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B. F. LANGER

2,432,907

BALANCER

Filed Sept. 28, 1944

2 Sheets-Sheet 1

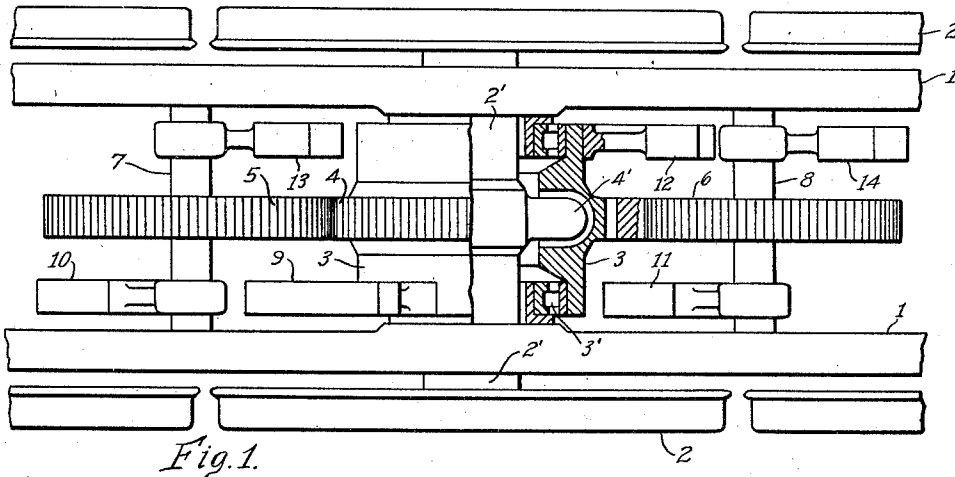


Fig. 1.

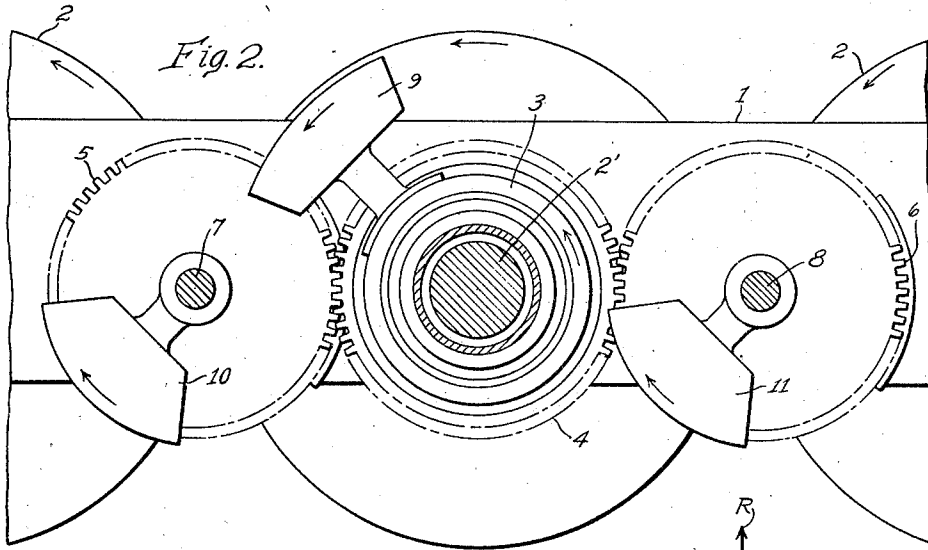


Fig. 2.

