United States Patent [19]

Leonard

[11] **3,710,751**

[45] **Jan. 16, 1973**

[54] **EXTENDED-SCALE INDICATORS**

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[22] Filed: **Sept. 28, 1970**

[21] Appl. No.: **75,928**

[52] **U.S. Cl.** **116/115.5,** 33/166

[51] **Int. Cl.** **B23q 17/00**

[58] **Field of Search**...........116/115, 115.5, 133, 129; 33/166; 74/10, 813

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Primary Examiner—Louis J. Capozi
Attorney—Paul S. Martin

[57] **ABSTRACT**

Novel extended-scale indicators of various types are disclosed, primarily for milling machine lead-screws. The described indicators include a sprocket on the lead-screw shaft, usually two looped or continuous tapes cogged to the sprocket, and a protective enclosure having idlers that guide the tapes in a compact serpentine path. The lengths of the tapes are related so that one tape precesses in relation to the other in successive sprocket rotations, including extended-scale indication in opposite directions of operation, starting at a common zero. One modification provides direct English-to-metric conversion. Another indicator provides turn-by-turn error calibration of the lead screw. Three identical individually adjustable indicators in tandem, having their zeros offset from each other, provide direct readings for centerline drawing dimensions and for drawing dimensions modified to allow plus and minus cutter off-set. Other tandem indicators are described.

16 Claims, 25 Drawing Figures

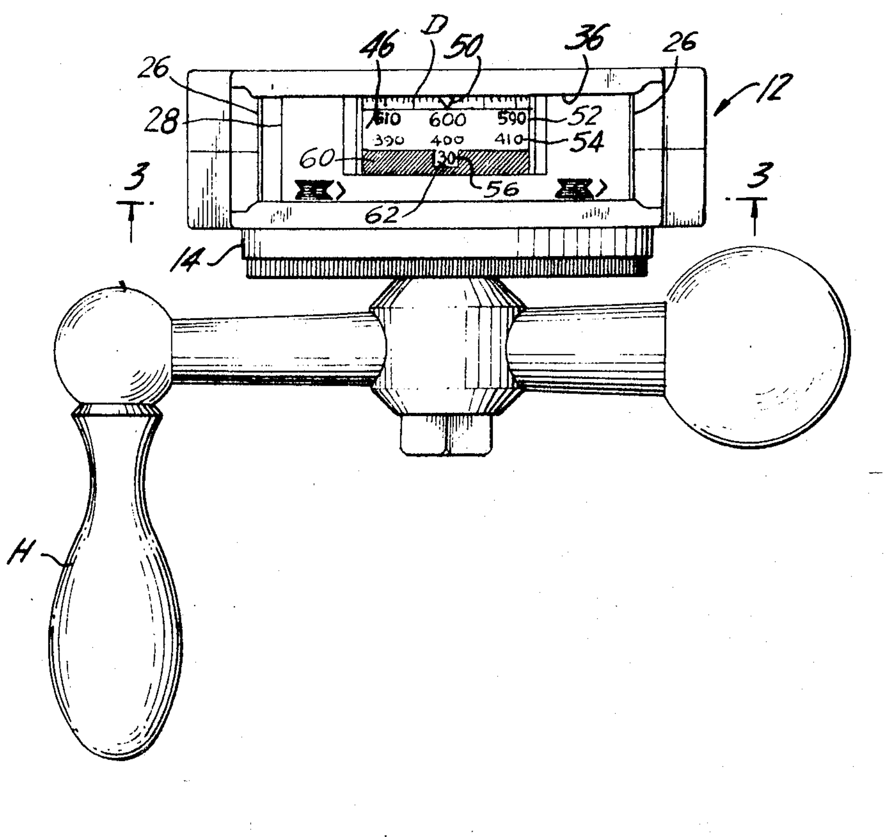


FIG. 2A

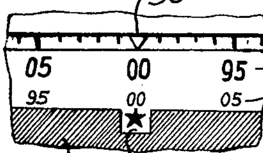


FIG. 1

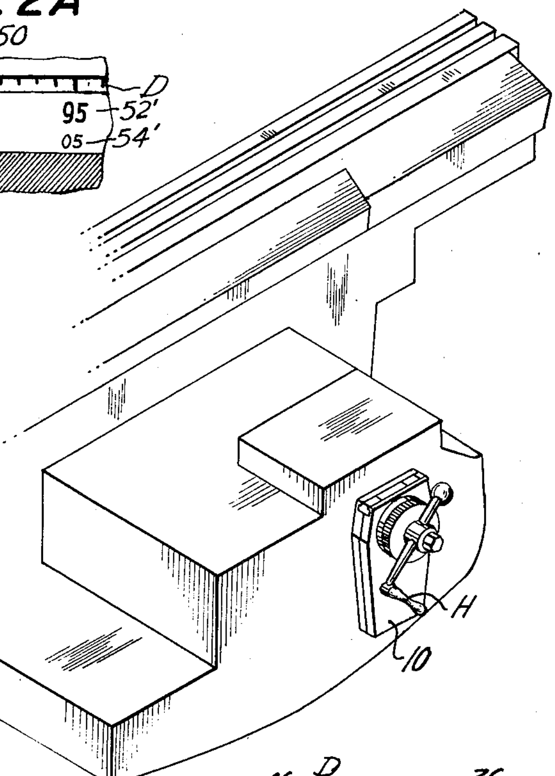


FIG. 4

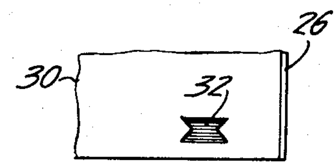


FIG. 5

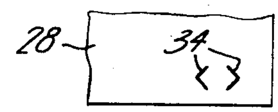


FIG. 6

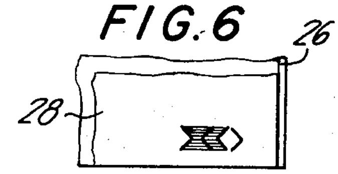
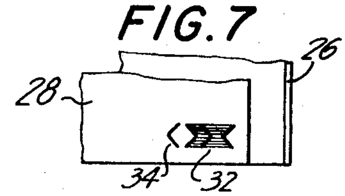


FIG. 7



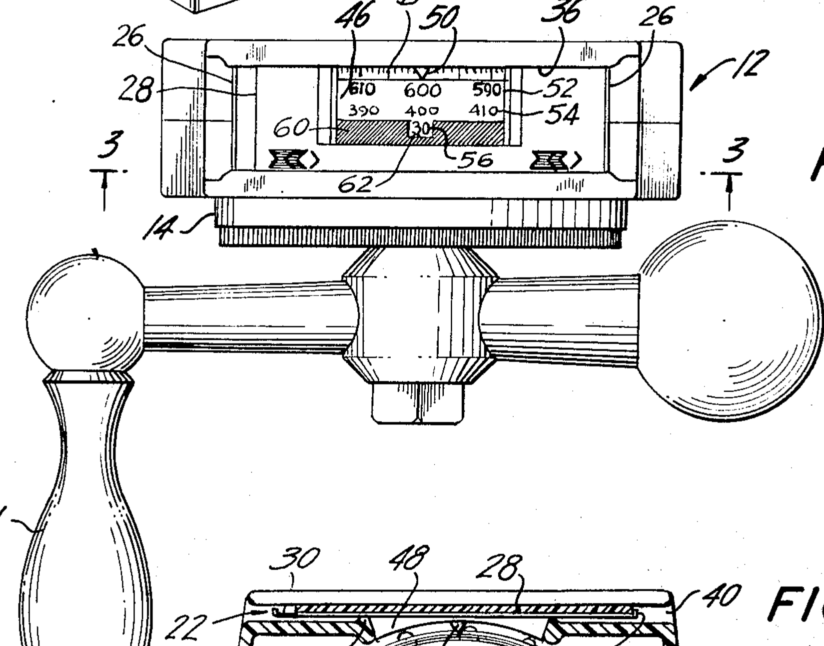


FIG. 2

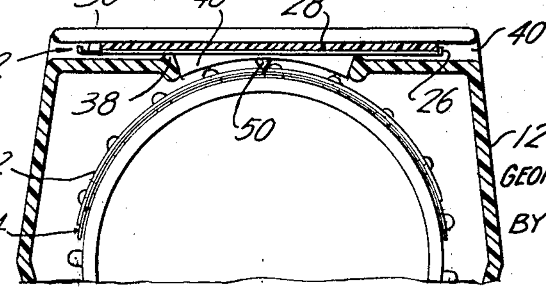


FIG. 3

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FIG. 8

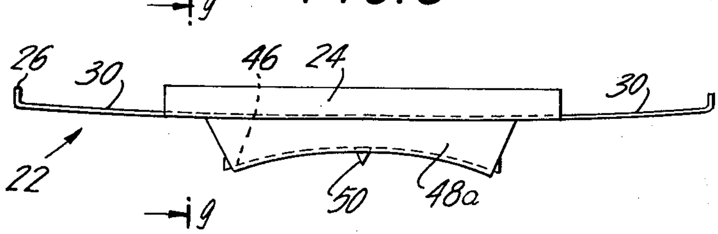
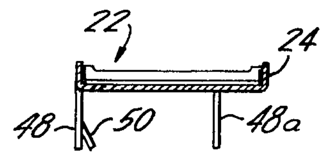


