(No Model.) 3 Sheets—Sheet 1.

C. A. BALL.

BALANCED STEAM ENGINE.

No. 489,917. Patented Jan. 17, 1893.

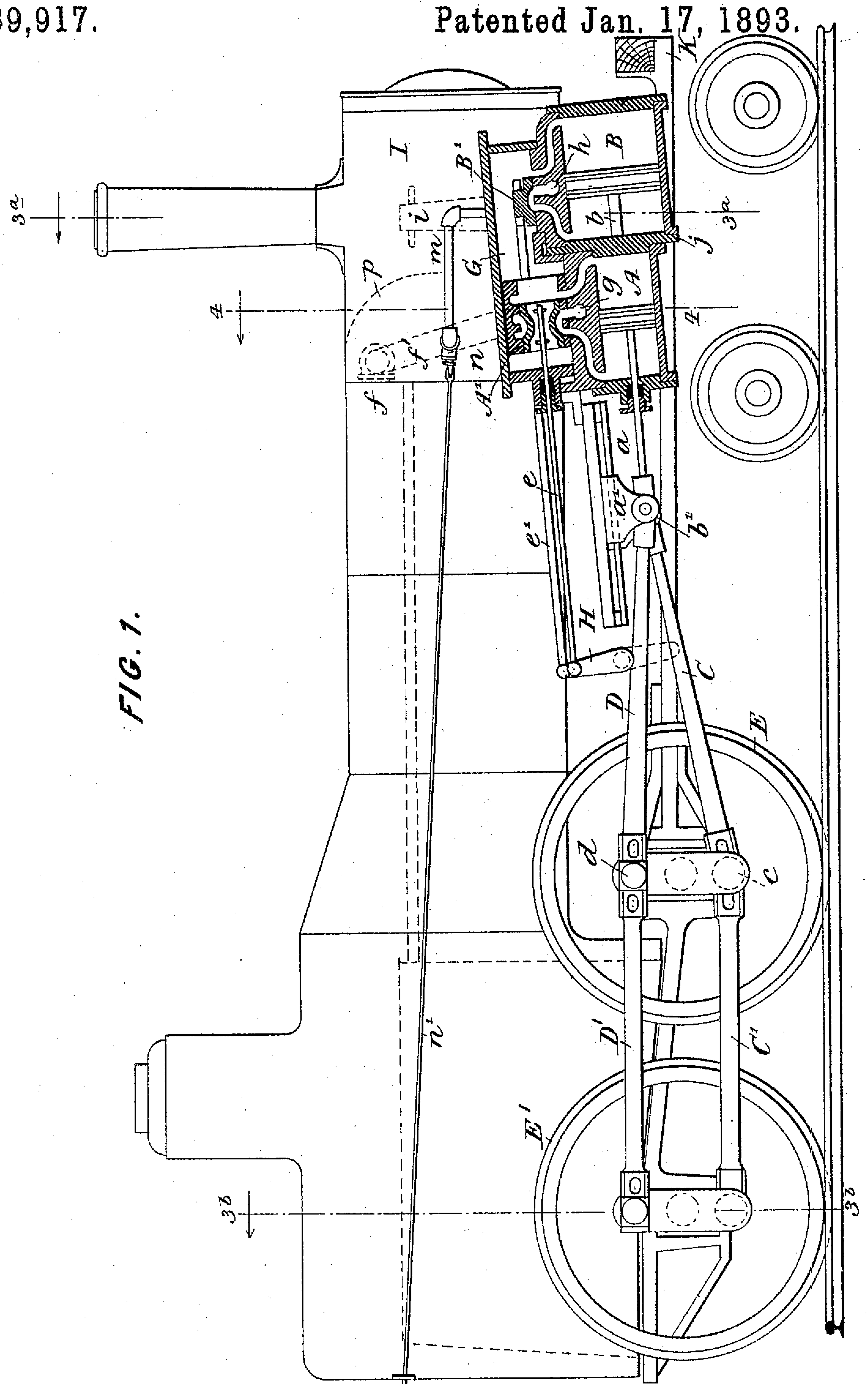


FIG. 1.