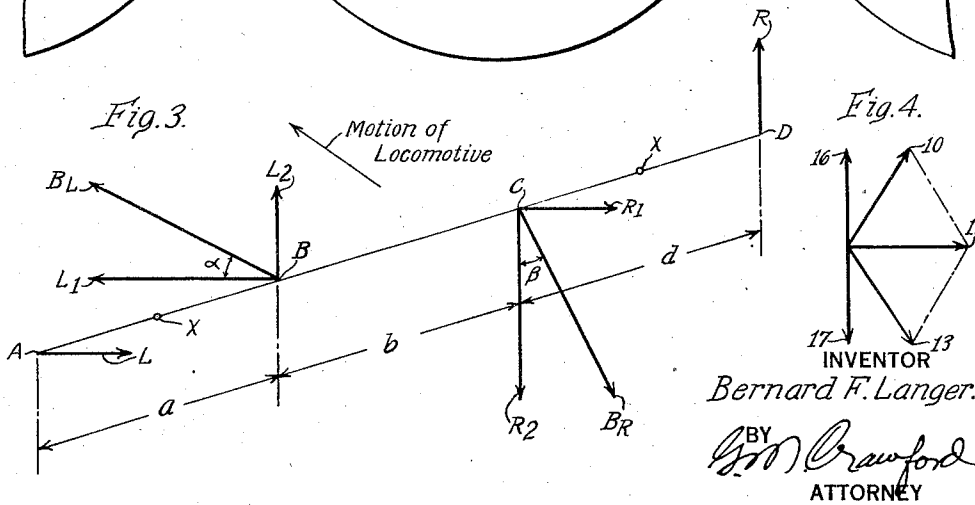


Fig. 3.

Fig. 4.

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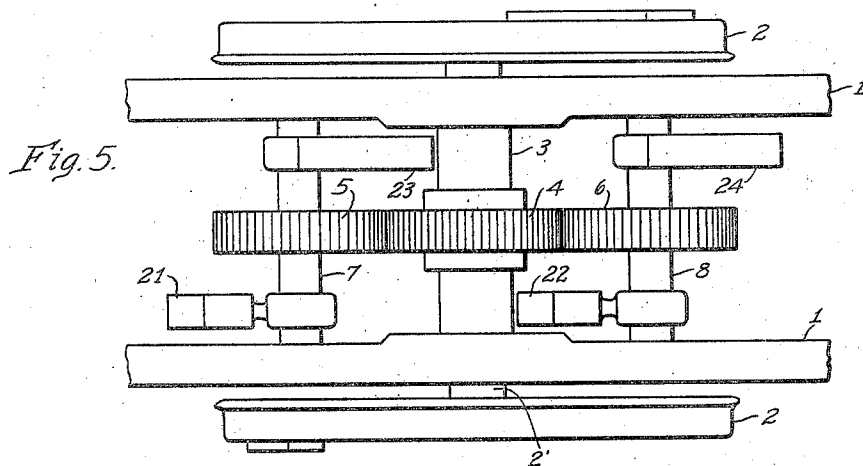
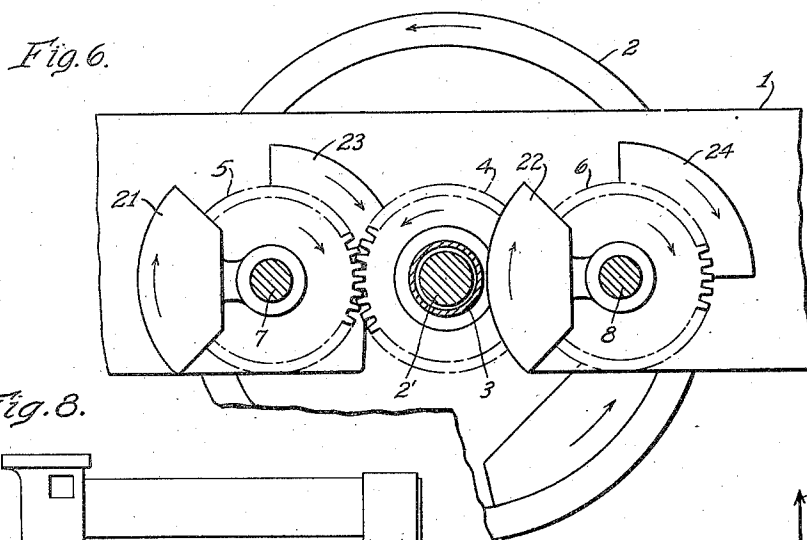
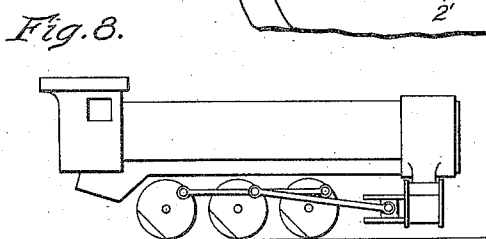
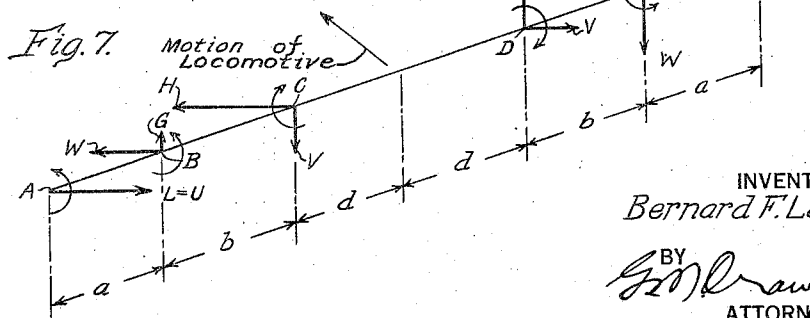
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2 Sheets-Sheet 2



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BALANCER

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5 Claims. (Cl. 105—108)

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My invention relates, generally, to balancers and, more particularly, to balancers for steam locomotives.

