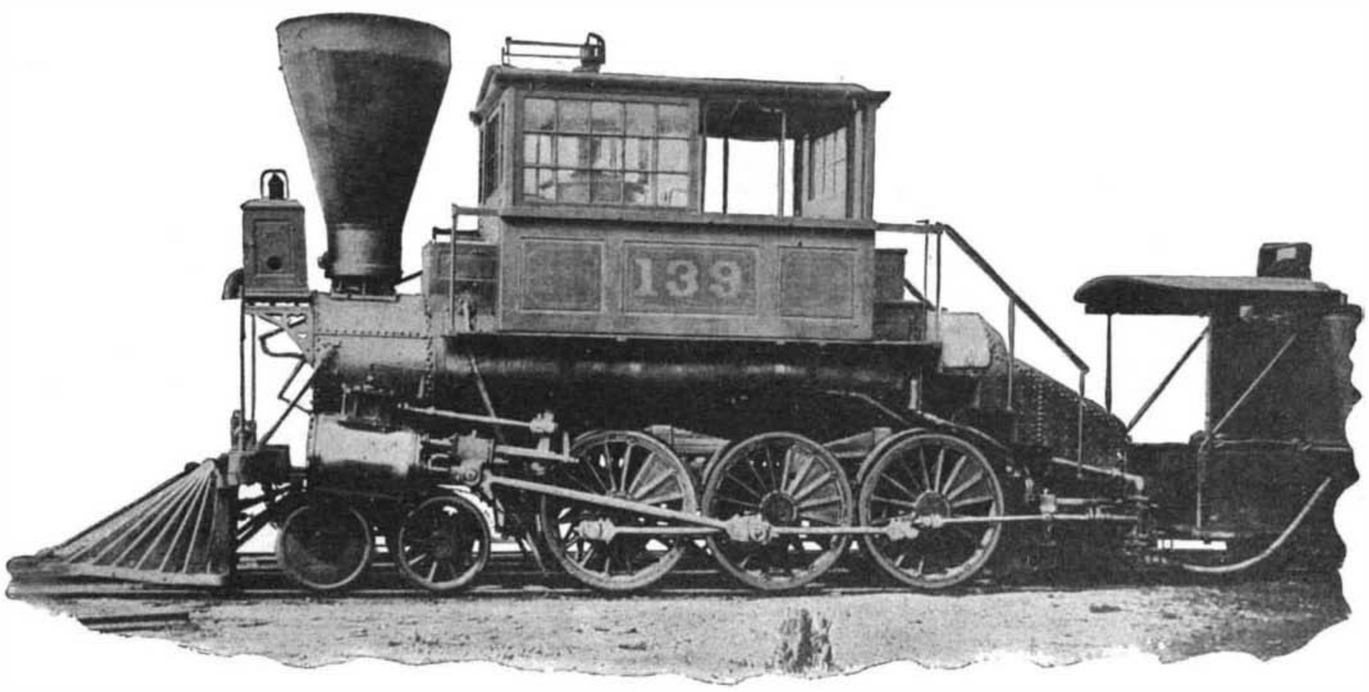
itself, but established a large factory provided with special tools for its manufacture, in which phonographs are turned out in great numbers.

The improvements reduced the instrument to about the size of an ordinary sewing machine. In its construction it is something like a very small engine lathe; the main spindle is threaded between its bearings and is prolonged at one end and provided with a drum for receiving the wax cylinder, upon which the sound record is made. Behind the spindle and the drum is a rod upon which is arranged a slide, having at one end an arm adapted to engage the screw of the spindle, and at the opposite end an arm carrying a head provided with two glass diaphragms which may be interchanged when desirable. One of these diaphragms is used when it is desired to talk to the phonograph, and when the speech is to be reproduced the other diaphragm takes its place. The cutter by which the impressions are made in the wax is attached to the center of the diaphragm and pivotally connected to a gravity arm attached to the side of the diaphragm cell. The reproducing cell contains a delicate glass diaphragm, to the center of which is secured a stud connected with a small curved steel wire, one end of which is attached to the diaphragm cell. The recording and reproducing points are formed of chalcedony.



CAMEL-BACK LOCOMOTIVE BUILT FOR THE B. & O. RAILROAD IN 1853.

Cylinders, 19 by 22 inches; drivers, 50 inches; weight, 71,000 pounds; steam pressure, 120 pounds.

The spindle of the phonograph is rotated regularly by an electric motor in the base of the machine, which is driven by a current from one or two cells of battery. The motor is provided with a sensitive governor which causes it to maintain a very uniform speed. The arm which carries the diaphragms is provided with a turning tool for smoothing the wax cylinder preparatory to receiving the sound record.