FIG. 9



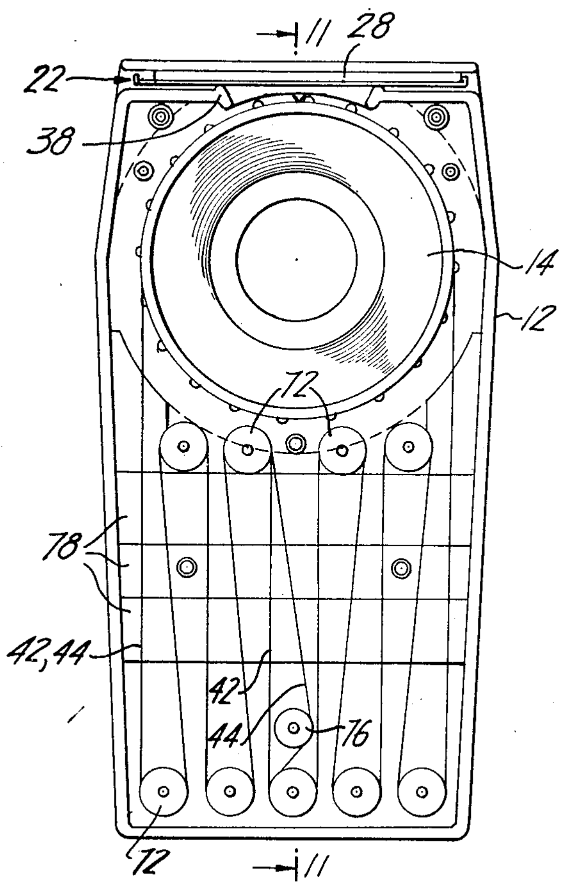


FIG. 10

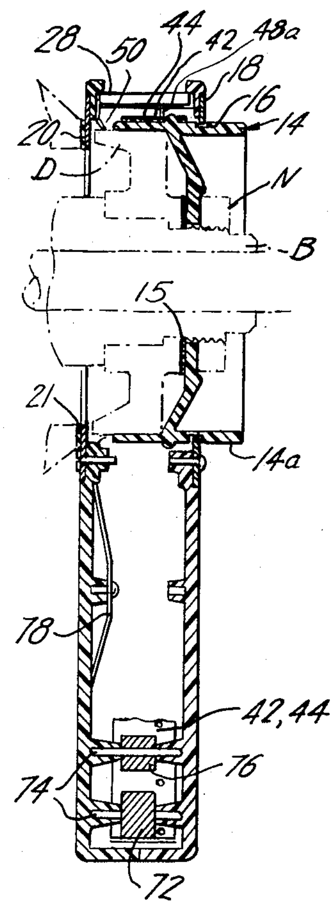


FIG. 11

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FIG. 12

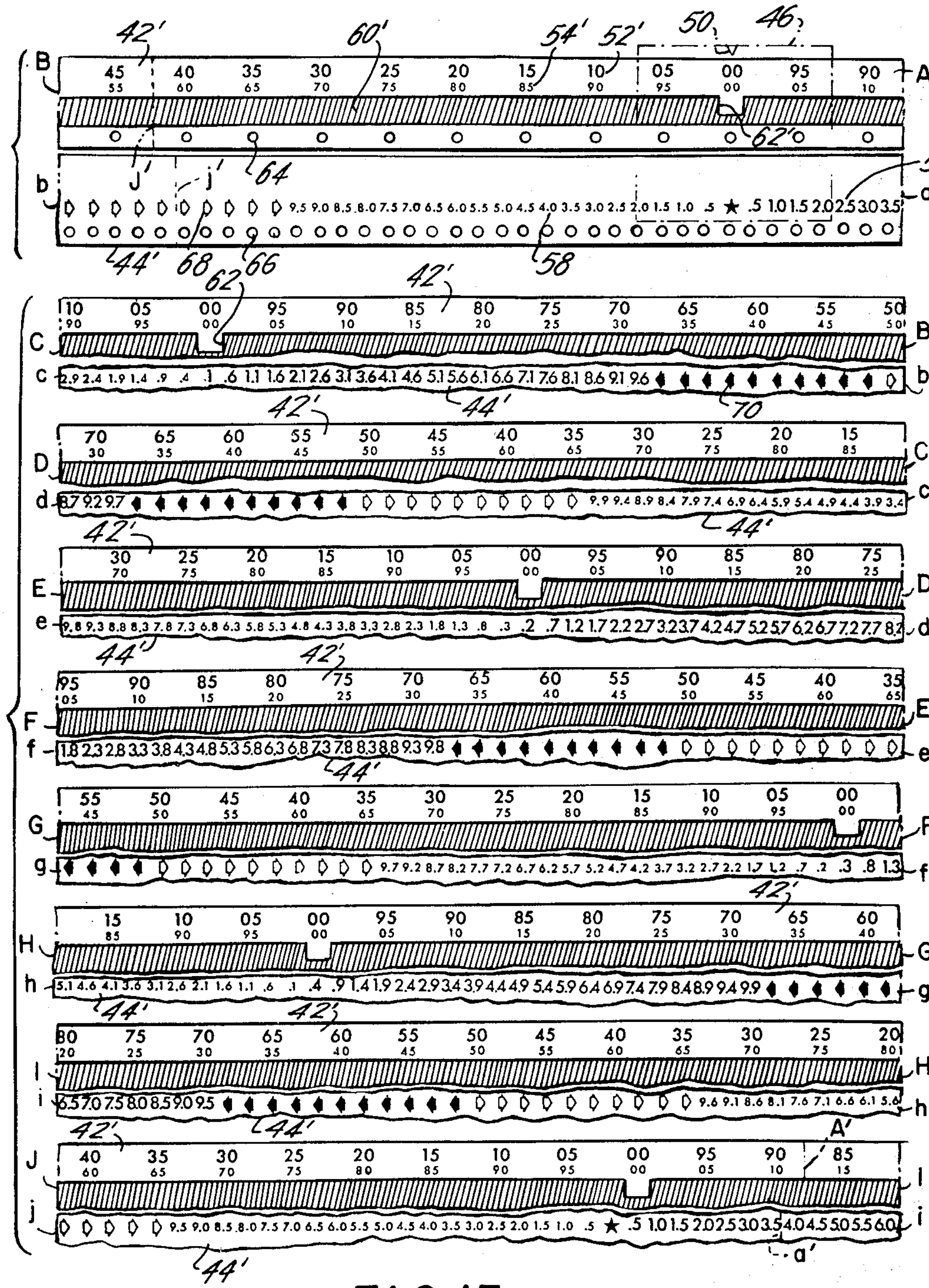

FIG. 13

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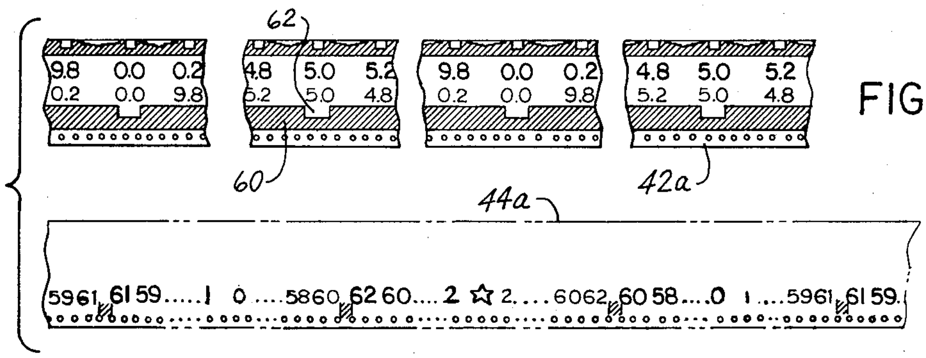