In a two cylinder steam locomotive it is impossible even to approach good balance of the oscillating forces by the methods now used. The reason for this is that the counterbalance weights are put in the wheels of the locomotive where their motion is rotational, whereas a large part of the vibrations originate in the reciprocating parts of the driving mechanism, such as the pistons and part of the connecting rods. The usual method of balancing steam locomotives is to put sufficient counterbalance weights in the wheels to counteract the rotating forces and about half of the reciprocating forces. The other half of the reciprocating force is absorbed by the inertia of the locomotive and results in vibration. An even more serious consequence is that the vertical component of the counterweight force has only the rail to react against and causes a fluctuation in the wheel load with each revolution. This fluctuation in wheel load is commonly known as "dynamic augment" and is one of the chief limitations to the speed of steam locomotives. To give some idea of the magnitude of this fluctuation, the example might be given of one popular type of high speed locomotive for which the dynamic augment at 100 M. P. H. is two-thirds of the wheel load. This means that the rail load of each wheel, even on smooth straight track, fluctuates between $\frac{1}{3}$ and $1\frac{2}{3}$ of its static value during each revolution.

An object of my invention, generally stated, is to provide a locomotive balancer which shall be simple and efficient in operation and which may be economically manufactured and installed.

A more specific object of my invention is to counterbalance the reciprocating force in a steam locomotive.

Another object of my invention is to prevent fluctuation in the wheel load of a locomotive of the reciprocating type.

A further object of my invention is to provide a locomotive balancer which will not increase the unsprung weight of a locomotive.

Still another object of my invention is to provide a balancer which can readily be added to an existing locomotive.

Other objects of my invention will be explained fully hereinafter or will be apparent to those skilled in the art.

In accordance with one embodiment of my invention, a hollow shaft or quill surrounds one of the driving axles of a locomotive and is rotatably

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mounted in the locomotive frame. The quill is driven by the shaft which it surrounds and it drives two other shafts mounted in the frame. Balancing weights are so disposed on these shafts that all the reciprocating force is counterbalanced.

For a fuller understanding of the nature and objects of my invention, reference may be had to the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a view, partially in plan and partially in section, of a portion of a locomotive structure embodying my invention;

Fig. 2 is a view, partially in side elevation and partially in section, of the structure shown in Fig. 1;

Fig. 3 is a vector diagram of the balancing system shown in Figs. 1 and 2;

Fig. 4 is a vector diagram of a slightly modified balancing system;

Fig. 5 is a view, in plan, of a modification of the invention;

Fig. 6 is a view, partially in side elevation and partially in section, of the structure shown in Fig. 5;

Fig. 7 is a vector diagram of the balancing system shown in Figs. 5 and 6, and

Fig. 8 is a diagrammatic view showing the location of the reciprocating and the rotating parts of a steam locomotive.

In practicing my invention, the rotating forces which are due to the inertia of the side rods, crank pins, etc. are counterbalanced in the usual manner, that is, by means of balance weights placed in the wheels of the locomotive. A novel feature of my system is the method of counterbalancing the reciprocating forces, which may be accomplished by means of the device shown in Figs. 1 and 2. These figures show the application of the device to a steam locomotive of the Pacific (4-6-2) type. There are many different ways in which the device could be arranged some of which will be mentioned hereinafter.

Referring to the drawing, the structure shown in Figs. 1 and 2 comprises a portion of a main frame 1 of a locomotive having driving wheels 2 secured to axles 2' in the usual manner. A hollow cylindrical member 3 surrounds the middle driving axle 2' and rotates in bearing 3' disposed in the locomotive frame 1. The member 3 may be compared to the quill in the well known quill drive utilized on electric locomotives. It is driven by the axle which it surrounds through a flexible coupling 4' which may be one of the types usually

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utilized on electric locomotives. The coupling 4', illustrated in the drawings, is similar to one commonly known as a "cup-drive." A gear 4 is secured to the outer surface of the cylindrical member 3. The gear 4 drives two other gears 5 and 6, which, in turn, drive shafts 7 and 8, respectively.

