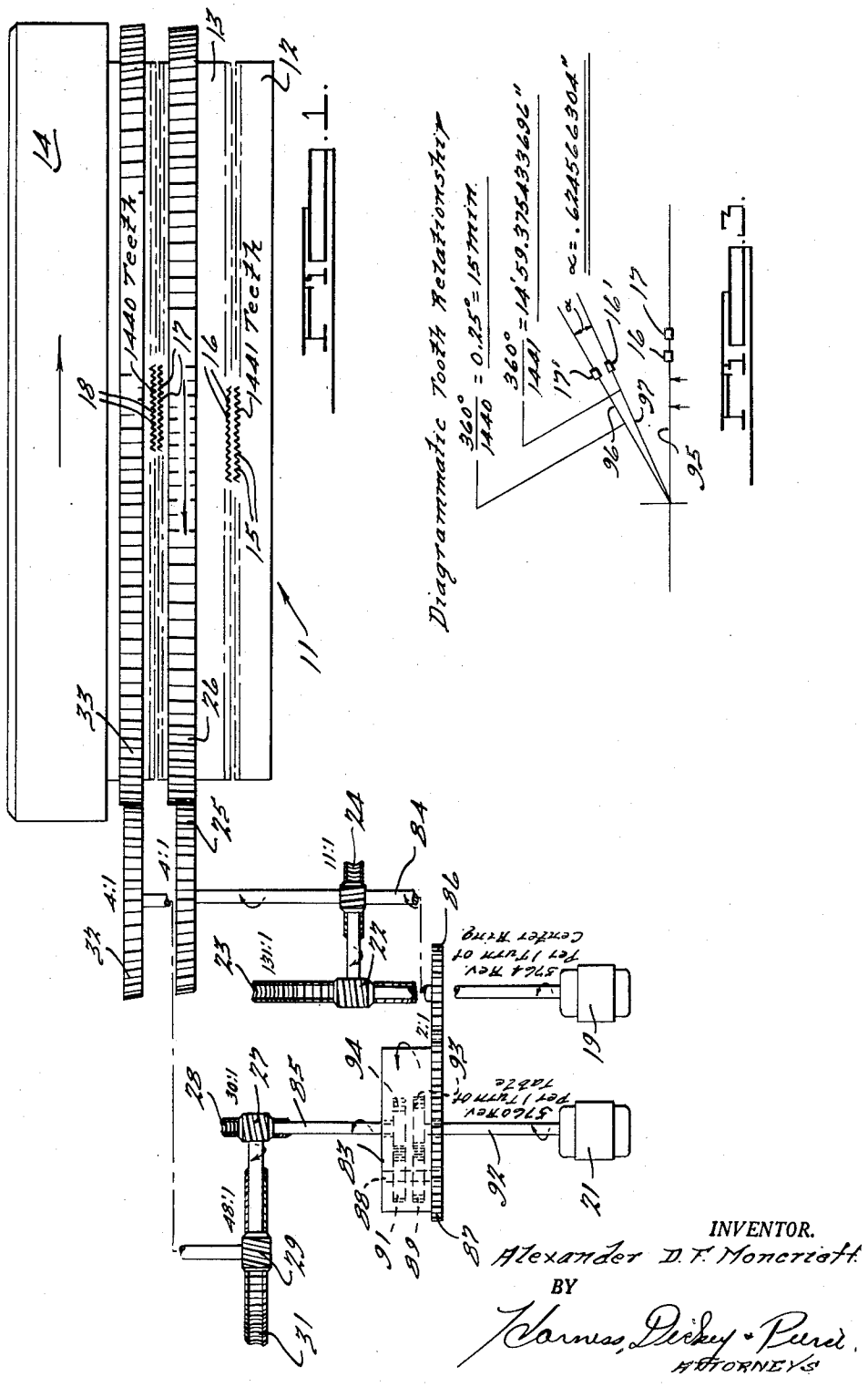
Sept. 1, 1964 A. D. F. MONCRIEFF 3,146,640

