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THE FOUR-CYLINDER BALANCED COMPOUND LOCOMOTIVE

SUPPLEMENT TO

THE SCIENCE OF RAILWAYS

BY

MARSHALL M. KIRKMAN.

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SUPPLEMENT TO VOL. XII (Page 301) OF THE SCIENCE OF RAILWAYS

In supplement to what is said in regard to Compound Locomotives in volume 12 "Science of Railways," "Engineers' and Firemen's Manual."

THE FOUR-CYLINDER BALANCED SYSTEM OF COMPOUND LOCOMOTIVES.

In the evolution of the Compound Locomotive a new departure has been made, and what is known as the "Four-Cylinder Balanced System" is receiving much attention from the motive power department of many railways, and has been successfully introduced upon several large railway systems.

Believing that an account of the Four-Cylinder Balanced System will be of interest and profit to our patrons, the publishers take pleasure in sending them this pamphlet describing particularly and in detail several examples of this style of Compound Locomotive.

THE WORLD RAILWAY PUBLISHING COMPANY
CHICAGO.

THE FOUR-CYLINDER BALANCED COMPOUND LOCOMOTIVE.

In the evolution of the compound locomotive a style known as the "Four-Cylinder Balanced" has been successfully adopted by several of the great American railways. Of this style of locomotive there are three types in use, known as the "Vauclain," "Cole" and "DeGlehn," the characteristics of which are shown in the following table:*

TYPE. LOCATION OF H. P. CYL.

Vauclain—Inside in line with L. P.
Cole—Inside and in front of L. P.
DeGlehn—Outside in line with L. P.

MAIN ROD CONNECTION.

Vauclain—Outside, front driver; inside, front axle.
Cole—Outside, rear driver; inside, front axle.
DeGlehn—Outside, rear driver; inside, front axle.

VALVE ARRANGEMENT.

Vauclain—Two, piston. One for each pair of low and high pressure cylinders.

Cole—Four, separate piston tandem arrangement. H. P. and L. P. on same stem on each side.

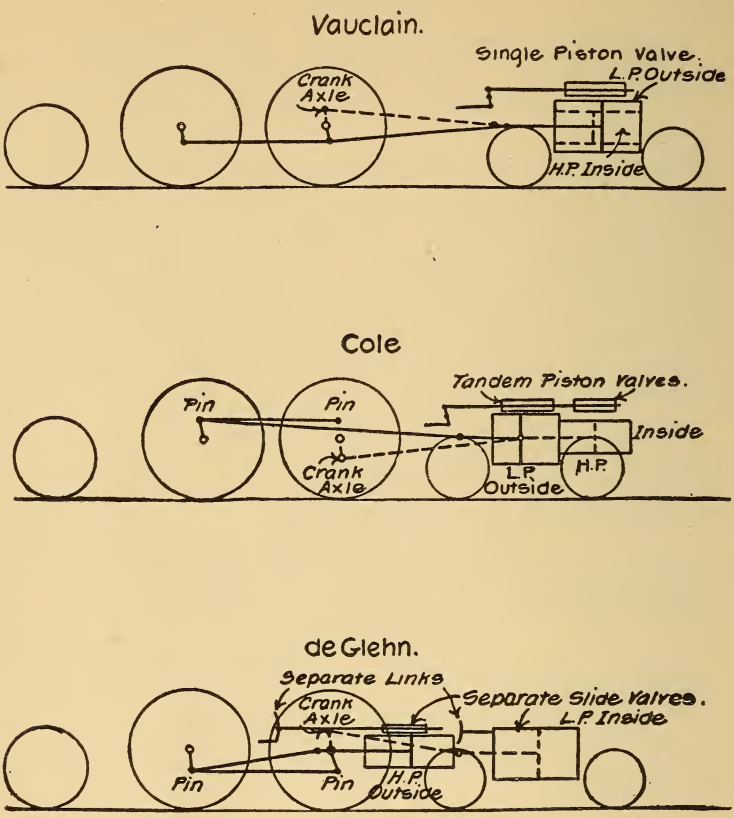
DeGlehn—Four, separate slide, separate valve gear. Two reverse levers.

VALVE MOTION.

Vauclain—Stephenson; two links.
Cole—Stephenson; two links.
DeGlehn—Walscheat (modified); four links.

It will be noted that each of these types has certain features in common with one or more of the others. The comparison shown in the following sketch will make the points of distinction and similarity more clear.

*There is yet a fourth type of four-cylinder compound locomotive known as the "Von Borries," but it has not been adopted by American railways.



The "*Vauclain*" type has high pressure cylinders inside and low pressure cylinders outside, all in the same horizontal plane in line with the smoke box, and all driving the front driving axle. A single piston valve worked from a single link motion effects the steam distribution for the pair of cylinders on each side. The advantages claimed for the "Vauclain" type are simplicity of valve mechanism and location of cylinders re-

quiring the least deviation from Standard American practice and balanced reciprocating parts.

The "*Cole*" type has high pressure cylinders inside, in advance of the smoke box, driving the front driving axle. The low pressure cylinders are outside in line with the smoke box, driving the rear driving axle. Two piston valves on a single stem serve the steam distribution for each pair of cylinders, and each valve stem is worked from an ordinary link motion. The advantages claimed for the"Cole"type are distribution of cylinder effort between driving wheels, simplicity of valve motion while providing separate valves for high and low pressure cylinders, perfect balance for reciprocating parts and compliance with American requirements for location of cylinders calling for insignificant changes in other parts of the machine.

The "*De Glehn*" type has high pressure cylinders outside and behind the smoke box, driving the rear drivers. The low pressure cylinders are inside under the smoke box, and drive the crank axle of the front drivers. Four separate slide valves and four Walschaert valve gears allow of independent regulation of the high and low pressure valves. The advantages claimed for the "De Glehn" type are distribution of crank effort, proper steam distribution in high and low pressure cylinders due to separate valve mechanisms and reverse levers, a perfect balance for reciprocating parts and protection against condensation by inside location of low pressure cylinders.