WITNESSES:
John A. Rennie
Fred White

INVENTOR:
Charles A. Ball,
By his Attorneys,
Arthur C. Fraser & Co.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

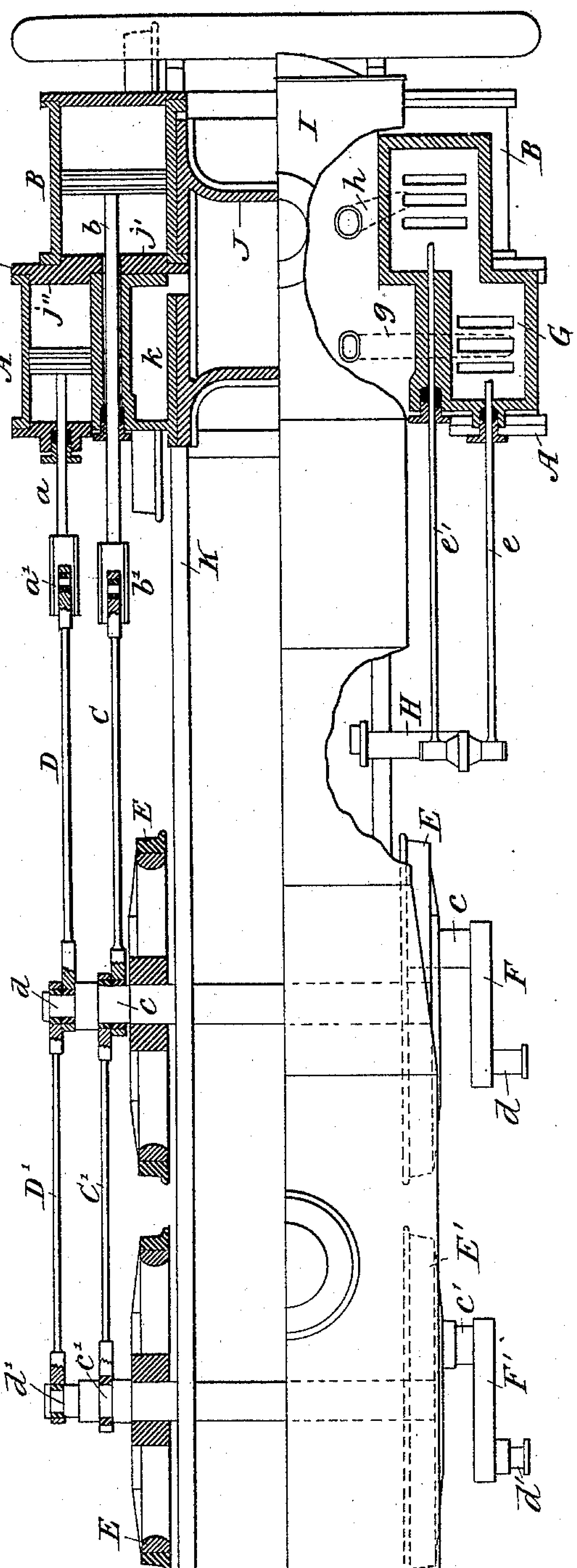
(No Model.) 3 Sheets—Sheet 2.

C. A. BALL.

BALANCED STEAM ENGINE.

No. 489,917. Patented Jan. 17, 1893.

FIG. 2.



WITNESSES:
John A. Rennie.
Fred White

INVENTOR:
Charles A. Ball,
By his Attorneys,
Arthur C. Fraser & Co.

(No Model.) 3 Sheets—Sheet 3.

C. A. BALL.

BALANCED STEAM ENGINE.

No. 489,917. Patented Jan. 17, 1893.

FIG. 4.