INDEXING DEVICE

Filed Aug. 2, 1961 4 Sheets-Sheet 1



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INDEXING DEVICE

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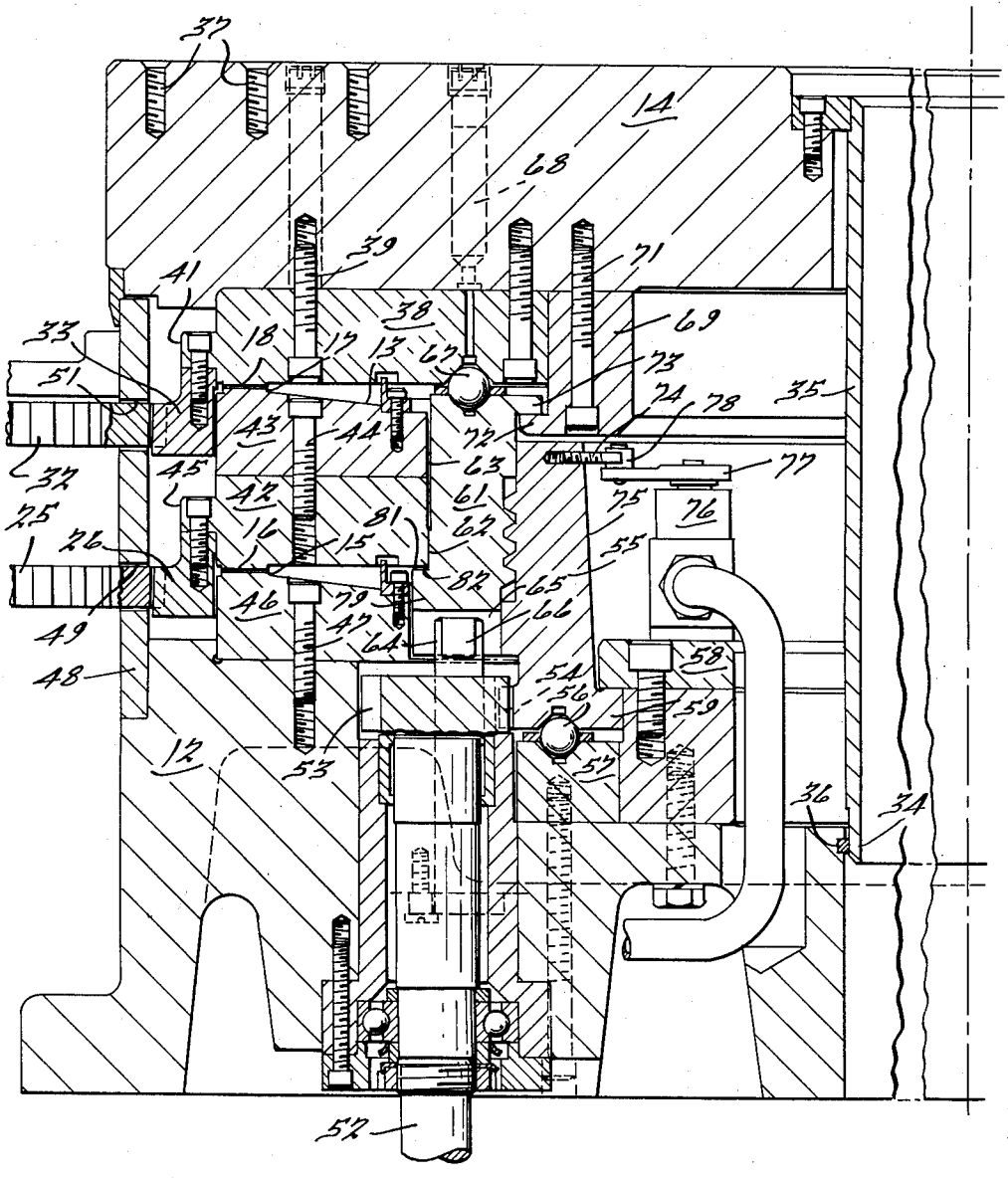

FIG. 2.

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Example Of Dividing 360° Into 7 Equal Parts
N = Required Indexes = 7
n = Index Positions n-1, n-2, n-3, Etc.

Index Position n	I Theoretical Angular Position From Start $\frac{n \times 360°}{N}$ Degrees	Min	Sec.	II No. of Teeth of Table (14) Advanced From The Start Position For Required Index Position Theoretical No. of Teeth $\frac{n \times 1440}{N}$	III Nearest Whole No. of Teeth Which Drive Motor 21 Advances 14	IV Decimal Not Yet Advanced	V No. of Teeth of Center Ring (13) Advanced From Start Position For Advancing Table (14) The Dec. Theoretical No. of Teeth Col. III × 1441	VI Whole No. of Teeth Which Drive Motor 19 Advances Ring 13	VII Actual Angular Position From Start Position In Degrees $= \frac{III \times 360}{1440} + VI \frac{360}{1440 \times 1441} + \frac{III}{A} + VI \times .000139°$ Degrees	Min	Sec.	Error To Required Position I To VII Sec.
n-1	51	25	42.857	205.714285	205	.714285	1029.284	1029	51	25	42.678	.179
n-2	102	51	25.714	411.428571	411	.428571	617.571	618	102	51	25.982	.268
n-3	154	17	8.571	617.142857	617	.142857	205.857	206	154	17	8.660	.089
n-4	205	42	51.428	822.857142	822	.857142	1235.141	1235	205	42	51.930	.089
n-5	257	08	34.285	1028.571428	1028	.571428	823.427	823	257	08	34.018	.267
n-6	308	34	17.142	1234.285714	1234	.285714	411.713	412	308	34	17.321	.179
n-7	360	0	0	1440.	0	0			360	0	0	0

Fig. 4.

