CHAPTER V.

THE MODERN STEAM-ENGINE.

"VOILÀ la plus merveilleuse de toutes les Machines; le Mécanisme ressemble à celui des animaux. La chaleur est le principe de son mouvement; il se fait dans ses différens tuyaux une circulation, comme celle du sang dans les veines, ayant des valvules qui s'ouvrent et se ferment à propos; elles se nourrit, s'évacue d'elle même dans les temps réglés, et tire de son travail tout ce qu'il lui faut pour subsister. Cette Machine a pris sa naissance en Angleterre, et toutes les Machines à feu qu'on a construites ailleurs que dans la Grande Brétagne ont été exécutées par des Anglais."—BELIDOR.

THE SECOND PERIOD OF APPLICATION—1800–1850 (CONTINUED). THE STEAM-ENGINE APPLIED TO SHIP-PROPULSION.

AMONG the most obviously important and most inconceivably fruitful of all the applications of steam which marked the period we are now studying, is that of the steam-engine to the propulsion of vessels. This direction of application has been that which has, from the earliest period in the history of the steam-engine, attracted the attention of the political economist and the historian, as well as the mechanician, whenever a new improvement, or the revival of an old device, has awakened a faint conception of the possibilities attendant upon the introduction of a machine capable of making so great a force available. The realization of the hopes, the prophecies, and the aspirations of earlier times, in the modern marine steam-engine, may be justly regarded as the greatest of all the triumphs of mechanical engineering. Although, as has already been stated, attempts were made at a very early period to effect this application of steam-power, they were not successful, and the steamship is a product of the present century. No such attempts were commercially successful until after the time of Newcomen and Watt, and at the commencement of the nineteenth century. It is, indeed, but a few years since the passage across the Atlantic was frequently made in sailing-vessels, and the dangers, the discomforts, and the irregularities of their trips were most serious. Now, hardly a day passes that does not see several large and powerful steamers leaving the ports of New York and Liverpool to make the same voyages, and their passages are made with such regularity and safety, that travelers can anticipate with confidence the time of their arrival at the termination of their voyage to a day, and can cross with safety and with comparative comfort even amid the storms of winter. Yet all that we to-day see of the extent and the efficiency of steam-navigation has been the work of the present century, and it may well excite our wonder and our admiration.

The history of this development of the use of steam-power illustrates most perfectly that process of growth of this invention which has been already referred to; and we can here trace it, step by step, from the earliest and rudest devices up to those most recent and most perfect designs which represent the most successful existing types of the heat-engine—whether considered with reference to its design and construction, or as the highest application of known scientific principles—that have yet been seen in even the present advanced state of the mechanic arts.

The paddle-wheel was used as a substitute for oars at a very early date, and a description of paddle-wheels applied to vessels, curiously illustrated by a large wood-cut, may be found in the work of Fammelli, "De l'artificioses machines," published in old French in 1588. Clark[1] quotes from

[1] "Steam and the Steam-Engine."

Ogilby's edition of the "Odyssey" a stanza which reads like a prophecy, and almost awakens a belief that the great poet had a knowledge of steam-vessels in those early times—a thousand years before the Christian era. The prince thus addresses Ulysses :

"We use nor Helm nor Helms-man. Our tall ships
Have Souls, and plow with Reason up the deeps;
All cities, Countries know, and where they list,
Through billows glide, veiled in obscuring Mist;
Nor fear they Rocks, nor Dangers on the way."

Pope's translation[1] furnishes the following rendering of Homer's prophecy :

"So shalt thou instant reach the realm assigned,
In wondrous ships, self-moved, instinct with mind;
* * * * *
Though clouds and darkness veil the encumbered sky,
Fearless, through darkness and through clouds they fly.
Though tempests rage, though rolls the swelling main,
The seas may roll, the tempests swell in vain;
E'en the stern god that o'er the waves presides,
Safe as they pass and safe repass the tide,
With fury burns; while, careless, they convey
Promiscuous every guest to every bay."