Following will be found full details and drawings of locomotives that have been constructed and put in operation of each of the three types mentioned.

VAUCLAIN FOUR-CYLINDER BALANCED COMPOUND.*

This locomotive is of the four coupled type. Its construction is illustrated in drawings Figures 1 to 7. The tractive power is 24,000 lbs. when working as a compound, and the cylinders are approximately equivalent to 18.9 in. simple cylinders. The weight on the drivers is 90,000 lbs., but with the balanced construction it is claimed a much greater weight than this can be placed on these wheels without injury to the track than would be caused by a locomotive of usual system of counterbalancing. The boiler is of the wide firebox type for coal burning. The mud ring is 5 in. wide at the sides, to assist circulation. The main bearings are $11\frac{1}{8}$x10 in., the crank pins 10x4 in., the wheel fits 10x$8\frac{5}{8}$ in. and the crank webs 20 in. wide by 5 in. thick.

The method of balancing and the light weights employed are clearly indicated in the drawing of the driving wheels, Fig. 3. A summary of the revolving weights is as follows:

REVOLVING WEIGHTS.

Pin No. 1. Inside. Pounds.	Pin No. 2. Outside. Pounds.	Pin No. 3. Pounds.
403	423	...
588	180	153
88	214	174
...	148	148
1,079	965	475

This leaves 1,079, minus 965, or 114 lbs. excess revolving weight on the inside of the main wheel. The reciprocating weights are as follows:

*This engine was built by the Baldwin Locomotive Works for the Atchison, Topeka & Santa Fe Ry., 1903.

RECIPROCATING PARTS.

	Inside.	Outside.
Piston	356	463
Crosshead	310	310
Main rod on crosshead pin	149	156
Totals	815	929

This leaves 929, minus 815, or 114 lbs. of reciprocating weight in the main wheel. The 114 lbs. of reciprocating weights are balanced in the main wheel by 114 lbs. excess revolving weight inside the main wheel, thus requiring no counterbalance in that wheel. The balance for 475 lbs. is required in the rear wheel and this is accomplished by a weight of 208 lbs. with a radius of 28½ in., as indicated in the diagram.

RATIOS AND DIMENSIONS.

Heating surface to volume of high pressure cylinders, = 571.
Tractive weight to heating surface, = 29.7.
Tractive weight to tractive effort, = 3.75.
Tractive effort to heating surface, = 7.92.
Heating surface to grate area, = 61.3.
Tractive effort X diameter of drivers to heating surface, = 578.
Heating surface to tractive effort, = 12.6 per cent.
Total weight to heating surface, = 61.7.
Gauge, 4 feet 8½ inches.
Cylinder, 15 and 25x26 inches.
Valve, balance piston.
Boiler—Type, wagon top.
Diameter, 66 inches.
Thickness of sheets, 11-16 and 13-16 inch.
Working pressure, 220 pounds.
Fuel, soft coal.
Staying radial.
Firebox—Material, steel.
Length, 107 15-16 inches.
Width, 66 inches.
Depth, front, 75⅞ inches; back, 67⅜ inches.
Thickness of sheets, sides, ⅜; back, ⅜; crown, ⅜; tube, 7-16 inch.
Water space, front, 4½ inches; sides, 5 inches; back, 4 inches.
Tubes—Material, iron, wire gauge No. 11.
Number, 273; diameter, 2¼ inches; back, 4 inches.
Heating Surface—Firebox, 190 square feet.
Tubes, 2,839 square feet.
Total, 3,029 square feet.
Grate area, 49.4 square feet.

Driving Wheels—Diameter outside, 73 inches.
Diameter of center, 66 inches.
Journals, main, 10x11 inches; others, 9x12 inches.
Engine Truck Wheels—Diameter, 34¼ inches.
Journals, 6x10 inches.
Trailing Wheels—Diameter, 44 inches.
Journals, 8x12 inches.
Wheel Base—Driving, 6 feet 4 inches.
Rigid, 15 feet.
Total engine, 29 feet 6 inches.
Total engine and tender, 58 feet 3½ inches.
Weight—On driving wheels, 90,000 pounds.
On truck, front, 52,000 pounds.
On trailing wheels, estimate, 45,000 pounds.
Total engine, 187,000 pounds.
Total engine and tender, about 327,000 pounds.
Tank capacity, 8,400 gallons.
Tender—Wheels, No. 8; diameter, 34¼ inches.
Journals, 5½x10 inches.

