expenses of such a ship are, necessarily, enormous, one of the great English companies having recently admitted that they run as high as $5,000 a day with a full complement of passengers. To furnish the 20,000 horse power for the engines of the St. Paul requires the consumption of 310 tons of coal per day; and the consumption of provisions by the passengers can be judged from the list of supplies carried for one trip, some of the items being as follows: 30,000 pounds of beef, 10,000 clams and oysters, 500 pounds of coffee, 3,000 pounds of butter, 3,000 pounds of sugar, 16 tons of potatoes, 15,000 eggs, and 140 barrels of flour.

In tracing the various stages of the development of the transatlantic steamship, it is found that each decade was marked by some radical departure from the practice of the decade which preceded it. In the accompanying table it is attempted to mark this progress approximately, showing the most important changes in construction, the approximate rise in boiler pressure, and the approximate improvement in engine performance:

Decade.	Development in construction.	Approximate boiler pressure.	Approximate lb. of coal per horse power.
1845-55	Iron in place of wood	10 to 20	4·5 to 3 5
1855-65	Screw in place of paddle wheel..	20 " 35	3·5 " 2·9
1865-75	Compound in place of simple engines .	35 " 60	2·9 " 2 2
1875-85	Steel in place of iron, and triple expansion engines....	60 "125	2·2 " 1·9
1885-95	Twin screws, quadruple expansion and forced draught....	125 "200	1·9 " 1·3

Space forbids a more extended treatment of a subject which has an increasing interest for all patriotic Americans; but enough has been said to show that the part played by the United States in the development of the transatlantic steamship has been far more extended and important than is perhaps generally supposed. It dates from the earliest records, when the Savannah opened the very first chapter of its history by her memorable voyage to Liverpool; and the easy triumphs of the Collins line in the fifties bid fair to be repeated in the history of the American line of to-day.

RAILROADS AND BRIDGES.

The railroad system of the United States is remarkable, alike for the rapidity and proportions of its growth, and for the fact that it expresses the adaptiveness and ingenuity of the American people more, perhaps, than any other field of enterprise to which they have directed their energy and capital. In the whole range of engineering work there is nothing more distinctively American than the American railroad; nowhere is the national faculty of adapting the means to the end more consistently manifest than in the development of this vast system of transportation. From its cheap prairie track, built at $15,000 a mile, to its superb "limited" trains, with their full complement of costly parlor, sleeping and dining cars, the whole system is the outcome of an attempt to satisfy the luxurious tastes of a people who were scattered over a vast area of more or less undeveloped country.

It was realized at the outset that it was neither expedient nor possible to build American railroads according to the expensive methods of European engineers. The conditions in the two countries were entirely different. The early roads in England and on the Continent were built through populous districts, and between large cities, and the day of the opening of a new line found passengers on every platform and freight in every yard. Large receipts were assured and dividends were certain. Hence it was good policy to construct the roadbed in the most solid manner, and lay out the line with a view to economy of operation. Hills were tunneled, deep cuttings opened, massive embankments raised, and every expedient known to the engineer and contractor was used in the effort to produce a line that should be at once level and straight. The result, as in the Great Western broad gage line, of Brunel, was a magnificent road, built at an appalling cost per mile.

U. S. MAIL LINES
TO
BALTIMORE

PHILA. WILMINGTON & BALTIMORE
RAILROAD,
Via Chester, Wilmington, Newark, Elkton & Havre De Grace.

On and after Monday next, November 24th, the Mail Line to Baltimore will leave the Depot, Eleventh and Market Streets, as follows:
Daily (except Sunday,) at 8 o'clock, A. M.; and Daily, at 4, P. M.
The above Lines will leave Baltimore for Philadelphia Daily (except Sunday,) at 9 o'clock, A. M., and 8 o'clock, P. M.
The Line, via New Castle and Frenchtown, by Steamboat from Dock Street Wharf, will be discontinued on and after that day.

WHEELING AND PITTSBURGH.
Tickets through to Wheeling or Pittsburgh can be procured at the Depot. Fare to Wheeling, $13; Do. to Pittsburgh, $12.

FREIGHT ACCOMMODATION LINE.
A Passenger Car, attached to the freight train, leaves the Depot, daily (except Sunday,) at 1½ o'clock, P. M. Fare, $1.50.
November 22, 1845