It is stated that the Roman army under Claudius Caudex was taken across to Sicily in boats propelled by paddle-wheels turned by oxen. Vulturius gives pictures of such vessels.

This application of the force of steam was very possibly anticipated 600 years ago by Roger Bacon, the learned Franciscan monk, who, in an age of ignorance and intellectual torpor, wrote :

"I will now mention some wonderful works of art and nature, in which there is nothing of magic, and which magic

[1] "Odyssey," Book VIII., p. 175.

could not perform. Instruments may be made by which the largest ships, with only one man guiding them, will be carried with greater velocity than if they were full of sailors," etc., etc.

Darwin's poetical prophecy was published long years before Watt's engine rendered its partial fulfillment a possibility; and thus, for many years before even the first promising effort had been made, the minds of the more intelligent had been prepared to appreciate the invention when it should finally be brought forward.

The earliest attempt to propel a vessel by steam is claimed by Spanish authorities, as has been stated, to have been made by Blasco de Garay, in the harbor of Barcelona, Spain, in 1543. The record, claimed as having been extracted from the Spanish archives at Simancas, states the vessel to have been of 200 tons burden, and to have been moved by paddle-wheels; and it is added that the spectators saw, although not allowed closely to inspect the apparatus, that one part of it was a "vessel of boiling water"; and it is also stated that objection was made to the use of this part of the machine, because of the danger of explosion.

The account seems somewhat apocryphal, and it certainly led to no useful results.

In an anonymous English pamphlet, published in 1651, which is supposed by Stuart to have been written by the Marquis of Worcester, an indefinite reference to what may probably have been the steam-engine is made, and it is there stated to be capable of successful application to propelling boats.

In 1690, Papin proposed to use his piston-engine to drive paddle-wheels to propel vessels; and in 1707 he applied the steam-engine, which he had proposed as a pumping-engine, to driving a model boat on the Fulda at Cassel. In this trial he used the arrangement of which a sketch has been shown, his pumping-engine forcing up water to turn a water-wheel, which, in turn, was made to drive the paddles.

An account of his experiments is to be found in manuscript in the correspondence between Leibnitz and Papin, preserved in the Royal Library at Hanover. Professor Joy found there the following letter :[1]

"Dionysius Papin, Councillor and Physician to his Royal Highness the Elector of Cassel, also Professor of Mathematics at Marburg, is about to dispatch a vessel of singular construction down the river Weser to Bremen. As he learns that all ships coming from Cassel, or any point on the Fulda, are not permitted to enter the Weser, but are required to unload at Münden, and as he anticipates some difficulty, although those vessels have a different object, his own not being intended for freight, he begs most humbly that a gracious order be granted that his ship may be allowed to pass unmolested through the Electoral domain; which petition I most humbly support. G. W. LEIBNITZ.

"HANOVER, *July* 18, 1707."

This letter was returned to Leibnitz, with the following indorsement :

"The Electoral Councillors have found serious obstacles in the way of granting the above petition, and, without giving their reasons, have directed me to inform you of their decision, and that, in consequence, the request is not granted by his Electoral Highness. H. REICHE.

"HANOVER, *July* 25, 1707."

This failure of Papin's petition was the death-blow to his effort to establish steam-navigation. A mob of boatmen, who thought they saw in the embryo steamship the ruin of their business, attacked the vessel at night, and utterly destroyed it. Papin narrowly escaped with his life, and fled to England.

In the year 1736, Jonathan Hulls took out an English patent for the use of a steam-engine for ship-propulsion, proposing to employ his steamboat in towing. In 1737 he published a well-written pamphlet, describing this apparatus, which is shown in Fig. 66, a reduced fac-simile of the plate accompanying his paper.

[1] *Scientific American*, February 24, 1877.