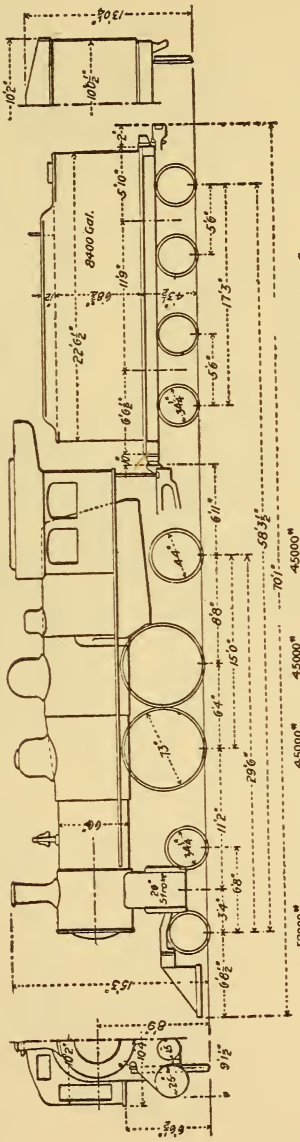


FIG 1—DIAGRAM OF LOCOMOTIVE AND TENDER

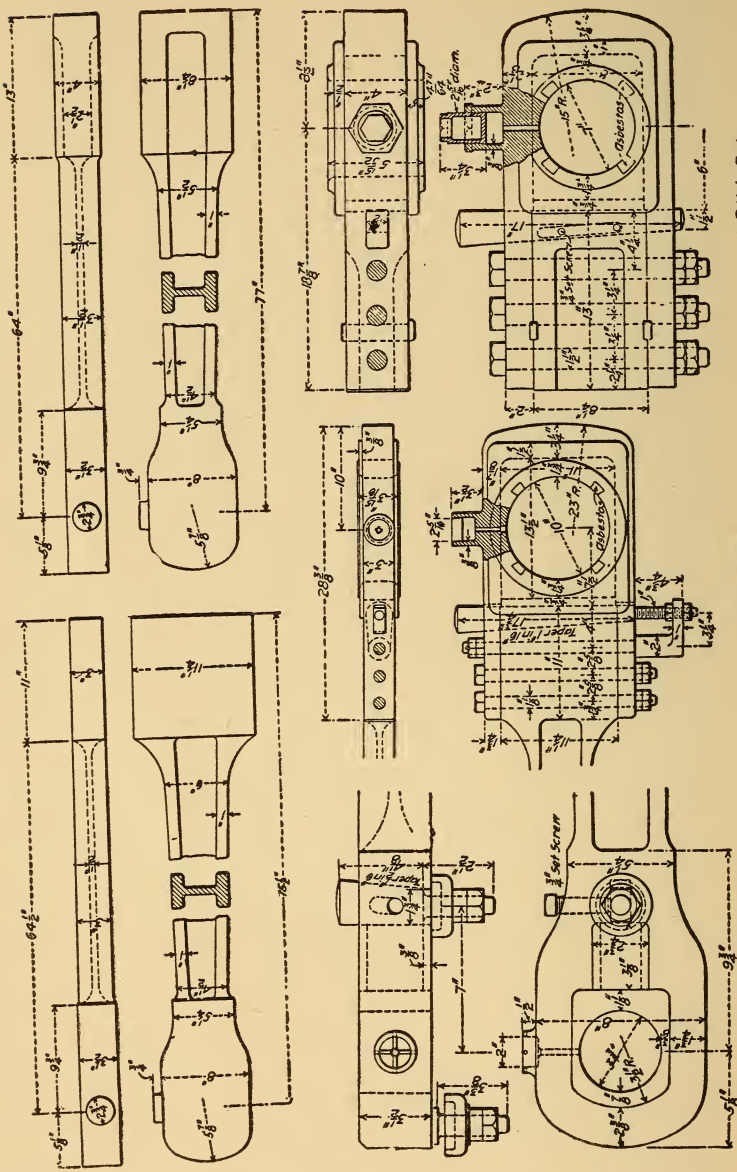


FIG 2.—THESE DRAWINGS ILLUSTRATE THE LIGHTNESS OF THE RODS

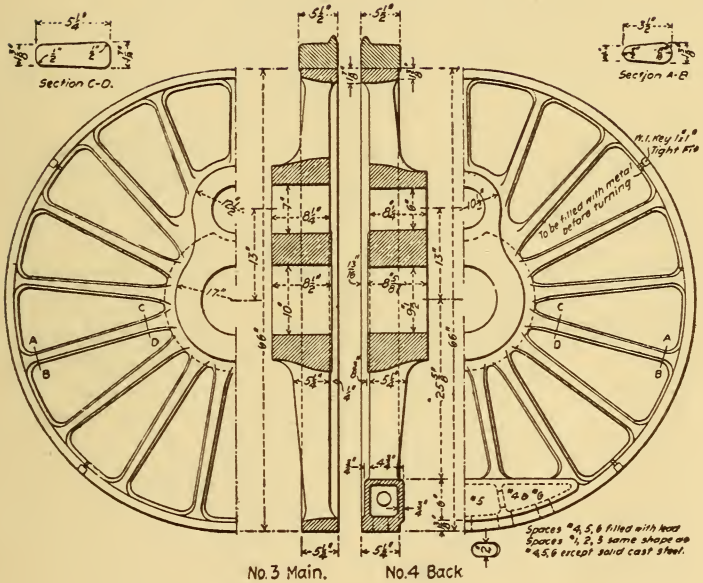
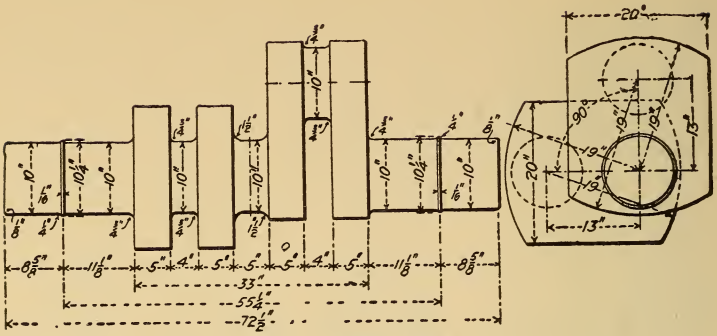


FIG. 3—MAIN AND REAR DRIVING WHEELS



THE CRANK AXLE.