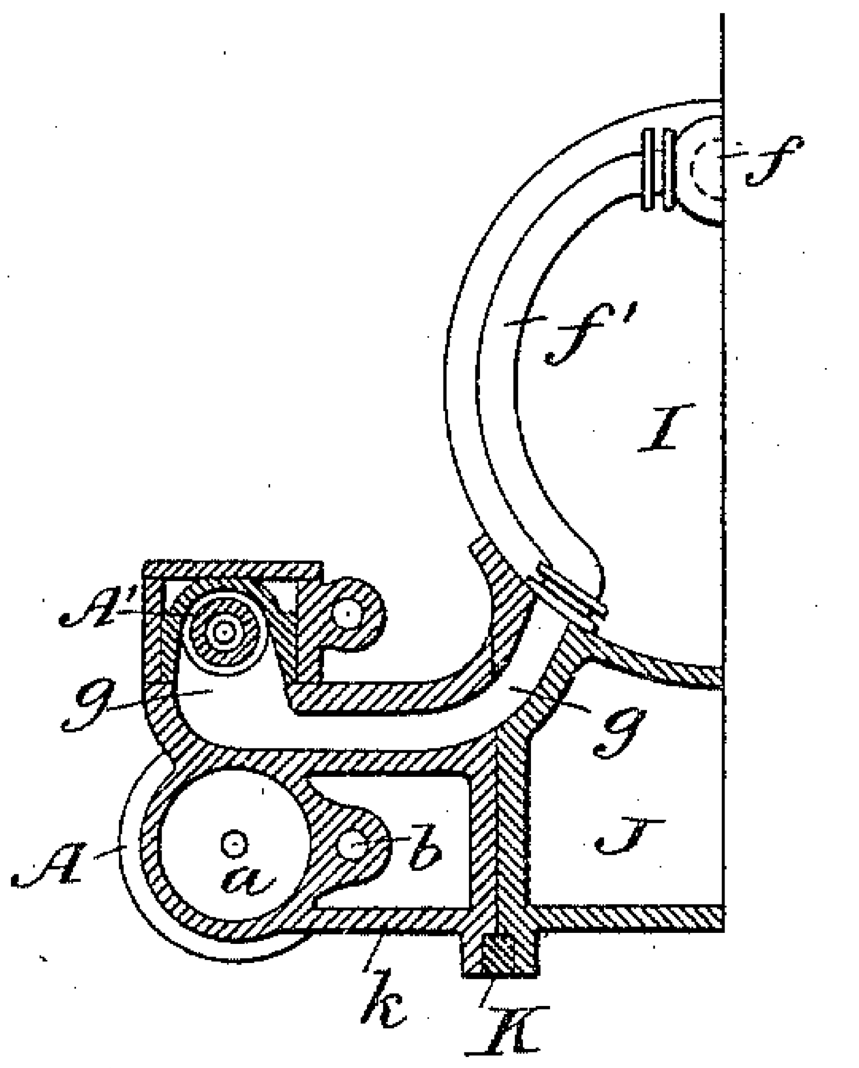


FIG. 5.

