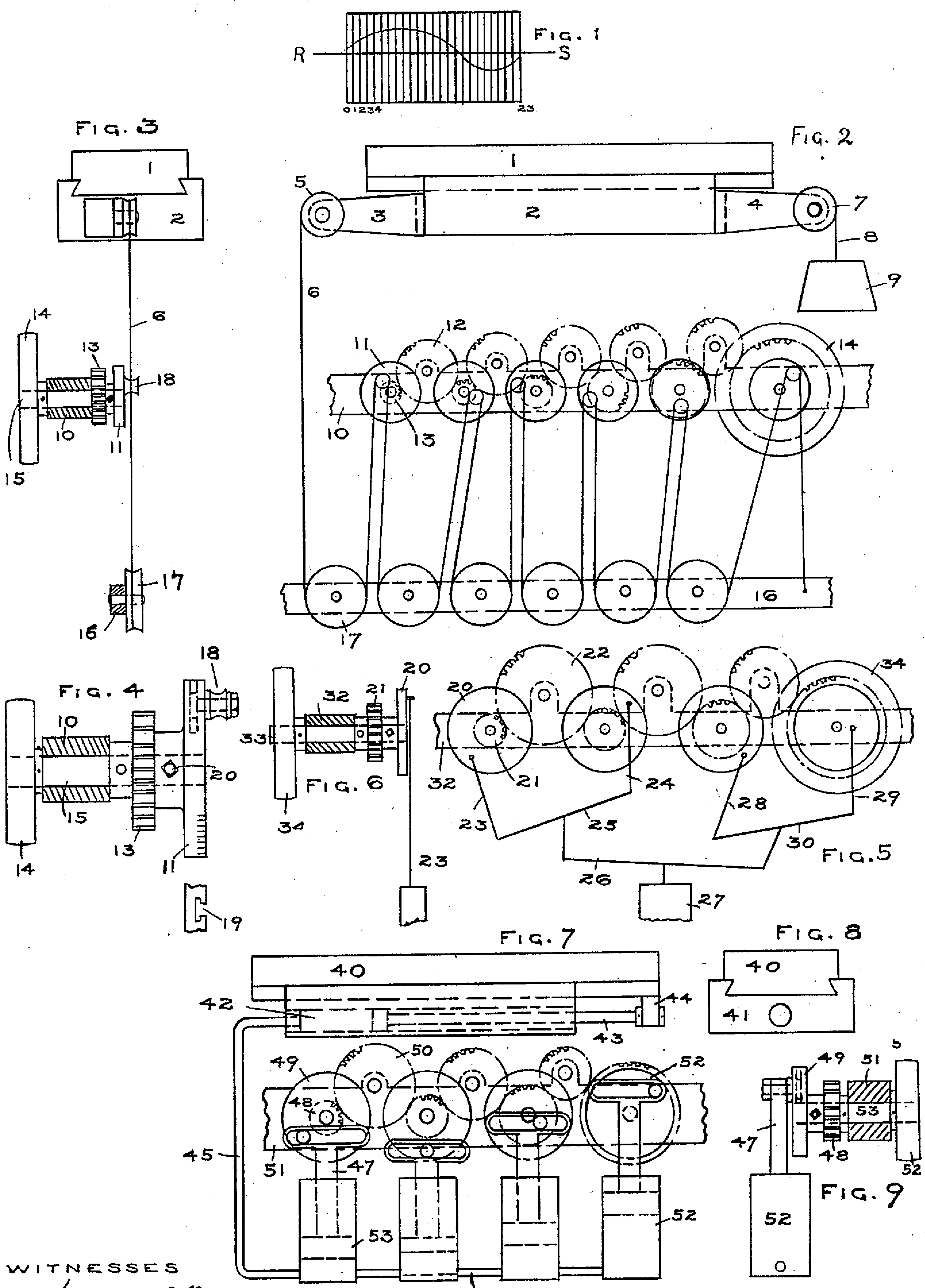
(No Model.) 2 Sheets—Sheet 1.

E. J. McCLELLAN.

COMPOUND HARMONIC MOVEMENT FOR MACHINES.

No. 594,032. Patented Nov. 23, 1897.



WITNESSES
C. H. McClellan
M. E. Barnett.