The first operation in the use of the machine is to bring the turning tool into action and cause it to traverse the cylinder. The turning tool is then thrown out, the carriage bearing the recording diaphragm is returned to the position of use, and as the wax cylinder revolves the diaphragm is vibrated by the sound waves, thus moving the cutter so as to cause it to cut into the wax cylinder and produce indentations which correspond to the movements of the diaphragm. After the record is made, the carriage is again returned to the point of starting, the receiving diaphragm is replaced by the reproducing diaphragm, and the carriage is again moved forward by the screw as the cylinder revolves, causing the point carried by the reproducing diaphragm to traverse the path made by the recording cutter. As the point follows the indentations of the wax cylinder the reproducing diaphragm is made to vibrate in a manner similar to that of the receiving diaphragm, thereby faithfully reproducing the sounds uttered into the receiving mouthpiece

The perfect performance of the phonograph depends upon its mechanical perfection—upon the regularity of its speed, the susceptibility of the wax cylinder to the impressions of the needle, and to the delicacy of the speaking diaphragm. No attempt is made in this instrument to secure loud speaking—distinct articulation and perfect intonation having been the principal ends sought.

The phonograph may be now used for taking dictation of any kind, for the reproduction of vocal music, for teaching languages, for correspondence, and for various other purposes too numerous to mention.

The wax cylinder upon which the record is made is provided with a rigid backing. It is very light and a mailing case is provided for safely mailing it. The recipient of the cylinder places it on his own phonograph and listens to the phonogram--in which he not only gets the sense of the words of the sender, but recognizes his expression, which will, of course, have much to do with the interpretation of the true meaning of the sender of the phonogram.

A very interesting and popular use of the phonograph is the distribution of the songs of great singers, sermons and speeches, recitations, the words of great men and women, music of many parts, the voices of animals etc., so that the owner of a phonograph may enjoy these things with little expense.

Passing over the application of the phonograph to dolls, we will refer briefly to the latest developments of the instrument. It has recently been determined to furnish a perfect phonograph for a moderate price which will reproduce any record with great fidelity. Purchasers will be able to provide themselves with records of any desired character, so that the most interesting of entertainments may be had at a moment's notice. This phonograph is driven by a spring motor in a manner similar to a music box. It is light, compact, and readily operated. Although it is designed for reproducing only, it may for a small additional cost be made to record or to both record and reproduce. The records are made on the recording phonograph, which is now so perfect as to leave nothing to be desired.

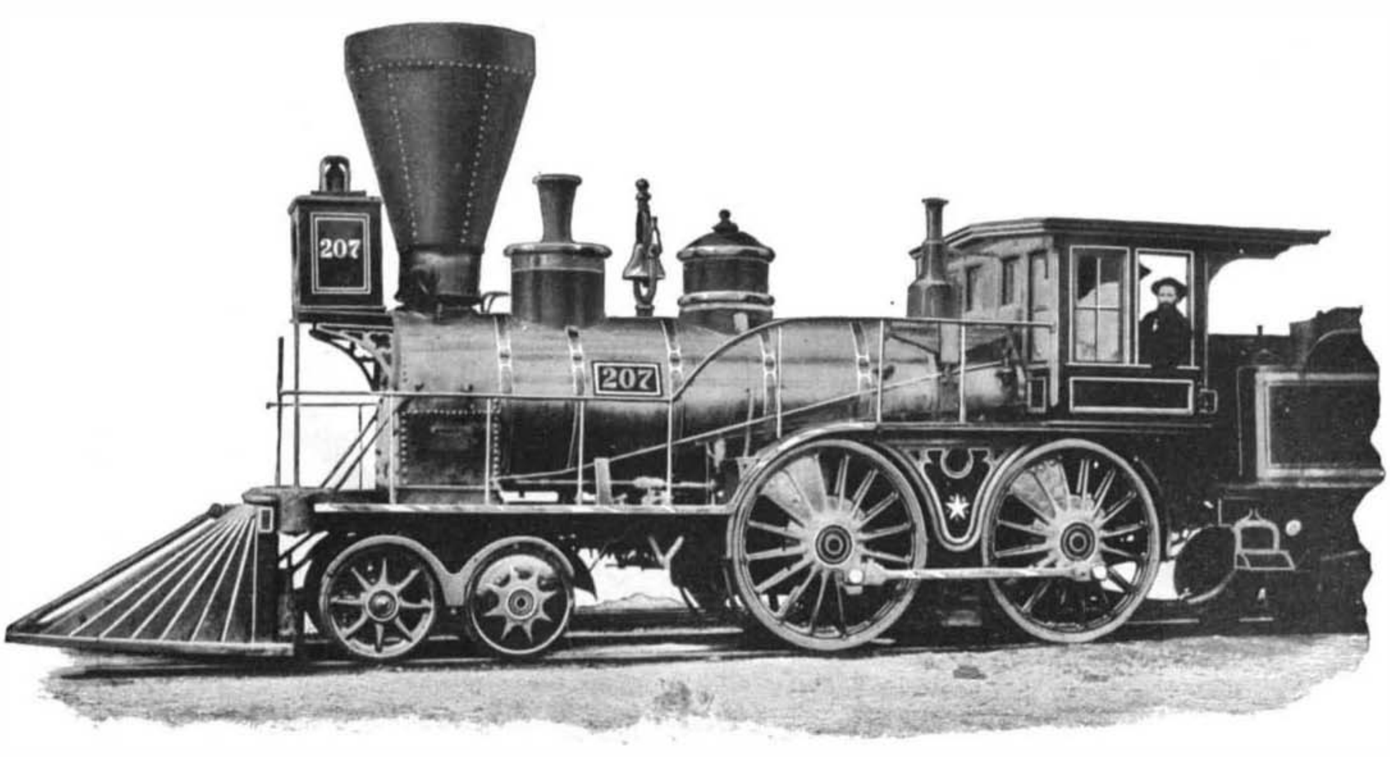
Other instruments of this class have been devised within a few years—the graphophone, which is similar to the phonograph, operating on practically the same principle, and the gramophone, which has a flat disk instead of a cylinder and makes a record which is a sinuous groove, by means of a laterally vibrating needle. It reproduces sound by the lateral vibrations caused by the following of the reproducing needle in the groove of the record.

