A. BARR AND W. STROUD.

APPARATUS FOR THE CONVERSION OF MOTION OF ONE TYPE INTO MOTION OF ANOTHER TYPE.

APPLICATION FILED AUG. 15, 1918.

1,339,643. Patented May 11, 1920.

FIG: 1.

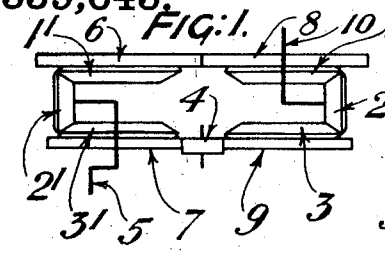


FIG: 2.

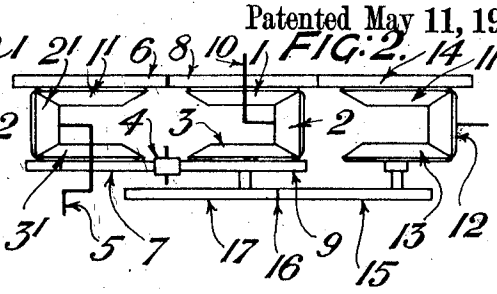


FIG: 4.

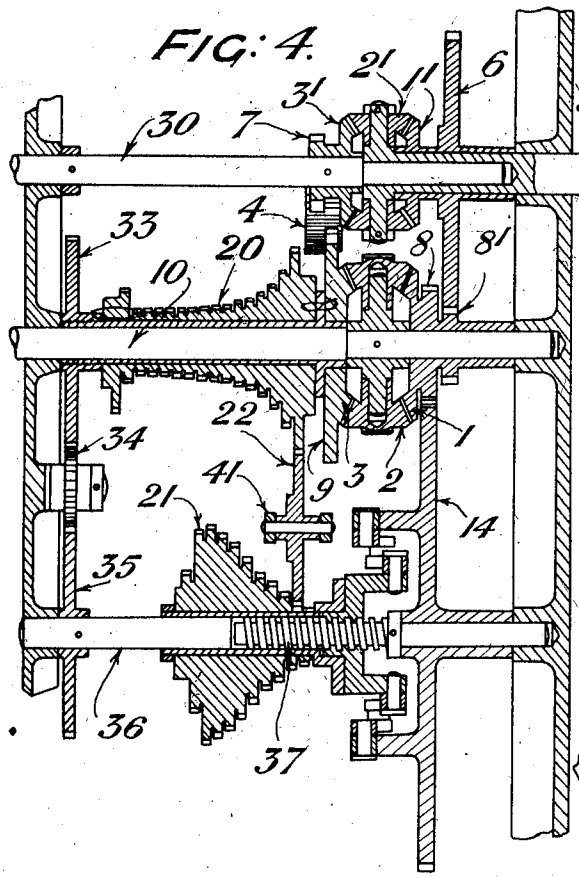


FIG: 5.

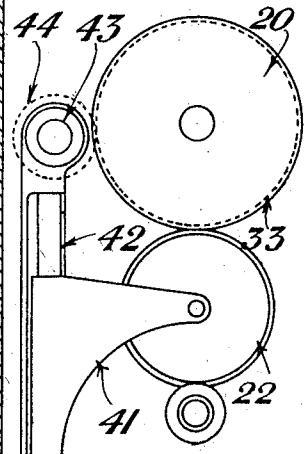


FIG: 6.

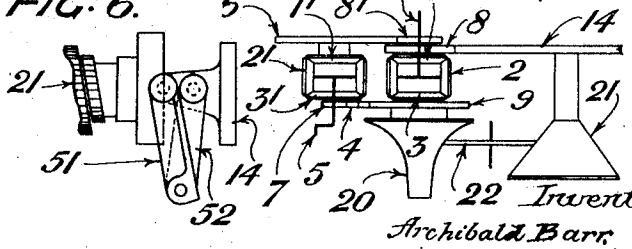


FIG: 3.

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APPARATUS FOR THE CONVERSION OF MOTION OF ONE TYPE INTO MOTION OF ANOTHER TYPE.

1,339,643. Specification of Letters Patent. Patented May 11, 1920.

Application filed August 15, 1918. Serial No. 250,087.

To all whom it may concern:

Be it known that we, ARCHIBALD BARR and WILLIAM STROUD, subjects of the King of Great Britain and Ireland, and both of Caxton street, Anniesland, Glasgow, Scotland, have invented new and useful Improvements in Apparatus for the Conversion of Motion of one Type into Motion of Another Type, of which the following is a specification.