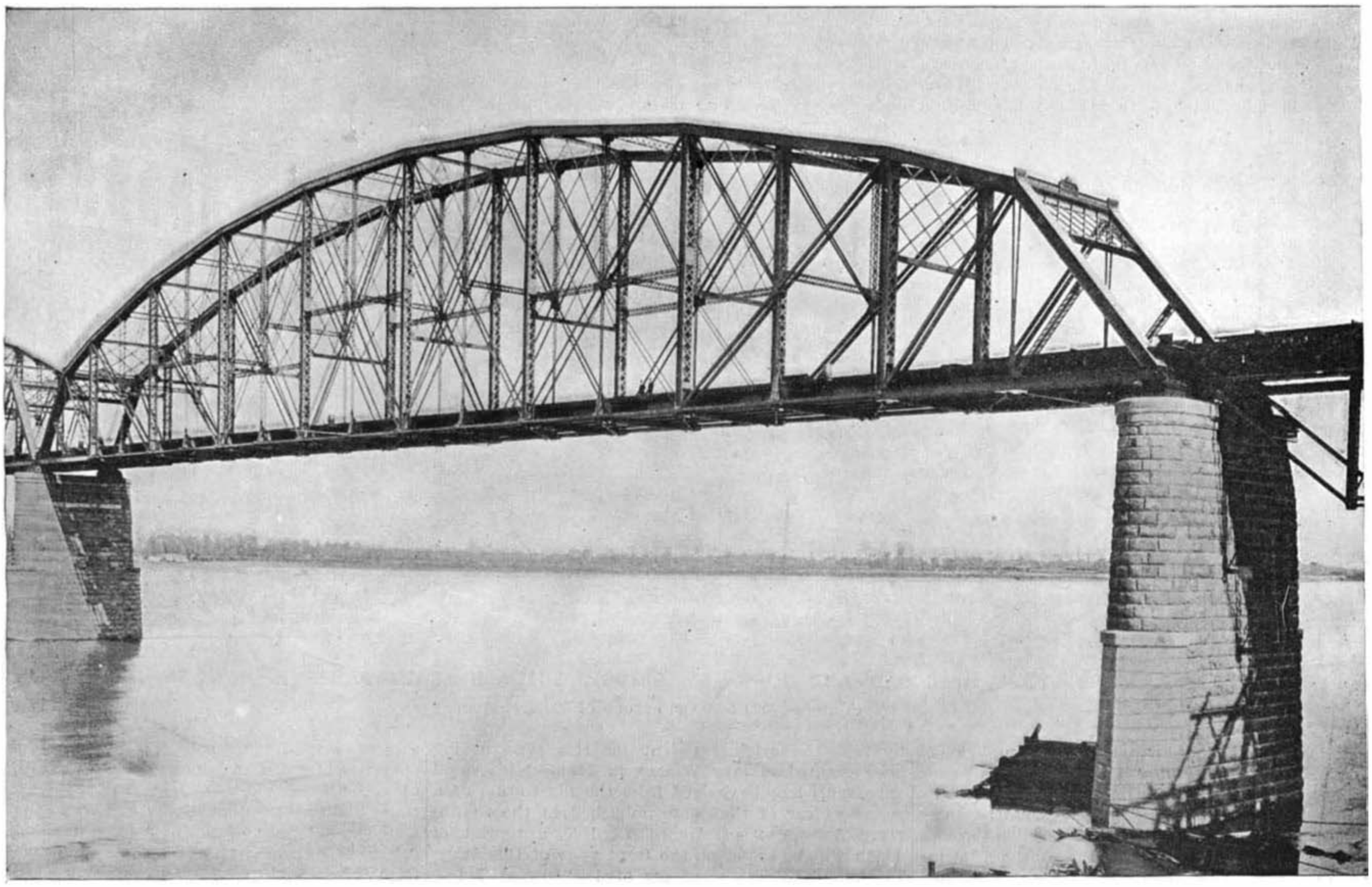
RAILROAD POSTER OF 1845.

With the exception of those which were built in the more populous States bordering on the Atlantic seaboard, the early railroads of America have had to do pioneer work. In Europe the railroad followed the population, and was the result of it. In America the population followed the railroad, which in some cases has been pushed out a thousand miles ahead of the onrolling wave of emigration. These conditions, coupled with the natural freedom of the American engineer from the restraints of tradition, and his tendency to work out any problem from its own proper point of view, have given us the American railroad of to-day.

In the first place the engineer dared to believe that a locomotive could climb a hill and swing round a curve —Mr. Brunel and his associates notwithstanding. So when the locating engineer came to a hill he preferred to go round rather than tunnel through it; and, if that was impossible, he carried his line over it, skillfully adjusting his survey to the topography of the country, and keeping the grade within the desired limit. Where one or two feet in a hundred had been considered the practicable limit of grade, he did not hesitate to use three and four; and where four and five degrees was the limit of curvature in Europe, he boldly ran in eight and ten degree curves, and on certain lines in later years increased this to sixteen and even twenty degrees! When this undulating and sinuous roadbed had been graded, and it came to the question of laying upon it the costly rails, ties and ballast the "coat was" again "cut according to the cloth," and, in obedience to an imperative economy, these items were cut down to the lowest practicable limit. And here it was that the mechanical engineer stepped in, and with rare ingenuity produced a locomotive and cars that were admirably adapted to travel upon track that was neither level, nor straight, nor smooth in its running. The swiveling truck solved the problem of the curves, the coupled driving wheels and heavy engines the problem of the grades, and the equalizing levers smoothed out the inequalities of the track. And thus it was that, in the adaptation of the track to the country and of the locomotive and cars to the track, the civil and mechanical engineer made possible the enormous development which has characterized the past half century of railroad building in the United States. Had they attempted to build as Brunel built the Great Western road in England, the development of the vast internal resources of the country would have been thrown back a whole generation.

In speaking thus of the early American roadbed, it is not intended to imply that the best American track of 1896 is one whit inferior to that of contemporaneous European railroads, for its improvement has generally kept pace with the increase of the traffic which passed over it, until to-day it is safe to say that the main lines of such roads as the New York Central, the Pennsylvania, the New Haven, and other leading companies, is as fine, and in some respects better, than the best to be found in Europe.

