying Apparatus."

The general object of the invention is to provide apparatus which is capable of transforming rectangular coordinates into polar coordinates, or for solving problems which are analogous to such transformation from rectangular to polar coordinates. For instance, in the well surveying equipment of the above entitled parent application, the present device is utilized for solving the analogous problem of combining two components of a well bore inclination into a single representation of that inclination, defined in terms of the angle of inclination and its direction.

In accordance with the invention, I employ apparatus including an element which is movable in two essentially perpendicular directions to a position having predetermined coordinates in those two directions. For transforming that position into polar coordinates, I provide a first electrical unit which is actuable in accordance with the distance between the element and a predetermined center, and a second electrical unit which is actuable in accordance with the rotary positioning of the element about the center. The element may be moved in the two desired directions by two essentially perpendicular screw and nut assemblies.

Both of the electrical units may be potentiometers swinging about the center of the device, the first potentiometer preferably being of the linear motion linear winding type, and the second preferably being of the rotary motion linear winding type. The rotary potentiometer may have the usual relatively rotatable contact and resistor parts, one of which, desirably the contact, is rotatable about the center in accordance with movement of the element whose coordinates are being determined. The other part of the potentiometer may also be rotatable if desired, to introduce a correction factor into the reading of the potentiometer. This correction factor, and the two input rectangular coordinates, may be introduced into the device by three electric motors; and the output polar coordinates may be read out by suitable indicators.

The above and other features and objects of the present invention will be better understood from the following detailed description of the typical embodiment illustrated in the accompanying drawing in which:

Fig. 1 is a plan view of a resolving device constructed in accordance with the invention;

Fig. 2 is a vertical section taken on line 2—2 of Fig. 1; and

Fig. 3 is an enlarged fragmentary vertical section taken on line 3—3 of Fig. 1.

The resolving device 10 illustrated in the drawing has a stationary frame structure 11 which may rest on a suitable supporting surface 12. This frame structure 11 includes four rigid members 13 interconnected at their ends to form a rigid rectangular horizontally extending frame, and four vertically extending corner posts or legs 14. At a location spaced above the members 13, legs 11 support an upper horizontal top plate 15.

Two parallel laterally spaced elongated rotary lead screws 16 are mounted to framework 11 for rotation about their individual parallel horizontally extending axes, the mounting typically being effected by suitable bearings 17 attached to the framework and journaling coacting unthreaded portions of screws 16. Bearings 17 are of course designed to prevent axial movement of screws 16, while allowing the desired rotary movement of these screws.

One of the screws 16 is mechanically driven by a motor 1–M, as through a connection including a reduction gear unit 18 and a pair of bevel gears 19. The second of the screws 16 is rotatably driven in unison with the first, typically by providing a pair of gears 20 on the two screws, with an intermediate power transmitting gear 21, mounted by one or more bearings 23, meshing with and transmitting power between the two gears 20.

A third screw element 22 extends perpendicularly to and between screws 16, and is rotatably journaled within a pair of bearing blocks 123 carried by the two screws. Each of these bearing blocks contains a threaded bore through which the corresponding screw 16 extends, so that rotation of screws 16 in unison acts to displace blocks 123 and their rotatably carried screw 22 axially relative to screws 16. The bearing engagement between blocks 123 and screw 22 is such as to allow rotary movement of screw 22 in the blocks, while preventing axial movement of screw 22 relative to the blocks.

The third screw 22 is driven by a motor 2–M, typically through a speed reduction gear unit 24 and a flexible drive connection represented at 25. Motors 1–M and 2–M may be mounted in any suitable manner to the framework 11, as by mounting the motors and their reduction gear units to a supporting platform 26 stationarily attached to and projecting laterally from one of the members 13. Screw 22 threadedly carries a nut element or block 27, which is actuated axially along screw 22 by and in accordance with rotation of that screw. The block 27 is suitably retained against rotary movement about the axis of screw 22, preferably by provision of a rod 28 rigidly carried by and extending between blocks 123. This rod 28 extends parallel to screw 22, and passes through a guide opening 29 in the block or nut 27, to slideably guide that block for only axial movement relative to screw 22.