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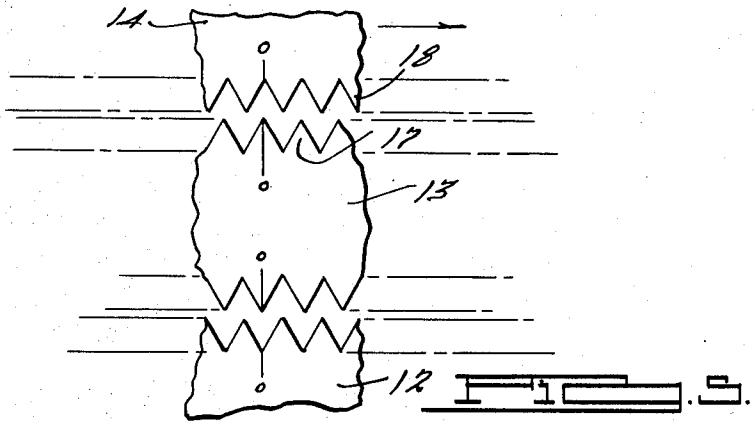

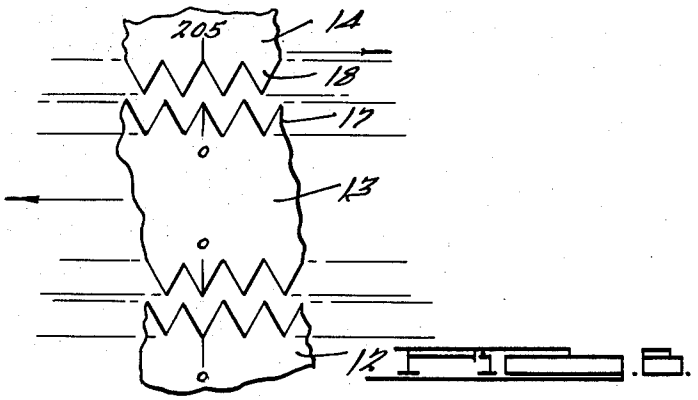

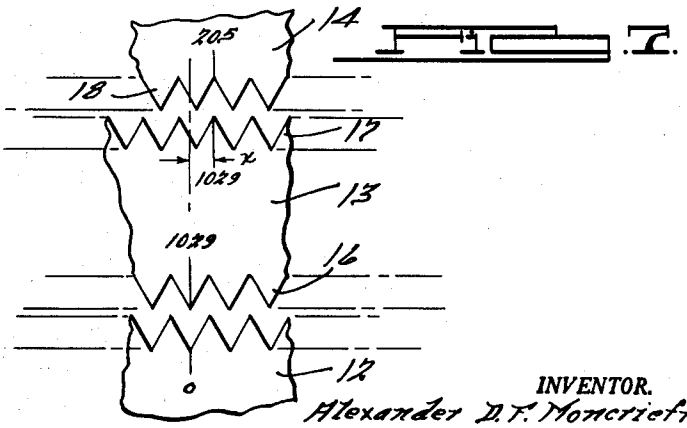

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3,146,640

INDEXING DEVICE

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Filed Aug. 2, 1961, Ser. No. 129,479
24 Claims. (Cl. 74—826)

This invention relates to indexing devices, and more particularly to constructions of this nature adapted to angularly locate workpieces and other objects with a high degree of accuracy for machining, inspection, checking of roundness, the location of objects or similar purposes.

It is an object of the invention to provide a novel and improved indexing device capable of locating objects at different angular positions with an extremely small amount of error, and without the necessity of optical or electrical readings.

It is another object to provide an improved indexing device or dividing head of this nature in which the locating means are arranged in a balanced manner with respect to the axis of rotation of the workpiece support, thereby further contributing to the accuracy and stability of the apparatus.

It is also an object to provide an improved indexing device having the above characteristics which is of relatively simple and reliable construction, requiring little maintenance, and may be adapted for either manual or automatic types of control.

Other objects, features and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a partially schematic side elevational view of the improved indexing device showing the driving trains with the table, center ring and base being illustrated in their separated positions;

FIGURE 2 is an enlarged fragmentary side elevational view in cross section of portions of the base, center ring and table with the means for separating these parts, the parts being shown in their engaged position;

FIGURE 3 is a diagrammatic view showing the relationship between the angular positions of the two sets of teeth;

FIGURE 4 is a chart showing an actual numerical example in which the indexing device is used to divide 360 degrees into seven equal parts;

FIGURE 5 is a diagrammatic view showing the relationship between the four sets of teeth when the parts are in an initial position;

FIGURE 6 is similar to FIGURE 5 showing the teeth after the head has been moved to the first position in column III of FIGURE 4; and

FIGURE 7 is a view showing the parts after the center ring has been rotated to its first index position shown in column VI of FIGURE 4.

In general terms, the illustrated embodiment of the invention comprises a circular base having a relatively large number of teeth (1441 teeth being illustrated by way of example) on its circumference, a center ring disposed adjacent the base, and a supporting table adjacent the center ring. The center ring is shown as having a set of 1441 teeth matching the teeth on the base, and the center ring and supporting table are shown as having matching sets of 1440 teeth each. It will be appreciated however that other ratios may be employed depending upon the accuracy desired.