The shafts 7 and 8 are mounted in bearings disposed in the main frame 1 of the locomotive. The gears 4, 5 and 6 all have the same diameter. Thus, the members 3, 7 and 8 comprise a system of shafts mounted in the main frame 1 which all rotate at an angular velocity equal to that of the driving wheels. As indicated by the arrows in Figure 2, the shaft 3 rotates in the same direction as the wheels, while 7 and 8 rotate in the opposite direction.

The shafts 3, 7 and 8 each have two counterweights mounted on them in angular relation, thereby making a total of six individual weights, 9, 10, 11, 12, 13 and 14. As shown in Figure 1, the weights 9, 10 and 11 are disposed on one side of the longitudinal center line of the locomotive, and the weights, 12, 13 and 14 are disposed on the other side of the center line.

The effect of the three weights which are on one side of the locomotive, for instance the left side, will be considered first. The weight 9 is attached to the shaft 3, weight 10 is attached to the shaft 7 and the weight 11 is attached to shaft 8. If all three weights have the same mass, and 9 rotates at twice the radius of either 10 or 11, the centrifugal force of 9 is equal to that of 10 and 11 combined. Any combination of masses and radii which makes 9 equivalent to 10 and 11 combined is satisfactory. As may be seen from Fig. 2, weights 9, 10 and 11 all reach their extreme fore and aft positions at the same instant. However, because of the different directions of rotation, 9 is in its uppermost position when 10 and 11 are in their lowermost position. Therefore, the vertical components of the centrifugal forces are cancelled. However, the horizontal components add. Therefore, the net result is a sinusoidally varying, longitudinally directed, reciprocating force exerted on the frame of the locomotive.

On the other side of the locomotive a similar set of three weights 12, 13 and 14 produces another reciprocating force. The phase relationship between these forces on each side of the locomotive can be adjusted to any desired value. By correct choice of the magnitude and phase position of the counterweights it is possible to counterbalance any system of longitudinal reciprocating forces in the plane of the axle centers both as to forces and moments.

The calculation of the correct magnitude and phase position of the weights is most easily done by means of vectors. In the vector diagram, illustrated in Figure 3, the line ABCD represents a horizontal line perpendicular to the longitudinal axis of the locomotive. The points A, B, C and D are the points at which this line intersects various vertical longitudinal planes in which we are interested. A and D are in the planes of the pistons and connecting rods of the locomotive. B and C are in the planes of the counterweights. The points X show the locations of the driving wheels. The vectors drawn from points A, B, C and D represent the reciprocating forces in magnitude and phase. The actual forces are the projections of the rotating vectors on a horizontal plane. The vectors rotate counterclockwise.

The vectors L and R represent the inertia forces

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of the left and right pistons and rods. They are 90° apart. B_L and B_R are the counterbalance forces required to produce equilibrium. Vector $B_L = L_1 + L_2$ and $B_R = R_1 + R_2$. The equilibrium equations are (1) $L_1 - R_1 = L$, (2) $R_2 - L_2 = R$, (3) $L_1 a = R_1 (a + b)$, and (4) $R_2 d = L_2 (b + d)$. From these equations we can determine L_1 , L_2 , R_1 and R_2 , from which we can find B_L and B_R in both magnitude and phase.

To take a simple example, let $L = R = 500$ lb. equivalent weight at the rim of the driving wheel and $a = b = d = 30$ inches. (These figures approximate an actual case). Substituting and solving, we get: $R_1 = L_2 = 500$ lb. $L_1 = R_2 = 1000$ lb.,

$$\alpha = \beta = \arctan 0.5 = 26^\circ 30'.$$

$B_L = B_R = \sqrt{1000^2 + 500^2} = 1120$ lb. equivalent weight at the wheel rim.

In Fig. 2, weight 9 is shown rotating at a radius about equal to that of the driving wheel and weights 10 and 11 have half that radius. Therefore each of the weights 9-14 inclusive should weight 560 lb. The angular spacing between any two weights on the same shaft (say weights 10 and 13 on shaft 7) should be $90^\circ + 2 \times 26^\circ 30' = 143^\circ$. All necessary angular relationships can be found from Fig. 3.