INVENTOR,
Edward Joseph McClellan.

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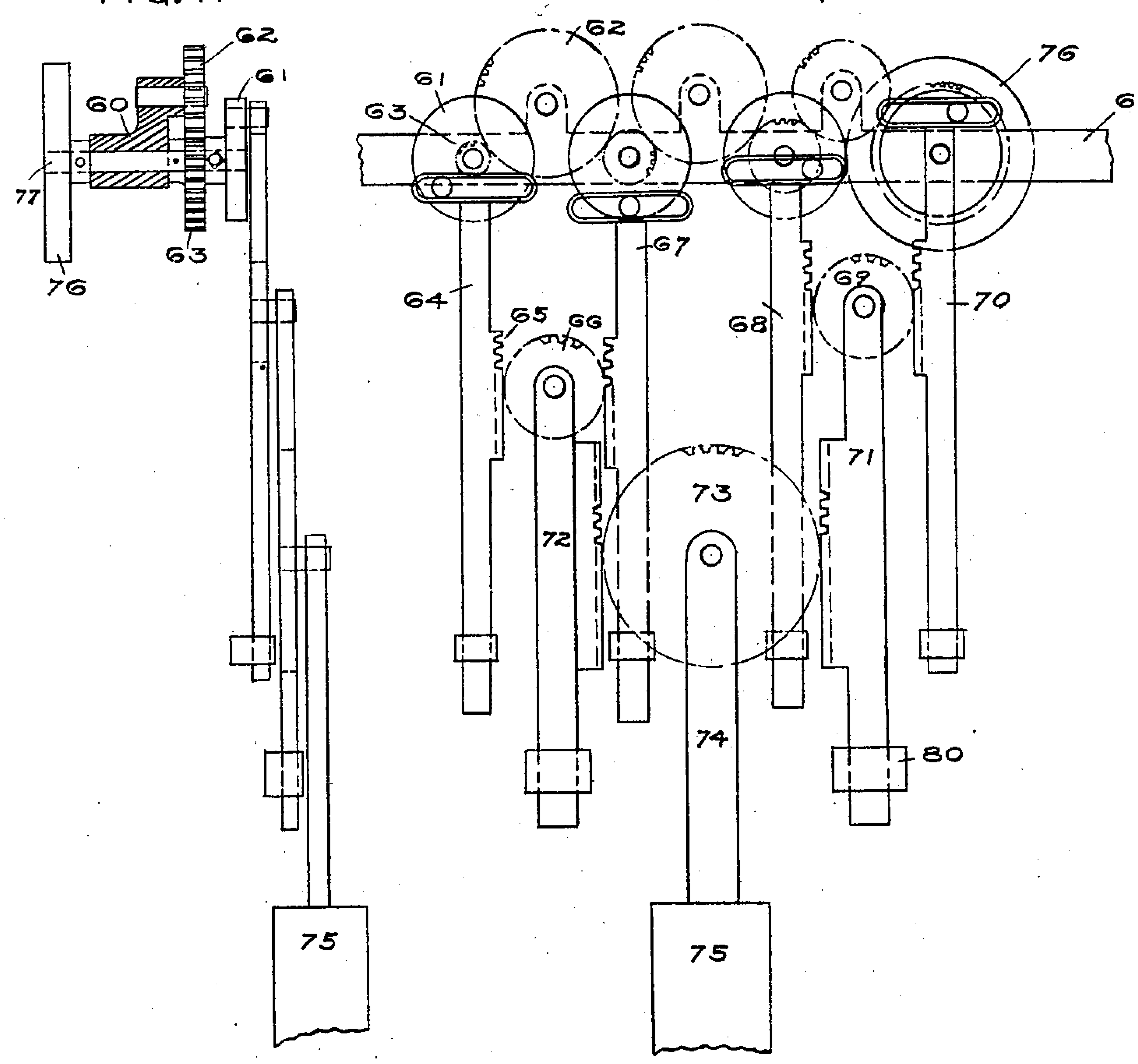
FIG. 11 FIG. 10.



