CHAPTER IV.

THE MODERN STEAM-ENGINE.

"THOSE projects which abridge distance have done most for the civilization and happiness of our species."—MACAULAY.

THE SECOND PERIOD OF APPLICATION—1800–'40. STEAM-LOCOMOTION ON RAILROADS.

INTRODUCTORY.—The commencement of the nineteenth century found the modern steam-engine fully developed in

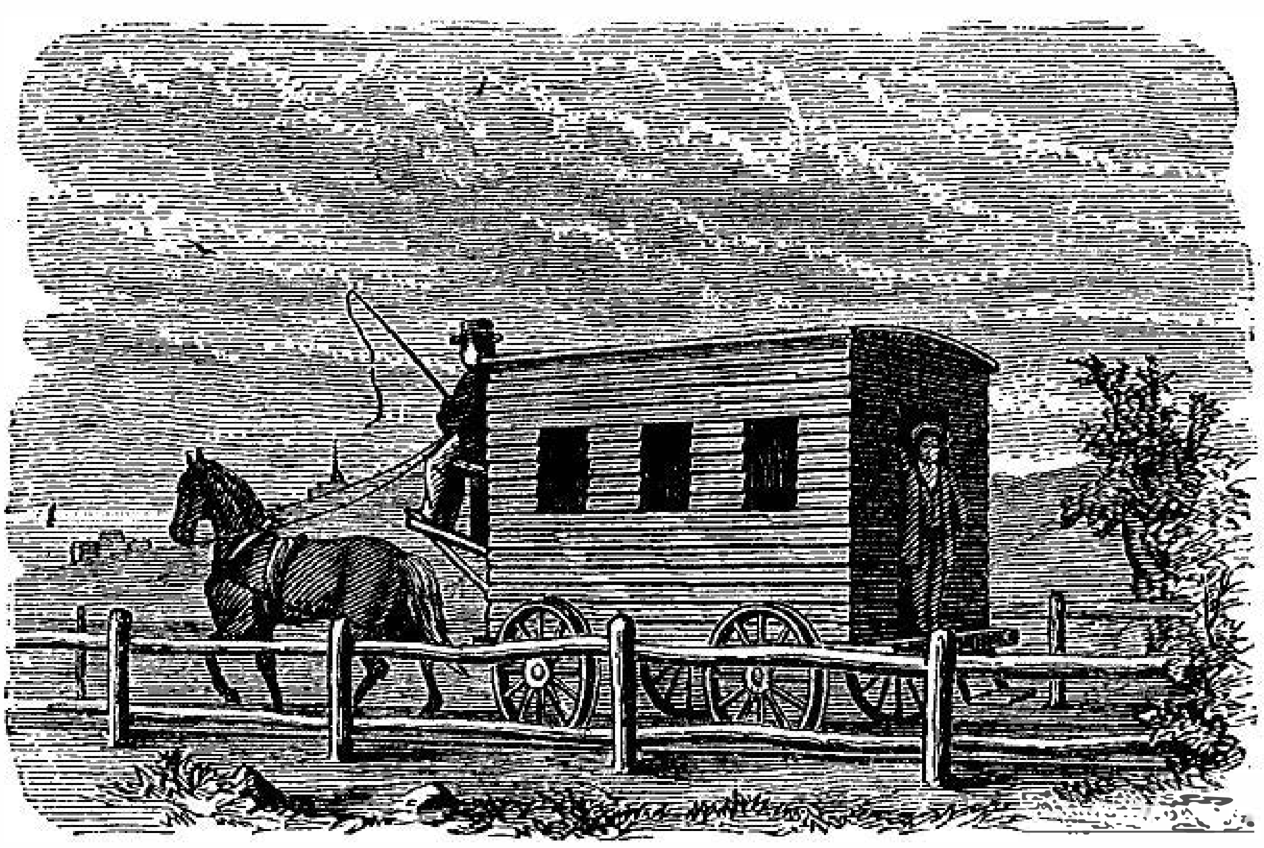


FIG. 40.—The First Railroad-Car, 1825.

all its principal features, and fairly at work in many departments of industry. The genius of Worcester, and Morland, and Savery, and Desaguliers, had, in the first period of the application of the power of steam to useful work, effected a beginning which, looked upon from a point of view which exhibits its importance as the first step toward the wonderful results to-day familiar to every one, appears in its true light, and entitles those great men to even greater honor than has been accorded them. The results actually accomplished, however, were absolutely insignificant in comparison with those which marked the period of development just described. Yet even the work of Watt and of his contemporaries was but a mere prelude to the marvellous advances made in the succeeding period, to which we are now come, and, in extent and importance, was insignificant in comparison with that accomplished by their successors in the development of all mechanical industries by the application of the steam-engine to the movement of every kind of machine.

The first of the two periods of application saw the steam-engine adapted simply to the elevation of water and the drainage of mines; during the second period it was adapted to every variety of useful work, and introduced wherever the muscular strength of men and animals, or the power of wind and of falling water, which had previously been the only motors, had found application. A history of the development of industries by the introduction of steam-power during this period, would be no less extended and hardly less interesting than that of the steam-engine itself.

The way had been fairly opened by Boulton and Watt; and the year 1800 saw a crowd of engineers and manufacturers entering upon it, eager to reap the harvest of distinction and of pecuniary returns which seemed so promising to all. The last year of the eighteenth century was also the last of the twenty-five years of partnership of Boulton & Watt, and, with it, the patents under which that firm had held the great monopoly of steam-engine building expired. The right to manufacture the modern steam-engine was common to all. Watt had, at the commencement of the new century, retired from active business-life. Boulton remained in business; but he was not the inventor of the new engine, and could not retain, by the exercise of all his remaining power, the privileges previously held by legal authorization.

The young Boulton and the young Watt were not the Boulton & Watt of earlier years; and, had they possessed all of the business talent and all of the inventive genius of their fathers, they could not have retained control of a business which was now growing far more rapidly than the facilities for manufacturing could be extended in any single establishment. All over the country, and even on the Continent of Europe, and in America, thousands of mechanics, and many men of mechanical tastes in other professions, were familiar with the principles of the new machine, and were speculating upon its value for all the purposes to which it has since been applied; and a multitude of enthusiastic mechanics, and a larger multitude of visionary and ignorant schemers, were experimenting with every imaginable device, in the vain hope of attaining perpetual motion, and other hardly less absurd results, by its modification and improvement. Steam-engine building establishments sprang up wherever a mechanic had succeeded in erecting a workshop and in acquiring a local reputation as a worker in metal, and many of Watt's workmen went out from Soho to take charge of the work done in these shops. Nearly all of the great establishments which are to-day most noted for their extent and for the importance and magnitude of the work done in them, not only in Great Britain, but in Europe and the United States, came into existence during this second period of the application of the steam-engine as a prime mover.

The new establishments usually grew out of older shops of a less pretentious character, and were managed by men who had been trained by Watt, or who had had a still more awakening experience with those who vainly strove to make up, by their ingenuity and by great excellence of workmanship, for advantages possessed at Soho in a legal monopoly and greater experience in the business.

It was exceedingly difficult to find expert and conscientious workmen, and machine-tools had not become as thoroughly perfected as had the steam-engine itself. These difficulties were gradually overcome, however, and thenceforward the growth of the business was increasingly rapid.

Every important form of engine had now been invented. Watt had perfected, with the aid of Murdoch, both the pumping-engine and the rotative steam-engine for application to mills. He had invented the trunk engine, and Murdoch had devised the oscillating engine and the ordinary slide-valve, and had made a model locomotive-engine, while Hornblower had introduced the compound engine. The application of steam to navigation had been often proposed, and had sometimes been attempted, with sufficient success to indicate to the intelligent observer an ultimate triumph. It only remained to extend the use of steam as a motor into all known departments of industry, and to effect such improvements in details as experience should prove desirable.

The engines of Hero, of Porta, and of Branca were, it will be remembered, non-condensing; but the first plan of a non-condensing engine that could be made of any really practical use is given in the "Theatrum Machinarum" of Leupold, published in 1720. This sketch is copied in Fig. 41. It is stated by Leupold that this plan was suggested by Papin. It consists of two single-acting cylinders, *r s*, receiving steam alternately from the same steam-pipe through a "four-way cock," *x*, and exhausting into the atmosphere. Steam is furnished by the boiler, *a*, and the pistons, *c d*, are alternately raised and depressed, depressing and raising the pump-rods, *k l*, to which they are attached by the beams, *h g*, vibrating on the centres, *i i*. The water from the pumps, *o p*, is forced up the stand-pipe, *q*, and discharged at its top. The alternate action of the steam-pistons is secured by turning the "four-way cock," x, first into the position shown, and then, at the completion of the stroke, into the reverse position, by which change the steam from the

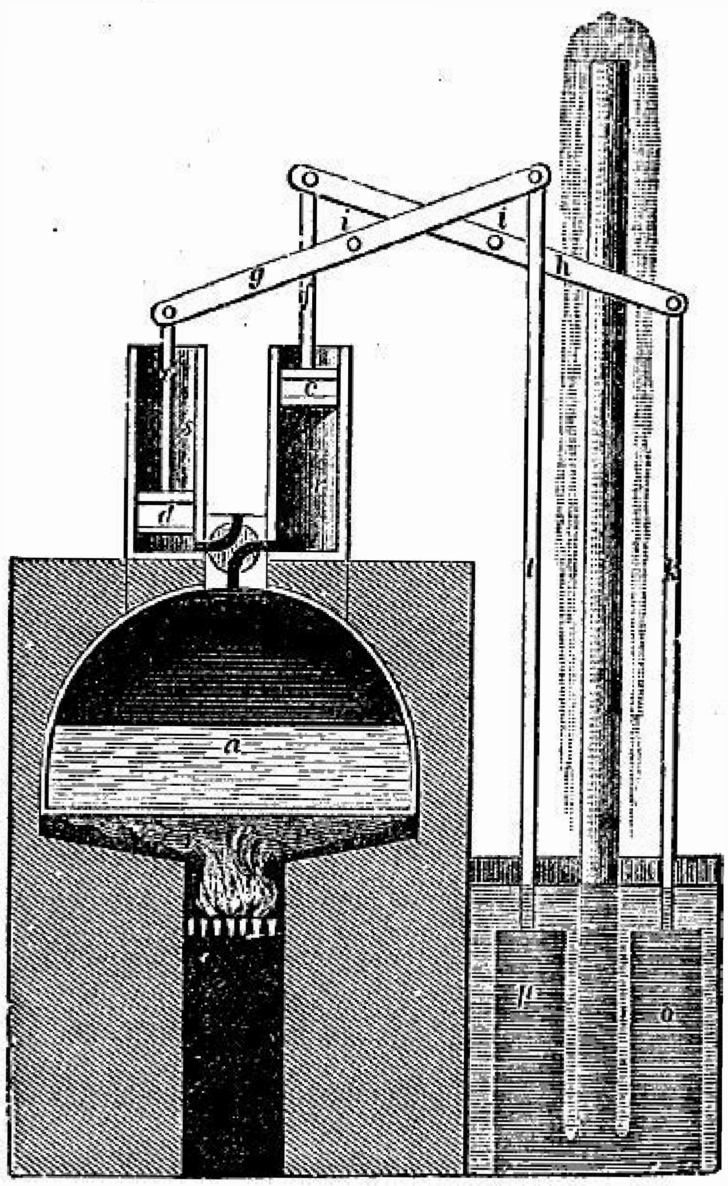


FIG. 41.—Leupold's Engine, 1720.

boiler is then led into the cylinder, s, and the steam in r is discharged into the atmosphere.[1]

Leupold states that he is indebted to Papin for the suggestion of the peculiar valve here used. He also proposed to use a Savery engine without condensation in raising water. We have no evidence that this engine was ever built.

The first rude scheme for applying steam to locomotion on land was probably that of Isaac Newton, who, in 1680, proposed the machine shown in the accompanying figure (42), which will be recognized as representing the scientific

[1] *Vide* "Theatrum Machinarum," vol. iii., Tab. 30.

toy which is found in nearly every collection of illustrative philosophical apparatus. As described in the "Explanation of the Newtonian Philosophy," it consists of a spherical boiler, *B*, mounted on a carriage. Steam issuing from the

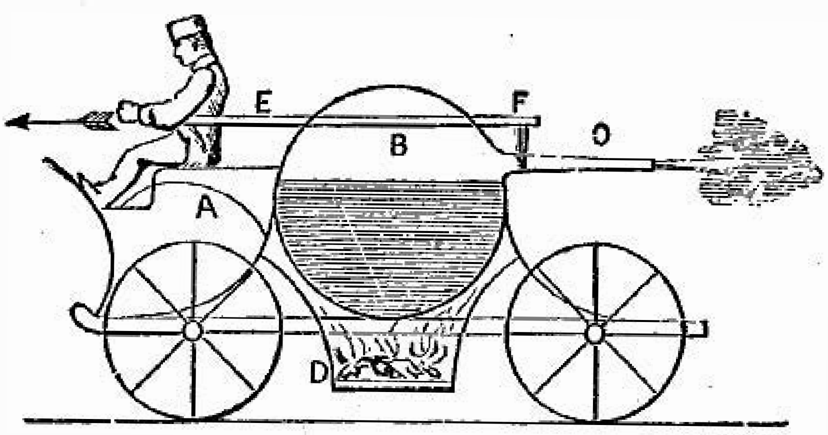


FIG. 42.—Newton's Steam-Carriage, 1680.

pipe, *C*, seen pointing directly backward, by its reaction upon the carriage, drives the latter ahead. The driver, sitting at *A*, controls the steam by the handle, *E*, and cock, *F*. The fire is seen at *D*.

When, at the end of the eighteenth century, the steam-engine had been so far perfected that the possibility of its successful application to locomotion had become fully and very generally recognized, the problem of adapting it to locomotion on land was attacked by many inventors.

Dr. Robison had, as far back as in 1759, proposed it to James Watt during one of their conferences, at a time when the latter was even more ignorant than the former of the principles which were involved in the construction of the steam-engine, and this suggestion may have had some influence in determining Watt to pursue his research ; thus setting in operation that train of thoughtful investigation and experiment which finally earned for him his splendid fame.

In 1765, that singular genius, Dr. Erasmus Darwin, whose celebrity was acquired by speculations in poetry and philosophy as well as in medicine, urged Matthew Boulton —subsequently Watt's partner, and just then corresponding with our own Franklin in relation to the use of steam-power —to construct a steam-carriage, or "fiery chariot," as he poetically styled it, and of which he sketched a set of plans. A young man named Edgeworth became interested in the scheme, and, in 1768, published a paper which had secured for him a gold medal from the Society of Arts. In this paper he proposed railroads on which the carriages were to be drawn by horses, *or by ropes from steam-winding engines.*

Nathan Read, of whom an account will be given hereafter, when describing his attempt to introduce steam-navigation, planned, and in 1790 obtained a patent for, a steam-carriage, of which the sketch seen in Fig. 43 is copied from the rough drawing accompanying his application. In the figure, *A A A A* are the wheels; *B B*, pinions on the hubs of the rear wheels, which are driven by a ratchet arrangement on the racks, *G G*, connected with the piston-rods; *C o* is the boiler; *D D*, the steam-pipes carrying steam to the steam-cylinder, *E E*; *F F* are the engine-frames; *H* is

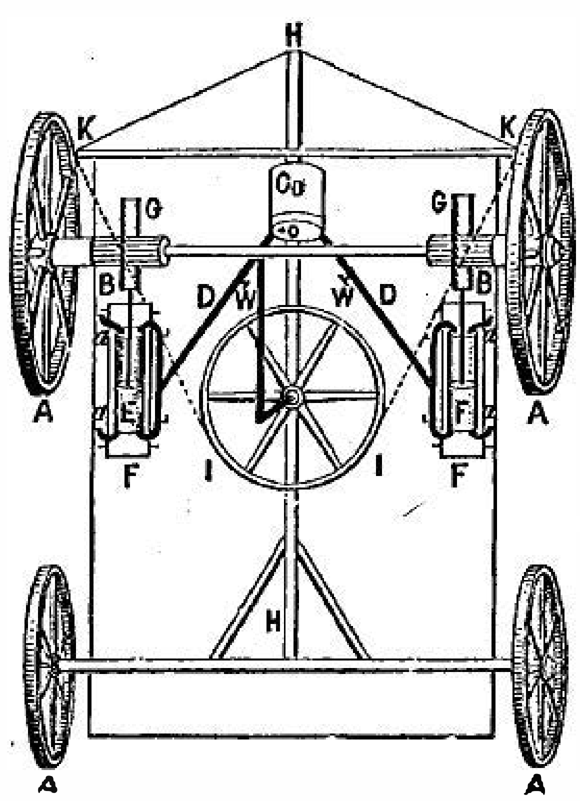


FIG. 43.—Read's Steam-Carriage, 1790.

the "tongue" or "pole" of the carriage, and is turned by a horizontal steering-wheel, with which it is connected by the ropes or chains, *I K, I K*; *W W* are the cocks, which serve to shut off steam from the engine when necessary, and to determine the amount of steam to be admitted. The pipes *a a* are exhaust-pipes, which the inventor proposed to turn so that they should point backward, in order to secure the advantage of the effort of reaction of the expelled steam. (!)

Read made a model steam-carriage, which he exhibited when endeavoring to secure assistance in furtherance of his schemes, but seems to have given more attention to steam-navigation, and nothing was ever accomplished by him in this direction.

These were merely promising schemes, however. The first actual experiment was made, as is supposed, by a French army-officer, Nicholas Joseph Cugnot, who in 1769 built a steam-carriage, which was set at work in presence of the French Minister of War, the Duke de Choiseul. The funds required by him were furnished by the Compte de Saxe. Encouraged by the partial success of the first locomotive, he, in 1770, constructed a second (Fig. 44),

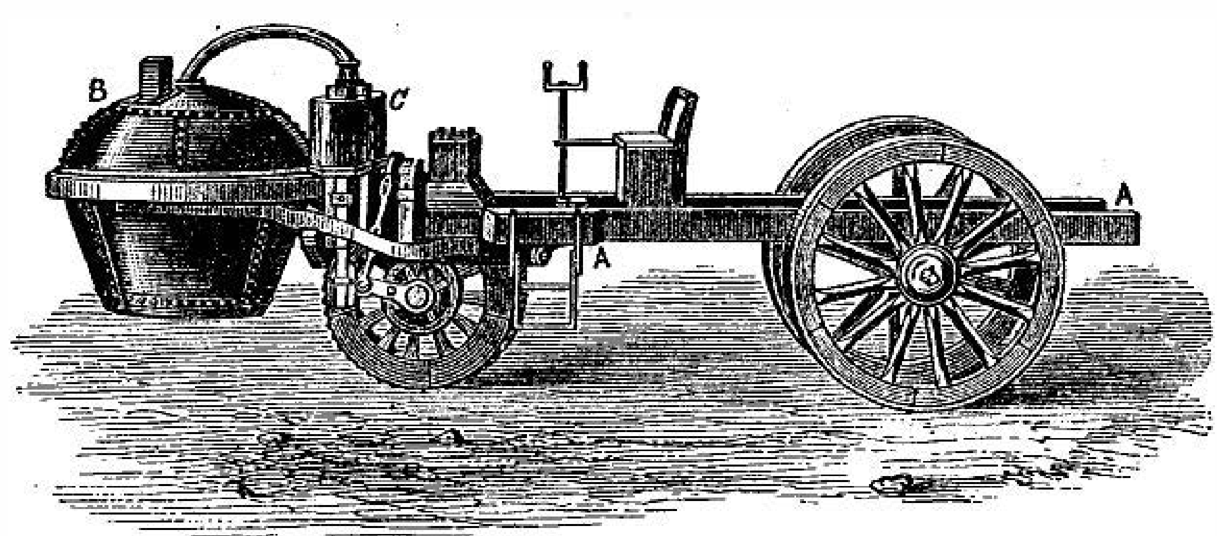


Fig. 44.—Cugnot's Steam-Carriage, 1770.

which is still preserved in the Conservatoire des Arts et Métiers, Paris.

This machine, when recently examined by the author, was still in an excellent state of preservation. The carriage and its machinery are substantially built and well-finished, and exceedingly creditable pieces of work in every respect. It surprises the engineer to find such evidence of the high character of the work of the mechanic Brezin a century ago. The steam-cylinders were 13 inches in diameter, and the engine was evidently of considerable power. This locomotive was intended for the transportation of artillery. It consists of two beams of heavy timber extending from end to end, supported by two strong wheels behind, and one still heavier but smaller wheel in front. The latter carries on its rim blocks which cut into the soil as the wheel turns, and thus give greater holding power. The single wheel is turned by two single-acting engines, one on each side, supplied with steam by a boiler (seen in the sketch) suspended in front of the machine. The connection between the engines and the wheels was effected by means of pawls, as first proposed by Papin, which could be reversed when it was desired to drive the machine backward. A seat is mounted on the carriage-body for the driver, who steers the machine by a train of gearing, which turns the whole frame, carrying the machinery 15 or 20 degrees either way. This locomotive was found to have been built on a tolerably satisfactory general plan; but the boiler was too small, and the steering apparatus was incapable of handling the carriage with promptness.

The death of one of Cugnot's patrons, and the exile of the other, put an end to Cugnot's experiments.

Cugnot was a mechanic by choice, and exhibited great talent. He was a native of Vaud, in Lorraine, where he was born in 1725. He served both in the French and the German armies. While under the Maréchal de Saxe, he constructed his first steam locomotive-engine, which only disappointed him, as he stated, in consequence of the inefficiency of the feed-pumps. The second was that built under the authority of the Minister Choiseul, and cost 20,000 livres. Cugnot received from the French Government a pension of 600 livres. He died in 1804, at the age of seventy-nine years.

Watt, at a very early period, proposed to apply his own engine to locomotion, and contemplated using either a non-condensing engine or an air-surface condenser. He actually included the locomotive-engine in his patent of 1784; and his assistant, Murdoch, in the same year, made a working-model locomotive (Fig. 45), which was capable of running at a rapid rate. This model, now deposited in the Patent Museum at South Kensington, London, had a flue-boiler, and its steam-cylinder was three-fourths of an inch in diameter, and the stroke of piston 2 inches. The driving-wheels were $9\frac{1}{2}$ inches diameter.

