Motive Power Development
Pennsylvania Railroad System

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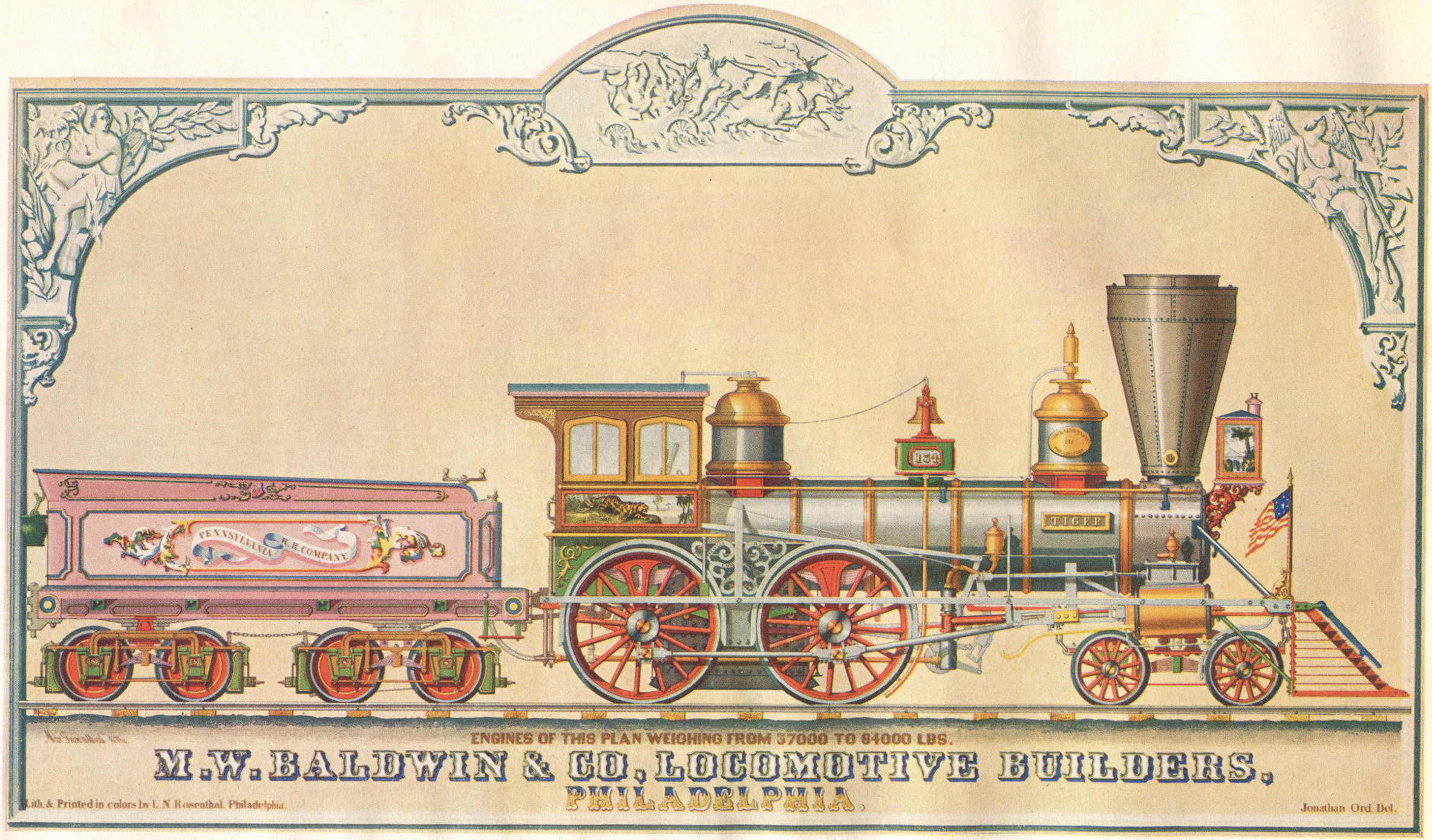
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The "Tiger," a Fast Passenger Locomotive built for the Pennsylvania in 1856

From a Lithograph showing the original colors

Cylinders, 15″ x 24″ Drivers, diameter, 66″ Weight on Drivers, 35,600 lb. Weight, total Engine, 59,100 lb.

Motive Power Development

ON THE

Pennsylvania Railroad System

1831-1924

By PAUL T. WARNER

FRANKLIN INSTITUTE
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Reprinted from BALDWIN LOCOMOTIVES

PHILADELPHIA
1924

THESE Articles were originally published in "Baldwin Locomotives," a Quarterly Magazine issued by The Baldwin Locomotive Works. Information for their preparation was obtained from the records of the Pennsylvania Railroad System and The Baldwin Locomotive Works; from the book by William B. Sipes, entitled "The Pennsylvania Railroad, Historical and Descriptive;" from "The History of the Pennsylvania Railroad Company," by William B. Wilson, and from articles by the late J. H. Caruthers which appeared in *The Railroad Gazette*. A large number of drawings prepared by Mr. Caruthers have also been consulted, and some of them are reproduced. Acknowledgments are also due Messrs. J. Snowden Bell and C. B. Chaney, of Brooklyn, N. Y., who furnished valuable information.

Motive Power Development
Pennsylvania Railroad System

1831-1924

CHAPTER I

THE LOCOMOTIVES OF THE PHILADELPHIA AND COLUMBIA RAILROAD AND THE EARLY RAILROADS OF NEW JERSEY, AND THE DEVELOPMENT OF THE PENNSYLVANIA'S MOTIVE POWER UP TO THE YEAR 1868.



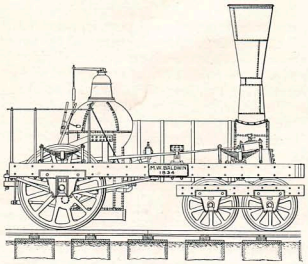
WHEN, in 1847, the public spirited citizens of Pennsylvania invested in the stock of the then newly organized Pennsylvania Railroad Company, they little realized that they were founding an organization which, during the succeeding three-quarters of a century, would develop into what is generally recognized as the greatest institution of its kind in the world. The present mileage of the Pennsylvania System is 10,519; the total track mileage, including sidings, being 25,292. There are in service 7,556 locomotives of all classes, and a total of 6,983 passenger train cars and 257,409 freight and work train cars. The total number of passengers carried during 1923 was 151,953,566, equivalent to 5,206,471,435 passengers carried one mile; while the total number of tons of freight hauled was 278,675,494, equivalent to the stupendous total of 53,484,857,000 ton-miles. The growth of the System to its present culmination constitutes a most remarkable chapter in the history of land transportation; and this is true, not only from an engineering, but also from a financial and a business point of view. The work of building up the Pennsylvania System has been accomplished on a conservative basis, using sound judgment, but never hesitating to make improvements which would enhance the value and efficiency of the property. The constant effort has been to build for the future, and to anticipate transportation requirements as far as financial conditions and the development of the art of railroading would permit. As a result of this policy, the Company has never passed through a receivership, and dividends have been paid with a regularity seldom equalled in any line of industry. The Pennsylvania System stands today as a demonstration of the far-sightedness and sound judgment of the men who have made it what it is.

Motive power development on the Pennsylvania has been accomplished along the same general lines as those on which the System has been built. The policy has been conservative in that new types or designs have not been introduced on a large scale until investigation and trial have fully demonstrated their fitness for the service. At the same time, expenditures have been liberal when the advantages of using new designs or more expensive materials have been proved to the satisfaction of the Motive Power Department. As a result of this policy, there has been developed a Department of Tests at Altoona, which in point of complete equipment and valuable research work accomplished has no equal among the railroads of the United States. Furthermore the results of locomotive tests made on the Altoona plant have been widely published, and railroads the world over have been able to profit by them.

The Pennsylvania has adhered strictly to the principle of training its own men and making promotions from within its ranks, with the result that sweeping changes within the organization have been practically unknown. Therefore, especially since the Motive Power Department standardized locomotive designs in 1868, the development of the power has been unusually consistent, and has followed a carefully determined policy. Experimental locomotives have at

times been purchased from various builders and even imported from abroad, and valuable results have been obtained from the operation of such locomotives. With few exceptions, however, all the locomotives now operating on the Pennsylvania were built from designs prepared by the Motive Power Department, and an engine built by contract is in all respects a duplicate of one of the same class constructed in the Company's shops at Altoona.

As the Pennsylvania Railroad Company



Type of Baldwin Locomotive Built for the Philadelphia & Columbia R. R., 1834

was not incorporated until 1846 and did not begin to function as a common carrier until 1849, it cannot be classed as one of the pioneer railroad organizations of the United States. Subsequently, however, it purchased or leased roads which were among the first to be built in this country, so that its history properly goes back to the early days of railroading. Some account of the locomotives used on the more important of these roads, therefore, naturally forms a part of the history of the Pennsylvania's motive power, and will be first presented in this series of articles.

The Philadelphia and Columbia Railroad

Among the railroads which were absorbed by the Pennsylvania System, probably the most important was the Philadelphia and Columbia, which constituted part of what was known as the Main Line of the Public Works of the Commonwealth of Pennsylvania. This line consisted of a combination of railroads and canals, the construction of which was authorized by the State Legislature in 1828. The contracts for the work were placed by the Canal Commissioners, under whose supervision the line was operated. This line consisted of a railroad from Philadelphia to Columbia, 82 miles; the Eastern Division of the Canal, from Columbia to Hollidaysburg, 172 miles; the Allegheny Portage Railroad, from Hollidaysburg to Johnstown, 36 miles, crossing the Allegheny Mountains; and the Western Division of the Canal, from Johnstown to Pittsburgh, 104 miles. The line was opened throughout its entire length in 1834, and at the time was considered a remarkable example of engineering skill. According to a report made by the Auditor General in 1843, the total cost to the State, of these roads and canals, was $14,362,320.35; but the System, while of great value to the public, did not prove remunerative.

The Philadelphia and Columbia Railroad had an inclined plane at either end, worked by stationary engines, for climbing the banks of the Schuylkill and Susquehanna Rivers respectively. The intervening railroad had frequent curves, the sharpest of 631 feet radius, and maximum short grades of 45 feet per mile, with longer grades of 30 feet per mile. It was at first used as a public highway for privately owned vehicles, which were drawn by horses. This practice was continued until April 1, 1844, when it was finally prohibited by law, owing to the confusion resulting from the use of two radically different types of motive power on the same railroad. The advantages of steam power had been early recognized, however, and by an act of the Pennsylvania Legislature approved April 15, 1834, the Canal Commissioners were authorized to use locomotives. Matthias W. Baldwin, founder of The Baldwin Locomotive Works, had by that time established himself in Philadelphia as a locomotive builder, and he received an order from the Commissioners for several engines. The first of these, the "Lancaster," was completed on June 25, 1834, and the second, the "Columbia," on September 2nd of the same year. These locomotives were of the 4-2-0 type with 9 x 16-inch cylinders and driving wheels 54 inches in diameter; and they weighed each 17,000 pounds in working order. The general design is clearly shown in an accompanying illustration.

These first locomotives were followed by

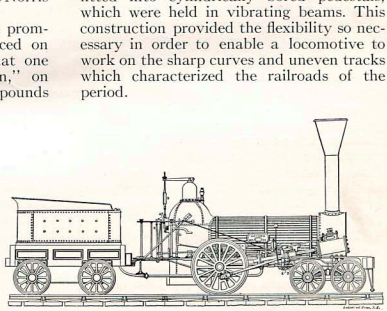
others of the same type, and up to October 30, 1835, ten of them had been placed on the road. Contemporary with these were five locomotives built by Robert Stephenson and Co., of New Castle-on-Tyne, England, and two others of American construction, built respectively by Coleman Sellers and Sons, and Long and Norris. The English locomotives, with their rigid wheel-bases and comparatively light parts, were generally unsatisfactory and often in need of repairs. The Baldwin engines were in high favor, regularly hauling gross loads of 75 tons over the road; while one of them made a record by hauling 100 tons. They represented a type which was Mr. Baldwin's standard up to 1842, and the total number of these Baldwin single-driver locomotives placed on the Philadelphia and Columbia R. R., according to the records of the builders, was 27.

Contemporary with these early Baldwin locomotives was a group having the same wheel arrangement, and built by William Norris, also of Philadelphia. The most important difference in the two designs was the position of the driving wheels which, in the Baldwin engines, were back of the firebox, while in the Norris engines they were in front of the firebox. The Baldwin engines, with their longer wheel base, were the more steady riders, while the Norris engines carried a larger portion of their weight on driving wheels, and had more adhesion and consequently greater hauling capacity. For this reason the Baldwin engines were generally preferred for passenger service and the Norris engines for freight.

The Norris locomotives came into prominence shortly after they were placed on the road by reason of the fact that one of them, the "George Washington," on July 10, 1836, hauled a load of 19,200 pounds up the inclined plane at Philadelphia. This plane had a length of 2800 feet and a grade of 1 in 14 (377 feet per mile). The locomotive attained a speed of 15 miles per hour, while carrying a steam pressure of 60 pounds. This was regarded as a remarkable performance, and it was directly responsible for the receipt, by Mr. Norris, of an order from England for similar locomotives to work on the "Lickey Incline," a grade of 1 in 37 on the Birmingham and Gloucester Ry.

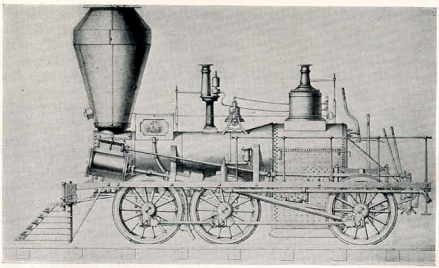
The "George Washington" was inside connected, and is stated as having cylinders 10¼ x 17⅝ inches and driving wheels 48 inches in diameter. It weighed 14,930 pounds with 8,700 pounds on drivers. It is reported as having hauled over the road a train of 35 cars weighing 137 gross tons, while a similar locomotive, the "Washington County Farmer," on one occasion hauled a train of 28 cars weighing 141¾ tons. This was the first outside connected Norris locomotive. Its performance, however, was subsequently exceeded by one of Mr. Baldwin's single driver engines, the "West Chester," which hauled a train of 51 four-wheeled cars, weighing 289 net tons, over the road, some of the track being of wood covered with strap rail. During the year 1837 a number of these Baldwin locomotives were operated at a cost for repairs of only 1.2 to 1.6 cents per mile.

The need for locomotives of greater capacity soon began to be felt, and in 1845 the Philadelphia & Columbia received from The Baldwin Locomotive Works a six-coupled locomotive of approximately 15 tons weight, having 14 x 18-inch cylinders and driving wheels 42 inches in diameter. This locomotive was equipped with the well-known Baldwin Flexible Beam Truck, in which the first and second axles were allowed a limited amount of lateral motion, the one to the right and the other to the left, or vice versa. To facilitate this, the coupling rods had spherical brasses and the driving boxes were fitted into cylindrically bored pedestals, which were held in vibrating beams. This construction provided the flexibility so necessary in order to enable a locomotive to work on the sharp curves and uneven tracks which characterized the railroads of the period.



Type of Early Norris Locomotive

This locomotive was followed by two of similar design, with cylinders 13½ inches in diameter, in 1847; and by two passenger locomotives of the American (4-4-0) type in



Six-coupled Locomotive with Flexible Beam Truck, as Built by The Baldwin Locomotive Works, 1845

1854. These were the last locomotives purchased by the Philadelphia & Columbia Railroad from The Baldwin Locomotive Works before the State Transportation System was purchased by The Pennsylvania Railroad Company in 1857.

In this connection, brief reference should be made to the portable boats which were designed and built for use on the State railroads and canals. These boats were constructed in sections, which could be coupled together when afloat and disconnected and placed on suitably designed eight-wheeled cars for transport over the railroads. In this way freight was carried over the entire System without transfer from cars to boats, or vice versa. A most interesting and complete description of these portable boats is given in a paper by J. Snowden Bell, which was published in 1920, as Baldwin Record No. 97.

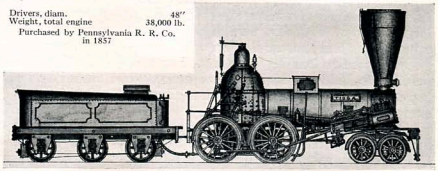
Only two Baldwin locomotives were built for the Allegheny Portage Railroad, and these were heavy engines of the ten-wheeled (4-6-0) type built in 1854 and 1856 respectively. One of them, as subsequently rebuilt at Altoona, is illustrated on page 17. Although, as previously mentioned, this railroad was only 36 miles in length, it was composed of ten inclined planes and 11 so-called levels, reached an altitude of 1339 feet, and was regarded as one of the wonders of the world.

The locomotives operated by the State System of railroads were 73 in number at the time the System was purchased by the Pennsylvania Railroad Company in 1857, and they had been furnished by various builders and represented a great variety of design. Five of them were condemned as unfit for service, and many of the remainder were subsequently rebuilt at the Altoona Shops, in order to conform them more nearly to the Pennsylvania standards.

The New Jersey Railroads

The State of New Jersey was a pioneer in building railroads for the general transportation of passengers and freight. As early as 1812, John Stevens applied to the State Legislature for authority to build a railroad within its borders, but nothing was accomplished at that time. In 1832, however, the Camden & Amboy Railroad was completed between Bordentown and Amboy, a distance of 26½ miles, and the following year was extended from Bordentown to Camden, N. J., opposite Philadelphia. This road, in conjunction with a line of steamboats operated between Amboy and New York, con-

Drivers, diam. 48"
Weight, total engine 38,000 lb.
Purchased by Pennsylvania R. R. Co. in 1857

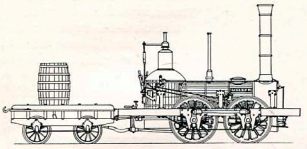


From a Drawing by C. H. Caruthers

The "Tioga," Built by Norris Bros. for the Philadelphia & Columbia R. R., 1848

stituted, at that time, the principal route between New York and Philadelphia, and was, because of its strategic location, a most important part of the country's transportation system.

The first locomotive to be used on the Pennsylvania Railroad Company's exhibit at the World's Columbian Exposition. The locomotive is permanently preserved at the National Museum in Washington.



From a Drawing by C. H. Caruthers

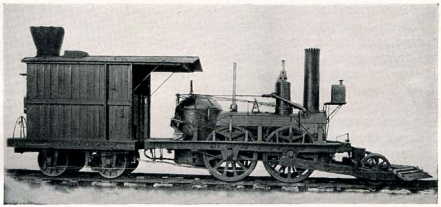
The "John Bull," first Locomotive on the Camden & Amboy R. R., as originally built and named "Stevens"

This locomotive is of special interest to The Baldwin Locomotive Works, in that it was carefully examined by Mr. Baldwin before he built his first locomotive, the "Old Ironsides."

Records show that very few Baldwin locomotives were built for the Camden and Amboy. The most interesting of them, from a historical point of view, was one of the 4-4-0 type named the "E. A. Stevans" and completed early in 1846. This locomotive was among the first of its type to be built by Mr. Baldwin, and its general design is shown in an illustration on page 8.

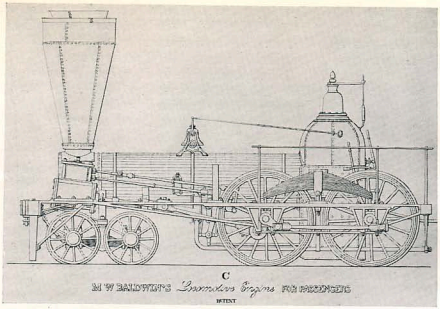
The motive power of the Camden and Amboy included two remarkable groups of locomotives to which at least a brief reference must be made. The first of these were the so-called "Monsters," which were freight locomotives of the 0-8-0 type, and of exceptional weight and capacity for their day. The original "Monster" was alleged to have been built at the Camden and Amboy Shops in Bordentown in 1834, although the date is uncertain and some accounts place its construction as late as 1850. It had inclined

Camden & Amboy was the "John Bull," which was built by Robert Stephenson and Co., of New Castle-on-Tyne, England. It was received by the road in August, 1831, and was put in service at Bordentown, N. J., on November 12th of that year. This locomotive was originally named "Stevens," but its name was changed to "John Bull" shortly after its arrival. It was of the well known "Planet" class, as built by the Stephensons at that time, with inside cylinders and two pairs of wheels of the same diameter, coupled by side rods. The cylinders were 9 x 20 inches; the wheels had a diameter of 54 inches, and the weight of the locomotive was 11 tons. This locomotive was placed in service by Isaac Dripps, Master Mechanic of the road; a genius who was destined to subsequently make a name for himself. Finding that the "John Bull," with its rigid wheelbase, was not well fitted to take the curves on the road, Mr. Dripps removed the side rods and improvised a two-wheeled leading truck, the wooden frame of which was hinged to the extremities of the front axle. This truck carried a crude form of pilot. It proved effective as a guide, and thus equipped the locomotive not only did duty on the Camden & Amboy for many years, but in 1893 travelled, under its own steam, to Chicago, where it formed part of the



The "John Bull" as rebuilt with Leading Wheels

cylinders whose pistons were connected to vibrating beams fulcrumed on bearings bolted to the smokebox front. From these beams the two rear pairs of wheels were rotated by connecting and coupling rods. The first and second pairs of wheels were independently coupled by rods, and the second axle was geared through an intermediate spur wheel to the third axle. The cylinders of this locomotive measured 18 x 30



Type of Baldwin Passenger Locomotive built for the Camden & Amboy R. R. in 1846
Cylinders, 13¾" x 18". Drivers, diameter, 60". Weight, total, about 37,000 lb.

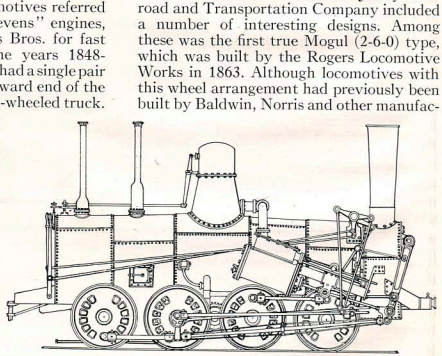
inches; the driving wheels were 48 inches in diameter, and the total weight of the locomotive was about 60,900 pounds. Anthracite was used as fuel.

The records seem to indicate that subsequent to the building of the original "Monster," three others were built at Trenton, N. J. At least one of these was rebuilt, in 1869, as a 4-6-0 type locomotive, and continued in service until 1875.

The second group of locomotives referred to included the famous "Stevens" engines, which were built by Norris Bros. for fast passenger service during the years 1848-1851. These locomotives each had a single pair of driving wheels, and the forward end of the engine was supported on a six-wheeled truck. Two of the locomotives had drivers seven feet in diameter, while on the remaining five the wheel diameter was eight feet. The cylinder diameters varied from 13 to 14 inches, and the stroke in all cases was 38 inches, except on one locomotive which had a 34-inch stroke. The weight in working order was 46,000 to 47,000 pounds. These locomotives suffered on account of low adhesion and boiler capacity. The boiler was set low down, and the firebox had a sloping roof sheet which extended under the driving axle. The fuel used was anthracite. These locomotives were slow in starting, and could handle only light trains, but made fast time when running. The majority of them were rebuilt as 4-4-0 type locomotives with 72-inch wheels, and were used in freight service.

From a historical point of view, one of the most interesting Baldwin locomotives built for service in New Jersey was the "Black Hawk," completed in May, 1835, for the Philadelphia and Trenton Railroad, and bearing the construction number 11. It was of the 4-2-0 type, and was the first Baldwin locomotive with outside cylinders. It was also the first to use a device, patented by E. L. Miller, for transferring part of the weight of the tender to the locomotive, in order to increase the adhesion when starting. This device was frequently used by Mr. Baldwin on his single driver locomotives. The "Black Hawk" is illustrated on page 10.

The locomotives of the New Jersey Railroad and Transportation Company included a number of interesting designs. Among these was the first true Mogul (2-6-0) type, which was built by the Rogers Locomotive Works in 1863. Although locomotives with this wheel arrangement had previously been built by Baldwin, Norris and other manufac-

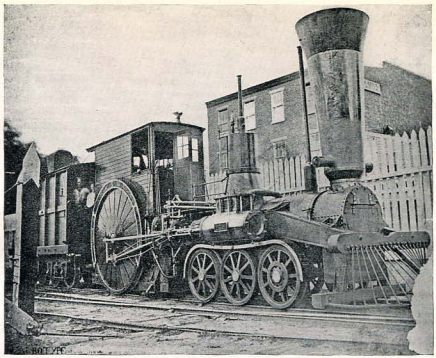


From a Drawing by C. H. Caruthers

The "Monster," Camden & Amboy R. R., as originally built
Cylinders, 18" x 30". Drivers, diameter, 48". Weight, total engine, about 60,900 lb.

turers, this was undoubtedly the first six-coupled locomotive to have a two-wheeled, swing bolster leading truck equalized with the forward drivers. This road also had among its passenger locomotives, a group of 4-4-0 engines, built at the Company's shops in Jersey City, with Stephenson link motion placed outside the driving wheels. One of these locomotives is shown in an illustration on page 10.

During the late sixties, the Camden and Amboy Railroad, the New Jersey Railroad and Transportation Company, and the Delaware and Raritan Canal Company, were consolidated under the name of the United New Jersey Railroad and Canal Company. In June, 1871, these lines were leased to the Pennsylvania Railroad for 999 years, and now form part of its New York, Amboy and Trenton Divisions.



Single-driver Locomotive "Stevens," built by Norris Bros. for the Camden & Amboy R. R., 1850
Cylinders, 13" x 38". Drivers, diameter, 96". Weight, total engine, about 47,000 lb.
There were seven locomotives of this general design.



Photo furnished by C. B. Chaney.
A Rebuilt "Stevens" Single-driver Locomotive on the Camden & Amboy R. R.

Cylinders	17" x 24"
Drivers, diam.	57"
Weight on drivers, about	62,000 lb.
Weight, total engine, about	71,000 lb.
Fuel	Hard coal

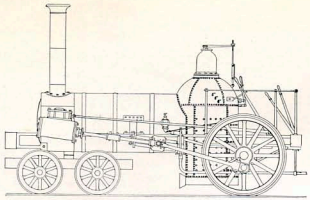
There were five locomotives of this class.

The Pennsylvania Railroad

Although the system of railroads and canals owned and operated by the State of Pennsylvania represented, at the time of its construction, a monumental piece of work, it soon became apparent that it was entirely inadequate to meet the increasing demands for transportation, and that what was



Mogul Type Locomotive, built by The Baldwin Locomotive Works for the New Jersey R. R. & Transportation Co., 1871



From a Drawing by C. H. Caruthers

The "Black Hawk," built for the Philadelphia & Trenton R. R. by The Baldwin Locomotive Works, 1835. The first Baldwin Engine with outside Cylinders

really required was a line of railroad traversing the entire State, and thus giving Philadelphia an outlet westbound which would enable it to successfully compete with other cities such as New York and Baltimore. Accordingly on April 13, 1846, the State Legislature passed an act incorporating the Pennsylvania Railroad Company, and the charter was granted by Governor Shunk on February 25, 1847. This charter authorized the Company to construct a line of railroad from Harrisburg to Pittsburgh, there being already railroad connection between Harrisburg and Philadelphia via the Harrisburg and Lancaster Railroad* and the Philadelphia and Columbia Railroad (State road).

Under the supervision of John Edgar Thomson, Chief Engineer of the new Company, who was a man of exceptional ability, the grading of the first 20 miles of line west of Harrisburg was let on July 17, 1847; and on July 22, 1847, the first 15 miles east of Pittsburgh were placed under contract. On September 1, 1849, the First Division, extending from Harrisburg to Lewistown, 61 miles, was opened. On December 10, 1852, cars were run through from Philadelphia to Pittsburgh, using the Portage Railroad over the mountains; and on February 15, 1854, the Pennsylvania's own line over the mountains was formally opened, and trains were run through without using the inclined planes. The system of State Railroads was purchased by the Pennsylvania Railroad Company on August 1, 1857, and the Harrisburg and Lancaster Railroad was leased on December 29, 1860, for 999 years, thus finally giving the Pennsylvania its own line between Philadelphia and Pittsburgh.

The early motive power history of the Pennsylvania Railroad was typical of that of the majority of the railroads of the period. There were in existence a comparatively large number of independent locomotive builders, each of whom had standards of his own which he naturally maintained were superior to those of his competitors; and as the Motive Power departments of the railroads were not sufficiently well organized to prepare designs, the result was a remarkable variety of locomotive types on each road, having detail parts which were anything but interchangeable. In the case of the Pennsylvania Railroad this condition was to some extent aggravated by reason of the various types of locomotives owned by the roads which were from time to time leased or purchased.