With the center ring and table initially in a zero position, indexing may be accomplished by first separating the teeth on the center ring and table, and effecting relative rotation between the table and the center ring in one

direction a distance equivalent to be nearest full number of teeth on the table below the theoretically desired angular position. With the center ring gear teeth separate from both the base and the table teeth, the center ring is rotated in the opposite direction a distance equivalent to a predetermined number of whole teeth on the base. In the embodiment illustrated, the ratio of this predetermined number to 1441 is as close as possible to the fraction of a tooth in the 1440 set still needed to advance the table to its true theoretical position.

A differential drive connection between the center ring and the table will advance the table this fraction of a 1440 tooth pitch as the center ring advances so that when the parts are in their final position and the tooth sets are brought together, they will be in matching relationship. The result will be indexing to a position equivalent to 1/1440–1/1441. Moreover, since the indexing device can be adjusted in multiples of 0.6245663 second, the indexing device is capable of indexing within less than one-half a second of arc with extreme accuracy.

Referring more particularly to the drawings, a preferred embodiment of the invention is illustrated and is comprised of an indexing device indicated generally at **11** in FIGURE 1. The indexing device **11** includes a stationary base **12** of circular shape, a center ring **13** and a work-supporting table **14**, these parts being coaxial with the base. Base **12** has a plurality of upwardly facing teeth **15**, 1441 teeth being shown in the illustrated embodiment. These teeth may be of any appropriate shape such as a sawtooth shape and have a relatively small depth, for example, 0.025 inch. Center ring **13** has a matching downwardly facing plurality of teeth **16**, 1441 in number, and an upwardly facing set of teeth **17**, this set having 1440 teeth. Table **14** has a downwardly facing set of teeth **18** matching teeth **17**. It will, of course, be understood that other types of tooth arrangements, such as tooth arrangements employing internal and external teeth may be utilized on the members **12**, **13** and **14**.

Means are provided for rotating center ring **13** and table **14**, this means including motors **19** and **21**, respectively. In order to facilitate use of limit switch positioning devices, the drive ratios between the motors and their respective driven components are such that four revolutions of each motor will cause its respective component to advance the distance equal to one tooth pitch of a particular set of teeth. More particularly, motor **19** drives a worm **22** and a worm wheel **23** having a 131:1 ratio, the worm wheel driving a second worm and worm wheel **24** having an 11:1 ratio, the total ratio thus being 1441:1. Worm wheel **24** drives a pinion **25** meshing with a driven gear **26** secured to center ring **13**, these elements having a 4:1 ratio so that four revolutions of motor **19** will cause center ring **13** to advance the pitch distance of one tooth of tooth sets **15** or **16**.

Motor **21** drives a worm **27** connected to a worm wheel **28** with a 30:1 ratio. Worm wheel **28** drives a worm **29** and a worm wheel **31** with a 48:1 ratio, giving a total ratio of 1440:1. Worm wheel **31** drives a pinion **32** meshing with a driven gear **33** secured to table **14**, these elements having a 4:1 ratio so that four turns of motor **21** will produce a movement of table **14** equal to the pitch of one tooth of sets **17** or **18**.

Details of construction of components **12**, **13** and **14** are shown in FIGURE 2. Base **12** has an annular portion seen in FIGURE 2 within which is disposed the lower end **34** of a cylindrical member **35**, this lower end having a seal connection **36** with the base portion. The upper end of member **35** is secured to table **14**, member **35** accommodating a shaft which may be integrally carried by workpieces (not shown) supported on the table. The table is provided with appropriate apertures **37** for securing the work to the table, and a member **38** carrying

teeth 18 is secured to the underside of the table by bolts 39. Gear 33 is secured to an outwardly extending flange 41 of member 38 and partially overlaps center ring 13, which comprises two parts 42 and 43 carrying teeth 16 and 17 respectively, these parts being connected by bolts 44. Gear 26 is secured to an outwardly extending flange 45 on part 42, this gear partially overlapping a member 46 secured to base 12 by bolts 47, member 46 carrying teeth 15.

If the parts are to be adjusted visually, appropriate indicia may be marked on parts 38, 42, 43 and 46 identifying their teeth by numbers. For example, a zero mark may be carried by part 46, markings to indicate 1441 teeth carried by part 42, indicia indicating 1440 teeth formed on part 43, and markings likewise showing the locations of 1440 teeth on part 38. The location and arrangement of these markings may be varied within the principles of the invention, and the markings may be omitted if limit switch systems controlled by the positions of parts 13 and 14 or the positions of their driving motors are used. A cover 48 mounted on base 12 surrounds gears 26 and 33, pinions 25 and 32 driving these gears through apertured portions 49 and 51 respectively in the cover.

Means are provided for selectively separating the sets of teeth, this means including a vertically positioned shaft 52 rotatably mounted within base 12 and driven by means such as a motor and worm wheel (not shown). The upper end of shaft 52 carries a pinion 53 meshing with a gear 54 formed on the lower end of a lead screw 55. The lead screw is rotatably supported at its lower end by anti-friction bearings 56 carried by a race 57 mounted in base 12, the lead screw being retained against axial movement by a retaining ring 58 disposed above an inwardly directed flange 59 on the lead screw. A nut 61 surrounds lead screw 55 and is disposed within apertures 62 and 63 within parts 42 and 43 respectively. Nut 61 is held against rotational movement by a pin 64 secured to base 12 and extending upwardly into a slot 65 formed in the lower end of the nut, flat surfaces 66 on the upper end of pin 64 cooperating with the slot surfaces to permit axial but prevent rotational movement of the nut.

