No. 686,266. Patented Nov. 12, 1901.

A. L. DE LEEUW.

DIVIDING ENGINE.

(Application filed June 17, 1901.)

(No Model.) 2 Sheets—Sheet 1.

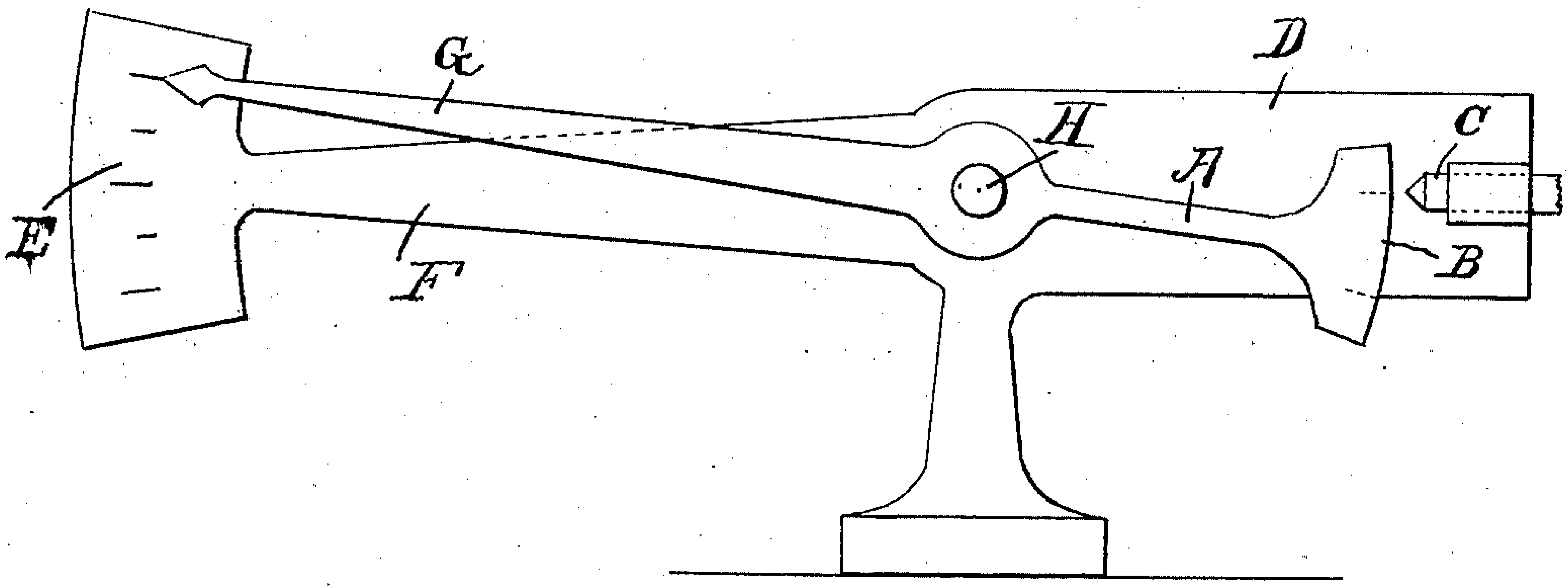

FIG. 1.