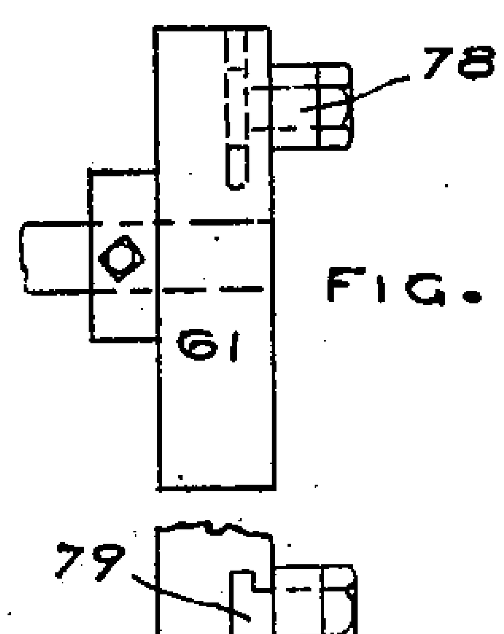


FIG. 12

WITNESSES

C. H. McClellan

M. E. Barnett.

INVENTOR

Edward Joseph McClellan

UNITED STATES PATENT OFFICE.

EDWARD JOSEPH McCLELLAN, OF NEW YORK, N. Y.

COMPOUND HARMONIC MOVEMENT FOR MACHINES.

SPECIFICATION forming part of Letters Patent No. 594,032, dated November 23, 1897.

Application filed May 4, 1896. Serial No. 590,092. (No model.)

To all whom it may concern:

Be it known that I, EDWARD JOSEPH McCLELLAN, a citizen of the United States, residing at New York, in the county of New York and State of New York, have invented an Improvement in Compound Harmonic Movements for Machines, of which the following is a specification, reference being had to the accompanying drawings.

The mechanism here described is a method of combining a number of crank motions in such a manner as to be able to produce any desired irregular motion, such as a cam motion, and which motion may be represented by a curve such as the development of a cam.

The invention is based on the researches of Fourier on harmonic motion, and known in physics as "Fourier's Theorem." Fourier demonstrated that the equation of any arbitrary curve can be expressed in a series of multiple sines with arbitrary coefficients. The reciprocating motion imparted by a revolving crank is a harmonic motion, and the amount of motion is equal to the sine of the angle through which the crank is turning.

In setting up the machine to produce any desired motion it is first necessary to obtain the Fourier equation of the curve representing the desired motion. This equation is readily obtained by mathematicians, but the calculations involved form no part of this invention and do not concern us here, but simply the result.

Let the curve shown in Figure 1 represent a certain motion which it is desired to produce by my mechanism. The curve is supposed to have been wrapped around a cylinder whose circumference equals 2π, and h in the formula below represents the abscissa or that part of the circumference of the cylinder corresponding to any ordinate y. The following are the values of the ordinates of the given curve for which I give the Fourier equation as an illustration:

No.	*h.*	Ordinate.
0	0°	13.3660
1	15°	14.0395
2	30°	14.3300
3	45°	14.3295
4	60°	14.1340
5	75°	13.8295
6	90°	13.4640
7	105°	13.0355
8	120°	12.5000
9	135°	11.7940
10	150°	10.8660
11	165°	9.7060
12	180°	8.3660
13	195°	6.9645
14	210°	5.6700
15	225°	4.6700
16	240°	4.1330
17	255°	4.1705
18	270°	4.8030
19	285°	5.9600
20	300°	7.5000
21	315°	9.3940
22	330°	10.8660
23	345°	12.2940

The Fourier expression for this curve is—

$$y=10+5\sin(h+30°)-\sin(2h-60°).$$

Assuming any value of h and substituting in the formula we get the corresponding ordinate. The axis of the curve is indicated by the line RS and shows how the curve passes above and below this line. In mechanically producing the value given by this equation, which is the same thing as automatically tracing the curve which represents it, the value of the sines are given by the rectilinear motion given by cranks, and the formula shows that several cranks will be required, one for each sine to be obtained, and also that the sines are to be added together, in the algebraic sense. The coefficients of the sines give the distances of the crank-pins from the center. The angles $h-30°$, $2h-60°$, &c., give the relative angular position of the cranks at any time. These angles, it will be noted, are successively multiple, and this shows that the respective cranks that are to produce the sines of these angles must rotate at corresponding multiple speeds, the first crank making one revolution, the next crank in order two revolutions, &c., in the production of one complete cycle.