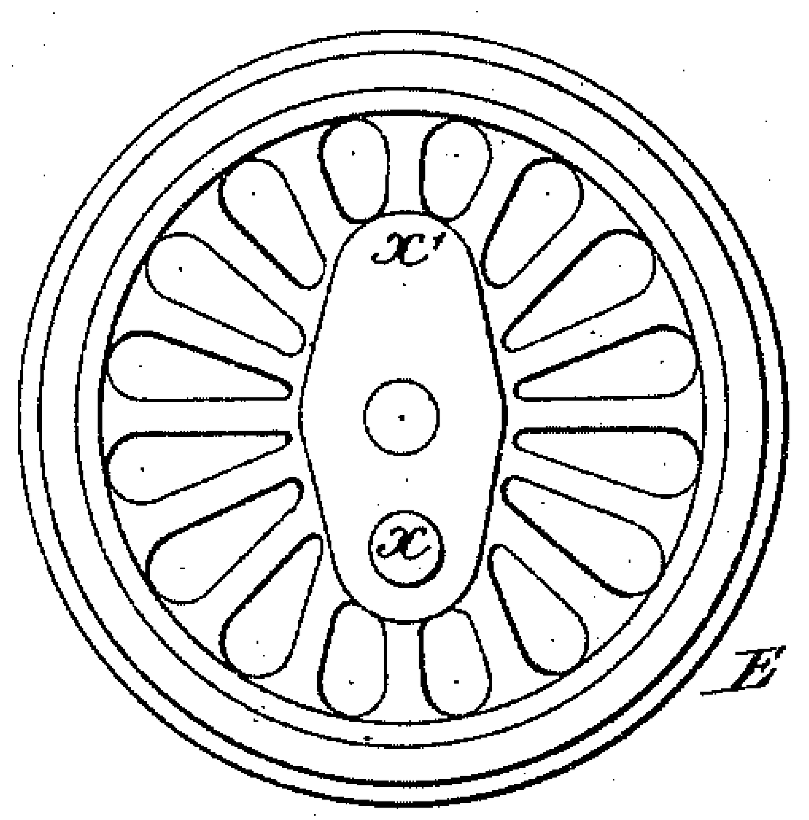
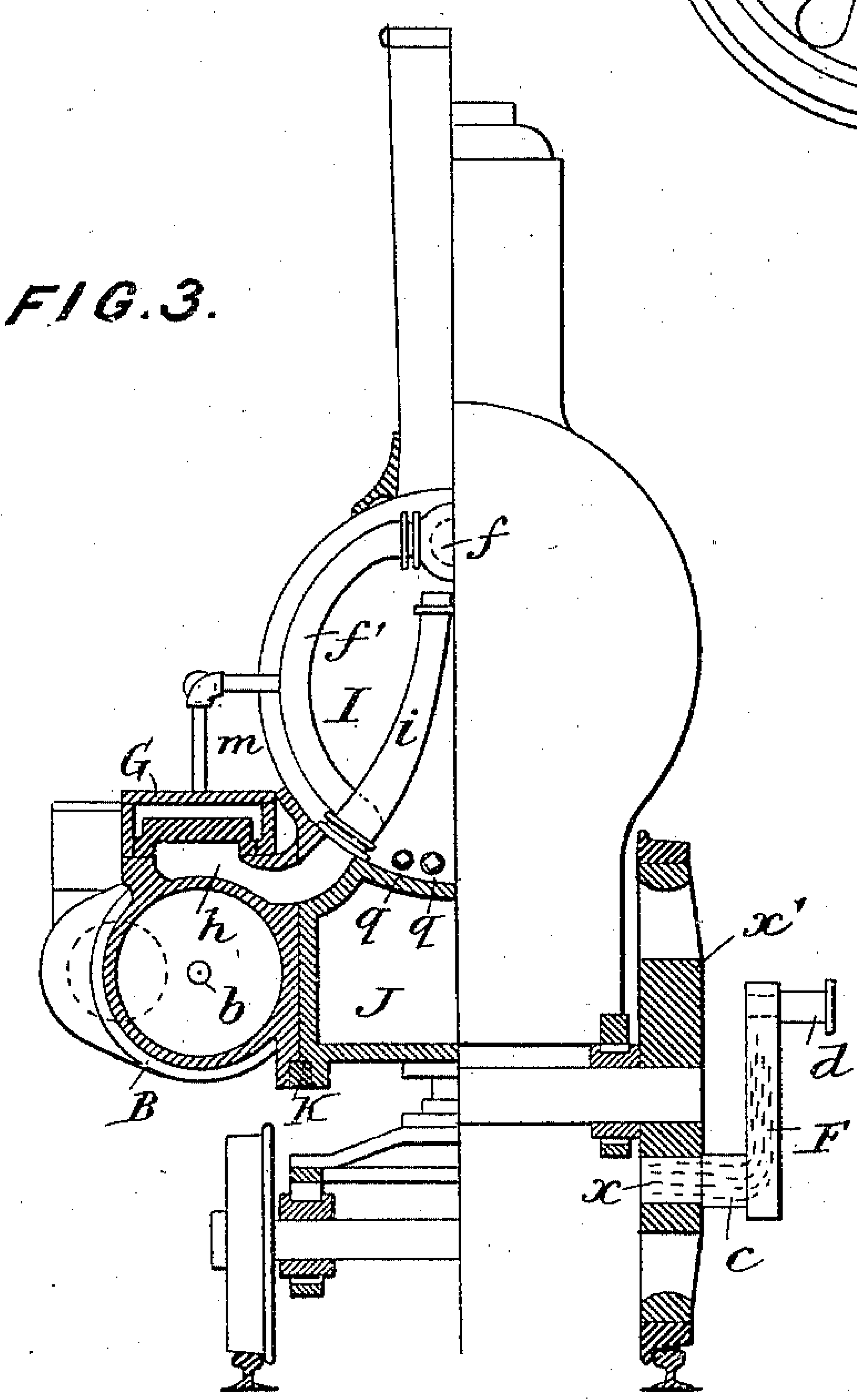


FIG. 3.



WITNESSES:
John A. Rennie
Fred White

INVENTOR:
Charles A. Ball,
By his Attorneys,
Arthur C. Fraser & Co.

