FOR·THE·INCREASE·AND·DIFFVSION·OF·KNOWLEDGE·AMONG·MEN·

PER ORBEM

·SMITHSONIAN·INSTITVTION·WASHINGTON·1846·

The East Hall. Contains Mechanical and Electrical Engineering Collections.

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 119

CATALOGUE OF THE MECHANICAL ENGINEERING COLLECTION IN THE UNITED STATES NATIONAL MUSEUM

MOTORS, LOCOMOTIVES, AND SELF-PROPELLED VEHICLES

EDITED AND COMPILED BY

CARL W. MITMAN

Curator, Divisions of Mineral and Mechanical Technology

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1922.

ADVERTISEMENT.

The scientific publications of the United States National Museum consist of two series, the *Proceedings* and the *Bulletins*.

The *Proceedings*, the first volume of which was issued in 1878, are intended primarily as a medium for the publication of original, and usually brief, papers based on the collections of the National Museum, presenting newly acquired facts in zoology, geology, and anthropology, including descriptions of new forms of animals, and revisions of limited groups. One or two volumes are issued annually and distributed to libraries and scientific organizations. A limited number of copies of each paper in pamphlet form is distributed to specialists and others interested in the different subjects as soon as printed. The date of publication is printed on each paper, and these dates are also recorded in the tables of contents of the volumes.

The *Bulletins*, the first of which was issued in 1875, consist of a series of separate publications comprising chiefly monographs of large zoological groups and other general systematic treatises (occasionally in several volumes), faunal works, reports of expeditions, and catalogues of type specimens, special collections, etc. The majority of the volumes are octavos, but a quarto size has been adopted in a few instances in which large plates were regarded as indispensable.

Since 1902 a series of octavo volumes containing papers relating to the botanical collections of the Museum, and known as the *Contributions from the National Herbarium*, has been published as bulletins.

The present work forms No. 119 of the *Bulletin* series.

William deC. Ravenel,
Administrative Assistant to the Secretary,
in charge of the United States National Museum.

Washington, D. C., December 23, 1921.

PREFACE.

In the year 1884 a Section of Transportation was organized in the United States National Museum for the purpose of preparing and assembling educational exhibits of a few objects of railroad machinery which had been obtained both from the Centennial Exhibition held in Philadelphia in 1876 and still earlier as incidentals to ethnological collections, and to secure other collections relating to the railway industry.

From this beginning the section was theoretically enlarged to include the whole field of engineering, but it has actually enlarged in the fields of mechanical engineering, especially the early developments of the steam engine, locomotive, and internal combustion engine; electrical engineering, particularly the development of the telegraph, telephone, and the electric light; metrology, particularly horology; and naval architecture.

The primary object of these collections is to visualize broadly the steps by which advances have been made in each field up to the present day; to show the layman the fundamental and general principles which are the basis for the developments, and to familiarize the engineer with other branches of engineering than his own.

While this purpose has been continually in mind to those in charge, an examination of the collections will show that none of them has reached the goal. Some lack the starting points; others have certain portions of their development completed; and but few may be said to be up to date. Many reasons might be given for this condition of affairs, the chief ones being:

1. The Museum is dependent almost wholly upon gifts or loans for augmenting its collections, and while those in charge know what objects are desirable, the general public does not.

2. Funds for the employment of preparators, model makers, etc., are limited, so that the completion of the collections in this way is a slow process.

3. Limited exhibition space, which has prevented in some instances the acquisition of objects of particular value to the collections.

The general limitations of the collections as noted are applicable to the mechanical engineering collection, and this catalogue is prepared in the belief that an acquaintanceship with the collection as it now stands will lead to the cooperation necessary to make it complete.

C. W. M.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

CATALOGUE OF THE MECHANICAL ENGINEERING COLLECTION IN THE UNITED STATES NATIONAL MUSEUM

MOTORS, LOCOMOTIVES, AND SELF-PROPELLED VEHICLES

EDITED AND COMPILED BY
CARL W. MITMAN
Curator, Divisions of Mineral and Mechanical Technology

PART I.

AGENTS OF POWER.

MECHANICAL ELEMENTS.

The desire or the necessity of moving some heavy object, probably a bowlder, led primitive man to the discovery of the lever and its power to do work. His first application undoubtedly was that of placing the end of a stick of wood or his ever-present club under the object and pulling upward on the other end. Thus was born the first mechanical element which has survived to the present day, and may be seen in a variety of forms, both simple and complex, such as the nail puller, can opener, scissors, cogwheel, typewriter action, etc.

Next in order of discovery, probably, was the inclined plane, a very old mechanical element, which is even to-day applied in mechanisms of wide variety. An explanation advanced as to how the placing of heavy stones in the building of the pyramids and temples of ancient Egypt was accomplished is to the effect that inclined roadways were built to the height desired and that the massive stones were then drawn up and set in place. Two inclined planes, placed back to back, form a wedge whose many uses need not be enumerated. Then followed at intervals of time the roller, the pulley and block, and the windlass, all coming into being as direct aids of muscular effort.

Model of Roller, Lever, and Inclined Plane. (Scale 1:6.) Made in the Museum.

The combination of these three powers made it possible for the engineers of antiquity in eastern and western nations to transport and lift in place the heavy objects of which monuments and temples were constructed. This ancient method is universally adopted for transporting heavy loads. Cat. No. 181,251 U.S.N.M.

Model of Method of Rolling a Marble Column. (Scale 1:6.) Made in the Museum.

This method of rolling a load was in vogue in Greece about 560 B. C. It is described by Vitruvius (Book X, chap. 6) and was adopted by Ctesiphon for transporting the columns from the quarry to the temple of Diana at Ephesus, during the sixth century B. C.

Cat. No. 181,257 U.S.N.M.

FIG. 1.—THE COMBINED APPLICATION OF THE ROLLER, LEVER, AND INCLINED PLANE.

Model of Method of Rolling a Marble Prism. (Scale 1:6.) Made in the Museum.

Vitruvius writes (Book X, chap. 6) that the stone "was 12 feet long, 8 feet wide, and 6 feet high," and that "Paeonius made two wheels about 15 feet diameter, and fitted the ends of the stone into

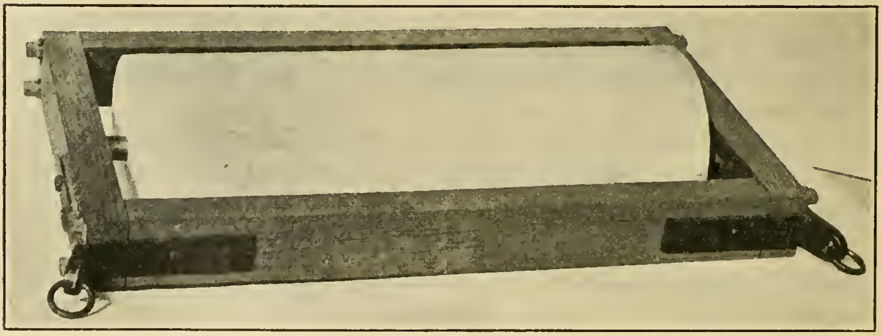


FIG. 2.—THE ROLLING LOAD.

these wheels. To connect the two wheels he framed into them, round their circumference, small pieces of 2 inches square, not more than 1 foot apart, each extending from one wheel to the other, and thus inclosing the stone. Round these bars a rope was coiled, to which the traces of the oxen were made fast, and, as it was drawn out, the stone rolled on by means of the wheels." The method of the rolling load was adopted by Paconius in the first century B. C. for transporting the new base of the colossal statue of Apollo from the quarry to the temple erected to that god.

Cat. No. 181,258 U.S.N.M.

NATURAL FORCES.

The time came in the course of civilization's advancement when power requirements exceeded those which could be developed by muscular energy, and accordingly man proceeded to utilize the natural forces about him. These included the domesticated animal, the wind and the water, whose potential energy was converted into work through the medium of the horse gin and treadmill, the windmill and the water wheel, respectively. Whereas man in turning a crank by hand could do work at the rate of about one-tenth horsepower a minute in an eight-hour day, the ox in the circular-track gin could develop five-tenths and the horse eight-tenths horsepower; the crude windmill about 4 horsepower; and the crude water wheel about the same amount.

WINDMILLS.

Wind for propelling ships was developed at a very early date, but the time of its use for industrial purposes is much later, the exact time being in dispute. Windmills were common beginning about the twelfth century A. D. It is said that the first type adopted to present the vanes or sails toward the wind was to float the mill on water and turn it as required. The next step was to put the mill on a post and turn the building on this as an axis. Following this the cap or roof only was revolved—a Dutch invention of the sixteenth century. The progressive improvements which followed consisted mainly in governing, regulating the sail area in accordance with the wind's force, first by reefing and later by altering the angles at which the sails were presented to the wind.

The windmill, of course, found its greatest application in flat country, and in Holland was probably more universally adopted than in any other country, there being at one time 12,000 mills in operation, averaging 8 horsepower each.

The modern windmill, used mainly for raising water, is much smaller through the use of steel and lighter metals. Disks, 6 to 30 feet in diameter, made up of a number of vanes, take the place of the cloth sail. In one type in particular there are two series of concentric blades fastened to the purlines of a braced radial frame. The blades are fixed at an angle of about 35° to the plane of the wheel and a peculiarly constructed mechanism turns the wheel edgewise to the wind to stop it, or to regulate the position to conform to the wind pressure.

WATER WHEELS.

It is quite probable that the current wheels used from time immemorial, particularly in the Orient, for raising water, and locally known as the Persian wheel, the Noria and the Tympanum, were the forerunners of the water wheel used for the development of power. At all events, water wheels were used to turn mill stones in 50 B. C., according to Strabo, and from this time on were gradually improved, particularly as to their efficiencies. This was brought about mainly through the mode of directing the water to the wheel so that there were developed many types, such as the overshot, undershot, breast, flutter, Barker, and several others whose efficiencies ranged from as much as 75 per cent to as little as 25 per cent.

The modern development of the water wheel is the turbine, a water wheel revolving on a vertical axis and having peculiarly shaped buckets or vanes. Its greater efficiency and ability to take advantage of high as well as low falls of water has practically caused the elimination of the earlier water wheel. Since its invention by Fourneyron in 1823, many types have been developed which, however, may be classified into high and low pressure turbines, and further subdivided according to the direction of flow of the water through the machine. Fourneyron directed the water to the center of the wheel and discharged it outward (radially). The Chase is just the reverse, the water entering at all points around the circumference and escaping at the center and downward. Another type, of which the Jonval is an example, invented in 1841, receives the water above and directs it downward through a set of guides to the wheel, the water discharging below.

Model of Leffel Double Turbine Water Wheel. Made and Presented by James Leffel & Co.

This belongs to the class of water wheels in which the water enters the buckets tangentially at the surface and is discharged at the center. This particular turbine has two sets of buckets, one with a central and the other with a vertical discharge, each receiving its water from the same set of guides at the same time and the water leaving each wheel independently. The two sets are cast together and attached to the same shaft. Cat. No. 180,193 U.S.N.M.

STEAM ENGINES.

Connected with the history of the steam engine are the names Hero, Anthemius, da Vinci, Porta, Branca, de Caus, Marquis of Worcester, Papin, Savery. Newcomen, and Watt, names of men whose efforts to utilize steam to do work, date, it is now believed, from 50 A. D. to 1760 A. D. If the steam engine is considered in its modern sense, however, then Hero's "aeolipile," and the engines made by Papin about 1690 A. D., are the only true ones, for those which followed Hero's and preceded Papin's engines were contrivances for raising water by steam and had no means of operating machinery directly, although they raised water which in turn operated a water wheel.

Hero's engine is a true rotary steam engine working on the same principle as that of the turbine. Branca (A. D. 1629) directed

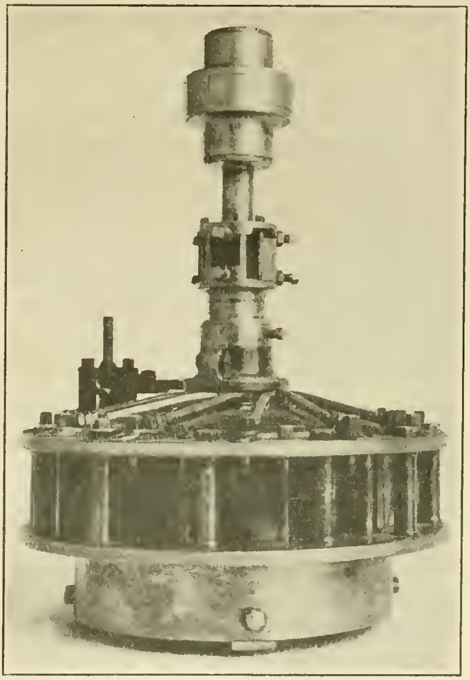


FIG. 3.—THE LEFFEL TURBINE.

steam to strike the vanes of a wheel, causing it to rotate. Dr. Denis Papin, of Blois, France, built a water elevator consisting of two vessels, one in which steam was generated and the other containing the water to be elevated. The former was equipped with a safety valve and the latter contained a float resting on the water and upon which the steam acted, thus decreasing the amount of condensation. This float was the precursor of the piston, invented by Papin. Thomas Savery patented in England a "fire engine" in 1698, which raised water by the direct pressure of steam alternating with atmospheric pressure, which proved to be the first practical application of steam power.

There existed at that time a great sphere for the employment of such an engine in the drainage of the mines of Cornwall and Devonshire, for, although the miners made use of both animal and water power to clear the workings from the steadily increasing flow of water, the deepening of the mines increased the difficulties of removing the water by these means, and the limit of their use had about been reached. Savery's engines were erected at several mines, but only at those whose depth did not exceed the maximum lifting capacity of the engine—about 80 feet. For deeper mines Savery proposed the erection of as many engines as the increased depth of the mine required; that is, a mine 250 feet deep would have three engines, one 80 feet from the bottom, another 80 feet above the first, raising water from a sump into which the first exhausted, and a third engine on the surface to raise the water the remaining distance. This maximum lift required a steam pressure of 30 pounds, and the fuel consumption of the engine was very high, so that the combination of the necessity for the use of several engines, of the danger of high boiler pressures, and of the low fuel efficiency greatly restricted the use of Savery's engine.

It is probable that this failure prompted Thomas Newcomen to turn his attention to the subject, and about 1705 he perfected an engine of the atmospheric type, which was without any of the features objected to in the Savery, and from which the modern steam engine can be directly traced. Newcomen's engine differed primarily from Savery's in that it raised water by atmospheric pressure alone, the steam being only used to create a vacuum.

Although Newcomen included all of the valuable features of the engines of his predecessors in those he built, the finished engine was so superior to any that had gone before that it was practically a new invention. It included the separate vessel in which to generate the steam; likewise, through an accident which punctured the cylinder, cold water was injected into the cylinder in order to effect a speedy vacuum under the piston; and a valve gear was provided whereby the machine could be made to repeat its movements automatically. Since Savery's patent was sufficiently general to cover Newcomen's engine, although the principal was different, the two joined hands in the construction of engines, and for upward of 60 years after the introduction of the first engine Newcomen engines proved to be the only economical agent for draining mines.

During the years 1763–1764 James Watt, while engaged in repairing a model of a Newcomen engine, was impressed by the enormous consumption of steam and made some experiments and measurements of the temperature, pressure, and volume of the steam generated in the model, and also of the quantity of water required to condense the steam. These experiments showed that the chief waste in the engine arose from cooling of the cylinder and piston surfaces by the water spray used to condense the steam. To reduce this waste, Watt invented the separate condenser, which when installed on a Newcomen engine cut the fuel consumption in half. He likewise covered the top of the cylinder to exclude the cold air and exposed it to the steam. These improvements, together with the air pump, were embodied in the patent secured by Watt in 1769 and extended in 1775 for a period of 25 years, just at the time when he entered into partnership with Matthew Boulton for the manufacture of single-acting beam pumping engines.

The changes Watt made in the construction of the engine rendered it almost a new machine. The most important of these improvements were:

(1) Surrounding the steam cylinder with a jacket, inclosing the whole in a casing, and doing away with the necessity of introducing into the cylinder water or other substances colder than the steam itself.

(2) Condensing the steam in a separate vessel.

(3) Removal of the uncondensed air or vapor by an air pump.

(4) Substitution of the expansive force of steam instead of the pressure of the atmosphere acting on the piston, whereby the engine ceased to be an *atmospheric* and became a *steam* engine.

(5) Use of grease to render the piston steam-tight instead of water, as formerly employed.

(6) Adaptation of the principle of expansion by cutting off the steam before the piston had finished its stroke.

(7) Introduction of the double-acting engine.

(8) The mechanism known by the name of "parallel motion." This was first designed for the double-acting engine to replace the toothed rack and sector required for giving an upward as well as a downward propulsion. It was afterwards applied to single-acting engines, being a much more suitable method of connecting the piston rod to the beam than the original arc and chain.

All of these inventions were protected by patents, but, independently of those thus secured, Watt made other alterations of very considerable value. Thus he changed the dome boiler formerly used with the atmospheric engine to the wagon-shaped one, which has since been applied generally to low-pressure engines. By this change more heating surface was gained for a given cubic content, the boiler was more easily made, and was of a more convenient form for setting. He also placed the boiler upon a separate foundation, removing it from beneath the cylinder. This was a great improvement, for in the atmospheric engine, the cylinder of which stood on the top of the dome boiler, the vibration caused by the motion of the engine soon rendered the boiler leaky and deranged the position of the cylinder.

The great demand which resulted for steam engines, after the introduction of Watt's engines, stimulated other inventors, the most prominent of whom probably was Jonathan Hornblower, who in 1781 patented and constructed the compound single-acting engine with a high-pressure cylinder placed between the low-pressure cylinder and the beam center. On account of the low boiler pressure in use at that time, this engine proved less economical than the Watt engine, and since it made use of the separate condenser was an infringement of Watt's patent of 1769.

Upon the expiration of the Watt patent, that is, about 1800, an advance began in the development of the steam engine which is still continuing. The vacuum became of relatively less importance; in fact, with the high-pressure engine it was sometimes dispensed with entirely. One of the first to advocate and introduce the high-pressure engine was Richard Trevithick, who patented in 1802 a semi-portable engine of this type. The application of this engine to the locomotive was probably the most important step.

Model of Hero's Rotary Steam Engine. Deposited by the United States Department of the Interior.

The philosopher, Hero, of Alexandria, Egypt, prepared a treatise entitled "Spiritalia seu Pneumatica." In it are described a number of interesting forms of water and heat engines, and among the latter an apparatus moved by the force of steam somewhat as represented in the model. This earliest of steam engines, which Hero called "aeolipile," consisted of a globe suspended between trunnions through one of which steam enters through pipes from a boiler below. The hollow-bent arms projecting from the globe cause the vapor to issue in such a direction that the reaction produces a rotary movement of the globe, just as the rotation of reaction water wheels is produced by outflowing water.

Cat. No. 244,887 U.S.N.M.

Model of Dr. Denis Papin's Atmospheric Steam Engine, A. D. 1690. Deposited by the United States Department of the Interior.

The apparatus proposed by Dr. Papin consists of an open-topped metal cylinder fitted with a piston and piston rod. A small quantity of water is placed in the bottom of the cylinder and heated by a fire placed underneath until the steam generated forces the piston to rise to the top. The fire was then removed and the steam gradually condensed, forming a vacuum within the cylinder, and thus causing the piston to move downward by air pressure with such force as to enable it by the aid of a rope and overhead pulley to lift a weight.

Papin stated that a cylinder 2½ inches in diameter, if thus worked, could raise a weight of 60 pounds once a minute through a height equal to the stroke. Cat. No. 244,888 U.S.N.M.

Copy of Drawing of Thomas Savery's "Fire Engine" in the Philosophical Transactions of the Royal Society, London, England, Volume 21, 1699.

In 1698 Thomas Savery patented an apparatus "for raising of water and occasioning motion to all sorts of mill works by the impellent force of fire." No drawing of the arrangement was deposited

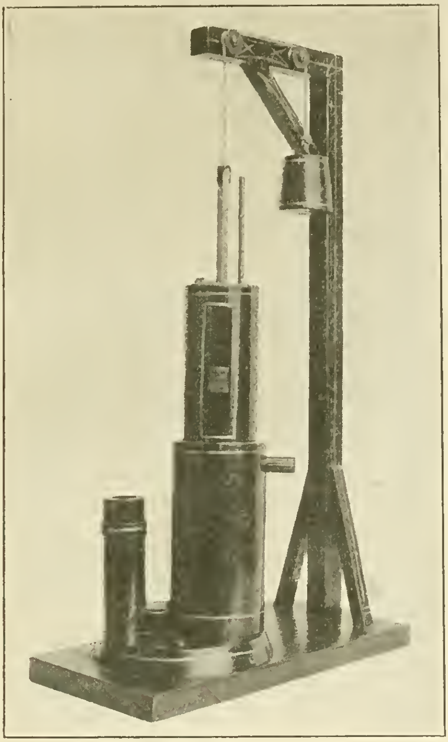


FIG. 4.—THE EARLIEST STEAM ENGINE WITH A PISTON, 1690.

with the patent, but in the following year a model of the machine was shown to the Royal Society and is illustrated in their Transactions.

The engine consists of a boiler and water receiver connected by a pipe permitting steam to pass from the boiler to the receiver. The receiver is provided with suction and delivery pipes and the corresponding valves. A hand-worked valve admitted steam to the receiver long enough to blow out all of the air. The valve was then closed and water from an overhead tank was turned on to the outside of the receiver which, acting as a surface condenser, condensed the steam, creating a partial vacuum within the receiver. This caused the water to be raised from the well or other reservoir through the suction pipe and into the receiver, where it assisted in the further condensation of the steam, which, in turn, resulted in the complete filling of the receiver with water. Steam was then turned into the receiver, and by its pressure forced the water out through the delivery pipe, the suction pipe in the meantime being closed by its non-return valve. Cat. No. 180,351 U.S.N.M.

Photographic Copy of an Engraving, Published in 1719, of Newcomen's Engine, Erected Near Dudley Castle, Staffordshire, England, in 1712.

This is believed to be the first engine constructed by Newcomen, and it is interesting to note that the self-acting valve gear usually ascribed to the year 1718 was in use here six years before.

The engine consisted of a vertical open-topped cylinder fitted with a piston, which by chains was connected with one end of a beam. The other end of the beam was similarly connected with the vertical rods of a pump. The center of the beam was fitted with trunnions so that it could oscillate, and its ends were provided with arched heads so that the chains resting on them would remain vertical when the beam worked. The cylinder rested on top of the boiler, so that when a valve was open steam could enter the cylinder and allow the piston, which was being pulled up by the weight of the pump rods at the other end of the beam, to rise. When the piston had reached the top of the cylinder, the steam was shut off and cold water from an overhead supply was admitted in a jet at the bottom of the cylinder, which condensed the steam and formed a partial vacuum, whereupon the weight of the air forced the piston downwards. Upon completion of this downward stroke, the injection water was cut off. Steam was then admitted for the next upward stroke, during which the hot water at the bottom of the cylinder was discharged through an eduction pipe, terminating in a nonreturn valve, while the air that had come into the cylinder with the steam and injection water was blown out through a snifting valve, so called from the noise it made. (*The Science Museum.*)

The top of the cylinder was constantly flooded with water to prevent the entrance of air into the cylinder. Soft packing was used around the piston, for cylinders at that early date could not be machine bored. They were made of brass, cast as thin as possible to reduce the heating and cooling losses.

The steam and injection valves of the engine were at first worked by hand, but the desire of a boy, Humphrey Potter by name (so the story goes), to play, rather than operate the valves, inspired him to attach cords to the oscillating beam, whereby these valves could be opened and shut. The legend on the print gives the dimensions of the engine's cylinder as 21 inches in diameter and 7 feet 10 inches long, and of the boiler as 5 feet 6 inches in diameter and 6 feet 1 inch high, containing 13 hogsheads (700 gallons) of water. The pump work was in two lifts, each of 75 feet.

Cat. No. 180,596 U.S.N.M.

Prints of James Watt's Steam-Jacketed Single-Acting Cylinder. Photomechanical Print from the Model in South Kensington Museum. Two Views.

The engine consists of an external cylinder closed at top and bottom, and an internal cylinder closed at top but opened at the bottom and fitted with a piston. The steam entering the latter would fill the part of the cylinder below the piston, also the space between the two cylinders, hence the inside cylinder is a *steam-jacketed* cylinder. A pipe connects the external cylinder to the separat coninder. A pipe connects the external cylinder to the separate condenser. Both the external and internal cylinders were made of tin plate roughly soldered up. Watt complained from first to last of its being leaky, and an experiment showed, as he expected, that it took as much steam from the boiler regardless of whether it was working or not. This model is presumed to be a very early one and may have been Watt's first attempt with a steam-jacketed cylinder kept hot and separate condenser kept cold. Cat. No. 180,623 U.S.N.M.

Print from a Model in South Kensington Museum of a Two-Cylinder Engine for Double Action.

In the patent of 1782 Watt states that there are various arrangements that may be made of the several engines.

A model in the South Kensington Museum is supposed to show a transition state, or an attempt to produce a double-acting engine, by two single-acting cylinders connected together by a chain over a pulley.

The print shows two single-acting vertical cylinders, their upper ends connected by a passage without valves, their pistons having single-acting valves opening upward, the eduction pipes entering the bottom of each cylinder and having conical valves. Within the eduction pipes is a small pipe terminating in a jet for injecting cold water, thereby converting it into a condenser. There are also air pumps for removing the water and air. Its action is as follows: While the steam in the left cylinder is being condensed, it is also entering the right cylinder, and, passing through the valve in its piston and the connecting passage between the upper end of the cylinders, it forces the left piston into the vacuum. When this piston arrives at the end of its stroke, the steam and injected water is reversed, a vacuum is formed under the right piston, and the steam enters the left cylinder, etc. The drum or pulley over which the chain passes is given a reciprocating motion which is communicated to a beam or connecting rod by a long pin on the drum.

Cat. No.180,627 U.S.N.M.

Print from a Model in South Kensington Museum of James Watt's Double-Acting Beam Engine. Patented, 1782.

In this engine the chain heretofore connecting the piston rod to the beam is discarded and a parallel motion substituted, enabling the piston to push as well as pull the beam. The engine is also double-acting, the steam and vacuum operating from opposite sides of the piston at the same time, both in the same direction, then both are reversed and the piston forced the other way.

Cat. No. 180,625 U.S.N.M.

Print of James Watt's Semirotary and Rotary Engine. Patented, 1782. Three Views.

The semirotary engine has a piston fixed in a radial line to the shaft to be turned, and the cylinder fits the piston as it moves backward and forward through a considerable arc of the circle; fixed inside the cylinder at one part is a fixed stop or cylinder bottom for the steam to act against either way, as it acts against the piston in either one direction or the other. It was intended to let the reciprocating shaft act with a spur wheel on two racks attached to the pump rods. There was an unfinished model of this engine in the "Watt Room" at Heathfield Hall, England, no doubt made partly by Watt's own hands. In a letter of Watt, dated 27 September, 1782, he speaks of this model as having been made so far in 1765 or 1766.

The rotary engine has a piston fixed as an arm, and a radial line to the shaft to be turned. The cylinder of the engine fits the piston in its revolution, there being at one point a flap valve hinged to the inside of the cylinder, whilst its other end rests on the shaft so as to form a cylinder bottom or point of contact for the steam to act against when acting also against the piston. This flap valve is at a slight angle to a radial line, so that when the piston comes around it can heave it up so as to get past. Cat. No. 180,621 U.S.N.M.

Print from a Model in South Kensington Museum of James Watt's Bull Engine. Patented, 1782. Two Views.

This engine is supposed to take its name from an engineer by the name of Bull, who put up some engines in Cornwall. It is peculiar in that the piston rod passes out at the bottom of the cylinder through a stuffing box, the beam being placed below.

Cat. No. 180,626 U.S.N.M.

Print of a Single-Acting Engine With a Balance Weight. Made According to James Watt's Patent, 1781.

The engine is single-acting and has an open-top cylinder, with air pump, condenser, and heavy balance weight on the connecting rod to give the impulse in one direction, whilst the piston on the other end of the beam, by means of the vacuum in the cylinder, gives the impulse in the other direction. Cat. No. 180,616 U.S.N.M.

Print from a Model Showing Two Rotary Motions in Opposite Directions from the Same Engine. James Watt's Patent, 1784. Two Views.

A crosshead is secured to the beam of the engine from the ends of which two connecting rods convey the power to two separate shafts by "Sun and Planet" devices. As the eight-hand shaft is placed lower than the other, its connecting rod is jointed to a lower part of the beam so that both may have an equal motion throughout their entire revolution. This was probably intended for rolling metals for coining. The gearing by spur wheel carries the power to a mill for slitting. Cat. No. 180,620 U.S.N.M.

Print of James Watt's "Crown Cam Motion," Patented, 1718. Adapted to a "Hoisting Engine." Two Views.

In this peculiar method a heavy crown cam is fixed on a vertical axis. Beneath it is a rocking frame having two friction rollers bearing on the inclined face of the cam on its opposite sides. The rocking frame is moved up and down from the beam of the engine. In all of the specifications of 1781 the engine was single-acting, and to produce power on the up and down strokes of the piston the connecting rod was heavily loaded. Cat. No. 180,618 U.S.N.M.

Print of James Watt's "Sun and Planet" Engine. Patented, 1781.

In this invention the Planet is an internal geared wheel on the connecting rod and is held in gear by means of a friction roller on the lower end of the rod running around a fixed oval cam or guide block. Cat. No. 180,619 U.S.N.M.

Print of James Watt's "Ladder Motion," with Two Fixed Guide Pins or Rollers. Patented, 1781.

The ladder consists of a long rack on the lower end of the connecting rod, as much like a ladder as possible, working against the teeth of a spur wheel fixed on the shaft. The bottom end of the connecting rod carries a friction roller working in a large opening in the guide plate, keeping the ladder always in gear with the spur wheel on the shaft. The fixed guide pins keep the ladder in gear the greater part of the up and down stroke whilst two projecting pins from the ladder, one at the top, another at the bottom, keep it in gear while passing the centers. Cat. No. 180,617 U.S.N.M.

Print of James Watt's Balance Wheel Rotative Engine.

Watt says in his specification:

When steam is cut off at one-quarter the stroke there must be an equalizing arrangement to enable the piston to complete its stroke when pumping. For this purpose the upper end of the piston rod is a rack working into a toothed segment. On the other end of the beam, in place of the old horsehead meshing also into this segment, is a pinion secured to the shaft by a flywheel. At any motion of the beam at the early part of the stroke power is expended to give the flywheel motion, and the momentum thus gained is expended again at the last or weakest portion of the stroke, thus equalizing the power.

Cat. No. 180,630 U.S.N.M.

Print which Shows the Converting of Reciprocating into Rotary Motion. James Watt, 1781.

It appears that J. Pickard in 1780 took out a patent for converting reciprocating into rotary motion by means of a "crank." It has been said that Watt would not attempt to make any terms with the man nor run the risk of a lawsuit. The use of pins in disks is represented. These were not called cranks in the specification, but "*points of attachment of the connecting rods*." Another sketch represents an eccentric on the shaft, the connecting rod embracing it and provided with three friction rollers or bearings. Another sketch represents the well-known "Sun and Planet" motion in which a spur wheel *rigidly fixed* on the end of the connecting rod gears into a spur wheel of equal diameter on the engine shaft and is held in gear by a projecting pin and friction wheel from the back of the planet wheel, traveling in a circular groove concentric with the shaft. A "Spur Planet" on the connecting rod and an internal geared disk on the shaft held in gear by a similar method to that shown in the preceding sketch is also represented. Cat. No. 180,615 U.S.N.M.

Print of Steam Indicator Diagrams Taken with Watt's Indicator by Edward Cooper, Esq., August, 1840.

There is one view of a full-power diagram, showing the card and the record made by the pencil during one revolution of the engine. The card is first ruled with perpendicular lines dividing the length of its horizontal movement into 10 equal spaces, corresponding with the stroke of the piston divided into the same number of equal divisions. The black horizontal line, the "atmospheric line," shows the position of the pencil when not affected by the steam or vacuum pressure. The column of figures at the left of the diagram shows the pressure in pounds to the square inch; those above the atmospheric line indicate the steam pressure, while those below show the atmospheric or vacuum pressure. The irregular black line was made by the pencil, that above the atmospheric line records the steam pressure during the forward stroke, and that below the line the vacuum pressure during the return stroke. The area inclosed between the perpendicular lines and the lines made by the pencil is computed to find the sum of the average steam and vacuum pressure to the square inch of the piston within that section, and the result in pounds and decimal parts placed below. The sum of these results is divided by ten to find the average pressure on the piston during its forward and return stroke. With this data, by quite simple rules the actual horsepower required from the engine to do the work at the time the diagram was taken is easily computed.

There is also a friction diagram taken to show the power necessary to run the engine and connecting machinery when not doing work. Cat. No. 180,629 U.S.N.M.

Print of James Watt's Steam Engine Indicator.

In this indicator the rocking beam is discarded and the spiral spring is placed above the piston, the cylinder being lengthened for this purpose. A pencil is attached to the upper end of the piston having an up and down motion only. The pencil rests upon a card secured to a light frame that has a horizontal motion corresponding to that of the piston in the engine's cylinder (though much less) given to it by a cord and weight. Cat. No. 180,631 U.S.N.M.

Prints from a Model of James Watt's Tilt Hammer.

The beam of the engine has its reciprocating motion converted into the rotary motion of a shaft by means of a connecting rod, crank, or other device. On the shaft is a flywheel and the cams for lifting the hammer. Two hammers are shown, one lifted by a cam under the "belly" of the helve like an ordinary forge hammer, except that the helve of the hammer is parallel with the shaft. The other hammer is lifted by another cam depressing the tail like an ordinary tilt hammer. Cat. No. 180,624 U.S.N.M.

Portion of Cylinder of a Jonathan Hornblower Steam Engine. Gift of the New Jersey Historical Society.