Anti-friction bearings 67 are disposed between the upper end of nut 61 and the underside of part 38, oil supply means 68 being provided for bearing 67. A retaining member 69 is secured by bolts 71 to the underside of table 14 and has an outwardly extending flange 72 engaging an inwardly extending flange 73 at the upper end of nut 61 to hold the nut against axial movement with respect to part 38.

In the illustrated embodiment having a tooth depth of 0.025 inch the lead of screw 55 and nut 61 is so chosen that an 80° turn of screw 55 will produce a lift for the nut of 0.110 inch. A limit switch operating pin 74 is secured to the upper end of lead screw 55 and extends inwardly within a recess 75 in the lead screw. Pin 74 is shown out of position in FIGURE 2, the purpose of the pin being to actuate a limit switch 76 having an operating arm 77 with a roller 78 engageable by pin 74. In the position of the lead screw shown in FIGURE 2, pin 74 would actually be 80° away from the position shown in this figure. The purpose of limit switch 76 is to stop rotation of lead screw 55 when the 80° turn is completed, that is, when the complete 0.110 inch of lift is attained. When in this position, the four sets of teeth will be separated as will hereinafter appear. The closed or engaged position of the four sets of teeth will determine the other rotational position of the lead screw, so that no limit switch is provided for said other position. Bearings 67 permit accurate rotation of table 14 when its teeth are disengaged but will be loose and in non-interfering relation with the table when the teeth are engaged.

The lower end of nut 61 has an outwardly extending flange 79 with an upper surface 81 which is disposed about 0.055 inch away from the undersurface 82 of part 42. Thus, when lead screw 55 rotates about 40°, surface 81 will engage surface 82. At this point, teeth 17 and 18 will be completely separated, since as was previously indicated, the overlap of these teeth is about 0.025 inch. Further rotation of lead screw 55 the other 40° will cause separation of teeth 15 and 16, permitting rotation of center ring 13 with table 14 still being free of the center ring.

A differential drive 83 is provided between shaft 84 on which worm wheel 24 is mounted and shaft 85 on which worm 27 is mounted. This differential drive comprises a gear 86 on shaft 84 and meshing with a gear 87 secured to the cage of differential 83, this cage being rotatably mounted on shaft 85. Gears 86 and 87 have a 2:1 ratio. Cage 83 carries an offset shaft 88 on which are mounted gears 89 and 91. The end of motor shaft 92 within cage 83 and rotatably connected thereto carries a gear 93, and the adjacent end of shaft 85 secured to worm 27 carries a gear 94. Gear 89 meshes with gear 93 and gear 91 meshes with gear 94. Gears 89, 91, 92 and 94 all have the same number of teeth and are of the same diameter.

It will thus be seen that one revolution of shaft 92 in the direction of its circular arrow will rotate shaft 85 one turn in the same direction. One revolution of shaft 84, however, in the direction of its circular arrow will cause rotation of shaft 85 one turn in the direction of its circular arrow, that is, opposite to the rotation caused by shaft 92. In effect, therefore, table 14 will be advanced in the direction of the arrow in FIGURE 1 $\frac{1}{1440}$ revolution for one full turn of center ring 13 in the direction of its arrow in FIGURE 1. This is because both gears 25 and 86 are mounted on shaft 84.

Pinions 25 and 32 are tapered as shown in exaggerated form in FIGURES 1 and 2, and gears 26 and 33 are correspondingly tapered. The taper is so arranged that when gears 26 and 33 are in their upper positions, that is, when the sets of teeth 15, 16 and 17, 18 are separated, the mesh of pinions 25 and 32 with gears 26 and 33 respectively, will be normal. However, when the parts are in the position shown in FIGURE 2, that is, with tooth sets 15, 16 and 17, 18 in engagement, there will be sufficient backlash between pinions 25 and 32 and their respective gears to permit accurate self-centering of table 14 and center ring 13 when these parts are lowered to bring the tooth sets into interlocking relation, thereby permitting the tooth sets to do all positioning when the tooth sets are engaged without interference from the pinions, gears and bearings.

FIGURE 3 illustrates diagrammatically the angular difference between the pitch of teeth 15 or 16 and the pitch of teeth 17 or 18. In this diagram, if the line designated 95 represents a zero radius, let it be assumed that a tooth 16 and a tooth 17 carried by center ring 13 both have centerlines coincident with line 95. The next adjacent tooth 17′ will be on a line 96 angularly spaced from line 95 by a distance equal to $\frac{360}{1440}$, that is, 0.25° or 15 minutes. The next adjacent tooth 16′ will be on a line 97 angularly spaced from line 95 a distance equal to $\frac{360}{1441}$, that is, 14 minutes 59.375433696 seconds. The difference equals 0.624566304 second.