FIG. 14

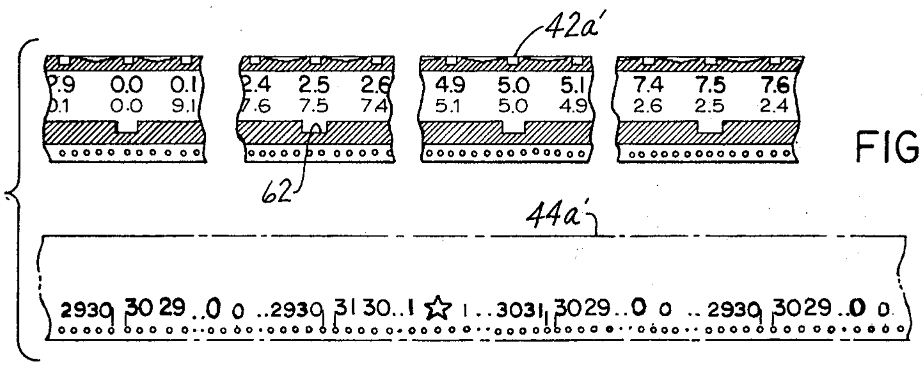

FIG. 15

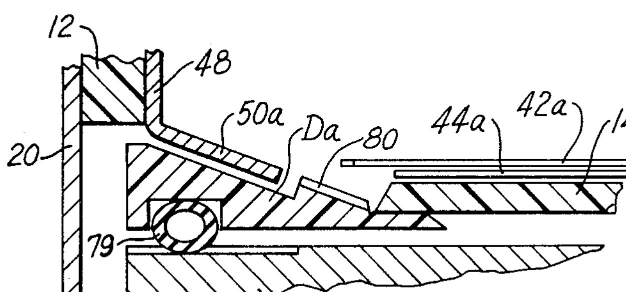

FIG. 16

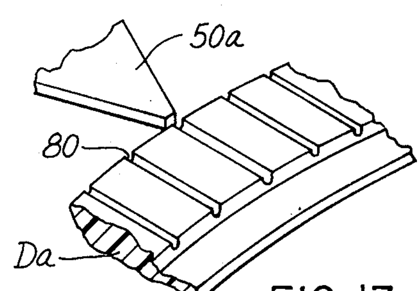

FIG. 17

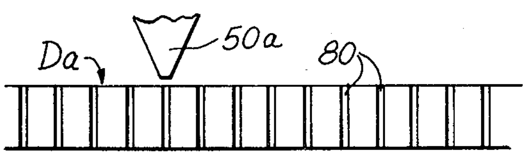

FIG. 18

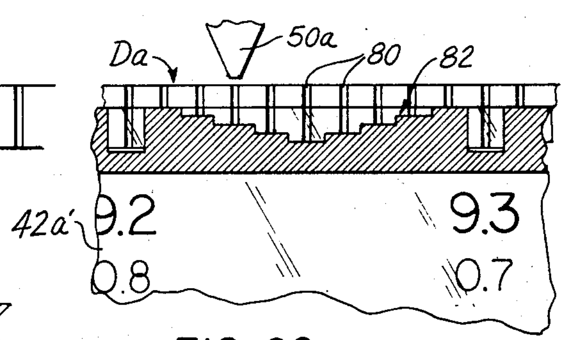

FIG. 20

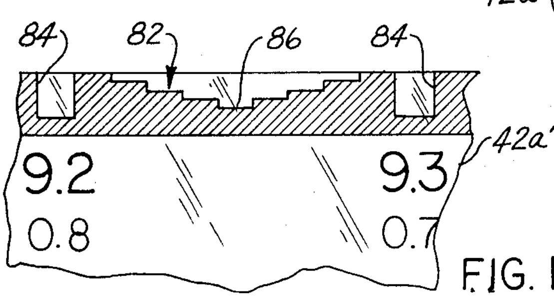

FIG. 19

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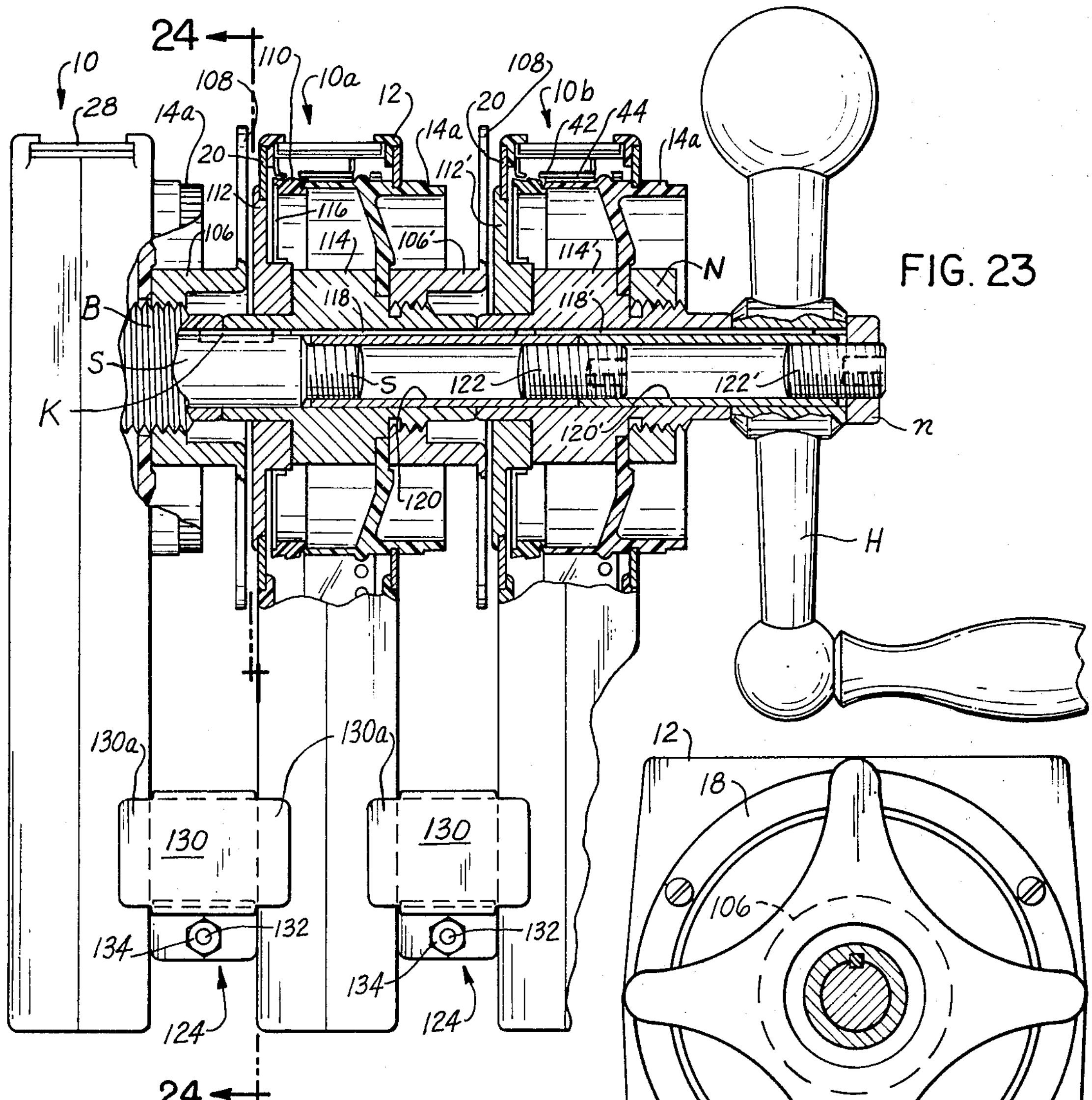

FIG. 23

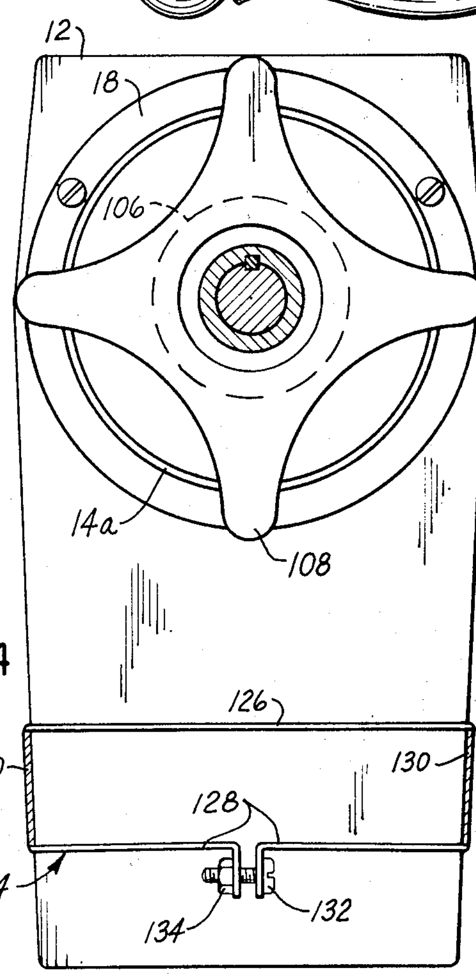

FIG. 24

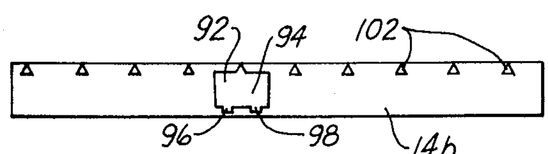

FIG. 21

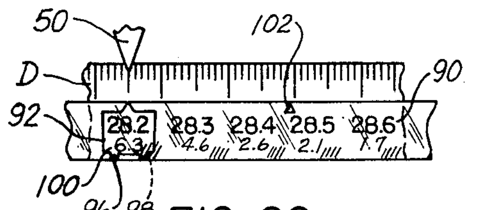

FIG. 22

EXTENDED-SCALE INDICATORS

This invention relates to scale indicators, especially useful for the lead screws of milling machines.

In many respects, the present invention is an improvement over the indicator in my prior U.S. Pat. No. 3,198,165 granted Aug. 3, 1965. That patent discloses an extended-scale indicator including two belts, one bearing small-scale-division numbers and the other bearing large-scale-division numbers. The two belts are operated in unison by a common sprocket at the viewing region. One belt is slightly longer than the other so that the large-division belt shifts incrementally in relation to the small-division belt for each cycle of the small-division belt. A mask forming part of the small-division belt covers most of the large-division belt, but apertures in the mask expose selected large-division numbers successively. Thus, while the numbers of the small-division belt as displayed at the viewing region advance from 0.000 to 0.990 and back to 0.000, the related numbers of the large-division belt as revealed at intervals by the apertures of the mask are (large-division belt vs. small-division belt): 0:0.000; 0:0.250; 0:500; 0:0.750; 1:0.000, continuing to 24:0.000.

In order to provide for the required incremental advance of the large-scale-division belt during a cycle of travel of the small-division belt, the two belts depend as loops of different lengths, held taut by the weight of respective idler pulleys whose axes are at different levels.

The two-belt indicator in that patent serves for indicating a distance from a starting position in one direction. To indicate operation in the reverse direction, both belts are lifted from a sprocket, reversed, and applied to the sprocket so as to display reverse-direction numbers. Pursuant to certain features of the invention, the two-belt indicator described in my patent is improved by making it more compact, by providing an enclosure that keeps the belts clean and protects them from damage, and by enabling operation of the indicator in either direction away from a starting "0.000"b without rearranging the belts on the sprocket.

The indicator in my patent was actually designed dimensionally as an attachment for a Bridgeport milling machine. One tape of the indicator in my patent gives a partial position reading, and the other tape completes a numerical reading each time an aperture of the mask appears at the viewing region. In the patent, an aperture of the mask appears at the viewing region at intervals representing a quarter-inch travel of the table. The table lead-screws of "the Bridgeport" have a pitch of 0.200 inch, so that 1¼ turns of the "Bridgeport" table-position lead-screws are needed to go from one complete numerical indicator reading to the next. Correspondingly, the lead-screw hand crank must be rotated an awkward 1¼ turns from each complete numerical reading to the next. A feature of the present invention resides in providing an indicator that gives a complete numerical reading once (or at least once) for each rotation of the hand crank.

The vertical lead screw of "the Bridgeport" (for table adjustment) has a pitch of 10 turns per inch. A further feature of the invention involves a distinctively different scale concept than in the indicators for the horizontal lead-screws.