As we look at the railroad map of the United States



THE MERCHANTS' BRIDGE, ST. LOUIS—TYPICAL MODERN DOUBLE TRACK STEEL RAILROAD BRIDGE.

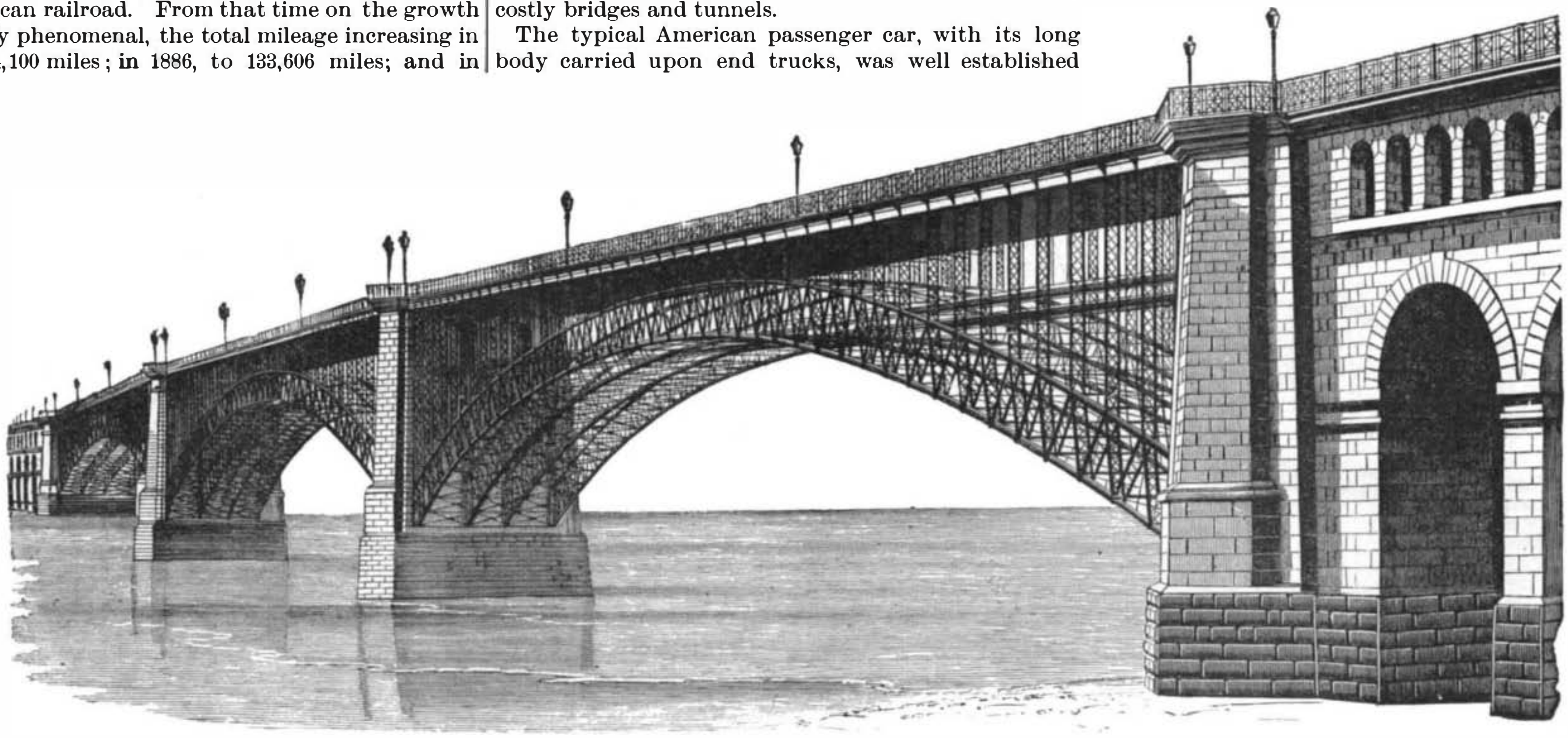
Three spans, 517 feet 6 inches, and six spans, 125 feet long.

for 1896, with its 181,082 miles of track spread out like a finely meshed network over the face of the country, it is difficult to realize that at the date of the foundation of the SCIENTIFIC AMERICAN there were less than 5,000 miles of track in the whole of the States, and that this represented a few small, disconnected lines, scattered through the Atlantic and Southern States, and a few fragmentary systems in the Middle States. Such roads as there were had been laid out with reference to the existing lines of transportation by road and river, and were largely supplementary to them. The Eastern roads were only just beginning to reach across the Alleghenies into the valley of the Mississippi; and as yet there was no sign of a through trunk line to the West, although several lines connected New York with Washington and other important points. It is interesting to note in passing that the stimulating effect of the new upon the old methods of transportation was seen in the rapid development of the river steamboat, which at this early period was far in advance of the ocean steamer, both in speed and accommodation.

Viewed in the light of its subsequent development, the railroad system of 1846 appears both disjointed and insignificant. In that year there were but 4,930 miles in the whole United States; in 1847, 5,598 miles; in 1848, 5,996 miles; in 1849, 7,365 miles; and in 1850, 9,021 miles. In the next decade some 20,000 miles were added, the total reaching 29,739 miles in 1860. Then came the blight of the war, the construction during the next five years averaging only 651 miles a year, and bringing the total up to 32,996 miles in 1865.