THE AMERICAN LOCOMOTIVE.

The first practical locomotive to turn its wheels upon a track in America was the Stourbridge Lion, an imported English engine. This notable event took place August 9, 1829. The first engineer to run a locomotive in America was Horatio Allen, who handled the throttle on this occasion. It is claimed that the first American-built locomotive to be put into active service was the Best Friend, which was constructed by Mr. E. L. Miller, for the South Carolina Railroad Company. This occurred in November, 1830.

In the earliest days of American locomotive building the influence of the original English models is traceable in the designs; but it was not long before the American mechanic began to strike out for himself, and build a machine specially adapted to local conditions. Various original and radical features were introduced, and with such rapidity, that in the brief interval of sixteen years between the trial trip of the Best Friend and the year 1846, which marks the opening of the half century with which we are dealing, the most important elements of the typical American eight-wheel engine, as we know it to-day, may be said to have been substantially established.

A comparative study of the cuts of early engines of this period will enable the reader to identify, in one design or another, those characteristic features which are distinctively American. He will find the leading truck, the four-coupled drivers, with the fire box between the axles, the bar frame, the outside cylinders, the equalizing levers, the "cow catcher," and the bell, and last, and perhaps as characteristic as any, the cab. In saying that the main features of the eight-wheel American engine were to be found represented in the locomotives of 1846, it is not to be understood that this was by any means, at that time, the accepted type, although it was destined shortly to become so. That was an age of investigation, and the student of American locomotive history is impressed with the number and variety of experimental engines which figured in the twenty years from 1841 to 1860. In the first place, the inside cylinders and the single driving wheel, which have been so very largely retained in English practice, were tried and found wanting for the requirements of those days. The celebrated Globe eight-wheeled inside connected engines were for many years a familiar feature on many New England roads, and it is but a few years since the last of them was consigned to the scrap heap. An engine of this type, with 15 by 22 inch cylinders, built for the Baltimore and



INSIDE-CONNECTED EIGHT-WHEELED LOCOMOTIVE BUILT FOR THE B. & O. RAILROAD IN 1854.

Cylinders, 15 by 22 inches; drivers, 60 inches; boiler, 44 inches diameter; weight, 56,000 pounds.