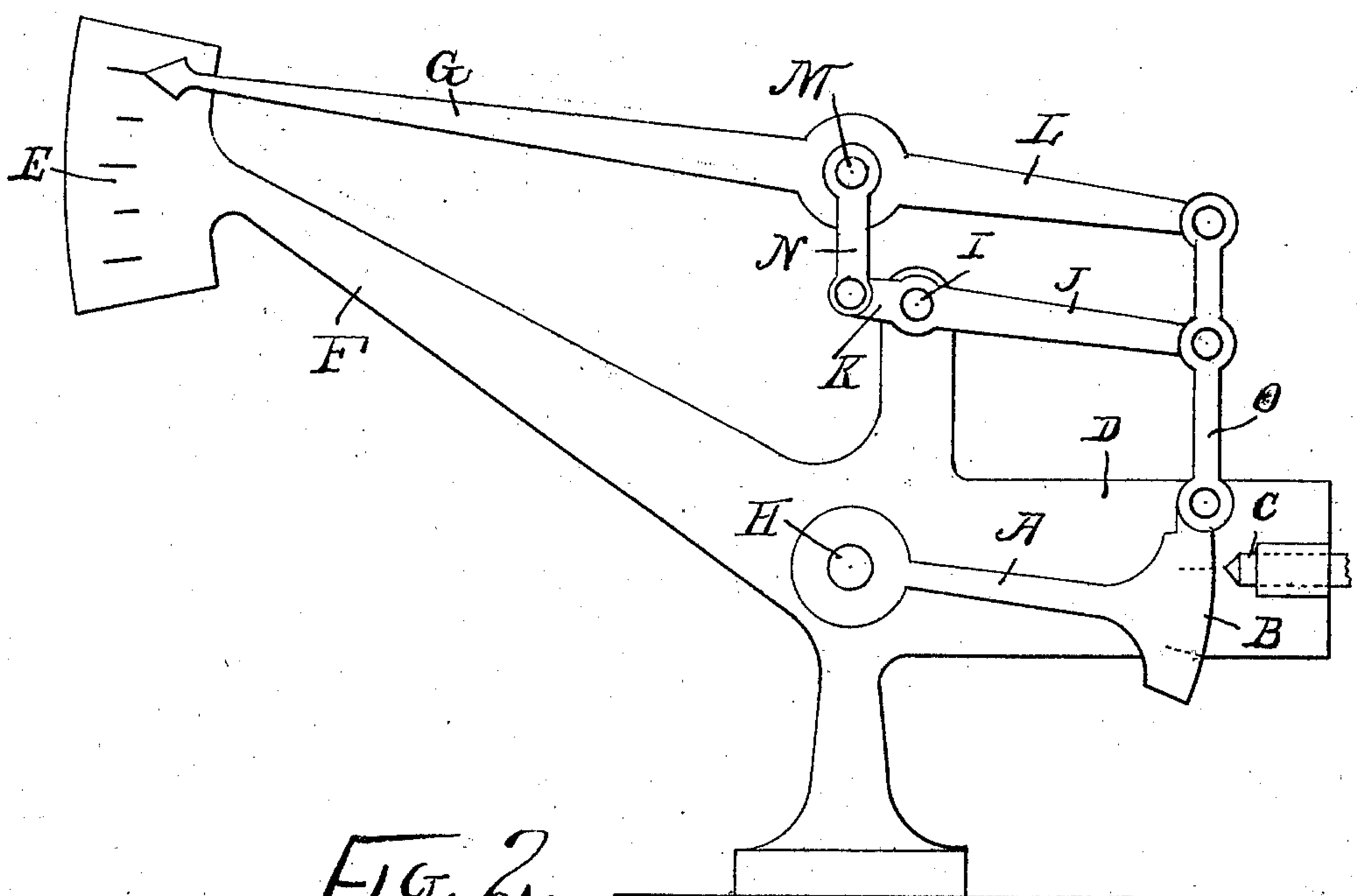

FIG. 2.

Witnesses:
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G. C. See.

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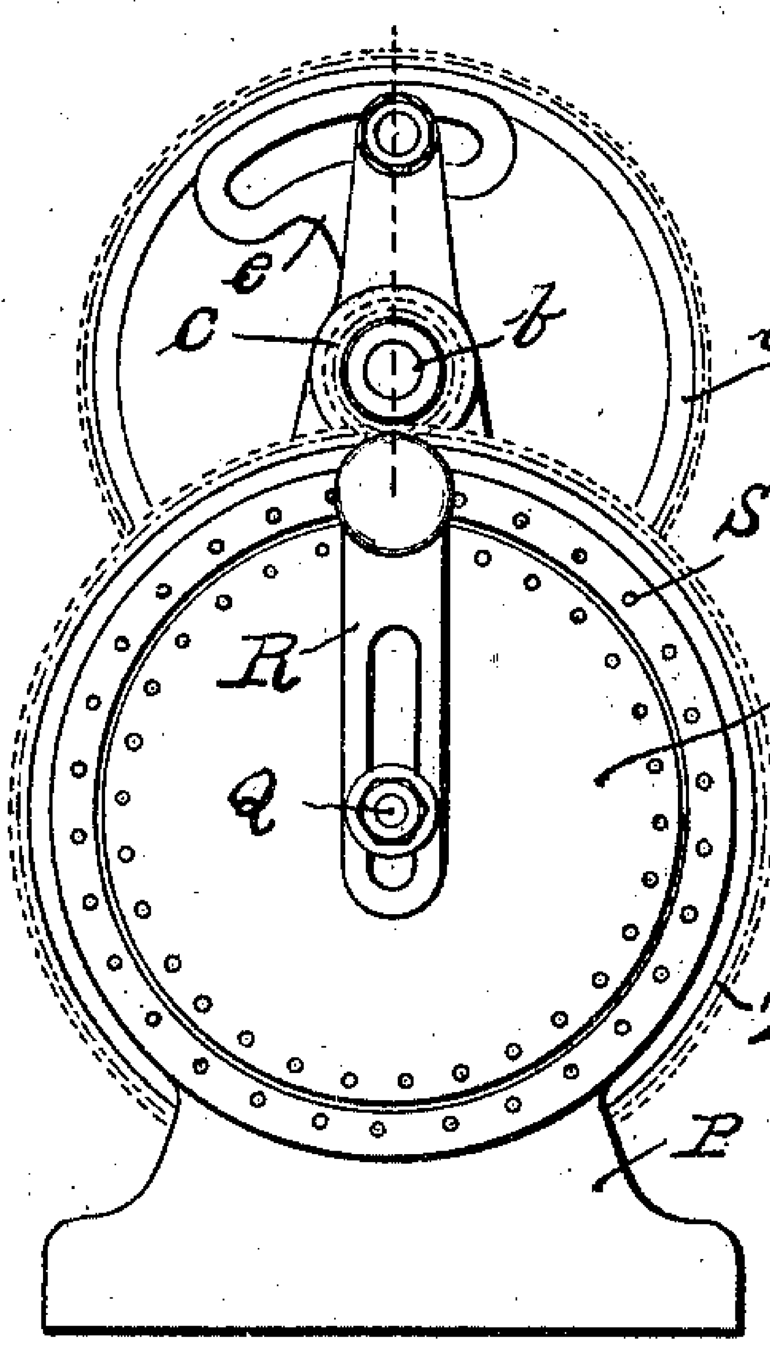