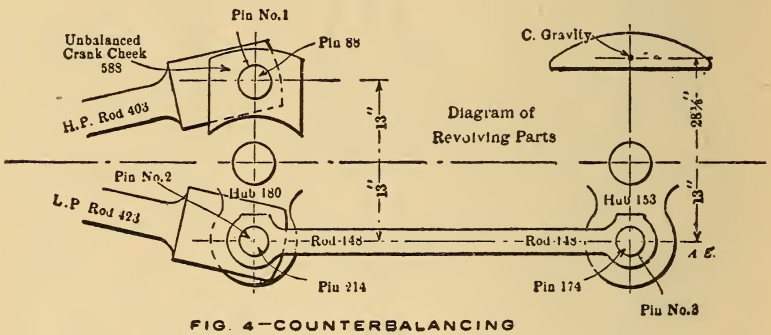
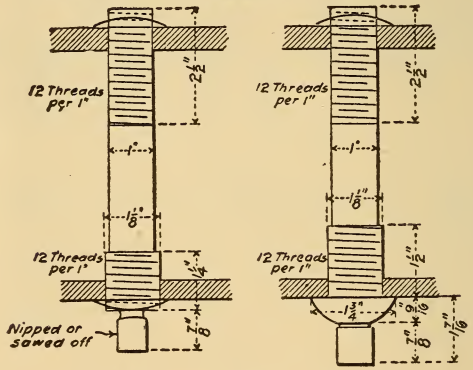


FIG. 4—COUNTERBALANCING



Style No.1. FIG 5 Style No.2.

ROWS OTHER THAN CENTER

CENTER ROWS

CROWN STAYS

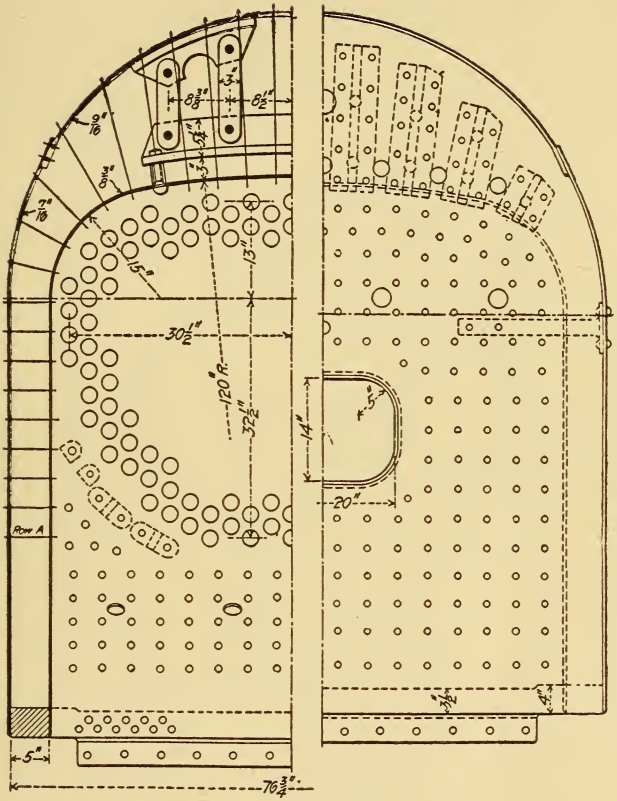


FIG 6—FIREBOX, SHOWING 5-IN MUD RING

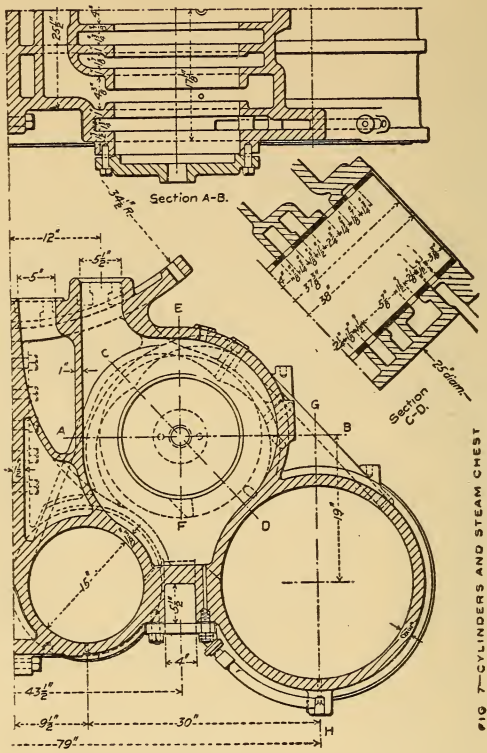


FIG 7—CYLINDERS AND STEAM CHEST

Another example of the Vauclain 4-Cylinder Balanced Compound is given in the following drawings (Figs. 8 to 12) and tables.*

This locomotive embodies the principles of the former designs but is especially arranged, in the matter of detail, to meet the conditions of the road for which it was built. The following indicate some of the leading differences between the two designs:

	Burlington.	Santa Fe.
Diameter of driving wheels	78 ins.	73 ins.
Weight on drivers	100,000 lbs.	90,000 lbs.
Total weight	192,000 lbs.	187,000 lbs.
Total heating surface	3,216.9 sq. ft.	3,029 sq. ft.
Grate area	44.14 sq. ft.	49.4 sq. ft.
Largest diameter of boiler	64 ins.	66 ins.
Length of tube	19 ft.	18 ft. 1 in.

With the same size cylinders, 15 and 25x26 in. in both engines, the tractive effort of the one is less than that of the other, the tractive effort of the former† being 21,400 lbs., whereas that of the latter‡ is 24,000 lbs., in compound working for both cases. In the design of the locomotive now being described, advantage is taken of the balancing of the reciprocating parts in order to increase the weight on driving wheels, which, in this case, is made 100,000 lbs. This engine has outside journals for the trailing whee The crank axles are forged, and 4½ in. pins are forced in through the crank pin portions. The crank cheeks are banded by tire steel hoops, finished all over, then heated, bent to shape and shrunk on. The following are the ratios and dimensions of the engine:

*Built by the Baldwin Locomotive Works for the Chicago, Burlington & Quincy, 1904.

†The A. T. & S. F. engine.

‡The C. B. & Q. engine.

RATIOS AND DIMENSIONS.