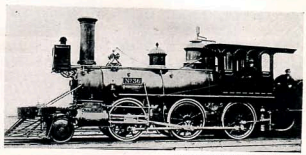


Photo furnished by C. B. Chaney

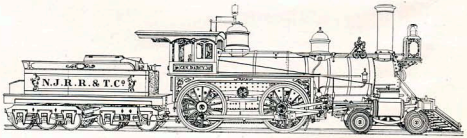
The first true Mogul Locomotive, built by the Rogers Locomotive Works for the New Jersey R. R. & Transportation Co., 1863

*The full name of this line, which was organized in 1835, was the Harrisburg, Portsmouth, Mt. Joy and Lancaster Railroad, but it is usually referred to as the Harrisburg and Lancaster.

Cylinders	16″ x 24″
Drivers, diam.	60″

Equipped with Stephenson link motion outside driving wheels.

Used in express passenger service between Jersey City and New Brunswick. Cut up by Pennsylvania R. R. in 1882.



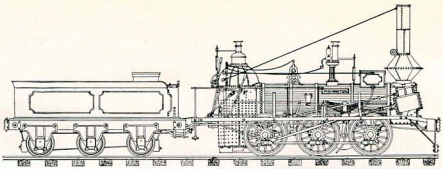
From a Drawing by C. H. Caruthers

American Type Passenger Locomotive, built by the New Jersey R. R. and Transportation Co. to Designs of John Headden, M. M., at the Jersey City Shops, 1867

Cylinders	13″ x 18″
Drivers, diam.	46″
Weight, total engine	34,675 lb.

Equipped with Baldwin flexible beam truck.

Originally built for the Harrisburg & Lancaster R. R. and transferred to the Pennsylvania in October, 1849. Subsequently partially rebuilt, and finally retired in 1858.

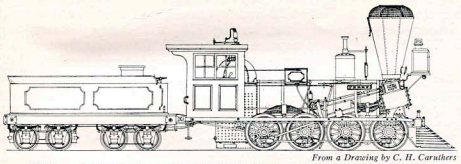


From a Drawing by C. H. Caruthers

Six-coupled Locomotive "Washington," built by The Baldwin Locomotive Works, 1847

Among the most notable builders whose locomotives were among those first used on the Pennsylvania, the names of M. W. Baldwin and of Norris Bros., of Philadelphia; Ross Winans, of Baltimore, and Smith & Perkins, of Alexandria, Virginia, stand out conspicuously. In addition to the locomotives ordered by and especially built for the Pennsylvania Railroad Company, a number were transferred from the Harrisburg and Lancaster Railroad, the operation of which was taken over by the Pennsylvania at the time of opening the First Division of the latter road in 1849. Frequent additions were made to the equipment as the line was extended and business increased, so that at the close of 1853, there were 79 locomotives in service, and this number had been increased to 133 by the close of 1856. In view of the variety of types and designs represented by these early locomotives, it is possible to refer rather briefly to only the most notable engines then in service.

Records show that the first Baldwin locomotives completed for the Pennsylvania were the "Dauphin" and "Perry," which were finished by the builders in November, 1848, previous to the opening of the road. They bore the Baldwin construction numbers 333 and 334, and were finally placed in service on the new line in November, 1849, and January, 1850, respectively. They were of the 0-8-0 type with Baldwin flexible beam trucks, and had hook motion valve gear for the main valves, and also independent valves which, when in operation, cut off the steam



From a Drawing by C. H. Caruthers

Eight-coupled Freight Locomotive with Flexible Beam Truck and Half-stroke Cut-off, built by The Baldwin Locomotive Works, 1848

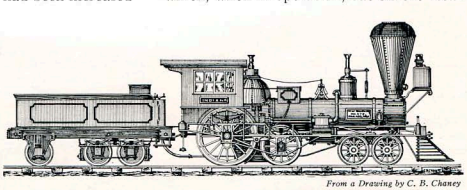
Cylinders	17″ x 22″
Drivers, diam.	43″
Weight, total engine	50,975 lb.

This and a similar locomotive, the "Dauphin," were the first Baldwin engines completed for the Pennsylvania. The "Dauphin" was placed in service in 1849 and the "Perry" in 1850. Both were shortly after sold to the Philadelphia & Reading Ry.

Cylinders	14″ x 20″
Drivers, diam.	72″
Weight on drivers	18,000-24,000 lb.
Weight, total engine	47,000 lb.

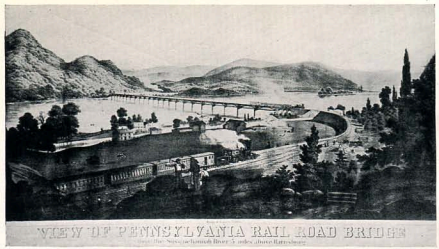
Weight could be transferred from intermediate to driving wheels by means of a lever.

There were three locomotives of this class.



From a Drawing by C. B. Chaney

Single-driver Fast Passenger Locomotive, built by The Baldwin Locomotive Works, 1849



From a photo, furnished by C. B. Chaney, of an old lithograph

The first Pennsylvania R. R. Bridge across the Susquehanna River at Rockville, Pa.
This was a wooden truss bridge, completed in August, 1849. It was partly destroyed by fire on July 17, 1868, was rebuilt and replaced by a double track iron truss bridge in 1877. This was, in turn, replaced by the present stone arch bridge in 1902.

at half-stroke. These two locomotives were shortly afterward sold to the Philadelphia and Reading Railroad, but a third one of similar design, the "Westmoreland," built early in 1850, remained in service on the Pennsylvania until 1866. The "Perry" is illustrated on page 11.

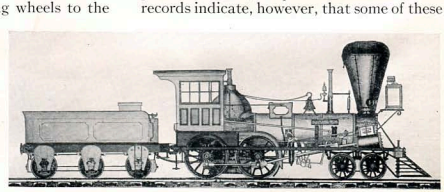
Records indicate that the first Baldwin engine built for the Pennsylvania to be actually placed in service on the road was the "Mifflin," a fast passenger locomotive completed in July, 1849. Two similar locomotives, the "Blair" and "Indiana," followed later in the year. As shown on page 11, these locomotives had a single pair of driving wheels back of the firebox, one pair of carrying wheels in front of the firebox, and a four-wheeled truck under the front end. The design was generally similar to that of the locomotive "Governor Paine," built by Mr. Baldwin for the Central Vermont Railroad in 1848-49. An unusual feature was a "traction increaser" for the purpose of transferring weight from the carrying wheels to the drivers in starting, and thus increasing the adhesion. These locomotives proved speedy with light trains, but their usefulness was very limited, and two of them were subsequently rebuilt as 4-4-0 type locomotives.

A group of 16 Baldwin locomotives of the 4-4-0 type, with driving wheels 54 inches in diameter, built during the years 1849-1852 and represented by the "Juniata" (below), were typical of a class of power extensively used at that time for general passenger and freight service. Contemporary with them were two other groups of 4-4-0 type locomotives with 60-inch wheels; one group, of three locomotives, having 15 x 20-inch cylinders, and the other group of four, having 13½ x 22-inch cylinders, and represented by the "Wyoming," illustrated on page 13. All these locomotives had hook valve motion and also independent valves designed to cut off at half-stroke.

During the period August, 1852, to January, 1853, Mr. Baldwin built for the Pennsylvania a group of 12 six-coupled freight locomotives with 18 x 22-inch cylinders and driving wheels 44 inches in diameter. Six of these locomotives had four-wheeled leading trucks, while the remaining six had a single pair of leading wheels placed immediately under the cylinders. Both designs are illustrated on page 13. The former type weighed approximately 64,500 pounds with 46,000 pounds on drivers, while the latter are stated to have weighed about 60,000 pounds with 48,000 pounds on drivers. The records indicate, however, that some of these

Cylinders	15" x 20"
Drivers, diam.	54"
Weight on drivers	25,825 lb.
Weight, total engine	45,275 lb.

Equipped with hook motion valve gear and half-stroke cut-off. There were 16 locomotives of this class.

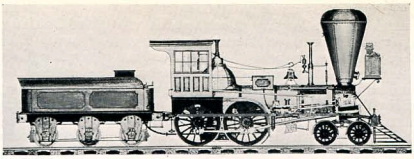


From a Drawing by C. H. Caruthers

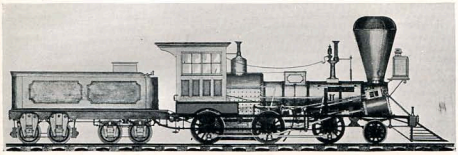
American Type Passenger Locomotive "Juniata," built by The Baldwin Locomotive Works, 1849

Cylinders	13½″ x 22″
Drivers, diam.	60″
Weight on drivers	22,875 lb.
Weight, total engine	38,675 lb.

There were four locomotives of this class. They had hook motion valve gear, and independent half-stroke cut-off.



American Type Passenger Locomotive "Wyoming," built by The Baldwin Locomotive Works, 1850



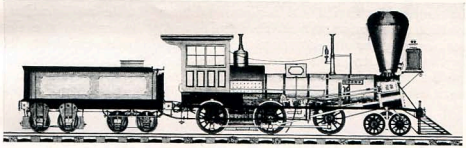
Six-coupled Freight Locomotive "Cumberland," built by The Baldwin Locomotive Works, 1852

Cylinders	18″ x 22″
Drivers, diam.	44″
Weight on drivers	48,200 lb.
Weight, total engine	59,600 lb.

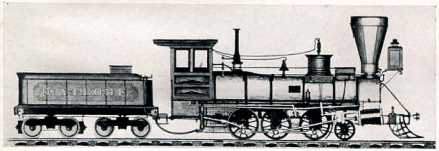
There were six locomotives of this class. All were subsequently rebuilt by the Railroad Company with four-wheeled leading trucks.

Cylinders	18″ x 22″
Drivers, diam.	44″
Weight on drivers	46,100 lb.
Weight, total engine	64,500 lb.

There were six locomotives of this class, one of which was probably sold to the Philadelphia and Columbia R. R. and repurchased by the Pennsylvania in 1857.



Six-coupled Freight Locomotive "Berks," built by The Baldwin Locomotive Works, 1852



Six-coupled Freight Locomotive, built by Smith and Perkins, Alexandria, Va., in 1852

Cylinders	17″ x 22″
Drivers, diam.	44″
Weight on drivers	41,800 lb.
Weight, total engine	54,200 lb.

Equipped with drop-hook valve gear, having separate eccentrics for front gear, back gear, and cut-off. One valve for each cylinder. Partially rebuilt in 1862 and worn out in 1874.

Cylinders	16″ x 22″
Drivers, diam.	78″
Weight on drivers	37,900 lb.
Weight, total engine	61,300 lb.

Equipped with hook motion valve gear and independent variable cut-off. Subsequently rebuilt with 66-inch drivers. There were three Wilmarth locomotives of this general design on the Pennsylvania.



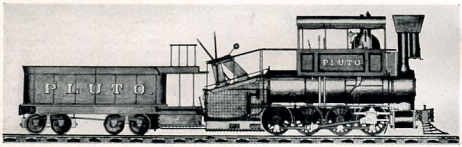
American Type Passenger Locomotive, built by Seth Wilmarth, Boston, 1852

The above Illustrations are from Drawings by C. H. Caruthers

latter carried as much as 18,000 or 19,000 pounds on the leading wheels, which was regarded as excessive. Hence these engines were subsequently rebuilt by the Railroad Company and four-wheeled trucks were substituted for the single pair of leading wheels originally applied.

In addition to the Baldwin locomotives of the 2-6-0 type, the reports of the Pennsylvania Railroad Company indicate that during the years 1852-1854, twelve locomotives with the same wheel arrangement were built

"Camel" locomotives, built by Ross Winans, of Baltimore, were placed on the Pennsylvania. These locomotives all had 19 x 22-inch cylinders and driving wheels 42 or 44 inches in diameter, and averaged 59,000 pounds weight each, in working order. The peculiarities of the Winans "Camels," with their long over-hanging fireboxes, firing chutes, cam-operated valve gear and other exceptional features, are well known and will not here be described in detail. The earlier of these locomotives underwent consider-



From a Drawing by C. H. Caruthers

"Camel" Locomotive for heavy Freight and Pushing Service, built by Ross Winans, 1853

Cylinders	19″ x 22″
Drivers, diam.	44″
Weight, total	59,100 lb.

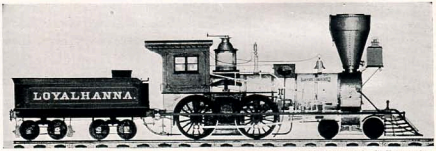
There were 11 locomotives of this class, built during 1853-1856. Some authorities give the wheel diameter of the "Pluto" and three other engines as 42″, and the total weight as 69,600 lb. All the "Camels" were subsequently rebuilt as Moguls.

for the road by Smith and Perkins, and two by Richard Norris and Son. Two Smith and Perkins' engines of this type were also built for the State Road, and were purchased by the Pennsylvania in 1857. In all these locomotives the leading wheels were held in rigid

able modification shortly after they were placed on the Pennsylvania, and the last five were built without the firing chutes and with the fireboxes closed at the rear. These Camel locomotives were all subsequently rebuilt as Moguls (2-6-0 type) at Altoona,

Cylinders	16″ x 24″
Drivers, diam.	60″
Weight on drivers	40,900 lb.
Weight, total engine	59,000 lb.

There were nine locomotives of this class, and three of similar design but with 72-inch drivers.



From a Drawing by C. H. Caruthers

American Type Passenger Locomotive, built by Richard Norris & Son, 1853

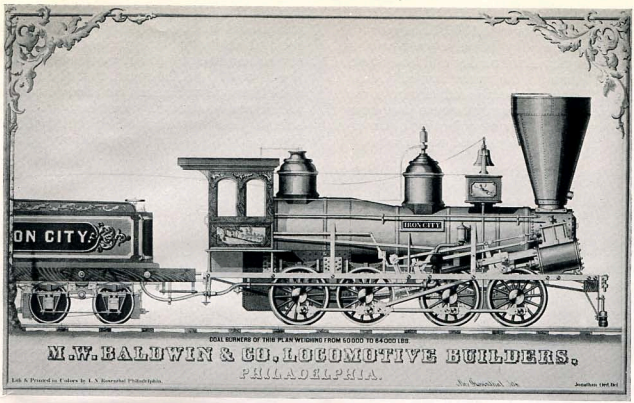
frames, and placed immediately back of the cylinders, as shown in the illustration of the "Latrobe" on page 13. This arrangement was undoubtedly originated by James Millholland, Master of Machinery of the Philadelphia and Reading Railroad, and was first used in the "Pawnee" class, built by that road early in 1852. It was a distinctly new design at the time, and was the forerunner of the true "Mogul" type, introduced about ten years later, and which subsequently became very popular.

During the years 1853-1856, eleven

and thus altered, several of them remained in service as late as 1880-1882.

The majority of the Norris locomotives placed in service on the Pennsylvania during this period were of the American (4-4-0) type. In 1853, 12 such locomotives were built for passenger service, three of them having 72-inch drivers and the remaining nine, 60-inch drivers. In 1853 and 1854, eight of similar type, with 54-inch drivers, were built for freight service.

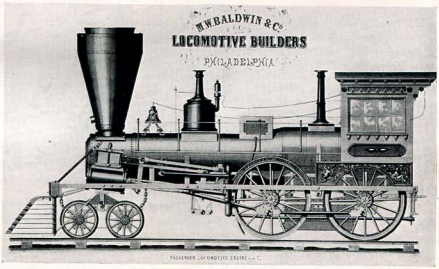
The Norris locomotives had quite a reputation for speed, but their details—especially



Eight-coupled Locomotive for Heavy Freight and Pushing Service, 1854. Equipped with Baldwin Flexible Beam Truck and Variable Cut-off
Cylinders, 19" x 22". Drivers, diam., 43". Weight, total engine, 66,000 lb.
There were four Locomotives of this class.

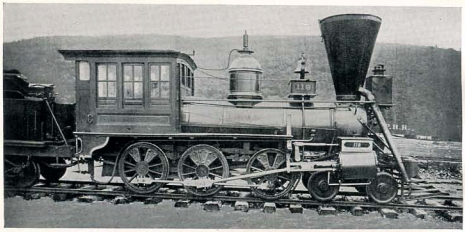
the frames—were of rather light construction, and some of the boilers were poorly stayed, so that explosions were relatively frequent.

In 1856, two Norris locomotives of improved design, with 16 x 24-inch cylinders and driving wheels 66 inches in diameter, were placed in passenger service on the Pennsylvania. These locomotives had the Stephenson shifting link motion, and were probably the first Norris engines to be so equipped. Valve gear design was a live topic at this time, and the importance of a simple and yet effective device for varying the point of cut-off at the will of the engineman was becoming fully recognized. Mr. Baldwin, in 1853, had patented a variable cut-off which used a separate valve sliding on a partition plate in the steam chest, and worked by an independent eccentric and rock shaft. The upper arm of this rock shaft was curved to form a radius arm, on which a sliding block, forming the termination of the upper valve rod, could be adjusted and held at varying distances from the axis, thus producing a variable travel to the upper valve. The first Pennsylvania locomotive to which this device was applied was the "True American," a passenger locomotive of the 4-4-0 type, with 16 x 22-inch cylinders and driving



Baldwin Passenger Locomotive with Independent Variable Cut-off, as built in 1854
The "Belle," "Flirt" and other eight-wheeled Pennsylvania Locomotives of the period were generally similar to this design.

wheels 66 inches in diameter, which was completed in August, 1853. The most peculiar feature of this valve gear was the device employed for raising and lowering the sliding block on the upper arm of the rock shaft. This device consisted of a quadrant, placed so that its circumference bore nearly against a curved arm projecting downward from the sliding block, and which curved in the reverse direction from the quadrant. Two steel straps, or chains, side by side, were interposed between the quadrant and this curved arm. One of the straps was connected to the lower end of the quadrant and the upper end of the curved arm, and the other, to the upper end of the quadrant and the lower end of the curved arm. When the quadrant was rotated by means of a lever in the cab, the position of the block was shifted and the travel of the cut-off valve altered; the effect being the same as though the quadrant and arm were geared together by teeth. Mr. Baldwin was very sanguine of the success of this device, his idea being that it would hold the block firmly in position on the rock shaft arm, thus preventing slip and consequent wear and lost motion. In practice it was found, however, that the straps would stretch sufficiently to allow them to buckle and break, and the chains would also stretch and frequently break altogether. Eventually, therefore, the quadrant was entirely abandoned and the block raised and lowered by means of a link connection.



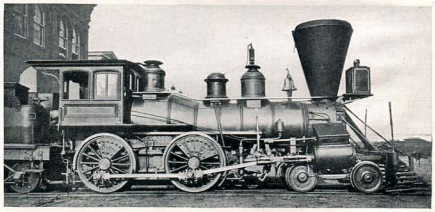
Cylinders	19″ x 22″
Drivers, diam.	48″
Weight on drivers	42,200 lb.
Weight, total engine	61,000 lb.

One of three locomotives, originally equipped with hook motion valve gear and Baldwin variable cut-off. When rebuilt as shown, Stephenson link motion was applied.

This locomotive, originally named "Aughwick," was cut up in 1872.

Ten-wheeled Freight Locomotive, originally built by The Baldwin Locomotive Works in 1855, as rebuilt at Altoona in 1867

The Baldwin variable cut-off was applied to a large number of Pennsylvania locomotives for both passenger and freight service. Among them were two fast passenger locomotives with 72-inch drivers, built late in 1854 and named "Belle" and "Flirt." The general design of these locomotives is shown in an illustration on page 15. This design was typical of the 4-4-0 type as built by Mr. Baldwin at that time, for both passenger and freight service.



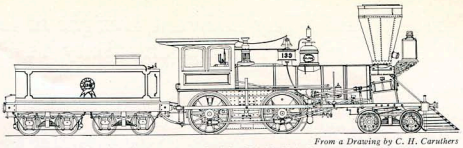
This locomotive was originally built for the Philadelphia and Columbia R. R. and named "Corporal Trim." It was purchased by the Pennsylvania in 1857, and numbered 187. It had 16″ x 22″ cylinders and 54″ driving wheels, and weighed 53,000 lb., with 32,200 lb. on drivers.

American Type Freight Locomotive, built by New Jersey Manufacturing Co., Paterson, N. J., 1856

The variable cut-off was also applied to

Cylinders	17″ x 22″
Drivers, diam.	56″
Weight on drivers	40,850 lb.
Weight, total engine	64,550 lb.

Equipped with hook motion valve gear and independent variable cut-off. Used in smoke burning tests of 1859, and worn out in 1876.



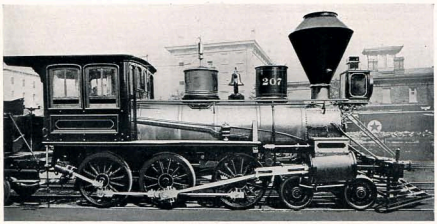
From a Drawing by C. H. Caruthers

American Type Freight Locomotive, built by The Baldwin Locomotive Works, 1857

freight locomotives of the 0-8-0 and 4-6-0 types, built during the years 1854-1856. The general designs of these locomotives are shown on pages 15 and 16.

The link motion, in the meantime, had been steadily finding increasing favor among American railway managers, and had occasionally been used by Mr. Baldwin at the tion which was frequently used by The Baldwin Locomotive Works until 1880. The "Tiger," shown in the frontispiece, was elaborately painted and decorated in accordance with the practice of the day, and represented, at that time, the highest development of the American passenger locomotive.

The introduction of the link motion



Cylinders	19″ x 22″
Drivers, diam.	48″
Weight on drivers, about	48,000 lb.
Weight, total engine, about	64,000 lb.

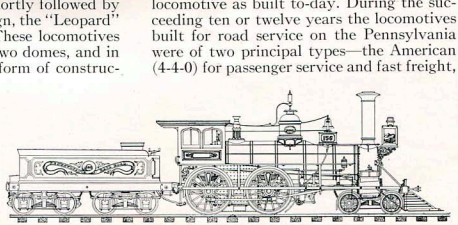
Originally named "Thos. H. Forsythe," and equipped with hook motion and Baldwin variable cut-off. Rebuilt as shown, with link motion and Gill & Co.'s smoke consuming firebox. A similar engine, No. 206, originally the "Wm. Hopkins," of the Allegheny Portage R. R., was used in the smoke consuming tests of 1859.

Ten-wheeled Freight Locomotive, built by The Baldwin Locomotive Works for the Allegheny Portage R. R. in 1854, and purchased by the Pennsylvania in 1857

urgent request of his customers. The first Baldwin locomotive for the Pennsylvania to be so equipped was the "Tiger," of the 4-4-0 type, built for fast passenger service in December, 1856. It was shortly followed by three others of similar design, the "Leopard" "Hornet" and "Wasp." These locomotives had straight boilers with two domes, and in this respect established a form of construc- marked an important step in locomotive development, and the most advanced types of the late fifties and early sixties embodied the principal characteristic features of the locomotive as built to-day. During the succeeding ten or twelve years the locomotives built for road service on the Pennsylvania were of two principal types—the American (4-4-0) for passenger service and fast freight,

Cylinders	16″ x 24″
Drivers, diam.	66″
Weight on drivers	40,675 lb.
Weight, total engine	63,800 lb.

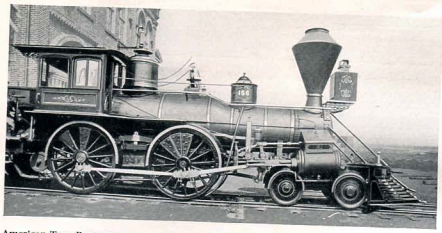
Smith's patent boiler with short tubes and 54″ combustion chamber. Used in smoke burning tests, 1859.



From a Drawing by C. H. Caruthers

American Type Passenger Locomotive, built by The Baldwin Locomotive Works, 1859

Three of the Many Different Designs of Locomotives Used on the Pennsylvania Sixty Years Ago



American Type Passenger Locomotive, originally built for the Philadelphia & Columbia R. R. by the Lancaster Locomotive Works in 1833, and named "Wheatland." Purchased by the Pennsylvania in 1857

Cylinders	16" x 20"
Drivers, diam.	60"
Weight on drivers	33,200 lb.
Weight, total engine	55,200 lb.

In 1860, this locomotive hauled H. R. H. the Prince of Wales from Pittsburgh to Philadelphia.

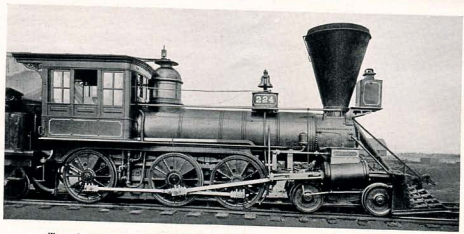
It was rebuilt at Altoona in that year, and again altered, as shown in the illustration, in 1866.

Cylinders	10" x 18"
Drivers, diam.	56"
Total weight in working order, about	40,000 lb.

This locomotive was followed by Nos. 217, built in 1861, and 251, built in 1863, which were of the same general design but with four-wheeled leading trucks. No. 217 was for a time operated with an officials' car rigidly attached to it, but this car was subsequently detached and the locomotive transferred to the Philadelphia and Erie Division.



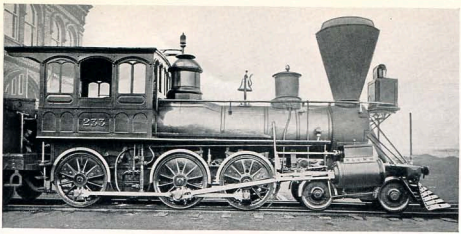
Four-coupled Tank Locomotive for Light Passenger Service, 1861
Baldwin Locomotive No. 1000



Ten-wheeled Freight Locomotive, built by The Baldwin Locomotive Works, 1861

This locomotive was one of three, with cylinders 16½" x 22" and drivers 50" diameter, and weighing, according to the Railroad Company's records, 57,000 lb. with 49,000 lb. on drivers.

Engines 231 and 232, built in 1862, and the first to be fitted with steel fireboxes, were of the same type as No. 224, but were somewhat heavier, with cylinders 18" in diameter.

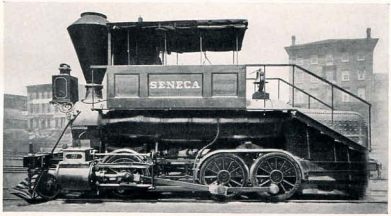


Ten-wheeled Freight Locomotive built by the Rogers Locomotive & Machine Works, Paterson, N. J., 1862
Cylinders, 18" x 22". Drivers, diam., 49". Weight on drivers, 49,000 lb. Weight, total engine, 66,000 lb.

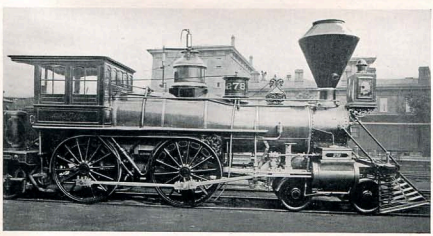
and the ten-wheeled (4-6-0) for heavy freight. It is interesting to note that these two types, although no longer suitable for the heaviest class of work, are still represented in the motive power equipment of the road by many fine locomotives built during the past 20 or 25 years.

Before referring more in detail to the locomotives built subsequent to 1860, some mention should be made of the increasing use of coal as fuel. When the Pennsylvania Railroad was first opened, wood was almost universally used as locomotive fuel, although various experiments had been made with burning coal; and anthracite was being used with greater or less success on a number of roads. In 1853, Enoch Lewis, then Second Assistant Superintendent, made a series of experiments with wood, coke and Pittsburgh and Allegheny coals, in order to determine what kind of fuel would be most economical and satisfactory. The results were generally favorable to the use of coal, especially when mixed with wood.

A far more elaborate series of tests was run in 1859, extending over a period of five months. The object was to determine whether it would be possible to use bituminous coal in passenger service without creating objectionable smoke; all the passenger locomotives on the road at that time being wood burners. Six locomotives were used in these tests, three of them, Nos. 120, 139 and 206, being Baldwin engines. Engine 139, illustrated on page 17, was of the 4-4-0 type designed for freight service, while Nos. 120 and 206 were of the 4-6-0 type, the latter having originally been built for the Allegheny Portage Railroad. The tests proved conclusively that it was possible to use bituminous coal in passenger service, provided the boilers of the locomotives had ample combustion space with means for properly baffling and mixing the gases.

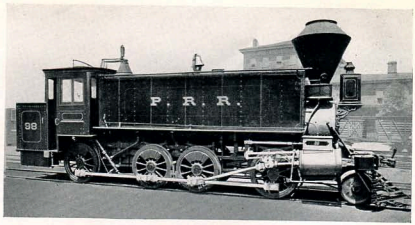


The "Seneca," a Winans Camel Locomotive, as rebuilt at Altoona in 1862



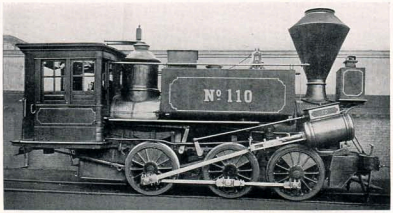
American Type Passenger Locomotive, built by Richard Norris & Son, 1863
Cylinders, 17" x 24". Drivers, diam., 66". Weight on drivers, 44,000 lb. Weight, total engine, 67,200 lb.