He proposed using the Newcomen engine, fitted with a counterpoise-weight and a system of ropes and grooved wheels, which, by a peculiar ratchet-like action, gave a con-

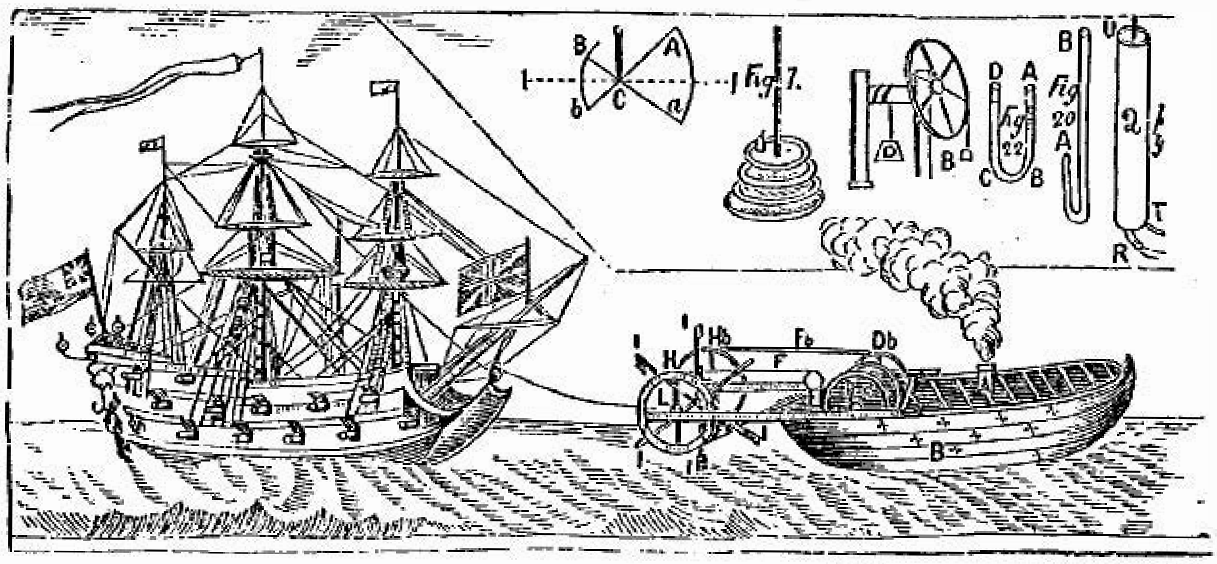

FIG. 66.—Hulls's Steamboat, 1736.

tinuous rotary motion. His vessel was to have been used as a tow-boat. He says, in his description: "In some convenient part of the Tow-boat there is placed a Vessel about two-3rds full of water, with the Top closed; and this Vessel being kept Boiling, rarifies the Water into a Steam, this Steam being convey'd thro' a large pipe into a cylindrical Vessel, and there condensed, makes a Vacuum, which causes the weight of the atmosphere to press down on this Vessel, and so presses down a Piston that is fitted into this Cylindrical Vessel, in the same manner as in Mr. Newcomen's Engine, with which he raises Water by Fire.

"*P*, the Pipe coming from the Furnace to the Cylinder. *Q*, the Cylinder wherein the steam is condensed. *R*, the Valve that stops the Steam from coming into the Cylinder, whilst the Steam within the same is condensed. *S*, the Pipe to convey the condensing Water into the Cylinder. *T*, a cock to let in the condensing Water when the Cylinder is full of Steam and the Valve, *P*, is shut. *U*, a Rope fixed to the Piston that slides up and down in the Cylinder.

"*Note.* This Rope, *U*, is the same Rope that goes round the wheel, *D*, in the machine."