UNITED STATES PATENT OFFICE.

CHARLES A. BALL, OF BROOKLYN, ASSIGNOR TO THE BALL COMPOUND LOCOMOTIVE COMPANY, OF NEW YORK, N. Y.

BALANCED STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 489,917, dated January 17, 1893.

Application filed September 26, 1891. Serial No. 406,941. (No model.)

To all whom it may concern:

Be it known that I, CHARLES A. BALL, a citizen of the United States, residing in Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Balanced Compound Locomotive-Engines, of which the following is a specification.

The desirability of balancing the thrusts transmitted from the piston to the crank in steam engines has long been recognized. With a single cylinder, the pushing and pulling strains transmitted from the piston to the crank react upon the frame and require to be resisted thereby. As these strains are transmitted to the frame through the bearing blocks or brasses, the thrust exerted against the bearings generates considerable friction. To overcome these objections balanced engines have been proposed having two cylinders the pistons of which act upon cranks one hundred and eighty degrees apart, so that while one is exerting a pushing thrust the other is exerting a pulling thrust, and by constructing the two cylinders to generate equal piston pressures the two thrusts are equalized so that they balance one another, thereby exerting the entire propulsive power in the effort to rotate the cranks, and relieving the frame and brasses from strain and obviating the friction in the bearings due to thrust against the brasses.

The attempts heretofore made to construct balanced engines have had little practical success by reason either of the complication introduced, or of the liability to the yielding or springing of the parts, which has been inseparable from such constructions.

Attempts have been made in the building of locomotives to provide for a double expansion of the steam after the manner common in compound engines, but thus far little practical success has attended such efforts. In some types of compound locomotives, the pistons of the high pressure and low pressure cylinders have been connected to travel together, thereby increasing the objection to the ordinary unbalanced or single cylinder engine by reason of the increased unbalanced weight of the moving parts, and the greater strain thrown upon the frame and brasses. Such inventions have also involved either complicated construction difficult to pack and unhandy of access, or have been liable to the objection of the too great projection of the low pressure cylinder at the side of the locomotive.

My invention aims to provide a construction of balanced compound engine applicable to locomotives, which shall be free from the objections heretofore existing to either balanced engines or compound engines, or to balanced compound engines.

I will proceed to describe the preferred construction of my invention with reference to the accompanying drawings, wherein

Figure 1 is a side elevation of a locomotive engine partly in vertical section in the planes of the axes of the cylinders and valve chests; Fig. 2 is a plan of the locomotive, half in horizontal section in the plane of the axes of the cylinders and of the driving wheels and cranks, and the other half partly in horizontal section through the steam chest in the plane of the valve rods; Fig. 3 is a front view of the locomotive, the left half being in vertical section on the line 3^a in Fig. 1, and the right half on the line 3^b in Fig. 1; Fig. 4 is a half section in the plane of the line 4—4 in Fig. 1; Fig. 5 is an elevation of one of the driving wheels.

The locomotive shown is of the usual type of American locomotive, with the exception of the differences which will be hereinafter described. Instead of having a single cylinder on each side of the locomotive, there are two cylinders, a high pressure cylinder A, and a low pressure cylinder B, the latter being arranged in front of the former as shown in Fig. 1, but with its center sufficiently nearer the middle line of the locomotive than that of the high pressure cylinder to enable the piston rod b of the low pressure cylinder to pass alongside of the high pressure cylinder, as clearly shown in Fig. 2. The piston rods a b of the two cylinders are fixed to cross-heads a' b' in the usual manner. To the cross-head b' of each engine is coupled a connecting rod C, which engages with a crank-wrist or stud c applied to the main or forward driver E. To the cross-head a' of each engine is coupled a connecting rod D, the other end of which engages with a crank-stud d formed on an outside crank F extending from the crank-wrist c, as best shown on the lower side of Fig. 2. In an engine with four drivers the rear drivers E′ are connected to the forward drivers E by parallel bars or side bars C′ and D′, each bar C′ engaging at one end the crank-wrist c of the driver E, and at the other end a similar crank-wrist c' of the rear driver, while the parallel bar D′ engages at one end the crank-wrist d of the crank F, and at the other end is coupled to a similar crank-wrist p' on a similar crank F′.