Heating surface to volume of high-pressure cylinders, 606.9.
Tractive weight to heating surface, 31.08.
Tractive weight to tractive effort, 4.67.
Tractive effort to heating surface, 6.65.
Heating surface to grate area, 72.88.
Heating surface to tractive effort, 15.03 per cent.
Total weight to heating surface, 59.68.
Tractive effort X diameter of drivers to heating surface, 518.8.
Gauge, 4 feet 8½ inches.
Cylinders, 15 inches and 25 inches x 26 inches.
Valves, balanced piston.
Boiler—Type, wagon top. Diameter, 64 inches.
Thickness of sheets, 11-16 inch and ¾ inch.
Working pressure, 210 pounds.
Fuel, soft coal.
Staying, radial.
Firebox—Material, steel.
Length, 96⅛ inches.
Width, 66¼ inches.
Depth, front, 70⅜ inches; back, 68⅜ inches.
Thickness of sheets, sides, ⅜ inch; back, ⅜ inch; crown, ⅜ inch; tube, ½ inch.
Water space, front, 4 inches; sides, 4 inches; back, 3 inches.
Tubes—Material, iron.
Wire gauge, No. 11.
Number, 274.
Diameter, 2¼ inches.
Length, 19 feet.
Heating Surface—Firebox, 166.4 square feet.
Tubes, 3,050.5 square feet. Total, 3,216.9 square feet.
Grate area, 44.14 square feet.
Driving Wheels—Diameter outside, 78 inches.
Diameter of center, 70 inches.
Journals, front, 10x10½ inches; back, 9½x12 inches.
Engine Truck Wheels (Front)—Diameter, 33 inches.
Journals, 6x10 inches.
Trailing Wheels—Diameter, 48 inches.
Journals, 8x12 inches.
Wheel Base—Driving, 7 feet 3 inches.
Rigid, 15 feet 6 inches. Total engine, 30 feet, 2 inches.
Weight—On driving wheels, 100,000 pounds.
On truck front, 50,000 pounds.
On trailing wheels, 42,000 pounds.
Total engine, 192,000 pounds.
Total engine and tender, 312,000 pounds.
Tank—Capacity, 6,000 gallons.
Tender—Wheels, number 8, diameter 37¼ inches.
Journals, 5x9 inches.
Service, passenger.

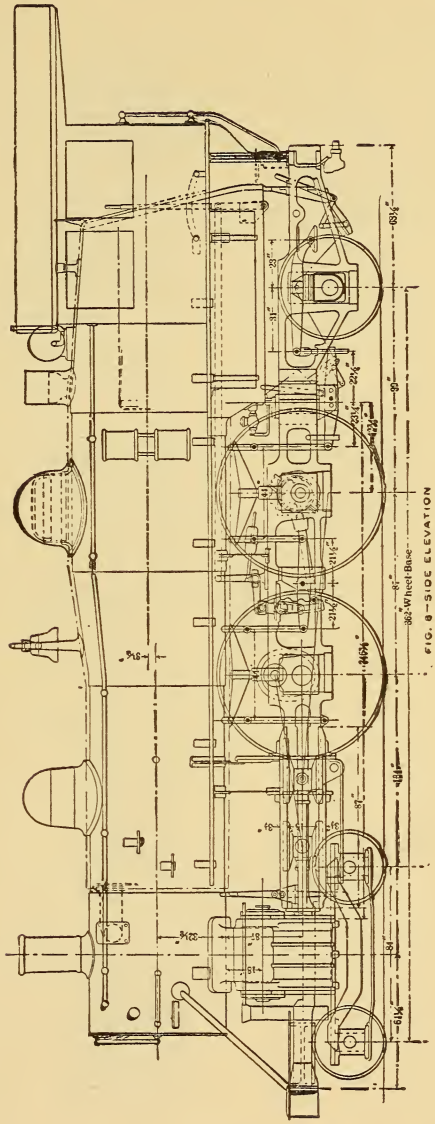


FIG. 8—SIDE ELEVATION
162-Wheel Base

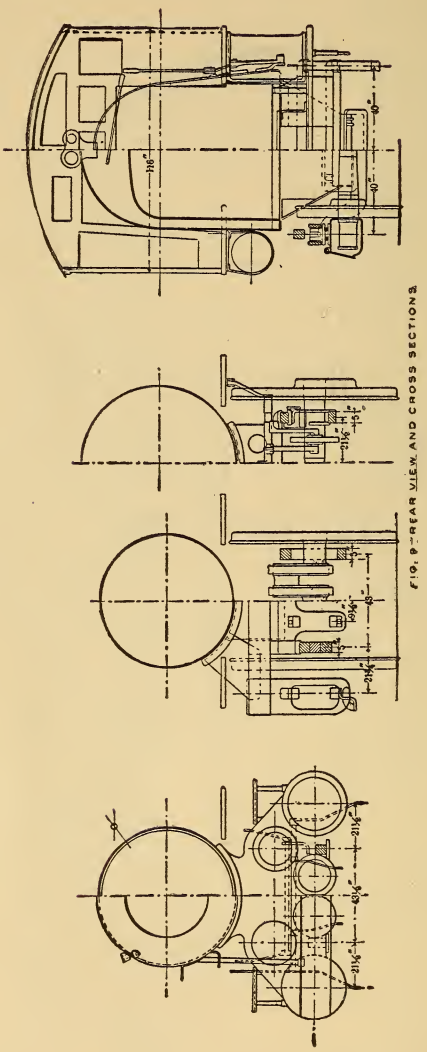


FIG. 9.—REAR VIEW AND CROSS SECTIONS.