This cylinder is part of the first stem engine on the western continent, imported from England in 1753. Concerning it the Hon. Joseph P. Bradley, Associate Justice of the Supreme Court of the United States, wrote under date of September 20, 1875.

> The steam engine (of which this is a portion of the cylinder) was the first ever erected on this continent. It was imported from England in the year 1753 by Col. John Schuyler for the purpose of pumping water from his copper mine

opposite Belleville, near Newark, New Jersey. The mine was rich in ore but had been worked as deep as hand and horse power could clear it of water. Col. Schuyler, having heard of the success with which steam engines (then called fire-engines) were used in the mines of Cornwall, determined to have one in his mine. He accordingly requested his London correspondents to procure an engine and to send out with it an engineer capable of putting it up and in operation. This was done in the year named, and Josiah Hornblower, a young man then in his twenty-fifth year, was sent out to superintend it.

Mr. Hornblower's father, whose name was Joseph, had been engaged in the business of constructing engines in Cornwall from their introduction in the mines there, about 1740, and had been an engineer and engine builder from the first use of steam engines in the arts, about 1720. The engines constructed by him and his sons were the kind known as Newcomen's engines, or Cornish engines. That brought to America by Josiah was of this description. Watt had not then invented his separate condenser nor the use of high pressure. But it is generally conceded that for pumping purposes the Cornish engine has still no superior.

About 1760 the Schuyler mine was worked for several years by Mr. Hornblower himself. The approach of the war in 1775 caused the operations to cease. Work was resumed, however, in 1792 and was carried on for several years by successive parties. It finally ceased altogether in this century, and the old engine was broken up and the materials disposed of. The boiler and large copper cylinder standing upright eight or ten feet high and as much in diameter, with a flat bottom and a dome-shaped top, was carried to Philadelphia. A portion of the clyinder was purchased by some person in Newark. In 1864 I met an old man named John Van Emburgh, then a hundred years old, who had worked on the engine when it was in operation in 1792. He described it very minutely and, I doubt not, accurately. It is from this description that I happened to know the kind of engine it was; although from the date of its construction and the use to which it was put, there could have been but little doubt on the subject. Cat. No. 180,143 U.S.N.M.

Model of R. F. Loper Steam Engine (Working). U. S. Patent, No. 4389, November 26, 1845. Transferred from United States Patent Office.

The engine is arranged to operate two parallel crankshafts in opposite directions and with equal velocities. A motion is brought about by means of a connecting rod extending from the steam crossheads to the two crank shafts, the center of vibration of the crossheads being centrally between the two. Cat. No. 251,297 U.S.N.M.

Model of John Ericsson Steam Engine. U. S. Patent, No. 6844, November 6, 1849. Transferred from United States Patent Office.

The engine is designed to use steam expansively. There are two vertical, single-acting beam engines placed side by side whose cranks are connected to the same shaft but 180 degrees apart, and whose cylinders are of different sizes. Steam is admitted to the smaller cylinder at the top and acts directly on the piston for a portion of its stroke, but is cut off at a given point and acts expansively for the remainder. At the end of the stroke a slide valve opens and the steam passes the top of the larger cylinder where it acts expansively on the piston, pushing it downward. The size of this second cylinder is such that the steam is able to exert as great a force for the full stroke as it exerted in the first cylinder. At the same time that the steam is passing to the second cylinder a portion is directed through a suitable passage to the underside of the piston of the first cylinder, so that while the piston of the second cylinder is moving downward by the expansive force of the steam the piston of the first cylinder is balanced during its return motion by the pressure of steam on both sides of it, thus making available the full pressure of the steam on the piston of the larger cylinder.

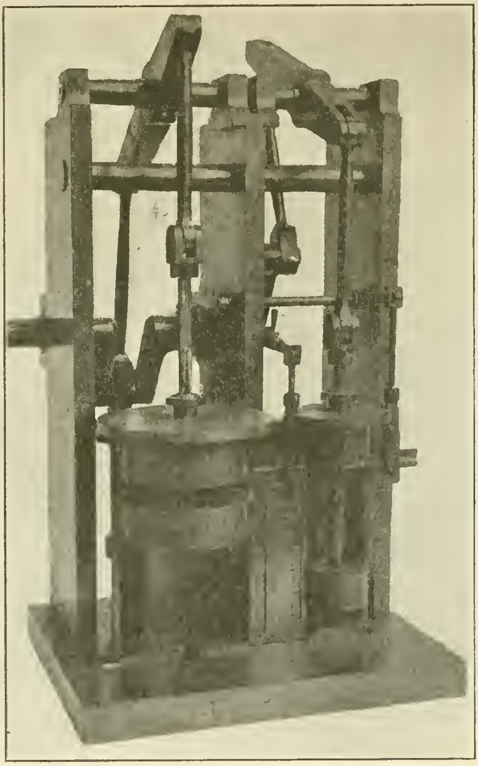


FIG. 5.—ERICSSON STEAM ENGINE, 1849.

The lower end of the second cylinder beneath the piston is in constant communication with the condenser. The upper end also communicates with the condenser by means of a valve-controlled passage which is opened when the piston reaches the end of its stroke and permits the exhaust of steam from the cylinder so that a vacuum is created above as well as below the piston, permitting

it to make its return motion in a vacuum while the piston of the first cylinder is being carried downward by direct steam pressure.
Cat. No. 251,299 U.S.N.M.

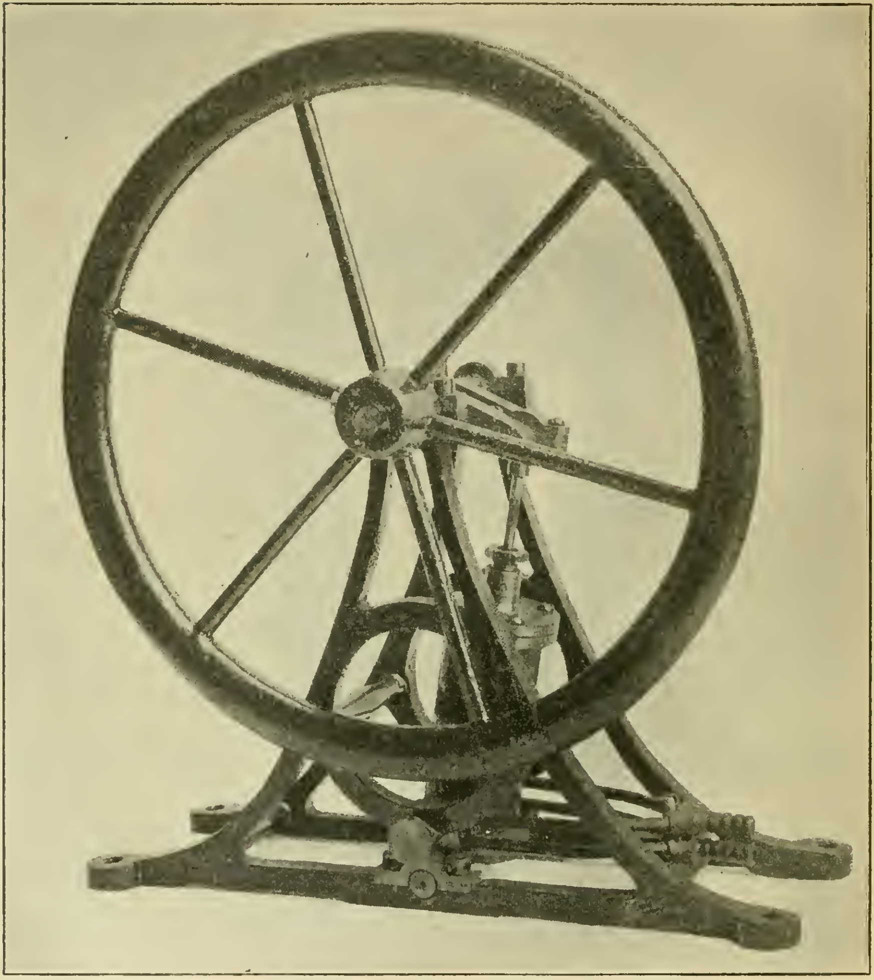


FIG. 6.—SCHLARBAUM OSCILLATING STEAM ENGINE, 1863.

Model of H. Schlarbaum Oscillating Steam Engine. U. S. Patent, No. 39756, September 1, 1863. Transferred from United States Patent Office.

The engine is a high-pressure, double-acting one. The axis of the vertically oscillating cylinder is near the base, forming a part of the lower cover of the cylinder and beneath the steam and exhaust ports. On each side of the cylinder and at right angles with the axis of oscillation is a steel-lined surface from which steam ports run to the upper and lower parts of the cylinder. The steam and exhaust pipes, which branch off from trunk lines so as to extend to each side of the cylinder, terminate in a steel-lined head or block which fits closely to the steel surfaces mentioned above. The openings in these blocks are of the proper diameter and distance from each other, so that all steam connections are shut off when the piston is at the end of its stroke and open when it is in the middle of its stroke. The changes of steam are made without any movement of the steam-conducting headpieces, but by the movement of the cylinder alone. Cat. No. 251,293 U.S.N.M.

Model of W. Sellers Oscillating Steam Engine. U. S. Patent, No. 127928, June 11, 1872. Transferred from United States Patent Office.

The engine is equipped with a curved link or arc, concave toward the axis of oscillation of the cylinder, which is provided with a

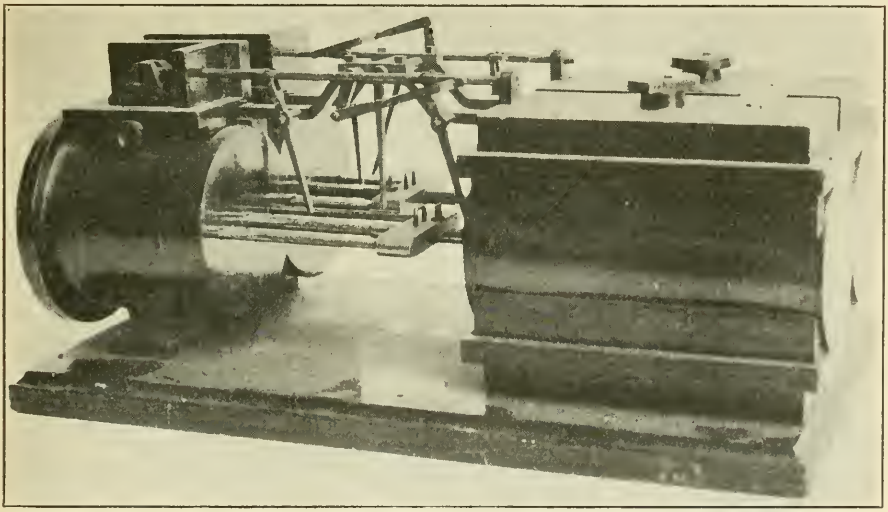


FIG. 7.—WORTHINGTON STEAM PUMP, 1859.

means of varying and adjusting the degree of its obliquity; an eccentric which operates this link; and a sliding block or die which transmits motion to the valve of the engine. The objects attained are, first, providing an improved means of operating the valve of the engine; and, second, providing an improved means of guiding the piston rod and diminishing the wear upon the stuffing box.

Cat. No. 251,296 U.S.N.M.

Model of H. R. Worthington Steam Pumping Engine. U. S. Patent, No. 24838, July 18, 1859. Transferred from United States Patent Office,

The engine consists of two direct-acting pumping engines so combined that the steam and exhaust valves of each engine govern the motive power of the other, thereby insuring the constant action of at least one pump piston upon the water to be raised and relieving the action of the pump from shocks and concussions.

The attachments to bring this arrangement about are alike on both engines. A complete cycle is as follows:

When steam enters the cylinder of one of the engines its piston commences to move and at some fixed point in its stroke it actuates the steam and exhaust valves of the other engine through a series of

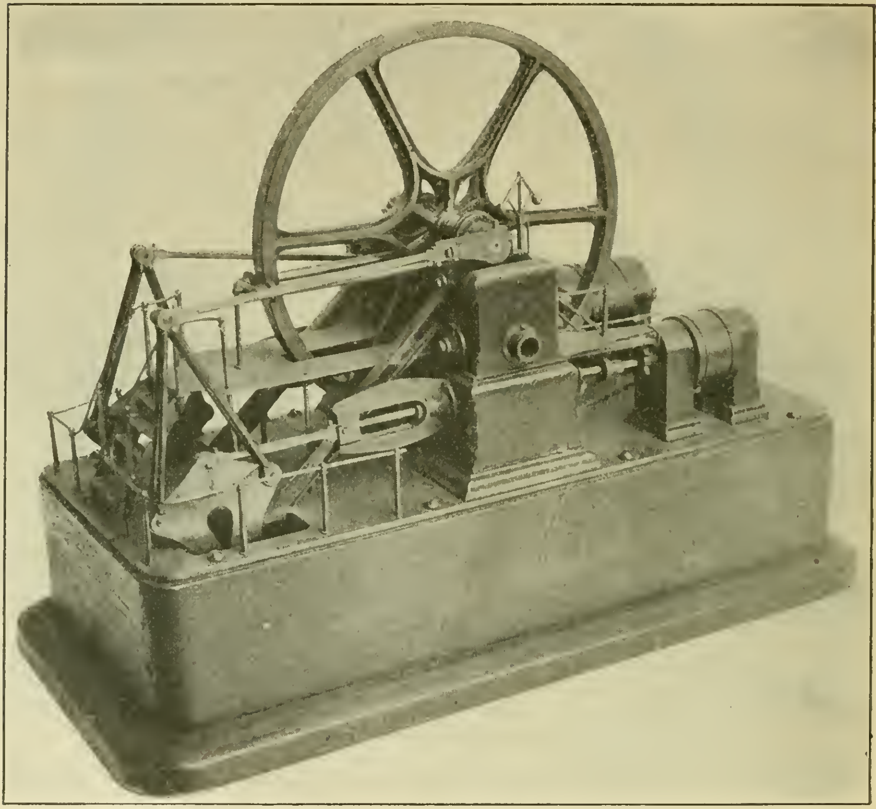


FIG. 8.—CORLISS STEAM PUMP, 1879.

levers. Still going on, it completes its stroke and finally terminates its motion by closing its own valve by means of a stopping lever. Meanwhile the piston of the second engine, having been set in motion by the first, has commenced its own stroke. On its way it encounters and moves the valve of the first engine through a series of levers; continues to the end of its stroke, closing its own valve, and rests until again called upon to move by the first engine. Thus one piston is put in motion, proceeds on its stroke, actuates the valve of the other engine, shuts its own valve, and stops with no power to move again until actuated by the operation of the other engine.

Cat. No. 251,300 U.S.N.M.

Model of George H. Corliss Steam Pumping Engine. U. S. Patent, No. 215803, May 27, 1879. Transferred from United States Patent Office.

The interesting feature of this engine is an oscillating lever having a fixed axis at one end and a connection with the crank and fly-

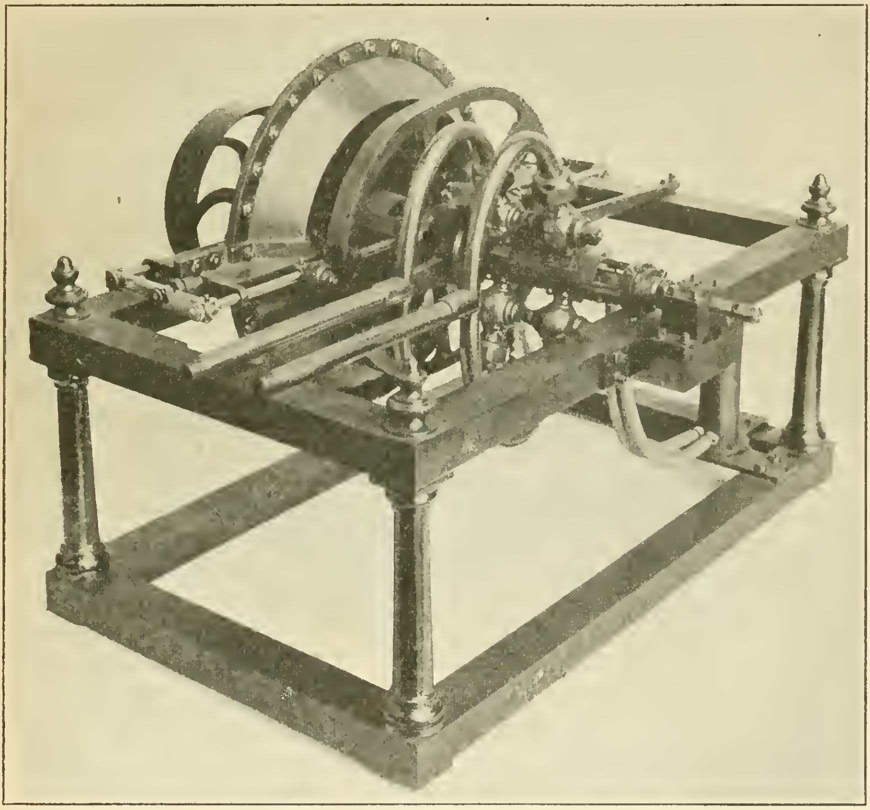


FIG. 9.—MILLER ROTARY ENGINE, 1859.

wheel at the other end which is in combination with a reciprocating pump piston or plunger connected to the above mentioned lever at a convenient point between its ends. It gives to the crank in its connection an increased stroke as compared with that of the pump.

A portion of the steam power applied to the pistons is directly utilized in working the pump plungers by means of a continuous piston rod which extends from the cylinder into and through the pump and is connected by a link to the middle of an upright lever oscillating on an axis on its lower end and connected by a horizontal connecting rod to the crank. In working steam at the high rates of expansion indispensable to the attainment of the best economic results, there must be applied to the pistons during certain parts of the stroke an amount of steam power largely in excess of that required to overcome the nearly uniform resistance of the water pressure on the plungers. As, in the regular operation of the engine, this excess is immediately transmitted to the flywheel to be applied to the plungers before the termination of each stroke, it is important that this transmission of power to and from the flywheel should be attended with the least possible loss by friction. The introduction of the upright levers diminishes this loss in an important degree.

Cat. No. 251,291 U.S.N.M.

Model of Charles Miller's Rotary Steam Engine, U. S. Patent, No. 23852, May 3, 1859. Transferred from United States Patent Office.

A two-cylinder engine of the revolving-piston type, the piston being elliptical in shape, with the major axes 90 degrees apart and revolving on a central shaft. Cat. No. 251,292 U.S.N.M.

Model of James Platt's Rotary Steam Engine, U. S. Patent, No. 34981, September 15, 1862. Transferred from United States Patent Office.

The engine is of that type in which the cylinder revolves about a stationary abutment head. Two pistons, one on each side of the abutment, work radially within and rotate with the cylinder. The cylinder is concentric with the shaft and is divided in a plane perpendicular to the axis of the shaft into two equal parts, secured together about the periphery. One half of the cylinder is secured firmly to the shaft, while the other half is bored centrally much larger and fitted with a stuffing box, through which and into the cylinder passes a stationary sleeve, inclosing the main shaft and carrying the abutment.

The pistons are parallel sided and are fitted into slots cut through the periphery of the cylinder but inclosed by piston boxes bolted to the outside of the cylinder. The piston rods, which work through stuffing boxes in the piston boxes, have crossheads attached to them to the ends of which are attached guide rods. One guide rod of each piston has attached to it two friction rollers which work on the inside and outside, respectively, of a laterally projecting rim of a stationary cam keyed to the sleeve surrounding the main shaft. This cam holds each piston stationary in relation to the cylinder and in contact with the edge of the abutment during half of its revolution farthest from the abutment and draws it out far enough to pass the abutment previous to its arrival, and in, after passing.

Steam and exhaust passages are led to the cylinder through the sleeve inclosing the main shaft. Cat. No. 251,294 U.S.N.M.

AIR AND INTERNAL COMBUSTION ENGINES.

The expansion of air upon being heated and its contraction on cooling has attracted the attention of many persons during the past

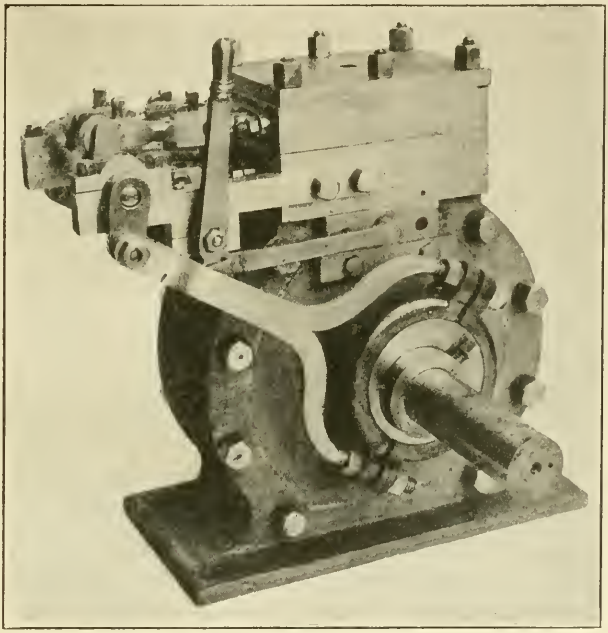


FIG. 10.—PLATT ROTARY ENGINE, 1862.

one hundred years, and has led to the invention of a variety of hot-air engines. The earliest of these having real merit was patented in England in 1827 by Dr. R. Stirling. The engine consisted of two chambers filled with air and connected by pipes with each end of a cylinder whose piston received a reciprocating action by the alternate expansion and contraction of the air. In addition the engine was equipped with a regenerator which absorbed some of the heat of the air as it passed out of the cylinder and gave it out to the incoming air. In later improvements made by Stirling the air was compressed before heating, and an engine was designed so that the same air could be used over and over again. This attempt at making a theoretically perfect engine was more economical in fuel consumption than any double-acting steam engine of that time. but the heavy expense in wear and tear and the burning out of parts counteracted its fuel efficiency.

The great restriction to the development of the hot-air engine has been the necessity of keeping the temperature low within the cylinder, with the result that its efficiency is limited.

John Ericsson of New York constructed an air engine in 1834 of simple design in which hot air admitted to a cylinder moved a piston while expanding down to atmospheric pressure. In 1852 Ericsson built some large engines to be used in propelling trans-Atlantic vessels. A ship was so equipped but never made an ocean trip other than from New York to Washington. For the reasons noted, large hot-air engines have since Ericsson's time been abandoned but small-powered engines are being made for light work.

The earliest internal-combustion engine was the gun. The use of gunpowder, however, as a means of obtaining mechanical power is of comparatively recent date, such experiments having been made during the latter part of the seventeenth century by Hautefeuille, Huygens, and Papin. Huygens in 1678–79 exploded a charge of gunpowder in the bottom of a vertical cylinder. The greater part of the air and of the gaseous products were expelled through nonreturn valves, but the remaining gas in cooling produced a partial vacuum below a piston, which then descended owing to the atmospheric pressure on the outside and in so doing did work by means of a cord over a pulley.

A period of over a hundred years ensued before any further experiments were made utilizing the explosion of inflammable gases. In 1794 an English inventor, R. Street, secured a patent, No. 1983, which involved the vaporizing of spirits of turpentine on a heated metal surface, mixing the vapor thus produced with air in a cylinder, firing the mixture by an outside flame, and driving a piston by the explosion produced. Another fifty years passed, when in 1844 one Stuart Perry of New York procured a United States patent for "an engine to be operated by the explosive mixtures of inflammable gases or vapors." Two years later a second patent was granted to Perry for improvements made on the original engine.

The first practical gas engine was developed in France by J. J. E. Lenoir and patented in 1860. Although it did not embody any new features, it was successful. To start the engine the fly-wheel was pulled over, thus moving the piston, which drew into the cylinder a mixture of gas and air through half its stroke. The gas was then exploded by an electric spark and moved the piston to the end of its stroke, the pressure meanwhile falling by cooling and expansion to that of the atmosphere when exhaust took place. In the return stroke the process was repeated, thus resembling a double-acting steam engine and having a one-stroke cycle. The engine was water cooled. The electric spark was supplied by two Bunsen batteries and an induction coil, the circuit being completed at the correct intervals by contact pieces on an insulating disk on the crank shaft.

On June 17, 1873, a United States patent was issued jointly to L. C. Errani and R. Anders, of Belgium, for new improvements in dynamic machines which the inventors called "a motor without gas." The invention is of interest in that petroleum (presumably the lighter oils) is stipulated and used for the propelling force. The motor is, in general, similar to an ordinary steam engine, including a cylinder, reciprocating piston, crank and flywheel, and valve gear for operating through a cam a main valve connected with the cylinder. Shortly after Errani and Anders received their patent, a patent was granted to J. Hock, of Vienna, Austria, Patent No. 151129, May 19, 1874, for improvements on the Errani and Anders motor, which improvements resulted in the making of the first practically successful oil engine.

The gas and oil engines developed up to this time were of the noncompression type. They were likewise heavy and awkward and gave little power. But about the time that Hock obtained his patent, G. B. Brayton, of Boston, Mass., obtained a patent, No. 151468, June 2, 1874, for an oil engine which worked on a constant pressure but without any explosion. This appears to be the earliest compression engine to use oil.

Probably the greatest improvement made in the internal-combustion engine was the compression of the explosive mixture in the engine cylinder before ignition and the introduction of a practical engine working on the four-cycle stroke. Both of these steps were made by N. A. Otto, of Germany, and patented in the United States August 14, 1877, Patent No. 194047. The compression of the explosive was Otto's idea, but the four-cycle stroke, it is now conceded, was proposed by A. Beau de Rochas, of France, in a treatise published in 1862, but it remained for Otto to develop it practically. Although Otto developed and patented his ideas to apply to the gas engine, the advantages were soon recognized and almost immediately applied to the oil engine and are still so applied, further improvements being mainly in the direction of higher compression.

Shortly after the introduction of the Otto gas engine, a motor of this type was brought out operated by an inflammable vapor produced by passing air on its way to the cylinder through the light oil known as gasoline. A further supply of gasoline was subsequently drawn into the cylinder to form the required explosive mixture which was then compressed and fired. The Spiel petroleum engine followed and was the first Otto cycle motor which dispensed with an independent vaporizing apparatus. A light oil of a specific gravity of not over 0.725 was injected directly into the cylinder on the suction stroke by means of a force pump. Upon entering it formed a spray, was mixed with air, vaporized, compressed, and ignited as in the gas engine.

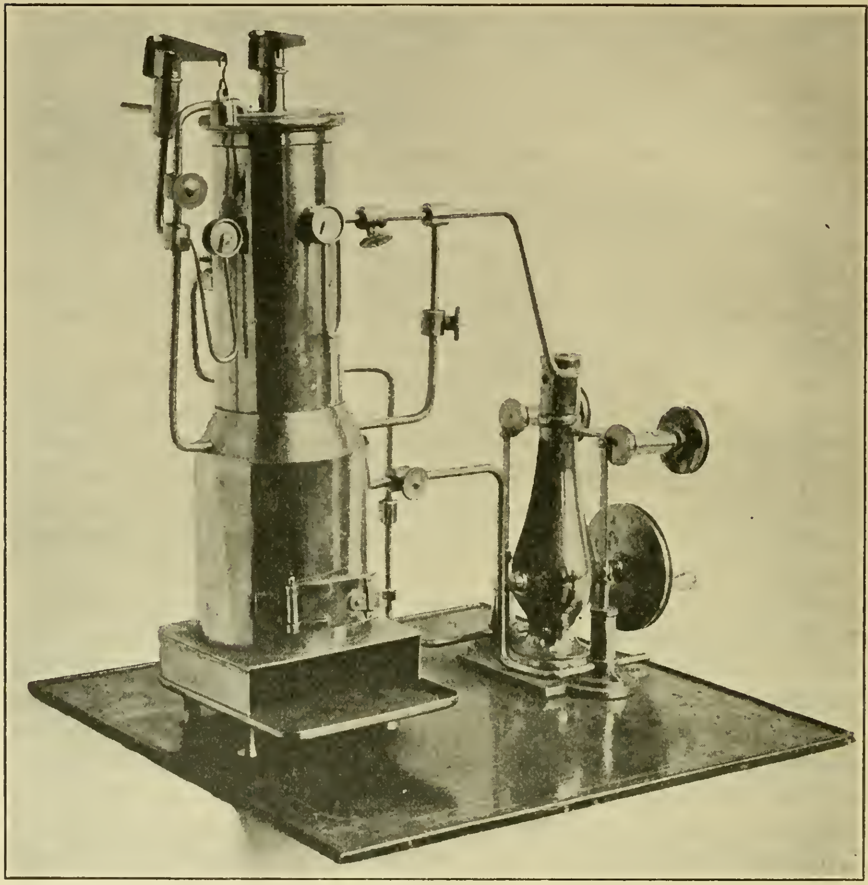


FIG. 11.—WHITING AIR AND STEAM ENGINE, 1879.

Model of James M. Whiting Air and Steam Engine, U. S. Patent, No. 217757, July 22, 1879. Transferred from United States Patent Office.

The engine consists of a tubular steam boiler of ordinary construction, having above it a hollow cylinder which is connected on one side and at the top by pipes from the boiler. There are also other pipe connections from the cylinder to an air pump and to the valve opposite the engine proper.

The cylinder is so constructed and connected with the boiler and encased in a jacket that the escaping heat may be utilized in keeping the cylinder hot. The steam and air are not superheated after being mixed in the cylinder, but the air is heated, expanded, and mixed with the steam within the heated cylinder and acts directly upon the piston of the engine. It is claimed that by heating and expanding the air and mixing it with the steam all at the same time a large amount of air may be used without condensing the steam and without losing any of the effective power resulting from the sudden expansion of the air.

The steam generated in the boiler may be used to act directly upon the engine or may be first sent through the preheated cylinder and mixed with air and from there proceed to the engine.

Cat. No. 251.285 U.S.N.M.

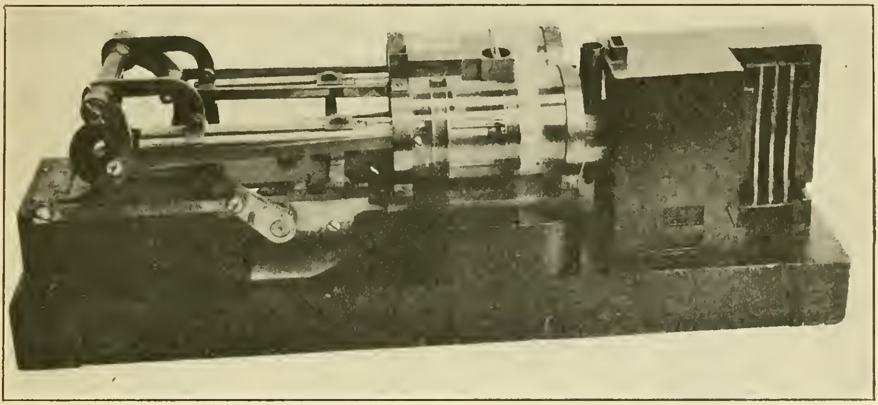


FIG. 12.—ERICSSON AIR ENGINE, 1855.

Model of John Ericsson Air Engine. U. S. Patent, No. 13348, 1855. Transferred from United States Patent Office.

The engine is single acting and consists of two cylinders open at one end connected by a crank shaft, the two cranks being 180 degrees apart. Each cylinder has two pistons, an inner or "supply" piston and an outer or "working" piston. The rods of the former pass through a stuffing box in the latter and are operated through a series of levers, rollers, and cams by the crank shaft. The "working" piston has two wrist pins on either side of the stuffing box and connected through suitable levers to the crank shaft.

Above the cylinders is a "regenerator" consisting of a box filled with coiled tubing through which the cold compressed air from the cylinder passes on its way to the heating coils and around which the hot air, after doing its work in the cylinders, is caused to circulate.

When the pistons of one cylinder are at the extremity of their outward stroke, those of the other cylinder are about to start on their outward stroke by the force of expansion of the hot air admitted from the heater. The outward movement of the pistons of cylinder No. 2 causes the pistons of cylinder No. 1 to start their instroke. The "working" piston moves slowly but the "supply" piston, through its mechanical connections to the crank shaft, moves rapidly and in so doing draws cold air after it through an open valve in the "working" piston, and drives expanded hot air ahead of it through the exhaust valve and into the "regenerator." When it reaches the end of its stroke the exhaust valve closes and the "working" piston continuing inward compresses the cold air ahead of it.

As the "working" piston approaches the "supply" piston and about reaches the end of its stroke an intake valve opens, admitting hot air from the heater. The expansion of this air in the cylinder head acting against the "supply" piston starts it on its outstroke to meet the "working" piston, thus assisting in the further compression of the cold air for an instant, after which the opening of a valve allows the compressed air to pass out of the cylinder and into the "regenerator" tubes. At the same time a valve opens in the "supply" piston, admitting hot air to the area between the two pistons, whose expansive force moves the "working" piston outward—the "supply" piston following by the action of the levers to which it is attached.

Cat. No. 251,279 U.S.N.M.

Model of John Ericsson Air Engine. U. S. Patent, No. 266052, March 30, 1880. Transferred from United States Patent Office.

The cylinder of the engine is open at the upper end and contains two pistons designated as the "working" piston and the "exchange" piston. The lower part of the cylinder is closed and is intended to be heated by any suitable type of burner or fireplace. The "working" piston, which is in the upper part of the cylinder, is packed so as to work air-tight. The "exchange" piston, which is of considerable length in an axial direction, is so much smaller than the cylinder that an annular space for the free passage of air is left between its exterior and the interior wall of the cylinder. This piston is hollow, the upper half being filled with cotton or other fibrous material, which in turn is separated from the lower end of the piston by a layer of charcoal or other nonconducting material so as to protect the cotton from the heat to which the bottom part of the piston is subjected. The "working" piston is connected by a hollow rod and short side links with a beam above the cylinder, the connection being at a short distance from the fixed center of oscillation of the beam.