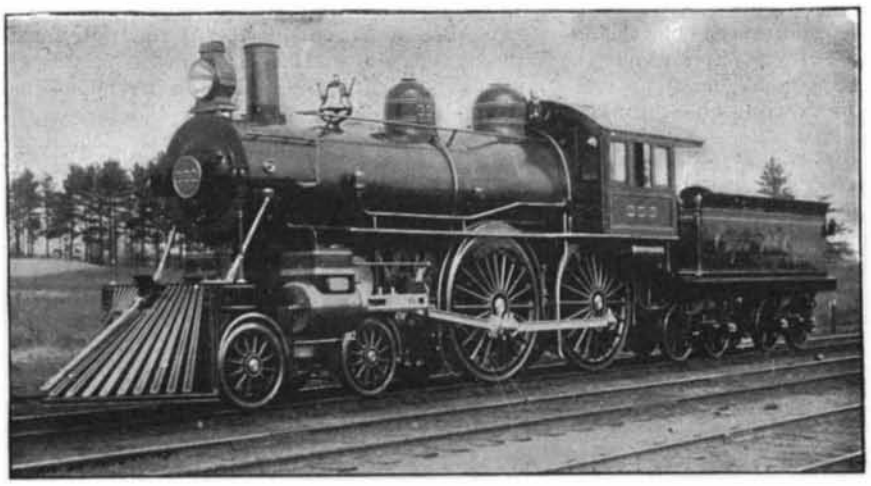
Ohio Railroad in 1854, is shown in the accompanying illustration. These, however, were notable exceptions to the general practice, which, early in the period under consideration, forsook the easy running of the inside connected for the greater handiness of the outside connected type.

If we would seek for the cause of the marked difference in the American and English locomotive, starting as they did from a common origin (there were between 25 and 30 engines in all imported from England), it will be found in the different conditions under which the two types had to do their work.

For reasons which are given elsewhere in this issue, the early English roads were built more solidly, and with lighter grades and easier curves than the early American roads. The relatively smooth and straight English track permitted the use of the more rigid plate frame engine with rigid wheel base, and it has continued to be the prevailing type. The cheaper and lighter American track, which was necessitated by the long stretches of thinly peopled country which had to be covered, called for a special make of locomotive, with lateral and vertical flexibility. The lateral adjustment was obtained by means of the leading truck, and the vertical adjustment by the equalizing levers. By these devices, the weight is carried upon three points of support, one forward beneath the cylinders, and one on each side of the fire box. The principle of leverage is so ingeniously applied, that the shock of any one wheel passing an obstruction is distributed and reduced before it reaches the main body of the engine. The combination of these two devices enabled high speeds to be maintained over track which would have ditched an English engine before it had run a mile.

The average dimensions of an 1846 engine were as follows: Cylinders, 15 or 16 by 20 and 22 inches; weight, 18 to 20 tons; drivers, 4½ to 5 feet diameter; and the steam pressure varied from 90 pounds to 120 pounds per square inch. In 1848 we find the Baldwin Locomotive Works undertaking to build an express engine to run sixty miles an hour, for which feat they provided her with 17¼ by 20 inch inside cylinders and a pair of 6½ feet drivers; and a little later they built a somewhat similar engine with 15 by 20 inch cylinders and a pair of 6 foot drivers. The single driver was fully tested, with the almost invariable complaint, after trial, that there was "in-

—a size which has never since been reached, although 7 foot drivers are becoming common in up-to-date practice. The ten-wheel engine, with six-coupled drivers, was patented by Septimus Norris in 1846, and the Rogers Locomotive Company turned out their first celebrated ten-wheelers in 1848.