The invention also involves novel features of more general application, also being applicable (for example) to multiple-dial indicators. (That type of indicator involves expensive gear coupling between the dials that is avoided in the preferred multiple-belt indicator described below.) As a generic feature, while two series of small-division numbers are displayed corresponding to both operating directions, there is no need to conceal the series not in effect. Only one series of large-division numbers is displayed, corresponding to the selected direction of displacement of the indicator from zero. The selectively displayed large-division numbers have an appearance that provides automatic visual identification with the series of small-division numbers that relate to the selected direction of displacement from zero.

A novel manipulatable reminder is provided, useful with the present extended-scale indicator and other scale indicators, to relate the table location to the reading of the indicator in a way that eliminates back-lash reading error. This is an extremely useful feature, which is added to standard machine tools of the type having inherent lead screw back-lash. Once a sequence of operations is decided, the setting of the reminder indicates the direction that the lead-screw crank should be operated in order to avoid a back-lash reading error, a very large and unacceptable error in many machine tools.

A still further distinctive and important feature of the invention resides in providing an indicator for a lead screw having a standard pitch in one system of units, especially inches, enabling adjustments of the lead screw to be made according to another system of units, especially metric. This is achieved here for "the Bridgeport" by a dual-tape indicator in which a small-division cyclic-number tape has a 500:127 ratio to the circumference of the sprocket, i.e., in which there are 500 sprocket holes (or an integral multiple of 500) and a sequence, effectively, of 127 sprocket teeth, as more fully explained below. The ratio 500:127 is a basic characteristic useful in indicators generally, and is not limited to the Bridgeport.

It will be recognized that, in an indicator having a sprocketed tape, highest standards of accuracy require the scale division marks to be carried by a dial, not by the tape. Lost-motion between the sprocket holes in the tape and the sprocket teeth would be but one source of error were the division marks carried by the tape. However, the circumference of the sprocket would have a number of division marks, equal to 127 times a small integer, e.g., 254 division marks about the sprocket circumference. The cyclic tape with its decimal numbers requires associated large or distinctive division marks every fifth or tenth one of the series of division marks, but the number "254" is obviously not divisible by 5 or by 10. High precision of division marks is here obtained with a tape-to-sprocket ratio of 500:127 by applying 254 division marks to a dial united to the sprocket, together with a gage pattern on the tape associated with the decimal series of numbers on the tape. The gage pattern of the tape establishes the important emphasis for every tenth one of the uniform division marks of the dial on the sprocket, and it also provides subsidiary emphasis for the fifth and other division marks in each group of 10.

A still further feature of the invention involves the concurrent use of multiple interlocked direct-reading indicators for various distinctive results. For example, two direct-reading indicators may be locked together on a common lead screw, one having a "metric scale" in relation to the lead screw and the other having an inch-system scale in relation to the lead screw. These indicators can be used for converting dimensions between the metric and inch systems; and these two indicators can also be used for adjustment of a machine tool in machining operations following a drawing having dimensions in both metric and inch systems. In another example, three identical indicators on each of the table lead screws of a milling machine can be used together to avoid calculations involving center locations as well as dimensions of the extremities of a cut made by a milling cutter of specified diameter. One of the three indicators is set to indicate centerline dimensions, a second indicator is set to indicate centerline-plus-cutter-radius, and the third indicator is set to indicate centerline-minus-cutter radius. Depending on the particular drawing dimensions being followed, different indicators are available for use directly, avoiding calculations involving the cutter diameter. Multiple complements of indicators locked together can also serve in executing sequences of machining operations to make multiple parts successively using a common piece of stock clamped to the work table.

In these and many other uses of tandem indicators, it is usually desirable and sometimes vital for each indicator to be separately adjustable and then individually locked to the lead screw while another indicator is(or is not) locked to the lead screw.

Accordingly, a feature of the invention resides in providing a lead screw, especially a lead screw in a milling machine, with a succession of indicators that are individually adjustable relative to the lead screw and which can be individually locked to the lead screw in their respective adjustments.

Many machines using a lead screw and a dial or a direct-reading scale for positioning an element, especially the table of an old and worn milling machine, have an inherent cause of inaccuracy, namely, the variations in the pitch of the lead screw along its length. A feature of the invention resides in providing the lead screw with an indicator that can be calibrated by the machine attendant to provide a correction value at each turn of the lead screw, in this way providing extended-scale, virtually continuous readings over all or any desired part of the operating range, to enable on old, worn or otherwise inaccurate machine to function with the accuracy of a new one. By this means, needed corrections in a worn milling machine of as much as 0.010 and more can be made known and available. The milling machine can then be operated to jig-borer accuracy, to a fraction of a thousandth.

The foregoing and other objects and novel features and their advantages are more clearly evident in the illustrative embodiment of the invention as shown in the accompanying drawings and described in detail below. In the drawing:

FIG. **1** is a fragmentary perspective of part of a milling machine drawn to reduced scale, showing a novel extended-scale indicator as an illustrative embodiment of the invention, coupled to the cross-feed operator.

FIG. **2** is a top plan view of a novel extended-scale indicator and the cross-feed operating handle of the milling machine of FIG. **1**, drawn to approximately full scale.

FIG. **2A** is a fragmentary top plan view of the viewing region of the indicator of FIGS. **1** and **2**, including another form of scale useful for the vertical feed screw of the same milling machine, the indicator being shown in its "common zero" position in readiness for operation in either of two opposite directions.

FIG. **3** is a fragmentary cross-section of the novel extended-scale indicator as seen from the plane **3—3** of FIG. **2**.

FIG. **4** is an enlarged fragmentary top plan view of a portion of a support for the transparent cover of the novel indicator, including a portion of a signal for indicating the direction of operation of the milling machine lead-screw to avoid back-lash error.

FIG. **5** is an enlarged fragmentary top plan view of a portion of the transparent cover of the novel indicator showing another portion of the signal for indicating the direction of lead-screw operation to avoid back-lash error.

FIGS. **6** and **7** are enlarged fragmentary views showing the parts of FIGS. **4** and **5** assembled so that the signal parts of FIGS. **3** and **4** complement each other to form direction signals to show operation of the novel extended-scale indicator to the right and to the left, respectively, in the direction required to avoid backlash error.

FIG. **8** is an enlarged front elevation of the cover support of FIG. **4**.

FIG. **9** is a cross-section of the cover support of FIGS. **4** and **8** as viewed from the plane **9—9** in FIG. **8**.

FIG. **10** is a front elevation of the novel indicator drawn to reduced scale and with the front half of a two-part enclosure removed.

FIG. **11** is a vertical cross-section of the novel indicator as viewed from the plane **11—11** in FIG. **10**.

FIG. **12** is a fragmentary view of the two extended-scale belts shown side-by-side, for use assembled in the novel indicator as in FIG. **2A**.

FIG. **13** is an approximately full-scale drawing of successive segments of the endless belts of FIG. **12** showing the entire length of the belts with some duplication, illustrating their relationships that become effective as the belts are advanced past the viewing region of FIG. **2A**.

FIG. **14** is a fragmentary illustration of the continuous tapes to be incorporated in an extended-scale indicator like that of FIGS. **1–11**, for providing a 0.200-inch lead screw with metric readings.

FIG. **15** is a fragmentary illustration of continuous tapes like those of FIG. **14**, for providing a 0.100-inch lead screw with metric readings.

FIG. **16** is an enlarged fragmentary cross-section of a modification of the dial-sprocket-pointer assembly for the extended-scale indicator of FIGS. **1–11**.

FIGS. **17** and **18** are an enlarged fragmentary perspective and an enlarged top plan view, respectively, of the pointer and the dial in FIG. **16**.

FIG. **19** is an enlarged fragmentary view of a small-scale-division tape shown in FIG. **15**.

FIG. **20** is an enlarged plan view showing the parts of FIGS. **18** and **19** assembled in operative relationship.

FIG. 21 is a developed view of the cylindrical face of a modified sprocket for a further modification of the indicator of FIGS. 1–11.

FIG. 22 is an enlarged detail showing a portion of the sprocket of FIG. 21 together with associated parts of this further modification of the extended-scale indicator of FIGS. 1–11.

FIG. 23 is a side elevation of three tandem indicators like that of FIGS. 1–11, shown partly in cross-section along the shaft axis therein, illustrating still further aspects of the invention.

FIG. 24 is a cross-section of the assembly of FIG. 23 as viewed from the section line 24—24 therein.

In the drawings, the illustrative form of extended scale indicator **10** is shown installed on a Bridgeport milling machine. Indicator **10** includes an enclosure **12** that is made of identical front and rear molded parts. A sprocket **14** (FIGS. 3, **10** and **11**) has a groove **16** which receives a split or segmented ring **18** secured to enclosure **12** to exclude dirt. Sprocket **14** encloses the standard dial D of the milling machine cross feed, leaving exposed the original scale divisions. Sprocket **14** is adjusted in relation to the scale divisions of the dial D, and the two are held in adjustment by double-faced adhesive tape **15** (FIG. **11**). Socket **14** and dial D as a unit are clamped to bushing B and handle H of the milling machine cross feed. At the rear, ring **20** bears a double-faced adhesive overlay **21** that adheres the enclosure **12** to the fixed structure of the milling machine, with ring **18** concentrically in groove **16**.

FIGS. 3–9 illustrate the construction of the extended-scale indicator at the region where the scale numbers are to be viewed. Resilient sheet-metal face member **22** has upstanding flanges **24** that form longitudinal guides for a transparent cover plate or bezel **28**. Member **22** has resilient panels **30** that are curved upward and have upstanding flanges **26** at their extremities. Flanges **26** limit the lengthwise shift of cover plate **28**. Because the cover plate is a little shorter than the distance between flanges **26**, the cover plate can shift a short distance lengthwise.