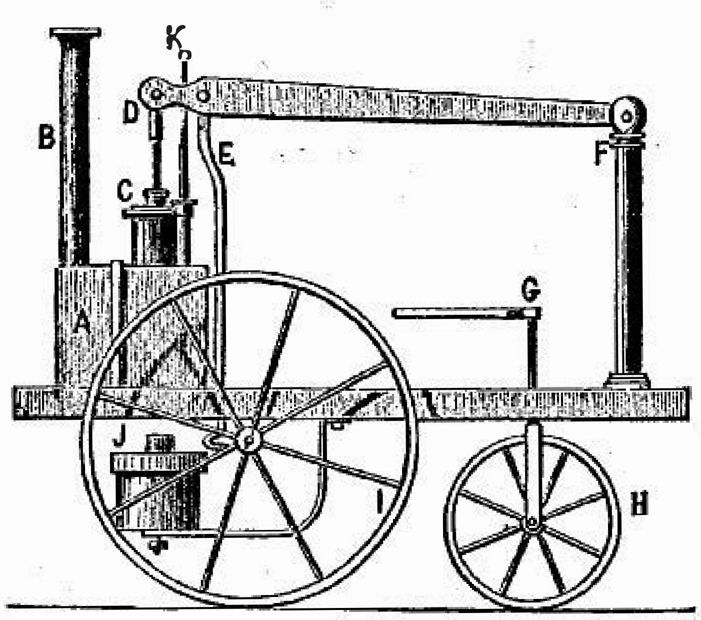
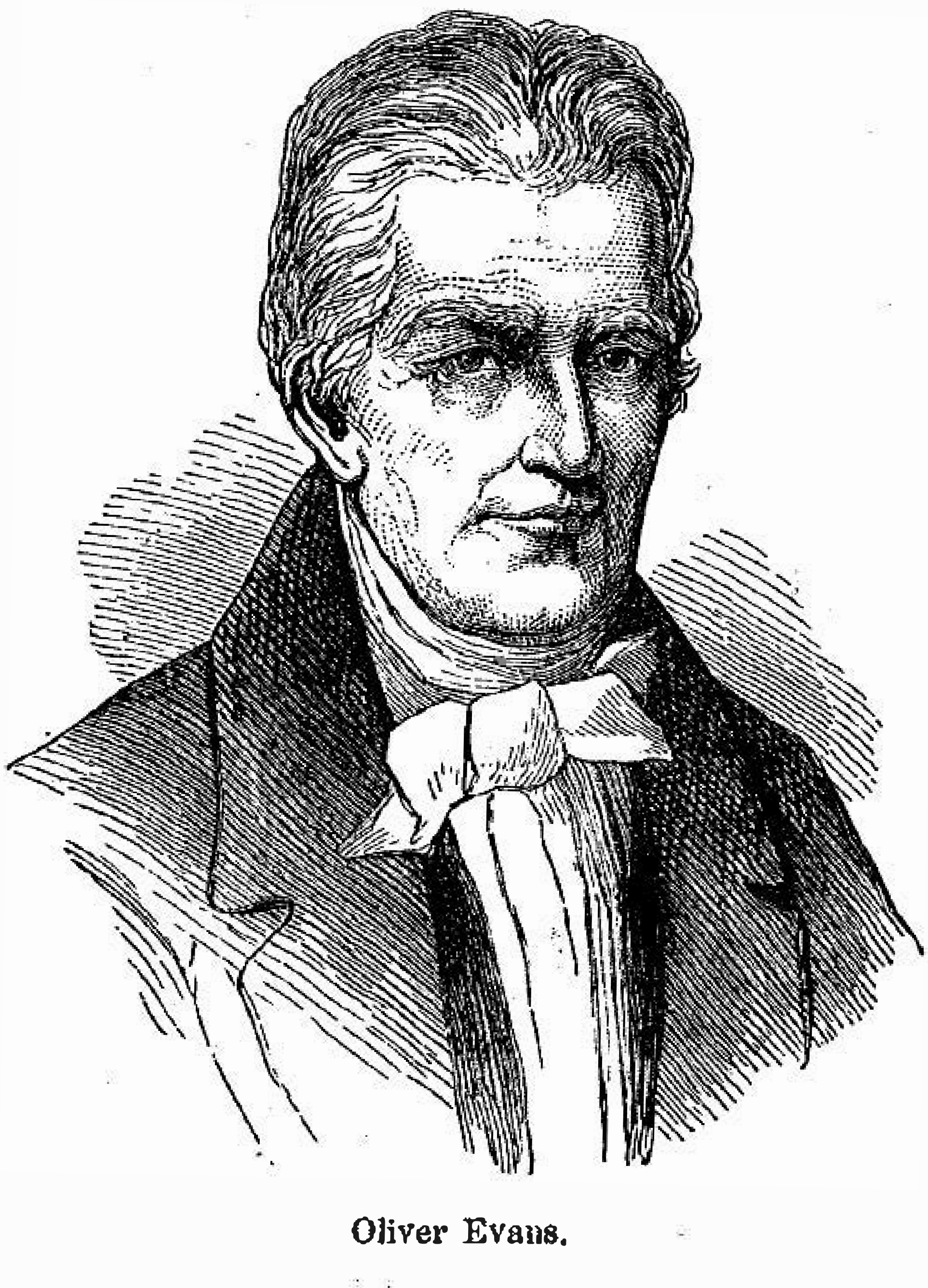


FIG. 45.—Murdoch's Model, 1784.

Nothing was, however, done on a larger scale by either Watt or Murdoch, who both found more than enough to claim their attention in the construction and introduction of other engines. Murdoch's model is said to have run from 6 to 8 miles an hour, its little driving-wheels making from 200 to 275 revolutions per minute. As is seen in the sketch, this model was fitted with the same form of engine, known as the "grasshopper-engine," which was used in the United States by Oliver Evans.

"To Oliver Evans," says Dr. Ernest Alban, the distinguished German engineer, "was it reserved to show the true value of a long-known principle, and to establish thereon a new and more simple method of applying the power of steam—a method that will remain an eternal memorial to its introducer." Dr. Alban here refers to the earliest permanently successful introduction of the non-condensing high-pressure steam-engine.

Oliver Evans, one of the most ingenious mechanics that America has ever produced, was born at Newport, Del., in 1755 or 1756, the son of people in very humble circumstances.



Oliver Evans.

He was, in his youth, apprenticed to a wheelwright, and soon exhibited great mechanical talent and a strong desire to acquire knowledge. His attention was, at an early period, drawn to the possible application of the power of steam to useful purposes by the boyish pranks of one of his comrades, who, placing a small quantity of water in a gun-barrel, and ramming down a tight wad, put the barrel in the fire of a blacksmith's forge. The loud report which accompanied the expulsion of the wad was an evidence to young Evans of great and (as he supposed) previously undiscovered power.

Subsequently meeting with a description of a Newcomen engine, he at once noticed that the elastic force of confined steam was not there utilized. He then designed the non-condensing engine, in which the power was derived exclusively from the tension of high-pressure steam, and proposed its application to the propulsion of carriages.

About the year 1780, Evans joined his brothers, who were millers by occupation, and at once employed his inventive talent in improving the details of mill-work, and with such success as to reduce the cost of attendance one-half, and also to increase the fineness of the flour made. He proved himself a very expert millwright.

In 1786 he applied to the Pennsylvania Legislature for a patent for the application of the steam-engine to driving mills, and to the steam-carriage, but was refused it. In 1800 or 1801, Evans, after consultation with Professor Robert Patterson, of the University of Pennsylvania, and getting his approval of the plans, commenced the construction of a steam-carriage to be driven by a non-condensing engine. He soon concluded, however, that it would be a better scheme, pecuniarily, to adapt his engine, which was novel in form and of small first cost, to driving mills; and he accordingly changed his plans, and built an engine of 6 inches diameter of cylinder and 18 inches stroke of piston, which he applied with perfect success to driving a plaster-mill.

This engine, which he called the "Columbian Engine," was of a peculiar form, as seen in Fig. 46. The beam is supported at one end by a rocking column; at the other, it is attached directly to the piston-rod, while the crank lies beneath the beam, the connecting-rod, 1, being attached to the latter at the extreme end. The head of the piston-rod is compelled to rise and fall in a vertical line by the "Evans's parallelogram"—a kind of parallel-motion very similar to one of those designed by Watt. In the sketch (Fig. 46), 2 is the crank, 3 the valve-motion, 4 the steam-pipe from the boiler, *E*, 5 6 7 the feed-pipe leading from the pump, *F*. *A* is the boiler. The flame from the fire on the grate, *H*, passes under the boiler between brick walls, and back through a central flue to the chimney, *I*.

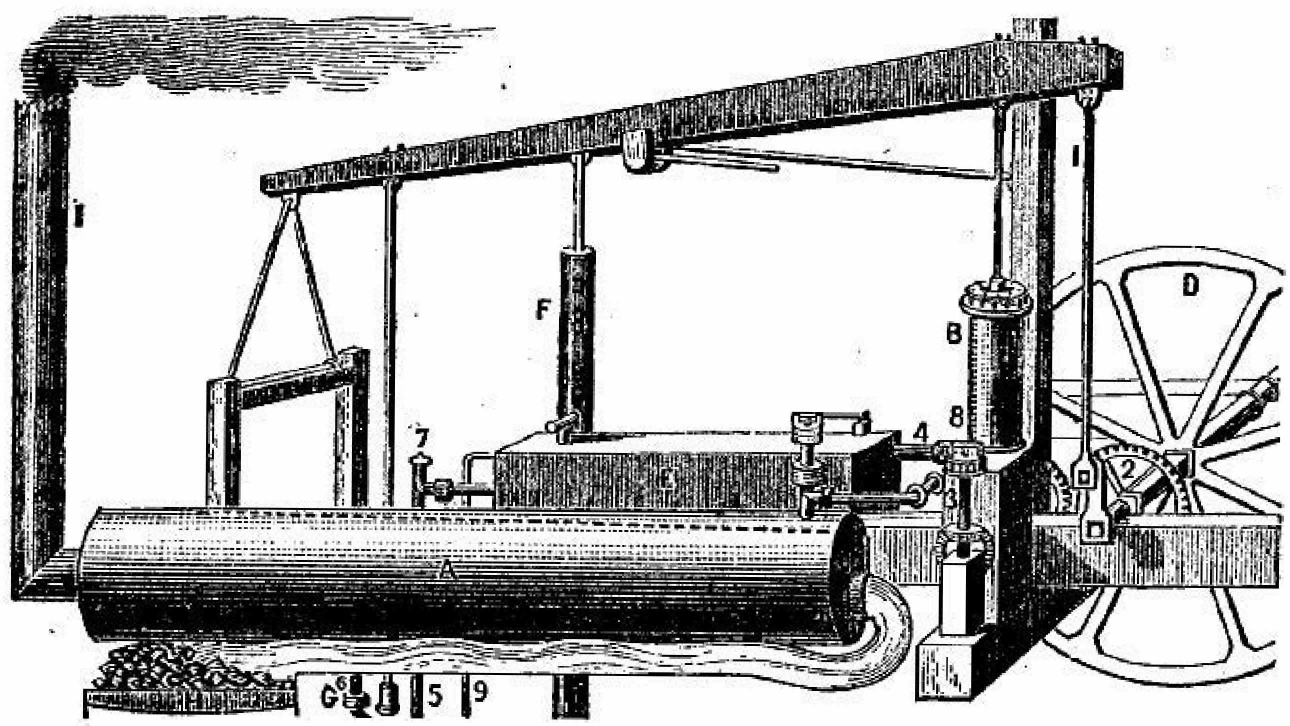


FIG. 46.—Evans's Non-condensing Engine, 1800.

Subsequently, Evans continued to extend the applications of his engine and to perfect its details; and, others following in his track, the non-condensing engine is to-day fulfilling the predictions which he made 70 years ago, when he said:

"I have no doubt that my engines will propel boats against the current of the Mississippi, and wagons on turnpike roads, with great profit. . . ."

"The time will come when people will travel in stages moved by steam-engines from one city to another, almost as fast as birds can fly, 15 or 20 miles an hour. . . . A carriage will start from Washington in the morning, the passengers will breakfast at Baltimore, dine at Philadelphia, and sup in New York the same day. . . .

"Engines will drive boats 10 or 12 miles an hour, and there will be hundreds of steamers running on the Mississippi, as predicted years ago."[1]

In 1804, Evans applied one of his engines in the transportation of a large flat-bottomed craft, built on an order of the Board of Health of Philadelphia, for use in clearing some of the docks along the water-front of the city. Mounting it on wheels, he placed in it one of his 5-horse power engines, and namedt the odd machine (Fig. 47) "Oruktor Amphibolis." This steam dredging-machine, weighing about 40,000 pounds, was then propelled very slowly from the works, up Market Street, around to the Water-Works, and

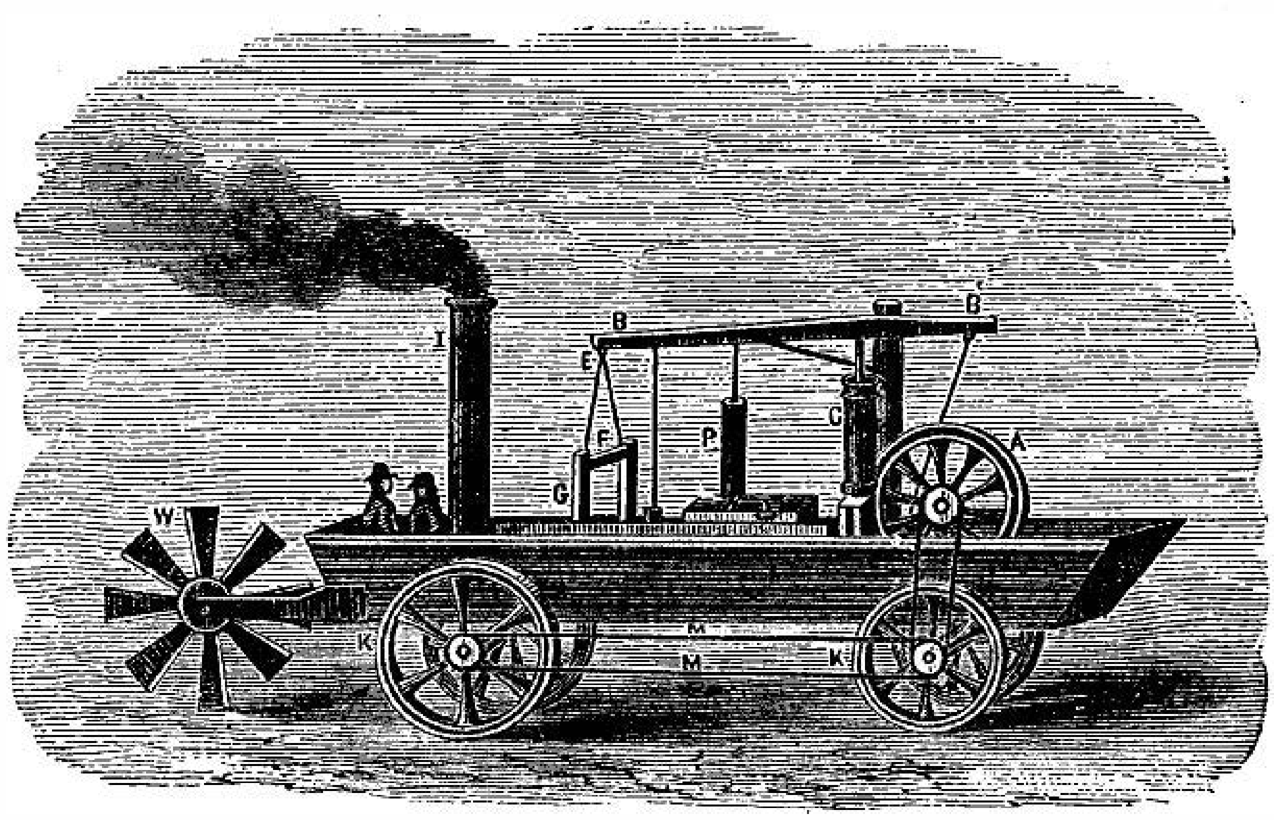


FIG. 47.—Evans's "Oruktor Amphibolis," 1804.

then launched into the Schuylkill. The engine was then applied to the paddle-wheel at the stern, and drove the craft down the river to its confluence with the Delaware.

In September of the same year, Evans laid before the Lancaster Turnpike Company a statement of the estimated expenses and profits of steam-transportation on the common road, assuming the size of the carriage used to be sufficient fort transporting 100 barrels of flour 50 miles in 24 hours,

[1] Evans's prediction is less remarkable than that of Darwin, elsewhere quoted.

and placed in competition with 10 wagons drawn by 5 horses each.

In the sketch above given of the "Oruktor Amphibolis," the engine is seen to resemble that previously described. The wheel, *A*, is driven by a rod depending from the end of a beam, *B′B*, the other end of which is supported at *E* by the frame, *EFG*. The body of the machine is carried on wheels, *KK*, driven by belts, *MM*, from the pulley on the shaft carrying *A*. The paddle-wheel is seen at *W*. Evans had some time previously sent Joseph Sampson to England with copies of his plans, and by him they were shown to Trevithick, Vivian, and other British engineers.

Among other devices, the now familiar Cornish boiler, having a single internal flue, and the Lancashire boiler, having a pair of internal flues, were planned and used by Evans.

At about the time that he was engaged on his steam dredging-machine, Evans communicated with Messrs. McKeever & Valcourt, who contracted with him to build an engine for a steam-vessel to ply between New Orleans and Natchez on the Mississippi, the hull of the vessel to be built on the river, and the machinery to be sent to the first-named city to be set up in the boat. Financial difficulties and low water combined to prevent the completion of the steamer, and the engine was set at work driving a saw-mill, where, until the mill was destroyed by fire, it sawed lumber at the rate of 250 feet of boards per hour.

Evans never succeeded in accomplishing in America as great a success as had rewarded Watt in Great Britain; but he continued to build steam-engines to the end of his life, April 19, 1819, and was succeeded by his sons-in-law, James Rush and David Muhlenberg.

He exhibited equal intelligence and ingenuity in perfecting the processes of milling, and in effecting improvements in his own business, that of the millwright. When but twenty-four years old, he invented a machine for making the wire teeth used in cotton and woolen cards, turningn them out at the rate of 3,000 per minute. A little later he invented a card-setting machine, which cut the wire from the reel, bent the teeth, and inserted them. In milling, he invented a whole series of machines and attachments, including the elevator, the "conveyor," the "hopper-box," the "drill," and the "descender,"nand enabled the miller to make finer flour, gaining over 20 pounds to the barrel, and to do this at half the former cost of attendance. The introduction of his improvementsninto Ellicott's mills, near Baltimore, where 325 barrels of flour were made per day, was calculated to have saved nearly $5,000 per year in cost of labor, and over $30,000 by increasing the production. He wrote "The Young Steam-Engineer's Guide," and a work which remained standard many years after his death, "The Young Millwright's Guide." Less fortunate than his transatlantic rival, he was nevertheless equally deserving of fame. He has sometimes been called "The Watt of America."

The application of steam to locomotion on the common road was much more successful in Great Britain than in the United States. As early as 1786, William Symmington, subsequently more successful in his efforts to introduce steam for marine propulsion, assisted by his father, made a working model of a steam-carriage, which did not, however, lead to important results.

In 1802, Richard Trevithick, a pupil of Murdoch's, who afterward became well known in connection with the introduction of railroads, made a model steam-carriage, which was patented in the same year. The model may still be seen in the Patent Museum at South Kensington.[1]

In this engine, high-pressure steam was employed, and the condenser was dispensed with. The boiler was of the form devised by Evans, and was subsequently generally

[1] *See* "Life of Trevithick."

used in Cornwall, where it was called the "Trevithick Boiler." The engine had but one cylinder, and the piston-rod drove a "cross-tail," working in guides, which was connected with a "cross-headt' on the opposite side of the shaft by two "side-rods." The connecting-rod was attached to the cross-head and the crank, "returningt' toward the cylinder as the shaft lay between the latter and the cross-head. This was probably the first example of the now common "return connecting-rod engine." The connection between the crank-shaft and the wheels of the carriage was effected by gearing. The valve-gear and the feed-pumps were worked from the engine-shaft. The inventor proposed to secure his wheels against slipping by projecting bolts, when necessary, through the rim of the wheel into the ground.t The first carriage of full size was built by Trevithick and Vivian at Camborne, in 1803, and, after trial, was taken to London, where it was exhibited to the public. *En route*, it was driven by its own engines to Plymouth, 90 miles from Camborne, and then shipped by water. It is not known whether the inventor lost faith in his invention; but he very soon dismantled the machine, sold the engine and carriaget separately, and returned to Cornwall, where he soon began work on a railroad-locomotive.

In 1821, Julius Griffiths, of Brompton, Middlesex, England, patented a steam-carriage for the transportation of passengers on the highway. His first road-locomotive was built in the same year by Joseph Bramah, one of the ablest mechanics of his time. The frame of the carriage carried a large double coach-body between the two axles, and the machinery was mounted over and behind the rear axle. One man was stationed on a rear platform, tot manage the engine and to attend to the fire, and another, stationed in front of the body of the coach, handled the steering-wheel. The boiler was composed of horizontal water-tubes and steam-tubes, the latter being so situated as to receive heat from the furnace-gases *en route* to the chimney, and thus to act as a superheater. The wheels were driven, by means of intermediate gearing, by two steam-engines, which, with their attachments, were suspended on helical springs, to prevent injury by jars and shocks. An air-surface condenser was used, consisting of flattened thin metal tubes, cooled by the contact of the external air, and discharging the water of condensation, as it accumulated within them, into a feed-pump, which, in turn, forced it into the lowest row of tubes in the boiler.

The boiler did not prove large enough for continuous work; but the carriage was used experimentally, now and then, for a number of years.

During the succeeding ten years the adaptation of the steam-engine to land-transportation continued to attract more and more attention, and experimental road-engines were built with steadily-increasing frequency. The defects of these engines revealing themselves on trial, they were one by one remedied, and the road-locomotive gradually assumed a shape which was mechanically satisfactory. Their final introduction into general use seemed at one time only a matter of time; their non-success was due to causes over which the legislator and the general public, and not the engineer, had control, as well as to the development of steam-transportation on a rival plan.

In 1822, David Gordon patented a road-engine, but it is not known whether it was ever built. At about the same time, Mr. Goldsworthy Gurney, who subsequently took an active part in their introduction, stated, in his lectures, that "elementary power is capable of being applied to propel carriages along common roads with great political advantage, and the floating knowledge of the day places the object within reach." He made an ammonia-engine—probably the first ever made—and worked it so successfully, that he made use of it in driving a little locomotive.

Two years later, Gordon patented a curious arrangement, which, however, had been proposed twelve years earlier by

Brunton, and was again proposed afterward by Gurney, and others. This consisted in fitting to the engine a set of jointed legs, imitating, as nearly as the inventor could make them, the action of a horse's legs and feet. Such an arrangement was actually experimented with until it was found that they could not be made to work satisfactorily, when it was also found that they were not needed.