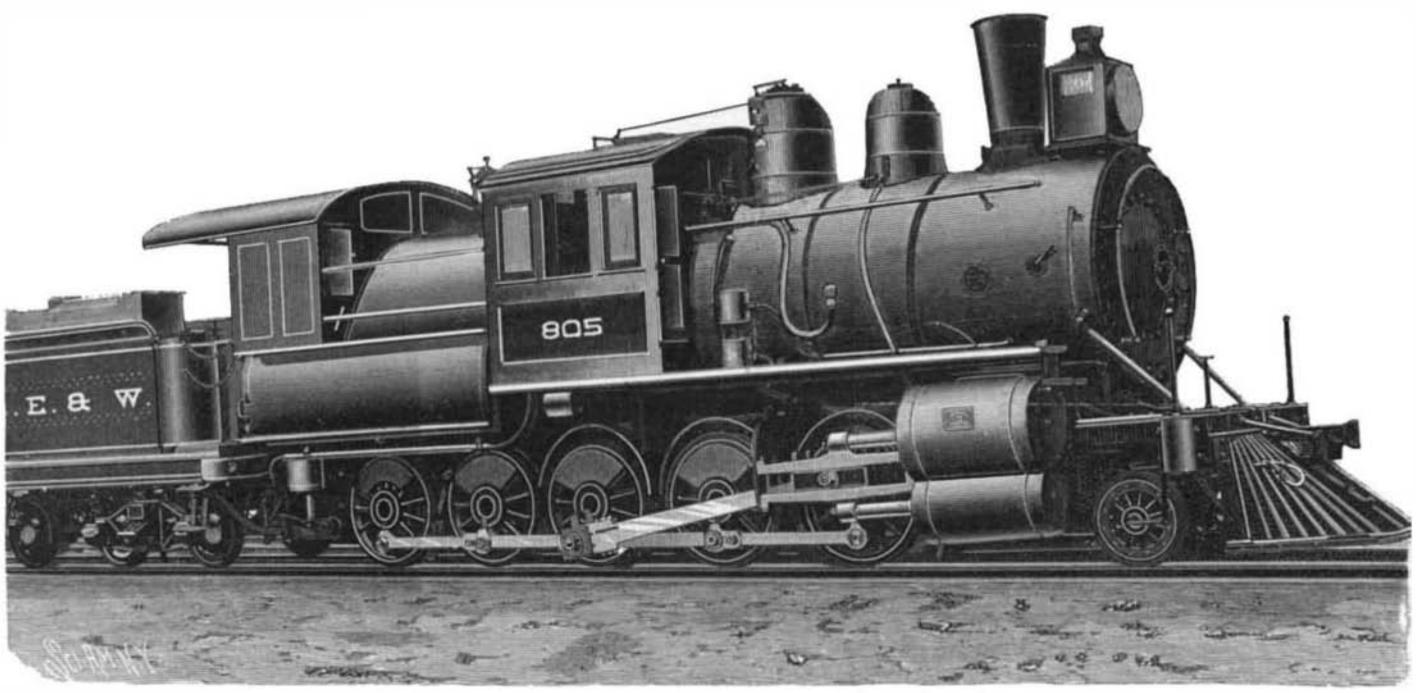
No. 999 OF THE N. Y. C. & H. R. R., 1893.

Cylinders, 19 by 24 inches; drivers, 86½ inches; weight, 62 tons; steam pressure, 190 pounds. A modern example of an American eight-wheeled express engine. Hauling the Empire State Express, the fastest train in the world; speed, 64·22 miles an hour, excluding stops.

The Stephenson link motion was first employed by Mr. William T. James, of New York, in 1832. It was first adopted as standard practice in American shops by Mr. Thomas Rogers, of the above works, in 1849, and with its reintroduction the evolution of the American locomotive, as to its essential features, may be said to have been complete. The subsequent development has consisted in the perfecting of details, and the variations from the type have been such as were called for by the particular class of service which had to be performed.

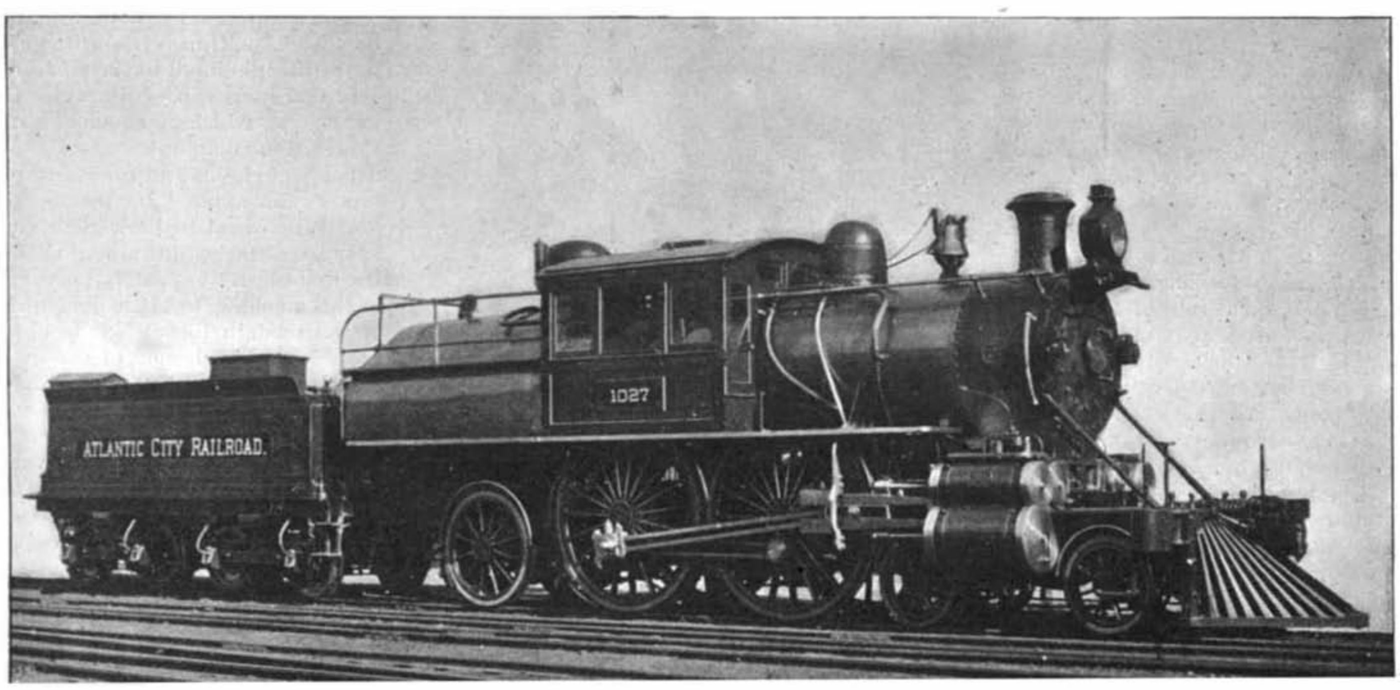
In addition to the points of divergence in practice between American and English builders already noticed, it may be said in general that the American locomotive has always been harder worked than the English, and that while it has never shown such economy in fuel consumption, it has always been able to get away with a bigger load. Where the English superintendent would run a train in two sections, each of which would constitute a load well within the hauling capacity of the engine, in America one locomotive would take the whole train, and would be pushed to its utmost capacity in the effort to keep within the schedule time. Where fuel was cheap and labor dear, it was found to be economical in the long run to dispense with one train crew, and push the locomotive to the full limit of its power, even if it did vomit black smoke and unburnt coal from the smoke stack. The difference in the cost of labor has had a potent influence in the development of the two types, especially in the past twenty or thirty years. Whereas the Englishman, with his copper fire box, brass tubes, deflector plate and mild exhaust, his inside cylinders, large single drivers, low piston speed, and light loads, was aiming at a high theoretical efficiency, the American, with his four, six, and eight-coupled drivers of small diameter, his big cylinder capacity, large steam ports, his huge boiler with its big heating surface, his roomy fire box and sharp exhaust, was aiming at large hauling capacity. It is sufficient to say that both have reached the goal; and that while the American locomotive will haul three tons to the English two, it will burn more fuel per ton in the effort.