The beam is connected at a much greater distance from the other side of the center by a connecting rod with a short crank on the main shaft of the engine. This short crank is also connected by a rod with one arm of a "bell" crank lever which has a fixed center of oscillation. The other arm is connected by arched side rods on opposite sides of the cylinder by an arched yoke. The piston rod of the "exchange" piston passes through the arched rods before mentioned.

The movement of the pistons is as follows: During the upward movement of the "exchange" piston the cool air from the upper part of the cylinder will be transferred by this piston through the annular space between it and the cylinder wall to the bottom and lower part of the cylinder. The air so transferred, becoming heated, expands

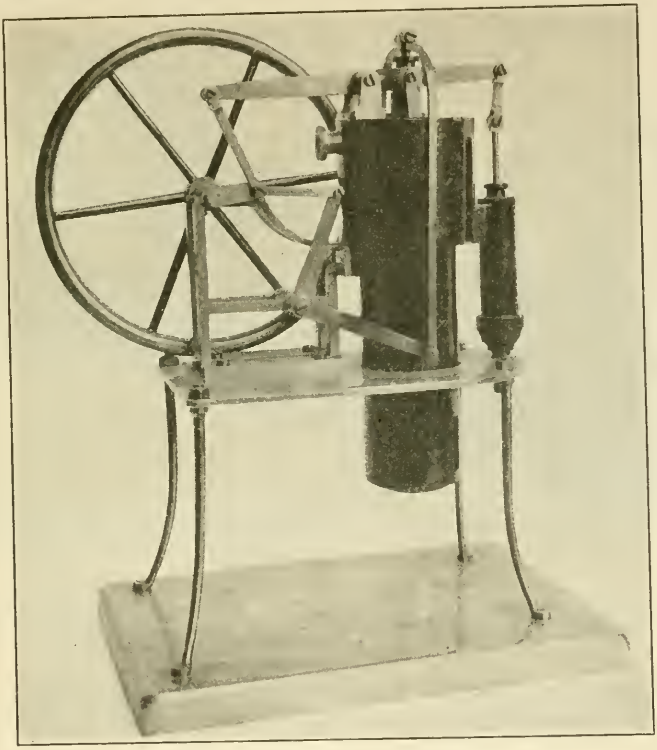


FIG. 13.—ERICSSON AIR ENGINE, 1880.

in the lower part of the cylinder, and its expansion causes it to force the "working" piston upward—the movement of the "exchange" piston being about three-fourths completed before the "working" piston commences its upward movement—and when the "working" piston has nearly completed the working stroke the "exchange" piston begins to descend and forces the hot air back from the lower to the upper or cooler part of the cylinder, completing its stroke by the time the "working" piston has made about one-third of its return stroke. The "working" piston is actuated by the air which is confined in the cylinder and which is caused to be heated and cooled alternately by the peculiar motion of the "exchange" piston. The water in a water jacket surrounding the upper portion of the cylinder is kept in circulation by a pump whose piston is connected with the main beam on the same side of the center of oscillation as the "working" piston.

By the arrangement of the crank shaft, the centers of motion of the beam and bell-crank lever, and their individual connections a long crank with a short stroke of the "working" piston is obtained.

Cat. No. 251,286 U.S.N.M.

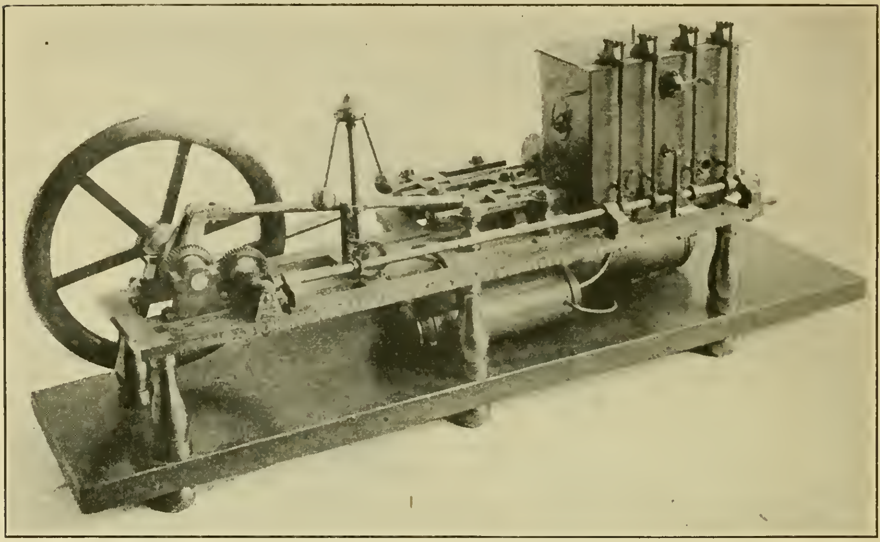


FIG. 14.—PERRY GAS ENGINE, 1846.

Model of Stuart Perry Gas Engine. U. S. Patent, No. 4800, October 7, 1846. Transferred from United States Patent Office.

This engine is "to be operated by the explosive mixtures of inflammable gases or vapors," the particular explosive mixture used, however, being that of air and gas generated from spirits of turpentine. The gas generator is part of the equipment and is situated within a water tank which also surrounds the engine cylinder.

Cylindrical tanks beneath the engine bed contain air under pressure filled at first by a hand pump, but after the engine is in motion by a pump operated by the engine. To operate the engine it is first necessary to heat the water in the tank by some outside means in order to vaporize the turpentine. Gas having been generated, the extraneous supply of heat is removed and air from the air-supply tanks is admitted into a valve box located above the retort. Through a slide valve some of this air enters the retort, is mixed with the gas, and exits through suitable apertures to passages leading to opposite ends of the cylinder. The admission of the gas to the cylinder through these intakes is controlled by valves operated by rods, which in turn are operated by appropriate cams on a shaft receiving motion from the crankshaft. The exhaust is in the under side of the cylinder.

The opening of the intake valve permits the gas to pass along the intake passage to the cylinder. At one point in its travel the gas passes over a hot platinum cup previously heated by the burning of a portion of the gas obtained through a by-pass from the valve box. The red-hot platinum ignites the gas and the resultant expansion forces the piston to the opposite end of the cylinder. Upon reaching the end of the stroke, the intake valve at this end of the cylinder opens, admits gas which is similarly ignited, and forces the piston back. Such is the cycle. The water in the tank serves a variety of purposes. It keeps the engine cylinder sufficiently cool for efficient operation—its temperature, however, is sufficiently high to vaporize the turpentine—and it lubricates the piston rod and prevents it from being overheated. Another interesting feature of the engine was the firing of the charge of gas by heated platinum, rather than a naked flame, as practiced by earlier inventors.

Cat. No. 251.278 U.S.N.M.

Model of G. B. Brayton Gas Engine. U. S. Patent, No. 125166, April 2, 1872. Transferred from United States Patent Office.

The motive power for the engine is obtained by burning a mixture of air and illuminating gas. The engine consists of a vertical cylinder having a double-headed piston. Upon the down stroke of the piston a quantity of gas and air mixed is drawn into the upper part of the cylinder, and upon the upstroke this same gas is forced out of the cylinder under pressure into a receiving tank, which acts as the supply tank for the gas to be used as the motive power.

The pressure maintained in the supply tank is at least 60 pounds to the square inch. In the bottom of the cylinder below the reach of the down-stroke of the piston there are placed a number of wire gauze diaphragms. They serve to guard the passages through which the gas is supplied to the engine and cut off the flame after the gas has been ignited from the supply which is flowing from the tank when the valve connection is open. This valve is controlled by means of a revolving cam on the main shaft. The design of the cam determines the length of time that the valve remains open, a spring causing it to close upon the instant that the cam ceases to hold it open. A constant flame of gas is maintained upon the upper surface of the wire gauze diaphragms which serve to ignite each charge of the gas as soon as it passes through the diaphragms. Consequently, upon ignition the steady expansion exerts a true pressure upon the piston and causes it to move upward. Upon completion of its upward stroke the momentum of the balance wheel, which is connected by means of a common crank and links to the piston, causes the piston to descend. In its descent a cam on the main shaft, acting upon a lever, opens an exhaust valve. Cat. No. 251,280 U.S.N.M.

Model of Errani and Anders Petroleum Dynamic Engine, U. S. Patent, No. 140021, June 17, 1873. Transferred from United States Patent Office.

The engine resembles an ordinary steam engine whose piston, however, is actuated by the expansive force resulting from the ignition at the beginning of the "outstroke" of a mixture of petroleum and

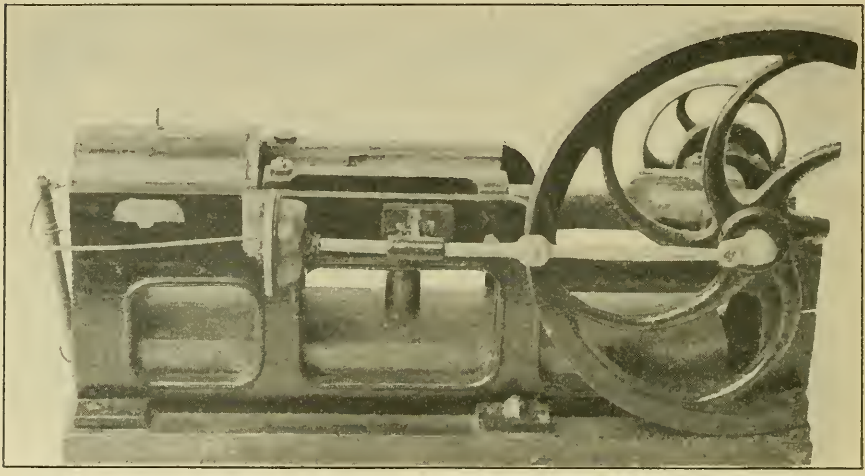


FIG. 15.—ERRANI AND ANDERS OIL ENGINE, 1873.

air sprayed into the cylinder through an aperture in its head. The oil-spraying device operates on the same principle as that of the household atomizer and cologne spray. Beneath the engine is an oil tank from the bottom of which protrudes a vertical tube. This is surrounded by an air chamber whose upper end terminates in a nozzle opposite the aperature in the cylinder head. Blasts of air obtained from a rubber bulb intermittently compressed by the action of a plunger operated by a crank on the main shaft fill the air chamber, forcing the oil up the tube and out of the nozzle together with air into the engine cylinder. Upon the ignition of the oil by an electric spark expansion moves the piston forward to the end of its stroke, and the impetus thus given to the flywheel returns the piston to its normal position ready for a repetition of operations. The quantity of oil sprayed into the cylinder is regulated by a cock in the charging pipe of the oil tank. When this cock is open all of the air forced into the air chamber by the bulb compressor passes out of the oil tank through the cock and exerts no pressure on the oil which, therefore, can not rise to the nozzle, and the engine stops.

Cat. No. 251,283 U. S. N.M.

Model of Julius Hock Petroleum Engine. U. S. Patent, No. 151129, May 19, 1874. Transferred from United States Patent Office.

This is one of the earliest types of internal combustion engines in which liquid petroleum is sprayed into the cylinder and ignited. Oil

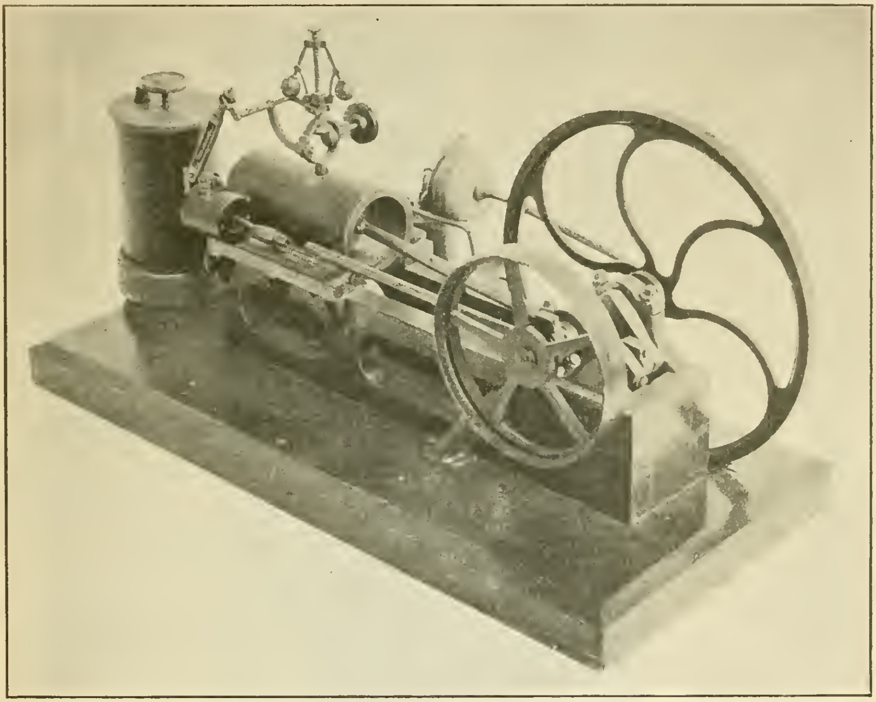


FIG. 16.—HOCK OIL ENGINE. THE FIRST SUCCESSFUL ONE, 1874.

is supplied to the motor from an air-tight tank, the quantity being regulated by raising or lowering a plunger immersed in the oil. The cylinder end of this oil supply pipe is nozzle-shaped and is screwed into the cylinder head. Arranged in the cylinder head also are one or more air nozzles directed across the path of the oil and supplied with air from a bulb similar to that on the Errani and Anders motor. The mixture of oil and air is ignited by a flame of gas directed horizontally into the cylinder through a hole in its head. The gas, which is naphtha, is obtained from a generator attached to the bulb compressor, which generator consists of a tank containing petroleum. Air from the compressor is forced through the petroleum, yielding a mixture of naphtha and carbonized air. A portion of this gas passes directly to the engine cylinder at intervals and the balance is stored in a tank to supply a gas burner whose flame is in the path of the petroleum igniting gas, and ignites it as it passes into the cylinder.

The engine cycle is as follows: The gas burner is lighted and the flywheel turned. During the forward motion of the engine piston a small amount of petroleum is admitted and atomized by air. After the piston has moved a quarter stroke the air bulb is compressed, causing a blast of carbonized air and gas to be emitted from the gen-

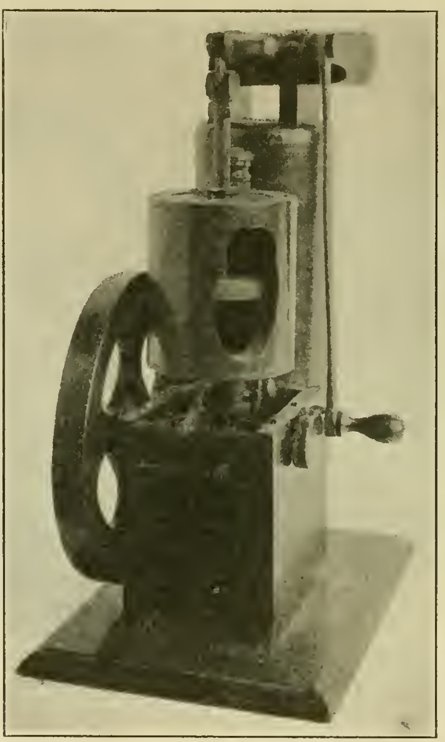


FIG. 17.—BRAYTON OIL ENGINE. OIL UNDER PRESSURE, 1874.

erator. The mixture exits through a nozzle, is immediately ignited by the flame of the gas burner, proceeds into the cylinder, and ignites the petroleum vapor within. The pressure created by the resulting combustion closes all valves and forces the piston forward to the end of its stroke and the impetus of the flywheel brings the piston back ready for the next charge. Cat. No. 251,282 U.S.N.M.

Model of G. B. Brayton Oil Engine. U. S. Patent, No. 151468, June 2, 1874. Transferred from United States Patent Office.

The engine consists of a vertical cylinder, single acting. On the crank shaft are two cams which operate the intake and exhaust valves located in the cylinder head. To the rear of the engine proper is an air tank with air under pressure as great as 60 pounds a square inch, maintained by the engine itself. A suitable valve regulates the amount of air passing out of the tank to the intake pipe. Surrounding the intake is an annular space stuffed with some absorbent material which is saturated at each revolution with a prescribed quantity of oil, the saturation being accomplished by a suction and force pump operated by a cam and connecting rod on the main shaft.

Above the intake pipe and the surrounding annular chamber is a circular opening in which is placed a wire gauze diaphragm on the upper surface of which gas is constantly burning, the gas being supplied from an outside source.

To operate the engine the gas above the wire diaphragm is ignited and the intake valve opened. Air from the tank enters the intake pipe and in passing upward permeates the absorbent material charged with oil through holes in the walls of the intake pipe. The oil now vaporized and mixed with air continues upward, passes through the wire-gauze diaphragm, and is ignited. The resultant expansion moves the piston upward and the impetus of the flywheel returns it. Should the temperature of the air be too low to vaporize the oil, its pressure is sufficient to drive the oil out of the absorbent in the form of a fine spray which upon striking the wire-gauze diaphragm is instantly vaporized, mixes with air, and is ignited as under normal conditions. Cat. No. 251, 281 U.S.N.M.

Model of N. A. Otto Gasoline Engine. U. S. Patent, No. 194047, August 14, 1877. Transferred from United States Patent Office.

In gas-motor engines constructed before the invention of Doctor Otto, an explosive mixture of combustible gas and air was introduced into the engine cylinder where it was ignited, resulting in a sudden development of heat and expansion of the gases. A great portion of the useful effect was lost, however, by the absorption of heat, because no special provision was made for allowing the gases to expand rapidly. In the Otto engine, however, an intimate mixture of combustible gas or vapor and air is introduced into the cylinder, together with a separate charge of air or gas that may or may not support combustibles, in such a manner and in such proportions, that the particles of the combustible gaseous mixture are more or less dispersed in an isolated condition in the air or other gas, so that on ignition, instead of an explosion ensuing, the flame will be communicated gradually from one combustible particle to another, thereby effecting a gradual development of heat and a corresponding gradual expansion of the gases which will enable the motive power so produced to be utilized in the most effective manner.

The engine is single-acting and when exerting its full power makes one explosion or working stroke in every four strokes. Assuming the piston to be at the end of its instroke and about to be moved through its outstroke by the momentum of a flywheel, a slide valve opens to admit air into the cylinder. As the outstroke proceeds, the air supply is cut off, and the combustible gas intimately mixed with air is drawn in until the piston has arrived at the end of its outstroke. The gas port then closes and the piston is caused, by the momentum of the flywheel, to perform its instroke, whereby the charge of gaseous mixture and air that filled the cylinder at atmospheric pressure will be compressed. About the time for the beginning of the second out-

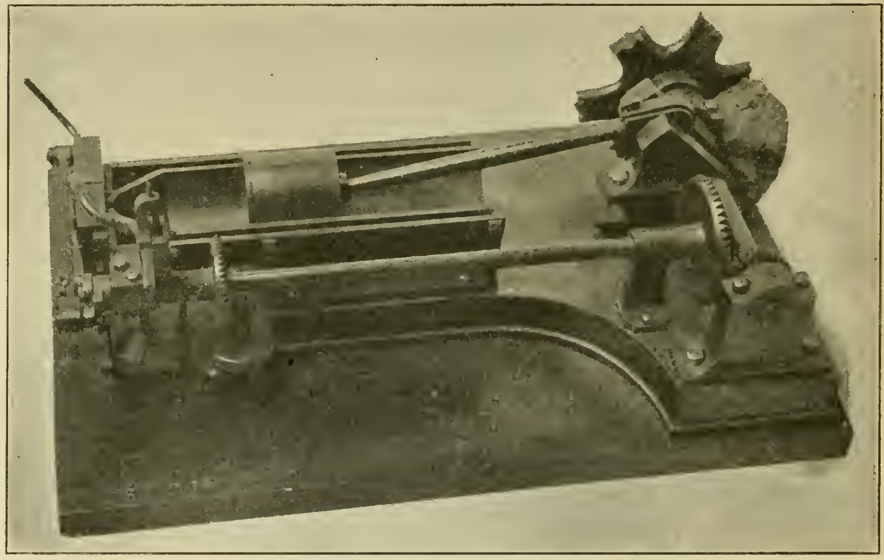


FIG. 18.—OTTO GASOLINE ENGINE. THE FIRST FOUR-CYCLE MOTOR, 1877.

stroke the gas is ignited and the gradual expansion of the gases causes the piston to complete its second outstroke. The second instroke then expels the products of combustion through an exhaust valve which remains open during this second instroke. The next outward stroke then commences a fresh cycle by taking in a new charge of air and gas.

By compressing the charge before firing it, nearly double the amount of air that otherwise would be permissible can be present in the mixture without preventing its being ignited, this additional cushion moderating the violence of the explosion and giving a more sustained pressure during the working stroke.

The cylinder is water-jacketed and the gas and air are admitted by a slide valve which serves also as an igniting valve, carrying a pocket of flame from an external light to a small port. The exhaust valve is of the drop type and is placed at the side of the cylinder. Both valves are actuated by a shaft driven by gearing at one-half the speed of the crank shaft. The speed of the engine is regulated by a centrifugal governor which, when the normal speed is exceeded, prevents the admission of gas so that no explosions take place until the speed has fallen to the prescribed limit. The engine may be arranged

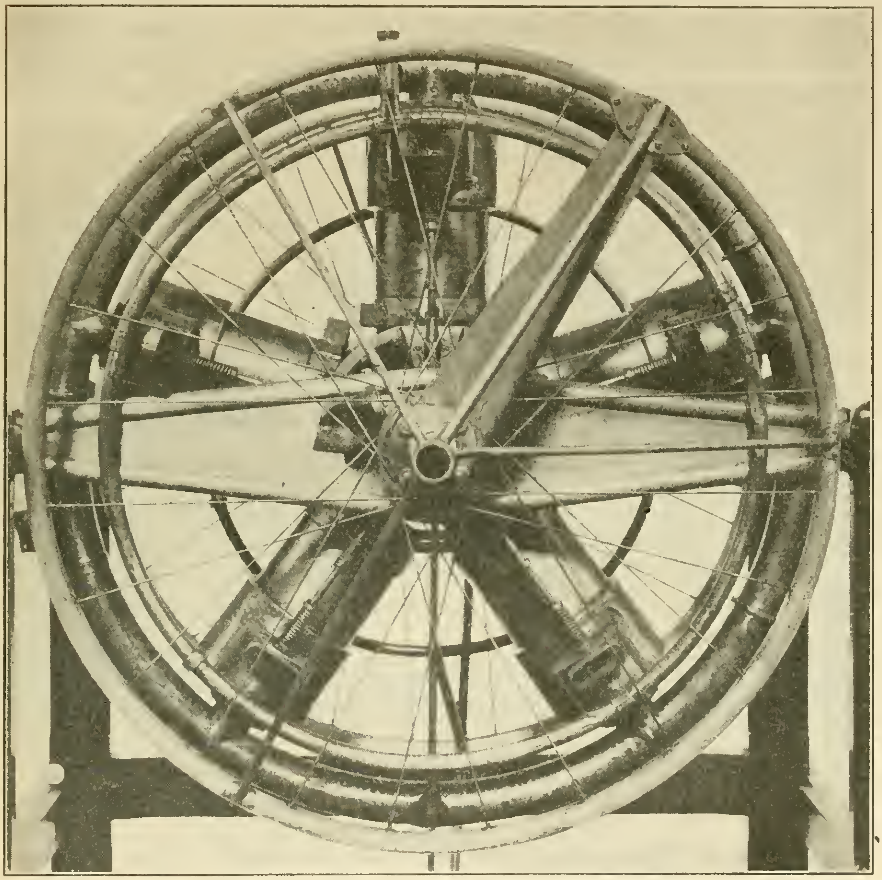


FIG. 19.—LANGLEY AERODROME ENGINE, 1901.

to be double-acting by providing the requisite valve gear for each end of the cylinder. Cat. No. 251, 284 U.S.N.M.

Five-cylinder Water-cooled Gasoline Motor. Made in the Smithsonian Institution Shops by Charles M. Manly for the full-size Langley Aerodrome, 1901.

This four-cycle engine has stationary cylinders arranged radially on a central drum. They are made of seamless steel tubing, lined with cast-iron liners one-sixteenth of an inch thick shrunk into them.

The combustion chambers entering the side of each cylinder near the top are turned out of solid steel forgings and secured to the cylinders by brazing.

All five piston rods operate on one crank pin. One of these rods is formed of a steel forging terminating in a sleeve which encircles the crank pin and is provided with a bronze lining in order to insure a proper bearing surface between the connecting rod and the crank pin. The upper half of this steel sleeve forms an integral part of the main connecting rod and is rounded off to a true circle on its exterior circumference except at the point where the rod joins it. The other four rods terminate in bronze shoes which bear on the exterior of the steel sleeve and are held in contact by cone nuts threaded to the sleeve and locked.

On one side of the crank shaft and near the crank arm is a double-pointed cam bearing on the exterior of the hub of the drum and driven by suitable gears at one-fourth the speed of the crank shaft. The cam operates the exhaust valves of all cylinders through rollers and punch rods in contact with the exhaust-valve stems.

The gasoline manifold consists of a tube bent to a circle and having five branch tubes each leading to one of the automatic inlet valves which fits removable cast-iron seats fastened in the upper part of each combustion chamber. The cooling water is led to the cylinder jackets on the starboard side through a circular tube connected by a pipe with a centrifugal pump. The hot water manifold is likewise circular and situated on the port side. The water is led from the jackets through the manifold and through two connections to two radiators.

The total weight of the engine is approximately 124 pounds, and the entire power plant including cooling water, carbureter, batteries, etc., weighs less than five pounds to the horsepower. Maximum power developed was 52 horsepower at 950 revolutions per minute.

Cat. No. 248,651 U.S.N.M.

Adams-Farwell Five-cylinder Revolving Gasoline Motor. Made by The Adams Co. Presented by the Gyro Motor Co.

This is a four-cycle air-cooled motor with the cylinders bolted together and revolving around a vertical crank shaft which is keyed to a stationary base. The pistons are connected to the same crank pin, which is part of the crank shaft, so that the pistons can travel only in a perfect circle about their common center. The circle described by the pistons being eccentric to that of the cylinders, the pistons approach and recede from the cylinder heads. The position of the cylinders in relation to each other permits the use of a single throw crank and also makes it possible to operate five valve rods from one cam, each rod operating two valves. The valves closing outwardly are held shut by centrifugal force, which also opens the inlet valve by its action on the valve rods. No throttle control is used, but the control consists in regulating the closing of the inlet valve so as to retain only the required charge of gasoline in the cylinder, allowing the balance of the gasoline to be drawn in by the next cylinder.

The cylinders are 4¼-inch bore and 3½-inch stroke, developing 36 horsepower at 1,500 revolutions a minute, the maximum speed. Total weight is about 97 pounds, equal to about 2.7 pounds to the horsepower.

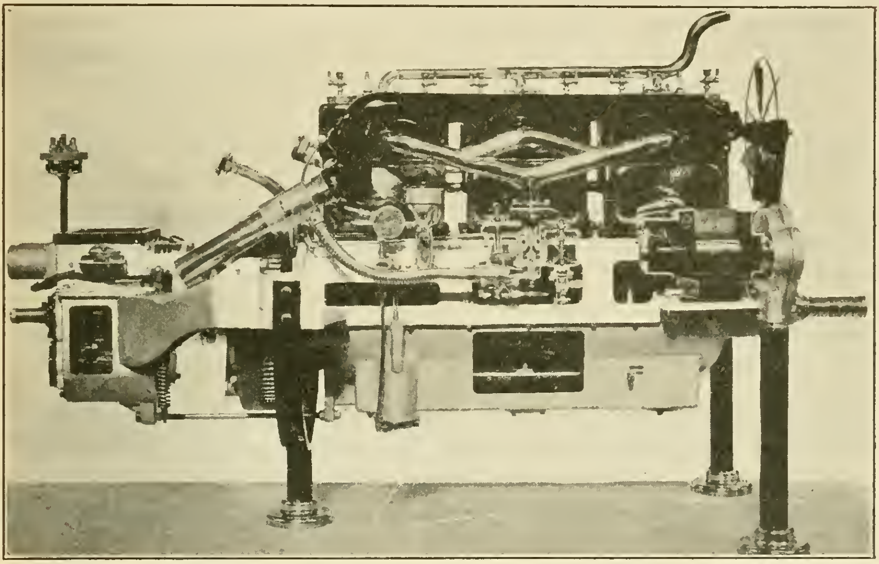


FIG. 20.—HAYNES SIX-CYLINDER AUTOMOBILE ENGINE, 1914.

This motor was used by Mr. Emile Berliner, of Washington City, in helicopter experiments during the years 1907–8.

Cat. No. 276,602 U.S.N.M.

Six-Cylinder Gasoline Motor. Made and Presented by the Haynes Automobile Co., 1914.

This is an example of the "power plant" designed for use in certain of the automobiles built by the Haynes Co. in 1914. Selected portions of the motor have been cut away so as to show the working parts in operative relation.

The engine has six water-jacketed L-head cylinders, 4¼-inch bore and 5½-inch stroke, cast in pairs and bolted to the crank case. The intake and exhaust valves are on the same side of the cylinders, the valves being of the poppet type operated by a cam shaft geared to the crank shaft. The oiling system is splash and gravity feed to the main bearings and idler gear and also a constant feed to the oil basins in the crank case. An oil pump of the plunger type operated by an eccentric on the cam shaft circulates the oil. The motor is equipped with the Leece-Neville electric starting and lighting system, composed of a generator, motor, storage battery, and starting control, operated through the clutch pedal. It is also fitted with the Vulcan electric gear shift, operated by a push-button switch. The buttons control the operation of a set of electromagnets, one for each of the three forward speeds and one for the reverse. To the clutch pedal is connected a mechanical neutral device and a small mechanical master switch which completes the circuit to the storage battery for energizing the electromagnets. Ignition is obtained through a high-tension magneto geared to the crank shaft. The carbureter is of the Stromberg make, whose inlet manifold is 1½ inches in diameter. The gasoline feed is under pressure supplied by a hand pump and mechanical air pump on the motor. The cooling water is circulated by a centrifugal pump geared to the crank shaft. Weight is 1,000 pounds, horsepower 65.

Cat. No. 283,279 U.S.N.M.

Single-Cylinder Unit of Sleeve-Valve Gasoline Engine, 1921. Sectioned and Hand Operated. Gift of Willys-Overland Co., Toledo, Ohio.

The particular feature of this engine is that the regulation of both the intake of gasoline vapors and the exhaust of the products of combustion are obtained by sliding sleeve valves—two cylindrical sleeves which glide silently up and down between the cylinder wall and the piston, one working within the other. Slotted openings in these sleeves register with each other and with the cylinder ports at the proper intervals, forming large passages for the intake and exhaust gases. In practically all other respects the engine has much in common with the generally used poppet-valve type of engine.

Each sleeve is raised and lowered by a connecting rod from an eccentric shaft which, in turn, is operated on the same principle as a cam shaft in a poppet-valve engine.

The engine is of the four-cycle type, that is, the piston makes four strokes—two up and two down—for every explosion that takes place. These strokes in order and operation are:

1. *Intake.*—During the first downward stroke of the piston the two sleeve-valve openings on the carbureter side, come opposite each other and at the same time opposite the opening in the intake manifold. Through this unobstructed opening gasoline vapor is drawn into the combustion chamber.

2. *Compression.*—When the intake or downward stroke is complete, the valve openings have moved past each other and past the intake manifold opening—in other words, the ports have closed, and the upward stroke of the piston compresses the gasoline vapor. This compression continues until the piston reaches the limit of its upward travel when—

3. *Power.*—At this moment a spark occurs at the spark-plug points, situated directly above the center of the piston, and the expansion of the ignited gasoline vapor forces the piston downward, turning the crankshaft.

4. *Exhaust.*—The momentum of the flywheel causes the crankshaft to continue to turn, and again forces the piston upward. During this upward stroke the openings in the sleeve valves on the exhaust side gradually come opposite each other and opposite the cylinder port opening into the exhaust manifold and the burnt gas is forced out of the combustion chamber.

The sleeve-valve gasoline engine was developed by Charles Y. Knight, of Chicago, Ill., and was patented in 1903. An engine was first installed in 1905 in an automobile built in the factory of the Garford Co., Elyria, Ohio. The following year it was adopted by the Daimler Automobile Co., of England; later by Panhard, of France; Mercedes, of Germany; and Minerva, of Belgium; and rather recently by Willys and Stearns, of the United States.

Cat. No. 307,212 U.S.N.M.

Four-Cylinder Gasoline Automobile Engine, 1921. Sectioned and Operated. Made and Presented by The Autocar Co.

This engine is the most recent design of The Autocar Co. for use in its automobile trucks. It is of four-cycle, poppet-valve type, water-cooled, with the cylinders cast in block with removable cylinder head. On the left-hand side of the engine are located the water pump, magneto, oil gauge, and oil-filler cap; and on the right-hand side, the carbureter, governor, and valve adjustments. The dimensions of the cylinders are $4\frac{1}{4}$-inch bore and $5\frac{1}{2}$-inch stroke, giving a horsepower of 28.9 (A. L. A. M. rating). The crank shaft is counterbalanced and mounted on two annular ball bearings and has no center bearing; the front bearing is 100 per cent oversize, and the rear bearing twice the size of the front, so as to carry the additional weight of the flywheel. This is a departure from general design, for, although ball bearings have been considered the ideal bearings for crank shaft mountings, it was difficult to maintain the alignment of the pistons on account of the whip or spring of the crank shaft when running at high speed. By use of a short crank shaft, due to block cylinder casting and the elimination of any center bearing coupled with the counter balancing of the crank shaft, these difficulties are reduced to a minimum, and the crank shaft is kept true at any engine speed without distortion.