The object of our invention is to provide improved means for the conversion of motion according to one law (or type) into motion according to another law (or type). For example, it provides means for the conversion of motions in accordance with those of the working head of a constant base rangefinder—which commonly follow the reciprocal law with reference to changes in range—into motions proportional to the changes of range, *i. e.*, the conversion of motions according to a reciprocal scale into motions according to a uniform scale; or again, for the conversion of motions according to a uniform scale of ranges into motions according to a logarithmic scale, or according to a scale of gunsight elevations corresponding to the ranges; or for other analogous purposes.

Patents with the same object in view are well known, but in mechanism generally for effecting such conversions of motions a difficulty arises when the velocity-ratio varies over wide limits at different parts of the conversion, *e. g.*, to convert a reciprocal scale of ranges extending from 3,000 to 30,000 yards into a uniform scale, with the velocity-ratio varying from 1 to 100, in one stage, the size of the mechanism required as at present known, for sufficient accuracy, would necessarily be great. A method has been proposed to effect conversions of this character in two (or more) stages, each, say, of 1 to 10, whereby a reduction in the size of the mechanism required is obtained.

Our present invention has for its object improvements in or connected with apparatus and the production of improved apparatus for use in the conversion of motion according to one law (or type) into motion according to another law (or type) in which the velocity-ratio may vary over wide limits (say, 1 to 100) at different parts of the conversion, by means of which apparatus the conversion may be effected in one stage, and the apparatus produced may be of small dimensions in comparison with mechanisms generally known for such purposes. Moreover, a novel process of conversion is made possible with the use of apparatus according to this invention in which the velocity-ratio of the motion to be converted passes through zero and extends on both sides thereof, and so is capable of producing positive and negative values of the velocity-ratios whereby a mechanical solution of the equation $y=f(x)$ may be furnished, where x denotes the motion applied to the apparatus, y the emergent motion and $f(x)$ is any function of x.

Apparatus according to this invention comprises three gear elements constituting a main differential gear with means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements in a predetermined progressively variable manner, whereby, for example, the motion of the first or the second element may be in accordance with the law A to be converted and the motion of the third element in accordance with the law B desired, or the motion of a part of mechanism provided for driving the first and second elements may be in accordance with the law A and the motion of the third element in accordance with the law B.

Denoting the elements of an ordinary differential gear by 1, 2, 3 in which 2 is the jockey element, it is clear that if the elements 1 and 3 are geared together in some suitable non-uniform way and provision made whereby the motions of 1 and 3 are in opposite senses, the motion imparted to jockey 2, according to this invention, will then correspond to the difference in the motions of 1 and 3, and the velocity-ratio of 2 compared with 1 (or 3) may be made as small as desired by adopting suitable non-uniform controlling gear, in fact, it may be made zero by arranging that the velocity of 1 is equal and opposite to that of 3. Further, the velocity-ratio of 2 may be made negative compared with (say) 1, in the following way:—If 1 is moved forward at a certain rate and 3 backward at a smaller rate, then we may regard 2 as moving forward at a rate depending on the differences of the rates of 1 and 3. As soon as the rate of motion of 3 equals that of 1, 2 becomes stationary, while if the rate of 3 exceeds

that of 1, 2 will move backward. By our invention it is thus possible to make 2 move in any prescribed manner forward or backward as may be desired. Further, in this way, if x denotes the motion imparted to the mechanism and y the emergent motion it is possible to obtain a mechanical solution of the equation $y=f(x)$ whatever the form of this function.

Taking then, as an example, the case of the conversion of a reciprocal scale of ranges into a uniform scale, we may gear the jockey element 2 of the differential gear to the working head of a rangefinder while we actually work by hand either the element 1 or 3. If then 1 and 3 be geared together in some suitable non-uniform way so that 3 moves in the opposite direction to 1, when, say, 1 is turned by hand, we may arrange that each revolution of 1 shall correspond to a definite change of range.

In certain cases it is conceivable that there may be a considerable resistance to the motion of 2, in which case considerable forces will have to be transmitted through the non-uniform gear between 1 and 3. This objection may be overcome by applying a direct drive to each of the elements 1 and 3. For instance, this may be done by providing a supplementary differential gear with an idle wheel, in which case a main differential gear 1, 2, 3 and a supplementary differential gear 1^1, 2^1, 3^1 are employed, 2 and 2^1 being the jockeys, 1 being directly geared to 1^1, and 3 being geared to 3^1 through an idle wheel. If now we apply a drive to 2^1 (according to a uniform scale) and obtain our drive to the rangefinder from 2 by suitable non-uniform gearing between 1 and 3 (as before) we may arrange that the motions of 2 shall be according to the required reciprocal scale. In this case 2 moves in accordance with the difference in the motions of 1 and 3 which are each directly driven, the non-uniform gear between 1 and 3 being employed to regulate the relative motions of 1 and 3. In this way the force transmitted through this non-uniform gear is appreciably reduced.