Between 1850 and 1860 the coal burning locomotive became common, and with the advent of coal the brass and copper tubes were discarded for iron tubing, which in turn was to give place to steel. This decade also saw the general introduction of the wagon-top boiler, and the influence of anthracite coal was seen in the long, sloping fire box, as shown in the celebrated "camel backs" of Ross Winans. The next decade saw the building, at the Baldwin works, of the "Consolidation," and the introduction of the Bissel truck, the swing bolster truck, and steel tubing. The two decades 1870 to 1890 were marked



FOUR-CYLINDER COMPOUND DECAPOD FREIGHT LOCOMOTIVE, 1893.

Weight of engine alone, 96 tons; hauling capacity, 4,600 tons; cylinders, 16 inches and 27 inches by 28 inches; heating surface, 2,443 square feet; steam pressure, 180 pounds.



distinct types, according to the work for which they were designed.

The year 1888-89 was memorable for the introduction of the compound engine into America. Compounding had already reached a high state of development in Europe, when the Pennsylvania Railroad determined to give it a trial in American service, and to this end purchased an English compound engine, designed and built by Mr. F. W. Webb, of the London and Northwestern Railway. The Pennsylvania, as she was called, was put to work on the company's regular trains and made an excellent record for economy.

Speaking of its performance, a prominent Pennsylvania official said at the time: "I am not at liberty to give exact figures as to the saving of coal shown by the Webb engine over our regular passenger locomotives, but I will say that it has been considerably over twenty-five per cent." The era of compounding, thus introduced, has resulted in its trial on most of the leading roads of the country, and invariably with a showing of large economy. The outside two-cylinder compound has been the favorite type. Two fine examples of the four-cylinder compound are shown in the accompanying cuts of an express passenger, and a heavy Decapod freight, engine, built by the Baldwin works under the Vauclain patents. By reference to the cuts it will be seen that the cylinders are arranged in pairs, the high pressure above the low pressure, the piston rods engaging a common crosshead. Piston valves are used, being placed on the inner side of the high pressure cylinders. The engines shown have the Wootton firebox, designed for burning low-grade coal, the total heating surface of the firebox of the passenger engine being 136½ feet, and of the freight engine 234¼ feet.

As illustrating the highest development of the simple eight-wheel express passenger engine, we have selected the New York Central engine No. 999, of Empire State Express fame, which is at present hauling the fastest train in the world, and holds a record speed for the mile of something over one hundred miles an hour.