FIG. 3.

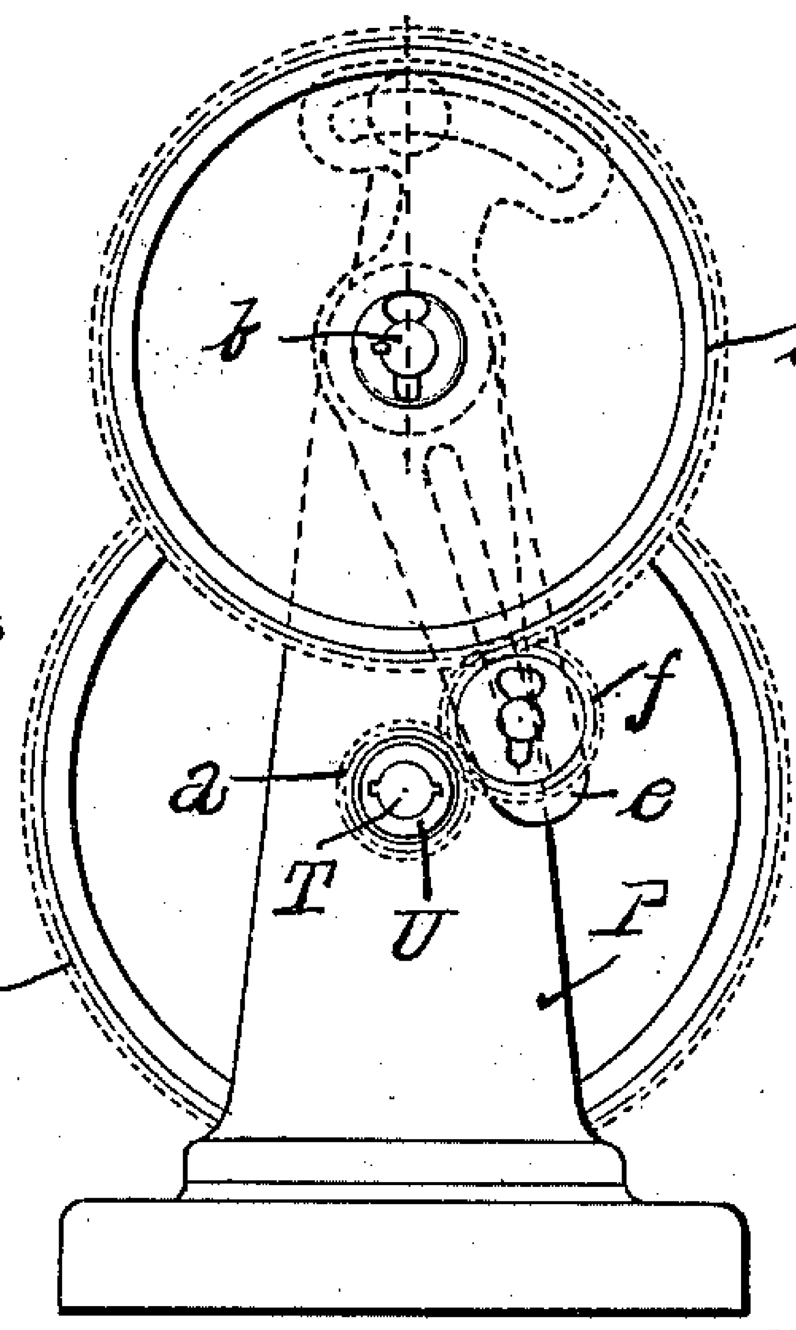

FIG. 4.