FIGURES 4 to 7 show an example of the use of the improved indexing device in which it is desired to divide 360° into seven equal parts. Starting from an initial position in which both table 14 and center ring 13 are in their zero position, it can be calculated that a theoretical angular position from the start for the first index position $n-1$ is 51° 25′ 42.857‴. (See column I, FIGURE 4.) Theoretically, table 14 should be advanced 205.714285 teeth (column II) to arrive at the required index position. The nearest whole number of teeth below this amount (column III) is 205.

Table 14 will therefore be raised by rotating lead screw 55, and will be driven by motor 21 from the position of FIGURE 5, in which the zero teeth of sets 17 and 18 are aligned, to the right, until tool No. 205 of teeth 18 is aligned with the zero tooth of teeth 17. This position is shown in FIGURE 6.

At this point the table still must be advanced 0.714285

of the pitch of a tooth **18** (column IV). Since one full rotation of center ring **13** in the direction of the arrow in FIGURE 1 would advance table **14** a full pitch of one tooth **18** in the direction of the arrow shown in FIGURE 1 for table **14**, we must theoretically advance center ring **13** 1029.284 teeth of teeth **16**, as shown in column V. The nearest whole number of teeth **16** is 1029 (column VI). Lead screw **55** is rotated further to lift center ring **13**, separating teeth **15** and **16**. Motor **19** is then driven in the direction of the circular arrow in FIGURE 1 until ring member **13** is driven in the direction of its arrow in FIGURE 6 from the position of FIGURE 6 to the position of FIGURE 7.

When the position of FIGURE 7 is reached, it will be noted that tooth No. 1029 of teeth **17** is not aligned with tooth No. 1029 of teeth **16** but is shifted therefrom a distance x equal to 0.714285 of the tooth pitch of teeth **17**. Due to the differential drive connection **83**, table **14** has been driven in the direction of the arrow in FIGURE 6 at the same time that ring **13** was moved, a distance equal to the same fraction (0.714285) of the pitch of teeth **18**. Teeth **17** and **18** will therefore be aligned, and lead screw **55** may be rotated to reengage the four sets of teeth.

At this point the actual angular position from the start of table **14** is shown in column VII of the chart. If we subtract this figure from the theoretical figure in column I, an error of 0.179″ is noted.

The succeeding index positions n–**1**, n–**2**, etc., are shown in the chart and the manner of attaining them will be obvious from the preceding description. For example, n–**2** will be achieved by rotating table **14** in the direction of the arrow in FIGURE 1 until tooth No. 411 is aligned with the zero mark on base **12**, and ring **13** will then be rotated in the direction of its arrow in FIGURE 1 until 618 teeth of teeth **16** move past the zero mark. At this point, of course, the tooth of teeth **16** aligned with the zero mark will not be tooth No. 618 but will be tooth No. 206 (1029 plus 618 minus 1441).

It will thus be seen that accurate positioning to within less than one-half second of the theoretical position is possible with the present invention. On a 10-inch diameter, one second of arc equals 0.000024 inch, and on a 42 inch diameter it equals 0.000102 inch. The construction as illustrated provides 2,075,040 possible positions (1440×1441).

The fact that table **14** carries a tooth set having 1440 teeth will further contribute to the versatility of the construction, in that exact indexing of 15 minutes is permitted. In many cases, a complete indexing operation may thus be carried out without utilizing movement of center ring **13**.

Motors **19** and **21** could of course be run successively or simultaneously, and the movements are adapted for either visual or automatic limit switch control. In the lowered or locked positions of the table and center ring, an extremely stable support is provided for the workpiece in view of the large bearing area of the teeth and their positions surrounding and spaced from the table axis. The construction of the components, particularly as shown in FIGURE 2, will contribute substantially to the positioning accuracy of the device. For example, the movement control afforded by lead screw **55** and its associated parts, and the tapered tooth arrangement described with respect to pinions **25** and **32**, will facilitate proper location of the table solely by the tooth sets. These and other features of the invention are especially valuable when extremely high accuracy of indexing location is required for objects to be positioned, machined, inspected, or the like.

While it will be apparent that the embodiment of the invention herein disclosed is well calculated to fulfill the objects of the invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. In an indexing device, at least three coaxial elements, a first of said elements having a first set of circularly arranged teeth, a second set of circularly arranged teeth on the second of said elements having a number of teeth different than the first set, a third set of teeth on the third of said elements matching and engageable with said first set of teeth, a fourth set of teeth on said third element matching and engageable with said second set of teeth, means for selectively separating and engaging said first and third sets of teeth, means for selectively separating and engaging said second and fourth sets of teeth, means for rotating said third element with respect to said first element, and means for rotating said second element with respect to said first and third elements, both of said selective means including means for maintaining the separated condition of their respective tooth sets during relative rotation thereof, whereby said relative rotation will take place without tooth contact.