This locomotive was originally the "Bedford," built by The Baldwin Locomotive Works in 1854, and a duplicate of the "Iron City," illustrated on page 15. It was probably the first locomotive to have the 2-8-0 wheel arrangement. The first road engine of this type, with separate tender, was the "Consolidation," built in 1866 for the Lehigh Valley R. R. to specifications prepared by Alexander Mitchell, M.M.



Eight-coupled Tank Locomotive for Heavy Pushing Service, rebuilt at Altoona in 1864

Subsequently a series of tests was made with engine 156, a new Baldwin of the 4-4-0 type equipped with what was known as the Smith boiler. This design incorporated a deep firebox with a long combustion chamber, suitable baffles and comparatively short tubes. The test was run to determine the relative heating value of a ton of coal and a cord of wood, the relative cost of the same delivered to the tender, and the increased cost of engine repairs due to the substitution of coal for wood. The report of the test stated that it was wise to "assume as a basis of our calculation that one pound of Pittsburgh coal is equivalent in heating value to 2.31 pounds of hard wood, and that one net ton of coal is equal to 1⅓ cords of hard wood." The relative cost of coal and wood as fuel was determined for the different divisions of the road, and the practicability of burning coal in passenger service was fully demonstrated.



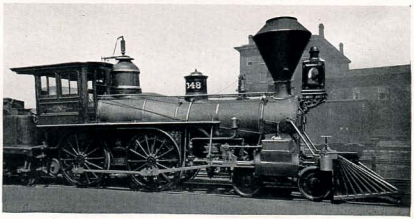
Six-coupled Switching Locomotive, built by The Baldwin Locomotive Works
Cylinders, 15" x 18". Drivers, diam., 44". Weight, total, about 55,000 lb.
Two engines of this class built in 1863.

Engine 156 is shown in an illustration on page 17.

In the efforts to burn bituminous coal successfully, unusual boiler designs, such as the Dimpfel and Phleger, were produced from time to time and put on trial; and experiments were made with a remarkable

Cylinders	17" x 24"
Drivers, diam.	66"
Weight on drivers	44,000 lb.
Weight, total engine	67,200 lb.

This was one of the last locomotives built at the Norris Works, before the plant was moved from Philadelphia to Lancaster. It bore the construction number 1178.

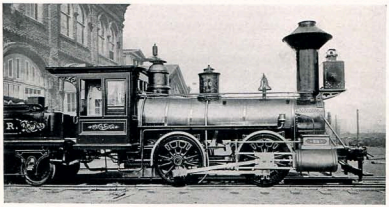


American Type Passenger Locomotive, Built by Richard Norris & Son, 1865

variety of combustion chambers, baffle plates, and other devices of a similar nature. The Pennsylvania Railroad, as has been indicated, did its share in determining the value of these various appliances. Experience fully demonstrated that success in burning coal depended quite as much upon the skill and care of the fireman as upon the special equipment used on the locomotive; and that it was useless to fill a boiler with devices that were expensive to maintain, even though, when in good order, they were effective in reducing smoke. The value of the firebrick arch, especially when using high volatile coal, was fully demonstrated in the Pennsylvania tests; and this device is today generally recognized as an essential part of the equipment of coal burning locomotives.



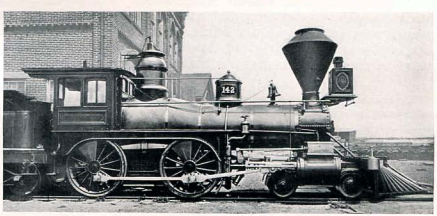
Ten-wheeled Freight Locomotive, built by Richard Norris & Son, 1864
Cylinders, 17″ x 24″. Drivers, diam., 54″. Weight on drivers, 58,000 lb. Weight, total engine, 75,000 lb.



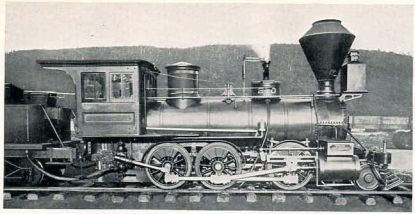
Four-wheeled Switching Locomotive with separate Tender, built by The Baldwin Locomotive Works, 1866
Cylinders, 14″ x 22″. Drivers, diam., 50″. Weight, total engine, about 42,000 lb.
Four engines of this class built 1866-1867.

While these developments in locomotive design and construction were taking place, equipment for the maintenance of the motive power and rolling stock was not being neglected. The town of Altoona, Pa., at the base of the eastern slope of the Alleghenies, had been established with the opening of the railroad, for the express purpose of housing the principal shops of the System. These shops were being steadily developed and enlarged, and represented at this comparatively early date, as they do now, the highest development of the railroad shop. Altoona, as early as 1860, had become a household word among American railroad managers, and the quality of the work turned out at its shops was generally recognized for its excellence.

It is interesting to note, in this connection, that on February 25, 1856, Andrew C. Vauclain, father of Samuel M. Vauclain, now President of The Baldwin Locomotive Works, entered the employ of the Pennsylvania Railroad at Altoona, and served in various executive capacities in the engine houses and shops until his



American Type Passenger Locomotive, built at Altoona Shops, 1867
Cylinders, 16″ x 24″. Weight on drivers (empty), 38,150 lb.
Drivers, diam., 61″. Weight, total engine (empty), 61,100 lb.



Cylinders	18" x 24"
Drivers, diam.	48"
Weight on drivers, about	56,000 lb.
Weight, total engine, about	66,000 lb.

This locomotive was originally built in 1853 or 1854, by Smith & Perkins, and was rebuilt at Altoona with new cylinders, frames and running gear. The two safety valves were mounted above the sand-box on separate branch-pipes, or "buckhorns," with the whistle between them. This locomotive was completely destroyed by fire in the Pittsburgh riots of 1877.

Mogul Type Freight Locomotive, as Rebuilt at Altoona Shops in 1865

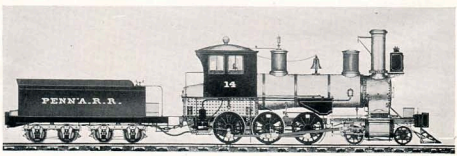
death on July 18, 1887. Mr. Samuel M. Vauclain served as an apprentice, machinist and foreman in the same shops until 1883, when he entered the service of The Baldwin Locomotive Works.

Baldwin locomotive number 1,000, illustrated on page 18, was completed on February 28, 1861. It was built for the Pennsylvania and bore the road number 212 and the name "M. W. Baldwin," and was a light passenger locomotive of the 2-4-0 type, with 10x18-inch cylinders and driving wheels 56 inches in diameter. Two other locomotives of similar design, but having four-wheeled leading trucks, were subsequently built.

On June 15, 1862, John P. Laird was appointed Master of Machinery, which position he held until May, 1866. Mr. Laird was an engineer of great ability, and he exerted a marked influence on the design and development of Pennsylvania motive power. Conspicuous among his devices were a balloon-shaped stack, which proved a great success as a spark arrester on coal burning locomotives, and a design of two-bar guide which has survived to the present day and is frequently used on heavy power. Mr. Laird was also active in rebuilding and modernizing many of the older locomotives, and in endeavoring, where possible, to standardize the many types and designs found on the road, the number of which had been materially increased when the Pennsylvania acquired the equipment of the State Transportation System in 1857.

The typical passenger locomotive of this period was of the "American" (4-4-0) type, with spread truck wheels, horizontal cylinders, plain slide valves and Stephenson link motion, and a wagon-top boiler having a deep firebox between the driving axles. The freight locomotive of the ten-wheeled (4-6-0) type was in many respects similar, except that a third pair of wheels was interposed between the truck and the leading drivers of the passenger locomotive. The largest passenger locomotives had 17 x 24-inch cylinders and driving wheels from 60 to 66 inches in diameter, while the heavy ten-wheelers, for freight service, had 18 x 22-inch cylinders and 54-inch driving wheels. Injectors were being substituted for pumps to a limited extent, and the need of a brake more efficient than the ordinary hand-brake, especially in passenger service, was becoming realized. The Loughridge Chain Brake was used to a considerable extent on the Pennsylvania, and was one of the most effec-

This locomotive represented a design introduced on the Philadelphia & Reading R. R. by James Millholland, and was purchased by the Pennsylvania for experimental purposes. It had 19 x 24-inch cylinders and 48-inch drivers, and weighed 70,000 pounds with 50,000 on drivers. These locomotives were popularly known as "Gunboats."



From a Drawing by C. H. Caruthers

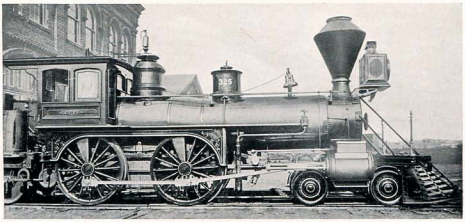
Ten-wheeled Freight Locomotive, built by the Norris Works at Lancaster, in 1866

Typical Heavy Passenger and Freight Locomotives Built for the Pennsylvania During the Sixties

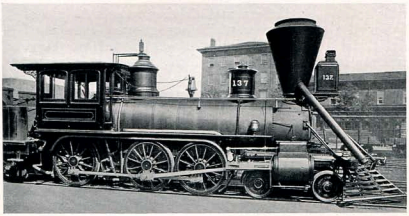
Cylinders	17″ x 24″
Drivers, diam.	66″
Weight on drivers, about	44,000 lb.
Weight, total engine, about	68,500 lb.

The friction wheel for operating the Loughridge chain brake is plainly seen back of the rear drivers.

Twenty-one locomotives of this general design were placed in service during 1863-1865.



American Type Passenger Locomotive, built by The Baldwin Locomotive Works, 1864



Ten-wheeled Freight Locomotive, built by The Baldwin Locomotive Works, 1864

Cylinders	18″ x 22″
Drivers, diam.	54″
Weight on drivers, about	50,000 lb.
Weight, total engine, about	70,000 lb.

Steel firebox, with combustion chamber 13½″ long.

Boiler fed by two injectors.

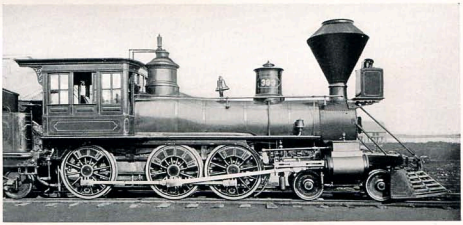
There were 20 locomotives of this class.

Cylinders	18″ x 22″
Drivers, diam.	55″
Weight on drivers, about	50,000 lb.
Weight, total engine, about	70,000 lb.

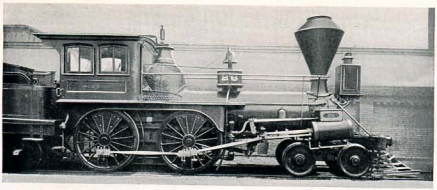
Steel firebox, with combustion chamber 24¾″ long.

Boiler fed by one injector and one pump.

There were 12 locomotives of this class.



Ten-wheeled Freight Locomotive, built by The Baldwin Locomotive Works, 1866



This locomotive was originally built by The Baldwin Locomotive Works in 1852, and was similar to the "Wyoming," illustrated on page 13. It was named "Butler." As here shown it was rebuilt to burn coal, and equipped with a Laird stack and link motion.

American Type Passenger Locomotive, as Rebuilt at Altoona Shops, 1866

tive devices of its class. It was arranged with a friction wheel, which could be pulled up against the right-hand rear driving wheel of the locomotive. As the friction wheel rotated a chain was wound up on its shaft, and the pull of this chain was transmitted to the brake-shoes throughout the train.

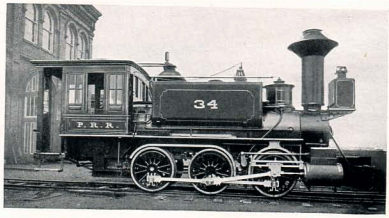
This period witnessed an increasing use of steel in locomotive construction, and the Pennsylvania was active in trying out this material. Steel fireboxes were first built by The Baldwin Locomotive Works for the Pennsylvania in 1861. English steel of a high temper was used, and the plates cracked in fitting them to the boilers; and it was necessary to take them out and substitute copper. American homogeneous cast steel, however, was successfully used for the fireboxes of engines 231 and 232, built in January, 1862. These were ten-wheeled freight locomotives with combustion chambers 36 inches deep, and the inside fireboxes and combustion chambers with the exception of the tube sheets (which were copper), were built of steel plates throughout. Steel boiler shells were first built by The Baldwin Locomotive Works for the Pennsylvania in 1868, and steel tubes were first used by the Works in three ten-wheelers built for this road in the same year.

The first application of the four-wheeled swing-bolster truck made by The Baldwin Locomotive Works occurred in 1867, when this device was applied to a group of American (4-4-0) type locomotives built for the Pennsylvania. Among these were four fast passenger locomotives, with 17 x 24-inch cylinders and driving wheels 66 inches in diameter, which bore the road numbers 419-422. Engine 422 was placed on the road September 9, 1867, and was in constant service until May 14, 1871, without being off its wheels for repairs, during which time it made 153,280 miles. This locomotive is shown in an accompanying illustration.

The Pennsylvania locomotives built during the late sixties were notable because of the simplicity of their outline and the absence of superfluous paint and brass work. The lavish use of polished brass and vivid colors was one of the most conspicuous features of the typical American locomotive built during this period; and the Pennsylvania, in dispensing with much of this deco-

Cylinders	15" x 18"
Drivers, diam.	44"
Weight, total engine	65,400 lb.

There were 14 locomotives of this class. The majority were retired between 1885 and 1889, while two remained in service until 1892.

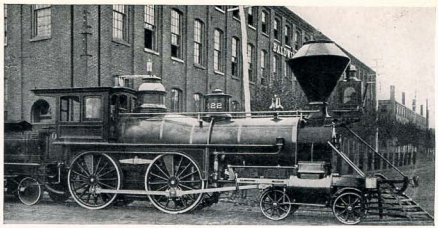


Six-wheeled Switching Locomotive, built by The Baldwin Locomotive Works, 1867

Cylinders	17" x 24"
Drivers, diam.	66"
Weight on drivers, about	45,000 lb.
Weight, total engine, about	70,000 lb.

Equipped with swing bolster leading truck.

This locomotive, in service on the Middle Division, made 153,280 miles from Sept. 9, 1867, to May 14, 1871, before being shopped for general repairs.



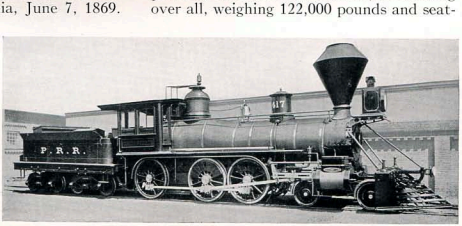
American Type Locomotive for Fast Passenger Service, built by The Baldwin Locomotive Works, 1867

ration, set a precedent which was eventually followed by all the railroads throughout the country.

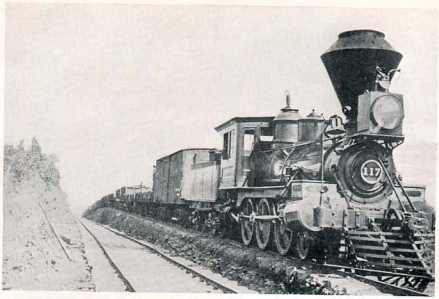
During this period, the mileage of the System was greatly increased because of the acquisition, through lease or purchase, of several important connecting lines. In 1860, control was acquired of the Northern Central Railway, running from Baltimore northward through Harrisburg to Sunbury, Pa., where it made connection with the Philadelphia and Erie. The latter road was leased on January 1, 1862, for 999 years. The Baltimore and Potomac, connecting the cities of Baltimore and Washington, was also acquired, and completed in 1873. This gave the Pennsylvania a through line from Washington to the Great Lakes. During the years 1867-1871, a large number of lines west of Pittsburgh were acquired through purchase or lease. Most important of these was the Pittsburgh, Fort Wayne and Chicago Railway, which had been opened for business on December 25, 1858, and was leased by the Pennsylvania, June 7, 1869. The acquisition of all these lines necessarily greatly increased the responsibilities of the Pennsylvania's Motive Power Department.

In 1867, the equipment of the Pennsylvania Railroad included 415 locomotives, 291 passenger train cars, and 8482 freight train cars. The Main Line between Philadelphia and Pittsburgh was 355 miles long, with double track, and represented the highest type of railroad construction at that time. Steel rails, first introduced on the road in 1864, were rapidly replacing the iron rails formerly used, with most satisfactory results. Four through trains were operated each way per day, the fastest making the trip in 13 hours 40 minutes east-bound and in 14 hours west-bound, representing an average speed, including stops, of approximately 25 miles per hour. The "Broadway Limited" now makes the run in 7 hours 50 minutes. On the New York Division, the 90 miles between New York and Philadelphia are now covered by numerous trains in two hours, whereas in 1867 the fastest train on the New Jersey Railways ran from Jersey City to West Philadelphia, approximately 88 miles, in 3 hours 35 minutes.

The standard Pennsylvania Railroad passenger coach of 1867 measured 53 feet long over bumpers, seated 54 passengers, and weighed, empty, 42,500 pounds. As compared to the modern steel coach, 80 feet long over all, weighing 122,000 pounds and seat-



Ten-wheeled Freight Locomotive, built by the New Jersey Locomotive and Machine Company, 1867
Cylinders, 18" x 22". Drivers, diam., 54". Weight, total engine, 73,000 lb.



A Pennsylvania Railroad Freight Train of the Civil War Period

The Locomotive was built by The Baldwin Locomotive Works in 1855, and was originally named "Black Oak." It was a duplicate of the "Aughwick," illustrated on page 16. It was subsequently rebuilt as shown, at Altoona, and was finally scrapped in 1878.

ing 88 passengers, its capacity was large in proportion to total weight; but the modern coach is far stronger and more completely equipped, and when the increased comfort and convenience of the passengers are considered, the additional weight per capita is fully justified.

The amount of traffic handled by the Pennsylvania in 1867 is indicated by the fact that 3,347,486 passengers were carried during the year, this being equivalent to 126,443,234 passengers carried one mile. A total of 4,000,538 tons of freight were hauled, the equivalent ton-mileage being 565,657,813.

John P. Laird, the value of whose work as Master of Machinery has been mentioned, resigned in May, 1866, and was succeeded by R. E. Ricker. He in turn resigned in 1867, and was succeeded by Alexander J. Cassatt on November 16th of that year. The need of standardizing locomotive details in the interest of efficiency and operating economy, had by this time become fully realized; and in 1868 complete drawings of a series of standard locomotives were prepared at Altoona, and with very few exceptions the motive power thereafter built, whether constructed in the Company's shops or by outside builders, conformed to the Pennsylvania's standard designs. A discussion of these new designs will be presented in the next chapter.



Photo furnished by C. B. Chaney

The West-bound Fast Mail in 1869

The Locomotive, No. 85, was a Norris, built in 1854 and rebuilt at Altoona in 1865. The picture was taken on the Middle Division near McVeytown, Pa.



Photo furnished by H. G. Boutell

The Iron Truss Bridge which carried the Tracks of the Middle Division across the Susquehanna at Rockville, near Harrisburg, from 1877 to 1902. This picture was taken about 1892. The Pennsylvania Limited, hauled by Class D10a Locomotive No. 568, is crossing the Bridge.

CHAPTER II

The Introduction of Standard Locomotive Designs, and Subsequent Motive Power Development up to the Year 1899.



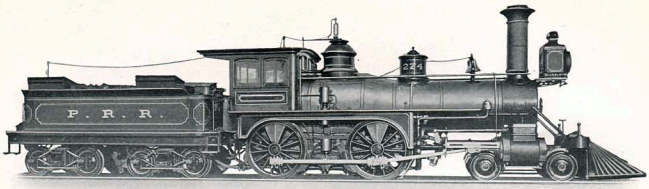
THE first group of standard locomotives, placed in service during the years 1868 to 1872, comprised eight classes for passenger, freight and switching service. In weight and capacity, these locomotives were closely similar to those that had immediately preceded them. The effort made was, not so much to increase the power per locomotive unit, as to design the locomotives for the particular conditions to be met, and to use interchangeable details as far as practicable in order to reduce maintenance costs. In these respects the work accomplished was successful, as the locomotives rendered excellent service and interchangeable details were incorporated in their construction to an unusual extent.

These locomotives were all designed to use bituminous coal as fuel, and the different classes were designated by the first eight letters of the alphabet. This system of class designation remained in effect until 1895, when it was revised by assigning one letter to each wheel arrangement, and following this with a figure, or a figure and letter combined, to indicate the different classes having that wheel arrangement. The old locomotives were re-classified on this basis. In the following discussion the old classification will be used, but the revised classification will be given in parenthesis in order that the locomotives may be more easily identified.

The characteristic features of the first eight classes of standard locomotives were as follows:

Class A (D1)—A locomotive of the American (4-4-0) type, for express passenger service. Cylinders, 17″ x 24″. Driving wheels, diameter, 68″.

Class B (D2)—A locomotive of the American type for mountain passenger helper service. Cylinders, 18″ x 24″. Driving wheels, diameter, 62″. Boiler of similar de-



American Type Locomotive, Class C (D3), built at Altoona, 1875

Cylinders	17″ x 24″	Tubes, diam.	2¼″	Wheel base, driving	8′ 6″	Weight, total engine	79,100 lb.
Drivers, diam.	62″	" number	135	" " total engine	23′ 5¾″	" " and	
Boiler, inside diam.	48⅜″	" length	10′ 7⅛″	" " " and		tender	139,000 lb.
Steam pressure	125 lb.	Grate area	17.6 sq. ft.	tender	44′ 6¼″	Tank capacity	2,400 U. S. gal.
Firebox	72⅝″ x 35″	Heating surface	1,083 sq. ft.	Weight on drivers	50,950 lb.	Fuel "	8,000 lb.
						Tractive force	11,890 lb.

sign to that used on Class A, but with a firebox of somewhat larger dimensions.

Class C (D3)—A locomotive of the American type for general passenger or fast freight service. Cylinders, 17″ x 24″. Driving wheels, diameter, 62″. Boiler of the same dimensions as that used on Class B.

Class D (G1)—A locomotive of the ten-wheeled (4-6-0) type for general freight service. Cylinders, 18″ x 22″. Driving wheels, diameter, 56″.

Class E (G2)—A locomotive of the ten-wheeled type for freight service on mountain grades. Cylinders, 18″ x 22″. Driving wheels, diameter, 50″. Boiler of similar design to that used on Class D, but with a firebox of somewhat larger dimensions.

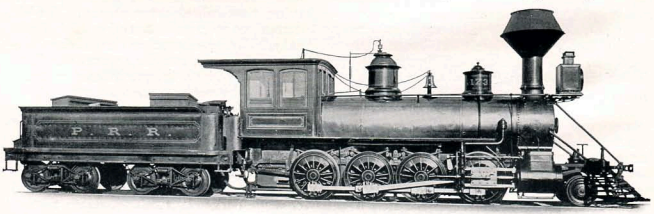
Class F (B1)—A six-coupled tank locomotive for switching service. Cylinders, 15″ x 18″. Driving wheels, diameter, 44″.

Class G (D5)—A locomotive of the American type for light passenger service. Cylinders, 15″ x 22″. Driving wheels, diameter, 56″.

Class H (B2)—A six-coupled locomotive, with separate tender, for switching service. Cylinders, 15″ x 22″. Driving wheels, diameter, 44″.

The records indicate that Classes C (D3), D (G1), and E (G2) were built far more extensively than any of the others. Classes A (D1) and B (D2), especially, were built in limited numbers only.

To these first classes there were added in 1873, an American type passenger locomotive for burning anthracite, generally similar



Consolidation Type Locomotive, Class I (H1), built at Altoona, 1875

Cylinders	20″ x 24″	Tubes, diam.	2½″	Wheel base, driving	13′ 8″	Weight, total engine	91,640 lb.
Drivers, diam.	50″	" number	138	" " total engine	21′ 6″	" " and	
Boiler, inside diam.	53⅝″	" length	12′ 9⅛″	" " " and		tender	152,000 lb.
Steam pressure	125 lb.	Grate area	23 sq. ft.	tender	48′ 4½″	Tank capacity	2,400 U. S. gal.
Firebox	96″ x 34½″	Heating surface	1,259 sq. ft.	Weight on drivers	79,400 lb.	Fuel "	8,000 lb.
						Tractive force	20,400 lb.

Cylinders	17″ x 24″
Drivers, diam.	68″
Steam pressure	125 lb.
Grate area	16.2 sq. ft.
Heating surface	1,049 sq. ft.
Weight on drivers	47,850 lb.
Weight, total engine	77,700 lb.
Tractive force	10,840 lb.



American Type Locomotive, Class A (D1), built at Altoona, 1872

to Class C and designated as C anthracite (D4); and in 1875 a locomotive of the Consolidation (2-8-0) type, for heavy freight service, and designated as Class I (H1). The C anthracite locomotives were specially designed for service on the lines in New Jersey, and in 1875 a number were built with driving wheels 68 inches in diameter, and designated as Class CA anthracite (D4a). These locomotives were placed in fast passenger service on the New York

and 86 Baldwin 4-6-0 type locomotives were classed as "D" engines, although these differed somewhat from the new standards. The remaining 413 locomotives were unclassified.

An unusually complete and interesting discussion of these standard locomotives is given in a work on "The Pennsylvania Railroad" by James Dredge, published in London in 1879. In this discussion special stress is laid on the extent to which inter-



Cylinders	17″ x 24″
Drivers, diam.	62″
Steam pressure	125 lb.
Grate area	28.7 sq. ft.
Heating surface	1,158 sq. ft.
Weight on drivers	56,200 lb.
Weight, total engine	81,800 lb.
Tractive force	11,890 lb.

American Type Locomotive, Class C anthracite (D4), built at Altoona, 1874

Division, and handled the traffic most successfully until 1881, when they were replaced with heavier power.

Records show that in 1873, out of a total of 873 locomotives in service on the System, 373, or 42.7 per cent, were classed as "standard." Of the remainder, one Baldwin 4-4-0 type locomotive was classed as a "C" engine

changeable details were used in the various designs. Thus for the ten different classes of locomotives, the maximum variation was only four different patterns of brass or iron castings for any given part. The following table shows the extent to which this interchangeability of castings was carried out:—

Cylinders	15″ x 22″
Drivers, diam.	56″
Steam pressure	125 lb.
Grate area	13.3 sq. ft.
Heating surface	721 sq. ft.
Weight on drivers	40,700 lb.
Weight, total engine	65,200 lb.
Tractive force	9,390 lb.



American Type Locomotive, Class G (D5), built at Altoona, 1873

Number of Castings	Common to Classes	Number of Castings	Common to Classes
26	A to I	1	G, F, H
15	A to E	15	D, E
14	A to C	7	B, D, E
16	A, C	1	E, G
6	A, B, D, E, G	2	D, E, F, H, I
6	A, B, C, D, E, I	3	D, E, G
6	A, B, C, G	1	E, H
6	A to H	2	D, E, G, H, I
5	A, B, C, D, E, G	1	D, E, I
3	A, B, C, D, E, G, I	1	I, C
3	D, G	24	F, G, H
1	B, C, H	4	G, H
1	A, D, F, G	5	F, H
1	C, E	1	F, G



Photo furnished by C. B. Chaney

A Class I (H1) Locomotive, built at Altoona in 1879, as equipped for Yard Service
The roomy cab is clearly shown in this picture.

The number of forgings used in each locomotive averaged 245, and with very few exceptions these were identical in Classes A, B, C and D. There was a greater variety in the remainder, especially in the Consolidation engine, Class I.

The majority of these early standard types are represented in the accompanying illustrations. Classes A to E all had wagon-top boilers with domes over the fireboxes, the latter being placed between the main and rear driving axles, except in the case of Class C anthracite, which had a long firebox extending over the rear driving axle. The firebox crown sheets were flat, and were stayed by crown bars. Brick arches were used on the bituminous coal burning passenger locomotives, and were supported on water tubes which extended upward from the front tube sheet to the crown sheet. Each boiler was fed by one pump and one injector. The conventional form of Stephenson link motion was employed, and on the ten-wheeled freight engines the rockers were placed in front of the leading drivers, and the eccentric rods were bent to clear the first driving axle. The crossheads were of cast iron, working in four-bar guides, and the connecting and coupling rods were fitted with strap stubs, with the exception of the front connecting rod stub, which was of the solid end type with an adjusting wedge for the brass.