During the same season, Burstall & Hill made a steam-carriage, and made many unsuccessful attempts to introduce their plan. The engine used was like that of Evans, except that the steam-cylinder was placed at the end of the beam, and the crank-shaft under the middle. The front and rear wheels were connected by a longitudinal shaft and bevel gearing. The boiler was found to have the usual defect, and would only supply steam for a speed of three or four miles an hour. The result was a costly failure. W. H. James, of London, in 1824–'25, proposed several devices for placing the working parts, as well as the body of the carriage, on springs, without interfering with their operation, and the Messrs. Seaward patented similar devices.[†] Samuel Brown, in 1826, introduced a gas-engine, in which the piston was driven by the pressure produced by the combustion of gas, and a vacuum was secured by the condensation of the resulting vapor. Brown built a locomotive which he propelled by this engine. He ascended Shooter's Hill, near London, and the principal cause of his ultimate failure seems to have been the cost of operating the engine.

From this date forward, during several years, a number of inventors and mechanics seem to have devoted their whole time to this promising scheme. Among them, Burstall & Hill, Gurney, Ogle & Summers, Sir Charles Dance, and Walter Hancock, were most successful.

Gurney, in the year 1827, built a steam-carriage, which he kept at work nearly two years in and about London, and sometimes making long journeys. On one occasion he made the journey from Meksham to Cranfordt Bridge, a distance of 85 miles, in 10 hours, including all stops. He used the mechanical legs previously adopted by Brunton and by Gordon, but omitted this rude device in those engines subsequently built.

Gurney's engine of 1828 is of interest to the engineer as exhibiting a very excellent arrangement of machinery, and as having one of the earliest of "sectional boilers." The latter was of peculiar form, and differed greatly in design from the sectional boiler invented a quarter of a century earlier by John Stevens, in the United States.

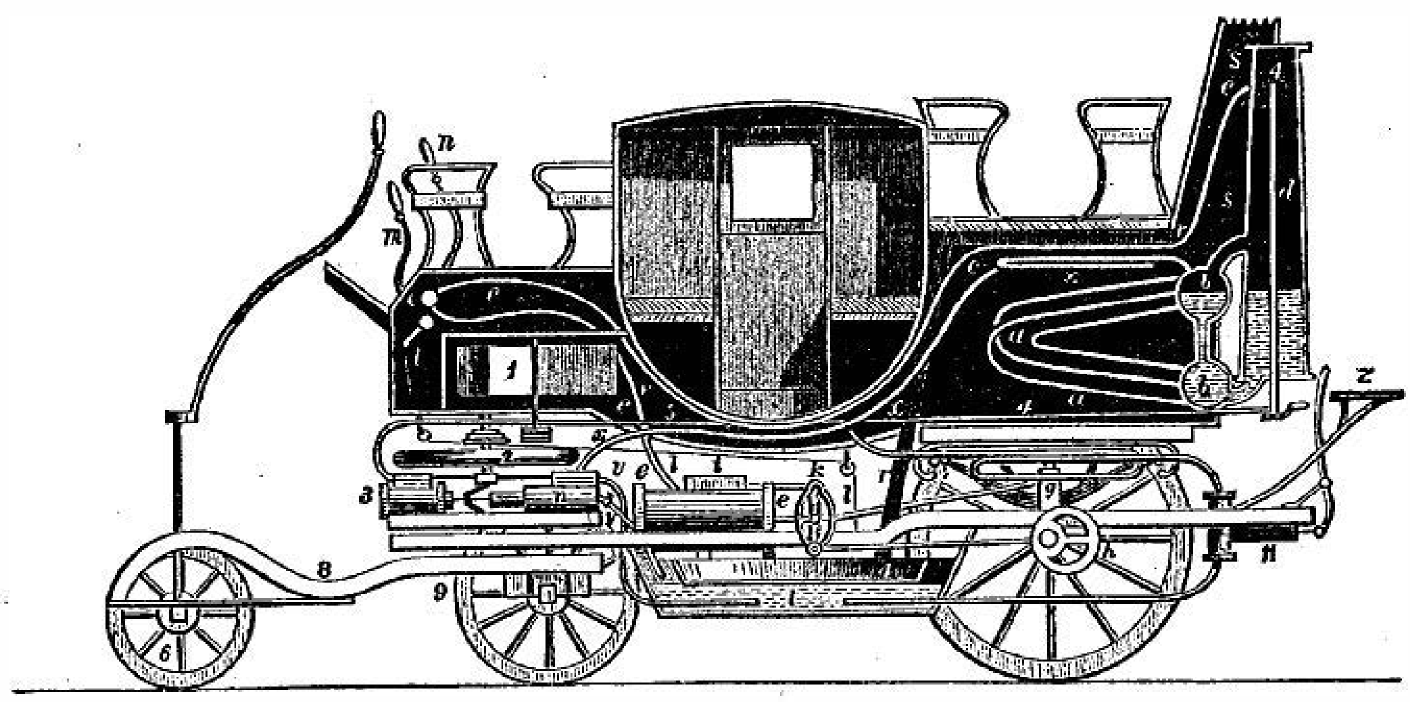


Fig. 48.—Gurney's Steam-Carriage.

In the sketch (Fig. 48) this boiler is seen at the right. It was composed of bent ◁-shaped tubes, *a a*, connected to two cylinders, *b b*, the upper one of which was a steam-chamber. Vertical tubes connected these two chambers, and permitted a complete and regular circulation of the water. A separate reservoir, called a separator, *d*, was connected with these chambers by pipes, as shown. From the top of this separator a steam-pipe, *e e e*, conveyed steam to the engine-cylinders at *f*. The cranks, *g*, on the rear axle were turned by the engines, and the eccentric, *h*, on the axle drove the valve-gearing and the valve, *i*. The link, *k l*, being moved by a line, *l l*, led from the driver's seat, the carriage was started, stopped, or reversed, by throwing the upper end of the link into gear with the valve-stem, by setting the link midway between its upper and lower positions, or by raising it until the lower end, coming into action on the valve-stem, produced a reverse motion of the valve. The pin on which this link vibrated is seen at the centre of its elliptical strap. The throttle-valve, *o*, by which the supply of steam to the engine was adjusted, was worked by the lever, *n*. The exhaust-pipe, *p*, led to the tank, *q*, and the uncondensed vapor passed to the chimney, *s s*, by the pipe, *r r*. The force-pump, *u*, taking feed-water from the tank, *t*, supplied it to the boiler by the pipe, *x x x*, which, *en route*, was coiled up to form a "heater" directly above the boiler. The supply was regulated by the cock, *y*. The attendant had a seat at *z*. A blast-apparatus, 1, was driven by an independent engine, 2 3, and produced a forced blast, which was led to the boiler-furnace through the air-duct, 5 5 ; 4 4 represents the steam-pipe to the little blowing-engine. The steering-wheel, 6, was directed by a lever, 7, and the change of direction of the perch, 8, which turned about a king-bolt at 9, gave the desired direction to the forward wheels and to the carriage.

This seems to have been one of the best designs brought out at that time. The boiler, built to carry 70 pounds, was safe and strong, and was tested up to 800 pounds pressure. A forced draught was provided. The engines were well placed, and of good design. The valve was arranged to work the steam with expansion from half-stroke. The feed-water was heated, and the steam slightly superheated. The boiler here used has been since reproduced under new names by later inventors, and is still used with satisfactory results. Modifications of the "pipe-boiler" were made by several other makers of steam-carriages also. Anderson & James made their boilers of lap-welded iron tubes of one inch internal diameter and one-fifth inch thick, and claimed for them perfect safety. Such tubes should have sufficient strength to sustain a pressure of 20,000 pounds per square inch. If made of such good iron as the makers claimed to have put into them, "which worked like lead," they would, as was also claimed, when ruptured, open by tearing, and discharge their contents without producing the usual disastrous consequences of boiler explosions.

The primary principle of the sectional boiler was then well understood. The boilers of Ogle & Summers were made up of pairs of upright tubes, set one within the other, the intervening space being filled with water and steam, and the flame passing through the inner and around the outer tube of each pair.

One of the engines of Sir James Anderson and W. H. James was built in 1829. It had two $3\frac{1}{2}$-inch steam-cylinders, driving the rear wheels independently. In James's earlier plan of 1824–'25, a pair of cylinders was attached to each of the two halves into which the rear axle was divided, and were arranged to drive cranks set at right-angles with each other. The later machine weighed 3 tons, and carried 15 passengers, on a rough graveled road across the Epping Forest, at the rate of from 12 to 15 miles per hour. Steam was carried at 300 pounds. Several tubes gave way in the welds, but the carriage returned, carrying 24 passengers at the rate of 7 miles per hour. On a later trial, with new boilers, the carriage again made 15 miles per hour. It was, however, subject to frequent accidents,t and was finally withdrawn.

WALTER HANCOCK was the most successful and persevering of all those who attempted the introduction of steam on the common road. He had, in 1827, patented a boiler of such peculiar form, that itt deserves description. It consisted of a collection of flat chambers, of which the walls were of boiler-plate. These chambers were arranged sidet by side, and connected laterally by tubes and stays, and all were connected by short vertical tubes to a horizontal large pipe placed across the top of the boiler-casing, and serving as a steam-drum or separator. This earliest of "sheet flue-boilers" did excellent service on Hancock's steam-carriages, where experience showed that there was little or no danger of disruptive explosions.

Hancock's first steam-carriage was mounted on three wheels, the leading-wheel arranged to swivel on a king-bolt, and driven by a pair of oscillating cylinders connected with its axle, which was "cranked" for the purpose. The engines turned with the steering-wheel. This carriage was by no means satisfactory, but it was used for a long time, and traveled many hundreds of miles without once failing to do the work assigned it.

By this time there were a half-dozen steam-carriages under construction for Hancock, for Ogle & Summers, and for Sir Charles Dance.

In 1831, Hancock placed a new carriage on a route between London and Stratford, where it ran regularly for hire. Dance, in the same season, started another on the line between Cheltenham and Gloucester, where it ran from February 21st to June 22d, traveling 3,500 miles and carrying 3,000 passengers, running the 9 miles in 55 minutes usually, and sometimes in three-quarters of an hour, and never meeting with an accident, except the breakage of an axle in running over heaps of stones which had been purposely placed on the road by enemies of the new system of transportation. Ogle & Summers's carriage attained a speed, as testified by Ogle before a committee of the House of Commons, of from 32 to 35 miles an hour, and on a rising grade, near Southampton, at 24½ miles per hour. They carried 250 pounds of steam, ran 800 miles, and met with no accident. Colonel Macerone, in 1833, ran a steam-carriage of his own design from London to Windsor and back, with 11 passengers, a distance of 23½ miles, in 2 hours. Sir Charles Dance, in the same year, ran his carriage 16 miles an hour, and made long excursions at the rate of 9 miles an hour. Still another experimenter, Heaton, ascended Lickey Hill, between Worcester and Birmingham, on gradients of one in eight and one in nine, in places ; this was considered one of the worst pieces of road in England. The carriage towed a coach containing 20 passengers.

Of all these, and many others, Hancock, however, had most marked success. His coach, called the "Infant," which was set at work in February, 1831, was, a year later, plying between London "City" and Paddington. Another, called the "Era," was built for the London and Greenwich Steam-Carriage Company, which was mechanically a success. The company, however, was financially unsuccessful. In October, 1832, the "Infant" ran to Brighton from London, carrying a party of 11, at the rate of 9 miles per hour, ascending Redhill at a speed of 5 miles. They steamed 38 miles the first day, stopping at night at Hazledean, and reached Brighton next day, running 11 miles per hour. Returning with 15 passengers, the coach ran 1 mile in less than 4 minutes, and made 10 miles in 55 minutes. A run from Stratford to Brighton was made in less than 10 hours, at an average speed of 12 miles an hour running time, the actual running time being less than 6 hours. The next year another carriage, the "Enterprise," was put on the road to Paddington by Hancock for another company, and ran regularly over two weeks; but this company was also unsuccessful. In the summer of 1833 he brought out still another steam-coach, the "Autopsy" (Fig. 49), which he ran to Brighton, and then, returning to London, manœuvred the carriage in the crowded streets without difficulty or accident. He went about the streets of London at all times, and without hesitation. The coach next ran between Finsbury Square and Pentonville regularly for four weeks, without accident or delay. In the sketch, a part of the side is broken away to show the machinery. The boiler, *A B*, supplies steam through the steam-pipe, *H K*, to the steam-engine, *C D*, which is coupled to the crank-shaft, *F*. *E* is the feed-pump. The rear axle is turned by the endless chain seen connecting it with the engine-shaft, and the rear wheels, *S*, are thus driven. A blower, *T*, gives a forced draught. The driver sits at *M*, steering by the wheel, *N*, which is coupled to the larger wheel, *P*, and thus turns the

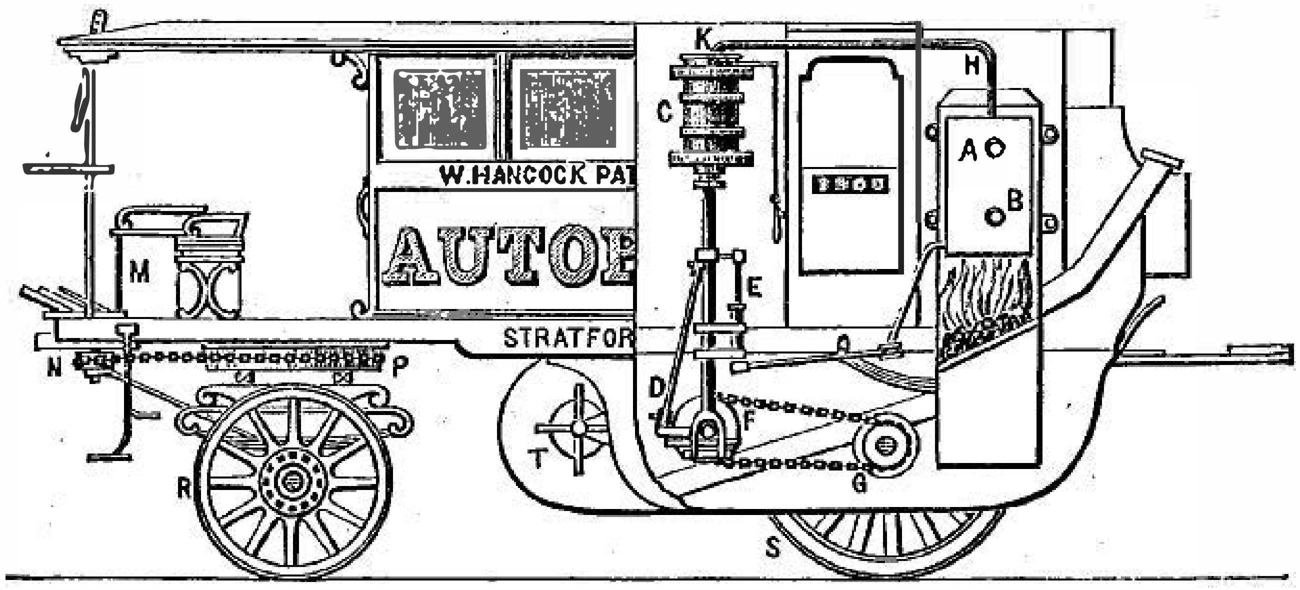


FIG. 49.—Hancock's "Autopsy," 1833.

forward axle into any desired position. In 1834, Hancock built a steam "drag" on an Austrian order, which, carrying 10 persons and towing a coach containing 6 passengers, was driven through the city beyond Islington, making 14 miles an hour on a level, and 8 miles or more on rising ground. In the same year he built the "Era," and, in August, put the "Autopsy" on with it, to make a steam-line to Paddington. These coaches ran until the end of November, carrying 4,000 passengers, at a usual rate of speed of 12 miles per hour. He then sent the "Era" to Dublin, where, on one occasion, it ran 18 miles per hour.

In 1835 a large carriage, the "Erin," was completed, which was intended to carry 20 passengers. It towed three omnibuses and a stage-coach, with 50 passengers, on a level road, at the speed of 10 miles an hour. It drew an omnibus with 18 passengers through Whitehall, Charing Cross, and Regent Street, and out to Brentford, running 14 miles an hour. It ran also to Reading, making 38 miles, with the same load, in 3 hours and 8 minutes running time. The stops *en route* occupied a half-hour. The same carriage made 75 miles to Marlborough in 7½ hours running time, stopping 4½ hours on the road, in consequence of having left the tender and supplies behind.

In May, 1836, Hancock put all his carriages on the Paddington road, and ran regularly for over five months, running 4,200 miles in 525 trips to Islington, 143 to Paddington, and 44 to Stratford, passing through the city over 200 times. The carriages averaged 5 hours and 17 or 18 minutes daily running time. A light steam-phaeton, built in 1838, for his own use, made 20 miles an hour, and was driven about the city, and among horses and carriages, without causing annoyance or danger. Its usual speed was about 10 miles an hour. Altogether, Hancock built nine steam-carriages, capable of carrying 116 passengers in addition to the regular attendants.[1]

In December, 1833, about 20 steam-carriages and traction road-engines were running, or were in course of construction, in and near London. In our own country, the roughness of roads discouraged inventors; and in Great Britain even, the successful introduction of road-locomotives, which seemed at one time almost an accomplished fact, finally met with so many obstacles, that even Hancock, the most ingenious, persistent, and successful constructor, gave up in despair. Hostile legislation procured by opposing interests, and the rapid progress of steam-locomotion on railroads, caused this result.

In consequence of this interruption of experiment, almost nothing was done during the succeeding quarter of a century, and it is only within a few years that anything like a business success has been founded upon the construction of road-locomotives, although the scheme seems to have been at no time entirely given up.

The opposition of coach-proprietors, and of all classes having an interest in the old lines of coaches, was most de-

[1] For a detailed account of the progress of steam on the highway, *see* "Steam on Common Roads," etc., by Young, Holley, & Fisher, London, 1861.

termined, and the feeling evinced by them was intensely bitter; but the advocates of the new system of transportation were equally determined and persevering, and, having right on their side, and the pecuniary advantage of the public as their object, they would probably have succeeded ultimately, except for the introduction of the still better method of transportation by rail.

In the summer of 1831, when the war between the two parties was at its height, a committee of the British House of Commons made a very complete investigation of the subject. This committee reported that they had become convinced that "the substitution of inanimate for animal power, in draught on common roads, is one of the most important improvements in the means of internal communication ever introduced.". They considered its practicability to have been "fully established," and predicted that its introduction would "take place more or less rapidly, in proportion as the attention of scientific men shall be drawn, byt public encouragement, to further improvement." The success of the system had, as they stated, been retarded by prejudice, adverse interests, and prohibitory tolls; and the committee remark: "When we consider that these trials have been made under the most unfavorable circumstances, at great expense, in totaltuncertainty, without any of those guides which experience has given to other branches of engineering; that those engaged in making them are persons looking solely to their own interests, and not theorists attempting the perfection of ingenious models; when we find them convinced, after long experience, that they are introducing such a mode of conveyance as shall tempt the public, by its superior advantages, from the use of the admirable lines of coaches which have been generally established, it surely cannot be contended that the introduction of steam-carriages on common roads is, as yet, an uncertain experiment, unworthy of legislative attention."

Farey, one of the most distinguished mechanical engineers of the time, testified that he considered the practicability of such a system as fully established, and that the result would be its general adoption. Gurney had run his carriage between 20 and 30 miles an hour; Hancock could sustain a speed of 10 miles; Ogle had run his coach 32 to 35 miles an hour, and ascended a hill rising 1 in 6 at the speed of 24½ miles. Summers had traveled up a hill having a gradient of 1 in 12, with 19 passengers, at the rate of speed of 15 miles per hour; he had run 4½ hours at 30 miles an hour. Farey thought that steam-coaches would be found to cost one-third as much as the stage-coaches in use. The steam-carriages were reported to be safer than those drawn by horses, and far more manageable; and the construction of boilers adopted—the "sectional" boiler, as it is now called—completely insured against injury by explosion, and the dangers and inconveniences arising from the frightening of horses had proved to be largely imaginary. The wear and tear of roads were found to be less than with horses, while with broadt wheel-tires the carriages acted beneficially as road-rollers. The committee finally concluded:

"1. That carriages can be propelled by steam on common roads at an average rate of 10 miles per hour.

"2. That at this rate they have conveyed upward of 14 passengers.

"3. That their weight, including engine, fuel, water, and attendants, may be under three tons.

"4. That they can ascend and descend hills of considerable inclination with facility and safety.

"5. That they are perfectly safe for passengers.

"6. That they are not (or need not be, if properly constructed) nuisances to the public.

"7. That they will become a speedier and cheaper mode of conveyance than carriages drawn by horses.

"8. That, as they admit of greater breadth of tire than other carriages, and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of roads than coaches drawn by horses.

"9. That rates of toll have been imposed on steam-carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered."

THE RAILROAD, which now, by the adaptation of steam to the propulsion of its carriages, became the successful rival of the system of transportation of which an account has just been given, was not a new device. It, like all other important changes of method and great inventions, had been growing into form for ages. The ancients were accustomed to lay down blocks of stone as a way upon which their heavily-loaded wagons could be drawn with less resistance than on the common road. This practice was gradually so modified as to result in the adoption of the now universally-practised methods of paving and road-making. The old tracks, bearing the marks of heavy traffic, are still seen in the streets of the unearthed city of Pompeii.

In the early days of mining in Great Britain, the coal or the ore was carried from the mine to the vessel in which it was to be embarked in sacks on the backs of horses. Later, the miners laid out wagon-roads, and used carts and wagons drawn by horses, and the roads were paved with stone along the lines traversed by the wheels of the vehicles. Still later (about 1630), heavy planks or squared timber took the place of the stone, and were introduced into the north of England by a gentleman of the name of Beaumont, who had transferred his property there from the south. A half century later, the system had become generally introduced. By the end of the eighteenth century the construction of these "tram-ways" had become well-understood, and the economy which justified the expenditure of considerable amounts of money in making cuts and in filling, to bring the road to a uniform grade, had become well-recognized. Arthur Young, writing at this time, says the coal wagon-roads were "great works, carried over all sorts of inequalities of ground, so far as the distance of nine or ten miles," and that, on these tram-ways of timber, "one horse is able to draw, and that with ease, fifty or sixty bushels of coals." The wagon-wheels were of cast-iron, and made with grooved rims, which fitted the rounded tops of the wooden rails. But these wooden rails were found subject to rapid decay, and at Whitehaven, in 1738, they were protected from wear by cast-iron plates laid upon them, and this improvement rapidly became known and adopted. A tram-road, laid down at Sheffield, for the Duke of Norfolk, in 1776, was made by laying angle-bars of cast-iron on longitudinal sleepers of timber; another, built by William Jessup in Leicestershire, in 1789, had an edge-rail, and the wheels were made with flanges, like those used to-day. The coned "tread" of the wheel, which prevents wear of flanges and reduces resistance, was the invention of James Wright, of Columbia, Pa., 40 years later. The modern railroad was simply the result of this gradual improvement of the permanent way, and the adaptation of the steam-engine to the propulsion of its wagons.