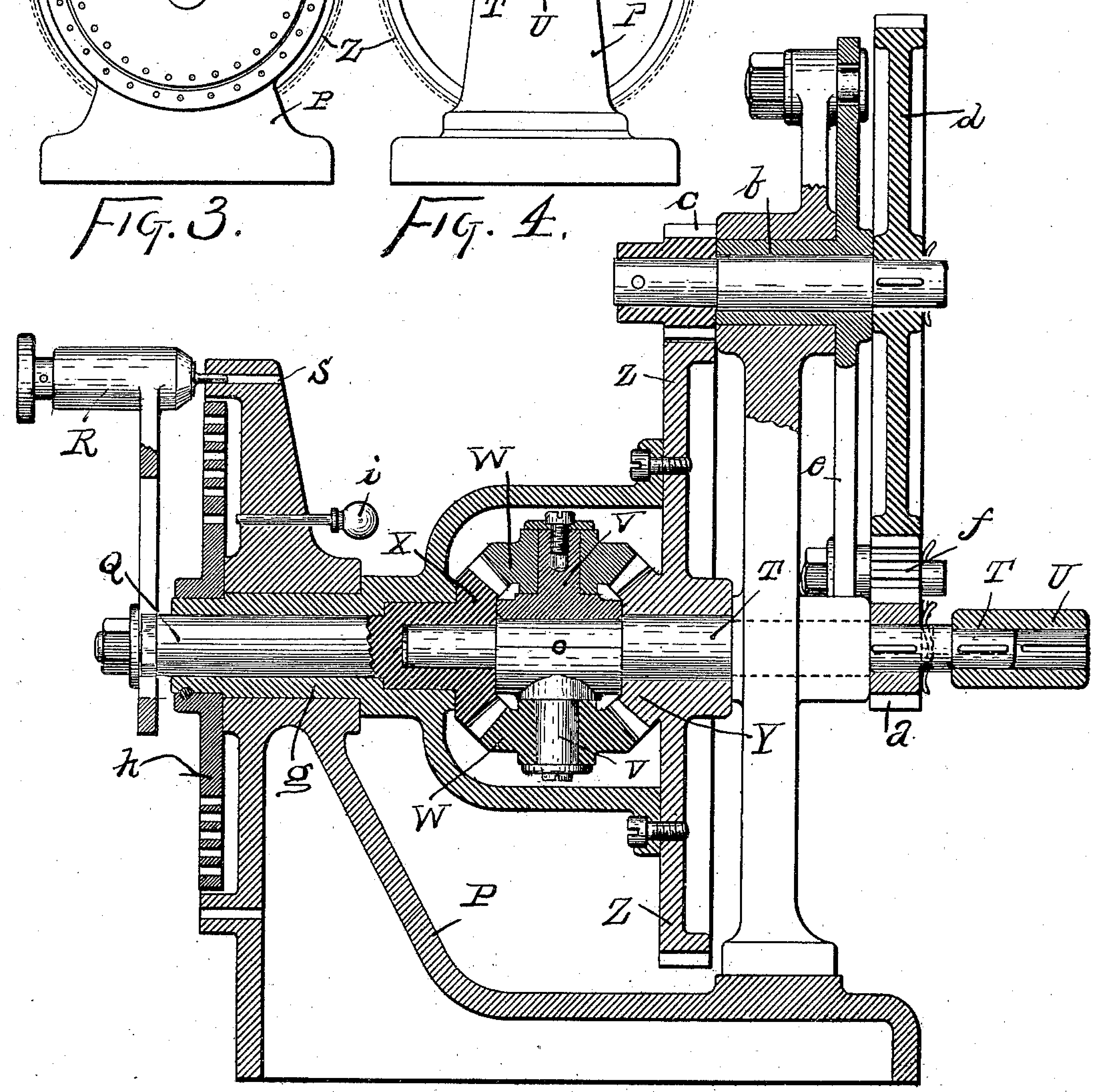

FIG. 5.

Witnesses:
E. R. Shipley.
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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

ADOLPH L. DE LEEUW, OF HAMILTON, OHIO.

DIVIDING-ENGINE.

SPECIFICATION forming part of Letters Patent No. 686,266, dated November 12, 1901.

Application filed June 17, 1901. Serial No. 64,848. (No model.)

To all whom it may concern:

Be it known that I, ADOLPH L. DE LEEUW, a citizen of the United States, residing in Hamilton, Butler county, Ohio, (post-office address Hamilton, Ohio,) have invented certain new and useful Improvements in Dividing-Engines, of which the following is a specification.

This invention relating to improvements in dividing-engines will be readily understood from the following description, taken in connection with the accompanying drawings, in which—

Figure 1 is a front elevation of a rudimentary model illustrating the general principle of ordinary dividing-engines; Fig. 2, a similar view of a model illustrating the general principle involved in my improved system of dividing-engines; Fig. 3, a rear end elevation of a dividing-engine exemplifying my present invention; Fig. 4, a front end elevation of the same, and Fig. 5 a vertical longitudinal section of the same.