All these early standard locomotives had short smokeboxes, and several different designs of stacks were used. The bituminous coal burning passenger locomotives were fitted with the "Smith" design, which was a straight stack combined with a basket-shaped spark arrester of perforated plate, extending from the top of the exhaust nozzle up inside the stack. The switching locomotives, and the majority of the freight locomotives, had diamond stacks, although the Laird and Smith designs were used on some of the earlier ten-wheelers. In all cases, adjustable petticoat pipes were placed above the exhaust nozzles. Some of the first anthracite burning passenger locomotives were fitted with diamond stacks, but the straight pattern was soon substituted. These straight stacks had extremely neat cast iron bases and tops, which, either in their original form or in a simplified design introduced later, were used on the road for many years. This design of stack is now, however, obsolete.

The boiler of Class I (H1) was known as the "Altoona type," and differed in many respects from those of the other classes. The barrel had a straight top with a dome in front of the firebox, and the roof sheet, at the front end, was 9½ inches below the top of the barrel. Both the crown and roof sheets sloped toward the rear at a rather steep angle, with a narrowing space between them which was almost entirely filled with water, so that there was very little steam liberating surface above the firebox. The crown and roof sheets were flat, and were stayed throughout by screw stays. The grate was composed of water tubes and two longitudinal solid bars, which could be

dropped when cleaning the fire. A generally similar arrangement was used on the other classes of standard locomotives.

Disregarding certain Baldwin locomotives of the American type built in 1867, which were subsequently assigned to Classes A (D1) and C (D3) because of their similarity to those classes, the first standard locomotive to be built by The Baldwin Locomotive Works was a Class D (G1) freight engine, completed in July, 1868. It bore the road number 154 and the builder's construction number 1744, and was the first of 255 Baldwin locomotives of this class, which were built on several orders during the years 1868-1873, and placed in service on the Pennsylvania and its controlled lines.



Cylinders	18" x 22"
Drivers, diam.	56"
Steam pressure	125 lb.
Grate area	14.5 sq. ft.
Heating surface	1,087 sq. ft.
Weight on drivers	58,400 lb.
Weight, total engine	83,500 lb.
Tractive force	13,520 lb.

Ten-wheeled Locomotive, Class D (G1), built at Altoona, 1871

The first of the Class I (H1) locomotives were built at the Altoona Shops in 1875, but in the latter part of the same year an order for 14 was placed with The Baldwin Locomotive Works. One of these, bearing the road number 369, together with a Class C (D3) passenger locomotive, road number 44, were included in the Baldwin exhibit at the Centennial International Exhibition, held in Philadelphia in 1876. The Baldwin Exhibition Catalogue contained interesting particulars, presented on the following page, regarding the work that these locomotives, and also Classes D (G1) and E (G2), were doing on the Pennsylvania Railroad.

The Class C locomotives were used in passenger service more extensively than any others, and the long non-stop runs noted in the before mentioned table were made possible by the use of track tanks, from which water could be picked up by scoops on the tenders. Experiments with this system of taking water were first made in 1870, and three years later the tanks were placed in regular service. It was through their use that it was possible to run the famous Jarrett and Palmer special theatrical train from Jersey City to Pittsburgh, on June 1, 1876, without a stop. The distance covered was 438.5 miles, and the train, which was hauled by Class C (D3) engine 573, made the run in 10 hours 5 minutes, at an average speed of 43.5 miles per hour.

As indicating the extent to which the standard locomotives were in use at this time, it is interesting to note that, in 1876, 56.6 per cent of the motive power on the entire System consisted of such locomotives, while on the Pennsylvania Railroad Division the percentage was 68.2.

In connection with these early standard locomotives, reference should be made to the use of the Westinghouse air brake. The first tests with this brake, which had been patented by the late George Westinghouse,



Cylinders	18" x 22"
Drivers, diam.	50"
Steam pressure	125 lb.
Grate area	16.3 sq. ft.
Heating surface	1,096 sq. ft.
Weight on drivers	62,100 lb.
Weight, total engine	84,800 lb.
Tractive force	15,150 lb.

Ten-wheeled Locomotive, Class E (G2), built at Altoona, 1872

Statement showing Rate of Speed, Number of Stops Made, Kind of Cars, and Average Weight of Five of the Express Trains on Pennsylvania Railroad Division

SCHEDULE	BETWEEN	Distance	Rate of Speed per hour	Number of Stops	Kind of Cars in Train							Average Weight of Train in Net Tons, exclusive of Engine	
					Passenger	Pullman	Combined	Baggage	Express	Mail	Postal	Postal Tender	Empty	Max. Loaded
Day Express	Pittsburgh & Altoona	117	32 6/10	none	1	2	1						101	112
Day Express	Altoona & Harrisburg	132	37 7/10	1	1	2	1						101	112
Day Express	Harrisburg & Philada.	105	34 1/10	none	1	2	1						101	112
Limited Mail	Philada. & Harrisburg	105	33 2/10	1	1	2	1			1	1		140	171
Limited Mail	Harrisburg & Altoona	132	37 7/10	none	1	2	1			1	1		140	171
Limited Mail	Altoona & Pittsburgh	117	33 4/10	none	1	2	1			1	1		140	171
Fast Line East	Pittsburgh & Altoona	117	31 3/10	none	2	4		1		1	1		205	253
Fast Line East	Altoona & Harrisburg	132	35 3/10	none	2	5		2	1	1	1		204	336
Fast Line East	Harrisburg & Philada.	105	29 3/10	none	2	5		2	1	1	1		264	336
Pacific Express West	Philada. & Harrisburg	105	25 2/10	2	2	4		1	5				241	319
Pacific Express West	Harrisburg & Altoona	132	28 8/10	11	3	4		1	4				246	318
Pacific Express West	Altoona & Pittsburgh	117	25 2/10	14	3	3		1	4				218	288
Cincinnati Express West	Philada. & Harrisburg	105	29 3/10	1	2	5		1	1	1			224	276
Cincinnati Express West	Harrisburg & Altoona	132	34 3/10	none	2	5		1	1	1			224	276
Cincinnati Express West	Altoona & Pittsburgh	117	31 3/10	none	2	5		1	1	1			224	276

Statement showing Run of Engines, Character of and Maximum Grades, Average Train Hauled, and Pounds of Coal Consumed per Engine Mile by Class C Engines on Pennsylvania Railroad Division

RUN OF ENGINES	BETWEEN	Character of Grades	Maximum Grade		Average Train	Pounds of Coal per Engine Mile	
			East	West		Average	Minimum
Day Express & Limited Mail	Philada. & Harrisburg	Undulating	40	49	5.0	34.0	30.0
Cin. Express & Fast Line	Philada. & Harrisburg	Undulating	40	49	8.0	40.0	35.0
Atlantic Express & Fast Line	Philada. & Harrisburg	Undulating	40	49	9.5	36.0	28.0
Day and Cin. Express	Harrisburg & Altoona	Ascending West		21	7.0	37.0	33.0
Fast Line, East and West	Harrisburg & Altoona	Ascending West		21	8.5	35.0	31.0
Cin. Express and Fast Line	Altoona & Pittsburgh	Undulating	52	95	7.5	46.0	41.0
Day Express & Limited Mail	Altoona & Pittsburgh	Undulating	52	95	5.0	42.0	37.5

On the 95 ft. grade between Altoona and Pittsburgh the C locomotives always had one helper, and sometimes two, on the above trains. On the 52 ft. grade coming East, fast Express Trains had one helper if seven or more cars. Atlantic Express made schedule time (25 miles per hour) with eight cars.

Number of Loaded Cars and Total Weight of Train Hauled by Standard Class I, E, and D Locomotives over given grades on Pennsylvania Railroad, Philadelphia and Erie and Susquehanna Divisions, and Average Pounds of Coal per Car per Mile

BETWEEN	Class of Engines	EAST 15 Miles per hour		Maximum Grade	WEST 15 Miles per hour		Maximum Grade	Average Pounds of Coal per Car per Mile	REMARKS
		Number of Loaded Cars	Total Weight of Train, exclusive of Engines. Net Tons		Number of Loaded Cars	Total Weight of Train, exclusive of Engines. Net Tons			
Philada. & Columbia	I.	35	735	40	30	630	49	4.2	I Engines haul 40 cars East 10 miles per hour.
Philada. & Columbia	E.	24	504	40	20	420	49	4.9	
Philada. & Columbia	D.	22	462	40	18	378	49	5.2	
Columbia & Harrisburg	I.	70	1470		65	1365	17	2.7	Short grade of 30 ft. East and 37 ft. West.
Columbia & Harrisburg	E.	55	1155		51	1071	17	3.2	
Columbia & Harrisburg	D.	48	1008		45	945	17	3.4	
Erie & Langdon's	I.	24	504	71					
Erie & Langdon's	D.	15	315	71					
Renovo & Jersey Shore	I.	80	1680						Grade of 26 ft. for 4 miles, remainder of run about level. I Engines very often haul this train at rate of 25 miles per hr.
Renovo & Jersey Shore	D.	45	945						
Susquehanna Division	I.	85	1785						
Susquehanna Division	D.	55	1155						

The records show that on at least one occasion, a Class I locomotive on the Susquehanna Division hauled as many as 110 loaded cars into Harrisburg. These locomotives developed a maximum tractive force of 20,400 pounds, and were, at that time, among the most powerful freight haulers in service in this country.

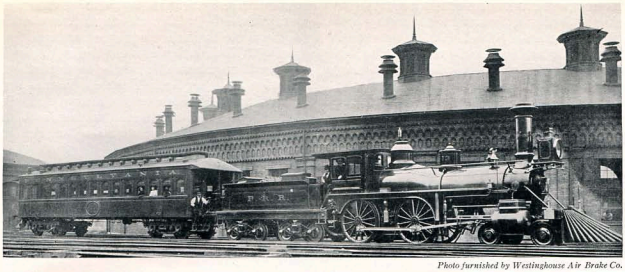


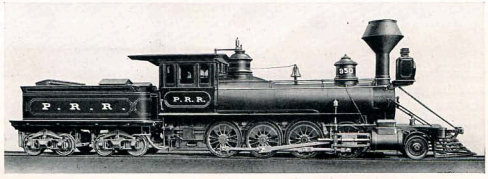
Photo furnished by Westinghouse Air Brake Co.

One of the first Trains to be equipped with Westinghouse Air Brakes. The locomotive, a Class A (D1), built at Altoona in 1869, was the third Pennsylvania Engine fitted with Air Brake Equipment

were made on the Pennsylvania September 18, 1869. It was definitely adopted by the road in 1870, and the first new cars to be equipped with it were built in May of that year. These early brakes used straight air, the automatic feature having not yet been developed. The first automatic brakes used by the Pennsylvania were supplied by the Westinghouse Air Brake Company in October, 1875. This type of brake was adopted by the road as standard in 1878, and the first new cars to be equipped with it were a number of postal cars built at Altoona in May of that year.

Although the Class I (H1) locomotives were the first road engines of the Consolidation type to be constructed at Altoona, they were not the first of that type to be placed in service on the Pennsylvania System. In 1870, three Baldwin Consolidations, with 20 x 24-inch cylinders and driving wheels 49⅛ inches in diameter, were built for the Philadelphia and Erie Division; and in 1873, nine additional locomotives of generally similar dimensions were ordered for the Northern Central Railway. As built, these locomotives were lettered in accordance with Pennsylvania standards, and bore the road numbers 950 to 953 inclusive, and 1146 to 1150 inclusive. They had wagon-top boilers 50 inches in diameter at the front end, with shells of iron and inside fireboxes of steel, and were equipped with water tube grates and variable exhaust nozzles. The accompanying illustration of locomotive number 950 represents the design.

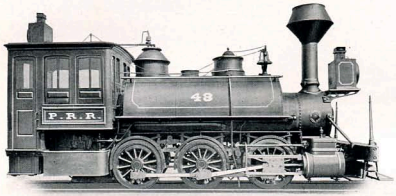
The earlier classes of standard locomotives were designed during the administration of A. J. Cassatt, who served as Superintendent of Motive Power and Machinery from November 16, 1867, to April 1, 1870. The designs were prepared by John B. Collin, who held the position of Mechanical Engineer from 1866 to 1886. Mr. Cassatt was followed successively by Isaac Dripps, George Clinton Gardner, and Frank Thomson, each serving short terms. Succeeding them was Theodore N. Ely, who was appointed Superintendent of Motive Power of the Pennsylvania Railroad and the United Railroads of New Jersey on July 1, 1874. In 1882, Mr. Ely's jurisdiction was extended to cover all the lines East of Pittsburgh; a position



Consolidation Type Locomotive, built by The Baldwin Locomotive Works, 1873

Cylinders	20″ x 24″	Grate area	25.8 sq. ft.	Weight on drivers, about	87,000 lb.
Drivers, diam.	49″	Heating surface	1,361 sq. ft.	Weight, total engine, about	96,000 lb.

which he held until 1893, his headquarters being at Altoona. From the latter date until his retirement on July 1, 1911, he served as Chief of Motive Power of the lines East and West, with office at Philadelphia. During the period of Mr. Ely's administration at Altoona, the requirements of a constantly increasing passenger and freight traffic were met by larger locomotives of the American



Cylinders	15″ x 18″
Drivers, diam.	44″
Steam pressure	125 lb.
Grate area	10.7 sq. ft.
Heating surface	713 sq. ft.
Weight, total engine	71,300 lb.
Tractive force	9,780 lb.

Six-coupled Switching Locomotive, Class F (B1), built at Altoona, 1869

and Consolidation types, which were built in preference to new types. These locomotives, however, not only showed increased size and power, but also an improved efficiency, accompanied by a refinement of detail and symmetry of outline, which exerted a marked influence upon locomotive design throughout the country. The old rule of thumb methods

ants of the highest ability, who worked with their chief in raising the department to the high plane which it has since occupied.

In 1880, in order to meet the increasingly difficult requirements of the fast passenger service on the New York Division, work was started at Altoona on a new design of American type locomotive, known as Class K (D6), which represented a marked increase in capacity over any passenger locomotives previously built for the Pennsylvania. The first of these locomotives, bearing the road number 10, was placed in service March 25, 1881, and was followed by seventeen others, the last of which were built in 1883. These locomotives had 18 x 24-inch cylinders and driving wheels of the

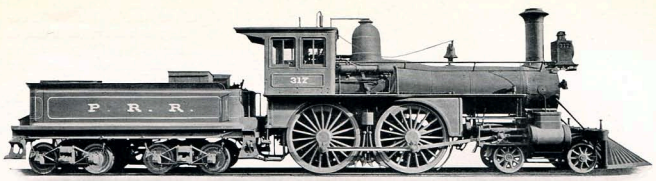
Cylinders	15″ x 22″
Drivers, diam.	44″
Steam pressure	125 lb.
Grate area	13.2 sq. ft.
Heating surface	856 sq. ft.
Weight, total engine	64,700 lb.
Tractive force	11,950 lb.



Six-coupled Switching Locomotive, Class H (B2), built at Altoona, 1873

formerly so much in vogue, were discarded; and designs and specifications were prepared, and tests were conducted, on a strictly scientific basis. As a result, the motive power department of the Pennsylvania no longer existed merely as a shop adjunct, but assumed an importance of the first rank in the organization of the railroad. Mr. Ely, throughout his term of service, selected assistant

large diameter (for that period) of 78 inches, and carried a steam pressure of 140 pounds, as against 125 pounds carried by the previous standard locomotives. They were equipped for burning anthracite fuel, and had wagon-top boilers with long fireboxes placed entirely above the engine frames. The grate was composed of water tubes and drop-bars, and had an area of 34.7 square



American Type Locomotive, Class K (D6), built at Altoona, 1881

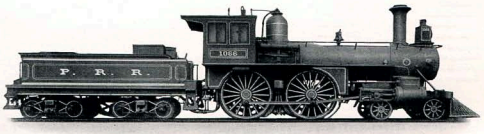
Cylinders	18″ x 24″	Tubes, diam.	1⅞″	Wheel base, driving	7′ 9″	Weight, total engine	96,700 lb.
Drivers, diam.	78″	" number	201	" " total engine	22′ 8″	" " " and tender	157,000 lb.
Boiler, inside diam.	49¼″	" length	10′ 10½″	" " " " and tender	47′ 10″	Tank capacity	2,400 U. S. gal.
Steam pressure	140 lb.	Grate area	34.7 sq. ft.	Weight on drivers	64,900 lb.	Fuel "	12,000 lb.
Firebox	119⅝″ x 41⅝″	Heating surface	1,230 sq. ft.			Tractive force	11,860 lb.

feet. The earlier locomotives of this type, as shown in the accompanying illustration of engine 317, had short smokeboxes and horizontal frame rails between the drivers. On those subsequently built, and represented by engine 1066, illustrated on this page, an extension front was used and the top frame rail and firebox mud-ring were inclined, thus giving room for a deeper firebox throat.

The machinery and running gear details of these locomotives represented most careful designing, and included a number of features which were, at that time, of special interest. In order to easily handle a locomotive having unbalanced slide valves and carrying a steam pressure of 140 pounds, a power reverse gear was applied. This device, which was bolted to the right hand side of the boiler immediately in front of the cab, consisted of two horizontal cylinders whose pistons were mounted on the same rod. This rod was connected, at its middle point, to a rocking lever whose lower end was pinned to the reach rod. The forward cylinder was arranged to receive steam at either end, according to the direction in which the gear was to be shifted; while the rear cylinder was filled with oil, and functioned as a locking device for holding the gear in any desired position. The mechanism was controlled by a hand lever placed in the cab, and was so arranged that, when steam was admitted to shift the gear, a valve was opened to permit free communication between the two ends of the oil cylinder. This device proved reliable in service, but when balanced slide valves were subsequently adopted it was abandoned as being no longer necessary.

The Class K (D6) locomotives were fitted with two-bar guides and alligator type crossheads, instead of the four-bar design of guide used on previous passenger locomotives. The main rods were of rectangular section, with forked end stubs at the rear, while the side rods were of I-section with solid end stubs. As it was impossible, on account of the width of the firebox, to place the springs above the driving boxes, they were underhung, and were connected by equalizers on each side. This arrangement worked out very satisfactorily, and was applied to all American type locomotives subsequently built with fireboxes above the frames.

The Class K (D6) locomotives had each



The illustration shows one of the latest Class K locomotives, as built with extended smokebox and sloping firebox mud-ring. The Class K locomotives were subsequently rebuilt with either 68″ or 72″ drivers, and placed in local passenger service.

American Type Locomotive, Class K (D6), built at Altoona, 1883

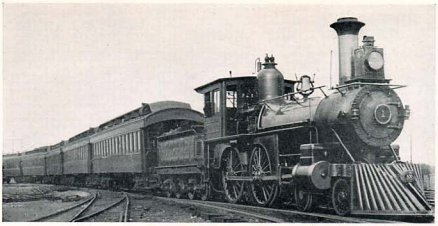


Photo furnished by C. B. Chaney

American Type Locomotive, Class K (D6a), as rebuilt with 72" Drivers and used in Local Passenger Service

two sandboxes, placed under the running boards and inside the wheel covers; and the dome casing was hemispherical on top, without beadings or fancy mouldings. As a result these locomotives were, for that day, very plain in outline, but won much favorable comment because of their symmetry and unusually neat appearance.

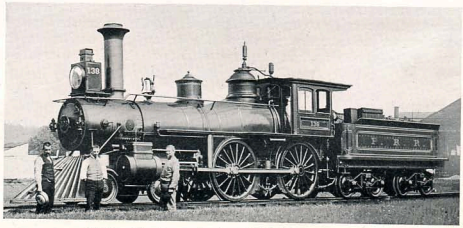
These locomotives did excellent work in high speed service on the New York Division. The fastest schedule then in effect allowed one hour fifty minutes for the 88½ miles between Jersey City and West Philadelphia, representing an average speed of 48.3 miles per hour, with three intermediate stops. A typical train was made up of five cars, and weighed about 130 tons. The running time today is practically the same, but the train loads average 600 to 800 tons, and trains exceeding 1000 tons in weight are sometimes handled on fast schedules. The heaviest locomotives now used in this service weigh over three times as much as those used in 1881, and develop a maximum tractive force of 44,460 pounds, as against 11,860 pounds for Class K (D6).

An important step in the development of the Pennsylvania System was taken in 1881, with the purchase of the Philadelphia, Wilmington and Baltimore Railroad. This line, in connection with the New York Division and the Baltimore and Potomac Railroad, gave the Pennsylvania a direct route, over its own tracks, between New York and Washington. The Philadelphia, Wilmington and Baltimore Railroad had in service a large number of Baldwin locomotives; and engine 56, illustrated on page 43, represented the class of power used by the road, at that time, for fast passenger service. These locomotives were, in course of time, replaced by locomotives built in accordance with Pennsylvania standards.

During the years 1881 and 1882, 31 locomotives designated as Class BA (D2a) were built at Altoona and placed in express passenger service. The design was based on that of Class B (D2), but had driving wheels 68 inches in diameter, as used on Class A (D1). As shown by the illustration of engine 138 on this page, these locomotives had extended smokeboxes, but were otherwise very similar in appearance to Class A.

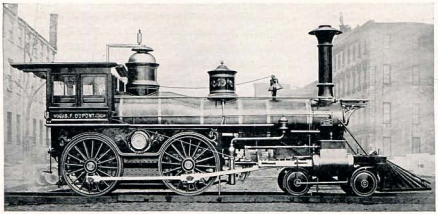
The success of the Class K (D6) locomotives led to the designing along similar lines, in 1882, of a locomotive with 17 x 24-inch cylinders and driving wheels 68 inches in

Cylinders	18" x 24"
Drivers, diam.	68"
Steam pressure	125 lb.
Grate area	17.6 sq. ft.
Heating surface	1,083 sq. ft.
Weight on drivers	53,750 lb.
Weight, total engine	82,200 lb.
Tractive force	12,150 lb.



American Type Locomotive, Class BA (D2a), built at Altoona, 1881

Representative Baldwin Locomotives Built for the Philadelphia, Wilmington & Baltimore R. R. and the Camden and Atlantic R. R.



Cylinders	16″ x 24″
Drivers, diam.	60″
Weight, total	62,000 lb.

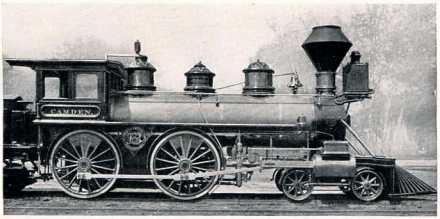
Boiler, Dimpfel type, with water tubes extending from the firebox crown through a large central flue, to a water space at the forward end of the barrel.

American Type Locomotive, Philadelphia, Wilmington & Baltimore R. R., 1852

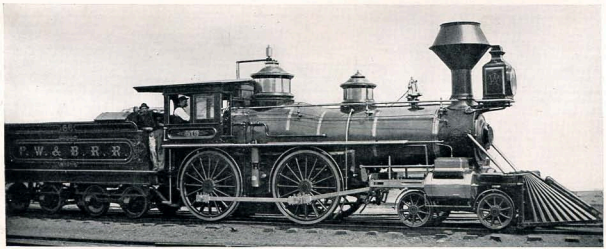
Cylinders	17″ x 22″
Drivers, diam.	66″
Weight on drivers	45,000 lb.
Weight, total engine	70,000 lb.

Boiler, straight top, 51″ in diameter, with two steam domes.

A typical fast passenger locomotive of the period.



American Type Locomotive, Camden & Atlantic R. R., 1871

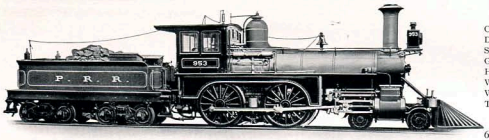


American Type Locomotive, Philadelphia, Wilmington & Baltimore R. R., 1875

Cylinders	17″ x 24″	Grate area	17.1 sq. ft.	Weight on drivers	48,700 lb.
Drivers, diam.	67 ¼″	Heating surface	1,107 sq. ft.	Weight, total engine	75,700 lb.

diameter, known as Class A anthracite (D7). This class was represented by engine 953, illustrated below. In this year a heavy design of six-wheeled switcher with separate tender, known as Class M (B3) was introduced. The most interesting feature of this design was the boiler, which was of the "Altoona" type with sloping firebox roof sheet, as used on the Class I (H1) Consolidation type locomotives.

To meet the increasingly difficult require-



Cylinders	17" x 24"
Drivers, diam.	68"
Steam pressure	140 lb.
Grate area	34.7 sq. ft.
Heating surface	1,280 sq. ft.
Weight on drivers	64,000 lb.
Weight, total engine	93,500 lb.
Tractive force	12,140 lb.

This design was also built with 62" drivers (Class D7a).

American Type Locomotive, Class A anthracite (D7), built at Altoona, 1882

ments of passenger service, three new designs of American type locomotives were introduced in 1883. These were Class N (D8), built to replace the old Class C(D3); Class O (D8a), built to replace Class B (D2), and Class P (D11a), a hard coal burner heavier and more powerful than any passenger locomotives previously placed on the road. Classes N and O had the same size cylinders and driving wheels as the locomotives they were designed to replace, the only increase in hauling capacity being that due to an increase in steam pressure from 125 to 130 pounds. The grate area remained the same, but the heating surface was increased 28 per cent and the total weight about 15 per cent. These locomotives were characterized by the same plain outline and absence of decoration found in Class K (D6) built two years previously.

The Class P (D11a) locomotives had 18½ x 24-inch cylinders and driving wheels 68 inches in diameter, and were designed for heavy express passenger service on the New York and other divisions where hard coal was used as fuel. Their success in this service led to their subsequent adoption on other divisions where bituminous coal was used, and they proved an exceedingly satisfactory locomotive for all-around passenger service and also, to a lesser extent, for fast freight service. In general design they were closely similar to Class K (D6), but with larger cylinders and smaller wheels they developed 21 per cent greater tractive force. With an increase in total weight of only about four per cent, there was an increase in heating surface of nearly 25 per cent, which gave Class P a material advantage in steaming capacity as compared with Class K.

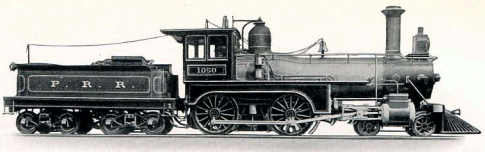
In 1883, the Camden and Atlantic Railroad, whose main line extended from Camden, New Jersey, to Atlantic City, passed under the control of the Pennsylvania. This line, in conjunction with the West Jersey Railroad, control of which had been acquired in 1871, gave the Pennsylvania excellent facilities for handling the heavy seashore traffic to southern New Jersey Coast resorts. The acquisition of these lines is worthy of notice, because of the influence

Cylinders	19" x 24"
Drivers, diam.	50"
Steam pressure	125 lb.
Grate area	15 sq. ft.
Heating surface	1,196 sq. ft.
Weight, total engine	91,700 lb.
Tractive force	18,410 lb.



Six-coupled Switching Locomotive, Class M (B3), built at Altoona, 1883

Cylinders	18″ x 24″
Drivers, diam.	62″
Steam pressure	130 lb.
Grate area	17.6 sq. ft.
Heating surface	1,392 sq. ft.
Weight on drivers	59,000 lb.
Weight, total engine	95,000 lb.
Tractive force	13,860 lb.



American Type Locomotive, Class O (D8a), built at Altoona, 1883. Class N (D8) was similar, but with cylinders 17″ in diameter

which their traffic requirements exerted on the future development of the Pennsylvania's motive power.

A representative passenger locomotive, as used on the Camden and Atlantic during the seventies, is illustrated on page 37.

In the meantime, the Class I (H1) locomotives continued to be the standard for heavy freight service, and during the years



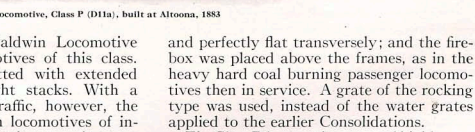
Cylinders	18½″ x 24″
Drivers, diam.	68″
Steam pressure	140 lb.
Grate area	34.7 sq. ft.
Heating surface	1,539 sq. ft.
Weight on drivers	67,800 lb.
Weight, total engine	100,600 lb.
Tractive force	14,370 lb.

This design was also built with 62″ drivers (Class D11).

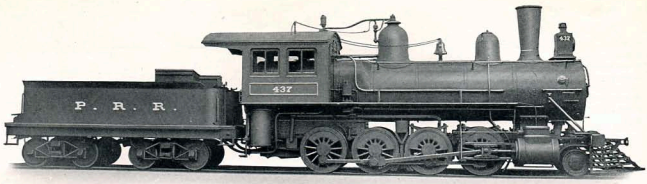
American Type Locomotive, Class P (D11a), built at Altoona, 1883

1882 and 1883 The Baldwin Locomotive Works built 56 locomotives of this class. These engines were fitted with extended smokeboxes and straight stacks. With a constantly increasing traffic, however, the time soon arrived when locomotives of increased hauling and steaming capacity were required, and accordingly in 1885, the first of a new design of Consolidation, known as Class R (H3) were built at Altoona. The cylinders and driving wheels of these locomotives were of the same dimensions as those of Class I, but by increasing the steam pressure from 125 to 140 pounds the tractive force was increased 12 per cent. As in the case of the earlier Consolidations, the boiler of Class R was, in many respects, the most interesting feature of the design. It was the first of the Belpaire pattern to be used on the Pennsylvania Railroad, and established a type which, with comparatively few exceptions, has been applied to all locomotives subsequently designed by the road. As used on Class R, it had a straight top barrel, with the dome immediately ahead of the firebox. The roof and crown sheets were horizontal, and perfectly flat transversely; and the firebox was placed above the frames, as in the heavy hard coal burning passenger locomotives then in service. A grate of the rocking type was used, instead of the water grates applied to the earlier Consolidations.