In the use of differential gears as above described, we have assumed that the drives are imparted to 1 and 3, and the part driven is connected to the jockey element 2, but in all cases (as is well-known in connection with differential gears) the drives may be imparted to any two of the three elements of the gear provided their effects on the third element are in opposite senses, while the third element is connected to the part to be driven.

Examples of construction according to this invention will now be described with reference to the accompanying drawing, in which:—

Figures 1, 2 and 3 are diagrammatic plan views. Fig. 4 represents a section of one form which the gear may take. Fig. 5 shows in side view a portion of the gear, and Fig. 6 is a plan of a detail.

In the drawing, 1, 2, 3 designate the elements of the main differential gear, and 1^1, 2^1, 3^1 the elements of the supplementary differential gear.

In Fig. 1 force is applied to a handle 5 to which the spindle of jockey 2^1 is fixed, thus the bevel wheels 1^1 and 3^1 tend to turn in the same sense. Fixed to 1^1 and 3^1 respectively are gear wheels 6 and 7. Gear wheels 8 and 9 are fixed to bevel wheels 1 and 3 respectively while 8 gears directly with 6, and 9 (through an idle gear wheel 4) with 7. Thus under the influence of the force applied to 5 the bevel wheels 1 and 3 tend to turn in opposite senses so that the motion of jockey wheel 2 (and shaft 10) is determined by the difference in the motions of 1 and 3. In Fig. 1 there is no device shown for controlling the relative motions of 1 and 3. In Fig. 2, however, mechanism is indicated for controlling the relative motions of 1 and 3. Here wheel 8 gears with a wheel 14 to which a bevel wheel 11 is fixed. Bevel wheel 11 gears with a bevel 12 whose spindle is fixed, and bevel 12 gears with a bevel 13 to which a toothed spiral 15 is fixed. Spiral 15 gears with a complementary toothed spiral 17 fixed to wheel 9. The two spirals 15 and 17 determine by their form the nature of the motion imparted to shaft 10. In the position shown in the figure spiral 17 will turn through a much larger angle than spiral 15, *i. e.*, wheel 9 will will turn through a much larger angle than wheel 8 and consequently in the position shown shaft 10 will turn in the same sense as wheel 9. This occurs when the place of gearing 16 of the two spirals is nearer the spindle of 9 than the spindle of 13. If the place of gearing 16 is, however, nearer the spindle of 13 than the spindle of 9 the shaft 10 will turn in the same sense as wheel 8. Thus as shaft 5 is turned in one sense shaft 10 will move (say) forward then stop and will then move backward.

In Fig. 4 (for which Fig. 3 is a diagrammatic representation) there is shown a section of the gear as applied (say) to the conversion of the reciprocal scale of a rangefinder into a uniform scale. In this case as the handle 5 is turned in one sense the shaft 10 will likewise have to move always in one sense, *i. e.*, not backward at one part and forward at another part. The speed of the wheel 1 is in all circumstances greater than that of wheel 3 (and their motions are in opposite directions) so that the speed of shaft 10 which depends on their difference in speed never falls to zero. In Fig. 4 the shaft 10 is used as the bearing for a toothed helico-spiral member 20 so that 10 and 20