In Fig. 1 of the drawings, A indicates a pivoted arm; B, an object carried thereby to have divisions produced upon it; C, a typifying tool to produce the divisions upon object B; D, a fixed arm supporting the tool C; E, a series of graduations to serve as the basis of the graduations to be produced; F, a fixed arm supporting the same; G, an index moving with A and B and reading on E, and H the pivot supporting G, A, and B.

Assume graduations E to comprise a distance of one inch in four divisions, and assume the length of G to be twice that of A. It is obvious that divisions produced on B will be to the graduations E directly as A is to G, that one inch moved through at E by G will represent one-half an inch movement at B, that the four spacings at E will permit of one, two, or four divisions at B, and that the four quarter-inch spaces at E can be caused to yield divisions at B equal to one-half inch or one-quarter inch or one-eighth inch. Calling E the "indexing" end of this apparatus and B the "graduating" end, it is obvious that the relation of the graduations to the indexing can be modified, but only in direct degree, by modifying the relative lengths of A and G. The model illustrated by Fig. 1 may be said to typify the general principle of all ordinary dividing-engines in which the radii of change-gears represent the relative radii A and G, such change-gears being a mere expedient for conveniently altering the length of the lever-arms A and G. This holds good no matter how complicated the gearing may be and no matter whether the indexing and graduations, either or both of them, be in arcs or in straight lines and no matter if screws or other devices be introduced adjunctive to the gearing. The defect in the system is the limitation imposed by the direct proportioning of the radii, thus requiring an extended number of change-gears for the production of an extended diversity of divisions. Especially in graduations involving prime numbers do such limitations become apparent by making necessary an indexing agent directly comprising the prime number to be produced in the graduations, no mere proportioning of gearing containing no multiple of the prime number being able to produce graduations representing the prime number.

Now, still considering Fig. 1, let us assume that while G is moving downwardly from one extremity to the other of the series of graduations E, G could be systematically bent downwardly, so as to change its relationship to A. In such case when G has traversed one inch at E, B would have moved less than one-half an inch, according to the modification of relative motion effected by the bending, similarly if while G was moving downwardly F were bent upwardly or A were bent downwardly or D were bent upwardly. In short, the bending of any one or more of the members during the indexing movement would result in adding to or subtracting from the graduating effect due directly to the proportion existing between the various radii.

It may be said that any dividing system comprises four members—viz., two coöperating indexing members, as typified in Fig. 1 by E and G, and two graduating members, as typified by C and B. In my improved system I cause the movement of some one of the four members of the system to react upon some other member of the system, so as to produce an effect greater or less than that due to mere proportioning of direct-acting members in the system. By this means I am able to greatly extend the dividing capacity of a given number of changeable indexing elements or change-gears and to graduate into prime numbers by means of indexing agents or change-gears not directly responding to the prime number. This scheme of "bending," so to speak, one member of the system relative to another may be gathered from Fig. 2.

In Fig. 2, it will be observed, G has been cut away from A and B and mounted on an independent pivot at M, which pivot is a movable pivot, and a prolongation L of G is connected to B by a link O. In the rudimentary model illustrated by Fig. 2 there will be certain inaccuracies of motion due to the linkages; but for present purposes they may be entirely ignored.

If M were a fixed pivot and J were absent, then the relative motions of G and A would be directly as their lengths, precisely as was the case in Fig 1; but M instead of being a fixed pivot is raised and lowered by link N under the influence of J K, rocking on fixed pivot I and reacted upon by A through the medium of link O. As seen in Fig. 2, G and A are parallel with each other; but when G shall have moved downward that parallelism will have been destroyed, for G will have moved through a greater angle than A by a difference representing the bend, which I have heretofore referred to. Assume E, as before, to represent one inch with four divisions, that the length of G is to L or A as two is to one, and that the length of K is to that of J as one is to five. Now as G descends one inch it tends to lift B a half-inch, when G L is considered as a simple lever; but the rising of B a half-inch causes J K to lower pivot M a tenth of an inch, this reaction tending to produce an excessive descent in G. In other words, while G is descending one inch its fulcrum M is descending in proportion to the rise of B, and consequently the one-inch descent of G will be satisfied by less than a half-inch rise of B. Calculation of the leverages will show the movement responding to an infinitely-converging series and that under the assumed values one-inch descent of G measured at E will be responded to by five-thirteenths of an inch rise at B. Here, it will be observed, a graduating value involving the number thirteen is got by means of radii comprising only the values of one, two, and five.