It will be seen later that I have provided in my mechanism all the means necessary to fulfil the conditions of the formula and can therefore produce the motion automatically. To drive the cranks at the successive multiple speeds, the crank-disks are geared together in the required ratio. To combine the crank motions, several methods may be employed. A continuous ribbon is attached to a fixed point at one end and passes alternately over a crank-pin which carries a small pulley and under a fixed pulley and then over a second crank-pin and under a second fixed pulley, and so on, the other end of the ribbon being attached to the slide that is to be moved. This plan is shown in Fig. 2, and it will be seen that the motion is doubled. Another plan is to connect each crank with the piston of a hydraulic cylinder and connect all the cylinders together by a pipe, so that they in effect form one, and then connect with the hydraulic cylinder of the slide which is to be moved. This plan is shown in Fig. 7. Still another plan is to connect each pair of cranks to the extremities of a bar and then connect the middle points of these bars to the ends of another set of bars until a single point of application is reached to which the slide to be moved may be attached. This plan is shown in Fig. 5. Other plans more or less practical can be devised to secure the desired end, that of combining the motions into a single resultant, but those shown will suffice.

Referring to the drawings, Fig. 1 shows an arbitrary curve representing a given motion. In this curve the distances along the axis O^{23} represent the equal intervals of time and the corresponding ordinates represent the position of the piece moved. In Fig. 2 is shown the combination of cranks as used with a continuous ribbon to move a slide. Fig. 3 is an end view of the same. Fig. 4 is a detail view, on a larger scale, of one of the crank-disks and connecting parts. Fig. 5 is a view of the crank-disks as connected by a series of levers. Fig. 6 is an end view of same. Fig. 7 is a view of the crank-disks as connected with a set of hydraulic cylinders, which are in turn connected to a hydraulic cylinder which imparts motion to the slide that is to be moved. Fig. 8 is an end view of the slide. Fig. 9 is an end view of the crank-disks and connecting parts. Fig. 10 is a view of the crank-disks as connected with slotted connecting-rods which engage rack-pinions in pairs, as shown. Fig. 11 is an end view of same. Fig. 12 is a view of the crank-disks with adjustable crank-pin with roller.

In Fig. 2 the slide 1 moves in the bearing 2. On the left-hand end of the slide a ribbon 6 is connected, passing over the pulley 5, held in the bracket 3. On the right-hand end of the slide the ribbon 8 is attached, which passes over the pulley 7 and carries the weight 9, which serves to pull the slide back and keep the ribbon taut. On the bar 10 are mounted a series of crank-disks 11. These crank-disks have each a gear 13 attached on the back and are held on shafts 15, which run in bearings in the bar 10. To drive the system of cranks, one of the shafts 15 has a pulley mounted on the rear end, to which power can be transmitted. The gears 13 on the backs of the crank-disks are of such relative diameters that the cranks make, respectively, one, two, three, four, five, six, &c., revolutions in the same time. The cranks are connected together by the intermediate gears 12. The ribbon 6 is fastened to a fixed point at the right-hand end of the bar 16 and passes over the pulleys 18, carried on the crank-disks, and under the fixed pulleys 17, as shown. The pulleys 18 on the crank-disks are adjustable in a T-slot 19 in the disks, as shown in Fig. 4, and the crank-disks are adjustable around the shafts 15, on which they are mounted and secured by the set-screw 20.

In Fig. 5 the crank-disks 20 are mounted on a bar 32 and carry a crank-pin on the front face and have a gear 21 fastened on the back, as described in relation to Fig. 2. The disks are connected by the intermediate gears 22 and run at successive multiple speeds, as in Fig. 2.

In the case of four disks, as shown, two cranks are connected by rods 23 24 to a bar 25, and two other disks are connected by rods 28 29 to a bar 30. To the middle of each bar 25 30 is connected a short rod connecting to the rod 26, and from the middle of this bar connection is made to the slide 27 to be moved. The crank-pins are adjustable from the center and the disks are adjustable around the shaft in the same manner as in Fig. 2. The system is driven by the pulley 34.