In Figs. 1 and 2 there is illustrated just one of the many forms which a device utilizing the same fundamental principles could take. Some of the more important variations are as follows:

(1) Any two weights on the same shaft, say 10 and 13 on shaft 7, could be replaced by three weights on the same shaft, two in the same planes already shown and the third in the plane of the center line of the locomotive. Fig. 4 illustrates how these weights would be arranged. The vectors 10 and 13 represent the forces from the correspondingly numbered weights of Fig. 1. The vectors 15, 16 and 17 represent the forces from an alternative system of weights. The counterweight 15 of Fig. 4 would be located in the gear 5 of Fig. 1. The counterweights 16 and 17 would replace 10 and 13 and be located 180° apart, instead of 143°.

(2) Figs. 1 and 2 show a device large enough to counterbalance the whole locomotive with a single unit. A larger number of smaller units could be utilized. This would be particularly applicable to locomotives with four or more driving wheels.

(3) A unit could be built with two, instead of three, rotating shafts. A single unit with two shafts in a horizontal plane would apply a pitching moment to the locomotive when one weight was up and another down. However, with an even number of such units, the pitching moments could be made to counteract each other.

(4) The two or three shafts comprising a single unit might not lie in the same horizontal plane.

(5) It is possible to use any desired combination of the old method of balancing and the one herein described in case the full benefits of the new method are not required.

(6) It is not necessary to have one of the balance shafts enclosing an axle as does shaft 3 in Figs. 1 and 2. A complete unit consisting of two or three balance shafts could be located between two axles and be driven from one of the axles.

(7) The gears used to drive the balance shafts could also be utilized to transmit tractive effort from one axle to another and thus eliminate side rods.

(8) Similar devices could be devised for use on three or four cylinder steam locomotives.

A further modification of my invention is illustrated in Figs. 5 and 6, in which like parts are

designated by the same reference characters as in Figs. 1 and 2. The balancing device illustrated in Figs. 5 and 6 is similar to the one shown in Figs. 1 and 2, with the exception that the counterweights which rotate in the same direction as the wheels are located in the wheels themselves, instead of on a separate shaft, such as the shaft or quill 3. Thus, the balance weights are located in four different planes, instead of in two planes as in the structure hereinbefore described. The method of obtaining correct cross balance with the weights in four planes is explained in the following analysis:

In Figure 7 the line ABCDEF runs across the locomotive through the center of the axle being balanced. A and F are in the planes of the left and right connecting rods. B and E are in the planes of the wheels. C and D are in the planes of the counterweights 21, 22, 23, and 24 of Figures 5 and 6.

The vectors at points B, C, D, and E represent in magnitude and direction components of the centrifugal forces of counterweights rotating about those points. The vectors at A and F represent the phase positions of the reciprocating forces from the pistons and connecting rods, but the magnitudes of these forces are the projections of the vectors on a horizontal plane. The direction of rotation of the vectors is shown by arrows. The equilibrium equations are:

$$(1) \quad U - W - H + V + G = 0$$

$$(2) \quad G - V + H - W = 0$$

$$(3) \quad U(a+b+d) - W(b+d) - Hd - Vd - G(b+d) = 0$$

$$(4) \quad G(b+d) - Vd - Hd + W(b+d) = 0$$

The solution of these equations is:

$$W = \frac{U}{4} \left(\frac{a+b+d}{b+d} + 1 \right)$$

$$G = \frac{U}{4} \left(\frac{a+b+d}{b+d} - 1 \right)$$

$$H = \frac{U}{4} \left(\frac{a+b+d}{d} + 1 \right)$$

$$V = \frac{U}{4} \left(\frac{a+b+d}{d} - 1 \right)$$

To take a simple example, suppose the reciprocating force is 500 lbs. equivalent weight at the radius of a driver on each side of the locomotive and $a=b=d=15$ inches. U for each axle is then

$$\frac{500}{3} = 167 \text{ lbs.}$$

for a 4-6-2 type locomotive. Then $W=104$ lbs., $G=20.9$ lbs., $H=167$ lbs., and $V=83.5$ lbs. The combined effects of weights 21 and 22 must equal the vector sum of forces H and V.

$$H + V = \sqrt{167^2 + 83.5^2} = 186 \text{ lbs.}$$

If the weights rotate at a radius about $\frac{3}{8}$ that of a driver each weight is

$$\frac{1}{2} \times \frac{8}{3} \times 186 = 248 \text{ lbs.}$$

One advantage of the device illustrated in Figs. 5 and 6 over the one illustrated in Figs. 1 and 2 is that the counterweighting in the wheels is just about the same as that used in the usual method of counterbalancing. This simplifies the conversion of old locomotives to the new method of counterbalancing. The device shown in Figs. 5 and

6 is also more compact than the one shown in Figs. 1 and 2.