The dimensions of these three engines, together with those of the Lake Shore and Michigan Southern engine No. 564 (Brooks Locomotive Works), to whose phenomenal run we refer later, are given in the accompanying table:

No. of Engine and Name of Company.	Engine and Builder.	System.	Cylinders.	Drivers.	Weight on Drivers.	Total Weight.	Heating Surface.	Steam Pressure.
No. 999. N. Y. C. and H. R. R.R.	Four-coupled express. N. Y. C. and H. R. R.R.	Simple.	19 in. × 24 in.	86½ in.	84,000 lb.	124,000 lb.	1,930 sq. ft.	190 lbs.
No. 1027. Atlantic City R.R	Four-coupled express. Baldwin.	Compound.	13 in. / 22 in. × 26 in.	84¼ in.	78,600 lb.	143,000 lb.	1,835 sq. ft.	190 lbs.
No. 564. L. S. and M. S. R.R.	Six-coupled express. Brooks.	Simple.	17 in. × 24 in.	66 in.	88,500 lb.	113,500 lb.	....	180 lbs.
No. 805. L. E. and W. R R.	Decapod freight. Baldwin.	Compound.	16 in. / 27 in. × 28 in.	50 in.	170,000 lb.	192,000 lb.	2,443 sq. ft.	180 lbs.

The Lake Erie freight engine is rated to pull 4,600 tons on the level, and on a run between West Carbondale and Ararat Summit, with a load of 1,107 tons, it consumed 8·28 pounds of fuel per car mile, with a water evaporation of 7·57 pounds per pound of coal. This is a really astonishing performance, when we bear in mind the grades and the loads. From Carbondale to Forest City, 25 cars, weighing in all 818 tons, were hauled for 5 miles over a 1·33 per cent grade; and from Forest City to Ararat Summit, 33 cars, weighing 1,107 tons, were hauled for 13·7 miles over a 0·95 of one per cent grade.

No. 999 is one of the class of New York Central engines which hauled a 361,000 pound train from New York to Buffalo, 436·32 miles, at the rate of 64·22 miles an hour, exclusive of stops. This superb locomotive, which was built at the shops of the New York Central and Hudson River Railroad, was on exhibition at the Columbian Exhibition at Chicago, and is the most popular and widely known engine in America to-day.

No. 564 to-day holds the record for long distance fast runs, having covered 86 miles at the rate of 72·92 miles an hour. This performance formed part of a 510 mile run with various engines from Chicago to Buffalo, at the rate of 65·07 miles an hour, exclusive of stops. The train load was 304,500 pounds, and the 86 mile run of No. 564 included 8 miles at 85·44 miles an hour, and 33 miles at 80·6 miles an hour, with one mile at 92·3 miles an hour. At this last speed the revolution of the drivers was 469 per minute, and the piston speed 1,878 feet per minute! This performance of No. 564 in hauling 152¼ tons for 33 continuous miles at 80·6 miles an hour is unquestionably the greatest locomotive feat that was ever officially recorded. That it should have been done by a six connected 5⅙ foot driver engine simply proves the value of great boiler capacity and large steam ports.

The growth of the locomotive industry can be best told in figures. In 1846 the Rogers Locomotive Company turned out 17 locomotives; in 1896 their yearly capacity is 300, and they have built 5,150 locomotives in all. In 1846 the Baldwin Locomotive Works turned out 42 locomotives; in 1896 their yearly capacity is 1,000, and they have built nearly 15,000 locomotives to date! It is estimated that to-day there are over 36,000 locomotives in service in America, representing a money value of not less than three hundred millions of dollars.

THE BICYCLE.

Lord Charles Beresford has said, "Whoever invented the bicycle deserves the thanks of humanity." At the present day the bicycle stands unrivaled as a means of healthy exercise and pleasure. The practical uses to which it may be put seem limitless, and now the bicycle is assisting the electric railroad and the automobile carriage to relegate the horse-drawn vehicle to the past. The evolution of the bicycle from the primitive forms has been by a series of positive steps, each step marking a distinct advance in the march of improvement. If for no other reason, the last half century is notable on account of the introduction and development of the bicycle, and nearly the whole history of this evolution falls well within the period we are considering.


THE VELOCIPEDE OF 1868.