An extended study of Fig. 2 will show at once that a similar differentiating result would be arrived at in case the reaction through lever J K were caused to change the relationship between some other pair of members than G and A and also in case that reacting motion were derived from some other member than A. Fig. 2 thus serves to illustrate the fact that with two indexing members and two graduating members in connection with reacting mechanism between any two of them there can be secured a proportioning between index and graduation different from that existing directly between any of the members of the system.

Having thus distinguished between the principle of my dividing-engine and that of the common art, I now proceed to describe an exemplifying practical apparatus applicable to general gear-cutting or milling machines or other graduating-machines, such apparatus being illustrated in Figs. 3, 4, and 5.

Referring to Figs. 3, 4, and 5, P indicates a housing; Q, an indexing-shaft to be turned for the purpose of ultimately producing the spacing movement of the object to be graduated; R, a detent hand-crank mounted on shaft Q and having the form and construction common in dividing-engines—that is to say, it carries a spring-detent to engage index-holes, and it is adjustable radially on its shaft, so that the pin can be brought closer to or farther from the center of the shaft; S, a fixed circular series of index-holes adapted to be engaged by the pin of the crank; T, a shaft disposed in line with shaft Q and constituting a transmission-shaft by which the spacing movement is given either directly or indirectly to the object to be graduated or divided; U, a coupling on the end of shaft T and adapted to serve in connecting that shaft separably with such further transmitting-shaft as may happen to be employed in the machine in connection with which this apparatus is to be employed; V, a pair of trunnions fast on and carried by shaft T; W, a bevel-gear loose on each of these trunnions; X, a bevel-gear fast on the inner end of indexing-shaft Q and engaging the bevel-gears W; Y, a bevel-gear loose on shaft T and also engaging the bevel-gears W; Z, a spur-gear fast with bevel-gear Y; *a*, a change-gear separably secured to shaft T; *b*, a counter-shaft disposed parallel with shafts Q and T; *c*, a pinion fast on this counter-shaft and engaging spur-gear Z; *d*, a change-gear separably mounted fast on counter-shaft *b* in the vertical plane of change-gear *a*; *e*, a quadrant mounted on the housing and angularly adjustable on the counter-shaft *b* as a pivot; *f*, an intermediate change-gear mounted on the quadrant and engaging change-gears *a* and *d*; *g*, a hollow hub fast with spur-gear Z and surrounding the bevel-gearing and the index-shaft Q and presenting its outer end near the indexing-crank; *h*, an index-plate fast on the hub *g* and provided with holes adapted to be engaged by the pin of the indexing-crank, and *i* an anchoring-pin supported by the housing and adapted to engage one of the holes of the index-plate.

Shaft T may itself carry the object which is to be graduated, or it may be coupled to the work-carrier or further transmitting-shaft of the main machine on which the apparatus is to be employed. In many types of machines—

such as gear-cutters, milling-machines, and the like—the work-carrier is provided with a worm-wheel, to which the dividing motion is given by means of a worm, and in such case the coupling U may well be employed in connecting separably with the shaft of such worm, the illustrated apparatus being mounted upon the machine convenient for such coupling. The uncoupling of the shafts readily permits of changing the gear a. It will at once be recognized that shafts Q and T constitute a divided shaft coupled by a jack-in-the-box, bevel-gear Y constituting the abutment for the jack-in-the-box system. Assuming the change-gears absent and that gear Y be held stationary, then it is obvious that shaft T will turn at half the rate of shaft Q. Remove the change-gears and then lock the index-plate by means of pin i and assume thirty holes in series S. Then a full turn of crank R will give a half-turn to shaft T, and if the crank be moved one space in series S, being one-thirtieth of a turn, a sixtieth of a turn will be given to shaft T. The jack-in-the-box has in this case simply acted as a reducing-gear between the two shafts. Instead of having gear Y act as a fixed abutment for the jack-in-the-box system it is to be caused to have a rotary motion through the medium of the gearing reacting between it and shaft T. Such rotary motion of gear Y will be in one direction or the other relative to that of shaft T, according to whether one or two intermediates are employed in the change-gear system. Very little analysis of the mechanism will show that it is responsive to the bending idea referred to in connection with Fig. 2, for while the gearing employed represents certain proportionate leverages the reaction of the gearing causes a change of relationship between shafts Q and T not in accordance with any direct proportioning of the gearing, but following rather an infinitely-converging series.