In the large division of his plate, *A* is the chimney; *B* is the tow-boat; *C C* is the frame carrying the engine; *D a*, *D*, and *D b* are three wheels carrying the ropes *M*, *Fb*, and *Fa*, *M* being the rope *U* of his smaller figure, 30. *H a* and *H b* are two wheels on the paddle-shafts, *I I*, arranged with pawls so that the paddle-wheel, *I I*, always turns the same way, though the wheels *H a* and *H b* are given a reciprocating motion; *F b* is a rope connecting the wheels in the vessel, *Db*, with the wheels at the stern. Hulls says:

"When the Weight, *G*, is so raised, while the wheels *D a*, *D*, and *D b* are moving backward, the Rope *F a* gives way, and the Power of the Weight, *G*, brings the Wheel *H a* forward, and the Fans with it, so that the Fans always keep going forward, notwithstanding the Wheels *D a*, *D*, and *D b* move backward and forward as the Piston moves up and down in the Cylinder. *L L* are Teeth for a Catch to drop in from the Axis, and are so contrived that they catch in an alternate manner, to cause the Fan to move always forward, for the Wheel *H a*, by the power of the weight, *G*, is performing his Office while the other wheel, *H b*, goes back in order to fetch another stroke.

"*Note.* The weight, *G*, must contain but half the weight of the Pillar of Air pressing on the Piston, because the weight, *G*, is raised at the same time as the Wheel *Hb* performs its Office, so that it is in effect two Machines acting alternately, by the weight of one Pillar of Air, of such a Diameter as the Diameter of the Cylinder is."

The inventor suggests the use of timber guards to protect the wheels from injury, and, in shallow water, the attachment to the paddle-shafts of cranks "to strike a Shaft to the Bottom of the River, which will drive the Vessel forward with the greater Force." He concludes: "Thus I have endeavoured to give a clear and satisfactory Account of my New-invented Machine, for carrying Vessels out of and into any Port, Harbour, or River, against Wind and Tide, or in a Calm; and I doubt not but whoever shall give himself the Trouble to peruse this Essay, will be so candid as to excuse or overlook any Imperfections in the diction or manner of writing, considering the Hand it comes from, if what I have imagined may only appear as plain to others as it has done to me, viz., That the Scheme I now offer is Practicable, and if encouraged will be Useful."

There is no positive evidence that Hulls ever put his scheme to the test of experiment, although tradition does say that he made a model, which he tried with such ill success as to prevent his prosecution of the experiment further; and doggerel rhymes are still extant which were sung by his neighbors in derision of his folly, as they considered it.

A prize was awarded by the French Academy of Sciences, in 1752, for the best essay on the manner of impelling vessels without wind. It was given to Bernouilli, who, in his paper, proposed a set of vanes like those of a windmill—a screw, in fact—one to be placed on each side the vessel, and two more behind. For a vessel of 100 tons, he proposed a shaft 14 feet long and 2 inches in diameter, carrying "eight wheels, for acting on the water, to each of which it" (the shaft) "is perpendicular, and forms an axis for them all; the wheels should be at equal distances from each other. Each wheel consists of 8 arms of iron, each 3 feet long, so that the whole diameter of the wheel is 6 feet. Each of these arms, at the distance of 20 inches from the centre, carries a sheet-iron plane (or paddle) 16 inches square, which is inclined so as to form an angle of 60 degrees, both with the arbor and keel of the vessel, to which the arbor is placed parallel. To sustain this arbor and the wheels, two strong bars of iron, between 2 and 3 inches thick, proceed from the side of the vessel at right angles to it, about 2½ feet below the surface of the water." He proposed similar screw-propellers at the stern, and suggested that they could be driven by animal or by steam-power.