It is necessary to go back to the last century for the germ of this great invention, when a strange device called a "hobby-horse" was introduced. It consisted of two wheels connected tandem by a rigid frame of wood. The rider sat on a saddle midway between the wheels and propelled it by means of strides on the ground. Naturally its motion was limited to a straight line. This rigid, non-steering bicycle, propelled by the feet on the ground, was the first step toward the modern machine. The second step was taken in 1818, when Baron Von Drais introduced a vehicle called a "draisienne," which resembled the foregoing machine, but the front wheel was so arranged that steering was possible. That such cumbersome means of locomotion soon fell into disuse is not to be wondered at. For a long time no real progress was made, though various systems and devices were introduced to enable the rider to propel himself, but they were mostly tricycles and were cumbersome and unmechanical. The third step consisted in the invention of a bicycle which was capable of being steered and which was propelled without touching the feet to the ground. This machine was credited to a Scotchman, Gavin Dalzell. The motion of the pedals was downward, the feet describing a small segment of a circle. The motion was transmitted to a crank attached to the axle of the rear wheel by levers. For a long time it was supposed that this invention dated from 1834, but in 1892 a close scrutiny of the matter resulted in the downfall of the legend, as a blacksmith's bill for the iron work was found, which proved that it was made in 1847, and also that another Scotchman named MacMillan had anticipated Dalzell's invention.


TANDEM VELOCIPEDE OF 1869.

It is to Ernest Michaux, a young French locksmith, fourteen years of age, that we are indebted for the next great step which made the modern bicycle possible. In 1855, while repairing a draisienne, he conceived the idea of applying cranks directly to the front wheel. He tried the device for a couple of days and then showed the machine to his friends. The driving mechanism was improved by Pierre Lallement, to whom the credit of the invention is sometimes given, but the French seemed to have settled the matter by erecting a monument to the memory of Ernest and Pierre Michaux at Bar-le-Duc in 1894. The Michaux bicycle or "velocipede," as it was called, attained great popularity. We illustrate a typical example of the machine as improved and ridden by the Hanlon Brothers, taken from an engraving published in the Scientific American for August 19, 1868. The popularity of the velocipede or "bone shaker" at that time knew no bounds; riding academies were established, races run and the machine even penetrated to the far East. The columns of the Scientific American of this period faithfully mirror the enthusiasm of the time. In the issue for March 20, 1869, among the "Velocipede Notes," appears an interesting item to the effect that thirty years previously Michael Faraday could be frequently seen driving his machine through the suburbs of London.

In 1869 M. Magee, a Parisian, still further improved the velocipede by making it entirely of iron and steel. In the same year rubber tires were used; these were both important steps in the development of the bicycle. In 1869 M. Michaux conceived the idea of making the front or drive wheel larger than the rear wheel, and various other improvements, such as a brake, were introduced. In 1874 M. Merchegay showed that weight would be reduced by using a large front wheel and a small rear wheel, and that the rider should be mounted directly over the axle of the front wheel. These ideas were carried out, and the popular "spider" or "ordinary" was the result. This machine remained in the ascendency for nearly fifteen years. In 1875 touring became popular, and the bicycle soon showed that it had come to stay. The new wheel weighed from 35 to 50 pounds, against 80 to 100 for the old velocipede. We present an engraving of a wheel of the best type of "ordinary."

There were certain undeniable dangers connected with the use of the high wheel, and accidents were many and serious. At length came signs that the design and construction of the wheel was in a state of transition. Various expedients were adopted to avoid the dangerous "header." The "Star" bicycle became a prime favorite. In this bicycle the small wheel was placed in front and the rider was mounted over the axle of the high rear wheel. They were propelled by levers, straps and ratchets, which enabled the wheel to be geared up, thus introducing one of the most important principles used in the modern machine.

In 1877 Rousseau, of Marseilles, introduced the "Kangaroo," in which a smaller front wheel was used. Power was communicated to the axle by means of independent chains and sprockets, to the latter of which power was applied by pedals; this arrangement allowed the wheel to be slightly geared up. About the year 1880, Starley introduced his famous "Rover." At the first blush the "safety" of to-day is unrecognizable in this machine, but it really embodied the vital points of the modern bicycle in its form. The wheels were both low, though not of the same size, and the rear wheel was driven by chains and sprockets, as in our latest wheels. The great superiority of this machine over the ordinary was soon recognized. Cycling became more popular, and by degrees the high wheel was abandoned by all the makers. The pneumatic tire was the greatest of all the advances since Michaux, and marks the last step in the improvement of the wheel of to-day.

The modern bicycle is distinguished from the older types of wheels on account of the difference in materials, frames and tires. Complex shapes, once thought impossible to produce except by casting, are now forged. Great improvements have been made in brazing together the parts and in cold swaging also, so that the joints are no longer considered the points of weakness.

Great improvements made in the manufacture of tubing during the last few years have rendered it possible to construct a good road wheel which weighs, when complete, only 19 to 22 pounds. By a series of careful