If, for instance, the ratio of speeds of the gears a and Z in the gear system $a\ d\ c$ Z is as one to ten (1–10), then one full turn of the handle R, and therefore of the bevel-gear X, will cause an amount of motion of the shaft T which can be expressed by the infinite converging geometrical series

$$\tfrac{1}{2}+(\tfrac{1}{2}\times\tfrac{1}{20})+\tfrac{1}{2}\times(\tfrac{1}{20})^2+\tfrac{1}{2}\times(\tfrac{1}{20})^3+\ldots$$

To prove this proposition, it will at first be assumed that the gears a, d, c, and Z are not present and that the bevel-gear Y is locked to the frame of the machine. Under these conditions one turn of the gear X (or shaft Q) will produce one-half ($\tfrac{1}{2}$) turn of the shaft T. As a matter of fact, however, the gear system $a\ d\ c$ Z does exist and the bevel-gear Y is not locked, but is free to turn and has been turned by the gear system $a\ d\ c$ Z a certain distance when the handle R has completed its full revolution and the index-pin is in the index-hole s. The gear Z therefore makes $\tfrac{1}{10}\times\tfrac{1}{2}$ of a turn, and consequently the shaft T makes $\tfrac{1}{2}\times\tfrac{1}{10}\times\tfrac{1}{2}$ of a turn in addition to the half-turn already accounted for. This additional rotation of shaft T causes again gear Z to move through a part of a turn, this being $\tfrac{1}{10}\times\tfrac{1}{2}\times\tfrac{1}{10}\times\tfrac{1}{2}$, which in its turn causes shaft T to move half this last amount. This additional movement of the shaft T reacts once more on gear Z and on gear Y, and so on *ad infinitum*, and always in such a manner that any additional movement of shaft T causes an additional movement of gear Z of one-tenth of that amount and of shaft T of one-twentieth of that same amount. The initial movement of shaft T being one-half turn, the first additional movement of this shaft will be $\tfrac{1}{2}\times\tfrac{1}{20}$ of a turn. The second additional movement of said shaft will be

$$\tfrac{1}{2}\times\tfrac{1}{20}\times\tfrac{1}{20}=\tfrac{1}{2}\times(\tfrac{1}{20})^2$$

of a turn. The third additional movement of said shaft will be $\tfrac{1}{2}\times\tfrac{1}{20}^2\times\tfrac{1}{20}=\tfrac{1}{2}\times\tfrac{1}{20}^3$ of a turn, &c., so that the total amount of movement of shaft T, expressed in full terms, may be represented by the infinite converging geometrical series

$$\tfrac{1}{2}+\tfrac{1}{2}\times\tfrac{1}{20}+\tfrac{1}{2}\times(\tfrac{1}{20})^2+\tfrac{1}{2}\times(\tfrac{1}{20})^3+\ldots,$$

of which the sum is $\tfrac{1}{2}\times\tfrac{20}{19}=\tfrac{10}{19}$. This shows that if a certain angular movement of the crank R produces an angular movement of the shaft T equal to one-twentieth of a complete revolution, provided no change-gears are used, and that gear Y is locked to the frame, then the same movement of R will produce $\tfrac{20}{19}\times\tfrac{1}{20}$ of a complete revolution, when Y is free to move and the gears a, d, c, and Z are present, as in Fig. 5.

The following course of reasoning shows the above result to be true and without resorting to the integration of an infinite series. Thus, still supposing that the ratio of speeds of gears a and Z is one-tenth, the question might be asked how much motion should be imparted to crank R in order to produce one complete turn of shaft T. One turn of shaft T would produce two turns of gear X if gear Y were held stationary. This gear, however, is turned to an amount of one-tenth of a complete circle, which, acting through gears W as through levers with equal arms, causes gear X to revolve one-tenth of a turn, but in opposite direction. The total resultant movement of gear X (and crank R) therefore is $2-\tfrac{1}{10}=\tfrac{19}{10}$ of a turn. As nineteen-tenths of a turn of crank R produces one full turn of shaft T, it follows that one turn of crank R produces ten-nineteenths of a turn of shaft T.

The foregoing shows that the shaft T makes ten-nineteenths of a full turn when the crank R makes a complete turn. This complete turn was gaged by a hole in S. In order to find what influence the plate h has on the resultant amount of motion, it will now be assumed that the pin of crank R is not put in the hole S, but that the complete turn of crank R is gaged by some other means. (Not shown in the drawings.) Gear Z makes one-nineteenth of a turn when shaft T makes ten-nineteenths of a turn, as an effect of the change-gear system. It may therefore be said that gear Z, and hence index-plate h, makes one-nineteenth of a turn for every full turn of crank R. If the index-pin originally were inserted in any one hole of the index-plate, if then the index-crank R were withdrawn and turned a complete turn, it would be found that the hole in plate h had advanced. This advance is one-nineteenth of a full turn. In order to insert the index-pin again in the same hole, the index-crank R must now be advanced one-nineteenth of a turn. This advance of crank R causes plate h to advance an amount equal to

$$\tfrac{1}{19}\times\tfrac{1}{19}=(\tfrac{1}{19})^2$$

of a turn. It is therefore necessary to advance crank R through $(\frac{1}{19})^2$ of a turn, which causes plate h to move an amount of $(\frac{1}{19})^3$, &c., *ad infinitum*. The total amount of motion of crank R therefor can be expressed by the infinite converging geometrical series