The Class R locomotives proved highly successful and were built in large numbers, and widely distributed over the System. The steam pressure was subsequently increased to 150 pounds, and a number of minor



Consolidation Type Locomotive, Class I (H1), built at Altoona in 1881, with extended Smokebox, straight Stack, and Air Brake Equipment



Consolidation Type Locomotive, Class R(H3), built at Altoona, 1886

Cylinders	20″ x 24″	Tubes, diam.	2½″	Wheel base, driving	13′ 10″	Weight, total engine	114,620 lb.
Drivers, diam.	50″	" number	183	" " total engine	21′ 9″	" " " and	
Boiler, inside diam.	59″	" length	13′ 0⅛″	" " " " and		tender	190,000 lb.
Steam pressure	140 lb.	Grate area	31.2 sq. ft.	tender	49′ 9″	Tank capacity	3,600 U. S. gal.
Firebox	107″ x 42″	Heating surface	1,732 sq. ft.	Weight on drivers	109,590 lb.	Fuel "	15,000 lb.
						Tractive force	22,850 lb.

changes made after an extended experience with the locomotives as originally designed.

The Baldwin Locomotive Works, during the years 1888-1890, built 111 Class R locomotives for the Pennsylvania System, some of which were assigned to the Northern Central and some to the Pittsburgh, Cincinnati and St. Louis. These were followed, in 1891, by five more which were experimentally fitted with Vauclain compound cylinders; and in 1892, 45 more were built, with single expansion cylinders.

The various groups of Class R locomotives differed slightly in appearance, but the general features of this interesting class are clearly shown in the accompanying illustration of engine 437, which was one of the first built.

In 1885, in addition to Class R, there was brought out a new design of four-coupled switching locomotive known as Class Q (A2). These locomotives were intended for service in certain sections of Philadelphia, where curves were so sharp as to prohibit the use of six-coupled locomotives.

On March 1, 1887, Axel S. Vogt was appointed Mechanical Engineer at Altoona, succeeding John W. Cloud, who had filled the position since the death of Mr. Collin on March 20, 1886. Mr. Vogt served in this capacity for more than 30 years, during which time he did most valuable work in improving motive power efficiency and refining the design of locomotive details.

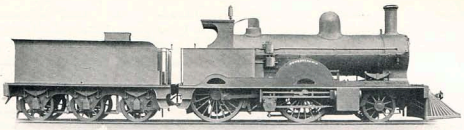
During the month of May, 1887, a passenger locomotive on the Philadelphia, Wilmington and Baltimore Railroad was operated on a special schedule with a view to establishing a mileage record. The locomotive made two round trips daily between Philadelphia and Washington, the total mileage covered during the 31 days being 17,360. Another experiment of unusual interest, conducted during the year 1887, was made with a locomotive which was equipped for burning petroleum. This experiment was carried out on the Pittsburgh Division, under the supervision of Dr. Charles B. Dudley, Chief Chemist; and proved conclusively that the use of this fuel in locomotives was entirely practicable, and that one pound of oil was equivalent in heating value to 1¾ pounds of coal. The relative



Cylinders	15″ x 24″
Drivers, diam.	50″
Steam pressure	125 lb.
Grate area	12.2 sq. ft.
Heating surface	602 sq. ft.
Weight, total engine	72,000 lb.
Tractive force	11,475 lb.

Four-coupled Switching Locomotive, Class Q (A2), built at Altoona, 1885

Cylinders, H. P. (2)	14″ x 24″
" L. P. (1)	30″ x 24″
Drivers, diam.	75″
Steam pressure	175 lb.
Grate area	20.5 sq. ft.
Heating surface	1457 sq. ft.
Weight on drivers	60,770 lb.
" total engine	99,350 lb.
Tractive force (compound)	16,400 lb.



Webb 3-Cylinder Compound Locomotive, built by Beyer, Peacock and Co. for experimental purposes, 1889

costs of coal and oil when burned as locomotive fuel in the eastern section of the country, however, were such that the extensive use of oil was prohibitive; but Dr. Dudley's experiments were of great value in establishing heating ratios for the two classes of fuels, and in demonstrating the fact that oil could be safely and efficiently burned in a locomotive boiler.

of the London and Northwestern. The wheel arrangement of the locomotive was 2-4-0, and the two pairs of drivers were independently rotated, no coupling rods being used. There were two high-pressure cylinders, placed outside, with their pistons connected to the rear drivers, and a single low-pressure cylinder, which was placed on the center line of the locomotive and rotated

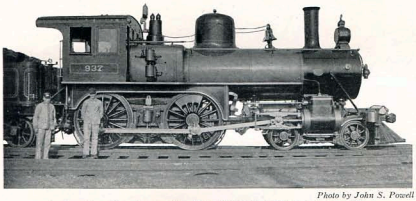


Photo by John S. Powell

American Type Locomotive, Class O (D10a), built at Altoona, 1891

Cylinders	18″ x 24″
Drivers, diam.	68″
Steam pressure	160 lb.
Grate area	17.3 sq. ft.
Heating surface	1,296 sq. ft.
Weight on drivers	66,900 lb.
Weight, total engine	103,500 lb.
Tractive force	15,550 lb.

This locomotive was finished and equipped for special service. The standard equipment is shown in the illustration of engine 568 on page ~~33~~ 27.

In 1888 a three-cylinder compound locomotive, of the type used by the London and Northwestern Railway of England, for express passenger service, was purchased by the Pennsylvania for experimental purposes. This locomotive was built by Messrs. Beyer, Peacock and Co., and the system of compounding employed was that introduced by F. W. Webb, Locomotive Superintendent

the forward pair of drivers through a cranked axle. This locomotive was tried out in various classes of passenger service, but while it represented very superior workmanship, it was of insufficient capacity for the work to be done. It was finally cut up in 1898. The illustration on this page shows the locomotive as equipped with a pilot, but before the English cab had been removed

Cylinders	18″ x 24″
Drivers, diam.	62″
Steam pressure	160 lb.
Grate area	17.3 sq. ft.
Heating surface	1,296 sq. ft.
Weight on drivers	66,000 lb.
" total engine	105,000 lb.
Tractive force	17,060 lb.

Originally equipped with straight stack having cast iron top, and two sand boxes under wheel covers.

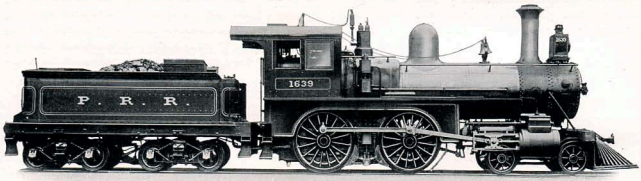


American Type Locomotive, Class O (D10), built at Altoona, 1891

and one of American design substituted.

In 1889, the designs of two American type passenger locomotives, Classes O (D8a), and P (D11a), were revised, and Belpaire boilers carrying a pressure of 160 pounds were substituted for the crown bar boilers carrying lower pressures which had been formerly used in these classes. The boiler diameter in each case was 54 inches, but this was subsequently increased to 57 inches, and the working pressure of Class P was raised to 175 pounds. The illustrations on page 47 and below, show these revised designs. The new Class O locomotives handled much of the fast passenger traffic on the Middle Division, which had a river grade throughout data were obtained from their performance.

Of the Baldwin and Schenectady locomotives, one from each builder was of the American type and one of the ten-wheeled type. Both Baldwin locomotives had Vauclain compound cylinders. The Schenectady eight-wheeler had single expansion cylinders, while the ten-wheeler was of the cross-compound (two cylinder) type. The locomotive built at Altoona, which was designated as Class T (D15), was also a cross-compound, designed on the Lindner System, and having the 4-4-0 (American type) wheel arrangement. This locomotive presented an unusual appearance, chiefly because of its low running boards, with wheel covers over



American Type Locomotive, Class P (D13c), built at Altoona, 1893

Cylinders	18½" x 24"	Tubes, diam.	1¾"	Wheel base, driving	7' 9"	Weight, total engine	114,500 lb.
Drivers, diam.	68"	" number	258	" " total engine	22' 8½"	" " " and tender	192,000 lb.
Boiler, inside diam.	56½"	" length	11' 3⅞"	" " " " and tender	48' 7¾"	Tank capacity	3,000 U. S. gal.
Steam pressure	175 lb.	Grate area	33.2 sq. ft.	Weight on drivers	79,500 lb.	Fuel "	15,000 lb.
Firebox	119¾" x 40"	Heating surface	1,571 sq. ft.			Tractive force	17,970 lb.

This general design was also built with drivers 62" in diameter.

practically its entire length; while Class P was used on the Philadelphia and Pittsburgh Divisions, where the grades were more severe, and also on the New York Division and the Seashore lines, where the work was difficult on account of heavy trains and high schedule speeds. In fact it was becoming evident that, especially on the New York Division, the traffic requirements would soon outgrow the capacity of the Class P locomotives. With a view, therefore, of designing power especially fitted to meet these conditions, two heavy passenger locomotives were purchased from The Baldwin Locomotive Works for experimental purposes in 1892, and two from the Schenectady Locomotive Works; while a fifth engine, of rather exceptional design, was built at the Altoona Shops. These locomotives were tried out on various divisions of the System, and valuable the drivers, which were strongly suggestive of British practice. It was the original intention to equip the boiler for burning fuel oil, but this was never actually done, the fuel used being bituminous coal.

The performance of these experimental locomotives was carefully studied and the results obtained were valuable, but none of the designs was duplicated. The Baldwin and Schenectady 4-4-0 type locomotives remained in service until 1911, while the others were retired at earlier dates.

In 1891, the design of the Class M (B3) switching locomotives was thoroughly revised, and a boiler of the Belpaire type, carrying a steam pressure of 160 pounds, was applied. The new Class M (B4) design was revised in 1893, by increasing the size of the firebox; and locomotives of this class, subsequently designated as B4a, continued to be

Cylinders	13" & 22" x 24"
Drivers, diam.	78"
Steam pressure	180 lb.
Grate area	38.5 sq. ft.
Heating surface	1,696 sq. ft.
Weight on drivers	83,900 lb.
" total engine	122,400 lb.
Tractive force (compound)	12,900 lb.

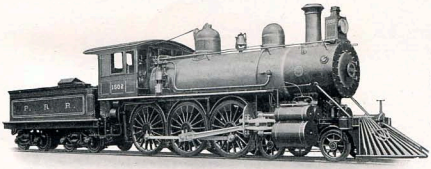


Experimental American Type Locomotive with Vauclain Compound Cylinders, built by The Baldwin Locomotive Works, 1892

built until 1904. As compared with the original Class M (B3) locomotives, Class B4a represented an increase in total weight of 18 per cent and in tractive force of 28 per cent.

In this connection reference should be made to the completion, during 1892, of the Juniata Shops just east of Altoona, which were specially designed and equipped for building new motive power. This plant had capacity for turning out 150 locomotives per year, and represented at that time the last word in shop construction. Electric and hydraulic power were extensively used, and the labor-saving equipment was most complete. The majority of the locomotives built at Altoona subsequent to 1892 have been constructed in this plant.

In 1893, six Class P locomotives of modified design (D14) were built at Altoona, three for service on the New York Division and three on the Maryland Division. One of the former, No. 1659, is illustrated on page 45. These locomotives were closely similar to the previous design of this class, represented by engine 1639, the most important change being an increase in wheel diameter from 68 to 78 inches. With no change in cylinder dimensions or boiler pressure, this resulted in a corresponding decrease in starting tractive force; but the larger wheels gave the new locomotives a distinct advantage in high speed service. As compared with the older Class P locomotives, a change was made in the appearance of the new design by placing the sandbox on top of the boiler, instead of using two sandboxes under the wheel covers.



Cylinders	14" & 24" x 24"
Drivers, diam.	72"
Steam pressure	180 lb.
Grate area	28.3 sq. ft.
Heating surface	2,135 sq. ft.
Weight on drivers	101,300 lb.
" total engine	132,000 lb.
Tractive force (compound)	16,500 lb.

Experimental Ten-wheeled Locomotive with Vauclain Compound Cylinders, built by The Baldwin Locomotive Works, 1892

Cylinders	19½" & 31" x 28"
Drivers, diam.	84"
Steam pressure	205 lb.
Grate area	30 sq. ft.
Heating surface	1,824 sq. ft.
Weight on drivers	95,200 lb.
" total engine	145,500 lb.
Tractive force (starting)	20,800 lb.



Compound American Type Locomotive, Class T (D15), built at Altoona, 1892



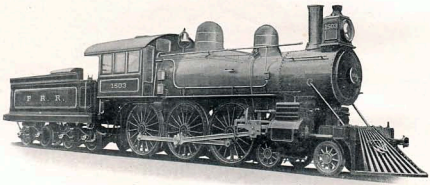
Cylinders	19″ x 24″
Drivers, diam.	78″
Steam pressure	180 lb.
Grate area	26.2 sq. ft.
Heating surface	1,816 sq. ft.
Weight on drivers	81,500 lb.
" total engine	126,700 lb.
Tractive force	17,000 lb.

Experimental American Type Locomotive, built by the American Locomotive Company (Schenectady Locomotive Works), 1892

With their large drivers and neat outline, these locomotives presented an unusually handsome appearance and became the subject of considerable comment.

Experience with the 1893 design convinced the Motive Power Department that further improvement could be made without a material increase in dimensions, and accordingly, in 1894, the Class P design was again thoroughly revised. The boiler dimensions of the 1893 (D14) locomotives were retained as being sufficient for the service requirements, but the cylinder diameter was increased from 18½ to 19 inches, and a careful study was made of the machinery for the purpose of reducing the weight of the reciprocating parts. The pistons were steel castings of dished section, and the cross-heads were of the same material, arranged for a modified form of four-bar guide, in which the two upper bars were replaced by a broad cast iron shoe, having a longitudinal strengthening rib in the center. The valve gear was redesigned, and the valve travel and steam lap increased from 5½ inches and 1 inch to 6 inches and 1⅛ inches respectively. At the same time, by increasing the thickness of the tires from 3 to 4 inches, the driving wheel diameter was increased from 78 to 80 inches. The standard Pennsylvania straight stack, with planished iron body and cast iron top, was replaced by

Cylinders	20″ & 30″ x 24″
Drivers, diam.	74″
Steam pressure	180 lb.
Grate area	26.2 sq. ft.
Heating surface	1,953 sq. ft.
Weight on drivers	106,000 lb.
" total engine	143,000 lb.
Tractive force (compound)	15,000 lb.

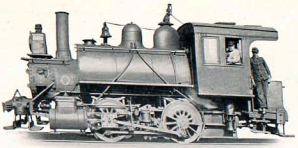


Experimental Compound Ten-wheeled Locomotive, built by the American Locomotive Company (Schenectady Locomotive Works), 1892



Cylinders	19″ x 24″
Drivers, diam.	50″
Steam pressure	160 lb.
Grate area	17.8 sq. ft.
Heating surface	1,353 sq. ft.
Weight, total engine	107,500 lb.
Tractive force	23,570 lb.

Six-coupled Switching Locomotive, Class M (B4a), built at Altoona, 1902



Four-coupled Switching Locomotive, Class Q (A2a), built at Altoona, 1892

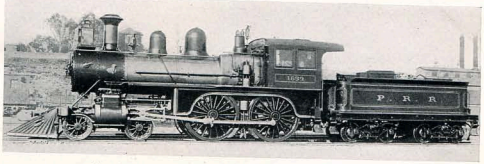
Cylinders	15″ x 24″	Weight, total	70,000 lb.
Drivers, diam.	50″	Tractive force	11,475 lb.

a cast iron tapered stack, 13½ inches in diameter at the choke; and a round case head-light was mounted at the top of the smokebox front. After a thorough trial in service, however, the old time standard stack was substituted for the tapered design, and the round case headlight was removed and one of conventional design, with

Railroad (Maryland Division), and a new design of American type locomotive, designated as Class L, subsequently D16, with several modifications, was built at Altoona in 1895 and for some years following. These locomotives were designed under the supervision of Mr. F. D. Casanave, who served as General Superintendent of Motive Power of the Lines East from March 1, 1893, to October 1, 1901. They were the result of a most thorough study of the service requirements, and were designed to develop maximum efficiency and capacity within the weight limits then permitted. The cylinder diameter (18½ inches) was the same as that of the earlier Class P locomotives, but the stroke was increased to 26 inches and the steam pressure to 185 pounds. The locomotives for service on heavy grade divisions were built with 68-inch driving wheels (Class D16), while those for high speed

Cylinders	18½″ x 24″
Drivers, diam.	78″
Steam pressure	175 lb.
Grate area	33.2 sq. ft.
Heating surface	1,583 sq. ft.
Weight on drivers	82,600 lb.
" total engine	122,600 lb.
Tractive force	15,660 lb.

Subsequently rebuilt with 68″ drivers for local service.



American Type Locomotive, Class P (D14), built at Altoona, 1893

rectangular case, was placed on top of the smokebox. An illustration on page 46 shows one of the locomotives as thus equipped. These engines, according to the revised classification, were designated as D14a.

After these locomotives had been used for some months on the New York Division they were renumbered and assigned to the Philadelphia, Wilmington and Baltimore

work on comparatively level divisions had drivers 80 inches in diameter (Class D16a). The pistons and cross-heads were generally similar to those used on the Class P (D14a) locomotives with 80-inch drivers, but on Classes D16 and D16a a box-shaped guide, as originated by Mr. Vogt, was used. This guide was open at the bottom and was made in two pieces, held together on the longi-



Cylinders	19″ x 24″
Drivers, diam.	80″
Steam pressure	175 lb.
Grate area	33.2 sq. ft.
Heating surface	1,583 sq. ft.
Weight on drivers	87,300 lb.
" total engine	127,050 lb.
Tractive force	16,110 lb.

Subsequently rebuilt with 68″ drivers for local service.

Photo furnished by C. B. Chaney

American Type Locomotive, Class P (D14a), built at Altoona, 1894

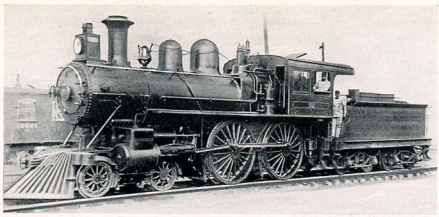


Photo furnished by C. B. Chaney

American Type Locomotive, Class P (D14a), with Straight Stack and Square Case Head-Light, as used on Maryland Division

tudinal center line by six horizontal bolts. The cross-head was a one-piece steel casting, made as light as possible, with a top bearing 19 inches long by 10 inches wide. As compared with the earlier Class P locomotives having cylinders 18½ inches in diameter, the weights of the reciprocating parts were as follows:

	Piston & Rod	Cross-head	Main Rod Recipro-cating	Total Recipro-cating
Class P.....	310	174	144½	628½
Class D16...	269½	146	121	536½

This showed remarkable progress in the important work of lightening the reciprocating parts.

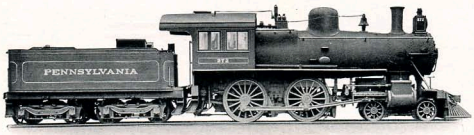
The boilers of Classes D16 and D16a were of the Belpaire type, with a conical ring forming the front half of the barrel and increasing the shell diameter from 60 inches at the smokebox to 68 inches at the dome ring. These boilers were built with horizontal crown and roof sheets, but the design was subsequently modified by sloping the crown and roof toward the rear at a moderate angle. The throat and back head were vertical. All water spaces were of liberal width, and the boiler details were very carefully worked out. As compared with the Class D14a locomotives, the increase in heating surface amounted to 20 per cent, while the grate area remained about the same.

Cylinders	18½" x 26"
Drivers, diam.	80"
Steam pressure	185 lb.
Grate area	33.2 sq. ft.
Heating surface	1,905 sq. ft.
Weight on drivers	93,100 lb.
" total engine	134,500 lb.
Tractive force	17,500 lb.



American Type Locomotive, Class L (D16a), built at Altoona, 1895

The locomotives with sloping crown and roof sheets and 68-inch drivers were designated as Class D16b, while those with 80-inch drivers were built in two groups, which differed in minor details, and were designated as Classes D16c and D16d respectively. With the smaller wheel, the maximum tractive force developed was 20,580 pounds, and with the larger wheel, 17,500 pounds. All the locomotives of this



Cylinders	18½" x 26"
Drivers, diam.	68"
Steam pressure	185 lb.
Grate area	33.2 sq. ft.
Heating surface	1,900 sq. ft.
Weight on drivers	97,100 lb.
" total engine	134,000 lb.
Tractive force	20,580 lb.

American Type Locomotive, Class D16b, built at Altoona, 1901

general design did excellent work and were widely distributed over the System, showing a high degree of efficiency and proving very reliable in operation. One of them, No. 816, a Class D16a locomotive built in November, 1895, was in service on the Middle Division for three years and four months before it was taken off its wheels for repairs. During this time it covered 305,037 miles, and was not raised from its driving boxes, nor were the tires turned, cylinders bored, valves faced, valve gear overhauled, or tubes taken out. The driving tires, which were manufactured by the Standard Steel Works, showed a wear of $\frac{5}{32}$ inch during this period.

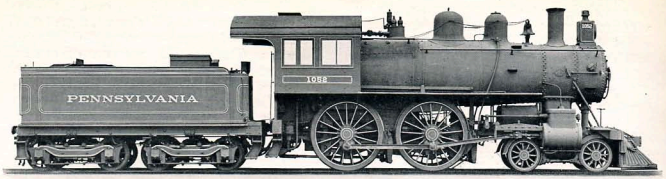
While the Pennsylvania was developing the American (4-4-0 type) to the maximum capacity permitted by the wheel loads which could be carried at that time, many roads were adopting the ten-wheeled (4-6-0) type for heavy passenger service. In this connection it is interesting to note that in 1866, several four-coupled locomotives were rebuilt at Altoona as Moguls (2-6-0 type) for passenger service, but were short lived as they were again rebuilt a few years later to the original wheel arrangement. One of these locomotives, number 347, is shown in an accompanying illustration.

In 1893, in order better to cope with the heavy traffic west of Pittsburgh, a group of locomotives of the ten-wheeled (4-6-0) type, known as Class X (G3) was turned out at the Fort Wayne Shops for service on the Pittsburgh, Fort Wayne and Chicago Railway. These locomotives had Belpaire boilers and closely followed standard Pennsylvania practice in design, and developed about 9 per cent higher tractive force than the heaviest Class P locomotives with 68-inch drivers (D13c), while carrying 46 per cent greater weight on drivers. One of these locomotives is illustrated on page 49.

In 1899, the ten-wheeled type was adopted, to a limited extent, for service on heavy grades east of Pittsburgh; and a number of large ten-wheelers, designated as Class G4, were built at Altoona. The most conspicuous feature of this design was a boiler of the radial stay type, carrying, for that period, the unusually high steam pressure of 225 pounds. As compared with Classes D16 and D16b, these locomotives developed 44 per cent greater tractive force and were among the most powerful of their type then in existence; but they never became a standard in the same sense as the heavy four-coupled passenger locomotives that had preceded them.



The Pennsylvania Limited, hauled by Class D16a Locomotive No. 296
Photographed in 1899, on the Philadelphia Division, near Merion, Pa.



American Type Locomotive, Class D16d, built at Altoona, 1902

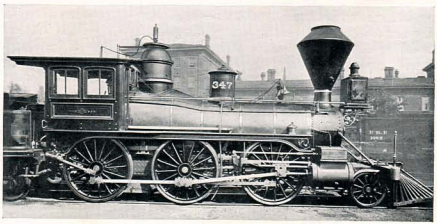
Cylinders	18½″ x 26″	Tubes, diam.	1¾″	Wheel base, driving	7′ 9″	Weight, total engine	138,000 lb.
Drivers, diam.	80″	" number	310	" " total engine	23′ 9½″	" " " and	
Boiler, inside diam.	58⅜″	" length	11′ 4¾″	" " " " and		tender	272,000 lb.
Steam pressure	185 lb.	Grate area	33.2 sq. ft.	tender	55′ 0¼″	Tank capacity	5,500 U. S. gal.
Firebox	119⅜″ x 40″	Heating surface	1,900 sq. ft.	Weight on drivers	98,000 lb.	Fuel "	25,000 lb.
						Tractive force	17,500 lb.

A modified design, with driving wheels 62 inches in diameter and known as Class G4a, was subsequently built for fast freight service west of Pittsburgh. Fifteen of these locomotives were constructed by The Baldwin Locomotive Works early in 1900.

While the motive power for passenger service was developing as described above, several new classes were being placed in heavy freight service. In 1895, the need of freight locomotives having increased hauling and speed capacity as compared with the Class R (H3) Consolidation engines began to be realized, and a number of heavy Moguls (2-6-0 type) were built at Altoona. Included among them were four experimental two-cylinder compounds, designed according to the systems of von Borries, Golsdorf, the Richmond Locomotive Works and the Pittsburgh Locomotive Works respectively.

The success of the single expansion Moguls (Class F1) led to the construction of additional locomotives of this type with certain details modified, and known as Class F1a. These locomotives developed a tractive force of 28,400 pounds, or 16 per cent greater than that of the H3b Consolidation type locomotives carrying a pressure of 150 pounds. The Moguls carried 127,000 pounds on three pairs of drivers, or approximately 10 per cent in excess of that carried on four pairs in the case of the Consolidation engines; while an increase of 12 inches in wheel diameter gave them a distinct advantage in speed. The boilers of these locomotives had Belpaire fireboxes and were similar in design to those of the Class D16b passenger locomotives, although differing somewhat in dimensions. On low grade divisions, these locomotives handled trains up to 2700 tons in weight, while they steamed freely and made excellent time.

In 1898, two new designs of Consolidation type locomotives were introduced—Class H5, for pushing service on the mountain grades west of Altoona, and Class H6, for heavy road service. Class H5, with a weight on drivers of 175,700 pounds and a tractive force of 43,400 pounds, ranked among the most powerful locomotives in existence at the time of its construction; and a close second was Class H6, which carried 166,400

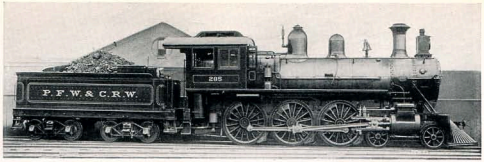


Mogul Type Passenger Locomotive, rebuilt at Altoona, 1866

This locomotive had 19 x 24-inch cylinders and 66-inch drivers, and weighed 64,300 lb. with 54,000 lb. on drivers. It was originally built by Norris in 1865 as a 4-4-0 type, and was again rebuilt to this type in 1870. It was cut up in 1876.

Cylinders	19″ x 24″
Drivers, diam.	68″
Steam pressure	180 lb.
Grate area	31.3 sq. ft.
Heating surface	1,901 sq. ft.
Weight on drivers	116,000 lb.
" total engine	146,500 lb.
Tractive force	19,500 lb.

This design was also built with 62″ drivers (Class G3a).



Ten-wheeled Locomotive, Class X (G3), built at Ft. Wayne Shops, 1893

pounds on drivers, and with a steam pressure of 205 pounds, developed a tractive force of 42,170 pounds. The boilers of the two classes were closely similar, as they were of the same diameter and had fireboxes of the same size; but the tubes of Class H5 were 4½ inches longer than those of Class H6, and the latter had a sloping back-head, the first to be used on the Pennsylvania. The same careful attention to details which for the motion work to spring out of line; and the eccentrics were of the twin pattern, the forward and backward eccentrics on each side being cast together and split horizontally to permit application to the axle. The boilers had Belpaire fireboxes, and were practically enlargements of those used on the Class D16b passenger and F1a freight locomotives. For such heavy locomotives, the two new classes were extremely



Cylinders	20″ x 28″
Drivers, diam.	72″
Steam pressure	225 lb.
Grate area	30.8 sq. ft.
Heating surface	2,816 sq. ft.
Weight on drivers	140,500 lb.
" total engine	184,300 lb.
Tractive force	29,750 lb.

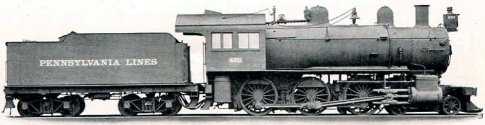
Ten-wheeled Locomotive, Class G4, built at Altoona, 1900

characterized the passenger and freight locomotives of the D16 and F1 groups respectively, was found in these new Consolidation type locomotives. Among other interesting features may be mentioned the cylinders, which were cast separate from the saddle; there being thus three principal castings in the cylinder group. The valve gear was arranged with double suspension hangers for the links, reducing the tendency neat in outline, and this feature was enhanced by a careful arrangement of piping, air drums and attachments.