At the beginning of the nineteenth century, therefore, the steam-engine had been given a form which permitted its use, and the railroad had been so far perfected that there were no difficulties to be anticipated in the construction of the permanent way, and inventors were gradually preparing, as has been seen, to combine these two principal elements into one system. Railroads had been introduced in all parts of Great Britain, some of them of considerable length, and involving the interests of so many private individuals that they were necessarily constructed under the authorization of legal enactments. In the year 1805 the Merstham Railway was opened to traffic, and it is stated that on that occasion one horse drew a train of 12 wagons, carrying 38 tons of stone, on a "down gradient" of 1 in 120, at the rate of 6 miles per hour.

Richard Trevithick was the first engineer to apply steam-power to the haulage of loads on the railroad. Trevithick was a Cornishman by birth, a native of Redruth. He was naturally a skillful mechanic, and was placed by his father with Watt's assistant, Murdoch, who was superintending the erection of pumping-engines in Cornwall; and from that ingenious and accomplished engineer young Trev-

Richard Trevithick.

ithick probably acquired both the skill and the knowledge which, with his native talent, enterprise, and industry, enabled him to accomplish the work which has made him famous. He was soon intrusted with the erection and management of large pumping-engines, and subsequently went into the business of constructing steam-engines with another engineer, Edward Bull, who took an active part, with the

Hornblowers and others, in opposing the Boulton & Watt patents. The termination of the suits which established the validity of Watt's patent put an end to their business, and Trevithick looked about for other work, and, not long after, entered into partnership with a relative, Andrew Vivian, who was also a skillful mechanic; they together designed and patented the steam-carriage already referred to. Its success was sufficiently satisfactory to awaken strong confidence of a perfect success on the now common tram-roads; and Trevithick, in February, 1804, had completed a

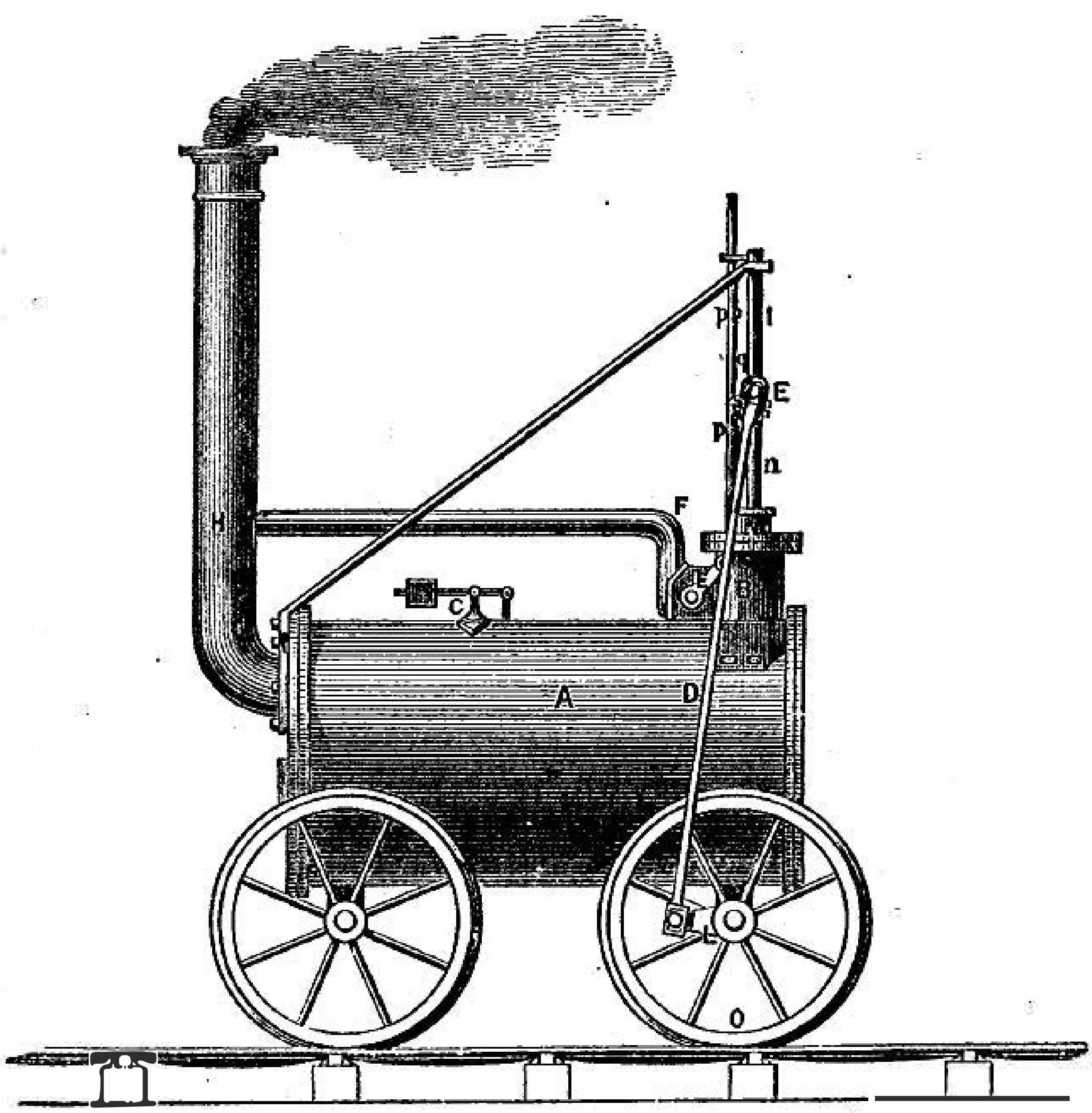


FIG. 50.—Trevithick's Locomotive, 1804.

"locomotived" engine to work on the Welsh Pen-y-darran road. This engine (Fig. 50) had a cylindrical flue-boiler, *A*, like that designed by Oliver Evans, and a single steam-cylinder, *B*, set vertically into the steam-space of the boiler, and driving the outside cranks, *L*, on the rear axle of the engine by very long connecting-rods, *D*, attached to its cross-head at *E*. The guide-bars, *I*, were stayedtby braces leading to the opposite end of the boiler. No attempt was made to condense the exhaust-steam, which was discharged into the smoke-pipe. The pressure of steam adopted was 40 pounds per square inch; but Trevithick had already made a numbert of non-condensing engines on which he carried from 50 to 145 pounds pressure.

In the year 1808, Trevithick built a railroad in London, on what was known later as Torrington Square, or Euston Square, and set at work a steam-carriage, which he called "Catch-me-who-can." This was a very plain and simple machine. The steam-cylinder was set vertically in the after-end of the boiler, and the cross-head was connected to two rods, one on either side, driving the hind pair of wheels. The exhaust-steam entered the chimney, aiding the draught. This engine, weighing about 10 tons, made from 12 to 15 miles an hour on the circular railway in London, and was said by its builder to be capable of making 20 miles an hour. The engine was finally thrown from the track, after some weeks of work, by the breaking of a rail, and, Trevithick's funds having been expended, it was nevertreplaced. This engine had a steam-cylinder 14½ inches in diameter, and a stroke of piston of 4 feet. Trevithick used no device to aid the friction of the wheels on the rails in giving pulling-power, and seems to have understood that none was needed. This plan of working a locomotive-engine without such complications as had been proposed by other engineers was, however, subsequently patented, in 1813, by Blackett & Hedley. The latter was at one time Trevithick's agent, and was director of Wylam Colliery, of which Mr. Blackett was proprietor.

Trevithick applied his high-pressure non-conducting engine not only to locomotives, but to every purpose that opportunity offered him. He put one into the Tredegar Iron-

Works, to drive the puddle-train, in 1801. This engine had a steam-cylinder 28 inches in diameter, and 6 feet stroke of piston; a boiler of cast-iron, 6¾ feet in diameter and 20 feet long, with a wrought-iron internal tube, 3 feet in diameter at the furnace-end and 24 inches beyond the furnace. The steam-pressure ranged from 50 to 100 pounds per square inch. The valve was a four-way cock. The exhaust-steam was carried into the chimney, passing through a feed-water heater *en route*. This engine was taken down in 1856.[1]

In 1803, Trevithick applied his engine to driving rock-drills, and three years later made a large contract with the Trinity Board for dredging in the Thames, and constructed steam dredging-machines for the work, of the form which is still most generally used in Great Britain, although rarely seen in the United States—the "chain-and-bucket dredger."

A little later, Trevithick was engaged upon the first and unsuccessful attempt to carry a tunnel under the Thames, at London; but no sooner had that costly scheme been given up, than he returned to his favorite pursuits, and continued his work on interrupted schemes for ship-propulsion. Trevithick at last left England, spent some years in South America, and finally returned home and died in extreme poverty, April, 1833, at the age of sixty-two, without having succeeded in accomplishing the general introduction of any of his inventions.

Trevithick was characteristically an inventor of the typical sort. He invented many valuable devices, but brought but few into even experimental use, and reaped little advantage from any of them. He was ingenious, a thorough mechanic, bold, active, and indefatigable; but his lack of persistence made his whole life, as Smiles has said, "but a series of beginnings."

It is at about this period that we find evidence of the intelligent labors of another of our own countrymen—one

[1] "Life of Trevithick."

who, in consequence of the unobtrusive manner in which his work was done, has never received the full credit to which he is entitled.

COLONEL JOHN STEVENS, of Hoboken, as he is generally called, was born in the city of New York, in 1749; but throughout his business-life he was a resident of New Jersey.

His attention is said to have been first called to the application of steam-power by seeing the experiments of John Fitch with his steamer on the Delaware, and he at once de-

Colonel John Stevens.

voted himself to the introduction of steam-navigation with characteristica energy, and with a success that will be indicated when we come to the consideration of that subject.

But this far-sighted engineer and statesman saw plainly the importance of applying the steam-engine to land-transportation as well as to navigation; and not only that, but he saw with equal distinctness the importance of a well-devised and carefully-prosecuted scheme of internal communication by a complete system of railroads. In 1812 he published a pamphlet containing "Documents tending to prove the superior advantages of Railways and Steam-Carriages over Canal-Navigation."[1] At this time, the only locomotive in the world was that of Trevithick and Vivian, at Merthyr Tydvil, and the railroad itself had not grown beyond the old wooden tram-roads of the collieries. Yet Colonel Stevens says, in this paper: "I can see nothing to hinder a steam-carriage moving on its ways with a velocity of 100 miles an hour;" adding, in a foot-note: "This astonishing velocity is considered here merely possible. It is probable that it may not, in practise, be convenient to exceed 20 or 30 miles per hour. Actual experiment can only determine this matter, and I should not be surprised at seeing steam-carriages propelled at the rate of 40 or 50 miles an hour."

At a yet earlier date he had addressed a memoir to the proper authorities, urging his plans for railroads. He proposed rails of timber, protected, when necessary, by iron plates, or to be made wholly of iron; the car-wheels were to be of cast-iron, with inside flanges to keep them on the track. The steam-engine was to be driven by steam of 50 pounds pressure and upward, and to be non-condensing.

Answering the objections of Robert R. Livingston and of the State Commissioners of New York, he goes further into details. He gives 500 to 1,000 pounds as the maximum weight to be placed on each wheel; shows that the trains, or "suits of carriages," as he calls them, will make their journeys with as much certainty and celerity in the darkest night as in the light of day; shows that the grades of proposed

[1] Printed by T. & J. Swords, 160 Pearl Street, New York, 1812.

roads would offer but little resistance ; and places the whole subject before the public with such accuracy of statement and such evident appreciation of its true value, that every one who reads this remarkable document will agree fully with President Charles King, who said[1] that "whosoever shall attentively read this pamphlet, will perceive that the political, financial, commercial, and military aspects of this great question were all present to Colonel Stevens's mind, and that he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country these fruits of his genius. The offering was not then accepted. The 'Thinker' was ahead of his age ; but it is grateful to know that he lived to see his projects carried out, though not by the Government, and that, before he finally, in 1838, closed his eyes in death, at the great age of eighty-nine, he could justly feel assured that the name of Stevens, in his own person and in that of his sons, was imperishably enrolled among those which a grateful country will cherish."

Without having made any one superlatively great improvement in the mechanism of the steam-engine, like that which gave Watt his fame—without having the honor even of being the first to propose the propulsion of vessels by the modern steam-engine, or steam-transportation on land—he exhibited a far better knowledge of the science and the art of engineering than any man of his time; and he entertained and urged more advanced opinions and more statesmanlike views in relation to the economical importance of the improvement and the application of the steam-engine, both on land and water, than seem to be attributable to any other leading engineer of that time.

Says Dr. King: "Who can estimate if, at that day, acting upon the well-considered suggestion of President Madison, 'of the signal advantages to be derived to the United States from a general system of internal communication and

[1] "Progress of the City of New York."

conveyance,' Congress had entertained Colonel Stevens's proposal, and, after verifying by actual experiment upon a small scale the accuracy of his plan, had organized such a 'general system of internal communication and conveyance,' who can begin to estimate the inappreciable benefits that would have resulted therefrom to the comfort, the wealth, the power, and, above all, to the absolutely impregnable union of our great Republic and all its component parts? All this Colonel Stevens embraced in his views, for he was a statesman as well as an experimental philosopher; and whoever shall attentively read his pamphlet, will perceive that the political, financial, commercial, and military aspects of this great question were all present to his mind, and he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country these fruits of his genius."

WILLIAM HEDLEY, who has already been referred to, seems to have been the first to show, by carefully-conducted experiment, how far the adhesion of the wheels of the locomotive-engine could be relied upon for hauling-power in the transportation of loads.

His employer, Blackett, had applied to Trevithick for a locomotive-engine to haul coal-trains at the Wylam collieries; but Trevithick was unable, or was disinclined, to build him one, and in October, 1812, Hedley was authorized to attempt the construction of an engine. It was at about this time that Blenkinsop (1811) was trying the toothed rail or rack, the Messrs. Chapman (December, 1812) were experimenting with a towing-chain, and (May, 1813) Brunton with movable legs.

Hedley, who had known of the success met with in the experiments of Trevithick with smooth wheels hauling loads of considerable weight, in Cornwall, was confident that equal success might be expected in the north-country, and built a carriage to be moved by men stationed at four handles, by which its wheels were turned.

This carriage was loaded with heavy masses of iron, and attached to trains of coal-wagons on the railway. By repeated experiment, varying the weight of the traction-carriage and the load hauled, Hedley ascertained the proportion of the weight required for adhesion to that of the loads drawn. It was thus conclusively proven that the weight of his proposed locomotive-engine would be sufficient to give the pulling-power necessary for the propulsion of the coal-trains which it was to haul.

When the wheels slipped in consequence of the presence of grease, frost, or moisture on the rail, Hedley proposed to sprinkle ashes on the track, as sand is now distributed from the sand-box of the modernnengine. This was in October, 1812.

Hedley now went tonwork building an engine with smooth wheels, and patented his design March 13, 1813, a month after he had put his engine at work. The locomotive had a cast-iron boiler, and a single steam-cylinder 6 inches in diameter, with a small fly-wheel. This engine had too small a boiler, and he soon after built a larger engine, with a return-flue boiler made of wrought-iron. This hauled 8 loaded coal-wagons 5 miles an hour at first, and a little later 10, doingnthe work of 10 horses. The steam-pressure was carried at about 50 pounds, and the exhaust, led into the chimney, where the pipe was turned upward, thus secured a blast of considerable intensity in its small chimney. Hedley also contracted the opening of the exhaust-pipe to intensify the blast, and was subjected to somen annoyance by proprietors of lands along his railway, who were irritated by the burning of their grass and hedges, which were set on fire by the sparks thrown out of the chimney of the locomotive. The cost of Hedley's experiment was defrayed by Mr. Blackett.

Subsequently, Hedley mounted his engine on eight wheels, the four-wheeled engines having been frequently stopped by breaking the light rails then in use. Hedley's engines continued in use at the Wylam collieries many years. The second engine was removed in 1862, and is now preserved at the South Kensington Museum, London.

GEORGE STEPHENSON, to whom is generally accorded the honor of having first made the locomotive-engine a success, built his first engine at Killingworth, England, in 1814.

At this time Stephenson was by no means alone in the field, for the idea of applying the steam-engine to driving carriages on common roads and on railroads was beginning,

George Stephenson.

as has been seen, to attract considerable attention. Stephenson, however, combined, in a very fortunate degree, the advantages of great natural inventive talent and an excellent mechanical training, reminding one strongly of James Watt. Indeed, Stephenson's portrait bears some resemblance to that of the earlier great inventor.

George Stephenson was born June 9, 1781, at Wylam, near Newcastle-upon-Tyne, and was the son of a "north-country miner." When still a child, he exhibited great mechanical talent and unusual love of study. When set at work about the mines, his attention to duty and his intelligence obtained for him rapid promotion, until, when but seventeen years of age, he was made engineer, and took charge of the pumping-engine at which his father was fireman.

When a mere child, and employed as a herd-boy, he amused himself making model engines in clay, and, as he grew older, never lost an opportunity to learn the construction and management of machinery. After having been employed at Newburn and Callerton, where he first became "engine-man," he began to study with greater interest than ever the various steam-engines which were then in use; and both the Newcomen engine and the Watt pumping-engine were soon thoroughly understood by him. After having become a brakeman, he removed to Willington Quay, where he married, and commenced his wedded life on 18 or 20 shillings per week. It was here that he became an intimate friend of the distinguished William Fairbairn, who was then working as an apprentice at the Percy Main Colliery, near by. The "father of the railroad" and the future President of the British Association were accustomed, at times, to "change works," and were frequently seen in consultation over their numerous projects. It was at Willington Quay that his son Robert, who afterward became a distinguished civil engineer, was born, October 16, 1803.

In the following year Stephenson removed to Killingworth, and became brakeman at that colliery; but his wife soon died, and he gladly accepted an invitation to become engine-driver at a spinning-mill near Montrose, Scotland. At the end of a year he returned, on foot, to Killingworth with his savings (about £28), expended over one-half of the amount in paying his father's debts and in making his parents comfortable, and then returned to his old station as brakeman at the pit.

Here he made some useful improvements in the arrangement of the machinery, and spent his spare hours in studying his engine and planning new machines. He a little later distinguished himself by altering and repairing an old Newcomen engine at the High Pit, which had failed to give satisfaction, making it thoroughly successful after three days' work. The engine cleared the pit, at which it had been vainly laboring a long time, in two days after Stephenson started it up.

In the year 1812, Stephenson was made engine-wright of the Killingworth High Pit, receiving £100 a year, and it was made his duty to supervise the machinery of all the collieries under lease by the so-called "Grand Allies." It was here, and at this period, that he commenced a systematic course of self-improvement and the education of his son, and here he first began to be recognized as an inventor. He was full of life and something of a wag, and often made most amusing applications of his inventive powers: as when he placed the watch, which a comrade had brought him as out of repairs, in the oven "to cook," his quick eye having noted the fact that the difficulty arose simply from the clogging of the wheels by the oil, which had been congealed by cold.

Smiles,[1] his biographer, describes his cottage as a perfect curiosity-shop, filled with models of engines, machines of various kinds, and novel apparatus. He connected the cradles of his neighbors' wives with the smoke-jacks in their chimneys, and thus relieved them from constant attendance upon their infants; he fished at night with a submarine lamp, which attracted the fish from all sides, and gave him wonderful luck; he also found time to give colloquial instruction to his fellow-workmen.

[1] "Lives of George and Robert Stephenson," by Samuel Smiles. New York and London, 1868.

He built a self-acting inclined plane for his pit, on which the wagons, descending loaded, drew up the empty trains; and made so many improvements at the Killingworth pit, that the number of horses employed underground was reduced from 100 to 16.

Stephenson now had more liberty than when employed at the brakes, and, hearing of the experiments of Blackett and Hedley at Wylam, went over to their colliery to study their engine. He also went to Leeds to see the Blenkinsop engine draw, at a trial, 70 tons at the rate of 3 miles an hour, and expressed his opinion in the characteristic remark, "I think I could make a better engine than that to go upon legs." He very soon made the attempt.

Having laid the subject before the proprietors of the lease under which the collieries were worked, and convinced Lord Ravensworth, the principal owner, of the advantages to be secured by the use of a "traveling engine," that nobleman advanced the money required. Stephenson at once commenced his first locomotive-engine, building it in the workshops at West Moor, assisted mainly by John Thirlwall, the colliery blacksmith, during the years 1813 and 1814, completing it in July of the latter year.

This engine had a wrought-iron boiler 8 feet long and 2 feet 10 inches in diameter, with a single flue 20 inches in diameter. The cylinders were vertical, 8 inches in diameter and of 2 feet stroke of piston, set in the boiler, and driving a set of wheels which geared with each other and with other cogged wheels on the two driving-axles. A feed-water heater surrounded the base of the chimney. This engine drew 30 tons on a rising gradient of 10 or 12 feet to the mile at the rate of 4 miles an hour. This engine proved in many respects defective, and the cost of its operation was found to be about as great as that of employing horse-power.

Stephenson determined to build another engine on a somewhat different plan, and patented its design in February, 1815. It proved a much more efficient machine than the "Blücher," the first engine.