THE ST. LOUIS BRIDGE AFTER THE GREAT STORM OF MAY 27, SHOWING INJURY TO STONE WORK ONLY.

At the close of the war, however, the nation devoted its energies and capital to the development of the vast natural resources of the country. One of the first and most important results of this industrial activity was the completion, on May 10, 1869, of the first continuous transcontinental road across America. This event, coupled with the consolidation about this time of the Hudson River and the New York Central Railroads, forming a trunk line to the West from New York City, marked the opening of a new era in the development of the American railroad. From that time on the growth was simply phenomenal, the total mileage increasing in 1876 to 74,100 miles; in 1886, to 133,606 miles; and in 1896, to 181,082 miles! Subsequent to the completion of the Union Pacific, the Southern Pacific Company gave the country, in 1882, another transcontinental route, by way of New Orleans; the Atchison, Topeka, and Santa Fe Company completed a Pacific coast connection through the belt of country lying between the Southern Pacific and the Union Pacific systems; the driving of the golden spike of the Northern Pacific Railroad in August, 1883, opened up the vast forests and wheat fields of the Northwest; and on June 18, 1893, the Great Northern, the latest of the transcontinental roads, dispatched its first through train to Seattle, on the Pacific coast.



THE ST. LOUIS STEEL RAILROAD AND HIGHWAY BRIDGE, BUILT BY CAPT. JAMES B. EADS IN 1874.

Two arches, 502 feet span; one of 520 feet span.

Thus was built up the most stupendous system of transportation in the world, with its 181,082 miles of track. An impressive sense of its magnitude is conveyed in the statement that its rails, if strung out in a single continuous line, could be wrapped around the earth fifteen times, with many a mile to spare!

With the growth of population and manufactures, and the consequent increase in dividends, there came a steady improvement of the roadbed and rolling stock. The introduction of Bessemer steel rails, with their increased stiffness and durability, produced a marked change in the character of the track. The old pear-shaped iron rail, of 40 to 50 pounds weight, was succeeded by the steel headed rail, and this gave place to the 75 pound steel rail of the last, and this in turn to the 100 pound steel rail of the present, decade. Greater attention was paid to ballasting and draining the road-bed, and as fast as the dividends of the company would allow, the lines were revised, the curvature and grades being reduced, and distances shortened by means of costly bridges and tunnels.

The typical American passenger car, with its long body carried upon end trucks, was well established by 1846, the original patent for this type having been granted to Ross Winans in 1834. Its general appearance may be judged from the illustration of a passenger car of that date published in the SCIENTIFIC AMERICAN of August 28, 1845, a reprint of which will be found on the front page of this issue. The standard passenger car of 1850-60 was 7 feet high, 10 feet wide, 50 feet long, and carried sixty passengers, and there were practically no variations of type. The extension of the railroads and the ever increasing length of the journeys called for special provisions for the comfort of the passengers; and in 1864, after several abortive attempts by various roads to produce a comfortable and popular sleeping car, Mr. Pullman brought out his first sleeper, the celebrated Pioneer. The success of this venture led to the formation, in 1867, of the powerful Pullman company, and under their management the sleeping car has developed to its present size and splendor. In 1887 Mr. Pullman patented the vestibule, a flexible diaphragm, which connects the ends of adjacent cars, keeping out the noise, dust, and cinders, and imparting a remarkable steadiness to the whole of the train. Steam heat has replaced the uncertain stove, and gas and the electric light the oil lamp; and what with parlor cars and observation cars, bath rooms and barber shops, and a host of conveniences that minister to one's ease and recreation, the five-day trip from the Atlantic to the Pacific may now be performed amid the multiplied comforts of a first-class city hotel.

Restrictions of space forbid more than a passing reference to the development of the many appliances designed to promote safety of travel. By far the most important of these was the continuous automatic air brake, designed by George Westinghouse, Jr., in 1868, in which year it was first practically applied on trunk roads. In this system, as finally modified, by means of a small lever, placed conveniently to hand, the engineer can instantly apply the brakes on every car, and should the train break apart, the brakes will set themselves automatically. The simplicity, certainty, and power of this brake are remarkable, and render it one of the most successful and life saving inventions of the age. In the celebrated Burlington brake trials in 1886-87 a train of fifty cars, a third of a mile long, running at forty miles an hour, was stopped in a third of its own length. Scarcely less important was the introduction of the Miller platform and coupler in 1863, and the Janney coupler, with many others at a later date; automatic signaling; the interlocking system of levers, whereby a contradictory signal, or an accident from a wrongly thrown switch, are impossible; the block system in the operation of trains, by which no two trains are allowed upon the same "block" or section of line at the same time; and the operation of the freight and passenger traffic upon separate pairs of a four track road; the last three of which improvements were importations from the English roads—in justice to their high efficiency be it said—where they had been standard practice for a great many years.