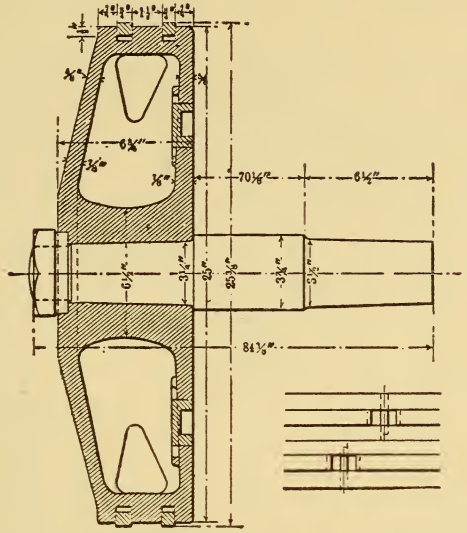


FIG. 10—LOW PRESSURE PISTON

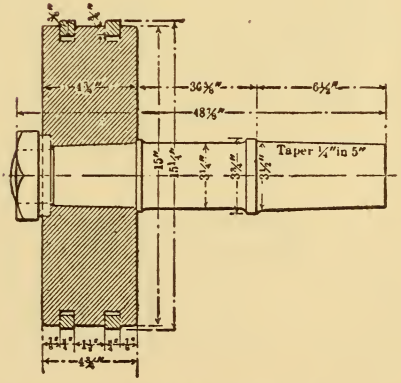


FIG. 11—HIGH PRESSURE PISTON

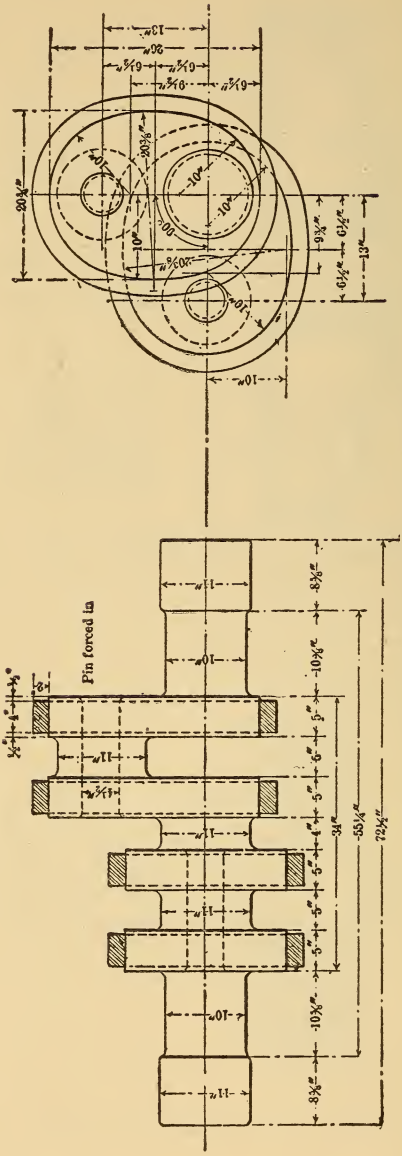


FIG. 12—CRANK AXLE SHOWING BANDING

COLE FOUR-CYLINDER BALANCED COMPOUND.*

In this locomotive, illustrated in drawings Figures 13 to 18, the low pressure cylinders are located in the position common to simple engines, being outside of the frames and attached by a saddle casting to the smoke arch. The high pressure cylinders are situated forward of the saddle casting and between the frames which are extended to such length as to support them. The pistons of the high pressure cylinders are connected to the forward axle, which is suitably cranked to accommodate such connections between the frames. The low pressure cylinders are connected to the rear pair of drivers. By this arrangement of cylinders long connecting rods are possible both inside and outside of the frames.

The cranks on each axle are at 90 degrees to each other and so disposed that the outside crank is at 180 degrees with its adjacent inside crank. The valves are of the piston type and the valves of both the high pressure and low pressure cylinders on one side are connected to the same valve stem and operate within a continuous valve chest which acts as a receiver between the high pressure and low pressure cylinders very much as in the design of Schenectady tandem compound. The valves are operated by the usual Stevenson link motion so that no complications are introduced in this particular. The high pressure cylinders are $15\frac{1}{2}$ inches in diameter by 26-inch stroke and the low pressure cylinders are 26 inches in diameter by the same length of stroke. The engine operates under 220 lbs. of steam and the outside diameter of drivers is 79 in. Applying these fig-

*Designed by F. J. Cole, mechanical engineer for the Schenectady Locomotive Works for the New York Central & Hudson River Railroad, 1904.

ures to the usual formula for four-cylinder compound locomotives proves that this engine is capable of a tractive power of 23,800 lbs.

This engine has been tested in high speed passenger service, hauling a train of 13 cars, and its performance was satisfactory. The general plan shows that the designer has been able to successfully adapt an entirely new arrangement of engines to the usual construction of an American Atlantic type. The crosshead and guide for the high pressure cylinders are located under the saddle of the low pressure cylinder, and it has taken considerable ingenuity to work out the detail. It appears to be a difficult place to get at for repairs and lubrication, but not more so than the valves of the inside connected English engines, and when crank axles and inside cylinders are used the method of repairing must be adaptable thereto.

The principal dimensions are as follows:

Weight in working order, 200,000 pounds.
Weight on drivers, 110,000 pounds.
Weight, engine and tender, in working order, 321,600 pounds.
Wheel Base—Driving, 7 feet.
Rigid, 16 feet 6 inches.
Total, 27 feet 9 inches.
Total, engine and tender, 53 feet 8 inches.

CYLINDERS.

Diameter of cylinders, 15½ and 26 inches.
Stroke of piston, 26 inches.
Diameter of piston rod, 3 inches.

VALVES.

Kind of slide valves, piston type.
Greatest travel of slide valves, 6 inches.
Outside lap of slide valves, 1 inch.
Inside clearance of slide valves, high pressure, ¼ inch; low pressure, ⅜ inch.
Lead of valves in full gear, ¼ inch lead forward motion when cutting off at 11 inches of the stroke.

WHEELS, ETC.

Diameter of driving wheels, outside tire, 79 inches.
Material of driving wheels, centers, cast steel.