can rotate independently. Considering Fig. 3, the functions of the parts 1, 2, 3, 1^1, 2^1, 3^1, etc., with the exception that 6 and 8 are geared together by 6 gearing with a gear wheel 8^1 fixed to 8, correspond to those of similar parts in Fig. 2, but instead of the controlling mechanism consisting of the two spirals 15 and 17 of Fig. 2, we have two toothed helico-spiral members 20 and 21 with an idle wheel 22 whose center is capable of motion in two dimensions in the plane of the paper. If the two helico-spiral members 20 and 21 are correctly formed motions of the member 20 and the gears 9, 3, 4 and 7 all directly geared together are according to a uniform scale while motions of the shaft 10 may be arranged to be in accordance with a reciprocal scale, thus when idle wheel 22 is gearing with the teeth on the large radius of 20 and with the teeth on the small radius of 21 (as shown in Fig. 4) any motion of 7 which is fixed to shaft 30 will produce a relatively large motion of 21 and therefore of bevel wheel 1 geared to 21 through wheels 14 and 8 and a relatively small motion of 20 and therefore of bevel wheel 3. It will be seen that 1 and 3 move in opposite senses so that the motion of 2 is determined by the motion of one less that of 3. With the idle wheel 22 in the position shown at Fig. 4 when handle 5 is turned shaft 10 will rotate rapidly backward relative to 20. If, however, idle wheel 22 is gearing with the teeth on the small radius of 20 and with the teeth on the large radius of 21 then the condition will be reversed and shaft 10 will now rotate slowly while 20 will be rapidly turned. If now shaft 10 be geared to the working head of a range-finder then starting from the position of the idle wheel 22 shown in Fig. 4, if we suppose handle 5 to be uniformly turned, shaft 10 is moved rapidly at the start (corresponding to low ranges), it gradually gets slower and slower as idle wheel 22 moves to the left in Fig. 4 and approaches shaft 10 until when 22 is nearest shaft 10 this shaft will be slowly rotating (corresponding to the highest range for which conversion is desired). In Fig. 4 it will be seen that the convolutions on the left of the two helico-spiral members are so arranged that the idle wheel 22 first approaches shaft 10 and then rapidly recedes from it. This is with the object of enabling the operator to rapidly approach the infinity position of the instrument.

Taking Fig. 4 in detail, wheel 7 is fixed to rotate with shaft 30 whose right hand bearing is supported by the shaft 31 to which handle 5 is fixed. Wheel 7 gears through idle wheel 4 with wheel 9 which is fixed to the helico-spiral member. All the parts 7, 4, 9 and 20 move in accordance with a uniform scale so that if it is desired to transmit the indication of the instrument to a distance in uniform steps it is sufficient to actuate a step-by-step transmitter by the shaft 30.

In order to suitably support the floating idle wheel 22 between the two helico-spiral members we may use the arrangement shown in Fig. 4. In this case the helico-spiral 20 is fixed axially and carries a wheel 33 gearing with an equal wheel 35 through idle wheel 34. Wheel 35 is fixed to shaft 36 upon which there is cut a screw thread 37 whose pitch is equal to the pitch of the spirals of part 20. Helico-spiral 21 is moved axially due to the rotation of screw 37 (upon which it is mounted as a nut) and is also moved axially due to its own rotation on the screw. Now, if the idle wheel 22 is carried toward the left so as to keep in mesh with the spiral 20 the helico-spiral 21 will move the appropriate amount to keep in mesh with the idle wheel.

In Fig. 5 is shown a side view of the support for the idle wheel 22 so designed as to move this idle wheel axially so as to maintain meshing. Its spindle is mounted on a frame 41 suitably guided so as to be incapable of rotation about the axis of a rod 42 upon which it can freely slide. Rod 42 is fixed to a nut upon screw 43 placed parallel to and behind shaft 10 but not shown in Fig. 4. A wheel 44 gears with wheel 33 so that as the member 20 is rotated 33 drives 44 and rotates 43 thereby translating the frame 41, perpendicular to the paper in Fig. 5 and parallel to the paper in Fig. 4, the pitch of the screw 43 and the ratio of the gearing 33, 35 being suitably chosen to cause 22 to remain in continuous mesh with the two helico-spirals 20 and 21. This condition is satisfied by the screw 43 being geared to the helico-spiral 20 by gearing in the inverse ratio of the pitches of the screw 43 and member 20, while rotation is imparted to the screwed shaft 36 proportional to the rotation of the helico-spiral 20 in such a way that the axial translation of the member 21, due to the rotation of the screw 36, is proportional to the angular rotation of the member 20, while the member 21 has also an axial translation proportional to its own rotation on the shaft 36, on which it is threaded as a nut.

Inasmuch as the helico-spiral 21 undergoes axial displacement in the operation of the apparatus and wheel 14 and member 21 must be fixed together as regards rotation about the axis of shaft 36 the one may be feathered with reference to the other for instance, or as shown in Fig. 4, and in another view in Fig. 6 we may connect 21 and 14 by a couple of hinged arms 51, 52.

In the arrangement described it has been mentioned that the uniform scale portion of the mechanism is geared to bevel wheel 3^1

so that one revolution of the handle 5 does not correspond to the same change in range at all parts of the travel. The mechanism could, however, be designed so that the uniform scale portion of the mechanism was geared directly to handle 5.