Some of the more striking evidences of progress in the past twenty years are gathered for comparison in the accompanying table:

	1876.	1896.
Mileage	74,100	181,082
Invested capital	$4,658,000,000	$11,565,000,000
Earnings (gross)	503,000.000	1,100,000 000
Number of locomotives	15,000	36,300
Weight of locomotives	30 to 50 tons	65 to 100 tons
Number of passenger cars	14,000	35,700
Weight of passenger cars	20 to 30 tons	30 to 50 tons
Number of freight cars	384,000	1,200,000
Capacity of freight cars	10 to 12 tons	30 to 40 tons
Speed of passenger trains	20 to 25 miles	40 to 50 miles
Number of employes	370,500	850,000

THE AMERICAN RAILROAD BRIDGE.

The deep canyons and ravines of the mountain passes, and the broad rivers of the plains, have necessitated the construction of a vast number of difficult and costly bridges as the railroads were gradually spread out over the country. Fifty years ago bridges were built almost entirely of wood, and the phenomenal growth of the railroad system was rendered possible by the abundant supply of suitable timber, and the free use of it in the form of pile and bent trestles, and what is known as the Howe truss bridge. The latter bridge, patented in 1840 by Mr. Howe, was for years the standard railroad bridge of America; and it is still doing excellent service in the West, where the magnificent pine and fir timber furnishes sticks of a size and quality that makes it possible to build this form of truss in spans of remarkable length and stiffness. On the lines of the Southern Pacific Railroad, in Oregon, there are to-day modified Howe trusses of wood, from 200 to 250 feet in span, which are carrying the heaviest engines and trains, and giving excellent service. The chords and braces of this form of truss are of timber, and the ties, which are vertical, are of round iron, with screwed upset ends, secured with nuts on the outer faces of the top and bottom chords. The braces are square ended, and bedded upon cast iron angle blocks, which rest upon the chords at the panel points. The excellence of this truss consisted in its simplicity, strength, cheapness, and ease of construction and erection. When the tie rods and small screw bolts were once delivered on the ground, the cross cut saw, the ax and the adz did the rest; and when saw mills were not available, the sticks could often be hewn from the standing timber on each side of the track—as was frequently done in crossing the Rocky and Cascade Mountains of the West—and framed and erected on the spot. The wooden Howe truss has been a potent factor in the development of the American railroad, and it anticipated by more than a generation the advent of the iron and steel truss.

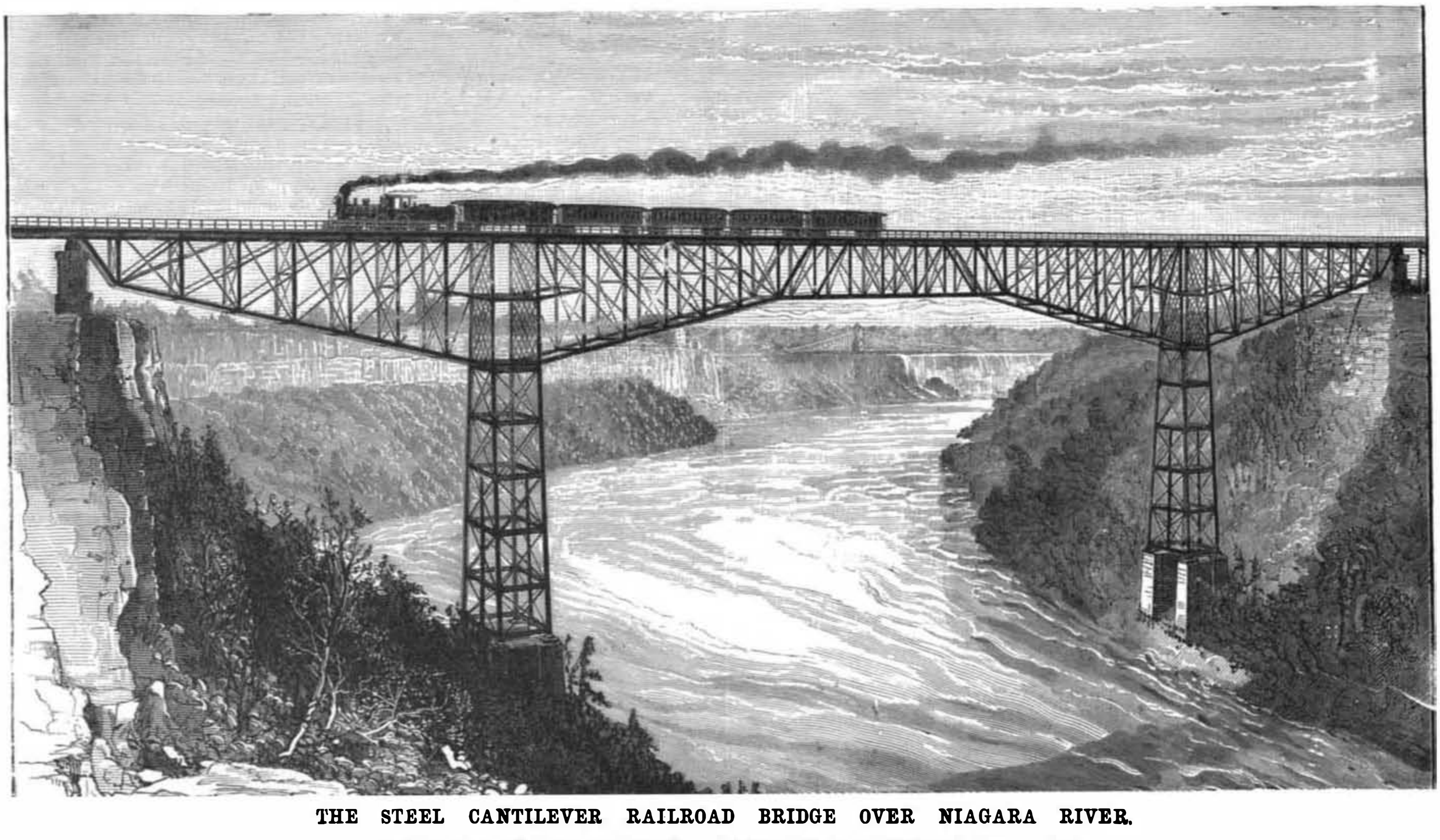
The Pratt truss, with vertical posts and inclined ties, patented in 1844, has become, in its various modifications, in the later age of steel construction, the prevailing national type.