On top of the cylinders A B is arranged a valve chest G, within which work two valves A′ and B′ for the high pressure and low pressure cylinders respectively. These are driven by valve-rods e e' respectively, which pass out through stuffing boxes at the rear end of the chest and are jointed at their ends to the upper arm of the usual rock-lever H of the valve motion or gear, which in this locomotive remains unchanged and is not further illustrated. The rod e is jointed to the lever H nearer its pivotal axis than the rod e' in order to impart differential speeds and travel to the two valves, the low pressure valve moving faster and farther than the high pressure. The rods e and e' are also pivoted on opposite sides of the upper arm of the lever H, so that the strain communicated to them is balanced in its effect upon the lever. I have shown the high pressure valve A′ as being a balanced or piston valve, and the low pressure valve as being an ordinary slide valve which may be balanced or not, but the employment of these particular types of valves not essential, the use of any suitable kind of valve being admissible.

The steam is taken from the boiler through a throttle in the dome, and thence by the usual steam-pipe extending to the front of the boiler and terminating at f in the smoke-box I, whence it extends in two branches f' within the smoke-box in the usual manner leading to the respective cylinders. Each branch f' communicates with a port g opening to the valve A′, which controls communication of this port with the cylinder ports of the high pressure cylinder. This cylinder exhausts into the valve chest G, from which the steam passes under the control of the valve B′ into the low pressure cylinder, and exhausts therefrom into a passage h, shown in Figs. 1 and 3, and thence into the exhaust nozzle i, which directs a jet upwardly into the stack to facilitate the draft in the usual manner.

The high pressure and low pressure cylinders are so proportioned as to expand the steam in such ratio that each piston exerts the same thrust through its rod as the other but in the opposite direction, so that the propulsive thrusts of the engine are balanced. A balance of weight is also attained by making the high pressure piston and its rod and connecting rod D of the same weight as the low pressure piston and its rod b and connecting rod C. By reason of the balancing of propulsive thrusts and of the weight of the respective parts, the engine runs with the minimum of strain on its frame and brasses, and consequently with the minimum of loss by friction, and the efficiency is increased not only to this extent, but also by reason of the greater economy attained in the double expansion of the steam. The strokes of the two pistons are synchronous, so that the low pressure cylinder takes the steam as fast as it is exhausted from the high pressure cylinder. By reason of the balancing of the pistons and connecting rods each by the other, the necessity of introducing a balance weight in the driving wheels is obviated, and consequently the "hammer blow" struck by the overweighted side of the drivers of ordinary locomotives upon the rails at each revolution is avoided. Each of the driving wheels is perfectly balanced, being constructed as shown in Fig. 5, and in the section on the right of Fig. 3, its hub being prolonged diametrically and bored with a hole x on one side to receive the inner crank-wrist, while the prolongation of the hub on the opposite side of the center at x' serves to balance the wheel. The reaction of the thrust of each piston instead of being taken up in the frame of the engine, has its reaction in the counter thrust of the other piston, these thrusts being transmitted directly from one cylinder to the other by reason of the two cylinders being fastened rigidly together. The function of the frame of the locomotive is consequently reduced to that of a mere means for holding the several parts of the locomotive in correct relative position, while the function of the brasses being relieved of all propulsive thrust, is reduced to that of mere bearing boxes for the rotating axles. For an engine of the same power as an ordinary single cylinder locomotive, the two cylinders will be of such proportions as to cause each piston to exert a propulsive thrust of one half that exerted by the single piston of the ordinary locomotive. Thus instead of the entire thrust being exerted on a crank on one side of the center of the driving axle, one half the thrust is exerted on each side of the center and in opposite directions.

In the building of locomotives for a gage of four feet eight and one-half inches, the builder is limited to an extreme width of nine feet two inches.