But a more remarkable essay is quoted by Figuier[1]—the paper of l'Abbé Gauthier, published in the "Mémoires de la Société Royale des Sciences et Lettres de Nancy." Bernouilli had expressed the belief that the best steam-engine then known—that of Newcomen—was not superior to some other motors. Gauthier proposed to use that engine in the propulsion of paddle-wheels placed at the side of the vessel. His plan was not brought into use, but his paper embodied a glowing description of the advantages to be secured by its adoption. He states that a galley urged by 26 oars on a side made but 4,320 toises (8,420 meters), or about 5 miles, an hour, and required a crew of 260 men. A steam-engine, doing the same work, would be ready for action at all times, could be applied, when not driving the vessel, to raising the anchor, working the pumps, and to ventilating the ship, while the fire would also serve to cook with. The engine would occupy less space and weight than the men, would require less aliment, and that of a less expensive kind, etc. He would make the boiler safe against explosions by bands of iron; would make the fire-box of iron, with a water-filled ash-pit and base-plate. His injection-water was to come from the sea, and return by a delivery-pipe placed above the water-line. The chains, usually leading from the end of the beam to the pump-rods, were to be carried around wheels on the paddle-shaft, which were to be provided with pawls entering a ratchet, and thus the paddles, having been given several revolutions by the descent of the piston and the unwinding of the chain, were to revolve freely while the return-stroke was made, the chain being hauled down and rewound by the wheel on the shaft, the latter being moved by a weight. The engine was proposed to be of 6 feet stroke, and to make 15 strokes per minute, with a force of 11,000 pounds.

A little later (1760), a Swiss clergyman, J. A. Genevois,

[1] "Les Merveilles de la Science."

published in London a paper relating to the improvement of navigation,[1] in which his plan was proposed of compressing springs by steam or other power, and applying their effort while recovering their form to ship-propulsion.

It was at this time that the first attempts were made in the United States to solve this problem, which had begun to be recognized as one of the greatest which had presented itself to the mechanic and the engineer.

WILLIAM HENRY was a prominent citizen of the then little village of Lancaster, Pa., and was noted as an ingenious and successful mechanic.[2] He was still living at the beginning of the present century. Mr. Henry was the first to make the "rag" carpet, and was the inventor of the screw-auger. He was of a Scotch and North-of-Ireland family, his father, John Henry, and his two older brothers, Robert and James, having come to the United States about 1720. Robert settled, finally, in Virginia, and it is said that Patrick Henry, the patriot and orator, was of his family. The others remained in Chester County, Pa., where William was born, in 1729. He learned the trade of a gunsmith, and, driven from his home during the Indian war (1755 to 1760), settled in Lancaster.

In the year 1760 he went to England on business, where his attention was attracted to the invention—then new, and the subject of discussion in every circle—of James Watt. He saw the possibility of its application to navigation and to driving carriages, and, on his return home, commenced the construction of a steam-engine, and finished it in 1763.

Placing it in a boat fitted with paddle-wheels, he made a trial of the new machine on the Conestoga River, near Lancaster, where the craft, by some accident, sank,[3] and

[1] "Some New Enquiries tending to the Improvement of Navigation." London, 1760.

[2] *Lancaster Daily Express*, December 10, 1872. This account is collated from various manuscripts and letters in the possession of the author.

[3] Bowen's "Sketches," p. 56.

was lost. He was not discouraged by this failure, but made a second model, adding some improvements. Among the records of the Pennsylvania Philosophical Society is, or was, a design, presented by Henry in 1782, of one of his steamboats. The German traveler Schöpffnvisited the United States in 1783, and at Mr. Henry's house, at Lancaster, was shown "a machine by Mr. Henry, intended for the propelling of boats, etc.; 'but,' said Mr. Henry, 'I am doubtful whether such a machine would find favor with the public, as every one considers it impracticable against wind and tide;' but that such a Boat *will* come into use and navigate on the waters of the Ohio and Mississippi, he had not the least doubt of, but the time had not yet arrived of its being appreciated and applied."