Tire held by shrinkage and retaining rings.
Driving box material, cast steel.
Driving journals, 10 inches diameter by 12 inches.
Main crank-pin journals, side, 6¾ inches by 4 inches; back, 6 inches diameter by 6 inches.
Side rod crank-pin journals, front, 5 inches diameter by 3¼ inches.
Engine truck journals, 6½ inches diameter by 12 inches.
Diameter of engine truck wheels, 36 inches.

BOILER.

Style, straight top, radial stay.
Outside diameter of first ring, 72¼ inches.
Working pressure, 220 pounds.
Material of barrel and outside of firebox, steel (Worth Bros.).
Thickness of plates in barrel and outside of firebox, 13-16 inch, 9-16 inch, ⅝ inch.
Firebox—Length, 96⅛ inches.
Width, 75¼ inches.
Depth, front, 80¼ inches; back, 69 inches.
Material, carbon steel.
Plates, thickness, ⅜ inch; tube sheet, ½ inch.
Water space, front, 4 inches and 5 inches; sides, 3½ inches and 5½ inches; back, 3½ and 4½ inches.
Stay bolts, Taylor iron, 1 inch diameter.
Tubes—Material and gauge, Worth, charcoal iron, No. 11, B. W. G.
Number, 390 2-inch.
Length over tube sheets, 16 feet.
Firebrick, supported on water tubes.
Heating Surface—Tubes, 3,248.1 square feet.
Water tubes, 23 square feet.
Firebox, 175 square feet.
Total, 3,446.1 square feet.
Grate surface, 50.3 square feet.
Exhaust nozzles, minimum, 5⅜ inches maximum, 5⅞ inches.
Smokestack—Inside diameter, 18 inches.
Top above rail, 14 feet 8 inches.
Boiler supplied by N. & Co. Monitor No. 11 injector.

TENDER.

Weight, empty, 51,600 pounds.
Wheels, diameter, 36 inches.
Journals, diameter and length, 5½ inches diameter by 10 inches.
Wheel base, 16 feet 9½ inches.
Tender frame, 10-inch channels.
Central bearings, Fox pressed steel frames and bolsters.
Water capacity, 6,000 U. S. gallons.
Coal capacity, 10 tons.
Brake, Westinghouse-American on all drivers and trailers, on tender and for train. Corrington consolidated and engineers' valve and parts.