$$1+\tfrac{1}{19}+(\tfrac{1}{19})^2+(\tfrac{1}{19})^3+\ldots\ldots,$$

of which the sum is nineteen-eighteenths. As one complete turn of crank R causes shaft T to move twenty-nineteenths of a turn, it follows that nineteen-eighteenths turns of crank R cause shaft T to move $\frac{19}{18}\times\frac{20}{19}=\frac{20}{18}$ turns. It must be remembered, however, that the operator does not count nineteen-eighteenths of a turn, but moves the crank through what must seem to him one turn as the index-pin is withdrawn from a hole, turned, and then enters the same hole again. In other words, though the movement of crank R over the index-plate is three hundred and sixty degrees its movement in space is $\frac{19}{18}\times 360°$.

The above shows that if a certain angular movement of the crank R produces an angular movement of the shaft T equal to one-twentieth of a complete revolution, provided no change-gears are used, and that gear Y is locked to the frame, then the same amount of motion of R relative to index-plate h will produce $\frac{20}{18}\times\frac{1}{20}$ of a complete revolution, when Y is free to move and the gears a, d, c, and Z are present, as in Fig. 5.

Again, assume the following values—viz., thirty holes in series S, fifteen teeth in change-gears a, seventy-five teeth in change-gear d, fifteen teeth in pinion c, ninety teeth in spur-gear Z. The gear ratio is thus one to thirty. Under these conditions if the crank be moved one space (one-thirtieth of a turn) shaft T will make one fifty-ninth or one sixty-first of a turn, according to whether two or one intermediates are employed at f. The apparatus can thus provide for fifty-nine or sixty-one graduations in a circle on T or U without the employment of prime-number gearing. Now with the gear values just assumed abandon fixed index-holes S and put the crank to the index-plate to a circle having thirty holes. It will be seen that if the change-gearing is removed and the hand-crank turned while locked to the index-plate shafts Q and T will turn together as if they were one. When the change-gearing is applied, however, the crank and index-plate cannot be turned while locked together, their motions being differential. With the values heretofore assumed, if the crank be turned one space of the index-plate the effect of the system will be to produce fifty-eight or sixty-two graduations at V, according to whether two or one intermediates are employed. In order to produce fifty-nine or sixty-one graduations when thus employing an index-plate, the total gear ratio should be one to sixty.

Reverting to the bending theory heretofore referred to in connection with Fig. 2, it will be seen that in Fig. 5 when the crank is employed in connection with fixed index member S then the bending or change of relationship effected by the reaction of the gearing takes place between shafts Q and T, while when the crank is employed in connection with the index-plate as an indexing member then the change of relationship effected by the reaction of the gearing is between shafts Q and T and between the two indexing members represented by shaft Q and the index-plate. While this reaction system greatly extends the capacity of change-gearing or index-graduations by adding prime-number possibilities, it puts no limitations on the usual capacity of the change-gears or graduations. It should be stated, however, that if a jack-in-the-box is employed then for a given usual effect to be produced a double effect must be given to the crank. In other words, where one turn of the crank would produce a given usual effect two turns would be required if a jack-in-the-box be employed.

It will be at once obvious that while the system has been illustrated in connection with indexing movements derived from a hand-crank any other impelling movement may be made similarly subjective to the reaction system, and it is also obvious that it is quite immaterial where the power be applied to produce the movement. Thus in Fig. 5 the crank being unlocked the advancing motion may be given by turning shaft T or any other part, Fig. 5 simply illustrating an ordinary case where the power is applied directly at the indexing-point.

A great variety of modifications and adaptations of the principle will suggest themselves to the skilled constructor. It is to be understood, of course, that while the particular device set forth and described represents the best mode in which I contemplate applying the principle of my invention it is, after all, a mere exemplification of the invention.

For rather extended discussions of the theory and possibilities of the system reference may be had to the *American Machinist*, (New York,) volume 23, pages 29-1153; volume 24, page 58; volume 24, page 314; volume 24, page 334, and volume 24, page 547.

I claim as my invention—

1. In a dividing-engine, the combination, substantially as set forth, with the members essential to the advancing of the object to be divided and to the admeasurement of the advance, of mechanism disposed between and connected with two of said members and arranged to cause the advancing motion of one member to react upon another member and modify the normal admeasured indexing effect.

2. In a dividing-engine, the combination, substantially as set forth, with the members essential to the advancing of the object to be divided and to the admeasurement of the advance, such members comprising angular indexing apparatus and a shaft adapted to turn and advance the object to be divided, of change-gearing connected with said shaft and indexing apparatus and adapted to cause the advancing motion of the shaft to react upon the indexing apparatus and modify the normal admeasuring effect thereof.

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