JohnnFitch, whose experiments will presently be referred to, was an acquaintance and frequent visitor to the house of Mr. Henry, and may probably have there received the earliest suggestions of the importance of this application of steam. About 1777, when Henry was engaged in making mathematical and philosophical instruments, and the screw-auger, which at that time could only be obtained of him, Robert Fulton, then twelve years old, visited him, to study the paintings of Benjamin West, who had long been a friend and protégé of Henry. He, too, not improbably received there the first suggestion which afterward led him to desert the art to which he at first devoted himself, and which made of the young portrait-painter a successful inventor and engineer. West's acquaintance with Henry had no such result. The young painter was led by his patron and friend to attempt historical pictures,[1] and probably owes his fame greatly to the kindly and discerning mechanic. Says Galt, in his "Memoirs of Sir Benjamin West" (London, 1816): "Towards his old friend, William Henry, of Lancaster City, he always cherished the most

[1] Some of West's portraits, including those of Mr. and Mrs. Henry, were lately in the possession of Mr. John Jordan, of Philadelphia.

grateful affection; he was the first who urged him to attempt historical composition."

When, after the invention of Watt, the steam-engine had taken such shape that it could really work the propelling apparatus of a paddle or screw vessel, a new impetus was given to the work of its adaptation. In France, the Marquis de Jouffroy was one of the earliest to perceive that the improvements of Watt, rendering the engine more compact, more powerful, and, at the same time, more regular and positive in its action, had made it, at last, readily applicable to the propulsion of vessels. The brothers Périer had imported a Watt engine from Soho, and this was attentively studied by the marquis,[1] and its application to the paddle-wheels of a steam-vessel seemed to him a simple problem. Comte d'Auxiron and Chevalier Charles Mounin, of Follenai, friends and companions of Jouffroy, were similarly interested, and the three are said to have often discussed the scheme together, and to have united in devising methods of applying the new motor.

In the year 1770, D'Auxiron determined to attempt the realization of the plans which he had conceived. He resigned his position in the army, prepared his plans and drawings, and presented them to M. Bertin, the Prime Minister, in the year 1771 or 1772. The Minister was favorably impressed, and the King (May 22, 1772) granted D'Auxiron a monopoly of the use of steam in river-navigation for 15 years, provided he should prove his plans practicable, and they should be so adjudged by the Academy.

A company had been formed, the day previous, consisting of D'Auxiron, Jouffroy, Comte de Dijon, the Marquis d'Yonne, and Follenai, which advanced the requisite funds. The first vessel was commenced in December, 1772. When nearly completed, in September, 1774, the boat sprung a leak, and, one night, foundered at the wharf.

[1] Figuier.

After some angry discussion, during which D'Auxiron was rudely, and probably unjustly, accused of bad faith, the company declined to advance the money needed to recover and complete the vessel. They were, however, compelled by the court to furnish it; but, meantime, D'Auxiron died of apoplexy, the matter dropped, and the company dissolved. The cost of the experiment had been something more than 15,000 francs.

The heirs of D'Auxiron turned the papers of the deceased inventor over to Jouffroy, and the King transferred to him the monopoly held by the former. Follenai retained all his interest in the project, and the two friends soon enlisted a powerful adherent and patron, the Marquis Ducrest, a well-known soldier, courtier, and member of the Academy, who took an active part in the prosecution of the scheme. M. Jacques Périer, the then distinguished mechanic, was consulted, and prepared plans, which were adopted in place of those of Jouffroy. The boat was built by Périer, and a trial took place in 1774, on the Seine. The result was unsatisfactory. The little craft could hardly stem the sluggish current of the river, and the failure caused the immediate abandonment of the scheme by Périer.

Still undiscouraged, Jouffroy retired to his country home, at Baume-les-Dames, on the river Doubs. There he carried on his experiments, getting his work done as best he could, with the rude tools and insufficient apparatus of a village blacksmith. A Watt engine and a chain carrying "duck-foot" paddles were his propelling apparatus. The boat, which was about 14 feet long and 6 wide, was started in June, 1776. The duck's-foot system of paddles proved unsatisfactory, and Jouffroy gave it up, and renewed his experiments with a new arrangement. He placed on the paddle-wheel shaft a ratchet-wheel, and on the piston-rod of his engine, which was placed horizontally in the boat, a double rack, into the upper and the lower parts of which the ratchet-wheel geared. Thus the wheels turned in the same direction, whichever way the piston was moving. The new engine was built at Lyons in 1780, by Messrs. Frères-Jean. The new boat was about 140 feet long and 14 feet wide; the wheels were 14 feet in diameter, their floats 6 feet long, and the "dip," or depth to which they reached, was about 2 feet. The boat drew 3 feet of water, and had a total weight of about 150 tons.