2. In an indexing device, a base having a first set of circularly arranged teeth, a center ring coaxial with said base, a table coaxial with said base and ring, and having a flat workpiece-supporting surface, a second set of circularly arranged teeth on said table having a number of teeth slightly different than said first set, a third set of teeth on said center ring matching and engageable with said first set of teeth, a fourth set of teeth on said center ring matching and engageable with said second set of teeth, means for selectively separating or engaging said first and third sets of teeth, means for selectively separating or engaging said second and fourth sets of teeth, means for rotating said center ring with respect to said base, and means for rotating said table with respect to said center ring and base, both of said selective means including means for maintaining the separated condition of their respective tooth sets during relative rotation thereof, whereby said relative rotation will take place without tooth contact.

3. In an indexing device, a base having a predetermined number of circularly arranged teeth, a table having a second number of circularly arranged teeth different from said predetermined number by one tooth, a center ring disposed between said base and table and having first and second sets of teeth matching said base teeth and table teeth respectively, means for selectively engaging and disengaging said first and second sets of teeth with said base and table teeth respectively, and independently operable means for rotating said table and said center ring relative to said base, said selective means including means for maintaining said table and center ring in separated condition whereby the table and center ring may have relative rotation during operation of each of said independently operable means.

4. In an indexing device, a circular base having a predetermined number of evenly spaced teeth, a circular supporting table having a second number of evenly spaced teeth differing from said predetermined number by a relatively small number of teeth and having a predetermined tooth pitch, a center ring having first and second sets of evently spaced teeth engageable with said base and table teeth respectively, means for selectively engaging and disengaging the table teeth from said second center ring set of teeth, means for rotating said table in one direction, means for selectively engaging and disengaging said first set of center ring set of teeth from said base teeth, means for rotating said center ring in the opposite direction, and means responsive to rotation of said center ring a predetermined portion of a revolution in said opposite direction for advancing said table in said one direction a corresponding portion of said table tooth pitch.

5. The combination according to claim 4, said last-mentioned means comprising a drive motor and drive train for said table, a second drive motor and drive train for said center ring, and a differential gear set connecting said center ring drive train and said table drive train.

6. In an indexing device, a circular base having an odd number of evenly spaced teeth, a circular supporting table rotatable coaxially with said base and having an even number of evenly spaced teeth, a center ring disposed between said base and table and rotatable coaxially therewith, a first set of center ring teeth interfitting with said base teeth, a second set of center ring teeth interfitting with said table teeth, and means for selectively shifting said interfitting tooth sets into and out of interlocking relation, both of said selective means including means for maintaining the separated condition of their respective tooth sets during relative rotation thereof, whereby said relative rotation will take place without tooth contact.

7. In an indexing device, a circular base having an odd number of evenly spaced teeth, a circular supporting table rotatable coaxially with said base and having an even number of evenly spaced teeth, a center ring disposed between said base and table and rotatable coaxially therewith, a first set of center ring teeth interfitting with said base teeth, a second set of center ring teeth interfitting with said table teeth, means for selectively shifting said interfitting tooth sets into and out of interlocking relation, first and second rotary driving means for said base and center ring respectively, and a driving train between each of said driving means and said base and center ring, the reduction ratios of said driving trains being such that said table and center ring will complete one full turn when their respective driving means have completed a predetermined whole number of turns.

8. In an indexing device, a circular base having an odd number of evenly spaced teeth, a circular supporting table rotatable coaxially with said base and having an even number of evenly spaced teeth, a center ring disposed between said base and table and rotatable coaxially therewith, a first set of center ring teeth interfitting with said base teeth, a second set of center ring teeth interfitting with said table teeth, means for selectively shifting said interfitting tooth sets into and out of interlocking relation, a first rotary driving means and driving train for rotating said table in one direction, a second rotary driving means and driving train for rotating said center ring in the opposite direction, and a differential connection between said center ring driving means and said table driving means, said differential connection driving said table in said one direction in response to rotation of said center ring in said opposite direction in proportion to the angular speed of said center ring.

9. In an indexing device, a base having a relatively large number of evenly spaced teeth, a table member rotatable coaxially with said base and having a relatively large number of evenly spaced teeth differing from said first number by one tooth, a center ring member disposed between said base and table member, a first set of teeth on said center ring member interfittable with said base teeth, a second set of teeth on said center ring member interfittable with said table member teeth, means for relatively moving said first and second center ring member teeth and their interfitting teeth into and out of interlocking relation, first means for rotating one of said members in one direction, second means for rotating the other member in the opposite direction, and means interconnecting said first and second rotating means and responsive to rotation of said other member in said opposite direction to rotate said one member in said one direction at a fraction of the angular speed of said second member equal to one over the number of teeth on said table member.

10. The combination according to claim 9, further provided with gears on said table member and center ring member, pinions for driving said gears, said gears being axially shiftable in response to movement of said teeth into and out of interlocking relation, and tapered teeth on said gears and pinions so shaped that each pinion will have a full driving connection when its gear is in one axial position with the corresponding member teeth in non-iterlocking position and a loose driving connection when its gear is in another axial position with the corresponding member teeth in interlocking position.