As seen in FIG. 4, part **32** of a direction signalling arrow is printed on panel **30**. Arrow part **32** has each of its ends notched to suggest an arrow tail. Transparent plate **28** has two oppositely directed arrow heads **34**. The arrow part **32**, arrow heads **34** and the extend of longitudinal shift of plate **28** between flanges **26** are proportioned so that, with plate **28** shifted to the right against one flange **26** (FIG. **6**), the right-hand arrow head **34** and arrow part **32** form a composite arrow pointing to the right. The left-hand arrow head **34** is virtually unnoticeable because it overlies and blends with arrow part **32**, both being dark. Shift of plate **28** to the extreme left as limited by the other flange **26** results in a composite arrow **32, 34** pointing to the left. As will be seen, this direction signal will be found useful in indicating to the machinist the direction he should operate the cross feed for reaching any given position. Panels **30** are resilient, and they bias plate **28** against the inside surface of the enclosure, sealing the viewing opening **36** of the enclosure against dirt. As seen in FIG. 3, member **22** rests against a pair of ribs **38**. Groove **40** is wide enough to allow panels **30** to be deflected downward far enough to remove flange **26** from the lengthwise path of cover plate **28**. This arrangement facilitates assembly of plate **28** into position over member **22**; it makes easy the removal and replacement of the cover plate (in case it should become badly scratched) and it provides spring bias to hold cover plate **28** in its sealing position covering the frame opening **36** of the enclosure.

Two endless belts **42** and **44** band overlie sprocket **14** in the space between the front and rear walls of enclosure **12**. Preferably, both belts are of transparent plastic film, and the portion of sprocket **14** behind the indicia-bearing areas of the belts in a bright color such as yellow or white. Face member or plate **22** has a belt-display opening **46** (FIG. **2**) partially framed by parts **48** and **48*a*** that are bent down out of the body of member **22**. A pointer **50** is struck out of part **48**. Pointer **50** extends close to the dial division marks of dial D, so that the original accuracy obtainable with the dial is preserved in the illustrated indicator. Part **48*a*** has arcuate clearance from tape **42**, but only a little clearance, so that part **48*a*** prevents the tapes from losing registration with the sprocket teeth.

An indicator containing belts or tapes **42** and **44** is especially useful for each of the table lead screws of the Bridgeport, which have a lead-screw pitch of 0.200 inch. Tape **42** has two series of numbers **52** and **54** that are of contrasting appearance. The numerals of these two series extend in two rows (as shown) all the way around the tape. The circumference or loop-length of tape **42** is five times the circumference of sprocket **14**, so that one-fifth of each series of numbers travels past pointer **50** in the viewing region each time sprocket **14** completes one full rotation. Each number series extends from zero to 1,000, at intervals of "10," **thus**: 000, 010, 020, 040 . . . 970, 980, 990 and back to 000. Consequently, if 000 is located at pointer **50** and sprocket **14** is rotated five times, the numbers 200, 400, 600, 800 and 000 appear at pointer **50** at the completion of the successive sprocket rotations. One series increases for one direction of rotation and the other series increases for the opposite direction of rotation. Beyond five sprocket rotations, the number series repeats, and hence the numeral series of belt **42** are cyclic.

Tape **42** has an opaque stripe **60** that overlies two series of numbers arranged in a row on tape **44**. There are apertures **62** in strips **60** adjacent numbers 000, 200, 400, 600 and 800 of tape **42** at the ends of successive complete sprocket rotations. There are 100 sprocket holes in tape **42**, one hole opposite each number, and there are 20 sprocket teeth on sprocket **14**.

Tape **44** has two series of numbers arranged in a row underlying stripe **60**. There are three sprocket holes in tape **44** in the linear space allocated to one sprocket hole of tape **42**. There is one sprocket hole opposite each number of tape **44**. The length of tape **44** is greater than that of tape **42** by the pitch of one sprocket hole of tape **44**. Consequently, when tape **42** is advanced one complete cycle past the viewing region, tape **44** advances less than one complete rotation, to the extent of the space allocated to one sprocket hole of tape **44**, that is, the small pitch of the sprocket holes of tape **44**. In the course of repeated rotations of sprocket **14**, tape **44** precesses one small sprocket-hole pitch. There are 301 sprocket holes in tape **44**.

At the end (or start) of successive rotations of sprocket **14**, starting with number 000 of tape **42** located opposite to pointer **50**, apertures **62** expose successive numbers of tape **44**. This occurs once for each full rotation of handle **14**, and is especially convenient to the machinist. Starting with "*" which represents a common zero of two series of numbers in a row on tape **44**, there are two series of numerals of contrasting appearance. Any one of these numbers complements the particular number of tape **42** that is opposite pointer **50**. Thus, number 3 (for example) on tape **44** may be located opposite pointer **50** adjacent number 600 of tape **42**, and this represents number 3.600 or a table position 3.600 inches away from that which existed when the "*" common zero was opposite pointer **50**. Two series of numbers can appear in apertures **62**, one series corresponding in appearance to numbers **52** and the other series corresponding to series **54**. Each series includes the following numbers, listed in the order of their display through apertures **62**: *, 0, 0, 0, 0, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3 . . . 28, 28, 29, 29, 29, 29, 29 and then arrow. In the course of many rotations of the sprocket, the sprocket teeth enter every hole in tape **42** and every third hole in tape **44**, and yet the sprocket holes that are "skipped" in one complete traverse of tape **44** past the viewing region are entered by sprocket teeth in the next two complete traverses of tape **44** past the viewing region. The indicator thus covers 30 inches of table travel in each direction from * as a continuous scale complemented by the scale divisions of dial D.

The vertical lead screw of a Bridgeport milling machine has a pitch of 0.100 inch. An indicator having tapes as shown in FIG. **2A** and in FIGS. **12** and **13** cover a 20-inch range of that lead screw. Numbers for the parts of this indicator are the same as the numbers of corresponding parts of the 0.200-inch-pitch indicator, but here they are primed. Belt **42'** has two series of numbers **52'** and **54'** that are of contrasting appearance. Belt **44'** has two series of numbers and other indicia that also contrast in appearance. Series **52'** matches the appearance of series **56'**, and series **54'** matches the appearance of another series **58'**. In FIGS. **12** and **13**, the belts are shown side-by-side, but they have the same relative positions (lengthwise) that they would have when assembled in the indicator with belt **42'** overlying belt **44'**. An opaque strip **60'** on belt **42'** overlies the indicia **56'** and **58'** of belt **44'** when the belts are assembled. Stripe **60'** is a mask that conceals indicia **56'** and **58'** except at intervals where the stripe has mask openings **62'**. These openings occur, in the case of the belts shown, opposite the zeros of both series of numbers **52'** and **54'**. Belts **42'** and **44'** have sprocket holes **64'** and **66'**, respectively, identical in number, distribution, etc., as has already been described in the case of tapes **42** and **44**.

Two broken-line representations of display opening **46** of member **22** are shown in FIG. **12**, representing the condition shown in FIG. **2A**. In this condition pointer **50** is opposite "00" and "oo" and it is also opposite the "*." This last symbol is the "common zero" or starting point for both directions of motion of the belts or tapes past display opening **46**.

It may now be assumed that the belts or tapes are operated from left to right past viewing opening **46**, utilizing the ascending large-size series of numerical indicia. The sprocket causes both belts to advance equally, in unison. The large-face numbers advance from "00" to "45" near the imaginary break B in belt **42'** at the left of FIG. **12**, continuing from B at the right in FIG. **13**, to "50" and back to a new "00." As belt **42'** advances past display opening **46**, mask aperture **62'** initially exposes the common-zero symbol "*" and mask **60** then conceals all of small-face number series **58'**, "off-scale" arrows **68'** and **70'**, and most of large-face number series **56'**. When the belt **44'** arrives at ".1" of number series **56'**, the next aperture **62'** exposes that number. Thus, for the first group of numbers "00" to "00" of series **52'** on belt **42'**, the numbers of series **56'** advance from zero to .1, for a change in the composite reading from ".000" to ".100." Accordingly, both belts are advanced in unison, and group (00 to 95) after group (00 to 95) of numbers in series **52'** pass the viewing opening **46**, one such group for each rotation of the hand crank. Mask apertures **62'** successively display "*", ".1", ".2", ".3", ".4", and ".5" of the large-scale-division series of numbers **56'**. In this sequence from "*" to ".5", tape or belt **42'** has completed one cycle past viewing opening **46**, and longer tape belt **44'** has advanced only one increment less (in the illustrated example). Continued advance of the belts brings numbers .6 to 1.0 and so on up to 9.9 into view for a maximum scale reading of 9.900 at that point and effectively to a reading of 9.995 in the course of the further advance of the belts. As shown in FIGS. **2** and **11**, the sprocket drum **14** complements the dial D of the Bridgeport milling machine which bears index marks subdividing the readings at pointer **50** from "00" to "05" into five places. Thus the extended scale reading here reaches 9.999, representing 10 inches of vertical feed, shown by 90 feet of travel of belt **42** whose circumference, in an example, is substantially 4½ feet long. Reverse operation of the extended scale indicator produces a further indication from "*" to 9.999 in another 90 feet of belt travel. When both extremes of "9.9" are exceeded, the scale shows "overshoot" arrows **68** and **70**, pointing the direction needed to manipulate the extended-scale indicator back into the numerical range. If a range greater than 9.9 of the large-scale-division tape were wanted, then 10.0 etc. or equivalent could be provided to the limit 15.0 for this tape.

The points in the belt represented by breaks A and *a* at the right of FIG. **12** (to the right of "90" and "3.5", respectively) incur a relative shift by the time ".5" is advanced into position opposite "00" as represented at the bottom of FIG. **13**. This shift is represented by the relative off-set between broken-line markers A' and *a'* at the bottom of FIG. **13**, representing the same points A and *a* of FIG. **12**. The The reverse relative shift would occur in one full reverse cycle of belt **42**, so that points J and *j* at the bottom of FIG. **13** would be related as J' and *j'* in FIG. **12**. Belt **44** has a sprocket hole opposite each significant number or other index mark that is to be located opposite 00 of belt **42**.