In 1846, Frederick Harbach patented an iron Howe truss, with cast iron top chord and braces, and wrought iron bottom chord and ties, and from that time on, during the next twenty years, a large variety of more or less useful trusses were introduced, conspicuous among which were the Whipple, the Bollman, the Fink, and the Post trusses.

Mr. J. H. Linville was the first engineer to introduce the typical long span railroad truss in America. His famous iron bridge over the Ohio, at Steubenville, in 1864, was followed in 1872 by the Cincinnati bridge of 420 feet span. To Mr. C. Shaler Smith belongs the credit of designing in 1876 the first long iron cantilever bridge, known as the Kentucky River bridge, which consisted of three spans of 375 feet. On July 4, 1874, the famous St. Louis arched bridge of Captain James B. Eads was opened. The great size of the arches—two of 502 and one of 520 feet span; the novel method of their erection—the arches being built out simultaneously from the piers, to which they were tied with temporary guy ropes; the daring but successful use of the pneumatic caisson for the deep foundations (107 feet below M. W. L.) of the piers; together with the original and admirable design of the trussed arches of the bridge—all conspired to mark this as one of the most brilliant feats of engineering that the world has ever

SUSPENSION BRIDGE OVER THE EAST RIVER, AT NEW YORK.

Length of span, 1,595½ feet; total length, 3,455 feet.



THE STEEL CANTILEVER RAILROAD BRIDGE OVER NIAGARA RIVER.

Length of span, 470 feet; total length, 910¼ feet; height, water to rail base, 239 feet.

seen. The destructive tornado of May 27, which tore asunder and scattered the massive masonry of the approaches to this bridge, failed to disturb the equilibrium of the steel arches themselves; and no finer tribute was ever paid to the skill of the bridge engineer than is offered in the photographic reproduction which we present on another page.

The scientific methods of bridge design and construction adopted by Captain Eads have been elaborated by subsequent engineers, until bridge designing is to-day perhaps the most exact branch of the engineering profession. The calculation of the strains in steel trusses is now a matter of mathematical certainty and precision. The various erratic forms of trusses have fallen into disuse, and a standard type of great excellence has survived, one of the latest examples of which is shown in the engraving on another page of the Merchants' Railroad Bridge at St. Louis, built in 1890 by the Union Bridge Company, of New York. The Merchants' bridge comprises three main spans, 517 feet 6 inches long, and six deck spans of 125 feet. The trusses are built entirely of steel and are pin connected, the tension members being steel eye bars, and the compression members consisting of built-up lattice posts and chords. The floor beams and stringers are plate steel girders, the latter being riveted at their ends to the bottom of the posts and vertical ties.

The distinctive features of this system of bridge construction are the concentration of material in large members, the great width of panel and height of truss, and the method of connecting the members at each panel point by means of a large, carefully turned and fitted steel pin. As compared with the European practice of riveting, the American practice conduces to greater accuracy of design and construction, and greater rapidity of erection. The Merchants' bridge, which contains 11,000,000 pounds of steel, and whose granite piers extend 70 feet below the water, was commenced and completed within thirteen months.

The superiority of the pin-connected over the riveted system of bridge construction has been clearly proved in the erection of cantilever bridges, a type which is now extensively used by American and European builders, and of which the great Forth bridge of Sir Benjamin Baker, with its two 1,710 foot spans, is the most monumental example. In its simpler forms, the cantilever is exceedingly ancient. There are bridges in China which are hoary with age whose construction is based upon this principle. The most valuable feature of the cantilever, as compared with the truss bridge, is the facility with which it lends itself to the crossing of rivers and ravines, where the depth of water or other natural features render it impossible to erect any temporary falsework. Perhaps the most notable early use of the cantilever system of erection in America was seen in the building of the above mentioned Eads bridge at St. Louis, where equilibrating portions of the steel arches were built out simultaneously on each side of the piers and tied back to them with steel ropes. Two of the best known cantilever bridges in America are the Niagara River bridge and the Poughkeepsie bridge across the Hudson River. The Niagara bridge has a clear span between towers of 470 feet, with an intermediate truss 120 feet long. Poughkeepsie bridge has three cantilever spans of 548 feet and two connecting spans of 525 feet each. The latter were erected by the aid of falsework, and the cantilevers were then built out in the usual manner. The bridge is designed to withstand a wind pressure of thirty pounds per square foot of surface, and to carry a uniform train load of 3,000 pounds per foot on each track, preceded by two 85 ton locomotives.