In the efforts heretofore made to build either balanced or compound locomotives with outside cranks, the arrangement of the two cylinders on each side, one outside of the other and in line with the inner and outer cranks, has involved the projection of the cylinders beyond this extreme limit of width, or else to avoid this it has been necessary to resort to awkward and unmechanical expedients. This difficulty is obviated in my improved locomotive by the relative arrangement of the cylinders in the manner best shown in the upper half of Fig. 2, namely, in the arrangement of the larger low pressure cylinder forward of and with its circumference intersecting the circumference of the smaller high pressure cylinder. This construction involves the lengthening of the piston-rod b' of the low pressure cylinder, which is not disadvantageous, and the carrying of this piston-rod close alongside of the smaller cylinder. Preferably the smaller cylinder is made with a longitudinal socket for receiving this rod, as shown best in Fig. 4. By this novel arrangement of the cylinders the larger cylinder is brought inward until its center is in line with the inner crank-wrist c, and the smaller cylinder is arranged as close as is practicable against the side of the piston-rod of the larger cylinder, so that the total projection beyond the outer faces of the driving wheels is approximately that of the outside diameter of the smaller or high pressure cylinder. By this means the cylinders are kept within the limit of width, and by a very convenient and practicable construction.

Instead of casting the cylinders and half the saddle in one piece as is the customary practice with single cylinder engines, I form the saddle J as a separate casting and bolt the several cylinders to it. The respective cylinders are cast as right and left cylinders, and each is bolted to the side of the saddle adjoining it, as shown at the left in Figs. 3 and 4, by embracing the frame K between them. The cylinders A and B are preferably made in two separate castings, each of which is bolted to a single cylinder head j, interposed between them which serves both for closing the adjoining ends of the two cylinders, and as a means of connecting them in such manner as to transmit the reciprocal propulsive thrusts between them. This interposed head is formed on one side with a boss entering the end of the smaller cylinder, and on the other side with a boss eccentric thereto entering the end of the larger cylinder. The boss j' on the front side enters the larger cylinder B, and has a central perforation for the passage of the low-pressure piston-rod b, while the smaller boss j'' on the rear side enters the high-pressure cylinder A; these relatively-eccentric bosses thus serve to hold the adjoining ends of the two cylinders in proper relative positions. The cylinder A being located so much farther out than the cylinder B, its casting is carried in by an extended portion or trunk k to bring it to the same plane as the meeting face of the cylinder B, as seen by a comparison of Figs. 3 and 4.

In compound locomotives, it is desirable to resort to the expedient as a means for facilitating the starting of the locomotive with a heavy train, of turning high pressure steam into the low pressure cylinder, and thereby acquiring momentarily a propulsive thrust considerably greater than that due to the normal action of the engine as a compound engine. At such times the high pressure steam acts equally on both sides of the piston in the cylinder A, which is consequently balanced and inert, the low pressure piston doing all the driving. The engine is consequently for the moment practically the same as an ordinary high pressure single cylinder engine, except that the low pressure cylinders are of larger diameter than are usually employed on such engines, and there is consequently the same unbalanced thrust resisted by the frame and brasses as in any ordinary locomotive, but to proportionately greater extent. It becomes consequently desirable to exert this thrust as close to the driving wheels, and consequently at a point as near to the brasses of the driving axles as possible, in order that the thrust may be increased as little as possible by leverage. This result is accomplished in my construction by the arangement of the low pressure cylinders with their piston-rods inside of the high pressure cylinders, and in line with the inner crank-wrists, which are close against the outer faces of the drivers.

As a means for turning high pressure steam into the low pressure cylinder, I have illustrated a branch steam-pipe m extending from the branch f' of the steam main passing outside the fire box, fitted with a throttle valve n and terminating in the steam chest G. The valve n may be operated by a rod n' from the cab or in any other suitable manner, the two rods on opposite sides of the boiler being connected together in any suitable way so as to be operated simultaneously. In starting, the engineer will first open the valves n, and then throw open the throttle, and will then close the valves n as soon as the engine is got under way, in order to economize steam by working it under double expansion.

In the ordinary running of the engine, the propulsive thrust as has been stated is divided between the crank-wrists c and d. A certain diameter of axle being found necessary in order to transmit the torsional strains from one driver to the other, I employ for the crank-wrist c a stud of the same diameter which is firmly keyed in the hole x in the hub of the driver, and is preferably forged integrally with the crank F. As one half of the total thrust is exerted against the stud d, and as its center is twice the distance from the center of the wrist c that the latter is from the center of rotation, it is obvious that this half of the thrust exerted against d will impart the same torsional strain to the wrist c as the entire thrust exerted against c would impart to the axle. Hence I make the wrist c of the same diameter as the axle. To insure the utmost strength, I make the wrist c and crank F of a single forging, bent at their junction so that the grain of the metal shall be uninterrupted, as indicated by the dotted lines in Fig. 3, which show the course of the grain. The crank-wrist d is formed of a stud fixed in the end of the crank-arm F.