As will be apparent, the described screws 16 and 22 driven by motors 1–M and 2–M, are capable of displacing block 27 to an infinite number of different positions within its plane of movement and about a central reference point or axis 30. Motors 1–M and 2–M may be energized by electrical input signals to actuate their respective screws 16 and 22 in a manner displacing nut 27 to a position having rectangular coordinates determined by the input signals. That is, motor 1–M is energized by a suitable control circuit for a period sufficient to move blocks 123 and screw 22 (by rotation of screws 16) a predetermined distance from a position of alinement with center point 30. Similarly, motor 2–M may be energized to rotate screw 22 and thereby move nut 27 along screw 22 to a position representing a second rectangular coordinate at a desired point in the plane of movement of block 27. After block 27 has been thus actuated by screws 16 and 22 to a particular position, the polar coordinates of that position with respect to center point or axis 30 are developed in electrical form by two potentiometers 31 and 32. The first of these potentiometers 31 is of the linear motion and linear winding type, and includes an elongated tubular body 33 which con-

tains a longitudinally extending linearly wound resistor winding 34 along which a movable contact 35 is slideable. The winding 34 may consist of a large number of turns of suitable resistor wire wound about an elongated electrically insulated carrier element 36. Contact 35 is carried by an elongated arm 37, which is guided for only longitudinal sliding movement relative to body 33 and resistor winding 34, the guiding action desirably being attained by means of one or more elongated guide rods 38 within and carried by body 33 and extending through guide openings 39 in an electrically insulative member 40 projecting from element 37. Also, body 33 may have a bearing portion at 41 which assists in guiding element 37 and the carried contact 35 for only the desired longitudinal movement. Contact 35 is of course suitably insulated from resistor winding 34 except at the point of contact between these parts. The opposite end of element 37 is pivotally attached at 42 to block 27.

Potentiometer 31 is mounted for swinging movement about axis 30 (which extends perpendicular to the plane within which block 27 moves). This mounting of potentiometer 31 for swinging movement may be effected by means of a shaft 43 which is journaled by bearings 44 for rotation about axis 30, and which is desirably retained against axial movement within bearings 44. Bearings 44 may be attached at first locations to the previously mentioned transverse plate 15, and adjacent a central opening 45 in this plate through which shaft 43 extends. At its lower end, shaft 43 has a portion 46 which is offset laterally from axis 30, and is rigidly attached to potentiometer body 33, as by a screw 47. The offset relation of portion 46 of shaft 43 is sufficient to allow movement of block 27 to the exact center of its plane of movement, that is to a position at which the pivotal connection 42 is exactly alined with the center axis 30. The mountnig of potentiometer 31 is such that element 37 and contact 35 move in planes which are parallel to or are the same as the plane of movement of block 27.

Potentiometer 32 serves to respond to the rotary positioning of block 27 about axis 30, and is a 360° rotary motion linear winding potentiometer. This potentiometer includes a shaft 48 which is rigidly attached to and in alinement with shaft 43 by a set screw 49, to thus rotate about axis 30 with shaft 43. If desired, an upper bearing 49 carried by a bracket 50 attached to plate 15 may be provided for journaling and accurately locating the upper end of shaft 48. Potentiometer 32 includes also an outer circular housing 51, which may itself contain a pair of bearing or bushing elements 52 journaling shaft 48 for rotation within housing 51. Housing 51 contains a circular 360° linearly wound resistor wire or element 53, which is electrically engaged by a relatively rotatable contact 54 rigidly attached to and rotatable with shaft 48. The outer surface of body 51 takes the form of a toothed gear, which meshes with and is driven by a worm gear 55, which is in turn driven by a motor 3–M mounted on plate 15.

The positions of the two potentiometers 31 and 32 are indicated to an operator by means of a pair of indicators 56 and 57 driven by two motors 4–M and 5–M respectively. These motors may be driven by null balance systems of the type represented generally in Fig. 1. For instance, in the case of potentiometer 31, the resistance element 34 of the potentiometer is connected to a battery 58 in parallel with the resistance element of a second potentiometer 59. The movable contacts of these two potentiometers are connected to an amplifier 60, whose output is utilized to drive motor 4–M. Motor 4–M in turn is mechanically connected to the movable contact of potentiometer 59 to actuate that potentiometer in accordance with rotation in either direction of motor 4–M. Motor 4–M always returns the movable contact of potentiometer 59 to a position corresponding to that of potentiometer 31, in which position there is no difference in potential between these two movable contacts, and as a result no current flows to the amplifier and motor 4–M. If contact 35 is moved from such a balanced position, a difference of potential is developed between the two movable contacts of potentiometers 31 and 59, causing current to flow to the amplifier and motor in a direction for driving the motor and thereby the movable contact of potentiometer 59 in correspondence with the movement of contact 35 along its resistor. This movement continues until there is again no difference in potential between the two movable contacts. The readout circuit between potentiometer 32 and motor 5–M is the same as that discussed above in connection with potentiometer 31, and includes a battery 58*a*, a readout potentiometer 59*a*, and an amplifier 60*a*. The two indicators 56 and 57 may be of any suitable type, such as suitable mechanical counters which are driven by motors 4–M and 5–M to positions representing directly the positions of the two motors and therefore the settings of potentiometers 31 and 32.