The depending lengths of belts **42** and **44** in the example above, if draped over sprocket **14**, would be about 2 feet. Enclosure **12** contains common idler pulleys **72** on respective pins **74**. These pulleys shape belts **42** and **44** into a compact serpentine or labyrinth-like configuration, and pulley **76** takes up the slack of the slightly greater length of belt **44**. Plate **78** is a lateral guide for the edges of the belts, directing the belts into proper position for cooperation with the teeth of sprocket **14**.

The belts move in unison past the viewing opening **46** in face member **22**, but because of the difference in their loop lengths the longer (inner) belt **44** advances an "increment" less than one full cycle each time belt **42** completes a cycle. This relative shift results in a change of the scale number that is displayed, but the shift does not involve relative sliding between the belts in their serpentine or labyrinth-like path over idlers **72**. Even though belts **42** and **44** are in face contact along nearly their whole lengths (excluding the short part of belt **44** that is diverted by idler **76**) there is no serious wear problem.

The extended-scale indicator that is added to the milling machine does not degrade the precision of the original milling-machine dial. As already noted, the divisions of dial D are utilized, and the dial and the sprocket are united in a way that precludes both erratic and progressive errors.

The common zero "*" or any other scale reading can be set in position for any job being done by loosening nut N (FIG. **11**), and manipulating knob portion **14***a* of the sprocket to set the indicator to the desired position and then locking sprocket **14** to the milling machine cross-feed by tightening nut N. With the nut N loose, the handle H can be manipulated for operating the table to any desired position without materially changing the indicator reading. This is because a limited amount of friction inherently present in the indicator resists shift of the indicator tapes out of any given reading. This friction will be found at many places, notably at the tape supporting parts including the sprocket **14**, rollers **72**, etc. In this way the table can be set at a desired starting position in relation to a given reading of the indicator.

The reversible arrows **32**, **34** form an important adjunct to the extended scale indicator for the milling machine lead screws. A certain amount of looseness or play is characteristic of lead screws. This play can be nullified as a source of error in many sequences of operations requiring exact setting of the table position by consistently approaching each required table setting by operating the lead screw consistently in the same direction for approaching and reaching each new setting. In the course of a series of such settings, it may be necessary to reverse the motion of the lead screw to reach a particular setting, but even then, the lead screw should be operated more than required in that reverse motion, completing the adjustment by operating the lead screw in the adopted consistent direction used in the other settings of a sequence. That direction is used consistently, with the aid of the direction-of-adjustment signal arrows.

A slightly modified structure compared with that already shown and described can be used in the Bridgeport, and for English-system lead screws generally, in converting such machines to settings according to the metric system. For example, it has already been noted that the table lead screws of the Bridgeport have a pitch of 0.200 and that the lead-screw indicator makes precisely one complete rotation

in operating the table through a distance of 0.200 inch. In accordance with a feature of the invention, a metric extended-scale indicator can be formed largely as shown in FIGS. **1–11** and thus far described, to replace or to supplement the existing dial.

A ratio of 25.4 to 10.000 has been accepted as a valid approximation for conversion of inch dimensions to millimeters. This is basic to the metric extended-scale indicator now to be described.

In an embodiment of a metric indicator for an "inch-system" lead screw, sprocket **14** is equipped with **127** sprocket teeth and outer small-scale-division tape **42***a* has 500 sprocket holes, and the ratio of the circumference of the sprocket to the loop-length of tape **42***a* is 127 to 500 (equal to 254 to 1,000). It is not necessary for all 127 sprocket teeth to be present, since obviously the operation of the sprocket and belt or tape would not change if many of the 127 teeth were removed. As a practical approximation, 20 sprocket teeth properly distributed around the sprocket at points chosen to simulate a 127-tooth sprocket will adequately serve for cogging the tapes to the sprocket. The second tape **44***a* in this illustrative metric indicator is made two sprocket holes longer than tape **42***a*, in order to allow a space of two sprocket teeth for the large-division-scale numbers, and accordingly "windows" or apertures **62** in stripe **60** are two sprocket teeth long.

An indicator tape **42***a* for the metric lead-screw indicator described to this point for a 0.200-inch lead screw has two cycles of fifty numbers from 0.0 to 9.8 by mm., by 0.2 mm. jumps. The large-scale-division tape **44***a* "*" representing "common zero" for two series of numbers enabling operation of the indicator in either desired direction with numbers increasing from zero. The numbers of each series on the large-division tape, starting with common "*" are: 0, 1, 1, 2, 2, . . . 60, 60, 61, with windows **62** occurring opposite the "0.0"s and the "0.5"s. These numbers complement the same-scale-division numbers on tape **42***a*, e.g., 61/0.0 to represent 610 mm. FIG. **14** is an illustration of the numbers of tapes **42***a* and **44***a* of a metric indicator for a "0.200-inch" lead screw.

A metric indicator for a "0.100-inch" lead screw, in an example, has one cycle of 100 numbers from 0.0 through 9.9 in sequence, by 0.1 mm. jumps, on tape **42***a'*. The large-scale-division markings are *, 0, 0, 0, 1, 1, 1, 1, 2, . . . 30, 30, 30, 30, 31, in each direction as before. These numbers are exposed by four windows **62**, respectively, opposite the numbers 0.0, 2.5, 5.0 and 7.5 of the small-scale-division tape **42***a'*. The range of the indicator for each direction of operation from "*" is **310** mm. FIG. **15** shows the numbers of illustrative metric-scale tapes **42***a'* and **44***a'* for a "0.100-inch" lead screw.

The metric-scale tapes obviously cannot be used with the original scale divisions on dial D. It is not even practical for a substitute for dial D to be used here, directly. This is because 254 dial marks are needed around the sprocket for providing 0.02 mm. division marks with the tapes described in connection with a metric indicator for a "0.200-inch" lead screw, and every tenth scale mark requires emphasis for easy and positive identification with a number on the small-scale-division tape. Likewise, 254 scale divisions are needed for providing 0.01 mm. division marks with metric tapes for the

"0.100-inch" lead screw, and every 10th division mark requires emphasis.

It would be possible to apply the scale division marks to the edge of the small-scale-division tapes. This would introduce inaccuracy due to various causes. For example, any looseness of the sprocket teeth in the sprocket holes would introduce error, and some looseness here is useful for easy operation and non-critical manufacture. The basic accuracy of the lead-screw dial is preserved and emphasis of the tenth-scale-marks is realized by means of the arrangement shown in FIGS. **16–20**.

In FIG. **16**, dial D*a* is a ring on the original dial D, centered on dial D by a resilient tube **79** (as of rubber) and cemented to the edge of sprocket **14**, here equipped with 127-pitch sprocket teeth. Dial D*a* has new and precisely formed uniform scale markings **80**, there being **254** of them around the dial circumference. Pointer **50***a* is a modified form of pointer **50** but the structure supporting the pointer here is otherwise unchanged. FIGS. **17** and **18** show the relationship of pointer **50***a* and division marks **80** of dial D*a*.

As seen in FIG. **19**, tape **42***a'* (for example) is equipped with a marginal gating pattern **82**, including deep gate apertures **84** (measured from the edge of the tape). There are shallow and progressively deeper steps between apertures **84**, the deepest step **86** being midway between apertures **84**. In FIGS. **16** and **20**, tape **42***a'* overlies part of the width of the ring in which scale marks **80** are formed. Tape **42**a' is transparent and gating pattern **82** is opaque. Apertures **84** are spaced apart at centers equal to the space between teeth marks **80**. In this way, when the gating pattern of tape **42***a'* overlies scale markings **80**, every scale mark opposite a number on the tape appears long, the "fifth" scale marks between the "tenth" scale marks are emphasized, and the stepped pattern facilitates reading the scale markings between the "fifth" and "tenth" scale markings. In FIG. **20** it is eminently easy to recognize the reading "9.23" opposite pointer **50***a*.

Each of the steps of the gating pattern, and apertures **84** as well, are as wide as the pitch of scale markings **80**. In this way, even if there is slight shift or drift of the tape in relation to the sprocket, within the latitude of one space between dial marks **80**, the dial reading remains unaffected. Every tenth mark **80** is emphasized in relation to different ones of those 254 marks in the course of successive rotations of the sprocket.

The precise structure thus far described is utilized in yet another important feature of the invention. In a further modification of the indicator, a means is provided for vastly improving the accuracy of "the Bridgeport" and of machines generally, that depend on accurate setting of an element by means including a lead screw equipped with a dial or an extended scale. The readings of an indicator such as a dial or a scale are linear, so the system presumes strict linearity of the adjustment effected by the lead-screw. This assumption may be inaccurate when a machine tool is new, but it is not valid after the machine has become worn. The invention, in one of its aspects, provides a virtually continuous means of knowing the reading error of the indicator in a machine of this kind.

In FIGS. **1–11**, it may be considered that tape **42** is omitted and that tape **44** and the sprocket are modified, as indicated in FIGS. **21** and **22**. Sprocket **14***b* is made black or any dark color, and has a number of isolated bright-colored areas. Tape **44***b* as supplied has a series of printed numbers **90**. The circumference of sprocket **14***b* relative to the loop length of tape **44***b* is such that precession occurs, being other than an integral multiple of the sprocket circumference. One bright-colored area **92** on the sprocket will underlie one number **90** as the bright area **92** and the number move across the viewing region of the indicator (There may be two diametrically opposite areas **92**, or more, depending on the proportions.) In successive rotations, successive numbers **90** overlie bright area **92** and become effective visually. The other dark-colored numbers are effectively obliterated, visually, by the dark color of the sprocket. These numbers form an extended-scale indicator.