Some changes are made in the smoke-box as follows:—The exhaust nozzles i being arranged opposite the low pressure cylinders B, are placed farther forward in the smoke-box I than is usual, and the smoke-stack is consequently also placed farther forward in order to bring it over them. By this means the smoke and gases issuing from the front ends of the boiler tubes are given a more ready and less obstructed passage to the stack than in ordinary locomotives, since they have not to turn so sharp an angle before entering the stack, and the deflecting plate P by which they are directed downwardly is not arranged so close to the top flues.

I have shown the cylinders A B in Fig. 1 as being mounted on an incline, this arrangement being advantageous as it lifts them sufficiently above the wheels of the forward truck to render their arrangement most convenient and admit of larger truck wheels than it is possible ordinarily to use, which is a great desideratum. This inclining of the cylinders is not admissible in an ordinary single locomotive, by reason of the up and down thrust exerted against the brasses tending to pump them up and down in their guiding pedestal at every stroke, but in my engines this difficulty is obviated by the balancing of the propulsive thrusts against the drivers, so that the advantages to be gained by lifting the cylinders may be realized.

My improved locomotive is designed most particularly for high speed passenger service, although applicable for other uses. By eliminating the reaction of the propulsive thrust upon the frame, and the friction due to this thrust upon the brasses, as well as by mechanically balancing the reciprocating parts, and by reason also of the avoidance of the "hammer blow" of the balance weights of the drivers, I have reason to anticipate being able to attain much higher speeds than are feasible with locomotives as now built, and by the adoption of the principle of compounding the consumption of coal for a given generation of power will be largely economized. At the same time the wear and tear of the locomotive, as well as the road bed, will be greatly reduced.

In my improved engine, access to the low pressure cylinder is from the outer end thereof, and to the high pressure cylinder at the inner end thereof.

The two cylinders may be cast in one piece, being bored out from opposite ends eccentrically, and the ends of the cylinders adjacent to one another being finished by a turning tool, but for most purposes I consider the construction of the cylinder as separate castings with the intervening single head *j* to be preferable, as the truing up of the cylinders is rendered more easy by having them open at both ends, and more complete access to them may be obtained in case of necessity by taking them apart.

I claim as my invention the following defined novel features substantially as hereinbefore specified, namely:—

1. In a balanced compound locomotive, the combination of two cylinders arranged end to end, the high-pressure cylinder being arranged to one side of the piston-rod of the low-pressure cylinder and the pistons connected to cranks at one hundred and eighty degrees apart, a valve-chest and valves for the two cylinders, a high-pressure steam inlet admitting steam through the high-pressure valve to the high-pressure cylinder, and said valve constructed to admit the exhaust from said cylinder to the valve-chest, the low pressure valve driven in the same direction as the high-pressure valve and constructed to admit steam from said chest to the forward end of the low-pressure cylinder when the steam is exhausting from the forward end of the high-pressure cylinder, and vice versa, and an exhaust outlet to which the exhaust from the low-pressure cylinder is admitted through said valve, whereby while the two valves move in the same direction the pistons move in opposite directions.

2. In a balanced locomotive, the combination of two cylinders arranged end to end but out of line, with the outer cylinder arranged close alongside of the piston rod of the inner one, a single valve-chest above both cylinders, separate valves in said chest, separate valve-rods *e e'* passing out through said chest, and a valve motion having a rock-lever H to which said rods are jointed on opposite sides, whereby the lever operates both rods simultaneously and each balances the resistance of the other.

3. In a balanced compound locomotive, the combination of high and low pressure cylinders arranged end to end, the high pressure cylinder arranged outside of and close alongside the low pressure piston-rod, a single valve-chest over both cylinders, two separate valves therein having valve-rods *e e'* passing out therefrom, and the rock-lever H of a valve-gear to which said rods are jointed, the high pressure valve rod being jointed thereto at a point nearer its fulcrum than the low pressure rod, whereby the low pressure valve is driven at a faster and longer stroke than the high pressure valve.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

CHAS. A. BALL.

Witnesses:
ARTHUR C. FRASER,
GEORGE H. FRASER.