From the foregoing description it is apparent that some of the advantages of my invention are decreased vibration of the locomotive and decreased forces applied by the wheels to tracks and bridges, thereby permitting the locomotive to operate at a higher speed. Furthermore, the balancing device, herein described, does not add to the unsprung weight of the locomotive, since it is mounted in the locomotive frame and not on the locomotive axles, as is the case with previously known balancing devices.

Since numerous changes may be made in the above-described construction and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In a locomotive having a frame, reciprocating pistons, side rods, crank pins, driving wheels and axles therefor, in combination, a rotatably mounted quill surrounding one of the axles, means for rotating said quill, shafts disposed on opposite sides of said quill and driven thereby in a direction opposite to that of the axles, said shafts being rotatably mounted in the locomotive frame and supported thereby, a plurality of balancing weights of predetermined magnitude and phase position rotated by said shafts at the same angular velocity as the driving wheels to counterbalance the reciprocating forces of the locomotive, and additional balancing weights of predetermined magnitude rotated in the same direction and at the same angular velocity as the wheels and cooperating with said first-named weights in counterbalancing the reciprocating forces.

2. In a locomotive having a frame, reciprocating pistons, side rods, crank pins, driving wheels and axles therefor, in combination, a quill surrounding one of the axles and rotatably mounted in the locomotive frame, means for rotating said quill at the same speed as the axle which it surrounds, a gear secured to said quill, shafts disposed on opposite sides of said gear and driven thereby at the same speed as said gear and in a direction opposite to that of the axles, said shafts being rotatably mounted in the locomotive frame and supported thereby, a plurality of balancing weights of predetermined magnitude and phase position rotated by said shafts to counterbalance the reciprocating forces of the locomotive, and additional balancing weights of predetermined magnitude rotated in the same direction and at the same angular velocity as the wheels and cooperating with said first-named weights in counterbalancing the reciprocating forces.

3. In a locomotive having a frame, reciprocating pistons, side rods, crank pins, driving wheels and axles therefor, in combination, a quill surrounding one of the axles and rotatably mounted in the locomotive frame, means for flexibly driving said quill from said axle, shafts disposed on opposite sides of said quill and connected in driving relation therewith, said shafts being rotatably mounted in the locomotive frame and rotated in a direction opposite to that of the axles, a plurality of balancing weights of predetermined magnitude and phase position rotated by said shafts at the same angular velocity as the driving wheels to counterbalance the reciprocating forces of the locomotive, and additional balancing weights of

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predetermined magnitude rotated in the same direction and at the same angular velocity as the wheels and cooperating with said first-named weights in counterbalancing the reciprocating forces.

4. In a locomotive having a frame, reciprocating pistons, side rods, crank pins, driving wheels and axles therefor, in combination, a quill surrounding one of the axles and rotatably mounted in the locomotive frame, means for rotating said quill, shafts disposed on opposite sides of said quill and driven therefrom in a direction opposite to that of the axles, said shafts being rotatably mounted in the locomotive frame and supported thereby, a plurality of balancing weights of predetermined magnitude and phase position rotated by said shafts at the same angular velocity as the wheels to counterbalance the reciprocating forces of the locomotive, and additional balancing weights of predetermined magnitude and phase position secured to said quill and cooperating with said first-named weights in counterbalancing the reciprocating forces.

5. In a locomotive having a frame, reciprocating pistons, side rods, crank pins, driving wheels and axles therefor, in combination, a quill sur-

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rounding one of said axles and rotatably mounted in the locomotive frame, means for rotating said quill at the same speed as the axle which it surrounds, shafts disposed on opposite sides of said quill and driven thereby in a direction opposite to that of the axles, said shafts being rotatably mounted in the locomotive frame and supported thereby, a plurality of balancing weights of predetermined magnitude and phase position rotated by said shafts at the same angular velocity as the driving wheels to counterbalance the reciprocating forces of the locomotive, and additional balancing weights of predetermined magnitude secured to said wheels and cooperating with said first-named weights in counterbalancing the reciprocating forces.

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