In describing the use of the illustrated apparatus, assume that we are given the rectangular coordinates of a point in a plane, and it is desired to obtain the polar coordinates of that point. The first step is to energize motor 1–M in accordance with one of the rectangular coordinates (parallel to the axes of screws 16), and to energize motor 2–M in accordance with the second and relatively perpendicular coordinate (parallel to screw 23). That is, motor 1–M may be fed an electrical signal, which is suitably controlled, to drive screws 16 until the center of pivotal connection 42 is offset the desired distance or coordinate 61 from center axis 30 in a direction parallel to screws 16. Similarly, motor 2–M is energized for a period sufficient to move block 27 along screw 22 to a point at which the coordinate 62 of pivotal connection 42 with respect to center 30 is the desired value. Such energization of motors 1–M and 2–M accurately positions pivotal connection 42 in accordance with the known rectangular coordinates relative to the center 30. Assuming that motor 3–M and housing 51 of potentiometer 32 are set in a predetermined zero position, indicators 56 and 57 will indicate the polar coordinates of pivotal connection 42 after the defined energization of motors 1–M and 2–M. That is, the setting of potentiometer 31 will correspond to the distance between axis 30 and the center of pivotal connection 42, while the setting of potentiometer 32 will correspond with the rotary position of pivotal connection 42 about axis 30. These settings of the potentiometers 31 and 32 are transmitted to indicators 56 and 57 by means of the previously described readout potentiometers 59 and 59*a*, motors 4–M and 5–M, and associated parts. If it is desired in the particular problem being handled to introduce a correction into the angle indicated by indicator 57 (which indicator preferably reads directly in degrees), motor 3–M may be energized to rotatively displace housing 51 and resistor element 53 of potentiometer 32 relative to pointer 54 and about axis 30, so that the reading at indicator 57 is appropriately corrected. As will be apparent, the illustrated apparatus may of course be utilized in numerous different situations where problems analogous to the one discussed above are to be solved.

I claim:

1. A resolver comprising an element movable in two different mutually perpendicular directions within essentially a predetermined plane and relative to a center axis extending essentially perpendicular to said plane, first means for actuating said element in one of said directions relative to said axis to represent a first coordinate of a point, second means for actuating said element in the second of said directions relative to said axis to represent a second coordinate of said point, a linear motion electrical control unit mounted to swing about said axis and connected to said element in a relation to be actuated thereby in accordance with the distance of said element

from said axis and to thereby control an output signal in accordance with said distance, and a rotary motion electrical control unit having an actuating part mounted for rotary movement about said axis and actuable about said axis in accordance with the rotary positioning of said element thereabout to thereby control an output signal in accordance with said rotary positioning, said rotary motion unit including two sections which are relatively rotatable about said axis one having a resistor element and the other having a contact movably engaging said resistor element, means for rotating a first of said sections about said axis in correspondence with the rotary movement of said element about the axis, and means for rotatively moving the second of said sections about said axis independently of the rotary movement of said first section and to positions of different orientation with respect to said perpendicular directions.

2. A resolver as recited in claim 1, in which said first section carries said contact and said second section carries said resistor element, said linear motion unit being a linear potentiometer connected to said first section for swinging movement therewith about said axis and adjustable radially of said axis.

3. A resolver as recited in claim 1, in which said linear motion unit is connected to one of said sections for swinging movement therewith about said axis.

4. A resolver as recited in claim 1, in which said element is movable by said actuating means to a position at which said point represented thereby coincides exactly with said axis, said linear motion unit including a body portion mounted to swing about said axis with one of said sections of the rotary motion unit but offset from said axis to avoid interference with movement of the element to said axis, said linear motion unit including also a second portion which is actuated by said element relative to said body portion and radially of said axis.

5. A resolver as recited in claim 1, in which said last mentioned means comprises an electric motor for rotatively adjusting said second section about said axis.

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