Another feature of the engine is the lubrication system. The oil is circulated by a gear pump driven from the cam shaft and located inside the lower engine pan. The oil is retained in a reservoir in the bottom of the crank case, where it is kept cool by the current of air continually passing around it. From this the oil is drawn by the

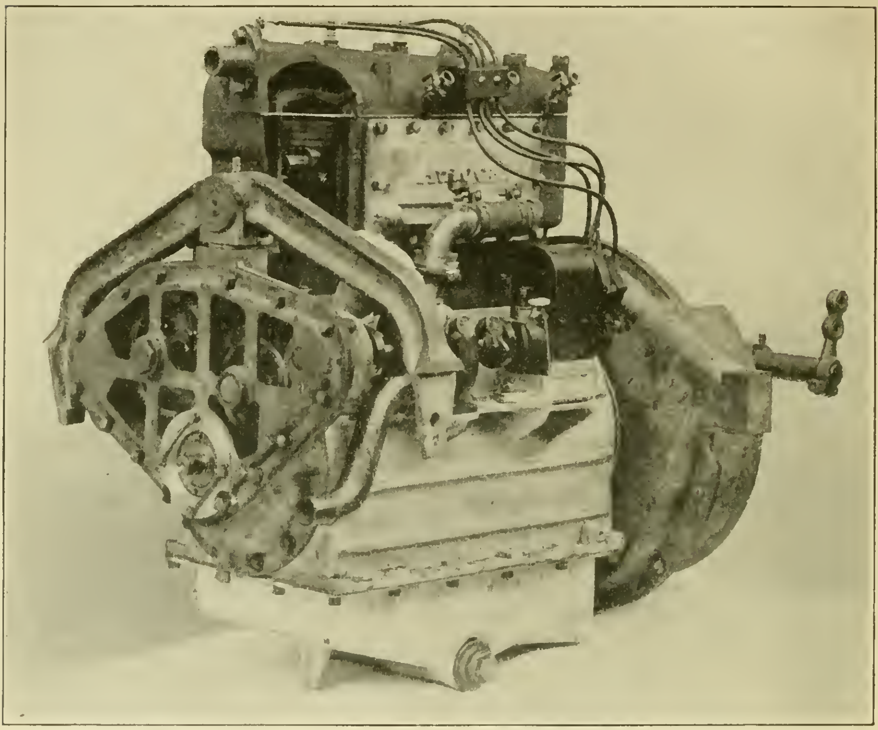


FIG. 21.—FOUR-CYLINDER GASOLINE AUTOMOBILE ENGINE, 1921.

gear pump through a heavy double strainer and forced under pressure to four standpipes, one directly beneath the center of each connecting-rod bearing. Each standpipe has a hole drilled on either side near the top, and at slow engine speeds oil flows out of these holes into a small cup-shaped pan secured to the standpipe beneath the oil holes. Inserted in the bottom half of each connecting-rod cap are two tubes extending inwardly to the connecting-rod bearings and of such a length and so spaced that when the connecting-rod cap is at its lowest position the tubes touch the oil in the cup-shaped pan and draw a small quantity up to the bearings. As the engine speed is increased, a large quantity of oil is forced through the standpipes and into the cup-shaped pans, raising the oil level in the pan. As the engine speed increases, the oil streams from the standpipes are enlarged, and as the tubes in the connecting-rod bearing now cut through the increased oil streams, the result is an automatic elevation of the oil line, always in proportion to the increased speed.

The ball bearings, cylinder walls, cam shaft, valve gear, and other internal parts of the engine are lubricated by the splash derived from the tubes, while the wrist pins are lubricated by oil scraped from the cylinder walls and led through the oil passage to the piston-pin bearings.

The water circulation is obtained with a centrifugal pump. The ignition system consists of a Bosch high-tension magneto, a wire to each spark plug, and a wire to the switch. The engine is equipped with a Stromberg carbureter. A governor is attached to regulate the speed of the motor. It is operated by a shaft, which is driven by the engine cam shaft and governs the engine speed to prevent the racing of the engine in low gears or when declutched.

Cat. No. 307,254 U.S.N.M.

MOTOR ACCESSORIES.

Stearns and Hodgson Steam Engine Governor. U. S. Patent No. 9236, August 31, 1852. Transferred from United States Patent Office.

The apparatus consists of two weighted arms to the upper extremities of which are secured toothed quadrants working in a cylindrical rack placed in the main spindle of the governor in an opening sufficiently long to allow the rack to have a reciprocal motion equal to the demand of the valve which it may govern. When set in motion, the arms and their weights recede from the spindle by the centrifugal force given them, and thereby cause the toothed quadrants to operate on the cylindrical rack, which produces a reciprocal motion without the intervention of pins, levers, or connecting links.

Cat. No. 251.287 U.S.N.M.

Charles Porter Steam Engine Governor. U. S. Patent, No. 20,894, July 13, 1858. Transferred from United States Patent Office.

The apparatus is a ball-and-arm type of centrifugal governor, light in weight and driven at a high velocity. It is equipped with a counterpoise of a weight much greater than the aggregate of the balls and arms and sufficient to balance the centrifugal force developed. Cat. No. 251.289 U.S.N.M.

D. A. Woodberry Automatic Steam Cut-off. U. S. Patent No. 107746, September 27, 1870. Transferred from the United States Patent Office.

The apparatus consists of a main eccentric swung from an axis upon a hub fixed to the crankshaft or upon an arm of the flywheel and adjusted laterally by means of an auxiliary eccentric. Two governor weights are firmly secured to springs which are in turn secured to an arm of the flywheel. The governor weights are hinged to links which at their opposite ends are attached to two arms of the auxiliary eccentric. When the crank shaft is put in motion, the centrifugal force of the weights will swing them outward partly revolving the auxiliary eccentric whereby the throw of the main eccentric is reduced and the valve caused to cut off sooner. If the motion of the crank shaft ceases or slows up, the weights produce an opposite effect upon the eccentric and valve, thus correcting any variation of speed in the engine. The arrangement of the weights is such that they precede their points of suspension in the direction of motion, and while at rest they lie near the crank shaft. By this means the liability of the weights to be thrown outward by their inertia when the engine is started suddenly, is avoided. Cat. No. 251,290 U.S.N.M.

Internal-Combustion Engine Magneto Equipped with an "Impulse Starter." Gift of Eisemann Magneto Corporation.

The magneto is coupled with a device which spins its armature, giving a hot spark with ordinary hand craking. The mechanism consists of an aluminum housing attached to the magneto shaft containing a spiral spring, which is compressed when the motor is turned over and automatically released.

By this operation the armature is given a sharp twist, causing a spark to be produced at the proper moment. The device does not have to be set by hand, and above 180 revolutions a minute is automatically drawn out of action. It produces the necessary rotating speed of the magneto armature to generate a spark and thereby eliminates the necessity of an auxiliary battery system, especially on engines cranked by hand, such as heavy trucks, tractors, marine engines, etc. Cat. No. 306,998 U.S.N.M.

PART II.

APPLICATION OF POWER TO TRANSPORTATION.

SELF-PROPELLED ROAD VEHICLES.

One of the greatest advantages of steam power which was recognized from the earliest time of its application is that its use is not fixed as to location, as is water power or wind power, but is free to be used where desired; that is, wherever power is required there it may be had by building a steam engine to generate it. This factor of mobility carried a step further gave to the world the first practical self-propelled vehicle when Cugnot, a French military engineer, mounted a steam engine on a three-wheeled truck and applied the power developed to propel it.

During the first half of the nineteenth century a large number of steam carriages were designed and built, particularly in England, some of them being successful and profitable. The men most prominent in this field in England were Gurney, Hancock, Dance, and Church, who built stage coaches and other public vehicles during the period from 1827 to 1834. About this time, however, laws imposing heavy highway tolls on mechanically propelled vehicles stopped further progress, and for over forty years little was done either in Europe or the United States beyond improving the type of farm tractor and steam roller. In the meantime the internal-combustion engine was being developed and improved without, however, the idea of its application to road vehicles.

As late as 1883 the oil engines produced were heavy and cumbrous, rotating at a speed of between 150 and 250 revolutions a minute. Gottlieb Daimler, however, about this time conceived the idea of a small oil engine with light moving parts, to run at a speed of 800 to 1,000 revolutions a minute. In 1886 he made his first experiment with a motor bicycle, and on March 4, 1887, ran for the first time a motor car propelled by a gasoline engine. While the motors developed by Daimler contained nothing new in their cycles of operation, great credit must be given him for realizing the possibility of producing durable and effective engines rotating at high speeds and for providing the first step in gasoline motive power development.

The possibilities of the gasoline engine brought to light by Daimler were almost immediately taken up and developed in Europe and the United States, especially by Benz in Germany; by Panhard, Levassor, Peugeot, de Dion, Delahaye, and Renault in France; by Napier, Lanchester, Royce, and Austin in England; and by Duryea Brothers, Haynes, Apperson, Olds, Winton, and others in the United States.

Electrically driven vehicles were the latest type to be developed, and, while possessing several advantages, are as yet confined to use within a small area of travel.

Model of Sir Isaac Newton's Locomotive, 1680. Made in the Museum.

This is a small model of a machine made to prove that a reaction of a jet of steam impinging upon the atmosphere would propel a vehicle. Cat. No. 181,282 U.S.N.M.

Photograph of Cugnot's Steam Traction Engine. Original in the Conservatoire des Arts et Metiers at Paris.

According to The Science Museum:

Nicholas Joseph Cugnot, a French military engineer, in 1769 made a steam carriage which, traveling on a common road and carrying four persons, attained a speed of two and a quarter miles an hour, but, the boiler power being insufficient, the supply of steam failed after running twelve or fifteen minutes. These results, however, induced the French Government to order the construction of an engine for the transportation of artillery which should be capable of carrying a load of about four and one-half tons and maintaining a speed of two and one-quarter miles on level ground. The machine was made in 1770 by Brezin, to Cugnot's designs, at a cost of £800, but was never tried, and is now preserved in the Conservatoire des Arts et Metiers at Paris.

It consists of a heavy timber frame supported on three wheels and carrying in front an overhanging copper boiler. The front wheel has a broad, roughened tire, and is driven by two single-acting, inverted, vertical cylinders 13 inches in diameter by 13-inch stroke. The pistons are connected by a rocking beam, and their motion is transmitted to the driving axle by pawls acting on two modified and reversible ratchet wheels. The distribution of steam to the two cylinders is performed by a four-way cock actuated by a tappet motion. A seat is provided for the driver, who, by means of gearing, was able to steer the machine, the boiler and engine turning together as a fore carriage through fifteen degrees either way. Cat. No. 180,126 U.S.N.M.

Model of Murdock Locomotive, 1784. Model made in the Museum.

This locomotive was designed and constructed by William Murdock in Birmingham, England, to test the action of high-pressure steam in propelling vehicles.

The machine is three-wheeled, a steering wheel in front, and two 9¼-inch driving wheels connected by a cranked axle behind. There is a rectangular boiler of copper with brazed joints which has an internal flue. A metal cup to hold alcohol is secured below the flue or fire box.

The steam cylinder is double-acting, is three-fourths of an inch in diameter, and has a 2⅛-inch stroke. The cylinder and valve chest are partly sunk into the boiler. A small safety valve is seated on the cylinder flange and loaded by a spring finger to retain the necessary steam pressure. A beam is carried by a post at the front end of the model and is connected at the other end with the piston rod, while a connecting rod is carried down to the crank pin of the driving axle. The steam valve is moved by the beam at each end of the stroke by a tappet action. The valve consists of two pistons connected by a tube, the space between the pistons being always open to the boiler, the exhaust from the lower end of the cylinder escaping through the connecting tube. As the valve derives its motion from the beam, the engine will continue running in either direction once it is started.

Cat. No. 181,283 U.S.N.M.

Print of Trevithick's First Road Locomotive, Camborne, England, 1801. Woodcut, three views, from the "Memorial Edition of the Life of Richard Trevithick. E. and F. N. Spon., London, England, 1883." Presented by Trevithick's granddaughter through Colonel Davis of London.

The first load of passengers was conveyed by this locomotive on Christmas Eve, 1801. It traveled on the common roads through Camborne and climbed up a steep hill. On a subsequent trial a casting broke and the engine was left by the roadside, caught fire, and was partially burned. On March 24, 1802, a patent was granted to Richard Trevithick and Andrew Vivian for steam engines for propelling carriages, etc. Cat. No. 180,738 U.S.N.M.

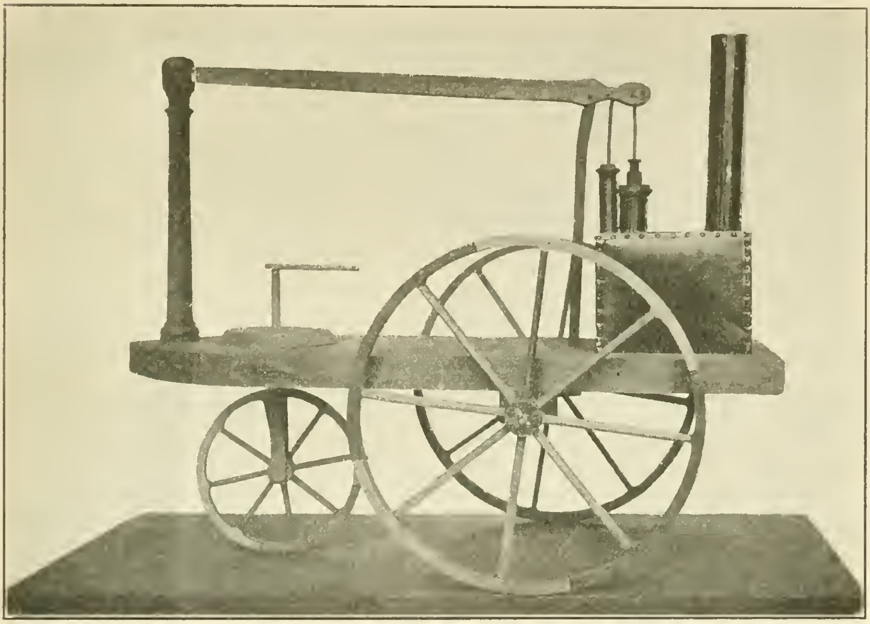


FIG. 22.—MURDOCK ROAD LOCOMOTIVE, 1784.

Print of Drawings of Richard Trevithick and Andrew Vivian accompanying their first patent for steam engines for propelling carriages. March 24, 1802. Deposited by J. E. Watkins.

The result of the Camborne experiment of 1801 was this road locomotive with vertical double-cylinder engines, the cranks being placed at a quarter turn.

Mickleman describes it thus:

It exhibits in construction the most beautiful simplicity of parts; the most sagacious selection of appropriate forms; their most convenient and effective arrangement and connection, uniting strength with elegance, the necessary solidity with the greatest portability; possessing unlimited power with a wonderful pliancy to accommodate to a varying resistance. It may, indeed, be called the *Steam Engine.* Cat. No. 180,739 U.S.N.M.

Print of Trevithick's Second Road Locomotive, London, England, 1803. Wood cut from the "Memorial Edition of the Life of Richard Trevithick, E. and F. N. Spon, London, England, 1803." Presented by Trevithick's granddaughter through Colonel Davis of London.

This locomotive was built at Tuckingmill, in Cornwall, and differed from its predecessor in having a horizontal cylinder in place of a vertical one and at the same time being of lighter construction. It was tried in Cornwall and then sent to London, where it ran for some time daily through the streets, sometimes at the speed of eight or nine miles an hour.

The engine had three wheels, the two driving wheels about eight feet in diameter, with a small steering wheel in front. The engine and boiler were between the driving wheels, the exhaust steam escaping up the chimney enabling the small boiler to make sufficient steam. The continual trials and their subsequent cost drained the pockets of the inventor and the steam carriage was sold for what it would bring. The engine portion became a hoop-iron rolling-mill engine. Cat. No. 180,741 U.S.N.M.

Model of Traction Engine. Patented by Cassius M. Miller, 1880. U. S. Patent, No. 227441. Transferred from United States Patent Office.

The tractor is steam driven, in which a combined vertical and horizontal boiler supported by springs from both the front and rear axles form the truck. The rear carrying wheels are driven from a countershaft supported by studs upon the rear axle and provided with a fast and loose pinion to engage with gear wheels on the traction wheels. The countershaft and axle are fixed with respect to each other to preserve the working contact of the gear wheels and pinions, but the boiler has an independent movement on the springs, which are applied to the studs. The countershaft, likewise, carries differential gearing to compensate for the unequal travel of the traction wheels when the machine turns to one side or the other. This differential gear is driven by a chain belt running over a sprocket wheel on the engine shaft and to a similar wheel from the main wheel of the differential gear. Cat. No. 251,277 U.S.N.M.

Model of Steam Traction Engine Patented by John C. Praul, 1879. U. S. Patent No. 221354. Transferred from United States Patent Office.

The propelling forces of this tractor are two pairs of vibrating levers or walking legs. These legs are of right-angular shape and connected at their apices by links or parallel bars attached overhead to a cross shaft. The forward end of the horizontal extension of each lever is attached to the wrists of the crank shafts. These crank shafts are aligned but independent, and in place of constructing each of them in one continuous angular piece it is formed in two parts, which are rigidly connected by an interposed annulus. The wrists of these two parts are attached to the annulus at opposite points on its side and the forward end of the walking legs are also attached at the same points, the revolution of the crank shaft and its annulus imparting a complex movement to the walking legs. This movement is not unlike that of the hind legs of a cow.

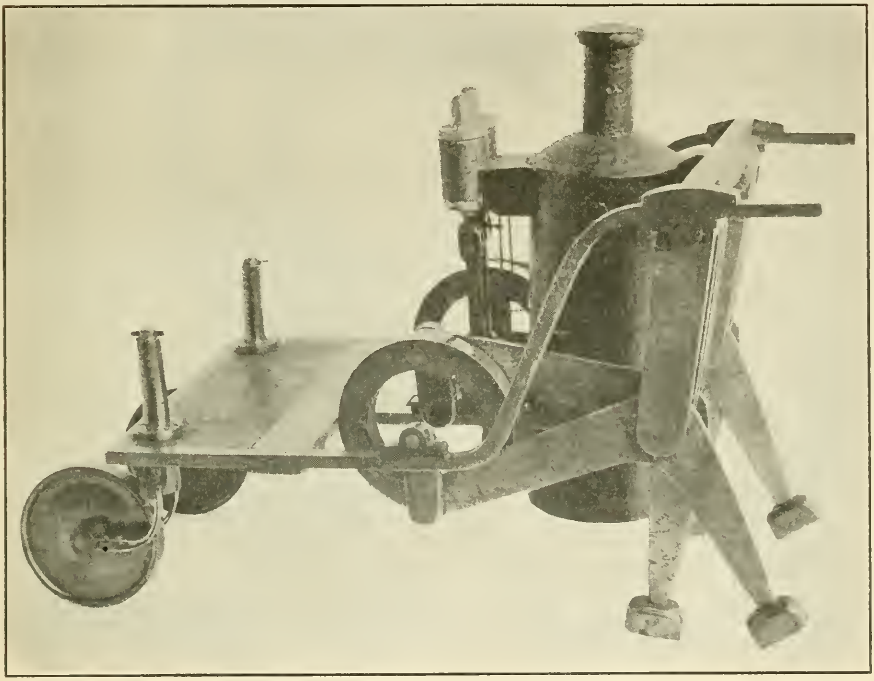


FIG. 23.—PRAUL STEAM TRACTOR, 1879.

When in operation the feet of each pair of legs will be alternately lifted from the ground and carried forward and again brought down, thus describing an approximately elliptical figure, while the legs as a whole will have a forward and backward movement, alternately rising and falling in consequence of the overhead links vibrating in the arc of a circle. The vertical extension of the legs is nearly aligned with the links overhead and the feet move in nearly a horizontal plane, so that the rear part of the body of the engine is carried smoothly or has a scarcely perceptible rising and falling movement during the time the legs are making their backward movement. A vertical boiler and the engine are carried on the rear portion of a platform, the front of which is supported on caster wheels, which are each connected with their pivots by means of two pairs of curved plate springs. Cat. No. 251,276 U.S.N.M.

Gasoline Automobile, 1892-1893. Gift of Inglis M. Uppercu, 1920.

This motor car was designed and constructed by Charles E. Duryea at Springfield, Massachusetts, during the year 1892–1893 and made a successful road test early in September, 1893. It is the

FIG. 24.—DURYEA GASOLINE AUTOMOBILE, 1892–1893.

second machine made by Duryea, the first having been completed in the autumn of 1892, which upon its trial was found to be satisfactory in design but lacking in power, and was therefore dismantled. The second machine duplicates the first in design but is equipped with a more powerful motor.

The motor is single cylinder, four cycle, water cooled, and is placed almost horizontally beneath the phaeton carriage body with its head extending backward and above the rear axle. The motor, transmission gears, and differential are swung in a frame supported at three points by rods, two at the rear axle and one at the center of the front axle. The power of the motor is transmitted through bevel gears to a main horizontal shaft, and thence by rawhide gears to a jackshaft paralleling the main shaft, at the extremities of which is secured a sprocket wheel 1½ inches in diameter. Chains connecting these sprockets with sprockets 22 inches in diameter attached to the inner faces of the rear wheel wooden spokes deliver the power to these wheels.

On the main shaft are two friction clutches, one for forward speed and one for reverse. These clutches are operated through wire-rope connections by an up or down movement of the steering handle, the steering mechanism being of the tiller type. The steering knuckles on the front wheels are the C type, the pivot line of which intercepts the plane of the wheel at the ground.

The motor-starting crank projects at the rear and turns the crankshaft by means of a pair of bevel gears. The motor is equipped with a spray type carbureter but without a float, gasoline being fed into the float chamber from a tank situated above the motor at a rate intended to give maximum power at the desired speed. If the motor slows down the accumulation of excess gasoline in the float chamber overflows into a tank beneath the motor, from which it is returned to the main supply tank through the medium of a hand pump. Ignition is obtained by a "make and break" electric spark, the "break" being made by a projection in the piston head.

Cat. No. 307,199 U.S.N.M.

Gasoline Automobile, 1893-1894. Gift of Elwood Haynes, 1910.

This motor car was designed by Elwood Haynes and built in Kokomo, Indiana, during the years 1893–1894. On July 4, 1894, a successful trial trip was made at a speed of six to seven miles an hour. The extreme dimensions of the car are, length, 7 feet 8 inches; width, 6 feet 6 inches; and height, 5 feet 2 inches.

As it now stands, the machine is not as it originally appeared, certain changes having been made about two years after the initial trial. These changes were the replacement of the one-horsepower engine by a two horsepower; the replacement of the 28-inch cushion-tire wheels with 36-inch pneumatic-tire wheels; and the substitution of a tiller type of steering mechanism for the original worm type attached to the center of the axle. To make this change, the axle was made rigid by the braces of a single piece of rectangular steel extending from the ends of the axle through the swiveled head and attached thereto. Bell cranks were then attached to the front wheel spindles and the latter arranged to swivel in forks attached to the ends of the axle.

The vertical water-cooled motor delivers its power by double chain and sprockets to a jackshaft forward, thence to the rear wheels by a second set of chains and sprockets. Friction clutches on the jackshaft are operated by a vertical T rod within reach of the driver. On the lower end of this rod is a sprocket wheel and chain at the ends of which are attached wire ropes running over pulleys and attached to the clutches. Braking is obtained by a friction band on the jack-shaft, operated by a hand lever.

The water tank is beneath the carriage seat, while the radiator and gasoline tank are beneath the floor toward the front. The carbureter feed is controlled by a foot pedal. The motor is cranked through the spokes of the right rear wheel. The chassis is a rectangular tubular

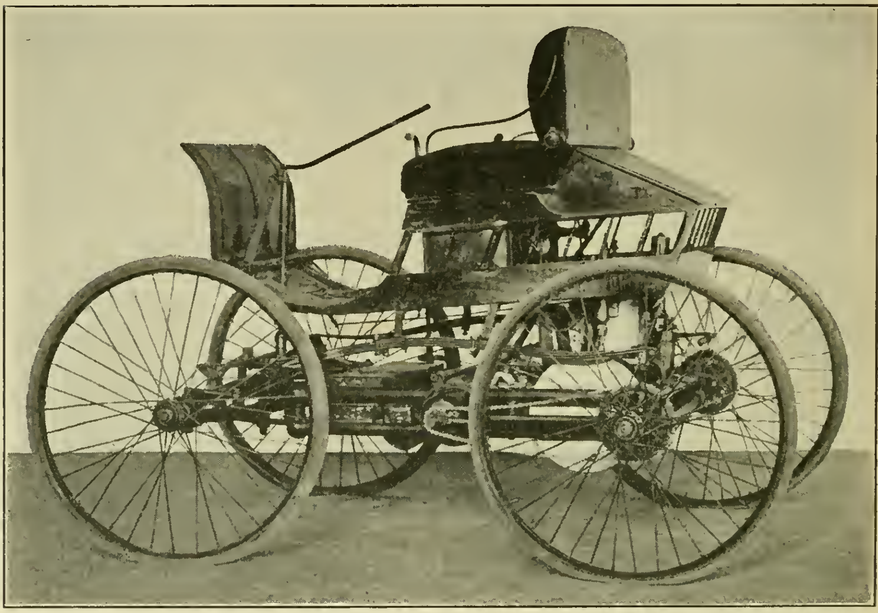


FIG. 25.—HAYNES GASOLINE AUTOMOBILE, 1893–1894.

frame upon which rests the auto body on semielliptical springs. Its total weight without passengers is 1,020 pounds.

Cat. No. 262,135 U.S.N.M.

Gasoline Automobile, 1894. Gift of Stephen M. Balzer, 1899.

This car was designed and built by Mr. Balzer in New York City in 1894. It is equipped with a three-cylinder air-cooled rotary motor whose power is transmitted through a chain of gears to a gear on the revolving shaft on which the rear wheels are mounted.

The rear wheels are 28 inches in diameter and the front wheels are 18 inches in diameter, equipped with pneumatic tires, and swung in forks of the bicycle type. Cat. No. 181,658 U.S.N.M.

Gasoline Automobile, 1896. Gift of the Olds Motor Works.

This machine was constructed by R. E. Olds in Lansing, Michigan, and was first successfully operated in 1896 at a speed of eight to ten miles an hour, carrying four passengers.

The car is equipped with a six horsepower single cylinder water-cooled motor placed horizontally beneath the rear portion of the carriage body, and with the crank shaft about midway between the

FIG. 26.—OLDS GASOLINE AUTOMOBILE, 1896.

front and rear axles. Power is transmitted through sprockets and chains to the rear driving wheels. The wheels are of wood equipped with solid rubber tires. Mounted on an extension of the crank shaft are friction clutches controlled by a vertically revolving post near the driver. The steering mechanism is of the tiller type, the right and left motions being transmitted to the wheel spindles through a radius rod.

The whole power plant is swung centrally beneath the body, the crank-shaft end of the motor being supported by curved iron straps attached to the front axle, and the cylinder head hanging from the rear portion of the body over the axle. A cellular water-cooling radiator is attached to the under side of the carriage body above the motor. The water tank is located below the rear seat of the carriage, while the gasoline tank is placed parallel to the motor, but beneath it.

Cat. No. 286,567 U.S.N.M.

Gasoline Automobile, 1901. Gift of The Autocar Company.

This motor car was designed and constructed by Louis S. Clarke, vice president and consulting engineer of The Autocar Co., in Ardmore, Pa., between September, 1901, and December of that year, and is believed to be the earliest motor vehicle equipped with shaft drive. It was first exhibited at the automobile show held in Madison Square Garden, New York City, December 11, 1901, having been driven

FIG. 27.—SHAFT DRIVEN AUTOCAR, 1901.

there under its own power from Ardmore, Pa., a distance of over 90 miles, in 6 hours and 15 minutes. The car was run by Mr. Clarke, exactly as built and as it now is, for over three years and covered a total of at least 5,000 miles.

The gasoline engine is of the opposed type, having two water-cooled cylinders each of 3¾ inches bore and 4-inch stroke, and equipped with automatic inlet valves. The transmission is of the selective type, having two forward speeds and reverse. The power is delivered to the rear wheels through a shaft coupled by two universal joints. Lubrication is effected from a dashboard sight-feed oiler. The frame is made of wood and reinforcing steel and is supported on the axles by four full elliptical springs. This car has a seating capacity for four persons, the two tonneau seats being entered from the rear. The wheel base is 66½ inches and the tread 56 inches.

Cat. No. 307,257 U.S.N.M.

RAILWAY LOCOMOTIVES.

The first practical locomotive engine designed to run upon rails was built in 1804 by Richard Trevithick, a Cornish mine captain, in southern Wales. In the same year Oliver Evans, of Philadelphia, Pennsylvania, built a steam dredging scow weighing about 4,000 pounds. To convey it from his shop to the river, he mounted the scow upon wheels and propelled it by the steam engine. This was the first self-propelled vehicle to run on American soil.

While Trevithick's locomotive in itself was successful, the cast-iron railway—the rail was an extended angle iron, having a 3-inch face upon which the wheels ran, the vertical face acting as a guide and being on the inside—proved faulty and broke continually, so that from an economic point of view the locomotive was more expensive than the horse. To devise a locomotive whose weight would have sufficient adhesion and still be light enough to prevent the breaking of rails engaged the attention of inventors for the next twenty years in England. Thus John Blenkinsop in 1811 patented a rack railway and locomotive and William Hedley in 1813 built a locomotive named "Puffing Billy" which had smooth wheels coupled together by gearing. It was the beginning of the grasshopper type of engine which became the fashion until 1829. George Stephenson in 1814 constructed his first locomotive, which was not a success, but in his second he used the direct action of the connecting rods on the driving wheels, and at first used coupling rods for connecting the wheels, but later discarded them for chain gearing, with the result that a successful type of locomotive was obtained and one superior to horse traction.

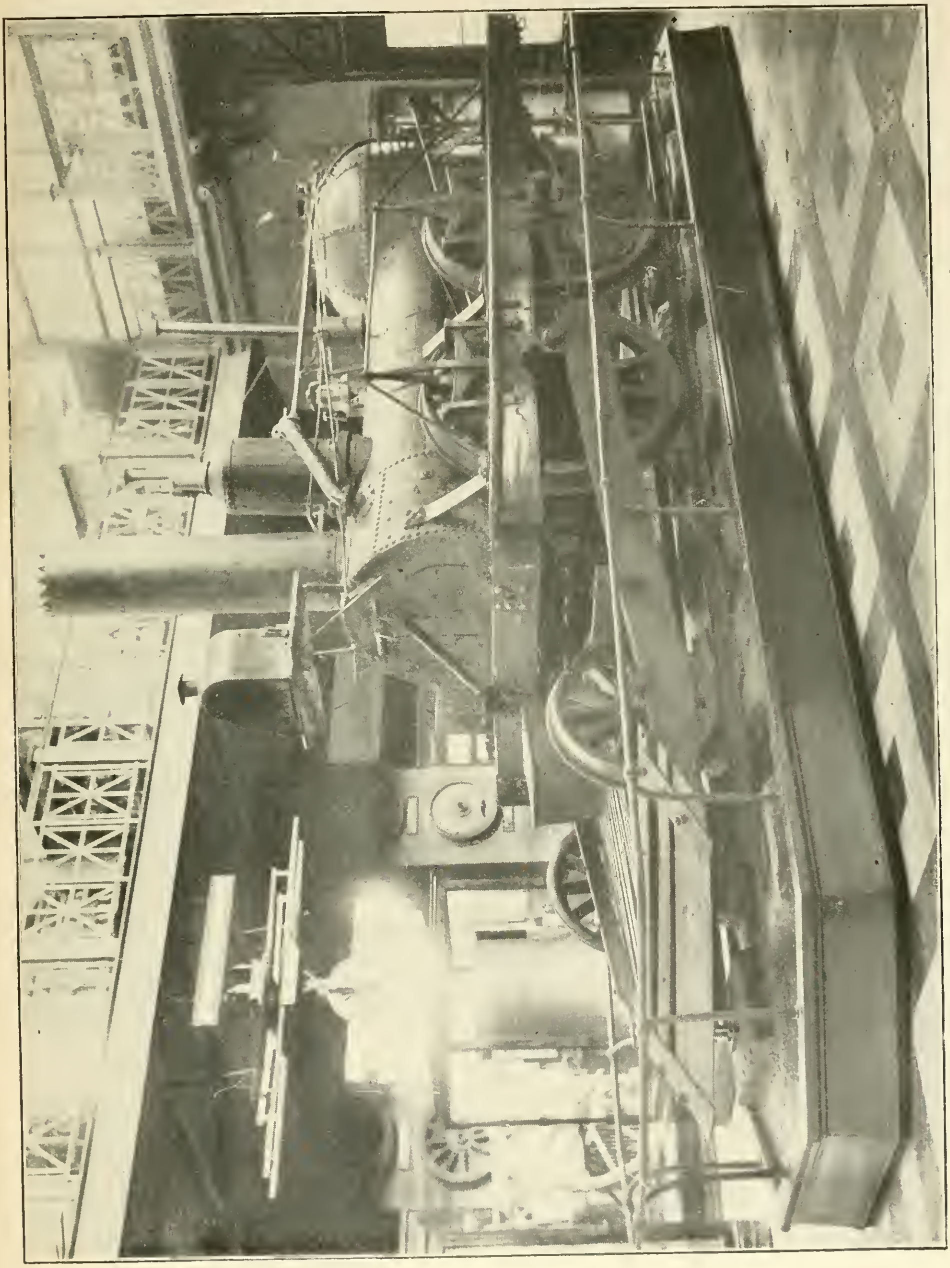
The results obtained by Stephenson's locomotive "Rocket," built in 1829 for the Liverpool and Manchester Railway, settled definitely the relative merits of the steam locomotive and the horse-drawn vehicle in favor of the former, and laid the foundation for the successful future of railway transportation.