No treatise on American bridge building, however brief it may be, can fail to make mention of the development of the wire suspension bridge. Among many other notable bridges of this type are the Niagara suspension bridge, of 821 feet span, the Covington and Cincinnati bridge, of 1,057 feet span, and the Allegheny bridge, with its two spans of 344 feet, all of which were designed by that gifted engineer, the late John A. Roebling, who subsequently raised an enduring monument to his genius in the design and erection of the great East River bridge, uniting the cities of New York and Brooklyn.

This noble structure is too familiar to call for more than a recapitulation of its leading features. The main span is 1,595½ feet long, and the total length, with the approaches, is 3,455 feet. The foundations for the towers were carried down 78 feet below high water by the pneumatic process, and the towers themselves extend 272 feet above high water, making a total height, from foundation to capstone, of 350 feet. The four cables, 15 inches in diameter, are of steel wires laid parallel and wrapped. The floor of the bridge is stiffened with four steel trusses, and carries two carriageways, two standard railway tracks and one footway. The trains are operated by a steel cable, and they carry an immense traffic, the total in 1894 amounting to 43,000,000.

Great as are the proportions of this bridge, it is likely, before long, to be surpassed by the proposed railroad bridge across the Hudson River, at New York, which is to have a main span of 3,254 feet, carried on twelve steel wire cables, 23 inches in diameter. The suspension towers, which will be built of steel plates and angles, will reach to a height of 587 feet above the water. It is not too much to say that this bridge, which is to carry six railroad tracks, side by side, will be the noblest constructive feat of any age or clime.

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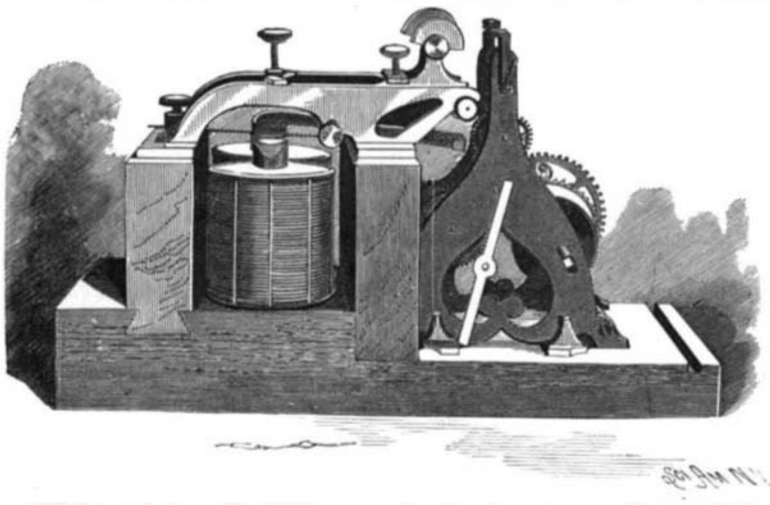
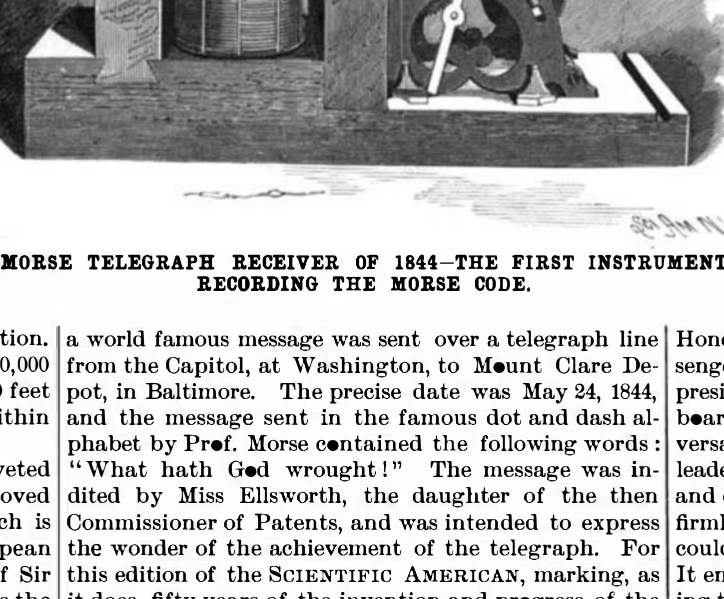
THE TELEGRAPH.



MORSE TELEGRAPH RECEIVER OF 1844—THE FIRST INSTRUMENT RECORDING THE MORSE CODE.

Fifty-two years and two months have passed since a world famous message was sent over a telegraph line from the Capitol, at Washington, to Mount Clare Depot, in Baltimore. The precise date was May 24, 1844, and the message sent in the famous dot and dash alphabet by Prof. Morse contained the following words: "What hath God wrought!" The message was indited by Miss Ellsworth, the daughter of the then Commissioner of Patents, and was intended to express the wonder of the achievement of the telegraph. For this edition of the SCIENTIFIC AMERICAN, marking, as it does, fifty years of the invention and progress of the scientific world, no more appropriate motto could be chosen, for it seems as if the last fifty years definitely showed man's powers and proved adequate to measure his ability. For the first suggestions of the telegraph we can go far back to the days of Otto van Guericke, whose experiments of transmitting through a conductor an ell in length an electric disturbance from his frictional machine with its globe of sulphur excited by rubbing against the hand is well known.