All the locomotives of Class H5 were built at Altoona, as were the first of Class H6. In addition, 65 of the latter class were built by The Baldwin Locomotive Works in 1899 and 1900. The last 40 of these locomotives had cast steel frames.

In this connection, brief reference should

Cylinders	20″ x 28″
Drivers, diam.	62″
Steam pressure	225 lb.
Grate area	30.8 sq. ft.
Heating surface	2,816 sq. ft.
Weight on drivers	142,000 lb.
" total engine	183,000 lb.
Tractive force	34,550 lb.



Ten-wheeled Locomotive, Class G4a, built at Altoona, 1901



Cylinders	20″ x 28″
Drivers, diam.	62″
Steam pressure	185 lb.
Grate area	30.1 sq. ft.
Heating surface	1,884 sq. ft.
Weight on drivers	127,000 lb.
" total engine	145,000 lb.
Tractive force	28,400 lb.

Mogul Type Locomotive, Class F1a, built at Altoona, 1898
The locomotive is shown as subsequently equipped for passenger service.

be made to the great improvements in the physical condition of the Pennsylvania System which had been effected during the period covered by this article. The Main Line had been practically rebuilt. Additional tracks and heavier rails had been laid, grades and curvature reduced where possible, improved systems of signalling installed, and every effort made to so maintain the System

large driving wheels and used in high speed service, have been omitted. The increase in tractive force for the American (4–4–0) type, which was used almost exclusively for passenger service, was 73 per cent; while in the case of the Consolidation type, used for heavy freight service, the increase was 107 per cent. The increased weight and capacity of switching locomotives, which

Cylinders	17″ x 24″
Drivers, diam.	50″
Steam pressure	160 lb.
Grate area	14.2 sq. ft.
Heating surface	899 sq. ft.
Weight, total engine	82,300 lb.
Tractive force	18,870 lb.



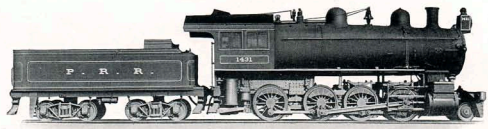
Four-coupled Switching Locomotive, Class U (A3), built at Altoona, 1895

that a constantly increasing traffic could be moved with maximum efficiency.

The table on page 51 clearly indicates the increase in the weight and capacity of passenger and freight locomotives which was effected during this period. In order to show a consistent advance in tractive force, certain notable locomotives, such as Classes D6 and D16a, which were built with

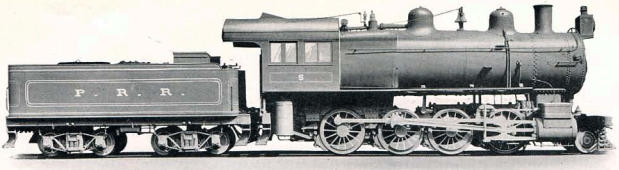
are not included in the table, is best shown by comparing Classes B2 and B4a, both of which were of the 0–6–0 type with separate tender. This shows an increase in total weight of 66 per cent, and in tractive force of very nearly 100 per cent.

At the close of the year 1899, the number of locomotives on the Lines East of Pittsburgh and Erie was 2327, and on the Lines



Cylinders	23½″ x 28″
Drivers, diam.	56″
Steam pressure	185 lb.
Grate area	33.3 sq. ft.
Heating surface	2,902 sq. ft.
Weight on drivers	175,700 lb.
" total engine	196,800 lb
Tractive force	43,400 lb.

Consolidation Type Locomotive, Class H5, built at Altoona, 1898



Consolidation Type Locomotive, Class H6, built at Altoona, 1899

Cylinders	22″ x 28″	Tubes, diam.	2″	Wheel base, driving	16′ 6½″	Weight, total engine	186,500 lb.
Drivers, diam.	56″	" number	369	" " total engine	24′ 9″	" " " and	
Boiler, inside diam.	69½″	" length	13′ 7½″	" " " " and		tender	300,000 lb.
Steam pressure	205 lb.	Grate area	33.3 sq. ft.	tender	56′ 8¾″	Tank capacity	6,000 U. S. gal.
Firebox	120″ x 40″	Heating surface	2,812 sq. ft.	Weight on drivers	166,400 lb.	Fuel "	22,000 lb.
						Tractive force	42,170 lb.

West of Pittsburgh, 1249, making a total of 3576. On the roads forming the Lines East, the percentages of standard locomotives were as follows: Pennsylvania Railroad, 99.5 per cent; Philadelphia, Wilmington and Baltimore Railroad, 89.3 per cent; Northern Central Railway, 100 per cent, and West Jersey and Seashore Railroad, 84.1 per cent.

While, as has been described, the Pennsylvania was developing existing locomotive types with a view of increasing their capacity and improving their efficiency, two features of great importance had been introduced into American practice. These were the wide firebox for burning bituminous coal, and the use of trailing wheels for the purpose of increasing boiler capacity in proportion to adhesion. These soon became recognized as essential features of American high-powered locomotives. Their introduction on the Pennsylvania Railroad, and the influence which they exerted on the subsequent development of this road's motive power, will be discussed in the third and last installment of this article.

Locomotive Development, Pennsylvania Railroad, 1868–1899

PASSENGER LOCOMOTIVES

Date	Type	P. R. R. Class	Cylinders, Inches	Drivers, Diam., Inches	Steam Pressure, Pounds	Grate Area, sq. ft.	Total Heating Surface, sq. ft.	Weight on Drivers, Pounds	Weight, Total Engine, Pounds	Tractive Force, Pounds	Tractive Force Increase, per cent*
1868	4–4–0	D3	17 x24	62	125	17.6	1083	50,950	79,100	11,900	100
1882	4–4–0	D7	17 x24	68	140	34.7	1280	64,000	93,500	12,140	103
1883	4–4–0	D11a	18½x24	68	140	34.7	1530	67,800	100,600	14,370	121
1893	4–4–0	D13c	18½x24	68	175	33.2	1571	79,500	114,500	17,970	151
1895	4–4–0	D16	18½x26	68	185	33.2	1905	93,600	135,300	20,580	173
1899	4–6–0	G4	20 x28	72	225	30.8	2816	140,500	184,300	29,750	250

FREIGHT LOCOMOTIVES

1869	4–6–0	G2	18x22	50	125	16.3	1096	62,100	84,800	15,150	100
1875	2–8–0	H1	20x24	50	125	23.0	1259	79,400	91,640	20,400	135
1885	2–8–0	H3	20x24	50	140	31.2	1732	100,590	114,620	22,850	151
1893	2–8–0	H3b	20x24	50	150	31.5	1498	115,000	127,000	24,480	162
1895	2–6–0	F1	20x28	62	185	30.0	1865	126,500	144,500	28,400	187
1898	2–8–0	H6	22x28	56	205	33.3	2812	166,400	186,500	42,170	278

*The tractive force of the lightest locomotive is taken as 100.



Climbing the Alleghenies

CHAPTER III

The Development of the Modern, High Power Steam Locomotive, and the Introduction of Electric Locomotives.



IN 1896, the West Jersey Railroad and the Camden and Atlantic Railroad, which, as has been mentioned, had previously passed under the control of the Pennsylvania, were combined to form the West Jersey and Seashore Railroad. The physical condition of the property was greatly improved, and especially was this true in the case of the former Camden and Atlantic, over which moved the high speed passenger traffic between Camden and Atlantic City. In response to the popular demand, the schedule speeds on this line were steadily increased until, in 1898, the fastest train was timed to run the 58.3 miles from Camden to Atlantic City in 55 minutes. As passengers were transferred from Philadelphia to Camden by ferry the train was frequently a few minutes late in starting, and exceptionally high running speeds were necessary in order to reach Atlantic City on time. For the first 18 miles the grades on the line are generally ascending, reaching a maximum of 27 feet per mile; while for the remainder of the distance they are level or slightly descending. Except in the immediate vicinity of the terminals, the line is practically free from curves sharp enough to require speed restrictions.

When this high speed service was first inaugurated, the trains were hauled by Class D16a (4-4-0 type) locomotives which, when not too heavily loaded, and under favorable conditions, could make the time; but it soon became evident that motive power of considerably greater capacity was required. The Atlantic (4-4-2) type, which had been developed by The Baldwin Locomotive Works in 1894 to meet difficult operating conditions on the Atlantic Coast Line, and had been adopted by several other roads, including the Atlantic City Division of the Philadelphia and Reading, was establishing itself as a most successful type for high speed passenger service. Accordingly in 1899, the Pennsylvania built three Atlantic type locomotives, designated as Class E1, for the high speed Atlantic City service. These locomotives, designed under the supervision of Mr. Axel Vogt, were notable both because of their capacity and the exceptional care with which all details were worked out. An excellent description of them, published in the June, 1900, issue of the *American Engineer and Railroad Journal*, closed with the following statement:

"We do not know of a more worthy example of American locomotive practice and one containing so many evidences of thoughtful skill in design and thoroughly good workmanship in construction."

The boiler of Class E1 was of the Belpaire type, with a wide firebox placed back of the driving wheels and above the trailers. The grate was 8 feet in length by 8 feet 6 inches in width, giving an area of 68 square feet. A combustion chamber 39 inches long, and separated from the firebox by a brick bridge wall, extended forward into the boiler barrel. These boilers proved exceptionally free steaming, and even when heavy trains were being handled at the highest required speeds, showed no signs of failing.

The cylinders and machinery details had many features in common with the Class H5 and H6 Consolidation type locomotives, and the 4-4-0 type locomotives of the D16 group, which were described in Part II of this article. A three-piece cylinder construction was used, and all steam and exhaust passages were of ample area and as free from abrupt bends as possible. The



Cylinders	20½″ x 26″
Drivers, diam.	80″
Steam pressure	185 lb.
Grate area	68 sq. ft.
Heating surface	2,320 sq. ft.
Weight on drivers	101,550 lb.
Weight, total engine	173,450 lb.
Tractive force	21,480 lb.

Atlantic Type Locomotive, Class E1, built at Altoona, 1899

guides were of the Vogt enclosed type, with light cast steel crossheads; and the main and side rods had thin webs and flanges, and were of minimum weight for the strength required. American balanced slide valves were used, with an outside steam lap of 1½ inches; and they were set with a maximum travel of 7 inches. This long travel was obtained by prolonging the upper end of the link to give several extra notches in the quadrant and, combined with a negative lead of $\frac{3}{32}$ inch, permit a cut-off of 83 per cent in full forward gear, thus increasing the power to start and accelerate trains rapidly.

These locomotives did excellent work, and on the Atlantic City run demonstrated their ability to easily haul trains weighing 300 tons back of the tender from Hammonton to Drawbridge, 27.4 miles, at an average speed of 75 miles per hour. Objection was raised, however, to the fact that, as the cab was placed over the middle of the boiler, the engineman and fireman were separated; and after various experiments with blocking off portions of the grates, a revised design (Class E1a) with a firebox 66 inches wide, and the cab at the rear, was prepared in 1900, and one locomotive was built and given a series of thorough trials. The result was the designing, in 1901, of Class E2, which was generally similar to Class E1a, but had a grate 6 inches wider, with a larger number of tubes, thus increasing the total heating surface from 2,429 to 2,640 square feet. The fireboxes of both Classes E1a and E2 were radially stayed, but the latter class carried a steam pressure of 205 pounds as against 185 in the earlier Atlantic type locomotives. The cylinder dimensions (20½ x 26 inches) and the driving wheel diameter (80 inches) of Class E1 were retained in Classes E1a and E2, as were also those features of the machinery which had proved so successful in Class E1. Instead of the rigid trailing wheels of Class E1, however, a two-wheeled radial trailing truck was employed in Classes E1a and E2. This truck was placed under the extreme rear end of the locomotive, and was equalized with the drivers on each side, by means of two short beams with a half-elliptic spring placed between them.

Class E2 proved highly successful, not only on the Seashore lines, but also on the



Atlantic Type Locomotive, Class E2, built at Altoona, 1901

Cylinders	20½″ x 26″	Tubes, diam.	2″	Wheel base, driving	7′ 5″	Weight, total engine	186,480 lb
Drivers, diam.	80″	" number	315	" " total engine	30′ 9½″	" " " and tender	320,500 lb.
Boiler, inside diam.	65 5/16″	" length	15′ 0″	" " " " and tender	60′ 6 7/8″	Tank capacity	5,500 U. S. gal.
Steam pressure	205 lb.	Grate area	55.5 sq. ft.	Weight on drivers	118,280 lb.	Fuel "	25,000 lb.
Firebox	111″ x 72″	Heating surface	2,640 sq. ft.			Tractive force	23,800 lb.

New York Division and the more level sections of the Main Line. For service on the heavy grades of the Pittsburgh Division, a new Class (E3) was designed, having cylinders 22 inches in diameter, but otherwise practically a duplicate of Class E2. In 1902 the designs of Classes E2 and E3 were revised to include Belpaire boilers; and with this change they became known as Classes E2a and E3a respectively. The excellent track conditions on the Pennsylvania made it possible to safely carry a load of 60,000 pounds per pair of drivers, so that these locomotives were enabled to do work the equivalent of which, on many other roads, required six-coupled locomotives.

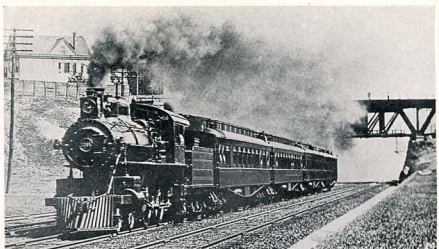


Photo furnished by C. B. Chaney. Original by F. W. Blauvelt

The Pennsylvania Special in 1902
Hauled by Class D16a Locomotive No. 1395

These locomotives were developed during the administration of W. W. Atterbury, now Vice-President in Charge of Operation, who served as General Superintendent of Motive Power of the Lines East from October 1, 1901, to January 1, 1903. He was succeeded on the latter date by Alfred W. Gibbs.

On June 15, 1902, a new train known as the Pennsylvania Special was placed in service between New York and Chicago, and was timed to make the run between the two cities, in each direction, in 20 hours. This was a comparatively light train, usually made up of four cars, and it was successfully handled, on the more level sections of the line, by American type locomotives of the Class D16 group. It made an excellent record for punctuality, but on account of severe freight congestion was withdrawn February 1, 1903.

In 1904 the Motive Power Department designed and installed a locomotive testing plant which was, at that time, the most complete in existence and has yet to be outclassed. This plant was first erected in the



Cylinders	22″ x 26″
Drivers, diam.	80″
Steam pressure	205 lb.
Grate area	55.5 sq. ft.
Heating surface	2,640 sq. ft.
Weight on drivers	118,400 lb.
Weight, total engine	190,600 lb.
Tractive force	27,410 lb.

Atlantic Type Locomotive, Class E3a, built at Altoona, 1902



Cylinders	14 ½″ & 23½″ x 25 ½″
Drivers, diam.	80 ½″
Steam pressure	227.5 lb.
Grate area	33.4 sq. ft.
Heating surface	2,576 sq. ft.
Weight on drivers	87,850 lb.
Weight, total engine	164,000 lb.
Tractive force	19,560 lb.

Balanced Compound Atlantic Type Locomotive, de Glehn System, built by the Societe Alsacienne de Constructions Mecaniques, Belfort, France, 1904

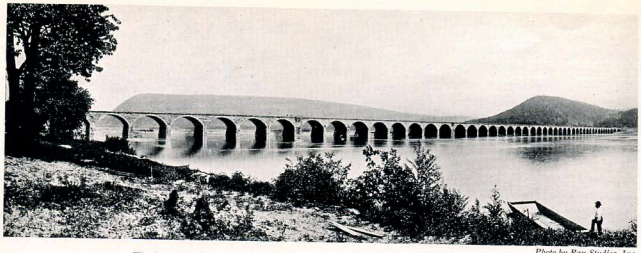


Photo by Rau Studios, Inc.

The Stone Arch Bridge across the Susquehanna at Rockville, Pa., completed in 1902

This bridge replaced the iron truss illustrated in Part II of this article. It is composed of 48 arches, is 3,830 feet long, 52 feet wide, carries four tracks and contains 440,000,000 pounds of stone.

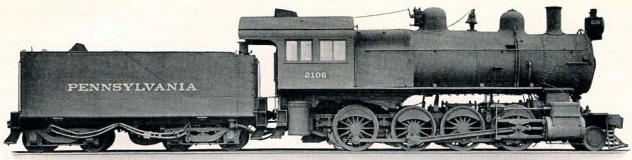
Transportation Building, as part of the Pennsylvania's exhibit, at the Louisiana Purchase Exposition, which was held at St. Louis during that year. It was subsequently removed to Altoona, and housed in a building specially designed for the purpose; and the results of the tests made on the plant have been of exceptional value, and have, to a material extent, influenced motive power development during recent years. The first of such tests were made while the plant was installed at St. Louis, and among the locomotives there tested was a balanced compound of the de Glehn type, which had been built in France and purchased by the Pennsylvania for experimental purposes. This locomotive was of the Atlantic (4-4-2) type, equipped with Walschaerts valve gear, and represented a high standard of design and workmanship. Valuable results were obtained from experiments conducted with it, but it lacked the capacity required for work in this country, and in 1912 was withdrawn from service.

Experience with this engine, however, prompted the Pennsylvania to extend its experiments with balanced compounds; and in 1905 the road purchased four balanced compound Atlantic type locomotives from American builders—two from the American Locomotive Company and two from The Baldwin Locomotive Works. One of each of these locomotives was placed in service east of Pittsburgh, and one on the lines west of that point. As shown by the illustration on this page of one of the Baldwin engines, the designs of these compounds were based on that of Class E3a. In the Baldwin design, all four cylinders were placed in line under the smokebox; and to permit the inside (high pressure) cylinders to drive on the leading coupled axle, the distance between that axle and the front truck was materially increased. The outside (low pressure) cylinders were connected to the rear pair of drivers. The short beams and springs between the rear drivers and trailers were replaced by a single long beam, on each side, which simplified the arrangement of the spring rigging. This plan was used on a large number of single expansion Atlantic type locomotives subsequently built at Altoona.

Cylinders	16″ & 27″ x 26″
Drivers, diam.	80″
Steam pressure	205 lb.
Grate area	55.5 sq. ft.
Heating surface	2,869 sq. ft.
Weight on drivers	127,000 lb.
Weight, total engine	204,000 lb.
Tractive force	23,500 lb.



Balanced Compound Atlantic Type Locomotive, Class E2S, built by The Baldwin Locomotive Works, 1905



Consolidation Type Locomotive, Class H6a, built by The Baldwin Locomotive Works, 1902

Cylinders	22″ x 28″	Tubes, diam.	2″	Wheel base, driving	16′ 6½″	Weight, total engine	194,500 lb.
Drivers, diam.	56″	" number	373	" " total engine	24′ 9″	" " " and	
Boiler, inside diam.	69½″	" length	13′ 8½″	" " " and		tender	342,000 lb.
Steam pressure	205 lb.	Grate area	49 sq. ft.	tender	58′ 1¾″	Tank capacity	7,000 U. S. gal.
Firebox	107″ x 66″	Heating surface	2,844 sq. ft.	Weight on drivers	175,700 lb.	Fuel "	27,000 lb.
						Tractive force	42,170 lb.

While the Atlantic type was thus being developed for fast passenger service, steady progress was being made in freight locomotive development. The Class H6 Consolidation type locomotives, with their long narrow grates, were proving difficult to fire; and the success of the wide firebox in passenger service led to its application to the Consolidation type in 1901, when two locomotives, designated as Class H6a, were built by The Baldwin Locomotive Works. In this design the firebox was placed over the rear drivers, and the grate area, as compared with Class H6, was increased from 33.3 to 49 square feet, or 47 per cent; while at the same time the length of the firebox was reduced from 120 to 107 inches. These locomotives showed marked improvement in steaming and fuel economy, and proved so successful that during the years 1902 to 1905 The Baldwin Locomotive Works built a total of 1,017 Class H6a locomotives for the Pennsylvania System, in addition to a large number which were built at Altoona. These locomotives were widely distributed, handling heavy freight traffic not only in the Allegheny Mountain districts, but also on the low grade divisions of the Main Line.



Cylinders	22″ x 28″
Drivers, diam.	56″
Steam pressure	205 lb.
Grate area	49 sq. ft.
Heating surface	2,844 sq. ft.
Weight on drivers	178,700 lb.
" total engine	200,700 lb.
Tractive force	42,170 lb.

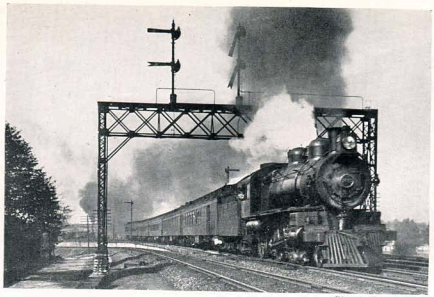
Consolidation Type Locomotive, Class H6b, built by The Baldwin Locomotive Works, 1905

In 1904 the Walschaerts valve gear was applied to the first American-built Mallet

Cylinders	20″ x 28″
Drivers, diam.	62″
Steam pressure	205 lb.
Grate area	47.1 sq. ft.
Heating surface	2,469 sq. ft.
Weight on drivers	142,900 lb.
" total engine	165,900 lb.
Tractive force	31,480 lb.



Mogul Type Locomotive, Class F3c, built by The Baldwin Locomotive Works, 1902



The Pennsylvania Special in 1906
Hauled by Class E3a Locomotive No. 1610

Photo by John S. Powell

locomotive, which was constructed during that year by the American Locomotive Company, for the Baltimore and Ohio Railroad. The advantages of this gear, especially from a structural point of view, became at once apparent; and in the following year it was adopted by a number of railroads, notably the Pennsylvania. It was first applied to ten Consolidation type locomotives, completed by The Baldwin Locomotive Works during June, 1905. These locomotives, designated as Class H6b, were equipped with piston valves and Walschaerts gear, but were in all other respects like Class H6a. Service results at once showed the great maintenance superiority of the new valve motion; and it was decided to apply it to a large number of Consolidation type locomotives then on order. A record breaking traffic was at that time taxing the facilities of the railroads, and the Altoona Shops and The Baldwin Locomotive Works were exerting every effort to meet the motive power demands of the Pennsylvania. Between October 10 and November 22, 1905, the Baldwin Plant turned out 160 Class H6b locomotives; and built, during the years 1905 to 1907, a total of 423 of these locomotives for the Pennsylvania System. One of them is illustrated on page 57.

These locomotives were equipped with piston valves 12 inches in diameter, and the steam chest centers were placed outside the cylinder centers in order to enable all parts of the gear to be located in the same vertical plane. This simplified the gear design, and eliminated twisting and bending strains as far as possible.

While the Consolidation type was thus being developed for heavy freight service, the Mogul (2-6-0) type was being built for fast freight work. The original Class F1 design, previously described, had been revised by enlarging the boiler and increasing the steam pressure. This new Class (F3) appeared in 1901. It was subsequently modified to include a wide firebox, radially stayed boiler (Class F3b), and this was in turn replaced by a wide firebox Belpaire boiler (Class F3c).

These locomotives all had slide valves and Stephenson link motion, and a total of 163 engines, representing these three classes, were built by The Baldwin Locomotive Works during the years 1901–1903. A locomotive of Class F3c is illustrated on page 57.

On June 11, 1905, the Pennsylvania Special, which had been withdrawn over two years previously, was re-established, and placed on an 18-hour schedule between



The Broadway Limited of Today
Hauled by Class K4s Locomotive No. 3881

Photo by John S. Powell

New York and Chicago, in both directions. This necessitated an average speed, including stops, of 50.2 miles per hour. The running time for the first 189 miles, from Jersey City to Harrisburg, was 196 minutes, representing an average speed of 57.8 miles per hour, with one intermediate stop. This fast time was successfully maintained with an excellent record for punctuality, until November 24, 1912, when the schedule was increased to 20 hours, and the name of the train changed to Broadway Limited. On December 1, 1917, under stress of exceptionally heavy traffic conditions, the train was withdrawn by order of the War Board; but on May 25, 1919, it was restored on a 20-hour schedule, and continues to operate as one of the most popular trains on the System.



Cylinders	22" x 26"
Drivers, diam.	80"
Steam pressure	205 lb.
Grate area	55.5 sq. ft.
Heating surface	2,640 sq. ft.
Weight on drivers	122,900 lb.
" total engine	190,400 lb.
Tractive force	27,410 lb.

Atlantic Type Locomotive, Class E3d, built at Altoona, 1906

The success of the Walschaerts valve gear on the Class H6b locomotives led to its application to the Atlantic type, and in 1906 Classes E2d and E3d were introduced. These locomotives were duplicates of Classes E2a and E3a respectively, except for the change in the valve gear and the fact that they had 12-inch piston valves instead of slide valves. The piston valves had a steam lap of $1\frac{5}{16}$ inches and were set with a maximum travel of 7 inches, or the same as that of the slide valves previously used. The gear was similar to that used on Class H6b, in that all parts of the motion were in the same vertical plane. Particular attention was given to removing all superfluous weight, and the result was a gear which was remarkably light for such a large locomotive.

In 1906, the weights of passenger trains between Pittsburgh and Chicago, on the Northwest System, had become so heavy that double-heading was frequently necessary in order to maintain schedules; and an experimental locomotive of the Pacific (4-6-2) type was purchased from the American Locomotive Company, in order to study the suitability of this type for the service requirements. The superheater had not yet become established in American locomotive practice, and this design represented practically the maximum capacity then obtainable in a fast passenger locomotive using saturated steam. The weight carried per pair of driving wheels averaged slightly more than 60,000 pounds, and the tractive force exerted was 32,620 pounds. The locomotive had a radially stayed, wide firebox, and the boiler proportions were most liberal throughout. This locomotive was thoroughly tested, hauling trains of twelve and more cars over an undulating profile having grades as steep as one per cent; and it demonstrated that suitably designed Pacific type locomotives could successfully meet the traffic requirements.



Photo by John S. Powell

Train No. 25, Metropolitan Express, in 1906
The leading locomotive is a Class E3a; the second, a Class E3d

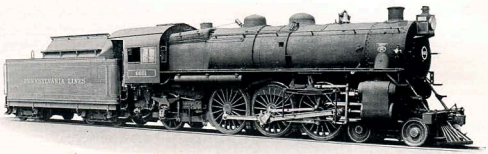
Following this experimental locomotive, a



Cylinders	24" x 26"
Drivers, diam.	80"
Steam pressure	205 lb.
Grate area	55.4 sq. ft.
Heating surface	4,629 sq. ft.
Weight on drivers	185,900 lb.
" total engine	278,800 lb.
Tractive force	32,620 lb.

Pacific Type Locomotive, Class K2, built at Altoona, 1911

new Pacific type designated as Class K2 was designed at Fort Wayne in 1910, and a large number were built at Altoona for service both east and west of Pittsburgh. In general dimensions Class K2 closely followed the experimental locomotive, but the design was modified to conform more nearly



Cylinders	26" x 26"
Drivers, diam.	80"
Steam pressure	205 lb.
Grate area	55.4 sq. ft.
Water heating surface	3,680 sq. ft.
Superheating surface	1,011 sq. ft.
Weight on drivers	193,000 lb.
" total engine	302,000 lb.
Tractive force	38,280 lb.

Pacific Type Locomotive, Class K3s, built by The Baldwin Locomotive Works, 1913

to the Pennsylvania standards, and a Belpaire firebox was applied. Subsequently, Class K2 was partially redesigned to use superheated steam; and in 1913, The Baldwin Locomotive Works built thirty superheated locomotives of the same general design, but with larger cylinders and mechanical stokers, for service west of Pittsburgh. These locomotives were designated as Class K3s; and one of them, bearing the Baldwin construction number 40,000, is illustrated on this page.

In this connection, reference should be made to the policy of the Pennsylvania regarding the use of superheated steam. The first locomotive on the System to be equipped with a superheater was Class K2 engine 7514, which was built at the Juniata Shops for the Lines West of Pittsburgh in 1910, and was superheated in 1911. The improvement effected was so marked that

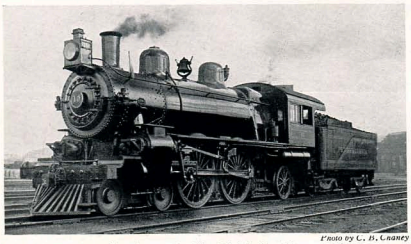


Photo by C. B. Cluney

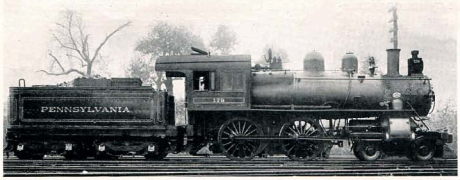
Atlantic Type Locomotive, Class E3sd, built at Altoona, 1908

Cylinders	22" x 26"
Drivers, diam.	80"
Steam pressure	205 lb.
Grate area	55.5 sq. ft.
Water heating surface	2,038 sq. ft.
Superheating surface	533 sq. ft.
Weight on drivers	127,200 lb.
" total engine	196,600 lb.
Tractive force	27,410 lb.