In the United States railway developments paralleled those of England. The South Carolina Railroad Co. was the first in the world to decide that its railroad should be operated by steam locomotives. Its construction was begun in 1827, but delays prevented its opening until after a portion of the Baltimore & Ohio Railroad was in operation. The first locomotive on the American continent designed to run on rails was bought in England and brought to this country for the Delaware & Hudson Canal Co., while the first American-built locomotive for actual service was designed by a merchant of Charleston, South Carolina, was built by the West Point Foundry, New York City, and tried out on the South Carolina Railroad in 1831. As early as 1812 John Stevens, of Hoboken, urged the building of railways operated by steam locomotives rather than the building of canals. In an endeavor to have a more convincing argument as to the feasibility of the steam locomotive, Stevens built a locomotive in 1825 and operated it on a circular track in Hoboken.

The whole country realized the necessity for means of transportation of commodities but the people were divided in their opinions as to the form it should take—canals or railroads. Governor De Witt Clinton, of New York, urged the building of canals, more particularly the Erie Canal; John Stevens, Peter Cooper, and others advised the building of railways. In 1829 Peter Cooper constructed a model locomotive and ran it over the completed portion of the Baltimore & Ohio Railroad. The result was that the company offered a premium of $4,000 for a locomotive, built in the United States, which would draw 15 tons gross weight at 15 miles an hour. This offer in time brought five locomotives to the company, all built at different places, all different in design, and in no way resembling the British models. The first was made by George W. Johnson, a machinist of Baltimore, Maryland. The second was the "York," designed by Phineas Davis and built by Davis and Gartner, of York, Pennsylvania. It consisted of upright cylinders attached to the vertical boiler and transmitted power to the four driving wheels through connections with the side rods. The third was built in Philadelphia, Pennsylvania, by a watchmaker named Stacey Costell. Ezekial Childs, another watchmaker of Philadelphia, supplied the fourth, and the fifth was built by William T. James, of New York.

From 1820 on, sentiment in favor of railroad building developed very rapidly and the men who took the lead in advocating railroads were the most influential in the country and had clear conceptions of what they wanted. The Camden & Amboy Railroad and Transportation Co. was incorporated in February, 1830, and was authorized to construct a railroad from the Delaware River to Raritan Bay, that is, across the State of New Jersey. Its first locomotive was the "John Bull," purchased in England of Robert Stephenson & Company, and received in Philadelphia in 1831. The Mohawk & Hudson Railroad Co., chartered in 1826, began the construction of its railroad between Albany, New York, and Schenectady, New York, in 1830, which was completed and opened in August, 1831, the first train being drawn by the locomotive "De Witt Clinton," designed by John B. Jervis and built at the West Point Foundry, New York City.

Matthias W. Baldwin upon request built a model locomotive and train for the Philadelphia Museum in 1831. Shortly after its completion Baldwin was engaged to build a locomotive for the newly incorporated Philadelphia, Germantown & Norristown Railroad Co. He took as a working model the locomotive "John Bull," and from



THE "JOHN BULL" LOCOMOTIVE. THE OLDEST COMPLETE LOCOMOTIVE IN AMERICA.

FOR EXPLANATION OF PLATE SEE PAGE 64.

it built "Old Ironsides," which was tried out late in 1832. His second locomotive was the "E. L. Miller," completed in 1834, which had very little that was decidedly original, but old forms were combined in a shape that produced the best locomotive then built, and the American locomotive of to-day is undoubtedly a direct development of the "E. L. Miller." Its particular features were a horizontal boiler with Bury's haystack fire box, one pair of driving wheels located behind the fire box, the Jervis four-wheel swiveling truck under the smoke box, and outside wooden frames sheathed with

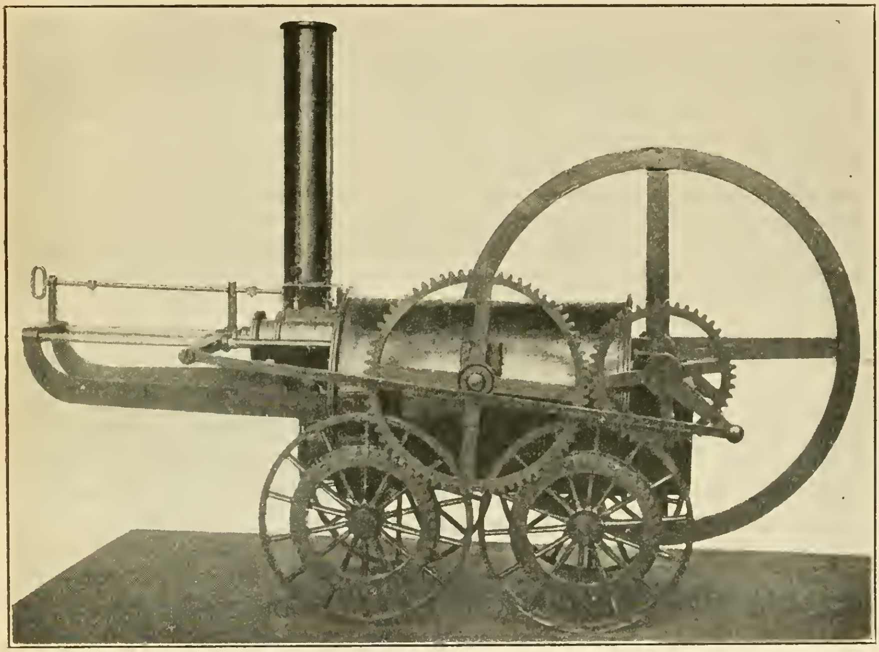


FIG. 28.—TREVITHICK LOCOMOTIVE, 1804.

iron. The cylinders, 10 by 16 inches, were secured between the smoke box and frames and transmitted power to the driving wheels through a half-crank axle. The engine weighed in working order about 16,600 pounds.

Model of Trevithick Locomotive, 1804. Made in the Museum.

While building some of his high-pressure steam engines at the Pen-Y-Darran Iron Works near Merthyr, Tydvil. in 1803, Trevithick undertook to construct a steam locomotive to haul trucks on a tramway a distance of about 9 miles. The engine was completed early in 1804, and upon its trial drew five wagons with a load of 13 tons at a speed of about 5 miles an hour, with a coal consumption of about 25 pounds a mile. It also drew empty wagons up an incline of one in eighteen at the rate of 4 miles an hour. Owing to the frequent breakages of the cast-iron tram parts, however, the locomotive was abandoned as such and used for stationary purposes. The model, therefore, represents the first steam engine that ran on a track by the force of high-pressure steam, relying wholly upon the adhesion of smooth wheels.

The locomotive had a single horizontal cylinder 8¼ inches in diameter by 54 inches stroke, inclosed in the boiler, which was of cast iron, 6 feet long and 4½ inches in diameter, with a wrought-iron furnace flue. The piston-rod crosshead was controlled by round guide bars, and from it passed two return connecting rods to the cranks on the flywheel shaft. on which was a spur wheel gearing into a larger intermediate spur wheel carried by a stud on the side of the boiler; this wheel geared into a spur wheel on each of the two travelling axles, so that the adhesion due to the total weight of the engine was available for traction. The traveling wheels were 45 inches in diameter and revolved at practically the same speed as the crank shaft, so that the tractive effort per pound of mean steam pressure in the cylinder was about forty pounds. The valve arrangement consisted of a four-way cock worked by a tappet rod from the crosshead. The steam was delivered into the chimney, where it was noticed that the waste heat rendered it invisible, and it made the draft much stronger. (*The Science Museum.*)

The total weight of the engine in working order was five tons.

Cat. No. 180,058 U.S.N.M.

Lithograph of Trevithick's Newcastle-upon-Tyne Railway Locomotive, 1805, from the "Memorial Edition of the Life of Richard Trevithick. E. and F. N. Spon, London, England, 1883." Five views presented by Trevithick's granddaughter through Colonel Davis, of London.

This locomotive was built in Newcastle about the end of 1804. It differed from its predecessor (the South Wales locomotive) in being fitted to run on a railway by using flanged wheels.

Cat. No. 180,740 U.S.N.M.

Print of Trevithick's London Circular Railway and "Catch-me-who-can" Locomotive, 1808. Woodcut from the "Memorial Edition of the Life of Richard Trevithick, E. and F. N. Spon, London, England, 1883." Presented by Trevithick's granddaughter through Colonel Davis, of London.

Between the close of 1800 and May, 1805, Trevithick had constructed two road locomotives in Cornwall, a tramway locomotive in Wales, and one railway locomotive in Newcastle. All these had some form of blast pipe. For the next three years Trevithick did nothing with the locomotive, but in 1808 he constructed, at his own cost, a locomotive and a circular railway on the southern half of the present Euston Square, London. The engine working on this railway was called "Catch-me-who-can." It weighed 10 tons and attained a speed of 12 miles an hour. It ran for some weeks, when a rail broke and it left the road and turned over. Trevithick, having expended all his means to convince the public of the utility of the locomotive, was compelled to give up his endeavors. There is no record to show that Trevithick ever resumed his labors in this branch of engineering. Cat. Nos. 180,734–735 U.S.N.M.

Photograph of "Locomotion," Engine No. 1, (1825) of the Stockton and Darlington Railway, England.

This is the first locomotive built for the first railway in the world and constructed for general traffic. The photograph was made at the Chicago Exposition of Railway Appliances in 1883, when the locomotive was exhibited by the Stockton and Darlington Railway.

The engine has two vertical cylinders, 10 inches in diameter by 24 inches stroke, each driving by side-connecting rods a pair of 48-inch driving wheels. These wheels are of cast iron and are coupled together by external rods that elevate the driving crank pins of the ordinary type driven by rocking shafts, which both receive their motion from a single eccentric on the leading axle, one shaft being rocked directly and the other through a "bell-crank" lever. A platform runs along each side of the boiler, and from one of these the engineer has control of the valve rods for disengaging and reversing. The tractive power for this engine per pound of mean pressure in the cylinders was 50 pounds, but the boiler pressure used was only 25 pounds per square inch. The exhaust steam from both cylinders was conveyed by two waste pipes to the chimney. The feed water was forced into the boiler by a single feed pump, 4 inches in diameter, driven by a lever from the crosshead. The boiler is 10 feet long and 4 feet in diameter, delivering into the chimney, which is 17½ inches in diameter.

The wheel base of the engine is 5 feet 4 inches, and the weight in working order is 6½ tons. The tender is built of timber and holds fifteen hundredweight of coal and carries an iron tank containing 240 gallons of water. (*The Science Museum.*)

This locomotive is estimated to have been about 20 horsepower and to have a speed of about 8 miles an hour.

Cat. No. 180,760 U.S.N.M.

Model of the "Rocket" Locomotive and Tender, 1829. Made in the Museum.

This model represents the celebrated engine constructed by R. Stephenson & Co. in 1829 to compete for the prize of £500 offered by the Liverpool and Manchester Railway in England to the makers of the most successful locomotive.

The competition commenced on October 6 and continued for eight days. "The Rocket" won the competition against four other entries. These were "The Novelty," made by Messrs. J. Braithwaite and J. Ericsson; "The Sans Pareil," made by Timothy Hackworth; "The

Perseverance," made by T. Burstall; and the "Cyclopede," made by T. S. Brandreth. Trials were conducted at Rainhill, near Liverpool, on a level piece of the line 1¾ miles in length, of which 220 yards at each end were allowed for starting and stopping. The competing engines were required to make ten double trips, going over the central 1½ miles at full speed, which was to represent a journey from Manchester to Liverpool. Then a fresh supply of water and fuel could be taken up and the second ten trips performed, which represented the return journey. The average speed throughout had to be no less than 10 miles an hour. "The Rocket" was the only en-

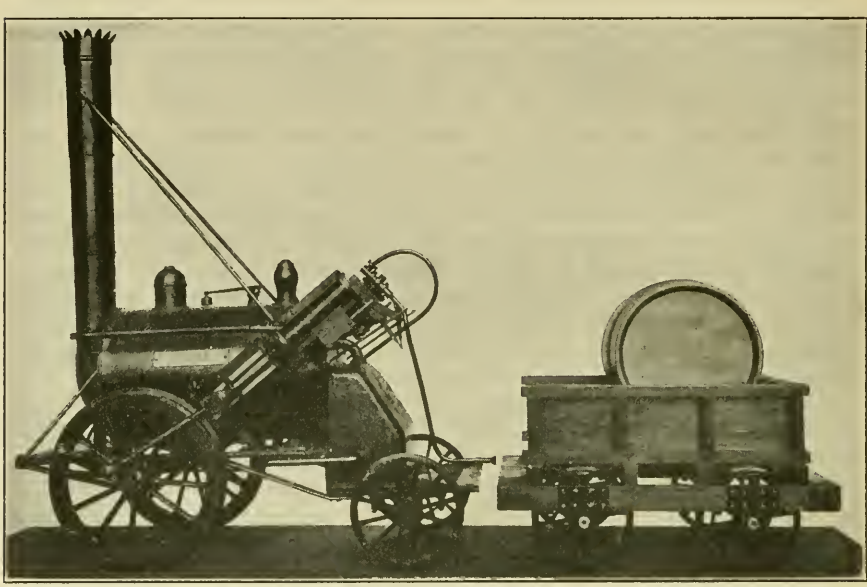


FIG. 29.—STEPHENSON "ROCKET," 1829.

gine to complete the journeys and fulfill all the conditions, and was, therefore, awarded the prize. She weighed 4¼ tons and drew a load of 12¾ tons. She completed the whole of the double journey at an average speed over the central portion of the track of 13.8 miles an hour, her maximum speed for one trip being 24.1 miles an hour.

The engine ran on four wheels and had two cylinders 8 inches in diameter by 17 inches stroke placed at the rear end of the boiler and inclined downward at 37 degrees with the horizontal; the piston rods drove the front wheels, which were 56.6 inches in diameter, thus giving a tractive factor of 19.4. The trailing wheels were 34 inches in diameter and the wheel base 7.17 feet. The cylinders were mounted on iron plates which were bolted to the boiler shell and supported by stays; these plates also carried the guide bars, which were of square section set diagonally, while the crossheads were of brass, in halves, bolted together and embracing the bars. The steam chests were below the cylinders and the slide valves were driven through an intermediate shaft and levers by a pair of eccentrics fixed to a loose sleeve which could be moved endwise along the shaft by a pedal so as to engage with either of two drivers, one set for forward and the other for backward running. The valve rods had gab ends, so that the valves could be disengaged and worked by hand levers when reversing. The crank pins had spherical ends to allow for irregular motion of the engine relative to the driving axle.

The boiler was a cylindrical shell 40 inches in diameter by 6 feet long, made in two rings, with a circumferential lap joint and longitudinal butt joints, the flat ends being secured by angle rings and tied together by longitudinal stays. The shell was traversed by 25 copper tubes 3 inches in diameter secured in holes through the end plates. The fire box shown is of the original design, but it is not certain how soon it was altered in shape. It was a separate chamber of copper bolted on to the back end of the barrel. It was rectangular in plan, with a sloping back, in which was the fire box. There were water spaces at the top, back, and sides, while there was a fire-brick lining in front below the tubes. Copper pipes connected the water and steam spaces of the fire box with those of the barrel. The total heating surface of the boiler was 138 square feet, that of the fire box being 20 square feet, and the grate area was 6 square feet. The chimney was nearly 15 feet high above the rails and was swelled out at the base to cover the tube ends, and was supported by stays from the cylinder plates.

Steam from the boiler was admitted to the cylinders by two pipes leading from a regulating cock fixed above the fire box, and which received steam from a dome through an internal pipe. The boiler pressure was limited to 50 pounds per square inch by two safety valves, one of which was loaded by a spring and lever, while the other was a lock-up valve covered by a small dome. A mercurial gauge was fitted beside the chimney and was arranged to indicate the steam pressure from 45 to 60 pounds. A water gauge was fitted behind one of the cylinders and two gauge cocks near the front end of the boiler. The feed water was introduced by a long stroke feed pump worked from one crosshead, while the exhaust steam was passed into the chimney by two pipes, each fitted with a brass nozzle 1.5 inches in diameter.

The framing of the engine was wholly between the wheels and was built of flat bar iron bent down at the rear end to accommodate the fire box and rear axle; to this the cast-iron guides were secured, and four brackets to support the boiler. The weight was transmitted to the axles by plate springs. The driving wheels were constructed with cast-iron bosses in which the crank pins were fixed, oaken spokes and fellies, and iron tires secured by bolts. The engine weighed 3.25 tons when empty and 4.25 tons in working order.

The tender was a four-wheeled wooden truck carrying the fuel in the body and the water in a large barrel above it. The axles had outside bearings and plate springs, the wheels were 36 inches in diameter and the wheel base was 4 feet. It weighed 3.2 tons when loaded, so that the total weight of engine and tender in working order was 7.45 tons. Cat. No. 180,243 U.S.N.M.

Model of John Stevens Experimental Locomotive, 1825. Made in the Museum.

The locomotive consists of a four-wheel platform truck upon which is mounted a vertical tubular boiler inclosed in a circular sheet-iron casing terminating in a conical hood that holds the furnace door.

and upon the hood rests the smoke-stack. The furnace and its grate are circular and are placed inside of the circle formed by the boiler tubes and thus are inclosed by them. The grate rests on the projecting ledge of the lower part of the boiler. A single horizontal cylinder with valve chest on top is situated alongside the boiler and transmits its power to a crank shaft on which is mounted a gear wheel. This gear engages a second and larger gear vertically beneath it, which in turn meshes into a rack rail situated midway between the rails and about on a level with them. Four vertical posts extending downward from the floor of the truck near each

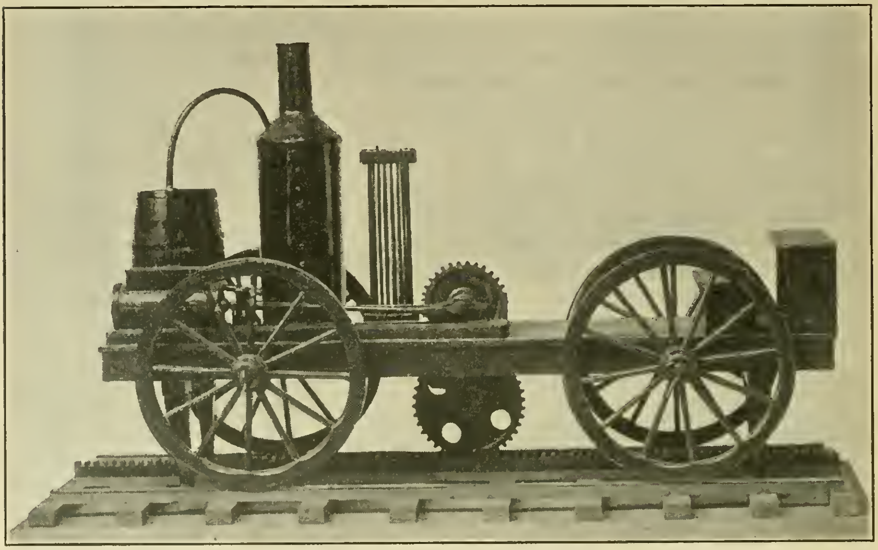


FIG. 30.—STEVENS' EXPERIMENTAL LOCOMOTIVE, 1825.

corner and terminating in rollers in contact with the inner face of the rails, guide the truck on the track.

The locomotive was operated by Stevens on a circular track at Hoboken, New Jersey, and carried six people at a speed of over twelve miles an hour. Cat. No. 181,241 U.S.N.M.

Original Tubular Boiler Designed and Patented by John Stevens in 1803, and Used on His Experimental Locomotive in 1825. Deposited by the Stevens Institute of Technology.

The boiler consists of twenty vertical tubes connecting the water chamber at the bottom with the steam chamber at the top. The outside diameter of the circle formed by the tubes is 12 inches, each tube being $40\frac{1}{2}$ inches long by $1\frac{1}{4}$ inches in external diameter.

The steam and water chambers are annular spaces of about 1 square inch cross section and $10\frac{1}{2}$ inches in diameter, containing each about 33 cubic inches.

The cap of the steam chamber is secured by ten large and five small bolts, the diameters of which are eleven-sixteenths and five-eighths of an inch, respectively. The steam outlet at the top is a pipe 1 inch in diameter, the water inlet being a similar aperture at the bottom.
Cat. No. 180,029 U.S.N.M.

FIG. 31.—HORSEPOWER LOCOMOTIVE, "THE FLYING DUTCHMAN," 1830.

Model of "The Flying Dutchman," Horsepower Treadmill Car. Made in the Museum.

In 1829 the South Carolina Railroad Company offered a premium of $500 for the best locomotive operated by horsepower. This premium was awarded to Mr. C. E. Detmold, who invented one which was worked on an endless-chain platform or treadmill.

When this horsepower locomotive was completed and tested upon the road in 1830 it carried 12 passengers at the rate of 12 miles an hour. It was propelled by one horse walking on the treadmill, which was connected by gearing to the carwheel axles.
Cat. No. 181,086 U.S.N.M.

Parts of the Locomotive "Stourbridge Lion" Consisting of boiler, wheels, walking beams, and one cylinder. The first locomotive on the Western Hemisphere to run on a railroad built for traffic. Gift of the Delaware and Hudson Canal Co.

The locomotive, "Stourbridge Lion," is a four-wheeled engine, all of whose wheels are "driving wheels" and 4 feet in diameter. The boiler is cylindrical and horizontal, 10½ feet long including the swell of the end plates, and 4 feet 2 inches in diameter. It is constructed of iron plates, one-half inch thick, and originally a chimney 18 inches in diameter rose from the top of the boiler near its forward end to a height of about 15 feet from the top of the rails. The fire box was cylindrical, 28 inches in diameter and extending into the boiler 4 feet, from which two flues 18 inches in diameter extended to the bottom of the smokestack. Besides the necessary openings for the passage of steam from the boiler, there was near the center of its top an oval opening 12 inches wide and 16 inches long, called a "manhole," for the convenience of cleaning or repairs. The front end of the boiler was ornamented with a representation of the face of a lion and the name "Stourbridge" was distinctly lettered on a plate attached to its side.

The boiler was originally supported on a strong, wrought-iron frame, the front two-thirds part of which rested on two, many plated heavy steel springs which rested on the axle of the forward wheels, and the rear one-third part rested on supports on the axle of the rear wheels.

Under the center of the boiler and supported by this iron frame was a small water tank from which water to supply the boiler was pumped.

The hubs of the wheels were of iron and were "made fast" to the axles so as only to turn with the axles. The spokes and fellies were of wood and painted bright red. The tires were of wrought iron 4 inches wide and ½ inch thick, formed of two plates each three-fourths of an inch thick and fitted one around the other. They were 4 feet in diameter, exclusive of the flanges, which projected three-fourths of an inch beyond the face of the tires.

A cylinder was placed upright on each side of the rear end of the boiler arranged for a stroke of 36 inches. The upper end of each piston rod was connected to one end of a lever 6 feet in length called a "walking beam," in form resembling the walking beam of a steamboat, the other end of which rested on fulcrums on the top of two movable or vibrative upright iron rods, connected together by cross braces, the bottom of the fulcrum rods working on hinge joints and the top being of such height that when the piston was at half stroke the beam would be level.

Attached to the head of each cylinder was an iron frame consisting of two upright posts so placed that the piston end of the beam would pass between them and permit the end of the beam to pass clear of it. The height of these frames was on a level with the head of the piston rod when at half stroke. These frames were firmly braced so as to hold them perfectly in place.

In the center of each walking beam a journal projected on each side to which two radius rods were attached, the other end of such rods being attached by journals to the head of the posts of the upright iron frames in such positions that their journals would be exactly in line with the piston-rod journal when the piston was at half stroke. By this arrangement the head of the piston rod was at all times kept in line with the center line of the cylinder.

The valves regulating the passage of steam into and out of the cylinders were operated by rods and cranks connected with eccentrics on the rear axles, the angle of the eccentrics being such that when one piston was at full stroke the other would be at half stroke.

The journals for connecting the crank rods with the walking beams were placed at a distance of 18 inches (one-fourth the length of the beam) from the piston-rod journal, thus making the diameter of the crank sweep equal to three-fourths of the stroke of the piston. Crank rods extended from these journals to the crank pins in the rear wheels and these, by horizontal connecting rods, were made to turn the forward wheels.

The exhausted steam was discharged from the cylinders into two pipes 2½ inches in diameter, one being attached to each cylinder and extending downward into the small water holder under the boiler, thus utilizing the heat of such exhausted steam in partially heating the water for supplying the boiler. From this small water holder one pipe extended forward under the boiler and upward across its front end, where it discharged into the chimney.

The engine was provided with two safety valves, one of which was placed back of the center of the boiler where the engineer could have ready access to it and the other was placed very near to and in the rear of the chimney and was so covered by a dome as not to be easily accessible. The reason for such arrangement may be inferred from one of the conditions contained in the offer by the Liverpool and Manchester Railway managers in 1829 of a £500 prize for the best locomotive for passenger trains, namely, "The boiler must have two safety valves, neither of which must be fastened down, and one of them completely out of control of the engineer."

The "Stourbridge Lion" was built by Foster, Rastrick & Co., in Stourbridge, England, a manufacturing town on the River Stour, about 15 miles west of Birmingham. It was manufactured especially for the Delaware & Hudson Canal Co. by order of Mr. John B.

Jervis, president of the company, who commissioned Horatio Allen, a prominent practical engineer, to arrange the details for this work.

In February, 1829, the "Stourbridge Lion" was sent by canal to Liverpool and consigned to William and James Brown, who were bankers for the Delaware & Hudson Canal Co., and on April 8, 1829, it was shipped from Liverpool on the *John Jay* for New York. The boat arrived in New York on May 14, and the parts of the locomotive were taken to the yard of the West Point Foundry Co., of which W. Kimball was the manager. This foundry was at the foot

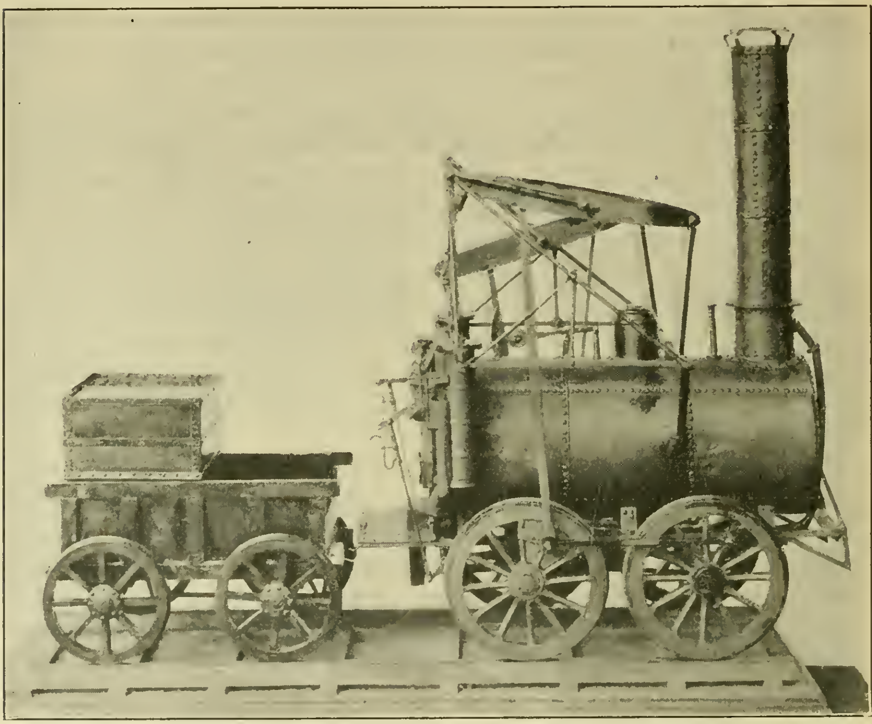


FIG. 32.—REPRODUCTION OF THE ORIGINAL "STOURBRIDGE LION" LOCOMOTIVE.

of Beach Street, North River, New York City. The locomotive was put together by David Matthew under the supervision of Horatio Allen, and was blocked up with wheels clear of the ground and run as an interesting exhibition to people who called to see it. It was later shipped up the Hudson River to Rondout, New York, and forwarded thence by the Delaware & Hudson Canal to Honesdale, Pennsylvania, arriving at that place on July 23. It was there elevated from the canal to the railroad track, which is said to have run on a trestle some distance from the canal. On August 8, 1829, the trial trip was made, and the locomotive, manned by Horatio Allen alone, ran out on the track a distance of about 1 mile to Seeleyville.

Horatio Allen's account of this trip is quite circumstantial, but does not agree with other statements which seem to be reliable. Mr. Allen says that he ran the locomotive 2 or 3 miles, while other statements are that the trip was not more than 1 mile long. It seems likely that, in addition to this first trial trip, a few other experimental trips were made and then the locomotive was laid aside.

Cat. No. 180,013 U.S.N.M.

Model of Locomotive "Stourbridge Lion." Made in the Museum.

There are quite apparent differences between this model and the partially assembled original locomotive on exhibition. As con-

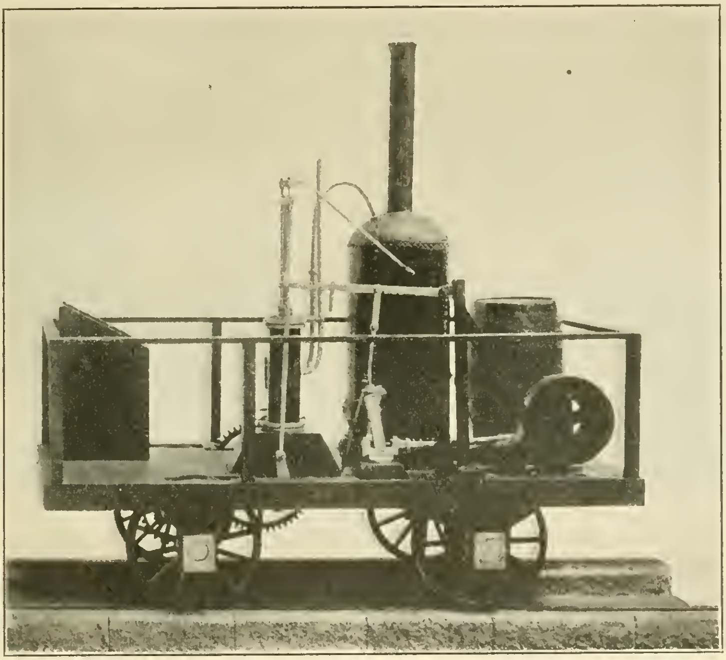


FIG. 33.—PETER COOPER EXPERIMENTAL LOCOMOTIVE, 1829.

structed, the model is a composite picture developed from numerous bits of what is believed to be reliable information gathered over a long period of years, and is considered to be a true likeness of the original as received from England. Cat. No. 215,649 U.S.N.M.

Model of the Experimental Locomotive "Tom Thumb," 1829. Made in the Museum.

This engine was designed and constructed by Peter Cooper in Baltimore, Maryland, and tested on the Baltimore & Ohio Railroad on August 28, 1829. On that occasion it drew a car carrying 24 passengers a distance of 13 miles in 72 minutes, and made the return trip in 57 minutes.

The engine was about the size of a modern hand car with one upright cylinder $\frac{3}{4}$ inch by $13\frac{1}{2}$ inches and an upright boiler, the tubes of which were made from gun barrels. The boiler was about as large as a kitchen boiler; stood upright in the car, and was filled above the furnace, which occupied the lower section, with vertical tubes. Draft for the fire was maintained by a revolving fan driven by a drum attached to one of the car wheels over which passed a cord that in its turn worked a pulley on the shaft of the revolving fan. The rotating action of the engine was transmitted to the wheels through a system of gears. Cat. No. 180,034 U.S.N.M.

Model of the "Best Friend" Locomotive, 1830. Made in the Museum.

This was the first locomotive built in the United States for actual service on a railroad. It was built at the West Point Foundry in New York City for the South Carolina Railroad and made its trial trip on January 15, 1831.

On March 1, 1830, a contract had been entered into with Mr. E. L. Miller, of Charleston, to construct a locomotive for the South Carolina Railroad that was to run 10 miles an hour and carry three times its own weight. Mr. Miller's locomotive was built at the West Point Foundry shops, at that time located at the foot of Beach Street, New York City. The "Best Friend" gave such good service that the managers of the road directed that a second locomotive be ordered from the same company with changes and modifications.

The Charleston Courier of January 17, 1831, described the initial trip as follows:

On Saturday last the first anniversary of the commencement of the railroad was celebrated. Notice having been previously given, inviting the stockholders, about one hundred and fifty assembled in the course of the morning at the company's building in Line Street, together with a number of invited guests. The weather the day and night previous had been stormy, and the morning was cold and cloudy. Anticipating a postponement of the ceremonies, the locomotive engine "Best Friend of Charleston" had been taken to pieces for cleaning, but upon the assembling of the company she was put in order, the cylinders new packed, and at the word the apparatus ready for movement. The first trip was performed with two pleasure cars attached, and a small carriage, fitted for the occasion, upon which was a detachment of United States troops and a fieldpiece which had been politely granted by Maj. Belton for the occasion.

Upon the return of the engine it was found necessary to tighten the packing, which occasioned some little delay. At about 1 o'clock she again started with three cars attached, upon which were upward of 100 passengers. At 2 o'clock a Federal salute was fired by the detachment of troops stationed upon the remains of the fortification erected during the Revolution near the Quarter House. At 4 o'clock the company commenced returning and were all safely landed at Line

Street before 6. The number of passengers brought down, which was performed in two trips, was estimated at upward of 200. A band of music enlivened the scene, and great hilarity and good humor prevailed throughout the day.