At a public trial of the vessel at Lyons, July 15, 1783, the little steamer was so successful as to justify the publication of the fact by a report and a proclamation. The fact that the experiment was not made at Paris was made an excuse on the part of the Academy for withholding its indorsement, and on the part of the Government for declining to confirm to Jouffroy the guaranteed monopoly. Impoverished and discouraged, Jouffroy gave up all hope of prosecuting his plans successfully, and reëntered the army. Thus France lost an honor which was already within her grasp, as she had already lost that of the introduction of the steam-engine, in the time of Papin.

About 1785, John Fitch and James Rumsey were engaged in experiments having in view the application of steam to navigation.

Rumsey's experiments began in 1774, and in 1786 he succeeded in driving a boat at the rate of four miles an hour against the current of the Potomac at Shepherdstown, W. Va., in presence of General Washington. His method of propulsion has often been reinvented since, and its adoption urged with that enthusiasm and persistence which is a peculiar characteristic of inventors.

Rumsey employed his engine to drive a great pump which forced a stream of water aft, thus propelling the boat forward, as proposed earlier by Bernouilli. This same method has been recently tried again by the British Admiralty, in a gunboat of moderate size, using a centrifugal pump to set in motion the propelling stream, and with some other modifications which are decided improvements upon Rumsey's rude arrangements, but which have not done much more than his toward the introduction of "Hydraulic or Jet Propulsion," as it is now called.

In 1787 he obtained a patent from the State of Virginia for steam-navigation. He wrote a treatise "On the Application of Steam," which was printed at Philadelphia, where a Rumsey society was organized for the encouragement of attempts at steam-navigation.

Rumsey died of apoplexy, while explaining some of his schemes before a London society a short time later, December 23, 1793, at the age of fifty years. A boat, then in process of construction from his plans, was afterward tried on the Thames, in 1793, and steamed at the rate of four miles an hour. The State of Kentucky, in 1839, presented his son with a gold medal, commemorative of his father's services "in giving to the world the benefit of the steamboat."

John Fitch was an unfortunate and eccentric, but very ingenious, Connecticut mechanic. After roaming about until forty years of age, he finally settled on the banks of the Delaware, where he built his first steamboat.

In April, 1785, as Fitch himself states, at Neshamony, Bucks County, Pa., he suddenly conceived the idea that a carriage might be driven by steam. After considering the subject a few days, his attention was led to the plan of using steam to propel vessels, and from that time to the day of his death he was a persistent advocate of the introduction of the steamboat. At this time, Fitch says, "I did not know that there was a steam-engine on the earth;" and he was somewhat disappointed when his friend, the Rev. Mr. Irwin, of Neshamony, showed him a sketch of one in "Martin's Philosophy."

Fitch's first model was at once built, and was soon after tried on a small stream near Davisville. The machinery was made of brass, and the boat was impelled by paddle-wheels. A rough model of his steamboat was shown to

Dr. John Ewing, Provost of the University of Pennsylvania, who, August 20, 1785, addressed a commendatory letter to an ex-Member of Congress, William C. Houston, asking him to assist Fitch in securing the aid of the General Government. The latter referred the inventor, by a letter of recommendation, to a delegate from New Jersey, Mr. Lambert Cadwalader. With this, and other letters, Fitch proceeded to New York, where Congress then met, and made his application in proper form. He was unsuccessful, and equally so in attempting to secure aid from the Spanish minister, who desired that the profits should be secured, by a monopoly of the invention, to the King of Spain. Fitch declined further negotiation, determined that, if successful at all, the benefit should accrue to his own countrymen.