Adjacent area **92** on sprocket **14***b* there is additional bright area **94**, having two ears **96** and **98**. The areas of tape **42b** that overlie the additional bright area upon successive rotations of the sprocket are available to the user for inscribing correction factors. This is done in the following way.

At some point in the range of the lead screw, the mid-point for example, the sprocket and the lead screw are operated in a selected direction to bring a preprinted number over bright area **92**, accurately positioned as determined by pointer **50**. Bezel **28** is removed, by flexing one panel **30** downward. This deflects edge **26** from the removal path of the bezel, which is then slipped out of the indicator leaving the tape **44***b* exposed and accessible for writing-in the applicable correction notations. A symbol representing "-plus" or "minus" representing the direction of the error or the required correction may be written directly; or it may be recorded (as shown) by applying a dark mark on the tape over ear **96** or **98**, and "**0**" is recorded on the tape over the additional bright area on the sprocket. Then the sprocket is rotated exactly one revolution to bring the additional bright area **94** opposite pointer **50**, operating the lead screw in the adopted direction in approaching the end-point of the adjustment so as to eliminate the back-lash error considered previously. This can be done by rotating the lead screw and the sprocket in the decided direction and stopping at the 360° point; or the lead screw and the sprocket can be rotated in the reverse direction more than 360°, to be followed by rotation of the sprocket in the decided direction to the 360° end-point of the adjustment. The distance moved by the milling-machine table or other element operated by the lead screw can be measured accurately in a routine way, and compared with the distance indicated by the new number over bright area **92** as compared with the previous number. Any error is recorded as a number **100** on tape **44***b* over bright area **94** and once again a mark is applied to tape **44***b* over ear **96** or **98** as a symbol representing the sign of the error to be added or subtracted in the adjustment. This procedure is continued until all (or any desired part) of the continuous scale readings **90** have an accompanying correction notation **100**. Bezel **28** is then slipped into place, and it is adjusted so that the proper arrow (FIG. **6** or FIG. **7**) is formed to show the direction of operation of the indicator and of the lead screw for which the correction is valid. Considering back-lash, and the opposite driving surfaces of the lead screw, a very different calibration would be needed for the opposite direction of operation.

As shown in FIG. 22, the error notation is "6.3." This represents the precise departure of the lead screw from linearity, when number **90** is opposite the pointer **50**. If some other setting is desired in the routine use of the machine, then the proper correction factor is determined by interpolating between the two error notations to either side of the desired setting. Interpolation is aided by nine uniformly distributed bright points **102** along the edge of sprocket **14*b*** and by a 10th such point forming part of bright patch **92**. For example, if two correction notations at opposite sides of a desired setting are "6.3" and "4.6," then the difference is to be apportioned between the extremes. If the indicated setting is three "points" away from the "6.3" error reading, then the correction is 6.3 minus 0.3 (6.3 − 4.6) or 5.8. The absolute scale markings "28.2" for which the calibration error is 6.3 in this example means "28.200"; and so, if the required setting turns out to be about 0.3 of a dial rotation away, e.g., 28.231, and if the applicable correction is **5.8**, and if this correction is "minus" as indicated by an entry over "ear" **98** adjacent the correction value "6.3", then the dial is set at 28.2252. Care must be taken to reach this setting by operating the hand crank in the right direction toward this end-point, as indicated by the arrows of bezel **28** for which the calibration is valid. The arrangement makes possible a degree of accuracy that may well exceed that of the new machine. A milling machine that is worn significantly can be operated with jig borer accuracy with the described extended-scale error calibration.

After all the desired error notations have been entered, bezel **28** is slipped into place, and it is set to indicate the direction of lead-screw operation for which the error notations are valid. The error notations can be revised from time to time, when further wear of the lead screw is noted.

A separate extended-scale indicator precisely like that in FIGS. **1–11** may be used with the calibration indicator just described, by uniting the separate extended-scale indicator to the calibration indicator in a manner described below. The added extended scale indicator can be adjusted to have any desired zero point, as may be appropriate to the job being done. That adjustment does not upset the calibration indicator.

Space permitting (as through the use of a wider sprocket) two bright areas **94** may be provided side-by-side, and in that modification two sequences of error notations might be inscribed as error calibrations applicable to the two directions of lead-screw operation, respectively, one being that represented by the selectively set arrows of bezel **28** and the other being applicable to the reverse direction of lead-screw operation.

FIGS. **23** and **24** show extended scale indicators assembled in tandem. As an example, two tandem indicators can be used together where one is of the form in FIGS. **1–13** giving "English" readings and the other is "metric" as represented in FIGS. **16–20**. This assembly is useful for a milling machine, in following a drawing having mixed "English" and "metric" dimensions, or for checking drawings involving a conversion from either system of dimensions to the other, and for various other uses. A calibration indicator can be fixed to a lead-screw shaft and used with a separate extended-scale indicator (FIGS. **1–11**) that is adjustable to establish a desired zero for each new job. Two or more identical extended scale indicators can be used for maintaining separate zeros in machining duplicate parts or multiple different parts out of a single piece of stock. A single lead-screw calibration indicator as described above can be used together with these multiple indicators.

The tandem lead-screw extended-scale indicators of FIGS. **23** and **24** include one such indicator **10** that is identical to that in FIGS. **1–11**. Two additional indicators **10*a*** and **10*b*** are of the same construction externally but are modified internally in particulars to be described. In this example, three extended-scale indicators are used in tandem for each of the two horizontal lead screws of the table in a Bridgeport milling machine. One of the three is adjusted so that its common zero indicates a drawing coordinate related to hole centerlines. A second identical indicator has its zero off-set from that of the first indicator in one direction so that it represents "plus" cutter off-set, and the third identical indicator has its zero off-set from the first indicator in the opposite direction so that it represents "minus" cutter off-set. In this way, the first indicators of the table lead screws show the relative position of the cutter axis, while the other two represent the desired positions of the cutter axis to make a cut whose edge or outline dimensions are shown on the drawing. The inclusion of three extended-scale indicators thus avoids the need for cutter off-set calculations, as a further expediting and error-reducing advantage. As with a single such indicator, the bezels **28** are set to provide arrows showing the adopted direction of operation, to be used consistently in order to avoid error due to lead-screw back-lash. Additionally, it is to be understood that a lead-screw calibration indicator can be added in precisely the same manner as will be described for the two added extended-scale indicators shown in FIGS. **23** and **24**.

All three extended-scale indicators **10**, **10*a*** and **10*b*** of FIG. **23** have enclosures **12** which contain the same form of sprocket **14** with its knob **14*a*** projecting out of the enclosure **12**. On each sprocket there is a pair of continuous or looped extended-scale tapes **42** and **44** as previously described.

Shaft S of the Bridgeport, being an extension of the lead screw, bears bushing B of the Bridgeport that supports the Bridgeport dial D, bearing sprocket **14** in unit **10**. A special clamping nut **106** locks sprocket **14** to bushing B, or releases the sprocket for adjusting the common zero of indicator **10**, as desired. Nut **106** has four arms **108** for operating nut **106**. The spaces between each of the units **10** and **10*a***, and between units **10*a*** and **10*b*** are available for operating knobs **14*a***, and the spaces between the arms **108** are available for the operator's fingers in adjusting the sprockets as desired.

Indicators **10*a*** and **10*b*** lack the original Bridgeport dial D. Rings **110** which bear scale division marks replace dial D in units **10*a*** and **10*b***. These rings **110** are united as by cement to the edges of the respective sprockets **14** of units **10a** and **10b**. A bearing ring **112** is fixed to ring **20**. Bearing ring **112** is journalled at its center hole on a bushing **114**, accurately supporting enclosure **12** at the proper axis. A centrally flanged annular bearing **116** fits in the scale-division-marked ring **110** and is journalled on bearing ring **112**, providing a support for the sprocket. Bushing **114** is threaded to fit another locking nut **106** (or original nut N of the Bridgeport) to clamp the sprocket in its desired adjustment. The center hole of the sprocket fits a cylindrical centering surface of the bushing, providing another bearing support for the sprocket spaced axially from annular plate **116**. This structure in units **10a** and **10b** provides stable centered support for the sprocket in any indicator that lacks dial D of the Bridgeport.

The shaft S of the Bridgeport, bearing the dial D, is long enough to carry the handle H and a further nut *n*. A key K is received in a keyway in shaft S and in a keyway in bushing B and (ordinarily) in a keyway in handle H. Here, however, key K extends in keyways in bushing B and in shaft S, and in a keyway in bushing **114**. Another key **118** is greatly elongated and extends along keyways in bushings **114** and **114'** so that these bushings are constrained against independent rotation Likewise a greatly elongated key **118'** extends along keyways in bushing **118'** and handle H.

Shaft S is elongated a modular distance by hollow internally threaded extension shaft **120**. Its length is equal to that required for one added tandem extended-scale indicator. A screw **122** is received and tightened in the right-hand end of shaft **120**, the internal threads extending only far enough for receiving half of the length of screw **122**. The part of screw **122** that projects (virtually integrally) from hollow shaft **120** simulates the threaded end *s* of original shaft S of the Bridgeport.

A duplicate hollow shaft **120'** and screw **122'** extend as a unit from shaft-and-screw unit **120, 122**. Its length is appropriate for the added indicator **10b**. Handle H is held on extension shaft unit **120', 122'** by nut *n*. Hollow shaft **120'** is threaded on screw **122** and tightened against shaft **120**. Shaft S and units **120–122, 120'–122'** behave as if it were a unitary shaft, in supporting indicators **10a** and **10b**, additionally carrying handle H. Bushings **114** and **114'** are carried by the extended shaft in just the same way as dial D is carried by shaft S, with the incidental exception that it is unnecessary for keys **118** and **118'** to be received in keyways in the modular shaft extension units **120–122** and **102'–122'**.