This second engine (Fig. 51) was also fitted with two vertical cylinders, *C c*, but the connecting-rods were attached directly to the four driving-wheels, *W W'*. To permit the necessary freedom of motion, "ball-and-socket" joints were adopted, to unite the rods with the cross-heads,

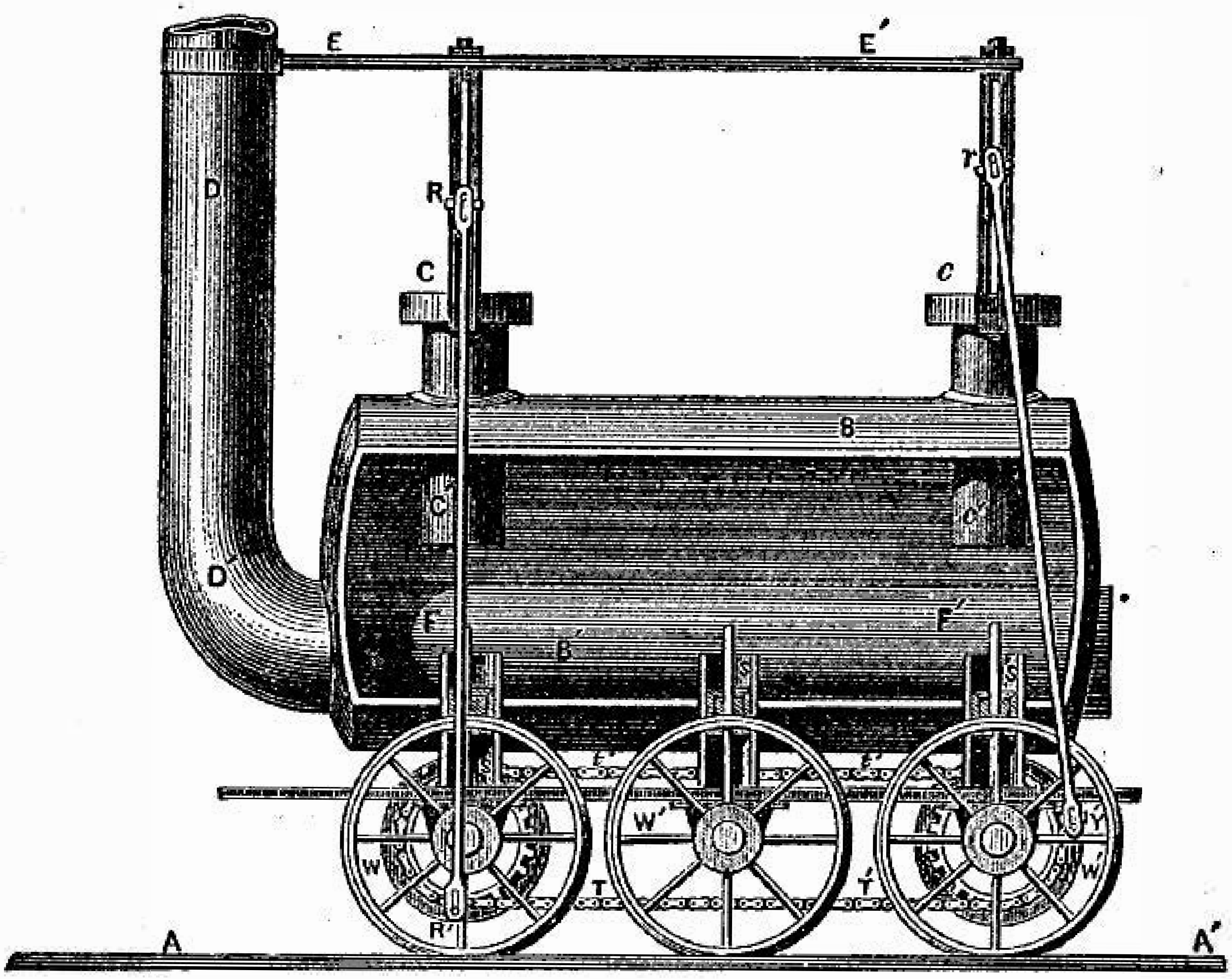


FIG. 51.—Stephenson's Locomotive of 1815. Section.

R r, and with the cranks, *R' Y'*; and the two driving-axles were connected by an endless chain, *T t'*. The cranked axle and the outside connection of the wheels, as specified in the patent, were not used until afterward, it having been found impossible to get the cranked axles made. In this engine the forced draught obtained by the impulse of the exhaust-steam was adopted, doubling the power of the machine and permitting the use of coke as a fuel, and making it possible to adopt the multitubular boiler. Small steam-cylinders, *S S S*, took the weight of the engine and served as springs.

It was at about this time that George Stephenson and

Sir Humphry Davy, independently and almost simultaneously, invented the "safety-lamp," without which few mines of bituminous coal could to-day be worked. The former used small tubes, the latter fine wire gauze, to intercept the flame. Stephenson proved the efficiency of his lamp by going with it directly into the inflammable atmosphere of a dangerous mine, and repeatedly permitting the light to be extinguished when the lamp became surcharged with the explosive mixture which had so frequently proved fatal to the miners. This was in October and November, 1815, and Stephenson's work antedates that of the great philosopher.[1] The controversy which arose between the supporters of the rival claims of the two inventors was very earnest, and sometimes bitter. The friends of the young engineer raised a subscription, amounting to above £1,000, and presented it to him as a token of their appreciation of the value of his simple yet important contrivance. Of the two forms of lamp, that of Stephenson is claimed to be safest, the Davy lamp being liable to produce explosions by igniting the explosive gas when, by its combustion within the gauze cylinder, the latter is made red-hot. Under similar conditions, the Stephenson lamp is simply extinguished, as was seen at Barnsley, in 1857, at the Oaks Colliery, where both kinds of lamp were in use, and elsewhere.

Stephenson continued to study and experiment, with a view to the improvement of his locomotive and the railroad. He introduced better methods of track-laying and of jointing the rails, adopting a half-lap, or peculiar scarf-joint, in place of the then usual square-butt joint. He patented, with these modifications of the permanent way, several of his improvements of the engine. He had substituted forged for the rude cast wheels previously used,[2] and had

[1] *Vide* "A Description of the Safety-Lamp invented by George Stephenson," etc., London, 1817.

[2] The American chilled wheel of cast-iron, a better wheel than that above described, has never been generally and successfully introduced in Europe.

made many minor changes of detail. The engines built at this time (1816) continued in use many years. Two years later, with a dynamometer which he designed for the purpose, he made experimental determinations of the resistance of trains, and showed that it was made up of several kinds, as the sliding friction of the axle-journals in their bearings, the rolling friction of the wheels on the rails, the resistance due to gravity on gradients, and that due to the resistance of the air.

These experiments seemed to him conclusive against the possibility of the competition of engines on the common highway with locomotives hauling trains on the rail. Finding that the resistance, with his rolling-stock, and at all the speeds at which he made his experiments, was approximately invariable, and equivalent to about 10 pounds per ton, and estimating that a gradient rising but 1 foot in 100 would decrease the hauling power of the engine 50 per cent., he saw at once the necessity of making all railroads as nearly absolutely level as possible, and, consequently, the radically distinctive character of this branch of civil engineering work. He persistently condemned the "folly" of attempting the general introduction of steam on the common road, where great changes of level and an impressible road-bed were certain to prove fatal to success, and was most strenuous in his advocacy of the policy of securing level tracks, even at very great expense.

Taking part in the contest, which now became a serious one, between the advocates of steam on the common road and those urging the introduction of locomotives and their trains on an iron track, he calculated that a road-engine capable of carrying 20 or 30 passengers at 10 miles per hour, could, on the rail, carry ten times as many people at three or four times that speed. The railway-engine finally superseded its predecessor—the engine of the common road—almost completely.

In 1817, Stephenson built an engine for the Duke of

Portland, to haul coal from Kilmarnock to Troon, which cost £750, and, with some interruptions, this engine worked on that line until 1848, when it was broken up. On November 18, 1822, the Hetton Railway, near Sunderland, was opened. George Stephenson was the engineer of the line—a short track, 8 miles long, built from the Hetton Colliery to the docks on the bank of the river Wear.t On this line he put in five of thet" self-acting inclines "—two inclines worked by stationary engines, the gradients being too heavy for locomotives—and used five locomotive-engines of his own design, which were called by the people of the neighborhood, possibly for the first time, " the iron horses." These engines were quite similar to the Killingworth engine. They drew a train of 17 coal-cars—a total load of 64 tons —about 4 miles an hour. Meantime, also, in 1823, Stephenson had been made engineer of the Stockton & Darlington Railroad, which had been projected for the purpose of securing transportation to tide-water for thet valuable coal-lands of Durham.t This road was built without an expectation on the part of any of its promoters, Stephenson excepted, that steam would be used as a motor to the exclusion of horses.

Mr. Edward Pearse, however, one of the largest holders of stock in the road, and one of its most earnest advocates, became so convinced, by an examination of the Killingworth engines and their work, of the immense advantage to be derived by their use, that he not only supported Stephenson's arguments, but, with Thomas Richardson, advanced £1,000 for the purpose of assisting Stephenson to commence the business of locomotive-engine construction at Newcastle. This workshop, which subsequently became a great and famous establishment, was commenced in 1824.

For this road Stephenson recommendedt wronght-iron rails, which were then costing £12 per ton—double the price of cast rails. The directors, however, stipulated that he should only buy one-half the rails required from the dealers in "malleable" iron. These rails weighed 20 pounds to the yard. After long hesitation, in the face of a serious opposition, the directors finally concluded to order three locomotives of Stephenson. The first, or "No. 1," engine (Fig. 52) was delivered in time for the opening of the road, September 27, 1825. It weighed 8 tons. Its boiler contained a sin-

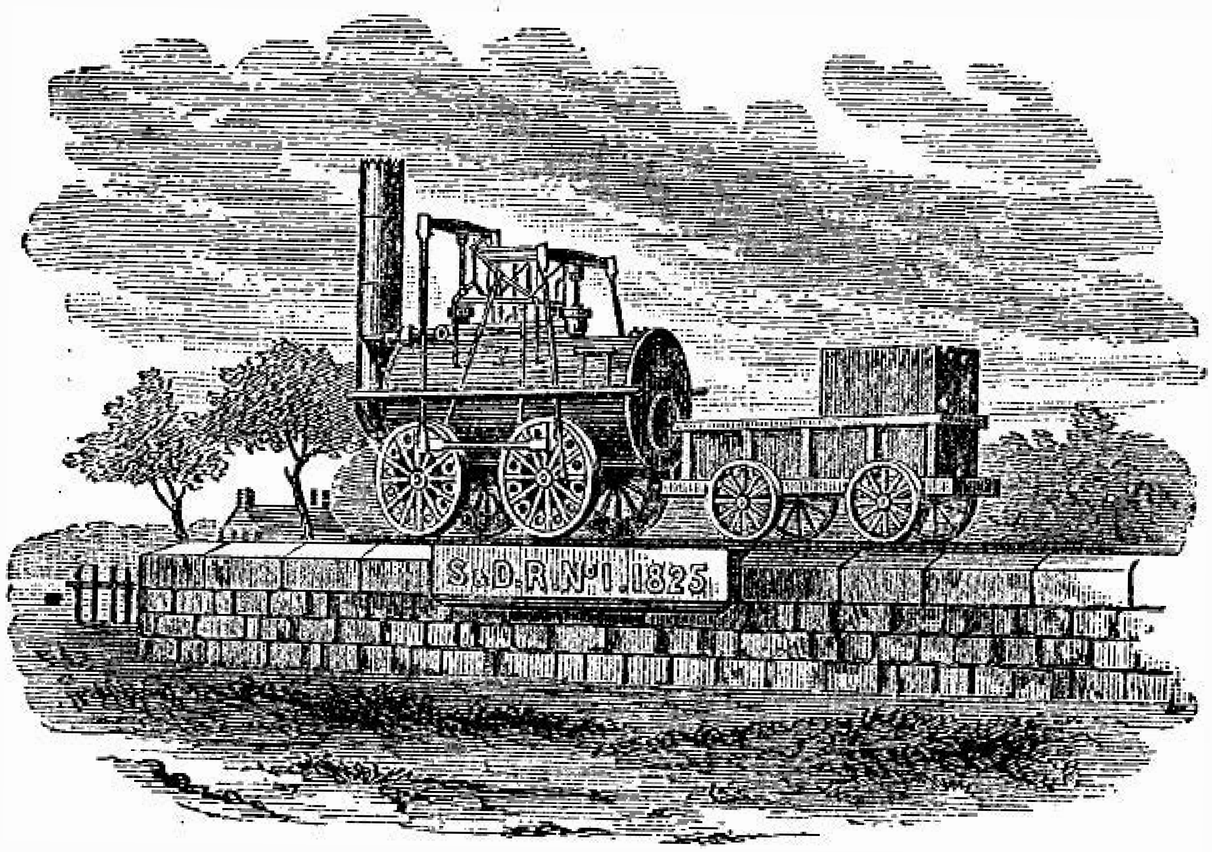


FIG. 52.—Stephenson's No. 1 Engine, 1825.

gle straight flue, one end of which was the furnace. The cylinders were vertical, like those of the earlier engines, and coupled directly to the driving-wheels. The crank-pins were set in the wheels at right angles, in order that, while one engine was "turning the centre," the other might exert its maximum power. The two pairs of drivers were coupled by horizontal rods, as seen in the figure, which represents this engine as subsequently mounted on a pedestal at the Darlington station. A steam-blast in the chimney gave the requisite strength of draught. These engines were built for slow and heavy work, but were capable of making what was then thought the satisfactorily high speed of 16 miles per hour. The inclines on the road were worked by fixed engines.

On the opening day, which was celebrated as a holiday by the people far and near, the No. 1 engine drew 90 tons at the rate of 12, and at times 15, miles an hour.

Stephenson's engines were kept at work hauling coal-

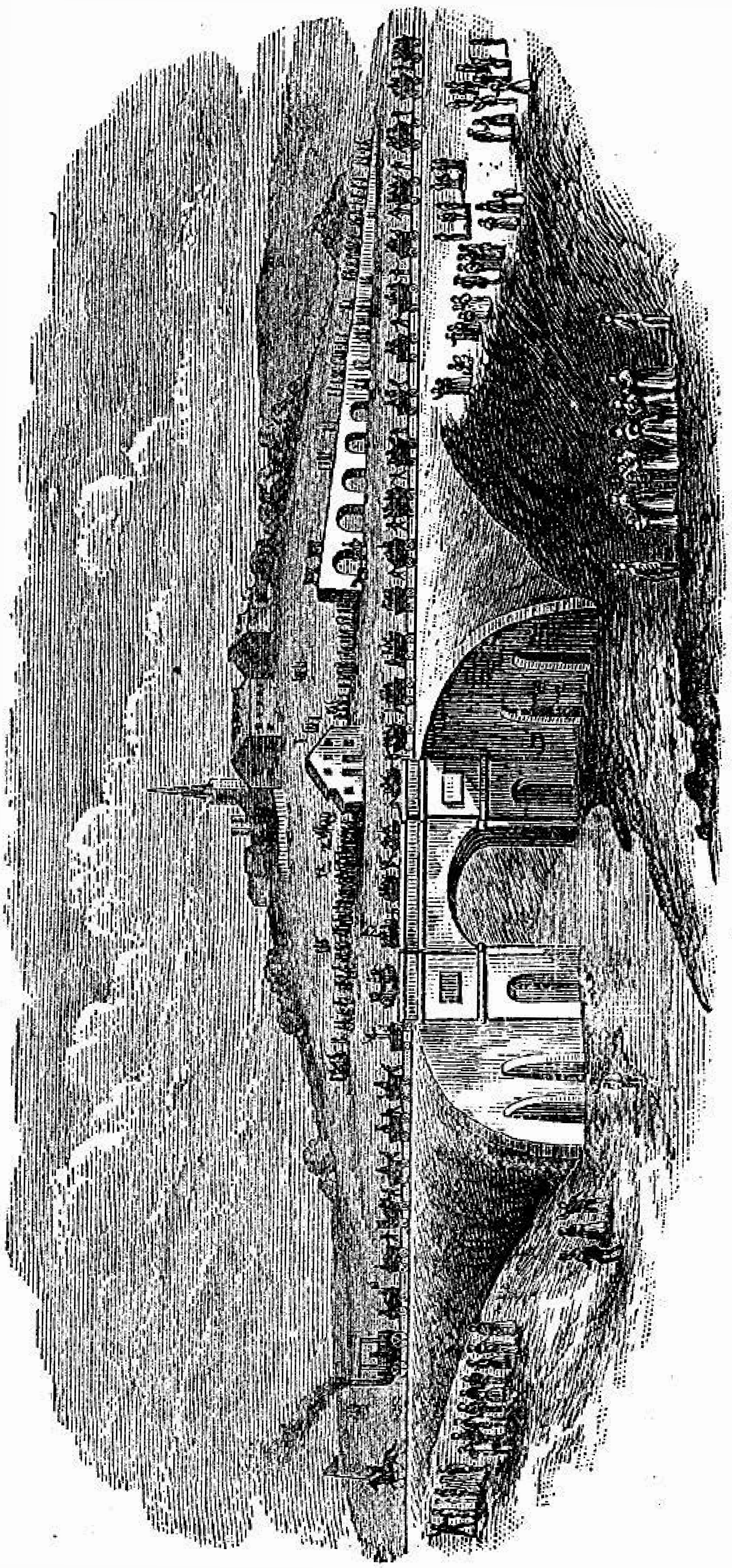


FIG. 53.—Opening of the Stockton and Darlington Railroad, 1825. (After an old engraving.)

trains, but the passenger-coaches were all drawn for some time by horses, and the latter system was a rude forerunner, in most respects, of modern street-railway transportation. Mixed passenger and freight trains were next introduced, and, soon after, separate passenger-trains drawn by faster engines were placed on the line, and the present system of railroad transportation was now fairly inaugurated.

A railroad between Manchester and Liverpool had been projected at about the time that the Stockton & Darlington road was commenced. The preliminary surveys had been made in the face of a strong opposition, which did not always stop at legal action and verbal attack, but in some instances led to the display of force. The surveyors were sometimes driven from their work by a mob armed with sticks and stones, urged on by land-proprietors and those interested in the lines of coaches on the highway. Before the opening of the Stockton & Darlington Railroad, the Liverpool & Manchester bill had been carried through Parliament, after a very determined effort on the part of coach-proprietors and landholders to defeat it, and Stephenson urged the adoption of the locomotive to the exclusion of horses. It was his assertion, made at this time, that he could build a locomotive to run 20 miles an hour, that provoked the celebrated rejoinder of a writer in the *Quarterly Review*, who was, however, in favor of the construction of the road and of the use of the locomotive upon it: "What can be more palpably absurd and ridiculous, than the prospect held out of locomotives traveling *twice as fast* as stage-coaches? We would as soon expect the people of Woolwich to suffer themselves to be fired off upon one of Congreve's ricochet-rockets, as trust themselves to the mercy of such a machine going at such a rate."

It was during his examination before a committee of the House of Commons, during this contest, that Stephenson, when asked, "Suppose, now, one of your engines to be going at the rate of 9 or 10 miles an hour, and that a cow were to stray upon the line and get in the way of the engine, would not that be a very awkward circumstance?" replied, "Yes, *very* awkward—*for the coo!*" And when asked if men and animals would not be frightened by the red-hot smoke-pipe, answered, "But how would they know that it was not *painted?*" The line was finally built, with George Rennie as consulting, and Stephenson as principal constructing engineer.

His work on this road became one of the important elements of the success, and one of the great causes of the distinction, which marked the life of these rising engineers. The successful construction of that part of the line which lay across "Chat Moss," an unfathomable swampy deposit of peat, extending over an area of 12 square miles, and the building of which had been repeatedly declared an impossibility, was in itself sufficient to prove that the engineer who had accomplished it was no common man. Stephenson adopted the very simple yet bold expedient of using, as a filling, compacted turf and peat, and building a road-bed of materials lighter than water, or the substance composing the bog, and thus forming a *floating* embankment, on which he laid his rails. To the surprise of every one but Stephenson himself, the plan proved perfectly successful, and even surprisingly economical, costing but little more than one-tenth the estimate of at least one engineer. Among the other great works on this remarkable pioneer-line were the tunnel, a mile and a half long, from the station at Liverpool to Edgehill; the Olive Mount deep-cut, two miles long, and in some places 100 feet deep, through red sandstone, of which nearly 500,000 yards were removed; the Sankey Viaduct, a brick structure of nine arches, of 50 feet span each, costing £45,000t; and a number of other pieces of work which are noteworthy in even these days of great works.

Stephenson planned all details of the line, and even designed the bridges, machinery, engines, turn-tables, switches, and crossings, and was responsible for every part of the work of their construction.

Finally, the work of building the line approached completion, and it became necessary promptly to settle the long-deferred question of a method of applying motive-power. Some of the directors and their advisers still advocated the use of horses; many thought stationary hauling-engines preferable; and the remainder were, almost to a man, undecided. The locomotive had no outspoken advocate, and few had the slightest faith in it. George Stephenson was almost alone, and the opponents of steam had secured a provision in the Newcastle & Carlisle Railroad concession, stipulating expressly that horses should there be exclusively employed. The directors did, however, in 1828, permit Stephenson to put on the line a locomotive, to be used, during its construction, in hauling gravel-trains. A committee was sent, at Stephenson's request, to see the Stockton & Darlington engines, but no decided expression of opinion seems to have been made by them. Two well-known professional engineers reported in favor of fixed engines, and advised the division of the line into 19 stages of about a mile and a half each, and the use of 21 fixed engines, although they admitted the excessive first-cost of that system. The board was naturally strongly inclined to adopt their plan. Stephenson, however, earnestly and persistently opposed such action, and, after long debate, it was finally determined "to give the traveling engine a chance." The board decided to offer a reward of £500 for the best locomotive-engine, and prescribed the following conditions:

1. The engine must consume its own smoke.

2. The engine, if of 6 tons weight, must be able to draw after it, day by day, 20 tons weight (including the tender and water-tank) at 10 miles an hour, with a pressure of steam on the boiler not exceeding 50 pounds to the square inch.

3. The boiler must have two safety-valves, neither of which must be fastened down, and one of them completely out of the control of the engine-man.

4. The engine and boiler must be supported on springs, and rest on 6 wheels, the height of the whole not exceeding 15 feet to the top of the chimney.

5. The engine, with water, must not weigh more than 6 tons; but an engine of less weight would be preferred, on its drawing a proportionate load behind it; if of only $4\frac{1}{2}$ tons, then it might be put only on 4 wheels. The company to be at liberty to test the boiler, etc., by a pressure of 150 pounds to the square inch.

6. A mercurial gauge must be affixed to the machine, showing the steam-pressure above 45 pounds to the square inch.

7. The engine must be delivered, complete and ready for trial, at the Liverpool end of the railway, not later than the 1st of October, 1829.

8. The price of the engine must not exceed £550.

This circular was printed and published throughout the kingdom, and a considerable number of engines were constructed to compete at the trial, which was proposed to take place October 1, 1829, but which was deferred to the 6th of that month. Only four engines, however, were finally entered on the day of the trial. These were the "Novelty," constructed by Messrs. Braithwaite & Ericsson, the latter being the distinguished engineer who subsequently came to the United States to introduce screw-propulsion, and, later, the monitor system of iron-clads ; the "Rocket," built from Stephenson's plans ; and the "Sanspareil," and the "Perseverance," built by Hackworth and Burstall, respectively.

The "Sanspareil," which was built under the direction of Timothy Hackworth, one of Stephenson's earlier foremen, resembled the engine built by the latter for the Stockton & Darlington road, but was heavier than had been stipulated, was not ready for work when called, and, when finally set at work, proved to be very extravagant in its use of fuel, partly in consequence of the extreme intensity of its blast, which caused the expulsion of unconsumed coals from the furnace.