Coming down later, however, we find attempts directly made in the line of telegraphy. In 1727, Stephen Gray, of the Charter House, London, transmitted electrification through a wire 700 feet, suspended in the air by silk threads. Other experiments of the same sort were made by different investigators. Twenty years later a wire stretched across the Thames was used, and the length gradually increased until we find the same investigator using wire 10,600 feet long in his experiments, and a year later Benjamin Franklin experimented with a wire stretched across the Schuylkill River.



MORSE FIRST MODEL—PENDULUM INSTRUMENT OF 1837, SHOWING THE RECORDING RECEIVER (1), PORTRULE (2), TYPE (3), AND EXAMPLE OF CHARACTERS PRODUCED (4 and 5).

A letter in the Scot's Magazine in 1753, signed by C. M., suggests an electric telegram operated by a frictional electrical machine; and in 1774, at Geneva, Lesage erected a telegraph line of 24 insulated wires, each corresponding to a letter of the alphabet. Many other attempts were made and signals were transmitted by static excitation produced by frictional machines. At the beginning of the present century the voltaic battery was invented. The investigators had at once an instrumentality for maintaining a current through a wire, by which the decomposition of water could be brought about, magnets attracted and other phenomena produced, and, in 1808, the Munich Academy of Science received from Sommering a communication describing a telegraph containing thirty-five wires, one for each letter of the alphabet and one for each number. At the transmitting end arrangements were provided for passing currents through any one of the wires. At the receiving end the electros were immersed in acid, and, completing the circuit, caused the evolution of bubbles of hydrogen. Each tube corresponded to a letter or a number.

Passing by many other attempts, we find, in 1839, the Wheatstone telegraph, fairly effectual, producing its signal by means of what are practically galvanometer needles. A bell alarm was used to call the operator. To produce a powerful enough sound, Wheatstone used a relay circuit, the first one in the history of the art. Henry, in 1832, had, as one result of his experiments in electricity, used the electric magnet in a signaling telegraph, and for him is claimed the glory of being the inventor of the first electro-magnetic telegraph.

Samuel F. B. Morse was born in Charlestown, Mass., on the 27th of April, 1791, but a little over a mile from Franklin's birthplace. He was educated as an artist, and won high triumphs as such, but was marked as a lover of science from his earliest days. His life was subject to more than the usual vicissitudes of an artist's existence. After traveling extensively in Europe and studying there, we find him sailing on the packet ship Sully, for the harbor of New York, in 1832. Philip Hone, in his interesting diary, states that among the passengers on his ship was S. F. B. Morse, the artist and president of the National Academy of Design. On board the ship Morse had his interest excited by a conversation in which Dr. Charles T. Jackson was the leader, who spoke of some of the wonders of electricity and of the electrical magnet. This seems to have fixed firmly in Morse's mind the idea that an electric telegraph could be constructed with the electric magnet as a basis. It engrossed his mind throughout the voyage, and during the six weeks which it lasted he jotted down in his note book different sketches of a proposed system of electrical telegraphy. He practiced his art and experimented with the telegraph, the latter, during the next few years, gradually wooing him from his brush. Prof. Daniel, of London, in 1835 invented the constant current battery, which proved a powerful adjunct to Morse's work. He was confronted at once with the difficulty that the current became enfeebled on too long a line, and used the relay circuit to overcome this trouble. In 1837 he explained his invention to Prof. Leonard D. Gale, of the University of the City of New York, who assisted him by his scientific counsel, and in the same year he interested in it Alfred Vail, a son of Judge Stephen Vail, proprietor of the Speedwell Iron Works, Morristown, N. J. An agreement was entered into between them, Vail supplying the money. The American patent was obtained on October 3, 1837, and Vail in secret quarters at the iron factory worked upon the invention.

Morse's original telegraph provided a pendulum carrying a pencil or marking device in constant contact with a strip of paper to be drawn beneath the point by machinery. As long as inactive, this would make a straight line upon the paper. The pendulum carried also an armature, and an electric magnet was placed near the armature. A current passed through the magnet would draw the pendulum to one side. On being released the pendulum would return, and in this way any amount of zigzag marks could be made on the paper as it traveled with the pencil constantly pressing upon it. Vail made some changes in the device and substituted for the pendulum and marking pencil the familiar lever with pencil of the more modern type of Morse machine, and substituted for the zigzag line the dot and dash alphabet.

In 1839 Morse began the hardest period of his life. He was dependent for his living upon what he could earn as a professor of art. At one time he went twenty-four hours without food. Toward the close of 1841, he writes that he has not a cent in the world, but affirms that he will not run in debt. In the next year he submerged in the New York Harbor between Castle Garden and Governor's Island a wire which he had insulated and sent signals through it. The experiments were repeated at Washington in a canal, in December of the same year, and Morse, in describing his experiments in 1844, announced his belief that signals could and would be sent across the Atlantic Ocean by electromagnetic telegraph. Sick, and tired at heart, agitating for an appropriation from Congress to test his invention, Morse found himself in December, 1842, with his personal funds reduced