In Fig. 7 the slide 40 is carried in the bearing-block 41. In the block 41 is the hydraulic cylinder 42, in which moves the piston 43, which is attached to the slide by the lug 44. Mounted on the bar 51 are shown four crank-disks 49, carrying gears 48 on the back and connected together by the intermediate gears 50 and driven at successive multiple speeds, as in Fig. 2. Attached to each crank is a slotted connecting-rod 47, carrying a piston 53 and working in a cylinder 52. These cylinders are connected by a pipe 45, which also serves to connect up to the cylinder 42, which moves the slide 40. The crank-pins and the disks are adjustable in the same manner as in Fig. 2. The system of cranks is driven by the pulley 52, carried on the rear of the shaft 53, belonging to the crank-disk in the extreme right hand.

Mounted on the bar 60 in Fig. 10 are the crank-disks 61, which have the gears 63 fastened on the back and are connected together by the intermediate gears 62 and driven at successive multiple speeds, as in Fig. 2. The whole train is driven by the pulley 76 on the rear end of the shaft 77 at the extreme right. The crank pins and disks are adjustable, as shown in Fig. 12, in the same manner as in the other figures. Connected to the two crank-disks on the left are the slotted connecting-rods 64 67, which have a rack cut on the edges, as shown at 65, and engage the pinion 66. Connecting with the two disks on the right are the rods 68 70, which gear into the pinion 69. On the pinions 66 69 are the rods 72 71, which gear into the pinion 73, and from the gear 73 connects the rod 74 to the slide 75 which is to be moved. The rods are guided in bearings 80.

In Fig. 2 it will be seen that the cranks are all acting on the ribbon 6, some taking up slack, while others are giving up slack, the resultant pull being transmitted to the slide 1, the weight 9 meanwhile keeping the ribbon taut.

In Fig. 5 it will be seen that the motion transmitted to the levers depends on the relative positions of the cranks and that the resultant motion is directly imparted to the slide.

In Fig. 7 the pistons add or subtract from each other in filling the cylinder 42, according as they are all moving down at once or some going up while others are going down, and the net result is transmitted to the piston 43 and consequently to the slide 40.

In Fig. 10 if one rod, 64, were going down and the other rod, 67, were going up at the same time the pinion 66 would get no motion whatever up and down except that due to the fact that the rod 64 is making more strokes than the rod 67. The resultant motion is clearly transmitted to the slide 75. Fig. 10 is kinematically the same as Fig. 5. The crank-disks may be graduated, as indicated in Fig. 4, to assist in setting the cranks at the required relative angles.

In Fig. 5 if the connecting-rod 29 of the fourth crank were adjusted clear into the center it is clear we would have a virtual combination of three cranks only, and it is obvious that if a combination of but three cranks only were wanted the connecting-rod 28 of the third crank could be connected directly to the extremity of the connecting-piece 26 and the connection-piece 30 dispensed with in that particular case. The same remarks apply to Fig. 10 and to any odd number of cranks. This mechanism is well adapted for use on an automatic screw-machine to produce a varied cycle of movements and has the advantage of universal adaptability to all conditions.

I claim—

1. The combination in a mechanical movement, of a connected series of revoluble cranks, said cranks having such relative angular positions and throws as determined by the harmonic equation of the curve representing the motion to be produced, as described, gearing connecting said cranks together and adapted to drive each crank at a speed proportional to the order in which the respective crank stands in the series, and suitable means, such as shown and described, for converting the rotary motions of said cranks into respective rectilinear motions and combining these rectilinear movements into one net resultant motion, substantially as described.

2. The combination in a mechanical movement, of a connected series of revoluble cranks, said cranks having such relative angular positions and throws as determined by the harmonic equation of the curve representing the motion to be produced, as described, gearing connecting said cranks together and adapted to drive each crank at a speed proportional to the order in which the respective crank stands in the series, slotted connecting-rods 64 67 from each pair of cranks and having a rack 65 on the side meshing with gears 66 69, connecting-rods 72 71 from the respective centers of gears 66 69, and a second set of gears 73 meshing with racks on 72 71, and so on until a single gear is reached which receives the net resultant motion, substantially as described.

EDWARD JOSEPH McCLELLAN.

Witnesses:
C. H. McCLELLAN,
M. E. BARNETT.