Mr. David Mathew, who was foreman of machinists in the West Point Foundry, Beach Street, New York City, when the "Best Friend" locomotive was built, writes the following particulars of the engine in a letter written in 1859 to William H. Brown, author of the "First Locomotive in America":

The "Best Friend" locomotive was a four-wheeled engine, all four-wheels drivers. Two inclined cylinders at an angle, working down on a double crank

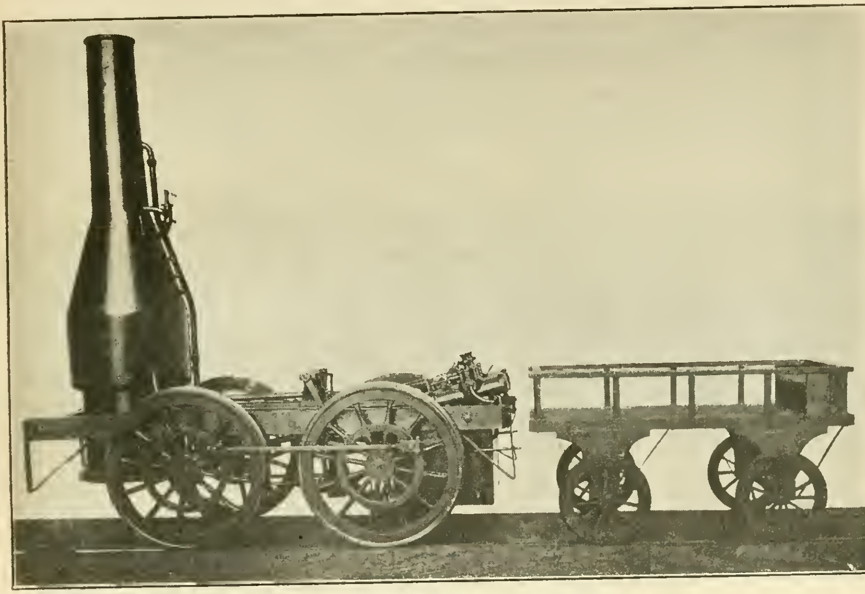


FIG. 34.—THE "BEST FRIEND" LOCOMOTIVE, 1831.

inside of the frame, with the wheels outside of the frame, each wheel connecting together with outside rods. The wheels had iron hubs, wooden spokes, and fellies with iron tires and iron web and pins in the wheels to connect the outside rods to.

The boiler was a vertical one in the form of an old-fashioned porter bottle. The furnace at the bottom was surrounded with water and all filled inside full of what we call teats running out from the sides and top, with alternate stays to support the crown of the furnace; the smoke and gas passed out through the sides at several points into an old jacket which had the chimney on it. The boiler sat on a frame upon four wheels, with the connecting rods running by it to come into the crank shaft. The cylinders were about 6 inches bore and 16 inches stroke and the driving wheels about 4½ feet in diameter. The whole machine weighed about 4½ tons.

Figured by present rules the traction force with 50 pounds boiler pressure was about 400 pounds. Also, at a speed of 20 miles an hour and a working steam at three-quarters stroke the engine would develop about 12 horsepower. Rich pine wood was the fuel used. Upon trial it was found that the wheels were too weak for lateral strains exerted upon them in rounding curves, and they had to be rebuilt with wrought-iron spokes.

The engine proved highly efficient and doubled the power and speed stipulated in the contract. Cat. No. 180,244 U.S.N.M.

Copy of the Original Drawing of the "West Point," the Second Locomotive Engine Built for Actual Service on a Railroad in the United States.

This locomotive was made for the South Carolina Railroad in 1830 by the West Point Foundry Association. It had the same size engine, frame, wheels, and cranks as the "Best Friend," but had a horizontal tubular boiler. The tubes were 2½ inches in diameter and about 6 feet long.

The public demonstration of this locomotive's power was made on March 5, 1831, on Sunday afternoon. The Charleston Courier of March 12th describes this trip as follows:

> The locomotive "West Point," under the charge of Stephen Lee Alison, underwent a trial of speed with the barrier car and four cars for passengers on our railroad. There were 117 passengers, of which number 50 were ladies, in the four cars, with 6 bales of cotton on the barrier car; and the trip to the Five-Mile House, 2¾ miles, was completed in eleven minutes. The 2¼ miles to the forks of Dorchester Road were completed in eight minutes. The safety has been insured by the introduction of the barrier car and the improvements of the formation of the flange of the wheels, which, we learn, was made by a young mechanic of the city, Mr. Julius D. Petsch, in the company's service.

The barrier car referred to was a car surmounted with six square bales of cotton strapped upon it by means of hoop iron, and was run with every passenger train, being placed between the locomotive and passenger cars as a means of protection from steam or hot water should an accident occur. Cat. No. 180, 711 U.S.N.M.

The Locomotive "John Bull," 1831. No. 1, Camden and Amboy Railroad Company. The Oldest Complete Locomotive in America. Built by George Stephenson and Son, Newcastle-upon-Tyne, England, 1830-31; Shipped from Liverpool July 14, 1831, on the Ship "Allegheny" Bound for Philadelphia. Gift of the Pennsylvania Railroad Company, 1885. Plate 2.

On November 12, 1831, in the presence of members of the New Jersey Legislature, with Isaac Dripps acting as engineer, in a train with two cars, this locomotive made the first movement by steam in the State of New Jersey, at Bordentown, where the Railroad Monument now stands. The "John Bull" was in continuous service from 1831 to 1865, during which time it was altered and added to. It was exhibited at the Centennial Exhibition, 1876, and at the Exposition of Railroad Appliances, Chicago, 1883. It was placed in the United States National Museum in 1885, where it remained until 1893, when (April 17–22) it was run under steam from New York to the World's Columbian Exposition, where for a time it made daily trips upon the exposition tracks. On December 13, 1893, it was returned to Washington, D. C., having made the last trip under steam on that date.

The original dimensions were as follows: Weight, 10 tons (22.425 pounds). Boiler, 13 feet long, 3 feet 6 inches in diameter. Cylinders, 9 by 20 inches. Driving wheels, 4 feet 6 inches in diameter: cast-iron hubs; locust spokes; tire of wrought iron, shrunk on; flange, 1½ inches deep. Sixty-two flues, 7 feet 6 inches long, 2 inches in diameter. Furnace, 3 feet 7 inches by 3 feet 2 inches high. Steam ports, 1⅛ by 6½ inches; exhaust ports, 1½ by 6½ inches. Throw of eccentric, 3½ inches. Grate surface, 10.08 square feet. Fire-box surface, 36 square feet. Flue surface, 213 square feet. Cat. No. 180, 001 U.S.N.M.

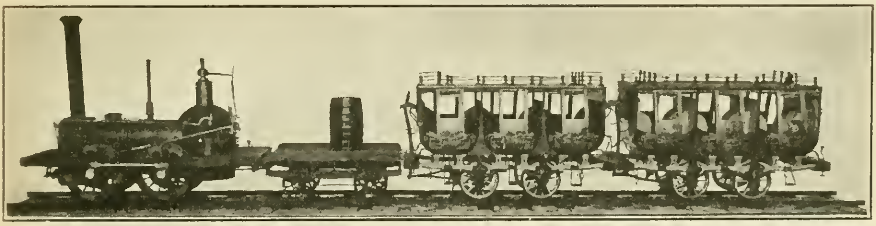


FIG. 35.—"JOHN BULL" AND TRAIN, 1831.

Model of Locomotive "John Bull" and Train. Made in the Museum.

This model represents the locomotive and train as it originally appeared on the date of the initial trip, November 12, 1831. By comparing the locomotive model with the actual engine as it now stands, the outstanding feature to be observed is the absence in the former of the pilot or "cowcatcher." The necessity for a pilot to remove obstructions off the track caused Isaac Dripps, master mechanic of the railroad, to design and add this forecarriage, which not only performed its specified duty but also carried some weight off the front driving wheels and performed, in a way, the functions of the swiveling truck.

Again, it will be observed that in the model the driving wheels are connected by rods (one on each side), while these are absent in the full-size machine. These rods were never used, owing to the sharp curves on the road.

The passenger coaches used were simply stage coaches, common at that time, equipped with flanged wheels. Cat. No. 233.510 U.S.N.M.

Copy of the Original Drawing of the "DeWitt Clinton," the Third Locomotive Engine Built for Actual Service on a Railroad in the United States. Made for John B. Jervis for the Hudson and Mohawk, a Railroad Between Albany and Schenectady, New York, in 1831, by the West Point Foundry Association.

The "DeWitt Clinton" had two cylinders, 5½ inches in diameter and 16 inches stroke; four wheels, all drivers, 4½ feet in diameter,

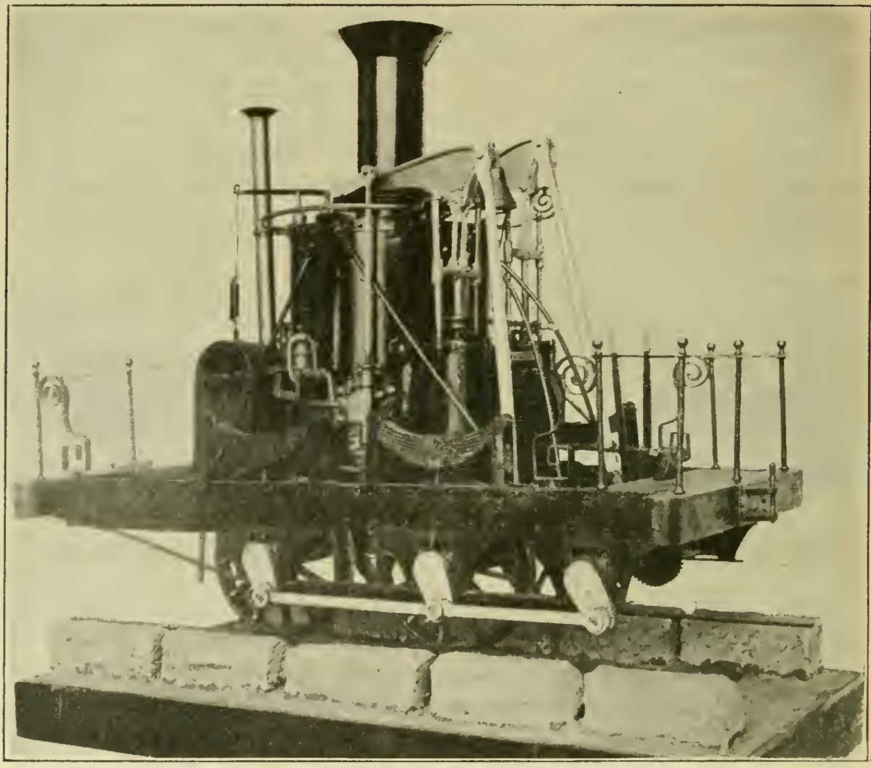


FIG. 36.—PHINEAS DAVIS "GRASSHOPPER" LOCOMOTIVE, 1831.

with all the spokes turned and finished. The spokes were wrought iron, hubs cast iron, and the wheels tired with wrought iron, with inside crank and outside connecting rods to connect all four wheels; a tubular boiler, with drop furnace, two fire doors, one above the other; copper tubes 2½ inches in diameter and about 6 feet long; cylinders on an incline, and the pumps worked vertically by bell crank. This engine weighed about 3½ tons without water, and would run 30 miles an hour with three or five cars on a level burning anthracite coal. It was the first engine to run in New York State on a railroad.

Cat. No. 222,113 U.S.N.M.

Model of the "Grasshopper" Locomotive, 1831. Made in the Museum.

The "Grasshopper" locomotive is so named from its peculiar motion. It was introduced by the Baltimore and Ohio Railroad in 1831, and remained in use on its line for many years.

The "Grasshopper" locomotive, more particularly called the "Atlantic" type, and which became for a time the standard form of engine on the Baltimore and Ohio Railroad, was designed by Phineas Davis, aided by Ross Winans, then assistant engineer of machinery of the Baltimore and Ohio Railroad. The "Atlantic"

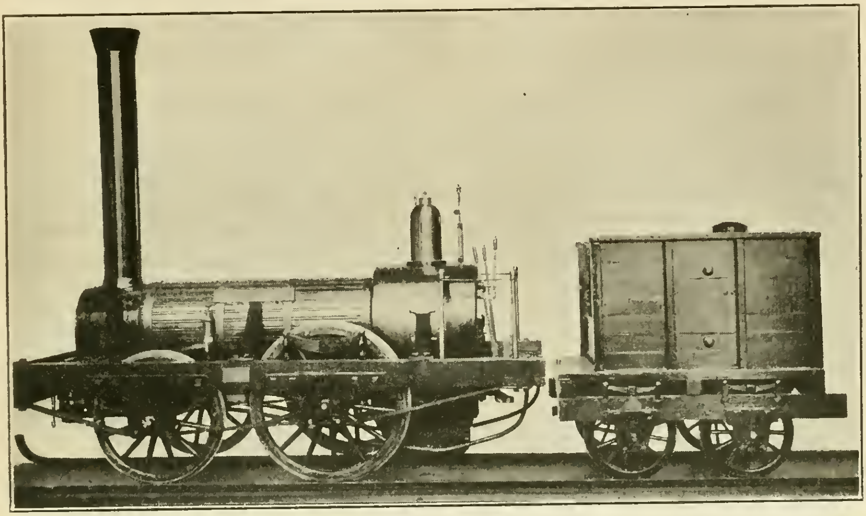


FIG. 37.—MATTHIAS BALDWIN "OLD IRONSIDES" LOCOMOTIVE, 1832.

had a vertical boiler with a fan driven by the exhaust steam for stimulating the fire.

There were two vertical cylinders 10 inches by 12 inches, whose power was transmitted to the supplementary driving shaft by means of a spur and pinion, which was geared up to make the wheels revolve twice for every turn of the crank. In this way wheels 3 feet in diameter were made equivalent to driving wheels 6 feet in diameter. About twenty engines of the "Atlantic" type were built and they worked very successfully in developing railroad traffic, going out of favor only when engines with a longer wheel base became necessary. Cat. No. 233,511 U.S.N.M.

Model of the Locomotive "Old Ironsides" and Tender, 1832. Gift of the Baldwin Locomotive Works.

This locomotive was the first built by Matthias Baldwin, the founder of the Baldwin Locomotive Works, in Philadelphia, and hauled the first passenger train in the State of Pennsylvania. The trial trip was made on the Norristown Railroad, November 23, 1832, traveling 6 miles at a speed of 28 miles an hour. After several successful trials "Old Ironsides" with improvements attained a speed of 30 miles an hour with the usual train attached.

The locomotive is a four-wheeled engine with the driving wheels in front of the fire box and the carrying wheels close behind the smoke box. In working order it weighed about 12,000 pounds. The cylinders were 9½ by 18 inches, the driving wheels were 54 inches, and the front wheels 45 inches. The boiler was 30 inches in diameter and contained seventy-two copper flues 1½ inches by 7 feet.

Cat. No. 180,114 U.S.N.M.

Photograph of the Locomotive "Pioneer," 1836. Purchased.

This locomotive was the thirty-seventh built by M. W. Baldwin and was completed in 1836 for the Utica and Schenectady Railroad. It was later sold to the Michigan Central Railroad and was called the "Alert." While owned by this road a few changes were made on the engine. Originally it had a single fixed eccentric for each cylinder, with two arms extending backward having drop hooks to engage with a pin on a rocker arm which actuated the valve rod. That motion was removed and double eccentrics with V-hook put in its place.

When the Chicago and North Western Railway began to lay its tracks in 1848, they purchased the "Alert" and renamed it the "Pioneer."

The "Pioneer" is the same type as Baldwin's second engine, the "E. L. Miller," but is larger and has 2 inches longer stroke and the improved valve motion just mentioned.

Cat. No. 180,046 U.S.N.M.

Model of the Locomotive "Sandusky," 1837. Made in the Museum.

This is the first locomotive built by Rogers, Ketcham, and Company, Patterson, New Jersey, completed in 1837, and placed in service on the Mad River and Lake Erie Railroad at Sandusky, Ohio, in 1838. Its cylinders were 11 inches in diameter by 16 inches stroke, with one pair of driving wheels 4 feet 6 inches in diameter, which were placed in front of the fire box. The engine had a truck in front with four 30-inch wheels; the cylinders were inside the frames and were connected to the wheel axle. The eccentrics were outside of the frame and the eccentric rods extended back to rocking shafts which were located on the footboard. The smoke pipe was of the bonnet type and had a deflecting cone in its center. The edges of the cone were curled over so as to deflect the sparks downward. The driving wheels were made of cast-iron with hollow spokes and rim, which at that time was a remarkable novelty. The section of the spokes was of the old form, and the rim was of very much the same shape as that in use at the present time. Another important improvement adopted in the construction of this locomotive was counterbalancing the weight of cranks, connecting rods, and piston. This counterbalancing was effected by casting the rim of the wheel opposite the crank in solid metal, while the other part of the wheel was made hollow. The importance of counterbalancing was not recognized until several years after it had been introduced by Rogers, Ketcham, and Company, and when attention was drawn to it many doubted the necessity of balancing anything more than the crank.

Cat. No. 180,245 U.S.N.M.

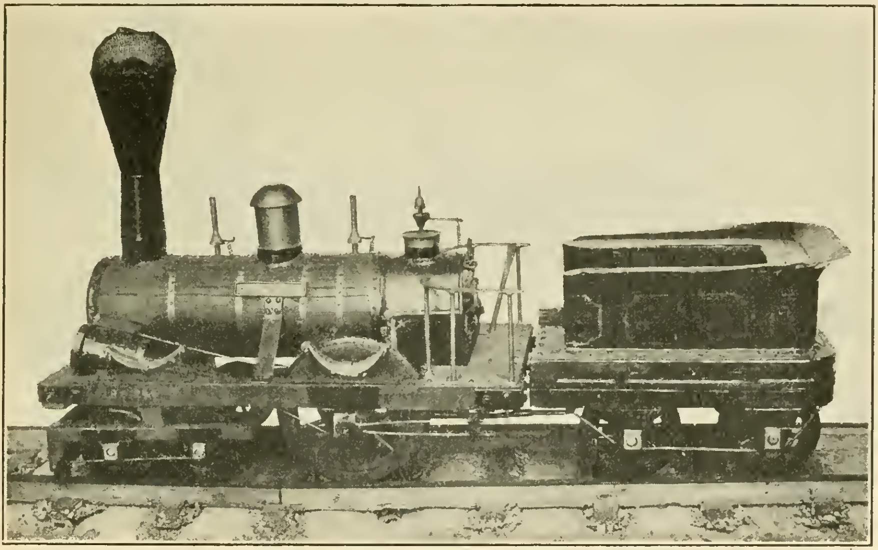


FIG. 38.—ROGERS, KETCHAM & CO. "SANDUSKY" LOCOMOTIVE, 1837.

Model of Locomotive Invented by Asa Whitney, U. S. Patent No. 1653, June 27, 1840. Transferred from the United States Patent Office.

To secure greater traction, this locomotive was designed to operate all wheels as drivers. The boiler, cylinders, etc., are secured to a framework supported on two four-wheel trucks. The forward truck is free to revolve about a center pin through the intervention of conical friction rollers traveling through circular arcs, and the rear truck likewise is equipped with rollers that it may conform to the curvatures and undulations of the track.

The power of the engine is transmitted to the wheels through two bell cranks and other connecting rods and cranks above and on each side of the boiler to a main central shaft beneath the boiler on which is a large spur wheel. This cog engages two cogs on either side of it secured to the axles of the middle wheels of the trucks, and through cranks on the extremities of these axles and connecting rods the power is communicated to the outside wheel axles. Thus all eight wheels are driving wheels. Cat. No. 251,271 U.S.N.M.

Model of Locomotive Invented by M. W. Baldwin. U. S. Patent No. 2759, August 25, 1842. Transferred from the United States Patent Office.

This locomotive contains features which will permit the wheels and axles to adapt themselves to the curves and undulations of the

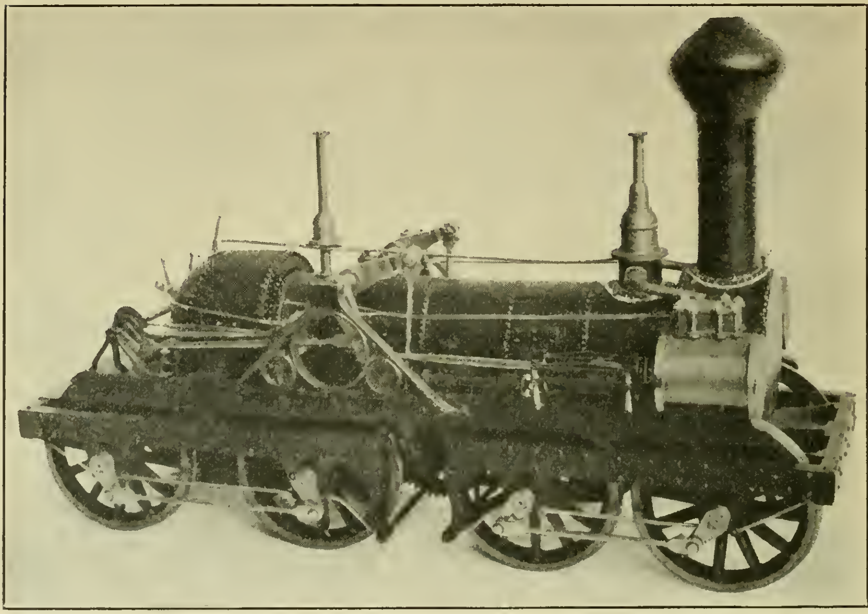


FIG. 39.—ASA WHITNEY LOCOMOTIVE, 1840.

railway bed. An adjustable pin is fixed vertically above the axles and to the frame on each side of the boiler, and extends downward and through a vibrating bar, terminating on the upper surface of the multileaf spring. The fore and aft ends of the spring are connected to the boxes in which the wheel axles revolve. The boxes are made so that they swivel in the plumber blocks which receive them, by boring cylindrical recesses in the blocks. These blocks are secured to the vibrating bar so that the parallelism of the axles is undisturbed. Cat. No. 251,274 U.S.N.M.

Model of Locomotive Invented by G. H. Nicolls, 1848. U. S. Patent No. 5532. Transferred from the United States Patent Office.

The object of this invention was to maintain the tractive power of a locomotive on ascending grades. The nature of the invention consisted in employing, in addition to the usual large driving wheels, a set of small drivers operated by an additional pair of engines. By this arrangement when the engine reached moderate grades the steam could be shifted from the engines of the large drivers to those of the small drivers. The difference in the diameter of the two sets, it was believed, would enable the pistons that operate the small drivers to work off all the steam generated in the boiler and to exert the required force to draw the train upgrade, although with reduced speed. When ascending grades of greater inclination, both sets of engines and drivers could be brought into play, and thus the locomo-

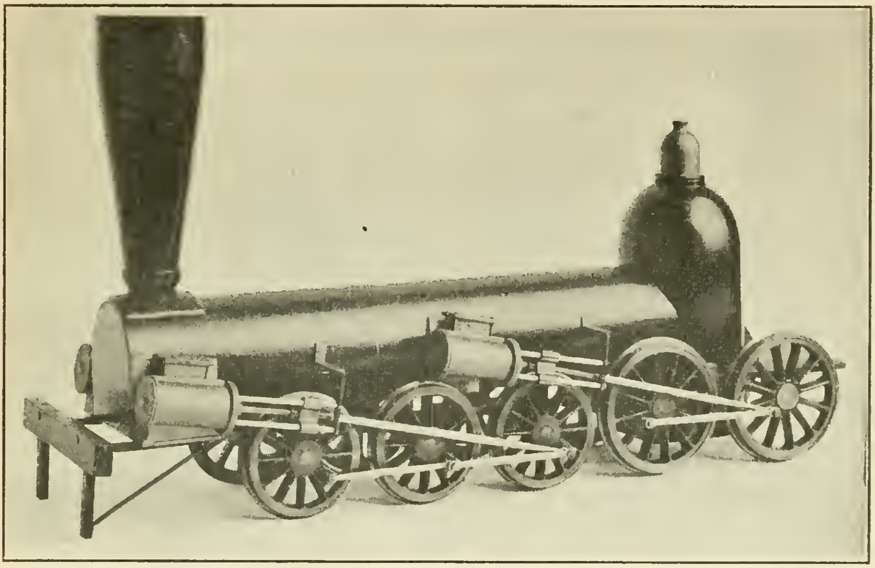


FIG. 40.—NICOLLS GRADE LOCOMOTIVE, 1848.

tive was adapted to all circumstances and rendered effective over the whole length of road without waste of power.

Cat. No. 251,270 U.S.N.M.

Model of Locomotive Invented by A. Cathcart in 1849. U. S. Patent No. 6818. Transferred from United States Patent Office.

The object of this invention was to enable a locomotive to draw cars up inclined planes without the use of stationary power. It consists in attaching auxiliary cylinders to the locomotive, which act upon a wheel considerably smaller than the ordinary driving wheels. This wheel is toothed and is connected with an intermediate driving wheel, which can be raised or lowered through a circular arc in which the axis of the small wheel is the center. This latter wheel is in turn lowered and gauges in a rack located between the rails.

Cat. No. 251,272 U.S.N.M.

Model of the Running Gear of a Locomotive. Patented in 1851 by Ross Winans and Incorporated in a Locomotive Used on the Baltimore and Ohio Railroad, Called "Carroll of Carrollton."

The early locomotive designers the world over made a common mistake in imagining that the size of driving wheels instead of the size boiler controlled the speed capacity of a locomotive. This idea led Ross Winans to invent and patent a locomotive which was called "Carroll of Carrollton." It had a single pair of driving wheels 7 feet in diameter and four-wheel trucks both front and rear. The deficiency of adhesion noticeable in other engines having larger driving wheels was supposed to be eliminated in this engine, but a trial did not prove this and the engine did not secure any success and never did any regular work. Cat. No. 251,273 U.S.N.M.

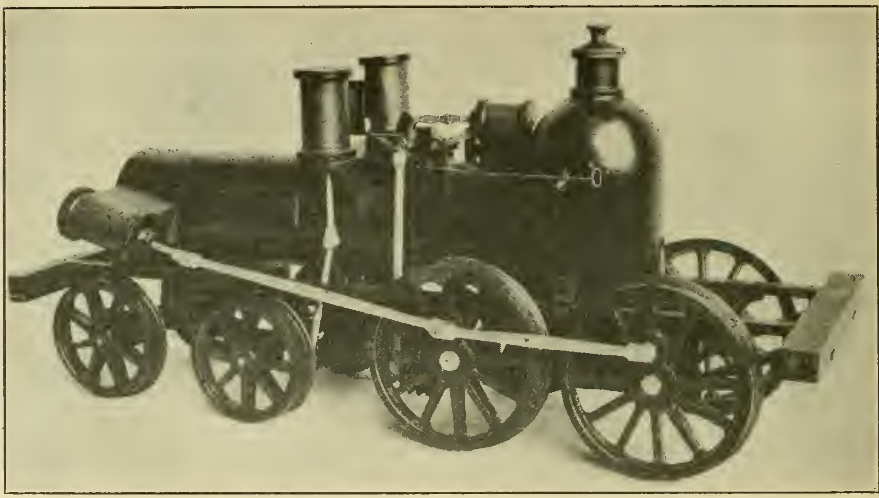


FIG. 41.—CATHCART RACK-RAIL LOCOMOTIVE, 1849.

A Complete Working Model of an "American" Type Locomotive. (Scale ½ inch equals 1 foot.) Made by George Boshart. Loaned by John S. Clarke, Ardmore, Pa., Vice President of The Autocar Company.

This model is as complete in its interior parts as in its exterior parts and can be operated under its own power with coal for fuel. It represents the passenger type, high-speed simple-cylinder locomotive of the period 1890–1900.

Of the "American" locomotive, Mr. Angus Sinclair, in his book, the "Development of the Locomotive Engine," writes:

For the first forty years of railroad operating, the dominating aim of designers and locomotive builders was to produce a locomotive suitable for all kinds of train service, one that would be fairly efficient and durable enough to make long mileage with small expense for repairs and subject to few failures. Except on the comparatively few railroads handling minerals and other heavy freight over steep grades, the eight-wheel locomotive, known for excellence as the American locomotive, was regarded as an ideal engine for hauling both passenger and freight trains. In 1870 probably 85 per cent of the locomotives at work on the American continent were of that type. Until the troublesome problem of how to move passenger and freight trains at the least possible expense became dominant in railroad counsels the American locomotive left nothing to be desired as railroad motive power.

The engine was the product of natural evolution, the survival of the fittest, and altogether admirable as a power producing motor. Lest this book be read when the American locomotive becomes classed with the dinosaurs, I may explain that it belonged to what is now denominated as the 4–4–0 class, having a four-wheel truck under the smoke box and two pairs of coupled drivers in front

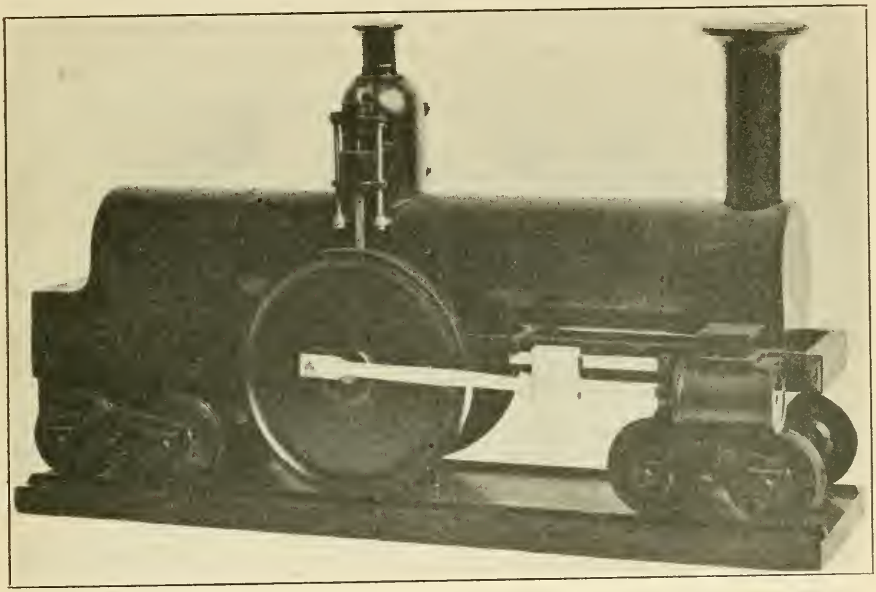


FIG. 42.—WINANS LOCOMOTIVE FOR INCREASED ADHESION, 1851.

and one pair behind the fire box. During the period of this engine's glory a deep fire box passed down between the frames and was compactly bounded by driving-wheel axles and coupling rods. About one-third of the total weight was generally carried on the leading truck.

The perfecting of this form of locomotive represents the most valuable engineering work performed on railroad motive power. The work of Evans, Trevithick, Hedley, Stephenson, Hackworth, Cooper, Baldwin, Dripps, Winans, Harrison, Eddy, Millholland, Rogers, Cooke, and Mason all produced contributions to the perfecting of the American locomotive, and very often the permanent gift of what is regarded as a fertile inventor will be identified as a very small part of that finished machine. We find the first groping toward a locomotive machine was a portable boiler with various accessories attached, such as cylinders and wheels. Then came an arrangement of rectangular beams forming a frame which carried the boiler and provided conveniences for holding the four wheels that carried the whole combination of power generating and transmitting appliances. For the track's sake the carrying burden is distributed over four pairs of wheels, two of them being in front. The clumsy outside wooden beams that acted as frames are abandoned for iron bars that are not susceptible to changes of temperature and form a light frame which carries the boiler securely and with small superfluous weight to which all operating mechanism is strongly fastened. The engine meets the essential requirements of lightness and strength sufficient to control the increasing power. The elementary locomotive with a single pair of driving wheels is deficient in adhesion and what seems a backward step is taken to make an important move forward. The first engines built before the advent of the swiveling truck were generally carried by two pairs of coupled wheels which gave sufficient adhesion. In the United States one pair of these wheels was abandoned for the leading truck, while in Europe the four-coupled arrangement was adhered to, but a single pair of carrying wheels was introduced in front or in the rear.

When it became apparent in the United States that a single pair of driving wheels made a very slippery engine, various forms of traction increases were resorted to with very little satisfaction. Then an engineer proposed adding an-

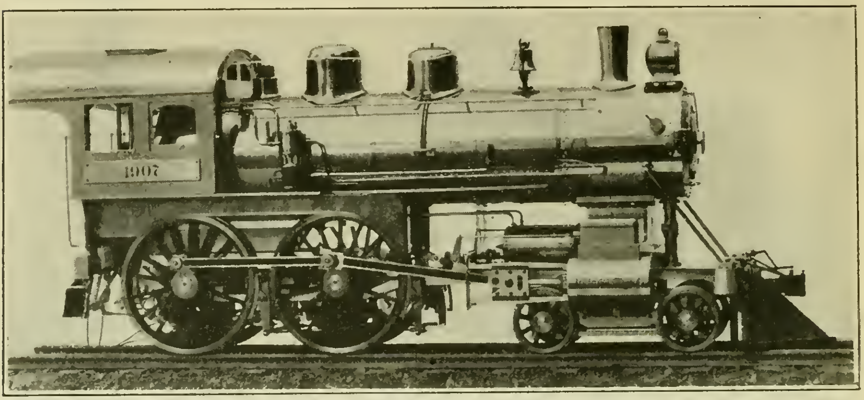


FIG. 43.—COMPLETE WORKING MODEL OF "AMERICAN" TYPE LOCOMOTIVE, 1900.

other pair of driving wheels, the same pair that had been thrown out by the Jervis truck, and won fame and fortune by the invention. The clan Campbell, led by their chief, the Duke of Argyll, have won many victories since, breekless, they first emerged from the wilds of Lorn, but no victory was so abiding and lucrative as that of Henry R. Campbell when he added a pair of driving wheels to the slippery locomotive.

Campbell gave the basis for the American locomotive, but it had to pass through much torturing experiments, due mostly to following of fallacies and fashions, before it emerged from the hands of its friends a highly perfected engine. The Campbell was rudimentary to a degree, but it provided a foundation to succeeding builders. A heavy outside wooden frame carrying a boiler and having pedestals to secure the four-wheel leading truck and the two pairs of driving wheels set very close together formed the visible outlines of the engine. The cylinders were inside under the smoke box and transmitted the power through a cranked axle. It was patented in 1836 and was noted for unyielding, hard-riding characteristics.