In the above we have described the application of our invention to a problem met with in connection with rangefinders where it is desired to convert motion according to a reciprocal scale of ranges into motion according to a uniform scale. This is done only by way of illustration and we do not confine ourselves to this particular application of the invention which may be used in other cases for the conversion of motions within limits as to the extent of these motions, *i. e.*, it is not a mechanism which can convey motion from one shaft to another continuously.

We claim:

1. Apparatus comprising three gear elements constituting a main differential gear, means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements in a predetermined progressively varying manner, for the purposes set forth.

2. Apparatus comprising three gear elements constituting a main differential gear, and three gear elements constituting a supplementary differential gear, the first and second elements of the supplementary gear being in driving connection with the first and second elements of the main gear respectively, means for imparting motion to the third element of the supplementary gear, the said driving connection being such that forces are transmitted to the first and second elements of the supplementary gear tending to drive the first and second elements of the main gear in opposite senses so far as their effects on the third element of the main gear are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements of the main gear in a varying manner, for the purposes set forth.

3. Apparatus comprising three gear elements constituting a main differential gear, means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements in a varying manner so that the motion of one of the first and second elements is in accordance with the law of motion A to be converted and that of the third element is in accordance with the law of motion B desired, substantially as set forth.

4. Apparatus comprising three gear elements constituting a main differential gear, and three gear elements constituting a supplementary differential gear, the first and second elements of the supplementary gear being in driving connection with the first and second elements of the main gear respectively, means for imparting motion to the third element of the supplementary gear, the said driving connection being such that forces are transmitted to the first and second elements of the supplementary gear tending to drive the first and second elements of the main gear in opposite senses so far as their effects on the third element of the main gear are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements of the main gear in a varying manner so that the motion of one of the elements of the supplementary gear is in accordance with the law of motion A to be converted and that of the third element of the main gear is in accordance with the law of motion B desired.

5. Apparatus comprising three gear elements constituting a main differential gear, means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element are concerned, associated with mechanism comprising toothed-spiral members for controlling the ratio of the motions imparted to the first and second elements in a varying manner, for the purposes set forth.

6. Apparatus comprising three gear elements constituting a main differential gear, means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element are concerned, associated with mechanism comprising two toothed helicospiral members, associated with means for imparting axial translation to one of the members and for imparting rotational motion to each, for controlling the ratio of the motions imparted to the first and second elements in a varying manner, for the purposes set forth.

7. Apparatus comprising three gear elements constituting a main differential gear, and three gear elements constituting a supplementary differential gear, the first and second elements of the supplementary gear being in driving connection with the first and second elements of the main gear respectively, means for imparting motion to the third element of the supplementary gear, the said driving connection being such that forces are transmitted to the first and second elements of the supplementary gear tending to drive the first and second elements of the main gear in opposite senses so far as their effects on the third element of the main gear are concerned, associated with mechanism comprising toothed spiral members for con-

trolling the ratio of the motions imparted to the first and second elements of the main gear in a varying manner, for the purposes set forth.

8. Apparatus comprising three gear elements constituting a main differential gear, and three gear elements constituting a supplementary differential gear, the first and second elements of the supplementary gear being in driving connection with the first and second elements of the main gear respectively, means for imparting motion to the third element of the supplementary gear, the said driving connection being such that forces are transmitted to the first and second elements of the supplementary gear tending to drive the first and second elements of the main gear in opposite senses so far as their effects on the third element of the main gear are concerned, associated with mechanism comprising two toothed helico-spiral members, associated with means for imparting axial translation to one of the members and for imparting rotational motion to each for controlling the ratio of the motions imparted to the first and second elements of the main gear in a varying manner, for the purposes set forth.

9. Apparatus comprising three gear elements constituting a main differential gear, means for applying to the first and second elements forces tending to drive them in opposite senses so far as their effects on the third element (the jockey) are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements in a predetermined progressively varying manner, for the purposes set forth.

10. Apparatus comprising three gear elements constituting a main differential gear, and three gear elements constituting a supplementary differential gear, the first and second elements of the supplementary gear being in driving connection with the first and second elements of the main gear respectively, means for imparting motion to the third element (the jockey) of the supplementary gear, the said driving connection being such that forces are transmitted to the first and second elements of the supplementary gear tending to drive the first and second elements of the main gear in opposite senses so far as their effects on the third element (the jockey) of the main gear are concerned, associated with mechanism for controlling the ratio of the motions imparted to the first and second elements of the main gear in a varying manner, for the purposes set forth.

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