The "Perseverance" could not attain the specified speed, and was withdrawn.

The "Novelty" was apparently a well-designed and for that time a remarkably well-proportioned machine. *A*, in Fig. 54, is the boiler, *D* the steam-cylinders, *E* a heater. Its weight but slightly exceeded three tons, and it was a

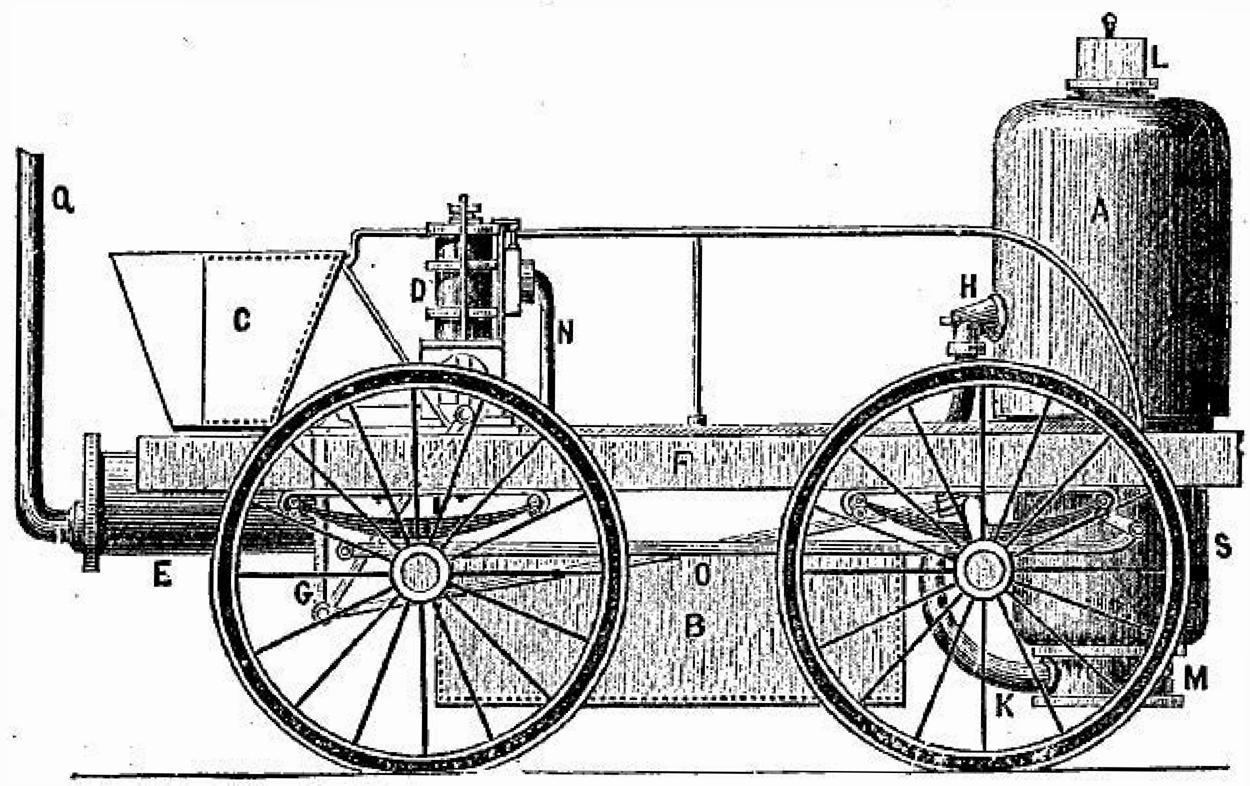


FIG. 54.—The "Novelty," 1829.

"tank engine," carrying its own fuel and water at *B*. A forced draught was obtained by means of the bellows, *C*. This engine was run over the line at the rate of about 28 miles an hour at times, but its blowing apparatus failed, and the "Rocket" held the track alone. A later trial still left the "Rocket" alone in the field.

The "Rocket" (Fig. 55) was built at the works of Robert Stephenson & Co., at Newcastle-upon-Tyne. The boiler was given considerable heating-surface by the introduction of 25 3-inch copper tubes, at the suggestion of Henry Booth, secretary of the railroad company. The blast was altered by gradually closing in the opening at the extremity of the exhaust-pipe, and thus "sharpening" it until it was found to have the requisite intensity. The effect of this modification of the shape of the pipe was observed carefully by means of syphon water-gauges attached to the chimney. The draft was finally given such an intensity as to raise the water 3 inches in the tube of the draught-gauge. The total length of the boiler was 6 feet, its diameter 40 inches. The fire-box was attached to the rear of the boiler, and was 3 feet high and 2 feet wide, with water-legs to protect its side-sheets from injury by overheating. The cylinders, as

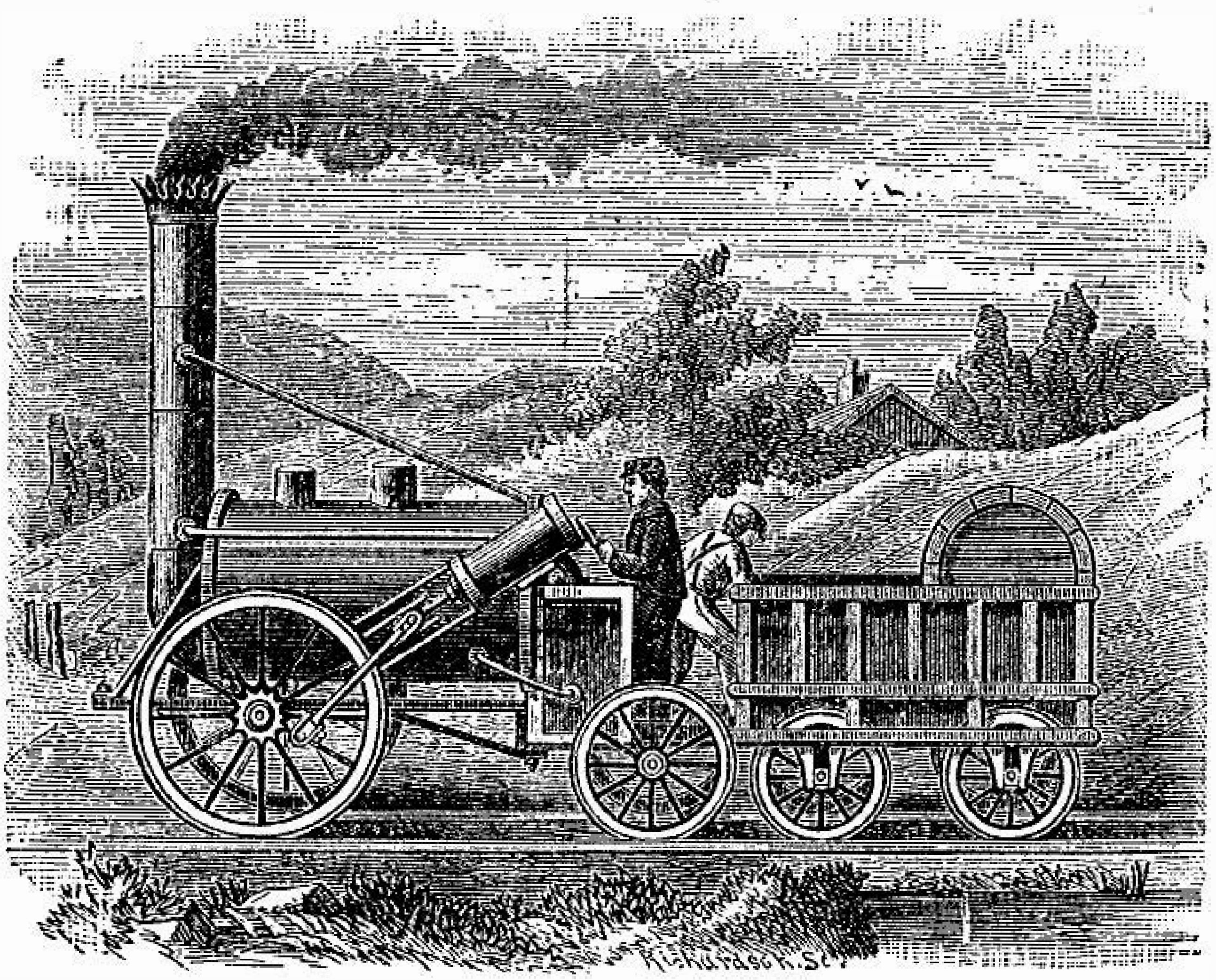


Fig. 55.—The "Rocket," 1829.

seen in the sketch, were inclined, and coupled to a single pair of driving-wheels. A tender, attached to the engine, carried the fuel and water. The engine weighed less than 4½ tons.

The little engine does not seem to have been very prepossessing in appearance, and the "Novelty" is said to have been the general favorite, the Stephenson engine having few, if any, backers among the spectators. On its first trial, it ran 12 miles in less than an hour.

After the accident which disabled the "Novelty," the "Rocket" came forward again, and ran at the rate of from 25 to 30 miles an hour, drawing a single carriage carrying 30 passengers. Two days later, on the 8th of October, steam was raised in a little less than an hour from cold water, and it then, with 13 tons of freight in the train, ran 35 miles in 1 hour and 48 minutes, including stops, and attained a speed of 29 miles an hour. The average of all runs for the trial was 15 miles an hour.

This success, far exceeding the expectation of the most sanguine of the advocates of the system, and greatly exceeding what had been asserted by opponents to be the bounds of possibility, settled completely the whole question, and the Manchester & Liverpool road was at once equipped with locomotive engines.

The "Rockett" remained on the line until 1837, when it was sold, and set at work by the purchasers on the Midgeholme Railway, near Carlisle. On one occasion, on this road, it was driven 4 miles in 4½ minutes. It is now in the Patent Museum at South Kensington, London.

In January, 1830, a single line of rails had been carried across Chat Moss, and, six months later, the first train, drawn by the "Arrow," ran through, June 14th, from Liverpool to Manchester, makingt the trip in an hour and a half, and attaining a maximum speed of over 27 miles an hour. The line was formally opened to traffic September 15, 1830.

This was one of the most notable occasions in the history of the railroad, and the successful termination of the great work was celebrated, as so important an event should be, by impressive ceremonies. Among the distinguished spectators were Sir Robert Peel and the Duke of Wellington. Mr. Huskisson, a Member of Parliament for Liverpool, was also present. There had been built for the line, by Robert Stephenson & Co., 7 locomotives besides the "Rocket," and a large number of carriages. These were all brought out in procession, and 600 passengers entered the train, which started for Manchester, and ran at times, on smooth portions of the road, at the rate of 20 and 25 miles an hour. Crowds of people along the line cheered at this strange and to them incomprehensible spectacle, and the story of the wonderful performances of that day on the new railroad was repeated in every corner of the land. A sad accident, the precursor of thousands to follow the introduction of the new method of transportation, while it repressed the rising enthusiasm of the people and dampened the ardor of the most earnest of the advocates of the railroad, occurring during this trip, assisted in making known the power of the new motor and the danger attending its use as well. The trains stopped for water at Parkside, and occasion was taken to send the "Northumbrian," an engine driven by George Stephenson himself, on a side track, with the carriage containing the Duke of Wellington, and the other engines and trains were all directed to be sent along the main track in view of the Duke and his party. While this movement was in process of execution, Mr. Huskisson, who had carelessly stood on the main line until the "Rocket," which led the column, had nearly reached him, attempted to enter the carriage of the Duke. He was too late, and was struck by the "Rocket," thrown down across the rail, and the advancing engine crushed a leg so seriously that he died the same evening. Immediately after the accident, he was placed on the "Northumbrian," and Stephenson made the 15 miles to the destination of the wounded man in 25 minutes—a speed of 36 miles an hour. The news of this accident, and the statement of the velocity of the engine, were published throughout the kingdom and Europe; and the misfortune of this first victim of a railroad accident was one of the causes of the immediate adoption and rapid spread of the modern railway system.

This road, which was built in the hope of securing 400 passengers per day, almost immediately averaged 1,200, and in five years reported 500,000 passengers for the year.[1] The success of this road insured the general introduction of railroads, and from this time forward there was never a

[1] Smiles.

doubt of their ultimate adoption to the exclusion of every other system of general internal communication and transportation.

For some years after this his first great triumph, George Stephenson gave his whole time to the building of railroads and the improvement of the engine. He was assisted by his son Robert, to whom he gradually surrendered his business, and retired to Tapton House, on the Midland Railway, and led a busy but pleasant life during the remaining years of his existence.

Even as early as 1840, he seems to have projected many improvements which were only generally adopted many years later. He proposed self-acting and continuous systems of brake, and considered a good system of brake of so great importance, that he advocated their compulsory introduction by State legislation. He advised moderate speeds, from considerations both of safety and of expense.

A few years after the opening of the Liverpool & Manchester road, great numbers of schemes were proposed by ignorant or designing men, which had for their object the filling of the pockets of their proposers rather than the benefit of the stockholders and the public ; and the Stephensons were often called upon to combat these crude and ill-digested plans.[†] Among these was the pneumatic system of propulsion, already referred to as first proposed by Papin, in combination with his double-acting air-pump, in 1687. It had been again proposed in the early part of the present century by Medhurst, who proposed a method of pneumatic transmission of small parcels and of letters, which is now in use, and, 15 years later,[†] a railroad to take the place of that of Stephenson and his coadjutors. The most successful of several attempts to introduce this method was that of Clegg & Samuda, at West London, and on the London & Croydon road, and again in Ireland, between Kingstown and Dalkey. A line of pipe, *B B*, seen in Fig. 56, two feet in diameter, was laid between the rails, *A A*, of the road. This pipe was fitted with a nicely-packed piston, carrying a strong arm, which rose through a slit made along the top of the pipe, and covered by a flexible strip of leather, *E E*. This arm was attached to the carriage, *C C*,

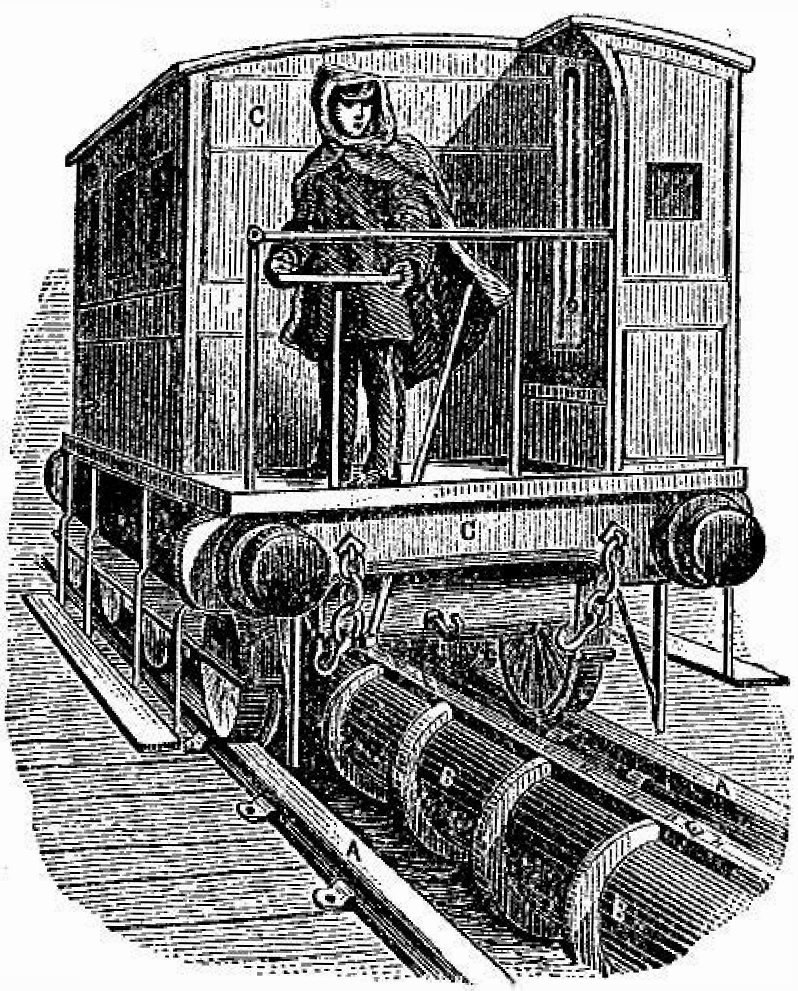


Fig. 56.—The Atmospheric Railroad.

to be propelled. The pressure of the atmosphere being removed, by the action of a powerful pump, from the side toward which the train was to advance, the pressure of the atmosphere on the opposite side drove the piston forward, carrying the train with it. Stephenson was convinced, after examining the plans of the projectors, that the scheme would fail, and so expressed himself. Those who favored it, however, had sufficient influence with capitalists to secure repeated trials, although each was followed by failure, and it was several years before the last was heard of this system.

A considerable portion of several of the later years of Stephenson's life was spent in traveling in Europe, partly on business and partly for pleasure. During a visit to Belgium in 1845, he was received everywhere, and by all classes, from the king down to the humblest of his subjects, with such distinction as is rarely accorded even to the greatest men. He soon after visited Spain with Sir Joshua Walmsley, to report on a proposed railway from the capital to the Bay of Biscay. On this journey he was taken ill, and his health was permanently impaired. Thenceforward he devoted himself principally to the direction of his own property, which had become very considerable, and spent much of his time at the collieries and other works in which he had invested it. His son had now entirely relieved him of all business connected with railroads, and he had leisure to devote to self-improvement and social amusement. Among his friends he claimed Sir Robert Peel, his old acquaintance, now Sir William, Fairbairn, Dr. Buckland, and many others of the distinguished men of that time.

In August, 1848, Stephenson was attacked with intermittent fever, succeeded by hæmorrhage from the lungs, and died on the 12th of that month, at the age of sixty-six years, honored of all men, and secure of an undying fame. Soon after his death, statues were erected at Liverpool, London, and Newcastle, the cost of the second of which was defrayed by private subscriptions, including a contribution of about $1,500 by 3,150 workingmen—one of the finest tributes ever offered to the memory of a great man.

But the noblest monument is that which he himself erected by the establishment of a system of education and protection of his working-people at Clay Cross. He made it a condition of employment that every employé should contribute from five to twelve pence each fortnight to a fund, to which the works also made liberal contributions. From that fund it was directed that the expenses of free education of the children of the work-people, night-schools for those employed in the works, a reading-room and library, medical treatment, and a benevolent fund were to be defrayed. Music and cricket-clubs, and prize funds for the best garden, were also founded. The school, public hall, and the church of Clay Cross, and this noble system of support, are together a nobler monument thant any statue or similar structure could be.

The character of George Stephenson was in every way admirable. Simple, earnest, and honorable; courageous, indomitable, and industrious; humorous, kind, and philanthropic, his memory will longt be cherished, and will long prove an incentive to earnest effort and to the pursuit of an honorable fame with hundreds of the youth who, reading his simple yet absorbing story, as told by his biographer, shall in later years learn to know him.

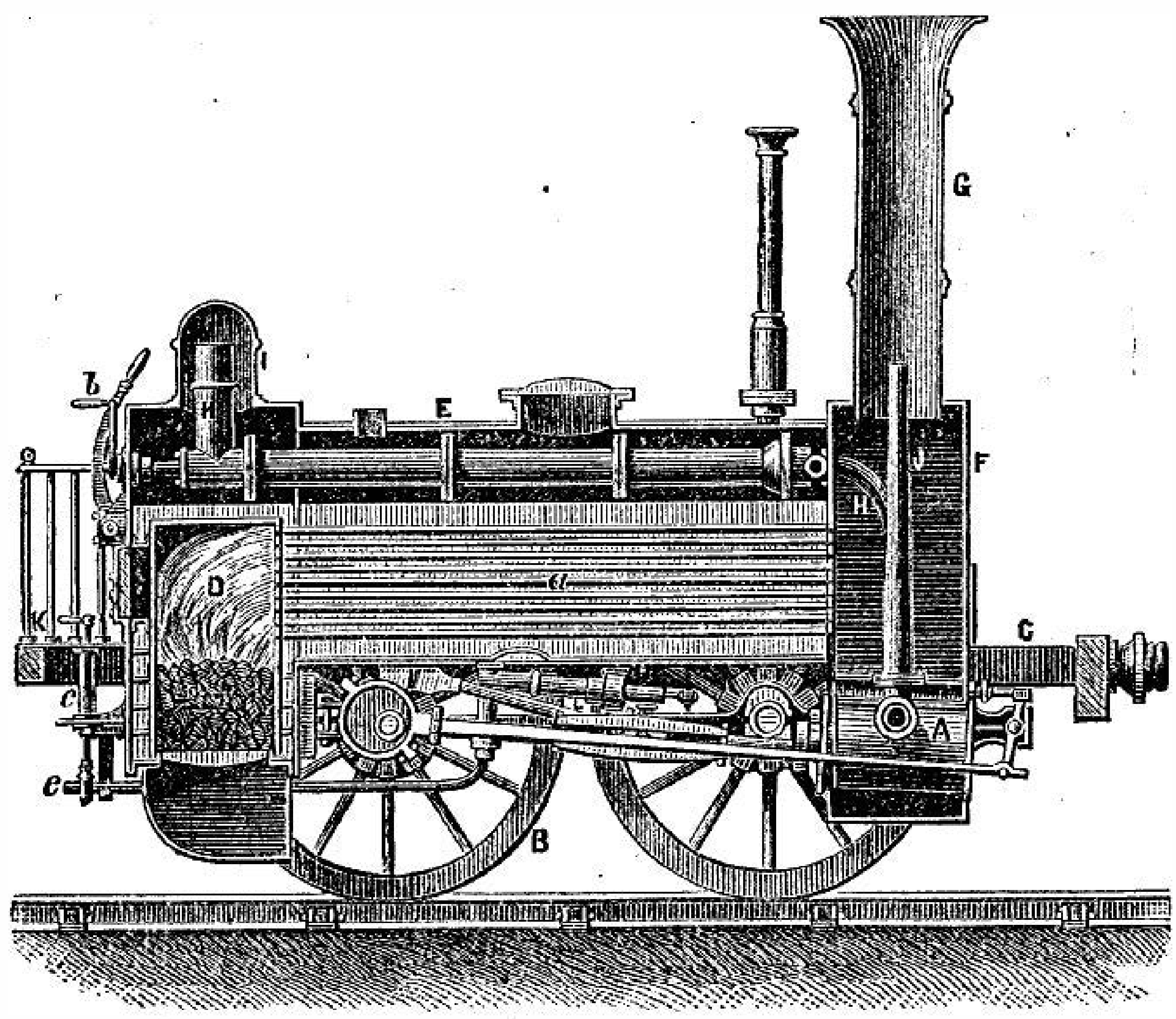


Fig. 57.—Stephenson's Locomotive, 1833.