For about twenty years, the "American" locomotive was the Rome toward which nearly all locomotive designers traveled. It was a pity that the public demand for increased speed of passenger trains and decreased freight charges should have moved railroad managers to command that more powerful locomotives should be provided. That was an order which had to be obeyed, and designers proceeded with the task of putting into form the modern locomotive.

The "American" locomotive reached its zenith in 1872. In that year the Baldwin Locomotive Works built 422 engines, the average weight in working order having been 64,000 pounds. Most of the engines were of the 4–4–0 type.

The favorite 4–4–0 soon reached the limit of its capacity. The grate area limits, the steam producing power of a boiler, and the first attempts to increase the capacity of the American locomotive were directed to increasing the size of the grates. The most popular engines of that type had deep fire boxes passing between the frames, providing a grate about 34 by 72 inches or 17 square feet. The intensity of the popular desire to keep that type of locomotive in use may be judged by the ingenious efforts made to enlarge the grate area. The first movement was increasing the distance between the driving wheels so that the grates could be lengthened. Side rods as long as nine feet came into use, but the increase of grate that resulted proved a short-lived remedy. Then came the practice of sloping the grate and raising the center line of the boiler. By this means the back of the grate was brought sufficiently high to pass over the rear axle, permitting the fire box to extend back an indefinite distance. This permitted the grate to be made as long as it could be fired. Such grates were sometimes made from 9 to 10 feet long, providing an area of about 30 square feet. That kind of fire box was always very unpopular with the enginemen and was wasteful of coal.

In 1891 William Buchanan, of the New York Central Railroad, cooperating with A. J. Pitkin, manager of the Schenectady Locomotives, brought out an abnormally large 4–4–0 locomotive to haul the heavy express trains. It was numbered 870, had cylinders 19 by 24 inches, driving wheels 78 inches diameter, weighed 120,000 pounds, of which 80,000 pounds were upon the drivers. The fire box, set above the frames, provided grate area which was 96 inches long and 40⅞ inches wide, a total of 27.3 square feet. There were 268 2-inch tubes 12 feet long which, with fire-box area, provided 1,851.5 square feet of heating surface.

That form of engine was largely copied and made heavier, one group having been made with the engine a total weight of 136,000 pounds with 90,000 pounds on the drivers. This was passing the limit, for 22,500 pounds weight pressing the rail beneath each wheel was more than steel rails or steel tires could endure in a fast running locomotive.

The locomotive of which this model was made by direct measurement was still in use in 1907 on the Pennsylvania Railroad.

Cat. No. 307,243 U.S.N.M.

PART III.

RAILWAY PERMANENT WAY.

Included in the exhibits of transportation are models of railways, models of rails of various designs and sections of over one hundred types of iron and steel rails used since the beginning of the railway era. The more important of these objects are referred to in the following general account of the development of the permanent way, the greater portion of which was prepared a number of years ago by Dr. J. Elfreth Watkins, late curator of the Division of Mechanical Technology.

EARLY TRAMROADS.

By careful calculation, a distinguished London engineer in 1802 found that while it cost 80 cents a ton a mile to transport bulky freight over turnpikes, the cost on horse tramroads of iron was only one-tenth of this amount. George Stephenson, while president of the "British Carring Companies," wrote "that by the introduction of the horse tramroad, the monthly expense of that company for coal carriage alone had been reduced from £1,200 to £300. An edition of "Wood's Treatise of Railroads," published in 1830, calls attention to the economical operation of the coal railroad, 9 miles long, near Mauch Chunk, Pennsylvania, then operated by horsepower, and

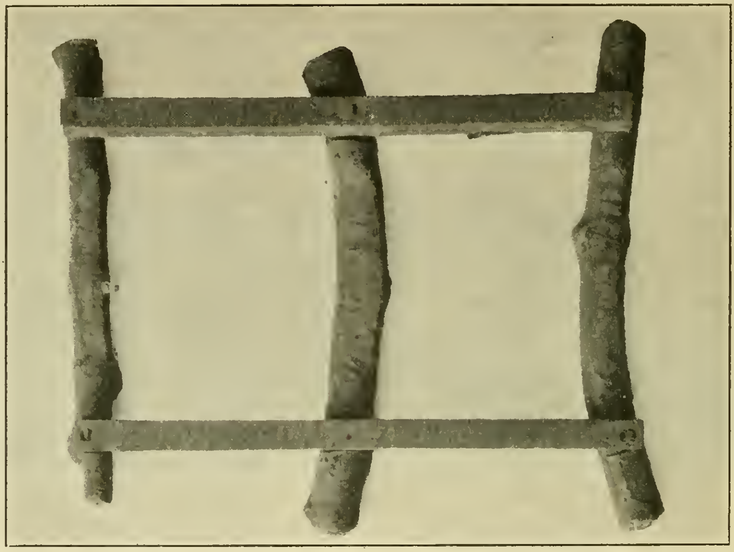


FIG. 44.—MODEL OF WOODEN RAILWAY AT NEWCASTLE, ENGLAND, 1672.

states that by this method "it has repaid its whole cost since 1827." In 1828 39 miles of the horse railway from Budweis to Lintz, constructed across the mountains which separate the Moldau and the Danube Rivers, was opened to traffic. This road was extended 41 miles farther in 1832, and for many years paid a dividend of 5 per cent upon a capitalization of $10.000 a mile, which was subsequently increased to a length of 130 miles in 1839.

The demand for a new fuel to replace wood was the necessity that became more and more urgent as the forests disappeared to satisfy the demands of a dense population. This condition of affairs directed thought toward devising improved methods for transporting pit coal from the collieries of Great Britain to the adjacent navigable streams or near seaports, with the result that railways were laid in the coal mines and from the mines to the adjacent watercourses. These ways consisted of squared timber rails laid in the ground and held to gauge by cross timbers to which they were fastened by wooden pins.

Roger North in 1672, in his biography of his brother Francis, the Lord Chancellor, describes a wooden railway (see fig. 44) which he had seen at Newcastle during the reign of Charles II, as follows: "The manner of the carriage is by laying rails of timber from the colliery down to the river exactly straight and parallel, and bulky carts are made with rowlets fitting these rails, whereby the carriage is so easy that one horse will draw four or five chaldrons of coal." The Newcastle chaldron weighed 5,936 pounds, so that one horse hauled 8 or 9 tons.

The price of iron was materially reduced as coal became cheap and abundant, and at length it became possible to use it in the construction of rails. The earliest iron used in track construction was cast in plates 3 or 4 feet long, 2 or 3 inches wide, and one-half or three-fourths of an inch thick. These plates were spiked on top of the wooden stringer rail where the wear was the greatest.

FIG. 45.—FISH-BELLY RAIL. PATENTED BY WILLIAM JESSOP, 1789.

As timber was expensive in England at the close of the Eighteenth Century many attempts were made to devise a cast-iron rail that should suit the traffic of the English tramroads. A fair impression can be obtained of the crude ideas that the early English tramway contractors had in regard to rails from the following description of specimens on exhibition:

Model of Cast-iron Edge Rail, 1789. Patented in England by William Jessop, Mine Engineer, and Laid on a Road in Loughborough.

The rail is fish-bellied and at first was not supported by a chair, the wood or stone block being hewn to fit the end of the rail. Near the ends the rail has a flat projecting base in which there are holes for the bolts which fastened them to the wooden block or sleeper.

Cat. No. 180,205 U.S.N.M.

Model of Cast Edge Rail, 1797, with Joints Supported by Chairs.

These were the first chairs adopted and were cast the reverse of the ends of the rail, having two bolts through the stem of the rail at each joint. They were laid on the Lawson Main Colliery, New

Castle-upon-Tyne, England, by Mr. Barnes, and were at first supported by timber but finally by stone blocks.

Cat. No. 180,207 U.S.N.M.

Model of Cast Edge Rail, 1802. Invented by Mr. Wyatt.

This rail was used on the railway at the slate quarry on Lord Penrhyn's estate near Bangor, North Wales. The general shape of the cross section of the rail is a hexagon. At each end a dovetail block, 2 inches long, is cast at the bottom. This is slipped into a chair which had previously been attached by a bolt to the wooden or stone support. Cat. No. 180,205 U.S.N.M.

Model of Cast-iron Tram Rail, 1803. Used on the Surrey Railway, England.

This rail is said to have been made "with flange higher in the middle and a nib under the tread to add strength." It has a rectangular notch, half square in the ends, the joints being completed by one square-headed iron spike, which is countersunk.

This rail, although an improvement, failed to give general satisfaction, and in a very short time became obsolete.

Cat. No. 180,209 U.S.N.M.

Model of Cast Rail with Concave Top, 1803.

This rail, patented by Josiah Woodhouse, is fastened to transverse crossties by bolts slipped into slits through the base. It was to be used also by road wagons and to be embedded in common roads.

Cat. No. 180,210 U.S.N.M.

Among the most interesting relics in the collection are two of the cast tram rails, 3 feet long, from the track extending from Pen-Y-Darran Iron Works to Navigation House, Abercynon, Wales. These rails were a portion of the original track upon which Trevithick's first locomotive ran in 1804, and are the gift of J. W. Widdowson, Esq., London and Northwestern Railway, England.

Model of Cast Tram Rail, Designed to be Laid Without Bolts or Spikes.

Charles Le Cann, of Llannelly, Wales, in 1808 received a premium of twenty guineas from the Society of Arts for the invention of this rail, which was ingenious in construction. Projecting pins, pyramidal in shape, are cast on the bottom of the tram rail at the points where the stone supports come under the rail, the joints being dovetailed into each other; the need of any other form of joint fixture was thus dispensed with. These rails are about 5 inches wide and weigh 42 pounds a yard. Cat. No. 180,211 U.S.N.M.

Model of Cast Rail, Patented by Losh and George Stephenson of Killingsworth, England, in 1816.

A half lap joint is used through which a horizontal pin is passed transversely to join the rails together, at the same time fastening them to the cast-iron chair. A large portion of the Stockton and Darlington Railroad was laid with this rail in 1825.

Cat. No. 180,213 U.S.N.M.

Early in the eighteenth century inventive genius increased the power of the stationary engine and the efficiency of the steam blast and of the machinery for working and handling iron. The puddling furnace, first used in 1784, was radically improved by Henry Cort about the beginning of the century. He also invented and introduced the rolling mill about the same time, so that it became possible to roll iron rails cheaply. These were at first rolled in lengths of about 12 feet. Models in the collection of the early English rolled rails are:

Bar Rail Laid in Lord Carlisle's Quarries, 1811.

Cat. No. 180,212 U.S.N.M.

Wrought-iron Edge Rail with Fish-bellied Web.

Rails used by Stephenson in 1829 in laying the Liverpool & Manchester Railway. Chairs were used at joints; rails were 15 feet long and supports 3 feet apart; the weight of rail was 35 pounds a yard.

Cat. No. 180,216 U.S.N.M.

THE AMERICAN RAIL AND TRACK.

During 1825–27 a few isolated coal tramroads existed in the mining regions in Pennsylvania and Virginia, and in the stone quarries in Massachusetts. These roads were laid with wooden rails, capped with thin merchant bar iron. About this time the Pennsylvania Society for the Promotion of Internal Improvement sent an engineer abroad to examine English railways. The fully illustrated report made by William Strickland, published during the year 1826, shows that rapid advances in track construction had been made in Great Britain during the preceding decade notwithstanding the fact that comparatively few locomotives were at work and only one railway for general traffic had been opened.

This report, without doubt, contained the most trustworthy information obtainable at that time by American railway projectors. But America presented a very different problem from England to the pioneer railway builders. England was an old country, rich in commerce and foremost in manufactures, of comparatively small area and very densely settled, having a population of nearly 200 to the square mile of territory, while the population of the whole United States was less than 4 to the square mile. In the seven States, Connecticut, Massachusetts, New York, New Jersey, Pennsylvania, Delaware, and Maryland, where most of the early railways were projected, the average population was a little over 35 to the square mile.

THE FIRST RAIL ROLLED WITH A BASE.

According to the minutes of the board of directors of the Camden and Amboy Railroad, September, 1830, Robert L. Stevens, president and chief engineer of that company, who had been ordered to visit England to inspect and report upon railroad matters there, was directed to purchase "all-iron rail," which the management of that company preferred to the wooden rail plated with strap iron. Mr. Stevens sailed a few days later, and it was during this voyage that he designed the first rail ever rolled with a base, whittling several model sections out of wood which he obtained from the ship's carpenter.

He was familiar with the Birkenshaw rail, with which the best English roads were then being laid, but he saw that, as it required an expensive chair to hold it in place, it was not adapted to our country, where metal workers were scarce and iron expensive. He also designed the "hook-headed" spike, which is substantially the railroad spike of to-day, and the "iron tongue," which has been developed into the fish bar, and the rivets which have been replaced by the bolt and nut to complete the joint.

The base of the rail which he first proposed was to be wider where it was to be attached to supports than in the intervening spaces. This was afterwards modified so that the base was made one width—3 inches—throughout. Stevens received no favorable answers to his proposals, but, being acquainted with Guest (afterwards Sir John Guest), then a member of Parliament and proprietor of large iron works in Dowlais, Wales, he prevailed upon him to have the rails rolled at his works. Guest became interested in the scheme, and accompanied Stevens to Wales, where the latter gave his personal supervision to the construction of the rolls. After the rolls were completed Guest hesitated to have them used, through fear of damage to the mill machinery, upon hearing which Stevens deposited a sum of money guaranteeing the expense of repairing the mill in case it was damaged. As a matter of fact, the rolling apparatus did break down several times. "At first," as Stevens, in a letter to his father, described it, "the rails came from rolls twisted and as crooked as snakes," and he was greatly discouraged. At last the mill men acquired the art of straightening the rail while it cooled. The first shipment, consisting of 550 bars 18 feet long, 36 pounds to the yard, arrived in Philadelphia on the ship *Charlemagne*, May 16, 1831.

The weight of the rails of the next shipment, several months afterwards, was increased to 42 pounds a yard, the rail being 3½ inches high. Over 30 miles of this rail was immediately laid down. It was fastened to stone blocks with hook-headed spikes; at the joints were iron tongues fastened to the stem of the rail by rivets put on hot. This was the standard rail of the Camden and Amboy Railroad during 1831–40.

From a letter written by Francis B. Stevens to James M. Swank, Esq., special agent of statistics, dated Hoboken, New Jersey, March, 1882, the following extracts are taken:

> I have always believed that Robert L. Stevens was the inventor of what is called the T-rail, and also of the method of fastening it by spikes, and I have never known his right to the invention questioned.
>
> Mr. Stevens's invention consisted in adding the broad flange on the bottom, with base sufficient to carry the load, and shaped so that it could be secured to the wood below it by spikes with hooked heads, thus dispensing with the cast-iron chair, and making the rail and its fastening such as it now is in common use.
>
> In the year 1836 and frequently afterward he spoke to me about his invention of this rail. The Camden and Amboy laid with this rail was opened October 9, 1832, two years after the opening of the Manchester and Liverpool Railroad. Of this I was a witness. This rail, long known as the old Camden and Amboy rail, differed but little either in shape or proportions from the T-rail now in common use but weighed only 36 pounds to the yard. For the next six or eight years after the opening of the Camden and Amboy Railroad it was little used here or abroad, nearly all the roads built in the United States using the flat iron bar, about 2½ or 3/4 inches, nailed to wooden rails; the English continuing to use the chair and wedges.
>
> My uncle always regretted that he had not patented his invention. He mentioned to me upward of forty years ago that when advised by his friend, Mr. F. B. Ogden, the American consul at Liverpool, who was familiar with the circumstances of his invention, to patent it, he found that it was too late, and that his invention had become public property.

Shortly after the first laying of the Stevens rails on the Camden and Amboy Railroad, the rivets at the joints were discarded and the bolt with the screw thread and nut, similar to that now used, was adopted as the standard.

The Stevens rail did not come into general use for several years, the next road to adopt it being the Boston and Providence, about 1840. On the Boston and Lowell Railroad in Massachusetts the fish-bellied rail was laid in chairs on stone blocks. As late as 1847 the Hudson River Road used the Stevens rail supported by chairs, but these were soon afterwards discarded.

CAST-IRON RAILS MADE IN AMERICA.

In Johnson's "Notes on the Use of Anthracite" are described tests of cast-iron rails made during 1841 at Lyman's foundry, near Pottsville, Pennsylvania. These rails were designed for colliery railways. They were only 6 feet long. For three or four inches at each end the rail had a section similar to the Stevens rail; for the remaining five and a half feet the rail was somewhat similar to the English bull-headed rail.

Previous to the year 1842, when Congress passed the celebrated high-tariff law, all imported iron rails were admitted to the country almost free of duty. The tariff on manufactured iron agreed upon by that Congress increased the cost of English rails so much that the railways were forced to seriously advocate the erection of American rolling mills for the special purpose of making rails.

The first rail mill erected in this country was located at Mount Savage, Allegany County, Maryland. The first rail was rolled in the summer of 1844. In honor of that event the Franklin Institute of Philadelphia awarded a medal to the proprietors in October, 1844.

The rail was of the ∩ form, similar to the Evans (British) patent, and the first few hundred tons manufactured were laid on the Baltimore and Ohio Railroad between Mount Savage and Cumberland. A section of this rail, which weighs 42 pounds to the yard, was presented to the museum by the late Colonel James Randolph, for many years consulting engineer of the Baltimore and Ohio Railroad Company.

The Stevens rail had come into general use in America before 1845, although several railway companies which had imported T-rails from England continued their use on their tracks until the rails were worn out. For this reason the T-rail without base was in use on the Boston and Worcester Railroad in 1850, and on the Hempstead branch of the Long Island Railroad as late as 1855. Every American road, however, without exception replaced the T-rail and strap-rail by rail of the Stevens pattern as rapidly as their financial condition permitted, continuing to import all rails from England until 1845.

In the "History of Iron of all Ages," Swank writes (p. 344):

"The Montour Rolling Mill at Danville, Pennsylvania, was built in 1845 expressly to roll rails, and here were rolled in October of that year the first T-rails made in the United States." Among other early rail mills were the following, with the date when they began to roll rails: Boston Iron Works, May 6, 1846; Trenton Iron Works, Cooper and Hewitt, proprietors, June, 1846; New England Iron Company, Providence, Rhode Island, September 1, 1846; Phoenix Iron Company, Phoenixville, Pennsylvania, November, 1846.

During the year 1848 a very interesting experiment was tried by the Camden and Amboy Railroad. Arrangements were made with Cooper and Hewitt at the Trenton Iron Works to roll a 92-pound rail, 7 inches high, with a base $4\frac{5}{8}$ inches wide; 15 miles of the Camden and Amboy road were laid with this rail during the following year. The engineer of that company believed that he had at last solved the problem of track construction, inasmuch as this rail gave an admirable opportunity for a strong joint. By experience it was found that this rail was too rigid and produced so much concussion by the train that the ends soon hammered out, and where the ballasting was imperfect great damage was caused to the rolling stock; consequently, the rail was soon after taken up. Much of this old rail found its way to the cities, where it was bought by architects and contractors for building purposes. A section is in the collection. It was laid between Bordentown and Burlington in 1849.

PEAR-SHAPED RAILS.

The early American T-rails were made of inferior iron, and this was one of the causes that led to the adoption of the section with a pear-shaped head, with which many roads were laid during the next fifteen or twenty years.

Sections of four of the pear-shaped rails described in the report of the Railroad Commission of the State of New York for 1845 are in the collection. They are:

New York and Erie Railroad. Fifty-six Pounds to the Yard. In Use in 1855.

Cat. No. 180,225 U.S.N.M.

New York Central Railroad. Fifty-six Pounds to the Yard. In Use in 1855.

Cat. No. 180,226 U.S.N.M.

Buffalo, Corning and New York Railroad. Sixty-two Pounds to the Yard. In Use in 1855.

Cat. No. 180,218 U.S.N.M.

Saratoga and Schenectady Railroad. Sixty-five Pounds to the Yard. In Use in 1855.

Cat. No. 180,217 U.S.N.M.

The obtuse angle between the lower side of the head and the stem of the rail made it difficult to apply a splice bar of any kind to advantage, and this fact led to the introduction of the ring joint (one iron ring passing through two slots, one in each stem of adjacent rails and passing around under the base of the rail and held in position by a wedge driven between the ring and the rail stem). Chairs and other joint fixtures attached entirely to the base of the rail were also experimented with, but generally without satisfaction, judging from the fact that none survived.

The difficulty in making good joints with the pear-headed rail was overcome by some of the engineers by planing away a portion of the head of the rail for a foot or 18 inches from each end. On the Pennsylvania Railroad and on the Belvidere-Delaware Railroad the rails in some cases were planed with special reference to the use of a splice bar, almost square at the rail head and base, as early as 1857.

In 1853 an interesting experiment was tried on the Boston and Lowell Railroad. After running for some time on the head (pear-shaped) of the rail it was inverted. The effect of three years' running on the base was to round over the outer edges.

COMPOUND RAILS.

The difficulty in obtaining satisfactory joint fixtures on the American pear-shaped section led to the introduction of the compound rail. One of wood and iron was designed by Benjamin H. Latrobe in 1841 for the Baltimore and Ohio Railroad. The Z iron was 5 inches high and weighed 45 pounds to the yard. The track consisted of longitudinal undersills, which supported the crossties, 3½ by 6 inches and 7 feet long. The wooden portion of rail was made to fit closely against the stem and under the head of the Z iron, to which it was joined by ⅝-inch bolts with screw nuts. The iron and wood stringer was laid to "break joints," so that no splice bars except a base plate was needed at the joints.

A Section of an Ingeniously Devised All-Iron Compound Rail on the Baltimore and Ohio Railroad in 1848 is in the Collection.

Cat. No. 180,344 U.S.N.M.

Several of the railway companies in New York laid a large mileage of compound rails of various patterns. Four sections of compound rails in the collection which were in use in New York in 1855 are:

New York Central Railroad. Sixty Pounds to the Yard.

Cat. No. 180,236 U.S.N.M.

New York Central Railroad. Seventy-five Pounds to the Yard.

Cat. No. 180.229 U.S.N.M.

Troy Union Railroad. Sixty-five Pounds to the Yard.

Cat. No. 180,235 U.S.N.M.

Troy Union Railroad. Sixty-five Pounds to the Yard.

Cat. No. 180.234 U.S.N.M.

When the track composed of this type of compound rails was new, it is described as being the finest track of the period. No satisfactory nut lock was in use at that time, however, and as the screw threads or rivets wore and traffic became heavier, the different parts of the rails could only be kept together by constant attention, in screwing up the nuts or putting in new rivets. As the rails laid were of iron, the wear of the inner surface was considerable, so that in a little while the track was badly damaged and the old solid rail was substituted.

STEEL RAILS.

The first steel rails in Europe are said to have been rolled at the Ebbw Vale Works in Wales, about 1855. The steel was produced by the Uchaturis process. Zerah Colburn states that "the quality of the steel is said to be equal to that used for razors." The difficulty in obtaining good iron on this side of the water led the more prosperous American companies to continue to import steel and iron rails from abroad for some years.

In Swank's "History of Iron in all Ages" it is written that "the first steel rails ever made in this country were rolled at the North Chicago Rolling Mills in May, 1865." These were experimental rails, only a few being rolled in the presence of a committee of the American Iron and Steel Association.

The first steel rails ever rolled in the United States upon order were rolled by the Cambria Iron Company at Johnstown, Pennsylvania, in August, 1867. In no one year during the next five years were more than 40,000 tons of Bessemer steel rails manufactured in the United States.

During 1870–1873 attempts were made by several rail manufacturers to roll rails that should have a steel head and iron web and flange—"steel top rail", as it was called. A considerable quantity of this rail was rolled by the Trenton Iron Company. While this experiment was reasonably successful, the lessened cost of making steel soon afterwards made it practicable to make the whole rail of steel.

The production of steel rails, which aggregated 90,000 tons in 1872, increased from year to year, so that in 1882, ten years later, the output reached nearly 1,500,000 tons, the price falling from $140 to $35, and to-day practically the whole permanent way of American railways, amounting to about 404,000 miles of track, is laid with steel rails.

PART IV.

EARLY HISTORY OF LAND TRANSPORTATION.

The transportation industry had its origin among human burden bearers in every portion of the inhabited globe, and primitive methods are still in vogue in many countries. When man secured control of the animal kingdom beasts of burden were trained to bear loads consisting of indivisible or aggregate units too heavy to be borne by human beings, the larger and more powerful beasts being trained to carry one or more persons at a time.

When it became necessary to move loads too heavy for men or beasts, new methods were adopted, animals being bred and trained for draught. Great weights were transported by animals, which, singly, in pairs, or in greater numbers, were taught by acting in unison to exert great tractive force.

Under these conditions it became necessary to devise vehicles of different kinds to be used for various purposes. The sled, made in many forms, especially in the regions where ice and snow are found, proved of great value. The movement of the "rolling load," composed sometimes of stone columns for buildings, and oftener of lesser weights in the marketing of the products of the forest and the field, required greater ingenuity. The roller under the load, before the invention of derricks, was the method employed in moving the largest stones ever employed by man. As skill and dexterity in the use of tools increased vehicles with wheels were devised and became an important factor in the development of civilization.

The ability to construct vehicles with wheels has been developed at different epochs and in different quarters of the globe. It is generally believed that the roller is the link which connects the use of the ancient sledge with the invention of the primitive solid wheel.

The wheelwrights of every nation have devoted earnest attention to the proper combination of wood, leather, bronze, and iron in the construction of vehicles with wheels and axles, suitable at first for the slow movement of heavy loads and later for rapid movement on common roads and turnpikes.

The perfecting of the wheel has led to the construction of thousands of types differing in the shape of the hubs, spokes, fellies, and tires and in the methods of fitting them together. Vehicles with heavy wheels, composed wholly of wood or of wooden parts held together with rawhide and elastic wood, having hubs lined with iron and tires of the same material, made to run upon axles of steel, now in common use, were not made at the beginning of the nineteenth century.

As wealth increased advantages to be gained from good roads were better appreciated, so that light and strong wheels composed entirely of steel were designed, which, combined with other products of the metal worker's art, have led to the construction of the highest type of wheel. To this mechanism was later added a tire of india rubber, the combination resulting in the construction of the bicycle, which embodies the results of the labors of the most skilled mechanics and which during the decade 1890–1899 was introduced into every civilized country of the globe.

Finally the continued improvement in roads and in the internal-combustion engine and the introduction of the pneumatic tire have resulted in the construction and rapid development of the automobile, which to-day represents the highest form of wheeled vehicle whose economic value can best be expressed in the fact that for every eleven persons in the United States there is one automobile in use.

Model of Indian Elephant with Howdah. (Scale 1 : 6.) Made in the Museum.

The small-eared Asiatic elephant has been domesticated for centuries in India, Burmah, and Siam. African elephants, distinguished by their large ears, were used for transportation in ancient times, but since the days of Hannibal all attempts to domesticate them have failed. The model shows the method of transporting men and merchandise in war or for commerce in Southern Asia.

Cat. No. 181,275 U.S.N.M.

Model of Llama with Panniers. (Scale 1 : 6.) Made in the Museum.

The llama is a small beast of burden noted for being sure-footed under a heavy load. General Bolivar (1783–1830) estimated that early in the nineteenth century as many as 300,000 llamas were used for transportation in the mining districts of Potosi alone. Since that time the horse and mule have come into more general use.

Cat. No. 181,310 U.S.N.M.

Model of Horse for Burden and Traction. (Scale 1 : 6.) Made in the Museum.

The horse was domesticated and used as a beast of burden before the dawn of history. Since the era of improvement in roads and in the construction of vehicles with wheels, the number of horses used for traction has greatly increased in both hemispheres. The domestication of the horse, now found in nearly every part of the world inhabited by man, and the adaptation of that animal to various methods of transportation, has exercised a very important influence upon the advancement of civilization. Cat. No. 181,332 U.S.N.M.

Model of Dromedary with Burden. (Scale 1 : 6.) Made in the Museum.

The camel has been used from the earliest Biblical times as a beast of burden; the dromedary, with a single hump, in Western Asia, Egypt, and Northern Africa; the bactrian, with two humps and long, thick hair, in the cold districts of Asiatic Russia. Camels are also used for traction in many farming communities of the East and by them merchandise is transported in many eastern countries. The camel is called "the ship of the desert."

Cat. No. 181,274 U.S.N.M.

Sedan Chair. Gift of Turkish Centennial Commission, 1876.

The Sedan chair, which receives its name from Sedan, France, where it was first made, was a very popular and widely used mode of transportation during the eighteenth century. They were both privately owned and hired, as is the modern taxicab.

The chair consists of an inclosed seat provided with a glazed door at the front and a window at each side. It was carried by two men by means of horizontal poles which slipped through metal sockets at each side. The outside frame of the chair is covered with leather decorated with paint while the inside is upholstered in brocaded cloth. The inside dimensions of the chair are 26 inches wide, 30 inches deep, and 4 feet 6 inches high. Cat. No. 181,182 U.S.N.M.

Sedan Chair. Gift of the First Japanese Trading Company, 1888.

This chair formerly belonged to Tokugawa Iyehito, the eleventh Taikun of Japan, who presented it to his daughter as a wedding gift when she was betrothed to Prince Hosokawa, a Duke of Higo.

The chair resembles a miniature one-room house whose four corners, however, are not vertical but inclined so that its ceiling area is less than that of the floor. It is covered by a double roof, the lower being a low arch, while the upper is a ridge roof of high pitch.

There are two sliding doors, one on each side of the chair, which are screened but permit perfect visibility of the occupant. There is also a screened opening in the front of the chair.

It is constructed of ebony, heavily inlaid and trimmed with gold. The interior is upholstered and decorated throughout in colors. It is carried by a pole supported on the shoulders of two men, the pole passing between the two roofs and extending 5 feet beyond the front and rear. The inside dimensions are 30 inches wide, 4 feet deep, and 30 inches high. Cat. No. 180,070 U.S.N.M.

Model of American Indian Travois. (Scale 1: 6.) Made in the Museum.

Long saplings are attached at the butt ends to a strap across the horse's breast and by thongs to the girth; the thin ends drag upon the ground often 6 or 8 feet. Forage, fuel, game, and oftentimes persons were conveyed from place to place by traveaux.

Cat. No. 181,254 U.S.N.M.

Model of Primitive Sledge. (Scale about 1: 6.) Made in the Museum.

The American colonists fashioned the sledge from the forked limb of a tree. Aborigines and early settlers also used the forked limb, a convenient shape provided by nature, for tongues and thills of sledges and carts. Cat. No. 181,252 U.S.N.M.

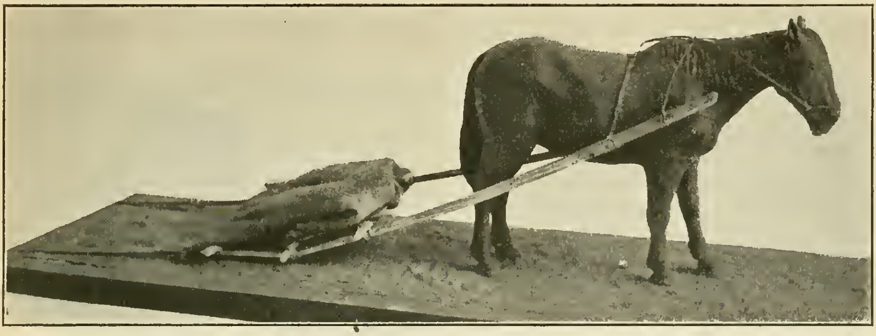


FIG. 46.—AMERICAN INDIAN TRAVOIS.

Model of Sledge of Split Logs. (Scale 1: 6.) Made in the Museum.

This form of sledge was used by the American colonists of the seventeenth century for carrying loads too heavy for the backs of man or beast. It is a crude sledge made with primitive tools and is known as the "buck" in eastern Pennsylvania.

Cat. No. 181,253 U.S.N.M.

Model of Colonial Sleigh, 1783. (Scale 1: 6.) Made in the Museum.

This form of sleigh was used by the American colonists in the eighteenth century. Owing to the bad roads, four horses were frequently attached to the sleigh, especially when long journeys were attempted. It has strongly built solid runners with body braced by iron rods. Cat. No. 181,256 U.S.N.M.

Model of Egyptian Sledge and Rollers. Made in the Museum. (Modeled After Mural Painting, Temple of Luxor, Thebes.)

The sledge was used in ancient Egypt on funeral occasions and for many other purposes. Cat. No. 181,255 U.S.N.M.

Model of Chinese Passenger Wheelbarrow. (Scale 1: 6.) Made in the Museum.

This vehicle, with one wheel, is used throughout China for transporting passengers and baggage from place to place. The wheel of twenty spokes, composed entirely of wood, has a heavy rim.

Cat. No. 181,279 U.S.N.M.

Korean Single-wheel Chair.

This vehicle, illustrating the application of the wheel to the carrying chair was long used for conveying persons of high rank from place to place in Korea in the Old Period. Its use is now prohibited. The wheel is 30 inches in diameter, has 32 spokes, a heavy hub, and broad rim shod with an iron tire, the cross section of which is V-shaped. The wheel is situated vertically beneath the chair seat.

Cat. No. 209,426 U.S.N.M.

FIG. 47.—BASHKIRS CHILD'S COACH.

Model of Bashkirs Child's Coach. (Scale about 1: 6.) Made in the Museum.

This coach is one of the oldest surviving types of vehicles for human transport and is a child's primitive vehicle from Russia. The wheels, pierced by burning, revolve on a crude axle, to which a tongue consisting of a forked stick is attached by thongs. The body, with arched top, is composed of tree bark sewn together.

Cat. No. 181,280 U.S.N.M.

Model of Nantucket Fish Cart. (Scale 1: 6.) Made in the Museum.