11. In an indexing device, a circular base having a relatively large predetermined number of upwardly facing evenly spaced teeth, a circular supporting table rotatable coaxially with said base and having a relatively large predetermined number of downwardly facing evenly spaced teeth, the number of table teeth and the number of base teeth differing by one tooth, a center ring having a first set of downwardly facing teeth interfittable with said base teeth, a second set of upwardly facing teeth on said center ring interfittable with said table teeth, means for axially shifting said table between an upper position in which its teeth are separated from said second set of center ring teeth and a lower position in which its teeth interfit with said second set of center ring teeth, means for rotating said table in one direction when in its upper position, means for axially shifting said center ring between an upper position in which its first set of teeth are separated from said base teeth and a lower position in which its first set of teeth interfit with said base teeth, means for holding said table in a position in which its teeth are separate from said second set of center ring teeth when said center ring is in its upper position, and means for driving said center ring in a direction opposite said one direction when said center ring is in its upper position.

12. The combination according to claim 11, further provided with means responsive to driving of said center ring in said opposite direction for driving said table in said one direction at a fraction of the speed of said center ring equal to one over the number of table teeth.

13. The combination according to claim 12, further provided with a first gear member on said table, a second gear member on said center ring, first and second pinion members for driving said respective gear members, and tapered teeth on at least one of each of said pinion and gear members, the tapered teeth on the member for driving said table being so shaped as to have a loose driving connection when said table is in its lower position, the tapered teeth on the member for driving said center ring being so shaped as to have a loose driving connection when said center ring is in its lower position, whereby slight angular shifting of said table and center ring will be permitted when their respective teeth are being interfitted.

14. The combination according to claim 12, further provided with an axially movable shifting member movable from a first position in which said table and center ring in their lower positions to a second position in which said table is in its upper position, and further movable in the same axial direction to a third position in which said center ring is in its upper position and said table is held at the same relative axial position with respect to said center ring as with said shifting member in its said second position.

15. The combination according to claim 14, said shifting member comprising a nut coaxial with said base, said nut having a first portion connected with said table and a second portion spaced a slight axial distance from said center ring when said nut is in its first position, a lead screw threadably mounted in said nut, means for rotating said lead screw, and means for preventing rotation of said nut.

16. In an indexing device, a base, a table above said base, a lifting element between said table and base, means for selectively raising and lowering said lifting element, facing annular raceways on said table and lifting element, anti-friction bearings each of which is movably mounted in both said raceways, and means disposed between said base and table and engageable by a portion of said table when said lifting element is moved to a predetermined lower position to limit the lower position of said table.

17. The combination according to claim 16, the relative positions of said last-mentioned means and said predetermined lower position of the lifting element being such that said bearings are slightly separated from the table raceway when the lifting element and table are in their lower positions.

18. In an indexing device, first, second, and third coaxial elements, a first set of teeth on said first element, a second set of teeth on said second element, a third set of teeth on said third element matching and engageable with said first set of teeth, a fourth set of teeth on said third element matching and engageable with said second set of teeth, a lifting element coaxial with said first, second and third elements, facing raceways on said second element and said lifting element, anti-friction bearings in said raceways, said lifting element being movable between a first position in which said second and fourth sets of teeth are disengaged in a second position in which second and fourth sets of teeth are engaged, and means for moving said lifting element between said positions.

19. The combination according to claim 18, said lifting element comprising an internally threaded nut, and a rotatable lead screw threaded within said nut.

20. The combination according to claim 19, said lifting element raceway being formed at one end of said nut, and a shoulder on said nut engageable with said third element in response to movement of said nut from its second position past its first position, whereby said first and third sets of teeth as well as said second and fourth sets will be disengaged.

21. The combination according to claim 19, said bearings being slightly separated from said second element raceway when said lifting element is in its second position.

22. The combination according to claim 19, further provided with a pair of annular facing raceways between said first element and said lead screw, and anti-friction bearings in said last-mentioned raceways.

23. In an indexing device, a circular base having a first set of upwardly facing teeth and an upwardly facing raceway inwardly of and coaxial with said teeth, a lead screw coaxial with and above said base, a downwardly facing raceway on the underside of said lead screw, anti-friction bearings in said raceways, means for preventing axial movement of said lead screw, a nut threadably mounted on said lead screw, means for preventing rotative movement of said nut, an upwardly facing raceway on the upper end of said nut, an outwardly extending annular shoulder on a lower portion of said nut, a circular table coaxial with and above said base, lead screw and nut, a downwardly facing annular raceway on said table, anti-friction bearings in said last-mentioned raceways, a downwardly facing set of annular teeth on said table having a number different than said first set of teeth, a center ring coaxial with and between said base and table, a first set of downwardly facing teeth on said center ring matching said base teeth, a second set of upwardly facing teeth on said center ring matching said table teeth, said nut having a lower first position in which the four sets of teeth are engaged, an intermediate position in which the table is lifted sufficiently to disengage it teeth from the upper center ring teeth, and an upper third position in which said shoulder engages and lifts said center ring to separate the lower center ring teeth from the base teeth, and means for rotating said center ring and table.

24. The combination according to claim 23, said last-mentioned anti-friction bearings being disengaged from said table raceway when said nut is in its lower position.

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