After the death of his father, Robert Stephenson continued, as he had already done for several years, to conduct the business of building locomotives, as well as of constructing railroads. The work of locomotive engine-building was done at Newcastle, and for many years those works were the principal engine-building establishment of the world.

After their introduction on the Liverpool & Manchester road, the engines of the firm of Robert Stephenson & Co. were rapidly modified, until they assumed the form shown in Fig. 57, which remained standard until their gradual increase in weight compelled the builders to place a larger number of wheels beneath them, and make those other changes which finally resulted in the creation of distinct types for special kinds of work. In the engine of 1833, as shown above, the cylinders, *A*, are carried at the extreme forward end of the boiler, and the driving-wheels, *B*, are coupled directly to the connecting-rod of the engine and to each other. A buffer, *C*, extends in front, and the rear end of the boiler is formed into a rectangular fire-box, *D*, continuous with the shell, *E*, and the flame and gases pass to the connection and smoke-pipe, *F*, *G*, through a large number of small tubes, *a*. Steam is led to the cylinders by a steam-pipe, *H H'*, to which it is admitted by the throttle-valve, *b*. A steam-dome, *I*, from which the steam is taken, assists by giving more steam-space far above the water-line, and thus furnishing dry steam. The exhaust steam issues with great velocity into the chimney from the pipe, *J*, giving great intensity of draught. The engine-driver stands on the platform, *K*, from which all the valves and handles are accessible. Feed-pumps, *L*, supply the boiler with water, which is drawn from the tender through the pipes, *e*, *f*.

The valve-gear was then substantially what it is to-day, the "Stephenson link" (Fig. 58). On the driving-axle were keyed two eccentrics, *E*, so set that the motion of the one was adapted to driving the valve when the engine was moving forward, and the other was arranged to move the valve when running backward. The former was connected, through its strap and the rod, *B*, to the upper end of a "strap-link," *A*, while the second was similarly connected with the lower end. By means of a handle, *L*, and the link, *n*, and its connections, including the counterweighted bell-crank, *M*, this link could be raised or depressed, thus bringing the pin on thenlink-block, to which the valve-stem was connected, into action with either eccentric. Or, the link being set in mid-gear, the valve would cover both steam-ports of the cylinder, and the engine could move neither way. As shown, the engine is in position to run backward. A series of notches, *Z*, into either of which a

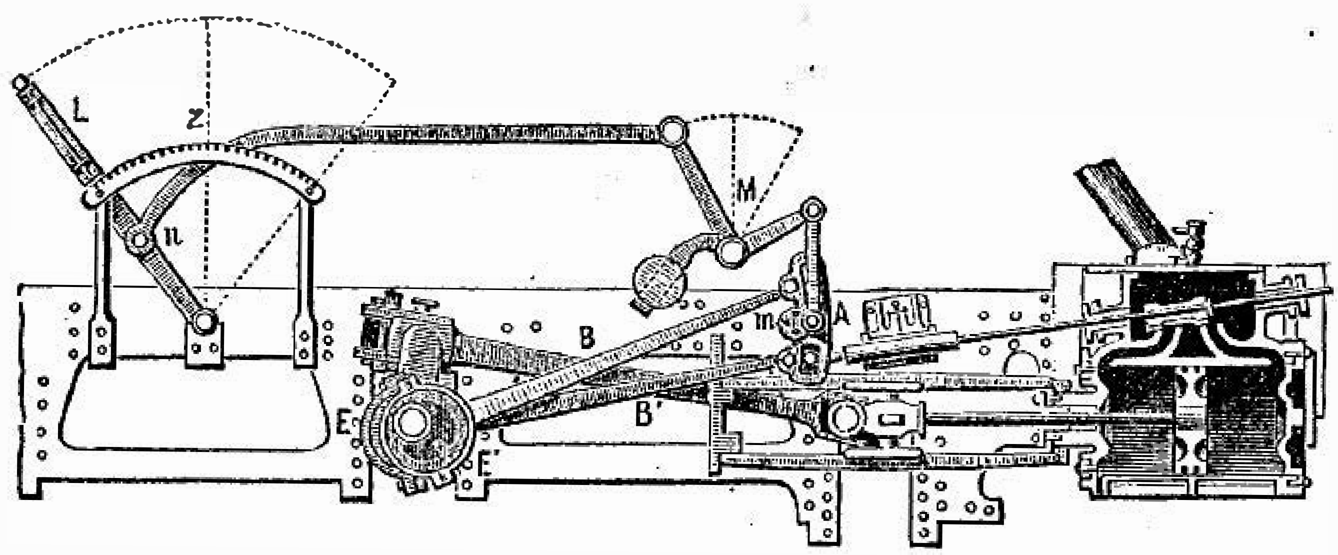


FIG. 58.—The Stephenson Valve-Gear, 1833.

catch on *L* could be dropped, enabled the driver to placen the link where he chose. In intermediate positions, between mid-gear and full-gear, the motion of the valve is such as to produce expansion of the steam, and some gain in economy of working, although reducing the power of the engine.

The success of the railroad and the locomotive in Great Britain led to its rapid introduction in other countries. In France, as early as 1823, M. Beaunier was authorized to construct a line of rails from the coal-mines of St. Étienne to the Loire, using horses for the traction of his trains ; and in 1826, MM. Seguin began a road from St. Étienne to Lyons. In 1832, engines built at Lyons were substituted for horses on these roads, but internal agitations interrupted the progress of the new system in France, and, for 10 years after the opening of the Manchester & Liverpool road, France remained without steam-transportation on land.

In Belgium the introduction of the locomotive was more promptly accomplished. Under the direction of Pierre Simon, an enterprising and well-informed young engineer, who had become known principally as an advocate of the even then familiar project of a canal across the Isthmus of Darien, very complete plans of railroad communication for the kingdom were prepared, in compliance with a decree dated July 31, 1834, and were promptly authorized. The road between Brussels and Mechlin was opened May 6, 1837, and other roads were soon built; and the railway system of Belgium was the first on the Continent of Europe.

The first German railroad worked with locomotive steam-engines was that between Nuremberg and Fürth, built under the direction of M. Denis. The other European countries soon followed in this rapid march of improvement.

In the United States, public attention had been directed to this subject, as has already been stated, very early in the present century, by Evans and Stevens. At that time the people of the United States, as was natural, closely watched every important series of events in the mother-country; and so remarkable and striking a change as that which was taking place in the time of Stephenson, in methods of communication and transportation, could not fail to attract general attention and awaken universal interest.

Notwithstanding the success of the early experiments of Evans and others, and in spite of the statesman-like arguments of Stevens and Dearborn, and the earnest advocacy of the plan by all who were familiar with the revelations which were daily made of the power and capabilities of the steam-engine, it was not until after the opening of the Manchester & Liverpool road that any action was taken looking to the introduction of the locomotive. Colonel John Stevens, in 1825, had built a small locomotive, which he had placed on a circular railway before his house—now Hudson Terrace—at Hoboken, to prove that his statements had a basis of fact. This engine had two "lantern" tubular boilers, each composed of small iron tubes, arranged vertically in circles about the furnaces.[1] This exhibition had no other effect, however, than to create some interest in the subject, which aided in securing a rapid adoption of the railroad when once introduced.

The first line of rails in the New England States is said to have been laid down at Quincy, Mass., from the granite quarry to the Neponset River, three miles away, in 1826 and 1827. That between the coal-mines of Mauch Chunk, Pa., and the river Lehigh, nine miles distant, was built in 1827. In the following year the Delaware & Hudson Canal Company built a railroad from their mines to the termination of the canal at Honesdale. These roads were worked either by gravity or by horses and mules.

The competition at Rainhill, on the Liverpool and Manchester Railroad, had been so widely advertised, and promised to afford such conclusive evidence relative to the value of the locomotive steam-engine and the railroad, that engineers and others interested in the subject came from all parts of the world to witness the trial. Among the strangers present were Mr. Horatio Allen, then chief-engineer of the Delaware & Hudson Canal Company, and Mr. E. L. Miller, a resident of Charleston, S. C., who went from the United States for the express purpose of seeing the new machines tested.

Mr. Allen had been authorized to purchase, for the company with which he was connected, three locomotives and the iron for the road, and had already shipped one engine to the United States, and had set it at work on the road. This engine was received in New York in May, 1829, and its trial took place in August at Honesdale, Mr. Allen himself driving the engine. But the track proved too light for the locomotive, and it was laid up and never set at regular work. This engine was called the "Stourbridge Lion"; it was built by Foster, Rastrick & Co., of Stourbridge, Eng-

[1] One of these sectional boilers is still preserved at the Stevens Institute of Technology.

land. During the summer of the next year, a small experimental engine, which was built in 1829 by Peter Cooper, of New York, was successfully tried on the Baltimore & Ohio Railroad, at Baltimore, making 13 miles in less than an hour, and moving, at some points on the road, at the rate of 18 miles an hour. One carriage carrying 36 passengers was attached. This was considered a working-model only, and was rated at one horse-power.

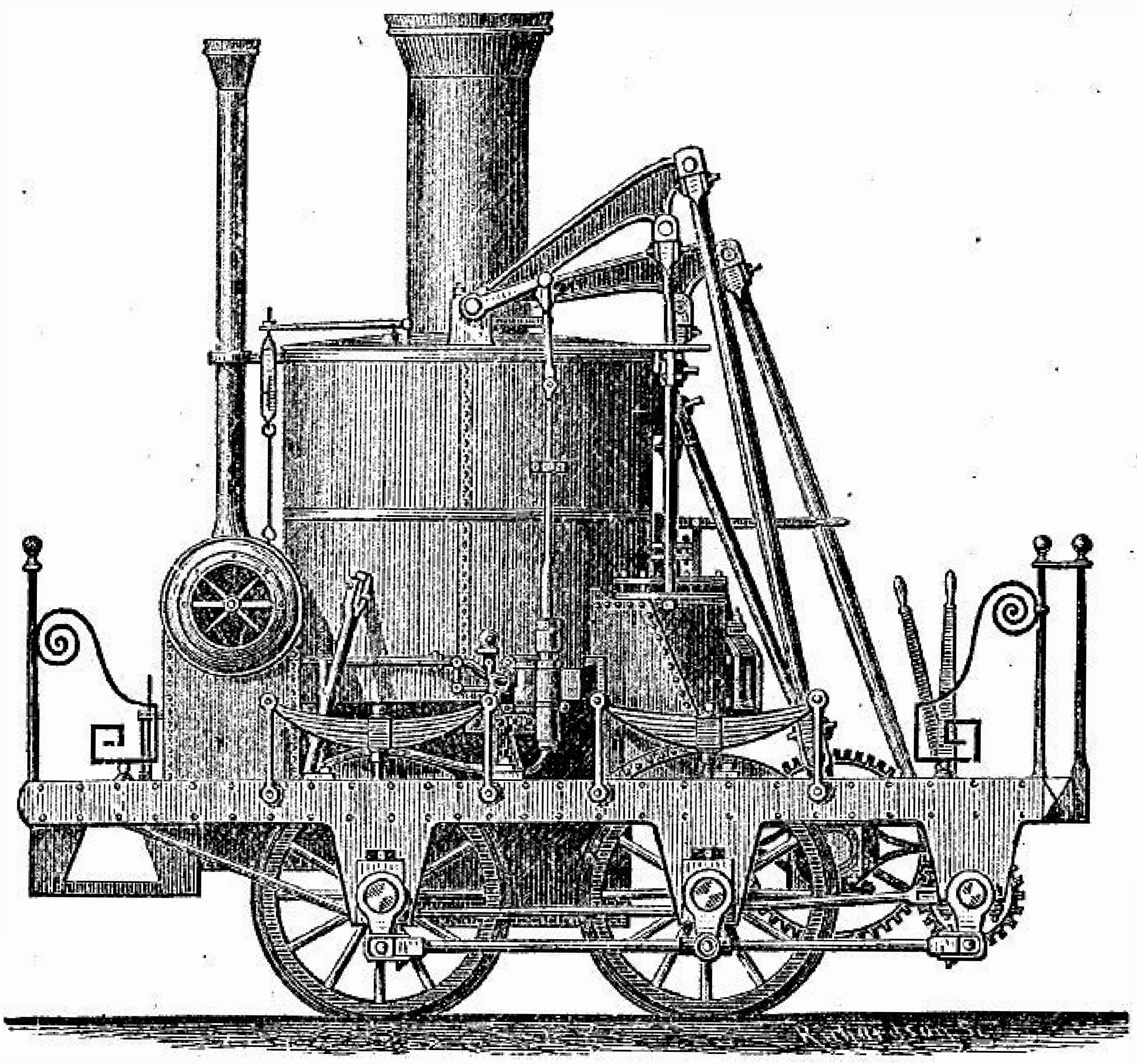
Ross Winans, writing of this trial of Cooper's engine, makes a comparison with the work done by Stephenson's "Rocket," and claims a decided superiority for the former. He concluded that the trial established fully the practicability of using locomotives on the Baltimore & Ohio road at high speeds, and on all its curves and heavy gradients, without inconvenience or danger.

This engine had a vertical tubular boiler, and the draught was urged, like that of the "Novelty" at Liverpool, by mechanical means—a revolving fan. The single steam-cylinder was $3\frac{1}{4}$ inches in diameter, and the stroke of piston $14\frac{1}{2}$ inches. The wheels were 30 inches in diameter, and connected to the crank-shaft by gearing. The engine, on the trial, worked up to 1.43 horse-power, and drew a gross weight of $4\frac{1}{2}$ tons. Mr. Cooper, unable to find such tubes as he needed for his boiler, used gun-barrels. The whole machine weighed less than a ton.

Messrs. Davis & Gartner, a little later, built the "York" for this road—a locomotive having also a vertical boiler, of very similar form to the modern steam fire-engine boiler, 51 inches in diameter, and containing 282 fire-tubes, 16 inches long, and tapering from $1\frac{1}{2}$ inches diameter at the bottom to $1\frac{1}{4}$ at the top, where the gases were discharged through a combustion-chamber into a steam-chimney. This engine weighed $3\frac{1}{2}$ tons.

They subsequently built several "grasshopper" engines (Fig. 59), some of which ran many years, doing good work, and one or two of which are still in existence. The first—

the "Atlantic"—was set at work in September, 1832, and hauled 50 tons from Baltimore 40 miles, over gradients having a maximum rise of 37 feet to the mile, and on curves having a minimum radius of 400 feet, at the rate of 12 to 15 miles an hour. This engine weighed 6½ tons, carried 50 pounds of steam—a pressure then common on both continents



59.—The "Atlantic," 1832.

—and burned a ton of anthracite coal on the round trip. The blast was secured by a fan, and the valve-gear was worked by cams instead of eccentrics. This engine made the round trip at a cost of $16, doing the work of 42 horses, which had cost $33 per trip. The engine cost $4,500, and was designed by Phineas Davis, assisted by Ross Winans.

Mr. Miller, on his return from the Liverpool & Manchester trial, ordered a locomotive for the Charleston & Hamburg Railroad from the West Point Foundery. This engine was guaranteed by Mr. Miller to draw three times its weight at the rate of 10 miles an hour. It was built during the summer of 1830, from the plans of Mr. Miller, and reached Charleston in October. The trials were made in November and December.

This engine (Fig. 60) had a vertical tubular boiler, in which the gases rose through a very high fire-box, into which large numbers of rods projected from the sides and top, and passed out through tubes leading them laterally outward into an outside jacket, through which they rose to the chimney. The steam-cylinders were two in number, 8 inches in diameter and of 16 inches stroke, inclined so as to connect with the driving-axle. The four wheels were all of the same size, 4½ feet in diameter, and connected by

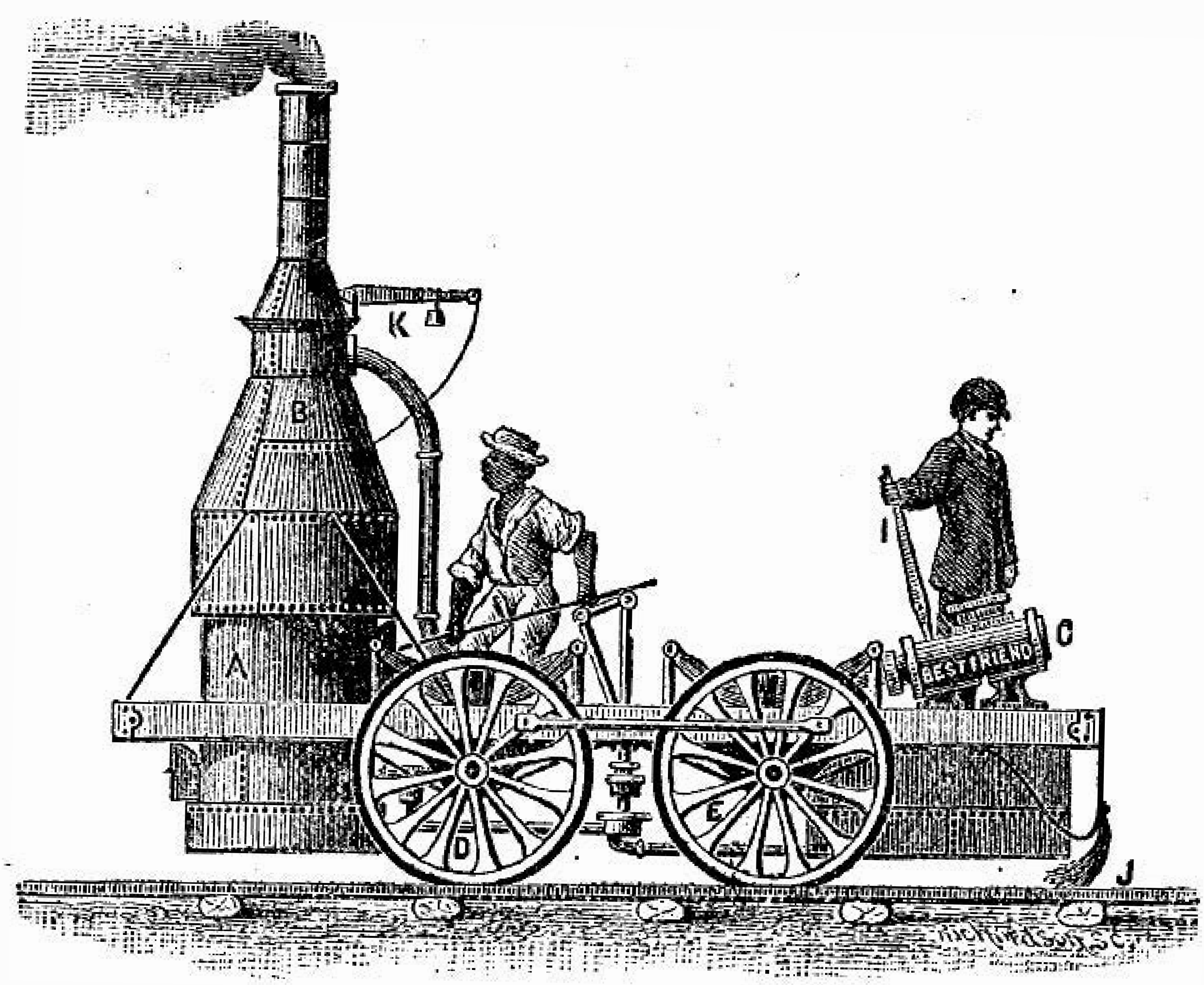


FIG. 60.—The "Best Friend," 1830.

coupling-rods. The engine weighed 4½ tons. The "Best Friend," as it was called, did excellent work until June, 1831, when the explosion of the boiler, in consequence of the recklessness of the fireman, unexpectedly closed its career.

A second engine (Fig. 61) was built for this road, at the West Point Foundery, from plans furnished by Horatio Allen, and was received and set at work early in the spring

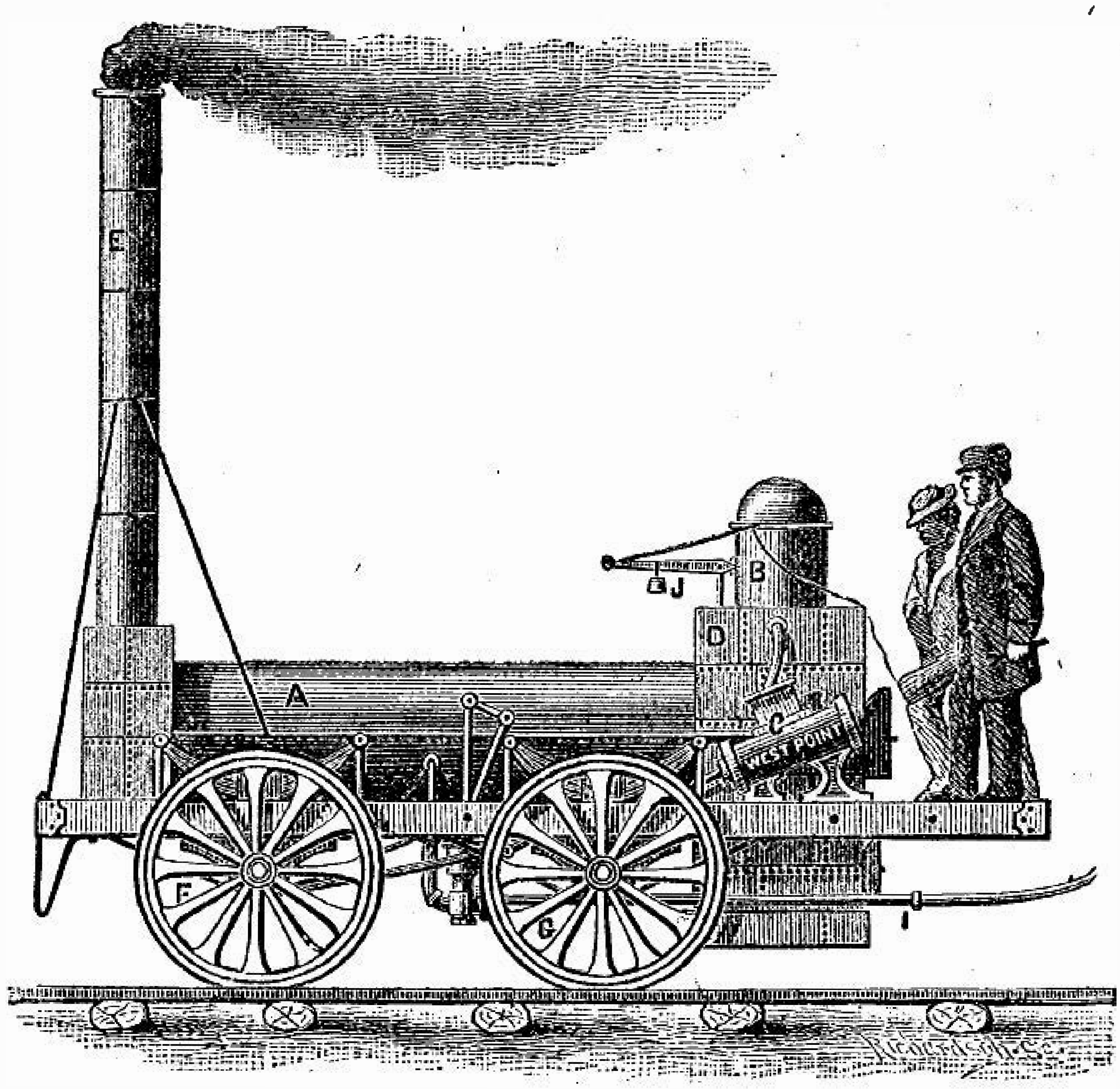


FIG. 61.—The "West Point," 1831.

of 1831. The engine, called the "West Point," had a horizontal tubular boiler, but was in other respects very similar to the "Best Friend." It is said to have done very good work.