Originally built to use saturated steam (Class E3d)

the superheater was adopted as standard on the Lines East in April, 1912, and the following year it became standard on all locomotives built for the System.

In addition to applying superheaters to all new power, a comprehensive program



Cylinders	20½" x 26"
Drivers, diam.	68"
Steam pressure	175 lb.
Grate area	33.2 sq. ft.
Water heating surface	1,404 sq. ft.
Superheating surface	347 sq. ft.
Weight on drivers	98,500 lb.
" total engine	141,100 lb.
Tractive force	23,900 lb.

Originally built to use saturated steam (Class D16b)

American Type Locomotive, Class D16sb, built at Altoona, 1930

was adopted for superheating existing locomotives. This program covers the superheating of all power heavy enough to still be of value, excepting locomotives which, on account of their age or condition, are scheduled to be cut up in the comparatively near future. It is found that under favorable conditions the use of superheat effects an economy in steam consumption per horse-power-hour of approximately 30 per cent, and an increase in horse-power output, per locomotive unit, of 40 per cent. The improvement is most noticeable in the case of locomotives with relatively small boilers, such as classes E3d and G4. The American type locomotives of the D16 group have also been materially improved by the use of superheat. In rebuilding them, the original slide valve cylinders, which were 18½ inches in diameter, have been replaced by piston valve cylinders 20½ inches in diameter; and 68-inch drivers substituted for 80-inch drivers, where the latter size were previously used. As thus rebuilt, these locomotives have proved exceedingly efficient in local passenger service.

It is interesting to note that the adoption of the superheater was contemporary with a rapidly increasing use of steel passenger train equipment on the Pennsylvania System, and a consequent increase in the weights of all classes of passenger trains. The first steel coaches built by the Pennsylvania were placed in service in 1906, and in the following year steel equipment was adopted as standard for all new passenger train rolling stock, and the wooden equipment is being retired as rapidly as conditions permit. The extended use of steel equipment was hastened in 1907 and the years following because of the approaching completion of the New York Terminal and the tunnels under the Hudson River, through which, as a measure of safety, only steel rolling stock was to be handled. The completion of this

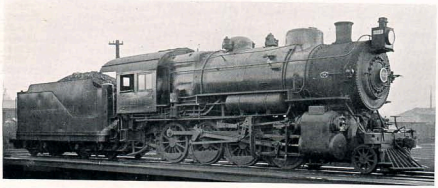


Photo by C. B. Chaney

A Class D16sb Locomotive in Local Passenger Service

terminal will be more fully discussed later in this article, when describing the Pennsylvania's electric locomotives, but it should be noted here that the use of superheated steam enabled the then-existing power to cope, for the time being, with the increased train weights resulting from the use of steel equipment.

The Class H6a and H6b locomotives continued the standard for heavy freight service until 1910, when the need for more powerful units again became apparent. Accordingly, Class H8 was designed, a Consolidation type which was a direct development of Class H6b, but of enlarged dimensions throughout. The cylinder diameter was increased 2 inches and the driving



Cylinders	24" x 28"
Drivers, diam.	62"
Steam pressure	205 lb.
Grate area	55.2 sq. ft.
Heating surface	3,842 sq. ft.
Weight on drivers	209,800 lb.
* total engine	242,000 lb.
Tractive force	45,330 lb.

Consolidation Type Locomotive, Class H8, built at Altoona, 1907

wheel diameter 6 inches. With the same steam pressure, this increased the starting tractive force by about 8 per cent, while the total weight of the locomotive was increased 20 per cent. The larger driving wheels and increased steaming capacity of Class H8, however, gave it a material advantage in point of speed; but tests with these locomotives demonstrated that if superheated steam were used, the boiler of Class H8 could supply larger cylinders and thus enable greater tractive force and horse-power to be developed without materially increasing the total weight of the locomotive. Accordingly in Class H9s, introduced in 1913, a superheater was installed and the cylinder diameter increased to 25 inches, thus raising the tractive force approximately 9 per cent with an increase in locomotive weight of less than 4 per cent. For service west of Pittsburgh a further step was taken, and Class H10s was developed with cylinders 26 inches in diameter, thus giving an increase of 17 per cent in tractive force as compared with Class H8 using saturated steam, but with no increase in boiler dimensions. Many of the Class H10s locomotives were equipped with the Crawford type of underfeed stoker.

The Class H9s and H10s locomotives represented the highest development of the Consolidation type as used on the Pennsylvania; and when in 1914 more powerful locomotives were required for freight service, the increased capacity was obtained by using the Mikado type, as will be subsequently described.

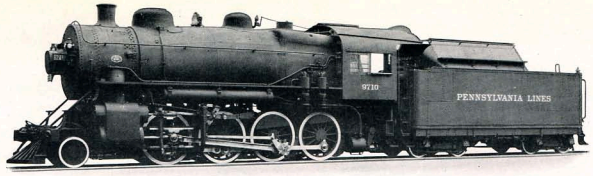
Cylinders	25" x 28"
Drivers, diam.	62"
Steam pressure	205 lb.
Grate area	55.2 sq. ft.
Water heating surface	3,066 sq. ft.
Superheating surface	781 sq. ft.
Weight on drivers	223,300 lb.
* total engine	251,000 lb.
Tractive force	49,180 lb.



Consolidation Type Locomotive, Class H9s, built by The Baldwin Locomotive Works, 1913

During the years 1910 to 1913, a total of 399 locomotives of the H8, H9 and H10 groups were built for the Pennsylvania System by The Baldwin Locomotive Works.

While these heavy Consolidations were being developed, several changes had taken place in the organization of the Motive Power Department. On July 1, 1911, Alfred W. Gibbs, who had served as General Superintendent of Motive Power of the Lines East since 1903, was appointed Chief



Consolidation Type Locomotive, Class H10s, built by The Baldwin Locomotive Works, 1915

Cylinders	26″ x 28″	Tubes, number	53½″, 36; 2″, 265	Wheel base, driving	17′ 01½″	Weight, total engine	247,500 lb.
Drivers, diam.	62″	" length	15′ 0″	" " total engine	25′ 01½″	" " " and	
Boiler, inside diam.	76¾″	Grate area	55.2 sq. ft.	" " " " and		tender	432,000 lb.
Steam pressure	205 lb.	Water heating surface	3,066 sq. ft.	tender	62′ 4⅞″	Tank capacity	8,000 U. S. gal.
Firebox	110½″ x 72″	Superheating surface	781 sq. ft.	Weight on drivers	223,000 lb.	Fuel "	34,600 lb.
Tubes, diam.	5½″ & 2″					Tractive force	53,200 lb.

Mechanical Engineer, with office at Philadelphia; and was succeeded by R. N. Durborow. Mr. Durborow died December 9, 1911, and was succeeded on January 1, 1912, by J. T. Wallis.

In the meantime an interesting step had been taken in the development of the Pennsylvania's passenger locomotives. Realizing that, with the possibility of carrying heavier wheel loads, the capacity of the Atlantic type could be increased beyond that attained in Class E 3d, an exceptionally heavy Atlantic type, Class E6, had been designed, and one locomotive built in 1910. This locomotive carried 133,300 pounds on driving wheels, developed a starting tractive force of 27,410 pounds, and had a boiler generally similar in design and dimensions to that used on the Class H8 Consolidation type locomotives. It was put through a series of severe tests, not only on the plant, but also on the road between Fort Wayne and Valparaiso, Indiana, where it was pitted against both saturated and superheated Pacific type locomotives, and showed remarkable power and speed capacity. These tests were conducted in September, 1911, the length of the run being 105 miles. The locomotive handled a nine-car train, start to stop, at an average speed of 75.31 miles per hour, and averaged 66.6 miles per hour with 13 cars and 58.05 miles per hour with 15 cars. On a previous occasion, with a light special train of three cars, this locomotive had maintained an average speed of 67.4 miles per hour from Altoona to Philadelphia, 235 miles, deducting three minutes for a stop at Harrisburg. The average speed from Altoona to Harrisburg was 69.6 miles per hour, while from Harrisburg to OB tower, a distance of 98.8 miles, it was 68.1 miles per hour.

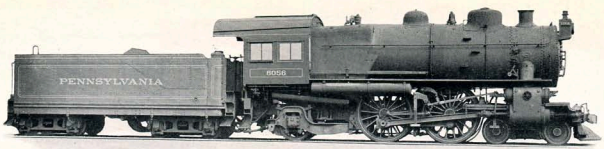
The Fort Wayne-Valparaiso tests proved that Class E6 was equal to the Class K2 Pacific type locomotives, at 40 miles per hour, and that at higher speeds it developed more draw-bar pull than Class K2 and hence, with the same train, could develop higher speed. Later it was found that the same relations existed when both locomotives used superheated steam.

In 1912 the Class E6 locomotive was partially rebuilt and equipped with a superheater, and two other heavy superheated

Cylinders	22″ x 26″
Drivers, diam.	80″
Steam pressure	205 lb.
Grate area	55.1 sq. ft.
Heating surface	3,582 sq. ft.
Weight on drivers	133,300 lb.
" total engine	231,500 lb.
Tractive force	27,410 lb.



Atlantic Type Locomotive, Class E6, built at Altoona, 1910



Atlantic Type Locomotive, Class E6s, built at Altoona, 1914

Cylinders	23½" x 26"	Tubes, number	5½", 36; 2", 242	Wheel base, driving	7' 5"	Weight, total engine	243,600 lb.
Drivers, diam.	80"	" length	15' 0"	" " total engine	29' 7½"	" " " and	
Boiler, inside diam.	76¾"	Grate area	55.1 sq. ft.	" " " " and		tender	403,000 lb.
Steam pressure	205 lb.	Water heating surface	2,892 sq. ft.	tender	63' 10½"	Tank capacity	7,000 U. S. gal.
Firebox	110⅝" x 72"	Superheating surface	806 sq. ft.	Weight on drivers	136,000 lb.	Fuel "	25,000 lb.
Tubes, diam.	5½" & 2"					Tractive force	31,275 lb.

Atlantic type locomotives were constructed, one of which was equipped with rotary valves. Early in 1913 these three locomotives were partially rebuilt and their original cylinders, which were 22 x 26 inches, were replaced by new cylinders 23½ x 26 inches in size, thus raising the tractive force to 31,275 pounds. Subsequently 80 of these locomotives, designated as Class E6s, were built at Altoona, and they proved an unqualified success in handling some of the most difficult fast passenger traffic on the System. This success was chiefly due to the exceptionally thorough care with which the design had been developed.

The aim and object sought in developing Class E6s was to obtain maximum power output in proportion to locomotive weight, and with a minimum consumption of fuel and water. That this was accomplished is evident from the fact that, on the testing plant, one of these locomotives developed a maximum of 2,488 indicated horse-power, or one horse-power for each 96.5 pounds of locomotive weight. At a cut-off of 15 per cent and a speed of 240 revolutions per minute, this same locomotive developed a horse-power-hour on 2.0 pounds of dry coal and 17.6 pounds of steam.

Class E6s was especially notable because of the light weight of its machinery, in which heat treated steel was largely used. Even the piston rod was hollow bored, and the piston was a steel casting, weighing complete, with rod and key, 402½ pounds. The cross-head worked in a three-bar guide, and was generally similar to that introduced on the Class D14a locomotives built in 1894. Reversing was effected by a screw gear, which was easier to handle than a lever, and saved space in the cab. A novel equalization system was used, as the front truck and leading drivers were equalized together by a central, longitudinal beam, while the rear drivers and trailing truck were separately equalized on each side of the locomotive. This arrangement provided increased flexibility and insured a correct distribution of weight between the front truck and the driving wheels under all conditions. Another interesting feature was the



Photo by C. B. Chaney

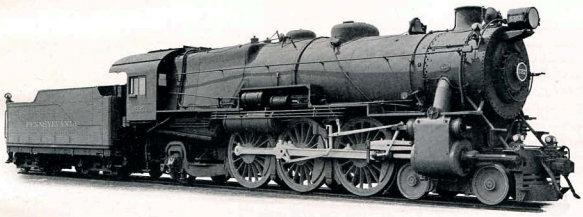
The "Congressional Limited," between New York and Washington, hauled by Class E6s Locomotive No. 737

rear truck, which was of the so-called KW type. In this design the truck frame itself, which was a one-piece steel casting, served as the rear equalizer also, and the main frames were supported directly upon it, by means of sliding bearings. This design of rear truck thereafter became standard on the Pennsylvania System, and it has also been applied, in somewhat modified form, to a large number of locomotives built for other roads.

The Class E6s locomotives were soon handling the most difficult high speed traffic on the New York and Seashore Divisions and also on the Main Line east of Altoona, proving nearly equal in starting capacity and superior at high speeds to the Class

an increase of 42 per cent as compared with Class E6s, and of 36 per cent as compared with Class K2s. On the testing plant this Class K4s locomotive developed a maximum of 3,184 indicated horse-power, and produced one indicated horse-power-hour on a minimum consumption of 1.52 pounds of dry coal and 14.96 pounds of superheated steam. One indicated horse-power was developed for each 97 pounds of total weight, so that in this respect the locomotive was very nearly as efficient as Class E6s.

The machinery and running gear details of Class K4s were closely similar to those of Class E6s, already described. In order to keep the boiler within the required limit of height and allow sufficient clearance



Pacific Type Locomotive, Class K4s, built at Altoona, 1924

Cylinders	27" x 28"	Tubes, number	5½", 40; 2¼", 236	Wheel base, driving	13' 10"	Weight, total engine	308,890 lb.
Drivers, diam.	80"	" length	19' 0"	" " total engine	36' 2"	" " " and	
Boiler, inside diam.	76⅝"	Grate area	70 sq. ft.	" " " " and		tender	468,000 lb.
Steam pressure	205 lb.	Water heating surface	4,050 sq. ft.	tender	71' 10"	Tank capacity	7,000 U. S. gal.
Firebox	126" x 80"	Superheating surface	1,215 sq. ft.	Weight on drivers	201,830 lb.	Fuel "	25,000 lb.
Tubes, diam.	5½" & 2¼"					Tractive force	44,460 lb.

K2s Pacific type locomotives. It soon became evident, however, that on the Pittsburgh Division a locomotive of materially greater power was needed, as it was frequently necessary to double-head heavy trains. Accordingly in 1914, a new Pacific type locomotive (Class K4s) was designed, and one locomotive was built at Altoona and put through a series of most exacting tests. Those features of Class E6s which had been largely responsible for its success were incorporated in this locomotive, which was, in fact, practically an E6s lengthened out sufficiently to accommodate a third pair of drivers, the cylinders being enlarged from 23½ x 26 inches to 27 x 28 inches and the boiler dimensions increased to suit. This raised the tractive force to 44,460 pounds,

above the rear drivers, the firebox throat and lower half of the rear barrel course were flanged out of a single plate. This eliminated the usual throat seam. In a similar manner, the upper half of the rear barrel course was flanged to form the hip joints for the Belpaire firebox connection. This work, requiring the use of specially designed dies, was successfully accomplished at the Juniata Shops.

After the original Class K4s locomotive had been thoroughly tested both on the plant and the road, it was duplicated in large numbers; and it is now the standard express passenger locomotive of the System. Its speed capacity is sufficient for any of the schedules now being operated, and on low grade divisions it can handle the heaviest



Photo by C. B. Chaney

Train No. 25, Metropolitan Express, ascending the Allegheny Grade with three Class K4s Locomotives

trains without assistance. The fact that these locomotives have been built during a period of ten years with changes in minor details only, is sure proof of the correctness of the original design. The most important change made is the substitution, in the locomotives built during 1923 and the following year, of a power reverse gear for the screw reverse formerly used.

Contemporary with Class K4s was a Mikado type locomotive, Class L1s, for heavy freight service. These two classes were in many respects similar, the boilers being alike, and interchangeable details being used wherever practicable. As compared with the Class H9s Consolidation type locomotives, Class L1s showed an increase in maximum tractive force of 25 per cent and in total weight of 30 per cent. Class L1s had higher steaming capacity in proportion to adhesion, and apart from its increased starting tractive force, proved far better qualified to handle heavy tonnage trains on long, hard pulls. As with Classes E6s and K4s, particular care was taken with the design of the machinery in order to reduce

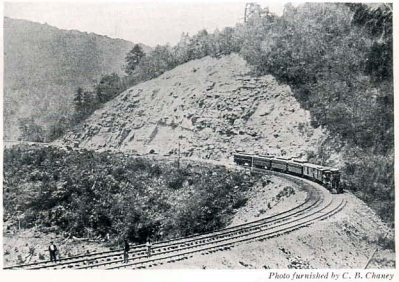


Photo furnished by C. B. Chaney

The Horse-Shoe Curve, Pittsburgh Division, in 1870



Photo by C. B. Chaney

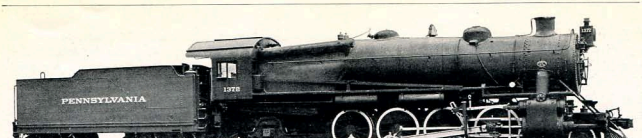
The Horse-Shoe Curve Today

The train is the Pennsylvania Limited, No. 2, composed of 12 cars, and hauled by two Class K4s Locomotives

the weight to a minimum. The driving axles, crank pins and piston rods were heat treated and hollow bored, and the main and side rods were also heat treated. The design throughout showed unusual refinement for a heavy freight locomotive.

In addition to 369 Class L1s locomotives which were built at Altoona, The Baldwin Locomotive Works built 205 locomotives of this class during the years 1915–1917.

Late in 1916, an experimental Decapod (2-10-0)



Mikado Type Locomotive, Class I1s, built by The Baldwin Locomotive Works, 1918

Cylinders	27" x 30"	Tubes, number	51½", 40; 2¼", 236	Wheel base, driving	17' 0½"	Weight, total engine	320,700 lb.
Drivers, diam.	62"	" length	19' 0"	" " total engine	36' 4½"	" " " and	
Boiler, inside diam.	76¾"	Grate area	70 sq. ft.	" " " " and		tender	503,000 lb.
Steam pressure	205 lb.	Water heating surface	4,050 sq. ft.	tender	73' 3½"	Tank capacity	9,000 U. S. gal.
Firebox	126" x 80"	Superheating surface	1,215 sq. ft.	Weight on drivers	240,200 lb.	Fuel "	35,000 lb.
Tubes, diam.	5½" & 2¼"					Tractive force	61,470 lb.

type locomotive, designated Class I1s, was built at the Juniata Shops, Altoona, and placed in heavy freight service. The object sought was to produce a locomotive of approximately 25 per cent greater capacity than the Class L1s Mikados, and to materially improve the efficiency, especially when working at slow speeds. In order to effect this, Class I1s was designed to develop its maximum tractive force when cutting off at 50 per cent of the stroke. Tests on the Altoona Plant demonstrated that, as a result of this, the steam consumption of Class I1s, when working in full gear at a speed of 7 miles per hour, was only 19.5 pounds per horse-power-hour as compared with 31.5 pounds for Class L1s under similar conditions. The indicated horsepowers developed by the two locomotives at this speed were respectively 1,740 and 1,230, representing an increase in power output of 41 per cent for Class I1s with a decrease of 12 per cent in actual steam consumption. The minimum steam consumption of Class I1s was 14.9 pounds per horse-power-hour, and a maximum of 3,486 indicated horsepower was developed at a speed of 25.3 miles per hour, on a steam consumption of 16.6 pounds.

After this first locomotive had been thoroughly tried out and its efficiency demonstrated, 123 locomotives of this class were built at the Juniata Shops and placed in service on the Pittsburgh Division. These were followed, during the years 1922 and 1923, by 475 more, which were built by The Baldwin Locomotive Works. These Baldwin engines were based directly on the original design, with such modifications in equipment as experience with the previous locomotives had proved desirable.

In order to develop tractive force in proportion to adhesion, Class I1s is built with large cylinders (30½ x 32 inches) and carries a boiler pressure of 250 pounds. The piston valves are 12 inches in diameter, have a steam lap of 2 inches, and are set with a travel of 6 inches when working in



Decapod Type Locomotive, Class I1s, built by The Baldwin Locomotive Works, 1922

Cylinders	30½" x 32"	Tubes, number	3¼", 200; 2¼", 114	Wheel base, driving	22' 8"	Weight, total engine	386,100 lb.
Drivers, diam.	62"	" length	19' 0"	" " total engine	32' 2"	" " " and	
Boiler, inside diam.	82"	Grate area	69.9 sq. ft.	" " " " and		tender	582,000 lb.
Steam pressure	250 lb.	Water heating surface	4,808 sq. ft.	tender	73' 0½"	Tank capacity	9,000 U. S. gal.
Firebox	126" x 79 ¾"	Superheating surface	2,283 sq. ft.	Weight on drivers	352,500 lb.	Fuel "	35,000 lb.
Tubes, diam.	3¼" & 2¼"					Tractive force	90,000 lb.

full gear. With such a long lap, there are certain positions of the pistons in which it would be difficult to start the locomotive. To obviate this, two auxiliary ports, measuring 1½ x ⅛ inches, are cut in each steam chest bushing, and are so located that the steam lap of the valve, with reference to them, is ¼ inch. These ports admit a sufficient quantity of steam to start the locomotive with the cranks in any position, but after starting, the amount of steam admitted through them is not sufficient to appreciably affect the shape of the indicator card.

The guides and crossheads of these locomotives deserve special mention. The crosshead is a one-piece steel casting of the under-



A Class I1s Locomotive in Service on the Pittsburgh Division

hung type. Each guide consists of two forgings which are bolted together longitudinally, and each forging is machined with two internally projecting horizontal ribs, which fit into corresponding channels in the crosshead. The bearing surfaces of the latter are tinned. This arrangement is a development of the Vogt guide, first applied to the Class D14a locomotives of 1894. In this case, the double longitudinal ribs are used to provide sufficient bearing area when backing up.

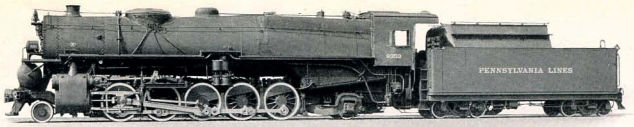
The main and side rods of Class I1s are of heat treated steel, and the piston rods, crosshead pins, crank pins and driving axles, are of the same material, hollow bored. The valve gear is of the Walschaerts type, controlled by a power reverse mechanism. Flanged tires are used on the front and rear drivers only, the three middle pairs having plain tires.

The boiler is in many respects similar to that used on the L1s Mikado type and K4s Pacific type locomotives, and the same ingenious arrangement of flanging the throat sheet in one piece with the lower half of the rear barrel ring, and the hip joints in one piece with the upper half, is used. The firebox has a combustion chamber, and the tubes are 19 feet long, or the same length as used in the Class L1s Mikado type locomotives. The boiler accessories include a mechanical stoker and a feed-water heater.

The Class I1s locomotives have now practically become the standard for heavy freight service on the Pennsylvania. They are giving excellent results, not only on the mountain divisions of the System, but also on comparatively level divisions where heavy drags are handled. Their speed capacity is equal to that of the Class L1s locomotives, and they can, if desired, be used in fast freight service.

For handling heavy coal and ore traffic on the Lines West of Pittsburgh, there were placed in service, in 1918 and 1919, two classes of 2-10-2 type locomotives, designated respectively as N1s and N2s. Class N1s was designed at Fort Wayne, and 35 of these locomotives were built by the American Locomotive Company and 25 by The Baldwin Locomotive Works. These are among the most powerful locomotives of their type in service, as they develop a tractive force of 84,800 pounds and weigh in working order, 439,100 pounds, with 352,300 pounds on drivers. In heavy ore traffic between Ashtabula, Ohio, and Conway Yard, near Pittsburgh, Pa., they handle 85 loaded ore cars, rated at 7,100 adjusted tons, or approximately 6,000 actual tons, over grades of 0.3 per cent.

These locomotives are designed to traverse curves as sharp as 23 degrees, and to facilitate this, lateral motion boxes are used on the first and fifth driving axles. All the tires are flanged, with the exception of those on the main drivers. An unusual feature is the arrangement of the equalization. The front truck and first pair of drivers are



2-10-2 Type Locomotive, Class N1s, built by The Baldwin Locomotive Works, 1919

Cylinders	30" x 32"	Tubes, number	51½", 54; 2½", 196	Wheel base, driving	22' 2"	Weight, total engine	435,000 lb.
Drivers, diam.	62"	" length	20' 10¾"	" " total engine	41' 11½"	" " " and	
Boiler, inside diam.	88¾"	Grate area	79.9 sq. ft.	" " " and		tender	642,000 lb.
Steam pressure	215 lb.	Water heating surface	4,721 sq. ft.	tender	82' 9¼"	Tank capacity	10,000 U. S. gal.
Firebox	143¼" x 80"	Superheating surface	1,749 sq. ft.	Weight on drivers	351,000 lb.	Fuel "	40,000 lb.
Tubes, diam.	5½" & 2½"					Tractive force	84,890 lb.

equalized by a beam placed on the center line; the three intermediate pairs of drivers are equalized together on each side, and the rear drivers are equalized with the trailing truck. The equalization system is thus broken at two points, instead of one, as is the usual practice in locomotives of this type.

Locomotive Works, were assigned to the Lines West of Pittsburgh.

In connection with these heavy road engines, reference should be made to a number of Mallet articulated locomotives, which, from time to time, have been placed in service on the Pennsylvania System. In

Cylinders	30" x 32"
Drivers, diam.	63"
Steam pressure	190 lb.
Grate area	88.3 sq. ft.
Water heating surface	5,145 sq. ft.
Superheating surface	1,569 sq. ft.
Weight on drivers	293,000 lb.
" total engine	380,000 lb.
Tractive force	73,830 lb.



2-10-2 Type Locomotive, Class N2s, built by The Baldwin Locomotive Works, 1919

The boiler is of the wagon top type with Belpaire firebox, and the maximum outside diameter is 99 inches. When built, the safety valves were set at 215 pounds, but the boiler is so designed that a pressure of 250 pounds can be safely carried. This boiler has a combustion chamber 5 feet long, so that ample firebox volume is provided. It is fired by a mechanical stoker.

The Class N2s locomotives, to which reference has been made, were of the standard heavy 2-10-2 type as built for the United States Railroad Administration. Thirty of these locomotives built by The Baldwin

1912, two such locomotives were purchased for experimental purposes. One of these was a compound of the 0-8-8-0 type, built by The Baldwin Locomotive Works; while the other, which was built by the American Locomotive Company, was of the 2-8-8-2 type, using high pressure steam in all four cylinders. Both were equipped with superheaters, and were tried out in heavy pushing service on the Allegheny Mountain grades. These designs were never duplicated, but in 1919 ten heavy compounds of the 0-8-8-0 type were built by The Baldwin Locomotive Works for heavy pushing and hump yard



Cylinders	25" & 39" x 30"
Drivers, diam.	56"
Steam pressure	205 lb.
Grate area	78 sq. ft.
Water heating surface	4,911 sq. ft.
Superheating surface	1,263 sq. ft.
Weight, total engine	408,700 lb.
Tractive force	82,800 lb.

Mallet Articulated Compound Locomotive, Class CC1s, built by The Baldwin Locomotive Works, 1912



Cylinders	26" & 40" x 28"
Drivers, diam.	51"
Steam pressure	225 lb.
Grate area	96 sq. ft.
Water heating surface	4,911 sq. ft.
Superheating surface	1,263 sq. ft.
Weight, total engine	458,150 lb.
Tractive force	99,700 lb.

Mallet Articulated Compound Locomotive, Class CC2s, built by The Baldwin Locomotive Works, 1919

service west of Pittsburgh, and a locomotive of the 2-8-8-0 type, designated as Class HC1s, was built at Altoona for road service with the intention, however, of first using it in pushing service on the Pittsburgh Division. The draw-bar pull is too great to handle trains not fully equipped with the strongest M. C. B. coupler, known as type D. This last named engine is of special interest because of its high capacity and the details of its construction.

Class HC1s was designed with a view of obtaining approximately the same degree of economy in fuel and water consumption as is realized by compounding, while avoiding the use of abnormally large cylinders and the consequent difficulty of exhausting large volumes of low pressure steam. To accomplish this, the same plan was adopted as in Class I1s, viz., cutting off the steam at half-stroke when developing full tractive force. With a steam pressure of 205 pounds, this requires cylinders 30½ by 32 inches in order to develop a maximum tractive force in proportion to adhesion.