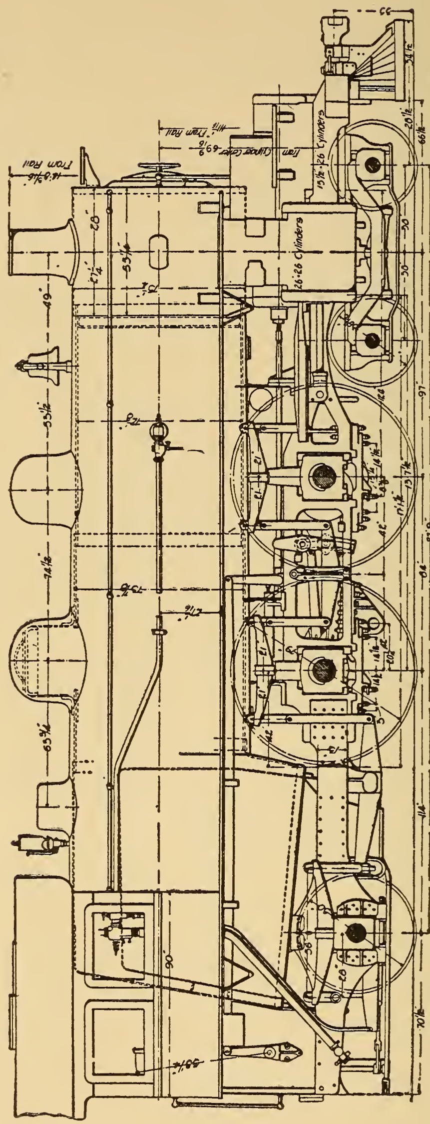


FIG. 13—SIDE ELEVATION

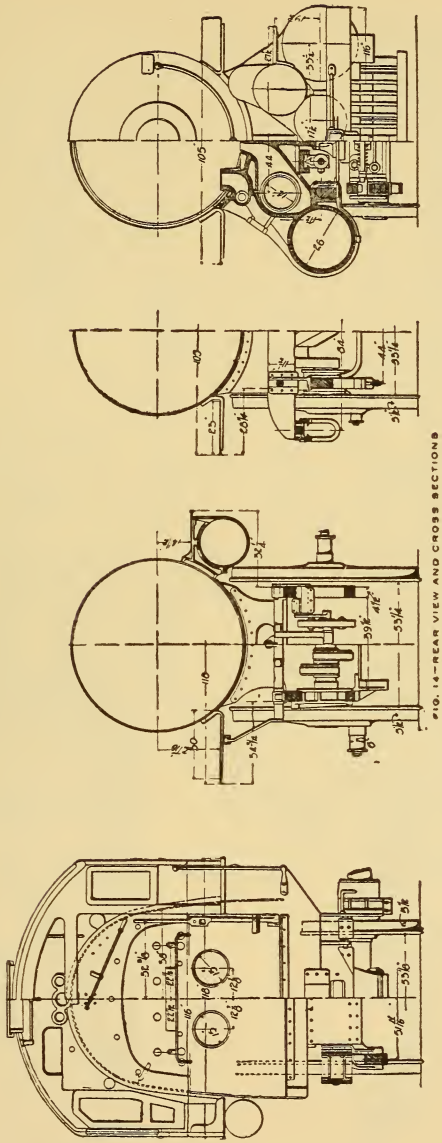


FIG. 14.—REAR VIEW AND CROSS SECTIONS

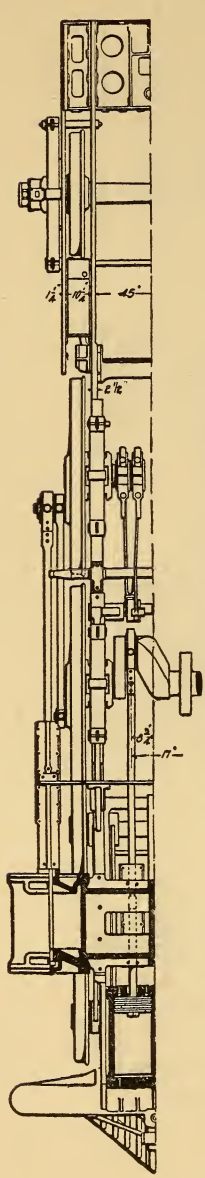


FIG 18—HALF PLAN OF RUNNING GEAR AND VALVE MOTION

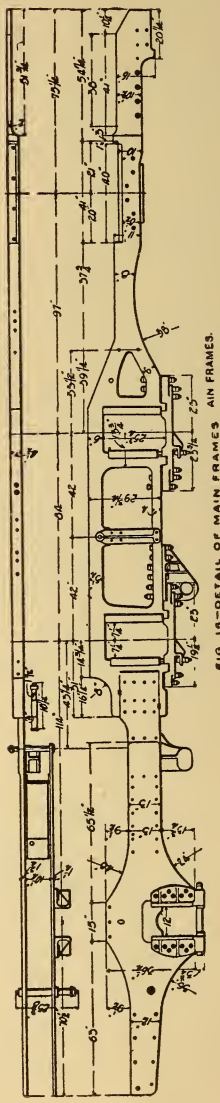


FIG 19—DETAIL OF MAIN FRAMES AIN FRAMES.

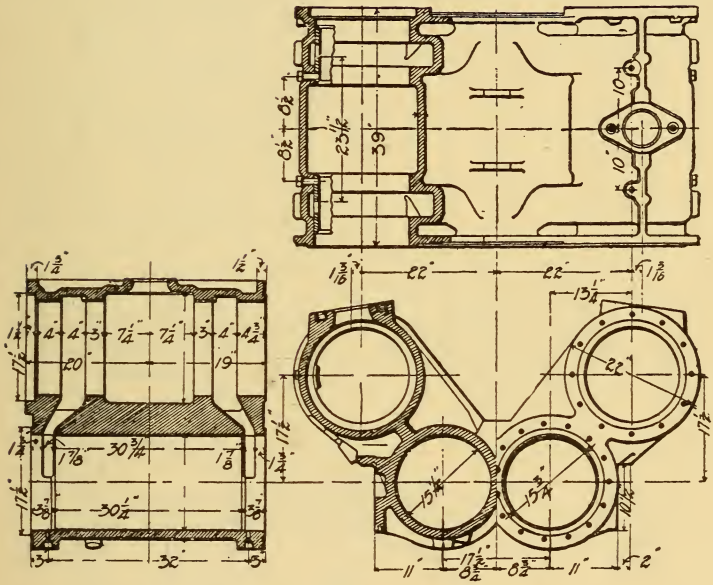


FIG. 17—HIGH PRESSURE CYLINDERS

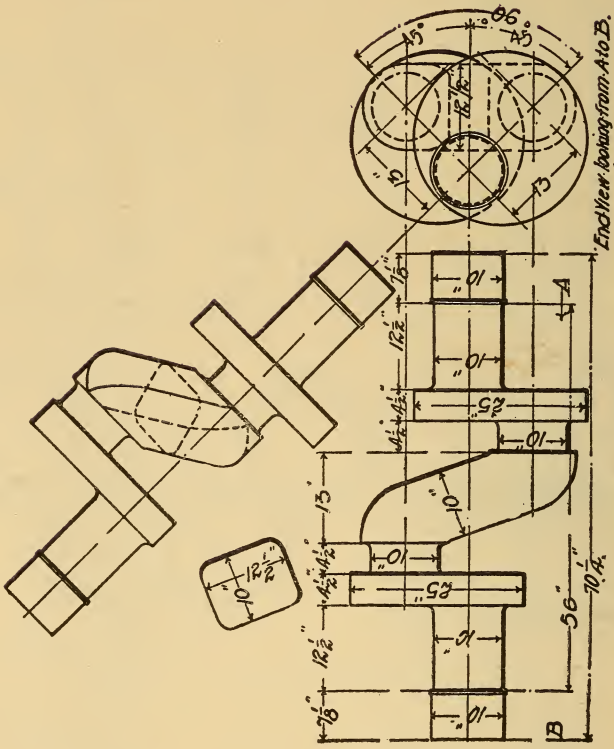


FIG. 18—TEN-INCH CRANK AXLE

DE GLEHN FOUR-CYLINDER BALANCED COMPOUND.*

This engine weighs about 160,000 pounds, with about 83,000 pounds on the driving wheels. Its maximum tractive effort is about 19,800 pounds running compound. Its grate area is 33.9 square feet. In France locomotives of the same type and but little lighter than the imported locomotive referred to have records of handling trains of from 200 to 300 tons at sustained speeds of 60 to 70 miles an hour for distances considerably in excess of 100 miles.

*Built in France for the Pennsylvania Railroad, 1904.

Kirkman's Complete Works.

THE SCIENCE OF RAILWAYS.

This great work is of inestimable value to those who look for advance in railway work; also to those who by greater knowledge of railway a seek to become more useful to their employers. It is a library of Refe and Instruction; a recognized standard work on railways, at once co clear and comprehensive. It represents forty years of continuous effort o part of the author, who has had nearly fifty years of practical experien a railway officer. Thus, through his thorough acquaintance with the busi coupled with years of study, aided by the advice and co-operation of ra men of genius and vast experience in different departments of the servic has been able to complete this great and lasting exposition of railway af

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