The Mohawk & Hudson Railroad ordered an engine at about this time, also, of the West Point Foundery, and the trials, made in July and August, 1831, proved thoroughly successful.

This engine, the "De Witt Clinton," was contracted for by John B. Jervis, and fitted up by David Matthew. It had two steam-cylinders, each $5\frac{1}{2}$ inches in diameter and 16 inches stroke of piston. The connecting-rods were directly attached to a cranked axle, and turned four coupled wheels $4\frac{1}{2}$ feet in diameter. These wheels had cast-iron hubs and wrought-iron spokes and tires. The tubes were of copper, $2\frac{1}{2}$ inches in diameter and 6 feet long. The engine weighed $3\frac{1}{2}$ tons, and hauled 5 cars at the rate of 30 miles an hour.

Another engine, the "South Carolina" (Fig. 62), was designed by Horatio Allen for the South Carolina Railroad, and completed late in the year 1831. This was the first eight-wheeled engine, and the prototype, also, of a peculiar and lately-revived form of engine.

In the summer of 1832, an engine built by Messrs. Davis & Gartner, of York, Pa., was put on the Baltimore & Ohio road, which at times attained a speed, unloaded, of 30 miles an hour. The engine weighed $3\frac{1}{2}$ tons, and drew, usually, 4 cars, weighing altogether 14 tons, from Baltimore to Ellicott's Mills, a distance of 13 miles, in the schedule-time, one hour.

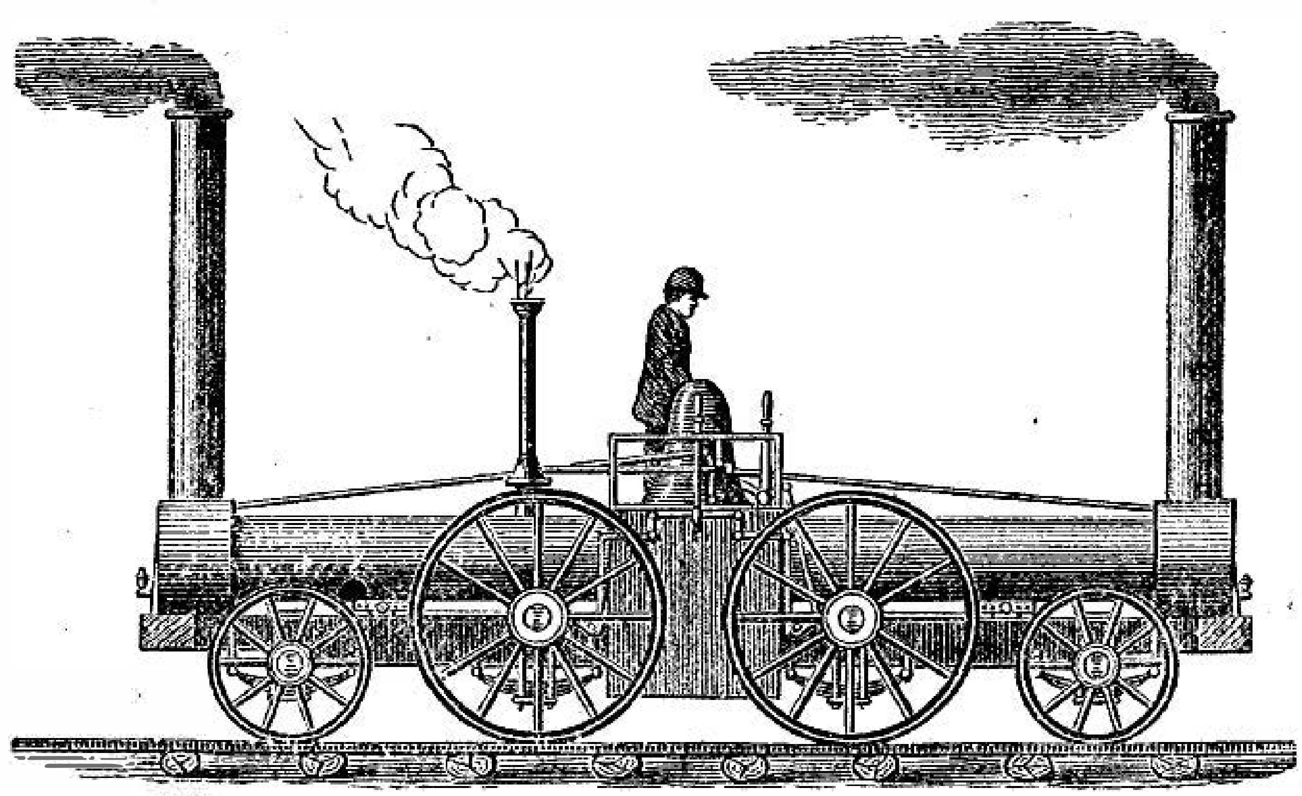


FIG. 62.—The "South Carolina," 1831.

Horatio Allen's engine on the South Carolina Railroad is said to have been the first eight-wheeled engine ever built.n

It was at about the time of which we are now writing that the first locomotive was built of what is now distinctively known as the American type—an engine with a "truck" or "bogie" under the forward end of the boiler. This was the "America" No. 1, built at the West Point Foundery, from plans furnished by John B. Jervis, Chief Engineer, for the Mohawk & Hudson Railroad. Ross Winans had already (1831) introduced the passenger-car with swiveling trucks.[1] It was completed in August, 1832, and is said by Mr. Matthew to have been an extremely fast and smooth-running engine. A mile a minute was repeatedly attained, and it is stated by the same authority,[2] that a speed of 80 miles an hour was sometimes made over a single mile. This engine had cylinders 9½ inches diameter, 16 inches stroke of piston, two pairs of driving-wheels, coupled, 5 feet in diameter each; and the truck had four 33-inch wheels. The boiler contained tubes 3 inches in diameter, and its fire-box was 5 feet long and 2 feet 10 inches wide. Robert Stephenson & Co. subsequently built a similar engine, from the plans of Mr. Jervis, and for the same road. It was set at work in 1833. In both engines the driving-wheels were behind the fire-box. This engine is another illustration of the fact—shown by the description already given of other and earlier engines—that the independence of the American mechanic, and the boldness and self-confidence which have to the present time distinguished him, were among the earliest of the fruits of our political independence and freedom.

These American engines were all designed to burn anthracite coal. The English locomotives all burned bituminous coal.

Robert L. Stevens, the President and Engineer of the Camden & Amboy Railroad, and a distinguished son of Colonel John Stevens, of Hoboken, was engaged, at the time of the opening of the Liverpool & Manchester Rail-

[1] "History of the First Locomotives in America," Brown.

[2] "Ross Winans *vs.* The Eastern Railroad Company—Evidence." Boston, 1854.

road, in the construction of the Camden & Amboy Railroad. It was here that the first of the now standard form of T-rail was laid down. It was of malleable iron, and of

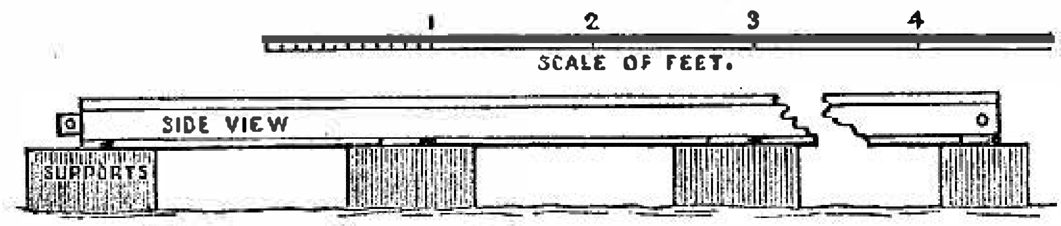
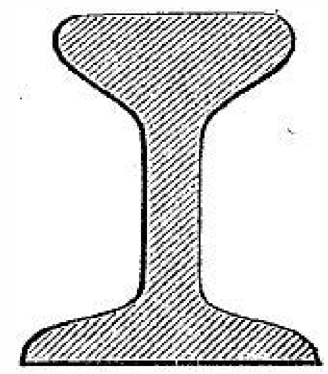


FIG. 68.—The "Stevens" Rail.



Enlarged Section.

the form shown in the accompanying figure. It was designed by Mr. Stevens, and is known in the United States as the "Stevenst" rail. In Europe, where it was introduced some years afterward, it is sometimes called the "Vignolles" rail. He purchased an engine of the Stephensons soon after the trial at Rainhill, and this engine, the "John Bull," was set up on the then uncompleted road at Bordentown, in the year 1831. Its first public trial was made in November of that year. The road was opened for traffic, from end to end, two years later. This engine had steam-cylinders 9 inches in diameter, 2 feet stroke of piston, one pair of drivers $4\frac{1}{2}$ feet in diameter, and weighed 10 tons. This engine, and that built by Phineas Davis for the Baltimore & Ohio Railroad, were exhibited at the Centennial Exhibition at Philadelphia, in the year 1876.

Engines supplied to the Camden & Amboy Railroad subsequent to 1831 were built from the designs of Robert L. Stevens, in the shop of the Messrs. Stevens, at Hoboken. The other principal roads of the country, at first, very generally purchased their engines of the Baldwin Locomotive Works, then a small shop owned by Matthias W. Baldwin. Baldwin's first engine was a little model built for Peale's Museum, to illustrate to the visitors of that then well-known place of entertainment the character of the new motor, the success of which, at Rainhill, had just then excited the attention of the world. This was in 1831, and the successful working of this little model led to his receiving an order for an engine from the Philadelphia & Germantown Railroad. Mr. Baldwin, after studying the new engine of the Camden & Amboy road, made his plans, and built an engine (Fig. 64), completing it in the autumn of 1832, and setting it in operation November 23d of that year. It was kept at work on that line of road for a period of 20 years or more. This engine was of Stephenson's "Planet" class, mounted on two driving-wheels $4\frac{1}{2}$ feet in diameter each, and two separate wheels of the same size, uncoupled. The steam-cylinders were $9\frac{1}{2}$ inches in diameter, 18 inches stroke of piston, and were placed horizontally on each side of the smoke-box. The boiler, $2\frac{1}{2}$ feet in diameter, contained 72 copper tubes $1\frac{1}{2}$ inches in diameter and 7 feet long. The engine cost the railroad company $3,500.

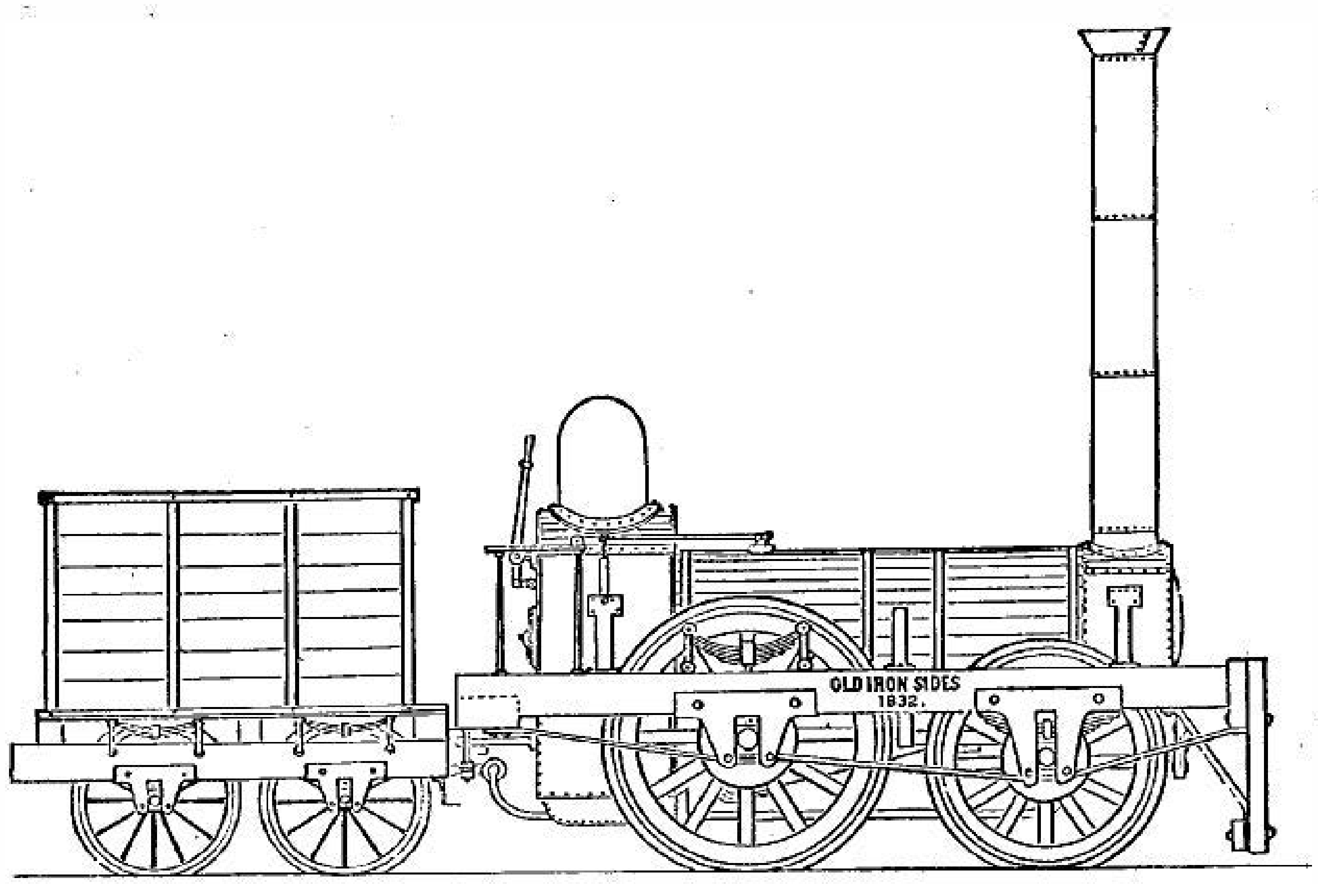


Fig. 64.—"Old Ironsides," 1832.

On the trial, steam was raised in 20 minutes, and the maximum speed noted was 28 miles an hour. The engine subsequently attained a speed of over 30 miles. In 1834, Mr.

Baldwin completed for Mr. E. L. Miller, of Charleston, a six-wheeled engine, the "E. L. Miller"† (Fig. 65), with cylinders 10 inches in diameter and 16 inches stroke of piston.

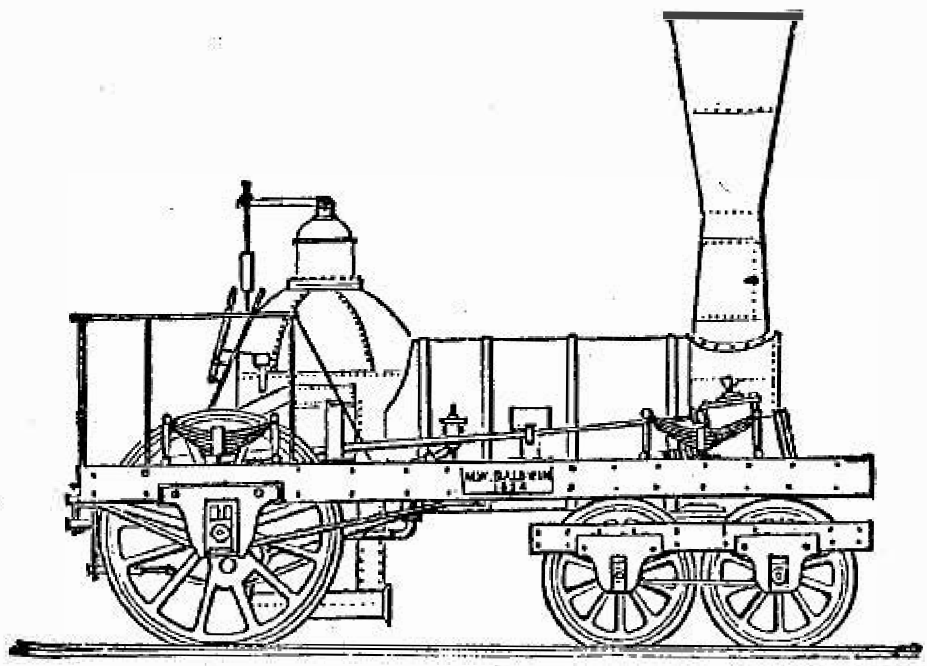


Fig. 65.—The "E. L. Miller," 1834.

He made the boiler of this engine of a form which remained standard many years, with a high dome over the fire-box. At about the same time, he built the "Lancaster," an engine resembling the "Miller," for the State road to Columbia, and several others were soon contracted for and built. By† the end of 1834, 5 engines had been built by him, and the construction of locomotive-engines had become one of the leading and most promising industries of the United States.† Mr. William Norris established a shop in Philadelphia in 1832, which he gradually enlarged until it, like the Baldwin Works, became a large establishment. He usually built a six-wheeled engine, with a leading-truck or bogie, and placed his driving-wheels in front of the fire-box.

At this time the English locomotives were built to carry 60 pounds of steam. The American builders adopted pressures of 120 to 130 pounds per square inch, the now generally standard pressures throughout the world. In the years 1836 and 1837, Baldwin built 80 engines.† They were of three classes: 1st, with cylinders 12½ inches in diameter and of 16 inches stroke, weighing 12 tons; 2d, with cylinders 12 by 16, and a weight of 10½ tons; and 3d, engines weighing 9 tons, and having steam-cylinders of 10½ inches diameter and of the same stroke. The driving-wheels were usually 4½ feet in diameter, and the cylinder "inside-connected" to cranked axles. A few "outside-connected" engines were made, this plan becoming generally adopted at a later period.

The railroads of the United States were very soon supplied with locomotive-engines built in America. In the year 1836, William Norris, who had two years before purchased the interest of Colonel Stephen H. Long, an army-officer who patented and built locomotives of his own design, built the "George Washington," and set it at work. This engine, weighing 14,400 pounds, drew 19,200 pounds up an incline 2,800 feet long, rising 369 feet to the mile, at the speed of 15½ miles an hour. This showed an adhesion not far from one-third the weight on the driving-wheels. This was considered a very wonderful performance, and it produced such an impression at the time, that several copies of the "George Washington" were made, on orders from British railroads, and the result was the establishment of the reputation of the locomotive-engine builders of the United States upon a foundation which has nevert since failed them. The engine had Jervis's forward-truck, now always seen under standard engines, which had already been placed under railroad-cars by Ross Winans.

In New England, the Locks & Canals Company, of Lowell, began building engines as early as 1834, copying the Stephensont engine. Hinckley & Drury, of Boston, commenced building an outside-connected engine in 1840, and their successors, the Boston Locomotive Works, became the largest manufacturing establishment of the kind in New England. Two years later,t Ross Winans, the Baltimore builder,tintroduced some of his engines upon Eastern railroads, fitting them with upright boilers, and burning anthracite coal.

The changes which have been outlined produced the now typical American locomotive. It was necessarily given such form that it would work safely and efficiently on rough, ill-ballasted, and often sharply-winding trackst; and thus it soon became evident that the two pairs of coupled driving-wheels, carrying two-thirds the weight of the whole engine, the forward-truck, and the system of "equalizingt" suspension-bars, by which the weight is distributed fairly among all the wheels, whatever the position of the engine, or whatever the irregularity of the track, made it the very best of all known types of locomotive for the railroads of a new country. Experience has shown it equally excellent on the smoothest and best of roads. The "cow-catcher," placed in front to remove obstacles from the track, the bell, and the heavy whistle, are characteristicst of the American engine also. The severity of winter-storms compelled the adoption of the "cab," or house, and the use of wood for fuel led to the invention of the "spark-arrestert" for that class of engines. The heavy grades on many roads led to the use of the "sand-box," from which sand was sprinkled on the track, to prevent the slipping of the wheels.

In the year 1836, the now standard chilled wheel was introduced for cars and trucks; the single eccentric, which had been, until then, used on Baldwin engines, was displaced by the double eccentric, with hooks in place of the linkt; and, a year later, the iron frame took the place of the previously-used wooden frame on all engines.

The year 1837 introduced a period of great depression in all branches of industry, which continued until the year 1840,tor later, and seriously checked all kinds of manufacturing, including the building of locomotives. On the revival of business, numbers of new locomotive-works were started, and in these establishments originated many new types of engine, each of the more successful of which was adapted to some peculiar set of conditions. This variety of type is still seen on nearly all of the principal roads.

The direction of change in the construction of locomotive-engines at the period at which this division of the subject terminates is very well indicated in a letter from Robert Stephenson to Robert L. Stevens, dated 1833, which is now preserved at the Stevens Institute of Technology. He writes: "I am sorry that the feeling in the United States in favor of light railways is so general. In England we are making every succeeding railway stronger and more substantial." He adds: "Small engines are losing ground, and large ones are daily demonstrating that powerful engines are the most economical." He gives a sketch of his latest engine, weighing *nine tons*, and capable, as he states, of "taking 100 tons, gross load, at the rate of 16 or 17 miles an hour on a level." To-day there are engines built weighing 90 tons, and our locomotive-builders have standard sizes guaranteed to draw over 2,000 tonston a good and level track. Trains weighing from 200 to 400 tons are drawn 50, 60, and probably at times, for short distances, 90 miles an hour, by engines weighing 50 tons and more, and developing from 1,200 to 1,800 horse-power.