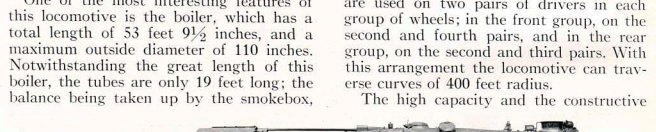
One of the most interesting features of this locomotive is the boiler, which has a total length of 53 feet 9½ inches, and a maximum outside diameter of 110 inches. Notwithstanding the great length of this boiler, the tubes are only 19 feet long; the balance being taken up by the smokebox, the 14-foot firebox and a barrel combustion chamber 11 feet 7¾ inches long. Owing to the great length of this combustion chamber, the throat sheet connection with the firebox is made with a fold or corrugation, in order to provide for expansion. Some exceedingly ingenious flanging work was required in the construction of this boiler, and the details throughout represent most skillful design and a high grade of workmanship.

There are two exhaust stands in the smokebox, one for each pair of cylinders; and each of these exhaust stands terminates in a double nozzle. In order to obtain a satisfactory ratio of stack diameter to length, four separate stacks, each 15 inches in diameter, are employed and are formed in one casting which, in external appearance, conforms to conventional lines. These stacks extend inside the smokebox, to a point 10 inches above the nozzle tips.

This locomotive is fired with a mechanical stoker, and is equipped with a hydro-pneumatic power reverse gear.

In order to facilitate curving, plain tires are used on two pairs of drivers in each group of wheels; in the front group, on the second and fourth pairs, and in the rear group, on the second and third pairs. With this arrangement the locomotive can traverse curves of 400 feet radius.

The high capacity and the constructive



Single Expansion Articulated Locomotive, Class HC1s, built at Altoona, 1919

Cylinders (4)	30½" x 32"	Tubes, number	334", 284; 234", 137	Wheel base, driving, each group	17' 11½"
Drivers, diam.	62"	" length	19' 0"	" " total engine	54' 8½"
Boiler, inside diam.	93¾"	Grate area	112 sq. ft.	" " " " and tender	97' 3¾"
Steam pressure	205 lb.	Water heating surface	6,652 sq. ft.	Weight on drivers	572,450 lb.
Firebox	168" x 96"	Superheating surface	2,914 sq. ft.	Weight, total engine	603,500 lb.
Tubes, diam.	334" & 234"			" " " and tender	814,000 lb.
				Tank capacity	13,000 U. S. gal.
				Fuel "	28,000 lb.
				Tractive force	135,000 lb.

details of this locomotive, stamp it as one of the most interesting designs in service at present. It has not thus far been duplicated, but it has done some excellent work on the Allegheny Mountain grades, and valuable operating data has been obtained as a result.

On February 1, 1919, Axel S. Vogt, whose valuable work as Mechanical Engineer has previously been referred to, retired under the pension regulations of the Company. He was succeeded by William F. Kiesel, Jr., who subsequently developed the designs of several notable classes of locomotives yet to be described.

Mr. Vogt, shortly after his retirement, entered the employ of The Baldwin Locomotive Works, serving in an advisory capacity in the Engineering Department. In this position he rendered valuable service until his death, which occurred on November 11, 1921.



Mountain Type Locomotive, Class M1, built at Altoona, 1923

Cylinders	27" x 30"	Tubes, number	314, 200; 2¼", 114	Wheel base, driving	18' 10"	Weight, total engine	383,100 lb.
Drivers, diam.	72"	" length	19' 6"	" " total engine	41' 0½"	" " and	
Boiler, inside diam.	82"	Grate area	70 sq. ft.	" " " and		tender	560,000 lb.
Steam pressure	250 lb.	Water heating surface	4,902 sq. ft.	tender	76' 7"	Tank capacity	7,700 U. S. gal.
Firebox	126" x 79⅜"	Superheating surface	2,283 sq. ft.	Weight on drivers	273,500 lb.	Fuel "	31,700 lb.
Tubes, diam.	3¼" & 2¼"					Tractive force	64,550 lb.

With the establishment of a regional organization, early in 1920, J. T. Wallis was appointed Chief of Motive Power, with jurisdiction over the entire System. In this broader field he has continued his direction of the development of the Pennsylvania's motive power to meet present and future traffic requirements.

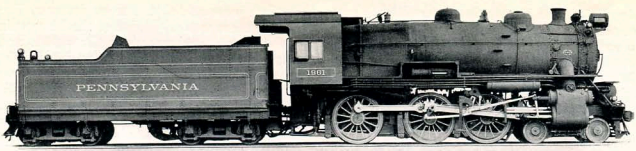
In the death of Alfred W. Gibbs, which occurred on May 19, 1922, the Motive Power Department lost one of the ablest of its officials. Mr. Gibbs took an active part in the development, not only of the steam locomotive, but also of the Pennsylvania's earlier electric locomotives, which will shortly be described.

In 1923 two new classes of passenger locomotives were added to the equipment. The first of these was an engine of the Mountain (4-8-2) type, designated as Class M1, and intended for heavy passenger or fast freight service. One locomotive of this class was built, with the idea of thoroughly trying it out before constructing additional units. This is one of the largest locomotives of its type thus far built, as it weighs, exclusive of tender, 383,100 pounds and develops a maximum tractive force of 64,550 pounds. The boiler pressure is 250 pounds, but the plan of cutting off at half stroke when developing full tractive force, which has proved so successful in Class I1s, is not used in this case; as the increase of weight of reciprocating parts required is not desirable in a high speed locomotive.

The details of construction of this engine in many respects follow those of the Decapod type locomotives. Especially is this true of the guides, crossheads, and other parts of the machinery. The boiler has a long combustion chamber and tubes of moderate length, and is of unusually high capacity for a passenger locomotive. The design is so worked out that a mechanical stoker can subsequently be applied, should this appear desirable.

This locomotive was subjected to a series of very thorough tests on the road and also on the stationary plant. The design is specially suitable for service on the Pittsburgh Division and on other parts of the System where heavy grades are encountered.

The second new design built in 1923 was a ten-wheeler (4-6-0 type), designated as Class G5s, and primarily intended for suburban



Passenger Locomotive, Class G5s, built at Altoona, 1923

Cylinders	24" x 28"	Tubes, number	5½", 36; 2", 242	Wheel base, driving	14' 3"	Weight, total engine	237,000 lb.
Drivers, diam.	68"	" length	15' 0"	" " total engine	26' 6"	" " " and	
Boiler, inside diam.	76¾"	Grate area	55 sq. ft.	" " " and		tender	413,800 lb.
Steam pressure	205 lb.	Water heating surface	2,862 sq. ft.	tender	62' 7¼"	Tank capacity	7,700 U. S. gal.
Firebox	110¼" x 72"	Superheating surface	798 sq. ft.	Weight on drivers	178,000 lb.	Fuel "	31,700 lb.
Tubes, diam.	5½" & 2"					Tractive force	41,330 lb.

passenger service. Forty of these locomotives were built at Altoona late in 1923, and fifty additional were turned out in 1924. These are among the largest locomotives of their type in use, and they are admirably fitted for heavy work where frequent stops must be made. With high starting tractive force and ample weight on drivers, they can accelerate trains rapidly, which is a first essential in suburban service. They are also being used, to a limited extent, for express passenger service where speeds are moderate and where the high steaming capacity of the Pacific type is not required. The details, throughout, closely follow those of other classes of locomotives designed by the Pennsylvania during the past few years, and Class G5s has already proved itself a most useful addition to the motive power equipment of the road.

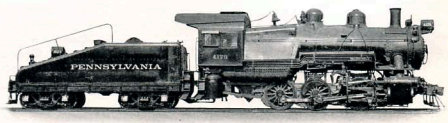
While, as has been described, the road engines were undergoing a consistent development, several notable designs of heavy switchers were placed in service. In 1902, a six-coupled switcher, weighing 170,000 pounds, and designated as Class B6, was built for the Lines West of Pittsburgh. This class continued to be built for some years, and 15 of these locomotives were constructed by The Baldwin Locomotive Works in 1913. The design subsequently underwent several modifications, the latest



Cylinders	22" x 24"
Drivers, diam.	56"
Steam pressure	205 lb.
Grate area	41.2 sq. ft.
Heating surface	2,495 sq. ft.
Weight, total engine	169,000 lb.
Tractive force	36,140 lb.

Six Coupled Switching Locomotive, Class B6, built by The Baldwin Locomotive Works, 1913

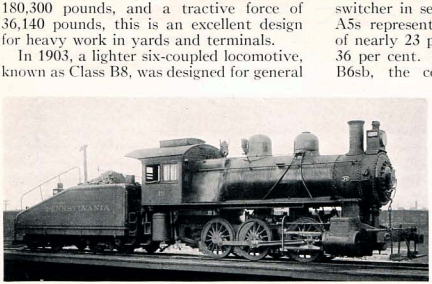
Cylinders	22" x 24"
Drivers, diam.	56"
Steam pressure	205 lb.
Grate area	61.6 sq. ft.
Water heating surface	1,907 sq. ft.
Superheating surface	464 sq. ft.
Weight, total engine	180,300 lb.
Tractive force	36,140 lb.



Six Coupled Switching Locomotive, Class B6sb, built at Altoona, 1924

being Class B6sb, which is now the standard heavy switcher on the System. These locomotives use superheated steam and have wide firebox boilers of the Belpaire type. With a total weight, all on drivers, of 180,300 pounds, and a tractive force of 36,140 pounds, this is an excellent design for heavy work in yards and terminals.

In 1903, a lighter six-coupled locomotive, known as Class B8, was designed for general



Cylinders	20" x 24"
Drivers, diam.	56"
Steam pressure	205 lb.
Grate area	31.6 sq. ft.
Heating surface	1,868 sq. ft.
Weight, total engine	143,450 lb.
Tractive force	29,870 lb.

Six Coupled Switching Locomotive, Class B8, built at Altoona, 1911

switching service on the Lines East. These locomotives have wide firebox, Belpaire boilers, slide valve cylinders and Stephenson link motion, and use saturated steam. They have done excellent work, but are somewhat handicapped because of their limited capacity. Sixty-two locomotives of this Class were built by The Baldwin Locomotive Works in 1905 and 1906.

For comparatively light work where curves

Cylinders	20" x 24"
Drivers, diam.	50"
Steam pressure	185 lb.
Grate area	38.3 sq. ft.
Water heating surface	1,009 sq. ft.
Superheating surface	219 sq. ft.
Weight, total engine	131,750 lb.
Tractive force	30,190 lb.

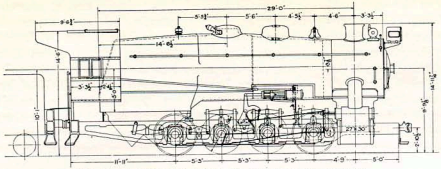


Four Coupled Switching Locomotive, Class A5s, built at Altoona, 1917

are sharp and clearances limited, there was designed in 1906, a locomotive of the 0-4-0 type, designated as Class A4. These locomotives weigh, exclusive of tender, 116,500 pounds and exert a tractive force of 25,830 pounds. In 1916 a new design, based on Class A4 and known as Class A5s, was built at Altoona. These locomotives are equipped with superheaters, and have larger cylinders and fireboxes than Class A4. With a weight of 131,750 pounds and a tractive force of 30,190 pounds they are among the most powerful locomotives of the 0-4-0 type in switcher in service previous to 1902, Class A5s represents an increase in total weight of nearly 23 per cent, and in tractive force 36 per cent. Comparing Classes B4a and B6sb, the corresponding figures are respectively 68 per cent and 54 per cent.

Designs have been prepared by Mr. Kiesel for a switcher of the 0-8-0 type, Class C1, which will weigh approximately 275,000 pounds. Following the principle of using a short cut-off which has worked out very satisfactorily in the case of Class I1s, this new switcher is designed to develop full tractive force when cutting off at 62½ per cent of the stroke. Its principal dimensions are shown on the diagram on page 74.

No discussion of the Pennsylvania's motive power would be complete without some account of the electrification thus far carried out, and the electric locomotives now in service. What has been accomplished is but the beginning of a comprehensive program which will ultimately include a large part of the mileage on the System.



Cylinders	27" x 30"
Drivers, diam.	56"
Steam pressure	250 lb.
Grate area	61.7 sq. ft.
Water heating surface	3,921 sq. ft.
Superheating surface	1,194 sq. ft.
Weight, total engine (estimated)	275,000 lb.

Eight Coupled Switching Locomotive, Class C1, designed in 1924

In this connection it should be noted that in 1906, the old West Jersey Railroad between Camden and Atlantic City was electrified, and has since been successfully operated on the multiple unit system. A similar system has handled the bulk of the suburban traffic on the Long Island Railroad, a subsidiary of the Pennsylvania, since 1905.

Early in the present century, it became evident that a complete reconstruction of the terminal facilities at New York would be necessary in order to provide for future traffic requirements. Under the guidance of President A. J. Cassatt, whose breadth of vision and rare judgment enabled him to fully comprehend the situation, plans were prepared for the construction of a terminal in the heart of New York City, to be connected with existing trackage in New Jersey by tunnels under the Hudson River, and with the Long Island by similar tunnels under the East River. All passenger traffic in the terminal district was to be electrically operated, and only steel equipment handled through the tunnels.

The franchise from the City of New York authorizing the construction of the tunnels and station, was granted October 9, 1902. Work on the tunnels was started June 10, 1903, and on the station May 1, 1904. The stone work was completed July 31, 1909, and the station was opened for business November 28, 1910.

In the meantime, the question as to what type of locomotive should be used was receiving most careful consideration. Three experimental locomotives were built, two of the double-truck type, and one of the 4-4-0 type. The latter, and one of the former, were arranged with quill drive, while the remaining double-truck locomotives had geared motors. Experience at that time indicated that certain types of electric locomotives produced severe lateral stresses on the track. In order to determine this point, tests were made on both a one-degree curve and tangent track, on the electrified section of the West Jersey and Seashore Railroad, near Franklinville, N. J. The section of track tested was laid with 80 specially designed recording ties, covering a distance of 165 feet. A device somewhat similar to that used in making Brinell tests was employed, whereby the lateral thrust against the rail caused a one-inch steel ball to make an impression on a piece of boiler plate. The three experi-

Drivers, diam.	72"
Wheel base, rigid	7' 5"
" total	55' 11"
Length overall	64' 11"
Weight on drivers	199,000 lb.
" total	313,000 lb.
Motors, number	2
" type	Westinghouse No. 315-A
Voltage	650 D. C.
Starting tractive force	66,000 lb.
Maximum horse-power	4,000



Photo by C. B. Chaney

Electric Locomotive for New York Terminal Passenger Service, Class DDI, built at Altoona, 1910
Fitted with Westinghouse Electrical Equipment

mental electric locomotives were tested at high speeds on this track, together with a double-truck Baldwin-Westinghouse locomotive built for the New York, New Haven and Hartford Railroad, and two Pennsylvania steam locomotives, a Class D16b (4-4-0 type) and a Class E2 (4-4-2 type). The two experimental double-truck locomotives showed the greatest amount of impact, one of them, in fact, putting kinks in the rail on tangent track. The 4-4-0 type proved the most satisfactory of the electric locomotives, giving results, as far as lateral thrust was concerned, comparable to those obtained with the steam locomotives.

As a result of these and other tests, the locomotives subsequently built for the New York Terminal service consisted of two semi-units, each of the 4-4-0 type, coupled together back to back. Each semi-unit has one Westinghouse direct current commutating-pole series type motor of 2,000 maximum horsepower, coupled through parallel rods and cranks to a jack-shaft which, in turn, is coupled to the drivers. The rated maximum tractive force of each complete locomotive is 66,000 pounds, but in service as high as 79,200 pounds has been registered.

The mechanical parts of these locomotives were built at Altoona, while the electrical equipment was furnished by the Westinghouse Electric and Manufacturing Company. The electric zone in which these locomotives are used extends from Manhattan Transfer, near Newark, N. J., where steam locomotives are detached from their trains, to the New York Terminal Station, a distance of 8.8 miles, and thence under the East River to the Sunnyside Yard on Long Island, where passenger cars are stored and trains are made up. The service is maintained by 33 locomotives. Trains of 14 cars, weighing 1,000 tons, have been successfully handled, and 850-ton trains are frequently started on the 1.93 per cent grades in the tunnels, by one locomotive.

During the first four years of service, these locomotives made the following record:

Miles run	3,974,746
Total engine failures	45
Total minutes detention	271
Miles per detention	88,328
Miles per minute detention	14,667

The cost of maintenance, during this period, averaged 7.2 cents per locomotive mile; while during the year May 1, 1915 to April 30, 1916, the maintenance cost approximated only 3.5 cents per locomotive mile. It would be difficult indeed, to find any other locomotives that could show an equally creditable record.

With the New York Terminal operating successfully, attention was next turned to Broad Street Station, Philadelphia, where relief from traffic congestion was becoming imperative. This is a terminal station with stub tracks, handling a very heavy suburban traffic, in addition to a large number of through trains which are run in and, to continue their journey, hauled out in reverse order by coupling a locomotive at the rear end. A study of the situation proved conclusively that, by electrifying the suburban traffic on the Main Line and the Chestnut Hill Branch, existing track and station facilities would be adequate for some years to come.



Train emerging from Hackensack Portal of Hudson River Tunnel

Conditions at the New York Terminal had made it advisable to use direct current, which was delivered to the locomotives from a third rail, at a tension of 650 volts. In the Philadelphia suburban zone, however, a careful study of the situation led to the use of alternating current delivered from an overhead wire at a tension of 11,000 volts. All-steel motor cars were built for this service, each

car being equipped with two 225-horsepower Westinghouse single phase air-blast-cooled motors mounted on one truck. Every car in the train is therefore self-propelling, but all are controlled, on the multiple-unit



A Multiple Unit Train in the Philadelphia Electrified Zone

system, by the motorman at the head end.

The electrification on the Main Line, extending as far as Paoli, 20 miles from Broad Street Station, was completed in 1915, and that to Chestnut Hill, 12 miles from Broad Street Station, in 1918. The Fort Washington Branch, 6.2 miles long, which joins the Chestnut Hill Branch at Allen Lane Station, was electrified early in 1924. The service on all these lines has proved an unqualified success.

In 1917, an electric freight locomotive of the 2-6-6-2 type, designated as Class FF1, was built for experimental purposes and placed in heavy freight and pushing service in the Philadelphia electrified zone. This locomotive is equipped with four Westinghouse three-phase motors, and can develop at the rail, 4000 horse-power continuously. In the event of electrifying the mountain section of the Pittsburgh Division, two of these locomotives could handle 3900 tons up the eastern slope of the Alleghenies, or 6300 tons up the western slope, at a speed of 20.6 miles per hour. This is undoubtedly the most powerful electric locomotive of any type yet to be built as a single unit.

The latest design of electric locomotive, which was placed in service early in 1924, is the result of an exceptionally careful study of the operating requirements, with a view of producing a design sufficiently flexible to be used, with only slight changes, in either passenger or freight service. Three locomotives have been built; one, designated Class L5, to use 25 cycle alternating current, received from an overhead wire at a tension of 11,000 volts, and two, designated Class L5a, to use 650-volt direct current received from a third rail. The first locomotive is being tried out in freight service in the Philadelphia zone, while the other two are in passenger service at New York. With the exception of certain features of the electrical equipment, these three locomotives are alike.

These locomotives are of the 2-4-4-2 type, the four pairs of drivers being held in the same rigid wheel base, but independently coupled in two groups of two pairs each. There are four single phase Westinghouse motors, two placed near each end of the locomotive. These motors will operate efficiently on either direct or alternating current, a fact which adds materially to the flexibility of the design. Each



Train No. 5, Pennsylvania Limited, passing through the Philadelphia Electrified Zone

pair of motors is geared to a jack-shaft, which is in turn coupled to the adjacent group of drivers.

The freight locomotive (Class L5) with a gear ratio of 30 to 118, develops a tractive force of 100,000 pounds at starting, of 59,000 pounds for one hour at a speed of



Electric Locomotive, Class FF1, built at Altoona, 1917
Fitted with Westinghouse Electrical Equipment

Drivers, diam.	72″	Weight on drivers	439,500 lb.	Motors, number	4
Wheel base, rigid	13′ 4″	" total	516,000 lb.	Voltage	11,000 A. C.
" " total	63′ 11″	Motors, type	Westinghouse 3-phase, No. 451	Tractive force, starting	140,000 lb.
Length overall	76′ 6¼″			Horse-power, maximum	7,640

21 miles per hour, and of 50,000 pounds continuously at a speed of 23 miles per hour. Corresponding figures for the passenger locomotive (Class L5a), geared 50 to 98, are 82,500 pounds at starting, 43,500 pounds for one hour at 35.9 miles per hour, and 37,000 pounds continuously at 37.8 miles per hour. The maximum service speed of this locomotive is 70 miles per hour.

The four pairs of driving wheels are compactly grouped on a rigid wheel base of 22 feet 3 inches, while the distance from the front or back driving wheels to the adjacent truck wheels is 16 feet 4 inches. The design of these trucks, which has been very carefully worked out, provides for a side swing of ten inches each way, with a maximum resistance of one-fourth the weight on the truck.

The frames consist of two end cradles, which carry the main motors, motor bearings, draft gear attachments, etc., and two intermediate or main frames, one on each side, extending over the driving pedestals. These main frames are exceptionally deep, their strength being sufficient to prevent springing, even when the pedestal caps are removed. The cab and superstructure are used for covering purposes only and do not contribute to the strength of the frame, hence they can be made of light material and are easily removable.

This type of locomotive has been worked out with the greatest care in all details, with a view to its future adoption as the standard electric motive power for road service on the Pennsylvania Railroad System. Its designing and construction thus contribute a most important step toward the goal of simplification and standardization of types, as all of these locomotives will be practically alike. The only variations required for different



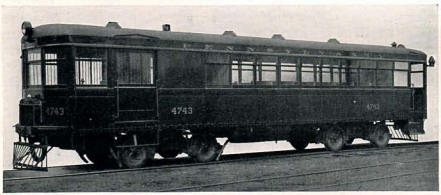
Electric Locomotive, Class L5, built at Altoona, 1924
Fitted with Westinghouse Electrical Equipment

Drivers, diam.	80″	Weight on drivers	308,600 lb.	Motors, number	4
Wheel base, rigid	22′ 3″	" total	408,600 lb.	Voltage	11,000 A. C.
" " total	54′ 11″	Motors, type		Tractive force, starting	100,000 lb.
Length overall	68′ 2½″		Westinghouse single-phase, No. 418	Horse-power, maximum	3,340

conditions of operation and current supply are found in the control apparatus and the gear ratios.

A lighter design of electric locomotive, similar in type but without trucks, will ultimately be built for switching service, so that all motive power requirements will be met. The entire electrification program is being prepared with characteristic Pennsylvania thoroughness, and with a view of providing the increased facilities which will surely be required in the future.

The Pennsylvania has in service a number of gasoline rail motor cars, which are being operated on branch lines where the traffic is too light to support steam service or warrant electrification. Results thus far indicate that these cars will prove successful and economical. One of them, built by the J. G. Brill Company of Philadelphia, is shown in an accompanying illustration. This car is 42 feet 8 inches in length, and weighs 30,000 pounds. It seats 38 persons in the passenger compartment, and has a baggage compartment 11 feet 3 inches in length, with emergency seats for eight additional persons. The engine is of the four cylinder, four cycle type, the cylinder dimensions being 4¾ x 6 inches.



Gasoline Rail Motor Car, built by J. G. Brill Company, 1923

On July 1, 1924, the total number of locomotives available for service on the Pennsylvania System was 7,556. These may be grouped according to service and type as follows:

Passenger Service

American (4–4–0) type	309
Atlantic (4–4–2) type	521
Ten-wheeled (4–6–0) type	164
Pacific (4–6–2) type	584
Prairie (2–6–2) type	1
Mountain (4–8–2) type	1
Odd, standard gauge	2
Narrow gauge	4
Total passenger	1,586

Freight Service

Mogul (2–6–0) type	217
Ten-wheeled (4–6–0) type	4
Consolidation (2–8–0) type	3,335
Mikado (2–8–2) type	579
Decapod (2–10–0) type	598
Ten coupled (2–10–2) type	190
Mallet articulated type	13
Narrow gauge	11
Total freight	4,947

Switching Service

Four coupled (0–4–0) type	140
Six coupled (0–6–0) type	790
Eight coupled (0–8–0) type	2
Mogul (2–6–0) type	15
Odd types	6
Total switching	953

Electric Locomotives

Passenger	67
Freight	2
Switching	1
Total electric	70

The aggregate tractive forces of the locomotives used in various classes of service are as follows:

Steam, Standard Gauge

Passenger locomotives	49,845,600 pounds
Freight locomotives	262,002,100 pounds
Switching locomotives	29,677,500 pounds
Total	341,525,200 pounds

Steam, Narrow Gauge

Passenger locomotives	50,100 pounds
Freight locomotives	128,400 pounds
Total	178,500 pounds

Electric

Passenger locomotives	2,214,000 pounds
Freight locomotives	123,000 pounds
Switching locomotives	56,000 pounds
Total	2,393,000 pounds

This represents an aggregate for all the locomotives on the System, of 344,096,700 pounds, or an average of 45,500 pounds per locomotive.

The tables on page 79 indicate the increase in weight and capacity of the Pennsylvania's passenger and freight locomotives from 1899 to the present time. The Class M1 and HC1s locomotives are in a certain sense experimental, but they have been included to indicate the ultimate thus far attained.

A comparison of the Class B4a locomotives, which were the heaviest switchers used by the Pennsylvania at the beginning of this period, with the new Class C1 locomotive recently designed at Altoona,

shows an increase in weight and capacity of approximately 156 per cent.

The most notable feature in connection with the development of the Pennsylvania's motive power is the thoroughness with which all problems have been worked out. New types and designs have not as a rule been duplicated until they have fully proved their fitness to economically and efficiently meet the service requirements, and all materials and special devices, before being adopted as standard, have been subjected to rigid tests to determine their ultimate economy. Because of this the policy of the Motive Power Department has sometimes been regarded as unduly conservative; but it has been fully justified by the final results attained. Furthermore the research work done in connection with locomotive development on this road has been of exceptional value, and has been studied and utilized the world over. It is safe to say that on no railroad has greater progress been made in raising the standard of motive power efficiency, and placing the locomotive on a plane where it is recognized as one of the greatest achievements of the mechanical world.



An Electric Locomotive, Class DD1, in New York Terminal Service

Steam Locomotive Development, Pennsylvania Railroad, 1899-1923

Passenger Locomotives

Date	Type	P. R. R. Class	Cylinders, Inches	Drivers, Diam., Inches	Steam Pressure, Pounds	Grate Area, sq. ft.	Water Heating Surface, sq. ft. #	Superheating Surface, sq. ft. ‡	Weight on Drivers, Pounds	Weight, Total Engine, Pounds	Tractive Force, Pounds	Tractive Force Increase, per cent*
1899	4–4–2	E1	20½x26	80	185	68.0	2,320	....	101,550	173,450	21,480	100
1901	4–4–2	E3	22 x26	80	205	55.5	2,640	....	115,300	183,500	27,410	128
1910	4–4–2	E6	22 x26	80	205	55.1	3,582	....	133,300	231,500	27,410	128
1910	4–6–2	K2	24 x26	80	205	55.4	4,629	....	185,900	278,800	32,620	152
1913	4–4–2	E6s	23½x26	80	205	55.1	2,892	806	136,000	243,600	31,275	146
1914	4–6–2	K4s	27 x28	80	205	70.0	4,050	1,215	201,830	308,890	44,460	206
1923	4–8–2	M1	27 x30	72	250	70.0	4,902	2,283	273,500	383,100	64,550	301

Freight Locomotives

1901	2–8–0	H6a	22 x28	56	205	49.0	2,844	....	175,500	195,500	42,570	100
1910	2–8–0	H8	24 x28	62	205	55.2	3,842	....	209,500	242,000	45,540	108
1913	2–8–0	H9s	25 x28	62	205	55.2	3,066	781	223,300	251,000	49,180	117
1913	2–8–0	H10s	26 x28	62	205	55.2	3,066	781	223,000	247,500	53,200	126
1914	2–8–2	L1s	27 x30	62	205	70.0	4,050	1,215	240,200	320,700	64,570	153
1916	2–10–0	I1s	30½x32	62	250	69.9	4,332	1,460	341,800	511,800	90,000†	213
1919	2–8–8–0	HC1s	(4) 30½x32	62	205	112.0	6,652	2,914	572,450	603,500	135,000†	320
1922	2–10–0	I1s	30½x32	62	250	69.9	4,808	2,283	352,500	386,100	90,000†	213

The Class I1s designs of 1916 and 1922 are both included in the above table because of differences in the types of superheaters used, and the fact that the 1922 design includes a feed-water heater.

*The tractive force of the lightest locomotive is taken as 100.

†Based on a mean effective pressure equal to 75 per cent boiler pressure.

‡Based on area of fire side of superheater tubes.

#Based on area of water side of tubes and flues.

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