Shaft S, bushings **13, 114** and **114'** and handle H are all keyed together so that they cannot rotate independently. The keyed interconnection is not depended on for holding them together as a unit. The keyed interconnection would introduce some possible looseness. However, these parts are held together to act dependably as a unit when nut *n* is tightened.

The three indicators **10, 10a** and **10b** are separately adjustable by virtue of the individual clamping nuts **112, 112'** and N which are loosened individually to adjust the respective sprockets **14** individually and tightened to lock the respective sprockets individually. In another construction, nuts **112** and **112'** can be omitted so as to depend on nut N when tightened to lock all the sprockets or to allow them to be manually rotated individually. However, in the preferred construction shown, there is no chance of a previous perhaps critical setting of one indicator being disturbed accidentally during the adjustment of a second indicator. This is an advantage realized through the use of separate clamping nuts for the sprockets of the respective indicators.

The enclosure **12** of indicator **10** is adhered to the frame of the milling machine by double-faced adhesive ring **21**, as shown in FIG. **11** and described previously. A clamp **124** unites the enclosures **12** of units **10** and **10a**, and another identical clamp **124** unites enclosures **12** of units **10a** and **10b**. Clamp **124** includes sides **126** and **128**, and ends **130**. Sides **126** and **128** are received between two enclosures **12**, but ends **130** include gripping portions **130a** that slope toward enclosure **12**; and these gripping portions have edges that dig into enclosures **12** when screw **132** and nut **134** of side **128** are tightened.

The three tandem extended-scale indicators **10, 10a** and **10b** are especially useful in connection with parts drawings having both centerline locations from a zero reference and locations of edges to be cut on a milling machine by a cutter having a chosen radius. An individual extended-scale indicator **10** has important advantages, notably in avoiding calculations and in avoiding turns-counting of a standard Bridgeport dial. The three duplicate tandem indicators avoid still further calculations when set individually to read centerline dimensions and dimensions modified to incorporate plus and minus cutter off-set dimensions, respectively.

It has been indicated that a calibration indicator as in FIGS. **16–20** can be used individually, but it can also be used as one of two or more tandem units. When this is done, its clamping nut (corresponding to nut **106**) should not include arms **108**. This is to avoid any possibility of thoughtless release of the sprocket **14** of such calibration unit. When a calibration extended-scale indicator has once been calibrated to indicate the relative corrections required at each point along a lead screw for true linear indications, there is no occasion for releasing and readjusting its sprocket **14**. An ordinary wrench-operated hexagonal nut would advantageously place nut **106**, requiring the attendant to be quite deliberate in releasing the sprocket of the calibration unit if adjustment should become necessary on occasion.

What is claimed is:

1. An extended-scale indicator having

i. means defining a viewing region including means for indicating particular indicia in said viewing region,

ii. a first member cyclically operable in either of two opposite directions relative to said viewing region, said first member having first and second endless sequences of small-division numerical indicia, said sequences being divided into the same number of groups including at least one group in each sequence, the indicia within any one group of the first sequence as indicated by said indicating means increasing in one direction of operation of said first member and the indicia within any one group of the second sequence as indicated by said indicating means increasing in the opposite direction of operation of said first member, the indicia of said first and second sequences including respective zeros aligned with each other for concurrent indication,

iii. a second member having two sequences of large-division numbers operable past said viewing region for individually complementing said small-division numerical indicia to constitute composite readings of the extended-scale indicator, said two sequences of large-division numbers having a common zero arranged to be indicated in a starting position in said viewing region when two of said small-division aligned zeros are in indicated position,

iv. said extended-scale indicator having means coupling said first and second members together for coordinated advance past said indicating means,

v. the large-division indicia of one of said two sequences thereof being arranged to reach the indicating means successively in increasing order each time the small-division zeros reach the indicating means during operation of said first and second members in one direction from said starting position, and

vi. the large-division indicia of the other of said two sequences thereof being arranged to reach the indicating means successively in increasing order each time the small-division zeros reach said indicating means during the operation of said first and second members in the opposite direction from said starting position.

2. An extended-scale indicator in accordance with claim 1, wherein said first and second members are endless belts and including an enclosure for said endless belts, said coupling means including a common sprocket in said enclosure, each of said belts having sprocket holes cooperating with said sprocket, and plural guide rollers distributed in said enclosure, said belts extending for the most part in parallel paths about said guide rollers, and a further guide roller for part of only the longer one of said two belts, for taking up the slack thereof.

3. An extended-scale indicator in accordance with claim 1, further including means for obscuring the sequence of large-division numbers corresponding to the direction of operation of said members opposite to the operating direction.

4. An extended-scale indicator in accordance with claim 1 wherein said first and second small-division sequences of numerical indicia contrast in appearance from each other and correspond in appearance with respective ones of said two sequences of large-division indicia.

5. An extended-scale indicator in accordance with claim 1 wherein, when said members are displaced in a given direction from said starting point and are operated in said given direction, one of said two sequences of large-division numbers increases and the other inherently decreases as the small-division zeros recur at the indicating means, said extended-scale indicator further including means for obscuring said other of said two sequences of large-division numbers when said members are displaced in said given direction from said starting position.

6. An extended-scale indicator in accordance with claim 1, wherein said indicating means includes an index marker for said small-division numerical indicia and a mask operable coordinately with said first member and disposed to obscure the large-division numbers of said second member, said mask being apertured for displaying said large-division numbers individually when said aligned zeros of the small-division groups of indicia reach said index marker.

7. An extended-scale indicator in accordance with claim 6, wherein said first and second indicating means are endless belts having a difference in length equal to a small integer multiplied by the space allocated to to a numeral.

8. An extended-scale indicator having first and second endless belts, means for supporting said belts at a common viewing region, means for effecting coordinated advance of said belts across said viewing region, said belts being of somewhat different lengths so that one belt shifts differential distances relative to the other in repeated cycles of advance of the belts across the viewing region, numerical indicia distributed along said first belt and arranged in plural duplicate groups starting at zero and increasing in value within the groups in the same direction along the first belt, a sequence of large-division numerical indicia distributed along said second belt, said first belt having an obscuring band disposed over the large-division indicia of the second belt at least at said viewing region, said obscuring band having apertures adjacent the zeros of said small-division indicia for displaying said large-division indicia individually, the large-division indicia complementing the values of said small-division indicia for displaying a regular progression of composite numbers as the belts advance across the viewing region.

9. An extended-scale indicator, including an enclosure having means forming a viewing region, a pair of endless belts of different lengths having respective portions disposed in said viewing region, said belts having, respectively, at least one sequence of small-division numerical indicia and at least one sequence of large-division numerical indicia, a plurality of rollers in said enclosure, each of said rollers forming a guide for both of said belts, said rollers forming a labyrinth-path for both of said belts, and guide means forming an extended-length guide path for the longer of said two belts at a definite location in said labyrinth path for taking up the slack in said longer belt and avoiding enforced sliding of one of the belts relative to the other along said labyrinth path, the difference in length between the belts being related to the spacing between the large-division numerical indicia to cause step-wise change thereof at the viewing region.

10. A metric indicator for a machine tool including a lead screw having an indicator shaft for a cyclic inch-system indicator, said metric indicator having means defining a viewing region, a sprocket for said indicator shaft, a small-scale-division cyclic continuous tape and a large-scale-division continuous tape having respective portions supported by the sprocket in the viewing region and having regular numerical sequences, the continuous tapes being of different lengths so that precession of the large-scale-division tape relative to the small-scale-division tape occurs in the course of successive cycles of the small-scale-division tape past the viewing region and so that successive readings of the large-scale-division tape are brought into the view-

ing region successively with successive zeros of the small-scalegdivision tape, the ratio of the circumference of the sprocket to the circumference of the small-scale-division tape being equal to 1.27 multiplied by the advance produced by the lead screw in inches per rotation of the indicator shaft, multiplied by a small integer greater than zero.

11. A metric indicator for a machine tool including a lead screw having an indicator shaft for a cyclic inch-system indicator, said metric indicator having means defining a viewing region, a unitary dial and sprocket for said indicator shaft, said dial having uniform regularly distributed scale divisions, and a continuous indicator tape on said sprocket, the ratio of the circumference of the sprocket to the circumference of the small-scale-division tape being equal to 1.27 multiplied by the advance produced by the lead screw in inches per rotation of the indicator shaft, multiplied by a small integer greater than zero, said indicator tape having decimal-series numerals distributed thereon for alignment with only certain of said scale divisions and the scale divisions other than said certain divisions forming intervening subdivisions.

12. A metric indicator in accordance with claim 11, wherein said indicator tape has a gating pattern distinguishing said certain scale divisions from at least the scale divisions at opposite sides of each of said certain scale divisions.

13. A multiple indicator for a work-table lead screw of a machine tool having a lead-screw indicator shaft, said multiple indicator including plural direct-reading indicators, each said indicator having an enclosure, a sprocket, and dual indicator tapes in said enclosure cogged to said sprocket and of different loop lengths, all arranged to provide continuous direct readings over a range covering many sprocket rotations, means for securing the enclosures of said plural indicators to each other and to a stationary part of the machine tool, and means for releasably locking said sprockets to the indicator shaft for rotation therewith and with each other and further adapting the sprockets to individual rotational adjustment relative to said shaft when the locking means is released.

14. A multiple indicator in accordance with claim 13 wherein said indicator shaft includes an individual modular shaft extension for each indicator in excess of one.

15. A multiple indicator in accordance with claim 13, wherein an individual locking means is provided for each indicator so that individual adjustment of each indicator is feasible while the other indicators are locked to retain the adjustment thereof.

16. A multiple indicator in accordance with claim 13, including three duplicate extended-scale indicators one of which provides direct readings of the work-table position while the other two provide "plus" and "-minus" off-set readings corresponding to said direct readings modified to allow for cutter off-set.

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