This vehicle comes from the region where the sandy soil prevents the wheel from being used. A long barrel of small diameter made for the purpose takes the place of a wheel. Its width is about equal to that of the body of the cart and is located to the rear.

Cat. No. 181,261 U.S.N.M.

Model of Greek Scytala. (Scale 1: 6.) Made in the Museum.

The four wheels are attached to two thick axles which revolve in transverse grooves and cut the sides of the body frame. Aristotle states that the scytala, which has four "pauc" (drum-shaped) wheels, "has many advantages over carts with wheels," arguing that "an axis impedes the progress of wheeled vehicles by pressing on the hub." Cat. No. 181,268 U.S.N.M.

Model of Ancient Egyptian Chariot. (Scale 1: 6.) Made in the Museum.

The original chariot of the Ptolemaic Era, complete in every part, made of birch wood, is preserved in the Florentine Museum, Italy. The wheels, of four spokes framed around the hub, are composed wholly of wood; the round rim is in four parts, the joints being scarfed for wrapping with thongs. Cat. No. 181,264 U.S.N.M.

Model of an Egyptian Chariot. (Scale 1: 6.) Made in the Museum.

The chariot was used in Egypt about 300 B. C. One original wheel, together with the front and side raves, found at Dashour by H. Abbot, is in the Museum of the New York Historical Society. The wheel is 39 inches extreme diameter. The forked brace to which the shafts are attached is also preserved. The construction of the floor and arrangement of the thongs, based upon close measurement, are hypothetical. The wheels have six spokes, with slot near the hub, and felly in six pieces with scarfed joints. The tire of wood, in six parts, also scarfed, is attached to the felly by a lacing of thongs. Cat. No. 181,265 U.S.N.M.

Model of Persian Farm Cart. (Scale about 1: 6.) Made in the Museum.

The cart, found in Persia in 1870, is used in Khosrovah for general purposes, where wheels of the kind represented last for years. The wheels have fifteen spokes; the felly is in five parts, joined by pins driven into the ends of flat spokes fitted into the rim. The axles and hubs are of wood. Cat. No. 181,276 U.S.N.M.

Model of Roman Farm Plaustrum. (Scale about 1: 6, after bas relief by Lucius Petus, Rome.) Made in the Museum.

This vehicle was used in ancient Rome in 300 B. C. to transport hay and other agricultural products from the farm to the market. Two wheels of solid wood are each straightened by two pairs of battens set at right angles. Cat. No. 181.270 U.S.N.M.

Model of Burmese Car of State. (Scale 1 : 6.) Made in the Museum.

This car was used in Burma up to about 1870 by the Phoongyes (priests) upon ceremonial occasions, when it was drawn by a pair of buffaloes. The wheels, without spokes, but composed wholly of wood, are strengthened by cross braces tied by thongs near the rims.
Cat. No. 181,273 U.S.N.M.

Model of East Indian Village Cart. (Scale 1 : 6.) Made in the Museum.

This type of cart has been in general use in Gujerat, India, since 1876, for hauling heavy or bulky loads. The wheels have four heavy

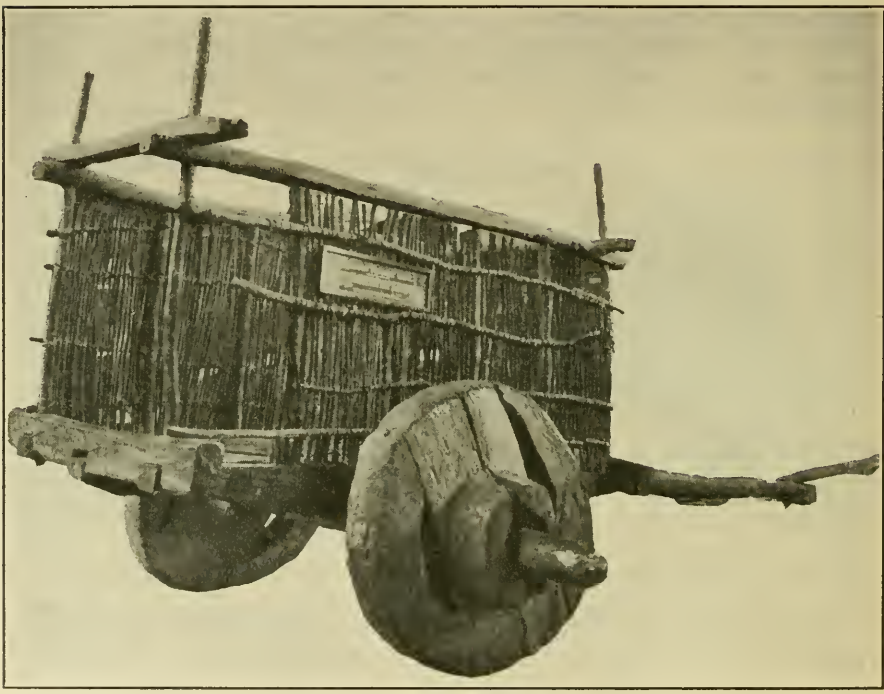


FIG. 48.—SPANISH OX CART, 1850.

fellies and only four spokes, which extend across the wheel and are framed on the outside of the hub. The axles and journals are generally of iron as shown. Cat. No. 181,281 U.S.N.M.

Model of Japanese Jinrikisha. (Scale 1 : 6.) Made in the Museum.

This vehicle, always drawn by men (called "Riksha Boys"), was introduced into Japan by an American missionary about the middle of the ninteenth century, and is in general use throughout that empire. The wheels have sixteen spokes, with metal bearings in hubs. The body is supported on springs attached to an iron axle.
Cat. No. 181.278 U.S.N.M.

"Carreta" or Ox Wagon. Presented by Schutter and Hotz.

This vehicle is of Spanish origin and was used extensively in Mexico and New Mexico until about 1880. It is devoid of all metal fittings and is made of cottonwood. The heavy wheels, composed of three pieces of thick timber, are held together by dowels of wood. The outer blocks show the traces of a rim. This type of wheel was introduced by the Spanish and is still to be found in Spain.

Cat. No. 180,132 U.S.N.M.

Model of Method of Rolling Tar Barrels. (Scale 1:6.) Made in the Museum.

The method of rolling loads by means of two tar barrels rolling on parallel axles in the same frame was in vogue in North Carolina

FIG. 49.—COLONIAL CHAISE, 1770.

in 1875 for transporting tar products obtained by "hacking" from the forest to the steamboat or railway. Cat. No. 181,260 U.S.N.M.

Model of Tobacco-Rolling Hogshead. (Scale 1:6.) Made in the Museum.

The method of transporting tobacco by means of the rolling hogshead was in use throughout Virginia and neighboring States from 1750 to 1861. Oxen, mules, and horses were employed in different localities. Cat. No. 181,259 U.S.N.M.

Model of American Colonial Chaise. (Scale 1: 6.) Made in the Museum.

The chaise was used in the American colonies in 1770. It is the "Old One-horse Shay" made famous by Oliver Wendell Holmes. The body was attached to the "running gear" by leather straps adjusted by buckles. The wheels have fourteen spokes, with metal tires. Axletrees, at first wholly of wood, were later strengthened by iron bars and wearing surfaces. The hubs were in emergency lined with thick leather when it was not possible to obtain the cast-iron "box."
Cat. No. 181,284 U.S.N.M.

FIG. 50.—CONESTOGA WAGON FOR FREIGHT, 1800.

Model of Conestoga Wagon. (Scale 1: 8.) Made in the Museum.

This wagon was used for transporting merchandise and often emigrants from the North and East across the Allegheny Mountains to Wheeling and Pittsburgh, on the way toward the South and West. Six and sometimes eight large horses composed the team. The four wheels, strongly built, with fourteen spokes and iron tires, ran upon axles of hickory often shod with iron skeins, the hubs being equipped with iron boxes. Cat. No. 180,044 U.S.N.M.

Model of American Stage Coach. (Scale 1:6.) Made in the Museum.

The stage coach, a vehicle for fast overland travel and mail conveyance, often in connection with steamboat lines, was in general use throughout the United States from the beginning of the nineteenth century until railway systems, extending into new territory, accommodated the travel. Through the agency of competing transportation lines the speed of the American horse for stages of eight or ten miles was materially increased. Four strong wheels, with iron tires and wooden spokes varying in number according to the dictum of local wheelwrights, were attached to strong and light running gears, differing in design and method of attaching springs and bracing.

Cat. No. 180,055 U.S.N.M.

FIG. 51.—OVERLAND STAGE COACH, 1800.

Model of Red River Cart, 1882. (Scale 1:6.) Made in the Museum.

According to Robinson's "Great Fur Land," published in 1872, "the only tools necessary not only to mend but to construct a [Red River] cart, are an ax, a saw, and an auger; with these the half-breed is independent. Huge trains of these vehicles are used for freighting over the northern plains." The wheels of twelve spokes are very much "dished." Rawhide is used in place of metal in strengthening the joints of the rims and hubs.

Cat. No. 181,309 U.S.N.M.

Model of An Automobile Truck, 1921. (Scale, One-fourth Actual Size.) Made and Presented by The Autocar Co.

The indispensability of the automobile truck to modern civilization has been demonstrated again and again, and more definitely than ever throughout the period of the World War. The effects of the material breakdown in the railway transportation system during that crisis were considerably allayed by the use of motor trucks moving over long distances, a feat which, prior to that time, had been considered impracticable, so that to-day, following peace-time pursuits, the automobile truck has come to be considered an essential part of the transportation systems of the country.

Among the mechanical features of the truck of which this model is a reproduction, are the following:

The frame on which the body rests is made of pressed steel of channel section and so fitted with cross members and braces as to combine strength and light weight with the desired flexibility. The frame rests on four semi-elliptical springs that are provided with the

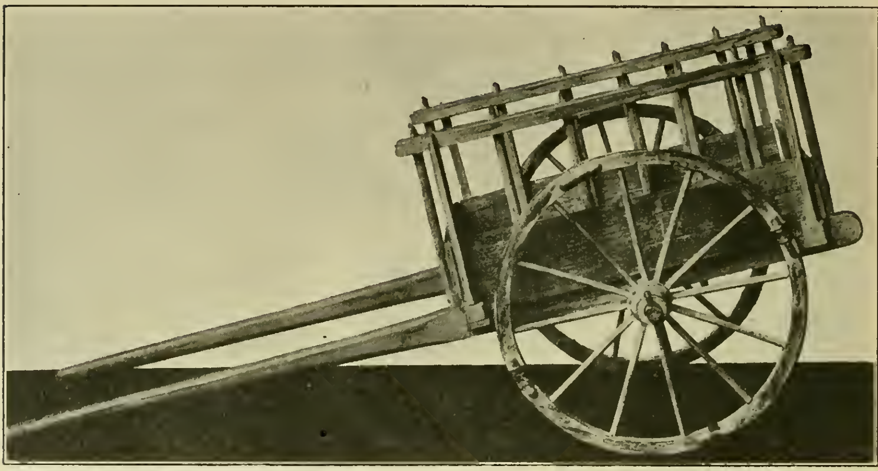


FIG. 52.—RED RIVER CART FOR FREIGHT, 1860.

necessary bushings and special lubricating devices so that they may be readily and easily lubricated. These, in turn, are supported on the front and rear axles, the front axle being of drop-forged steel of I-beam section. The front wheels are mounted on adjustable tapered roller bearings. The rear axle is of the full-floating Autocar double-reduction gear-driven type, the gear reduction being compounded through bevel and spur gears. This reduces the angularity of the propeller shaft, giving straight lines for the transmission of power.

The rear wheels are mounted on adjustable tapered roller bearings carried on an extension of the axle housing. By this means the rotating parts of the rear axle carry no part of the weight, their only function being to transmit the power to the rear wheels.

The gasoline four-cylinder engine is located under the driver's seat and is carried on the main frame by means of a three-point suspension. The power transmission is of the selective type, there being four forward speeds and one reverse. The transmission-gear housing is suspended from the main frame at three points, the power from the engine delivered to the transmission through a fabric-disk universal joint. Power is delivered to the rear wheels from the transmission through a tubular drive shaft equipped with universal joints at either end.

The general dimensions of the truck are as follows: Length of wheel base, 156 inches; length over all from front of bumper to end of frame, 259 inches; width over all to outside of hub caps, front wheels, 76½ inches; width over all to outside of hub caps, rear wheels, 81¼ inches; length of frame, back of cab, 176 inches; length of body, 16 feet; width of body, 6 feet; height of side racks, 40 inches; capacity, 20,000 pounds total—chassis, body, and load; wheel tread,

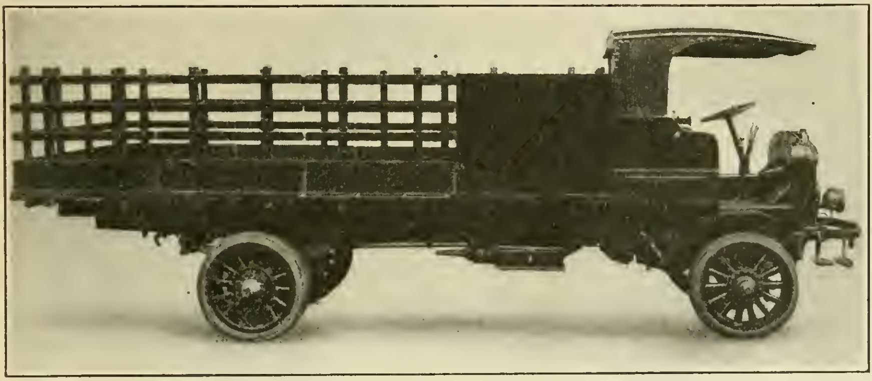


FIG. 53.—AUTOMOBILE TRUCK, 1921.

63 inches on front wheels and 65 inches on rear wheels; tires, 36 inches in diameter.

This type of truck is extensively used in all lines of business which have loads of variable bulk, such as general hauling, building supplies, and wholesalers' wares. Cat. No. 307,255 U.S.N.M.

Working Model of Automobile Truck with Tilting Body, 1921. (Scale one-fourth actual size.) Made and Presented by The Autocar Co.

The general specifications of this truck are almost identical to those of the truck just described except for the differences caused by the use of a shorter wheel base for the present truck. Its particular mechanical feature is the means for tilting the body, which may be pitched at an angle of 40 degrees.

The power is obtained from the transmission gears through a worm drive, the control being a hand lever mounted on the left-hand side of the chassis. A sliding gear, operated by the control lever, meshes with an idler gear and with a driving gear in the transmission housing. These gears are inclosed in a housing placed over the transmission housing. Through this set of gears power is thus transmitted through a driving-gear shaft connected by a universal joint to the power-hoist universal drive shaft. The lifting mechanism, inclosed in a casing, is carried on a steel subframe placed to the rear of the transmission housing. The power-hoist universal drive shaft is connected by a universal joint to a worm shaft on which a worm is keyed. The worm drives a worm gear placed beneath it and mounted on a shaft, on the farther end of which is a pinion. This pinion meshes with an intermediate shaft gear. Mounted on the same shaft as the latter gear is the crank-shaft drive pinion, and power is delivered through it to a large ring gear. This ring gear is

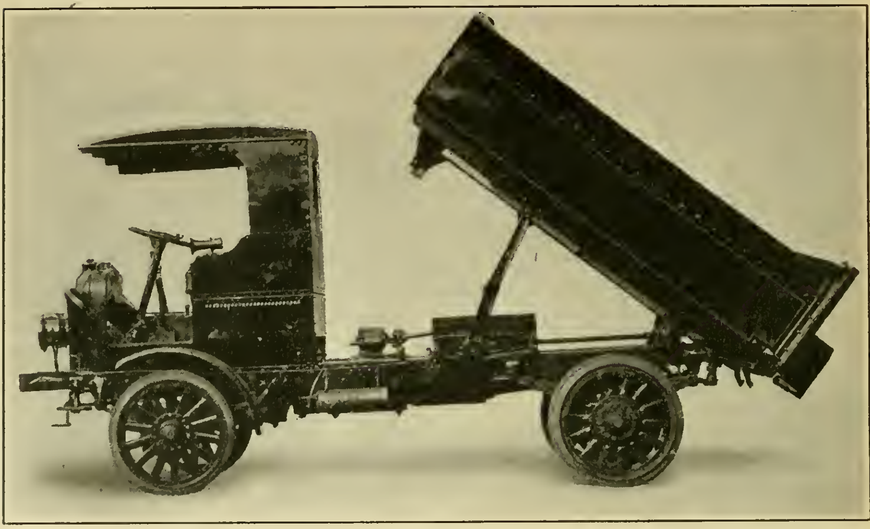


FIG. 54.—AUTOMOBILE TRUCK WITH TILTING BODY, 1921.

bolted on the ring-gear hub, which is carried on the crank shaft, the ends of which are splined, and the body lifting cranks fit over the ends. The body-lifting cranks and the body-lifting links are connected by a crank pin. The links are hinged to the body angle sills by means of link brackets and link pins. When power is applied through this set of gears, the body-lifting cranks are made to rotate, and when the cranks and links are straightened out fully the body has attained an angle of 40 degrees. Shift gears are also provided in this mechanism, so that a reverse motion is obtained in order that the body may be raised part way up and then, by means of changing the location of control lever, lowered to the frame. Hoisting of the body may be accomplished by rotating the crank arms in either direction. The body-lifting link brackets are fitted with bushings, whose diameter is about $\frac{3}{16}$ of an inch larger than that of the body-lifting link pins. This allows the body-lifting links to travel past dead center without any hard impact when the body touches the frame on the downward motion, and also prevents a jarring pull when the body is about to start on the upward motion. The rear end of the body is hinged to the chassis frame by means of two brackets bolted to the angle sills on the body. The body-hinged bracket shaft is carried in these two brackets.

The general dimensions of this truck are: Length of wheel base, 120 inches; length over all from front of bumper to end of frame, 223 inches; width over all to outside of hub caps, front wheels, 76½

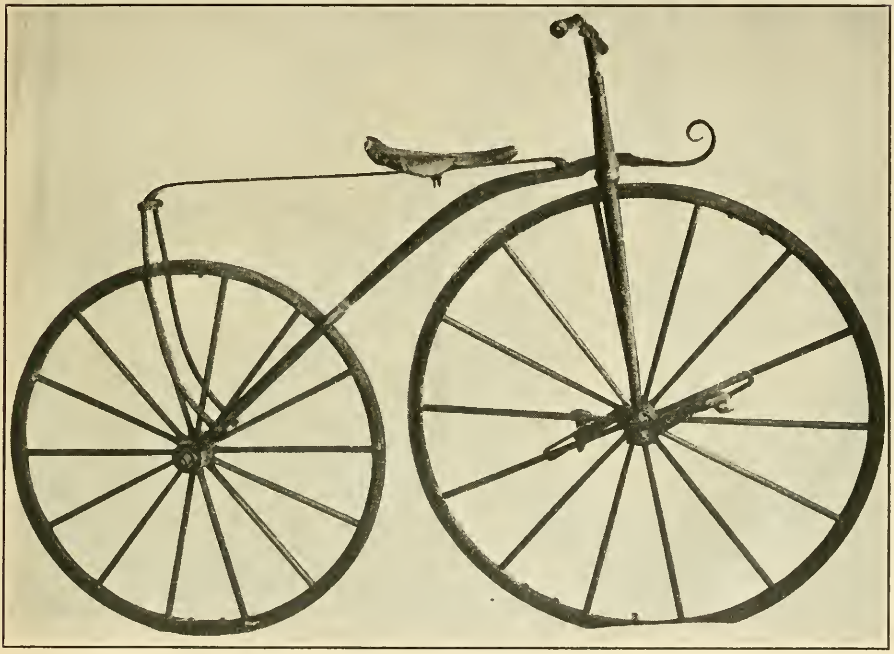


FIG. 55.—HANLON TYPE VELOCIPEDE, 1866.

inches; width over all to outside of hub caps, rear wheels, 81¼ inches; length of frame, back of cab, 140 inches; turning circle, 42 feet; capacity, 20,000 pounds—chassis, body, and load; tires, 36 inches in diameter; wheel tread, 63 inches on front wheels and 65 inches on rear wheels. Cat. No. 307,256 U.S.N.M.

CYCLES.

Velocipede. Made in Dayton, Ohio, 1866. Purchased 1888.

This machine is of the type developed by the Hanlon Brothers, who were the American contemporaries with Pierre Lallement of France, whose design of velocipede laid the foundation of modern cycling.

The frame is of wrought iron, the wheels of wood with iron tires, the front wheel being 36 inches in diameter and the rear wheel 30 inches. It is propelled by brass pedals fitted to slotted cranks on the front wheel, the rider sitting on a saddle mounted on a horizontal strap iron spring, supported over the front wheel by the socket head and over the rear wheel by curved iron struts extending vertically from the wheel bearings. The machine is steered by a straight line handle bar at the top of the wheel fork. The slotted crank arms permit leverages from 5¾ to 9¼ inches. The pedals revolve freely on

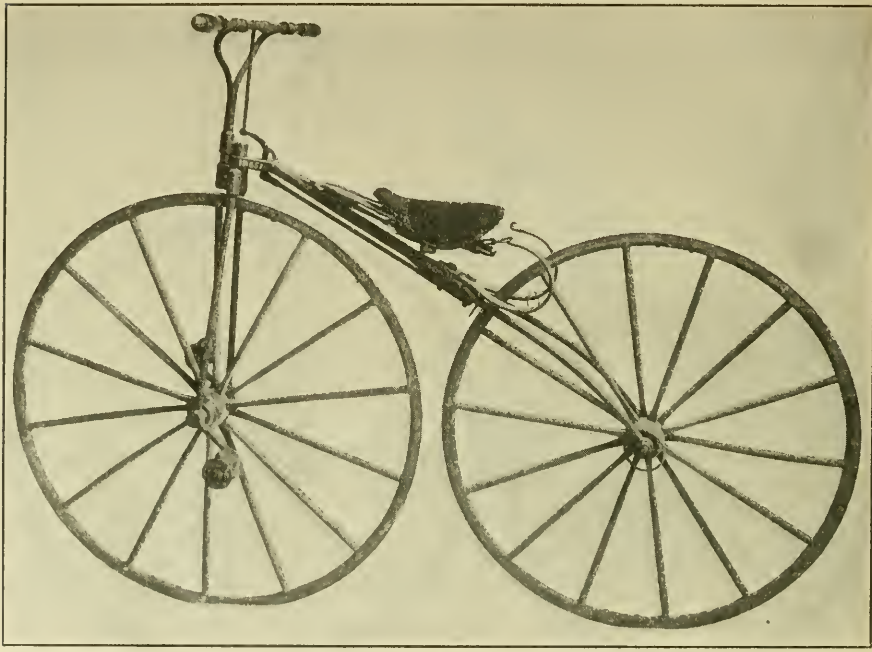


FIG. 56.—VELOCIPEDE, 1870.

the crank axle, but are held in the correct position by brass weights on their lower side, which weights are an integral part of the pedal casting. Cat. No. 180,456 U.S.N.M.

Velocipede, 1867. Gift of William Sturgis Bigelow, 1907.

This machine is very similar to the preceding one except that the strap iron spring of the "backbone" inclines to the rear. In addition, the machine is equipped with a brake on the rear wheel applied by a cord, which can be tightened by twisting the handle bar; also, foot rests are provided on an extension of the "backbone" beyond the handle bar.

Although the saddle position is adjustable, the rider sat so far behind his work that the power was badly applied and hills or rough roads were difficult to travel on. Cat. No. 247,884 U.S.N.M.

Velocipede, 1870. Gift of the Goodyear Rubber Company, 1897.

This machine is a further development of the Hanlon design, involving a steel spring and a strap seat suspension and an improved brake on the rear wheel operated by rotating the handle bar, which transmits pressure through a system of rods and springs.

The frame of the machine consists of a front-wheel iron fork pitched back slightly from the vertical, and a diagonal fork extending from the front-wheel socket head to the rear-wheel bearings. A strap saddle is suspended between the socket head and two springs midway of each branch of the diagonal fork. The machine is driven by metal spool pedals fitted to short cranks on the front

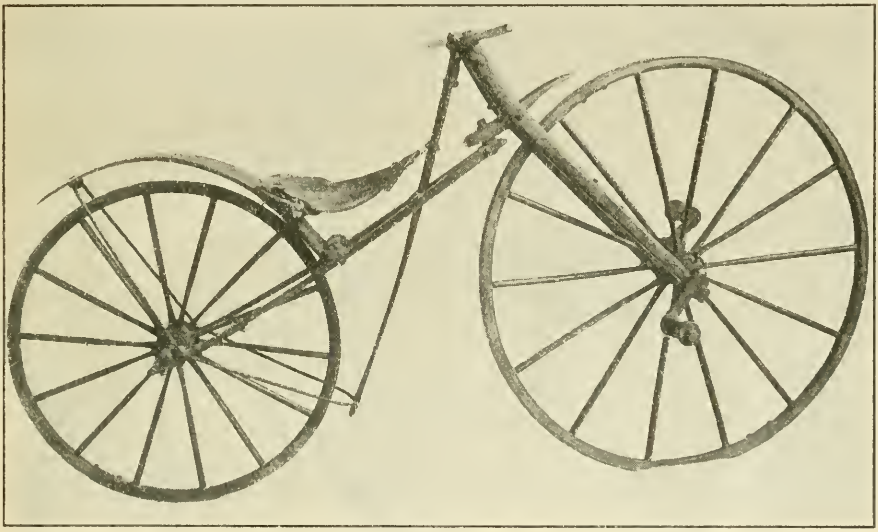


FIG. 57.—BICYCLE, 1879.

wheel. The wheels are of wood with iron tires, the front wheel 38 inches in diameter and the rear 30 inches.

Cat. No. 181,651 U.S.N.M.

Bicycle, 1879. Patent Allowed J. Shire, Detroit, Michigan. Gift of C Howard Buckler, 1907.

The frame of this machine is entirely of wood braced with iron. The front fork pitches backward at an angle of 45 degrees and terminates in a short handle bar. From a pivot back of the front fork and above the wheel a diagonal fork extends to the rear wheel bearings and a wood brace extends from the center of the handle bar downward between the branches of the diagonal fork to a point about three inches above the ground and in front of the rear wheel, which is attached to iron struts from each rear-wheel bearing. A broad wooden mud guard is fitted over the rear wheel, supported at one end by vertical iron struts extending from the rear wheel, and at the other to the diagonal rear-wheel fork. Secured to this mud guard is the saddle. The machine is driven by wooden spool pedals fitted to short cranks on the front wheel.

Cat. No. 248,087 U.S.N.M.

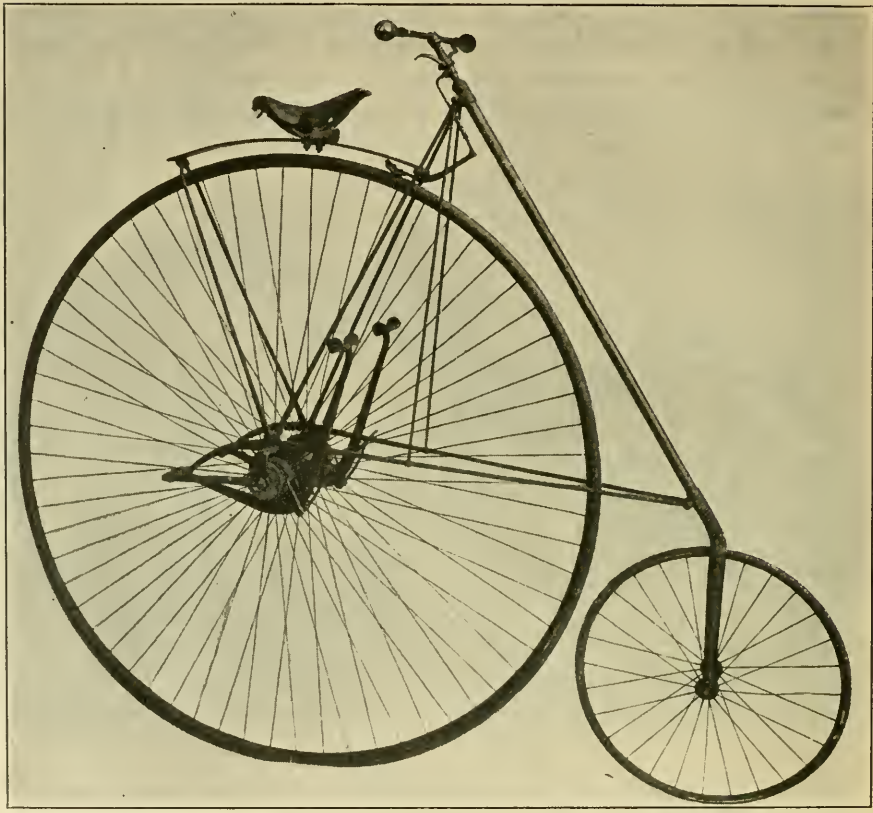


FIG. 58.—"GRASSHOPPER" BICYCLE, 1880.

"Grasshopper" Bicycle, 1880. Gift of Thomas M. Wilkins.

This machine consists of a metal frame with a 22-inch wire wheel in front and a 54-inch wire wheel in the rear. It was developed as a result of the tendency of its predecessor, the "Ordinary" (having the small wheel in the rear), to pitch the rider head first upon striking an obstruction in the road. The front wheel is swung in a fork whose branches join above the wheel and continue upward within a metal tube to the handle bar. The rear wheel is secured by a series of solid iron struts between this tube and its axles and to a short strap-iron plate on which the saddle is placed. The machine is driven by a system of levers and leather clutches on the rear wheel hub, with a spring to recover the pedals at each downward stroke. The wheels are equipped with solid rubber tires and spoon brake on the rear wheel operated from the handle bar.

Cat. No. 248,836 U.S.N.M.

Columbia Bicycle, 1885. Gift of E. H. Sithens.

This type of bicycle, sometimes known as the "Ordinary," having the large front wheel and small rear wheel, was very much in favor from 1880–1890. The frame is constructed of steel tubing. The front

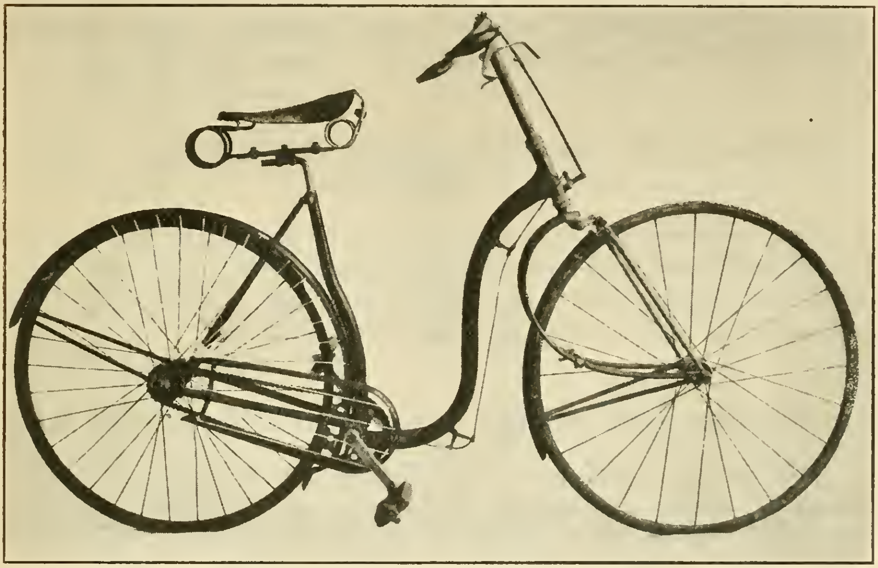


FIG. 59.—LADY'S "VICTORIA" BICYCLE, 1887.

wire-spoke wheel is 54 inches in diameter, equipped with solid tires. The pedal cranks are fitted with two holes for adjusting the position of the pedals, and a spoon brake operating on the top of the front wheel is controlled by a lever from the right handle bar.

This particular machine has been ridden over 10,000 miles and was used to some extent in racing events. Cat. No. 307,216 U.S.N.M.

"Star" Bicycle, 1881. Gift of Robert Atwater Smith.

This machine was made by the H. B. Smith Machine Company, Smithville, New Jersey. It consists of a small 22-inch wire wheel in front and a large 36-inch wire wheel in the rear, joined by a triangular wrought-iron bar frame. The riding saddle is fitted to a short metal plate fastened at one end to the main frame and at the other to struts from the rear wheel axle. The machine is driven by treadles of the "grasshopper" type. It is equipped with curved handlebars, spoon brake on the rear wheel, a solid rubber tire on the front wheel, and a pneumatic tire on the rear wheel. Cat. No. 279,005 N.S.N.M.

Safety Bicycle, 1883. Marked "Psycho, St. John Works, Coventry, England." Gift of J. E. Hosford.

This type of bicycle incorporates all of the advantages of the high-wheeled type with none of the disadvantages. The rear wheel, 36 inches in diameter, is driven by means of a chain and sprocket through a sprocket and pedals fitted in the frame directly beneath the rider. The equipment includes curved handlebar, spade handles, and brake on the front wheel, solid wire wheels, and oil lamp.

Cat. No. 218,118 U.S.N.M.

Safety Bicycle, 1885. Marked "New Rapid. Made in England." Gift of H. K. Griffith, 1899.

This machine consists of a heavy iron frame with a 30-inch wire front wheel and a 32-inch wire rear wheel, both having steel rims and solid rubber tires. It is driven by chain and sprockets, the pedals being placed vertically beneath the saddle.

Cat. No. 201.660 U.S.N.M.

Lady's Bicycle, 1887. Marked "Victoria." Gift of May H. Mead, 1903.

This machine consists of a drop frame with spring-fork attachment to the forward wheel. It is driven by chain and sprockets, steered by a curved handlebar with spade handles. The brake acts on the rear wheel connected by wires and levers on the handlebar. The wire wheels are 28 inches in diameter, equipped with solid rubber tires. The machine was made by the Overman Wheel Company, Boston, Massachusetts. Cat. No. 214,971 U.S.N.M.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
▽