In September, 1785, Fitch presented to the American Philosophical Society, at Philadelphia, a model in which he had substituted an endless chain and floats for the paddle-wheels, with drawings and a descriptive account of his scheme. This model is shown in the accompanying figure.

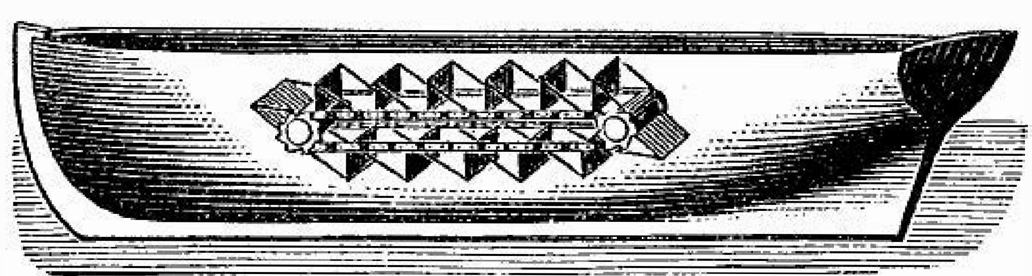

FIG. 67.—Fitch's Model, 1785.

In March, 1786, Fitch was granted a patent by the State of New Jersey, for the exclusive right to the navigation of the waters of the State by steam, for 14 years. A month later, he was in Philadelphia, seeking a similar patent from the State of Pennsylvania. He did not at once succeed, but in a few days he had formed a company, raised $300, and set about finding a place in which to construct his engine. Henry Voight, a Dutch watchmaker, a good mechanic, and a very ingenious man, took an interest in the company, and with him Fitch set about his work with great enthusiasm. After making a little model, having a steam-cylinder but one inch in diameter, they built a model boat and engine, the latter having a diameter of cylinder of three inches. They tried the endless chain, and other methods of propulsion, without success, and finally succeeded with a set of oars worked by the engine. In August, 1786, it was determined by the company to authorize the construction of a larger vessel; but the money was not readily obtained. Meantime, Fitch continued his efforts to secure a patent from the State, and was finally, March 28, 1787, successful. He also obtained a similar grant from the State of Delaware, in February of the same year, and from New York, March 19.

Money was now subscribed more freely, and the work on the boat continued uninterruptedly until May, 1787, when a trial was made, which revealed many defects in the machinery. The cylinder-heads were of wood, and leaked badly; the piston leaked; the condenser was imperfect; the valves were not tight. All these defects were remedied, and a condenser invented by Voight—the "pipe-condenser"—was substituted for that defective detail as previously made.

The steamboat was finally placed in working order, and was found capable, on trial, of making three or four miles an hour. But now the boiler proved to be too small to furnish steam steadily in sufficient quantity to sustain the higher speed. After some delay, and much distress on the part of the sanguine inventor, who feared that he might be at last defeated when on the very verge of success, the necessary changes were finally made, and a trial took place at Philadelphia, in presence of the members of the Convention—then in session at Philadelphia framing the Federal Constitution—August 22, 1787. Many of the distinguished spectators gave letters to Fitch certifying his success. Fitch now went to Virginia, where he succeeded in obtaining a patent, November 7, 1787, and then returned to ask a patent of the General Government.

A controversy with Rumsey now followed, in which Fitch asserted his claims to the invention of the steamboat, and denied that Rumsey had done more than to revive the scheme which Bernouilli, Franklin, Henry, Paine, and others, had previously proposed, and that Rumsey's *steam-boat* was not made until 1786.

The boiler adopted in Fitch's boat of 1787 was a "pipe-boiler," which he had described in a communication to the Philosophical Society, in September, 1785. It consisted (Fig. 68) of a small water-pipe, winding backward and forward in the furnace, and terminating at one end at the point at which the feed-water was introduced, and at the other uniting with the steam-pipe leading to the engine. Voight's condenser was similarly constructed. Rumsey

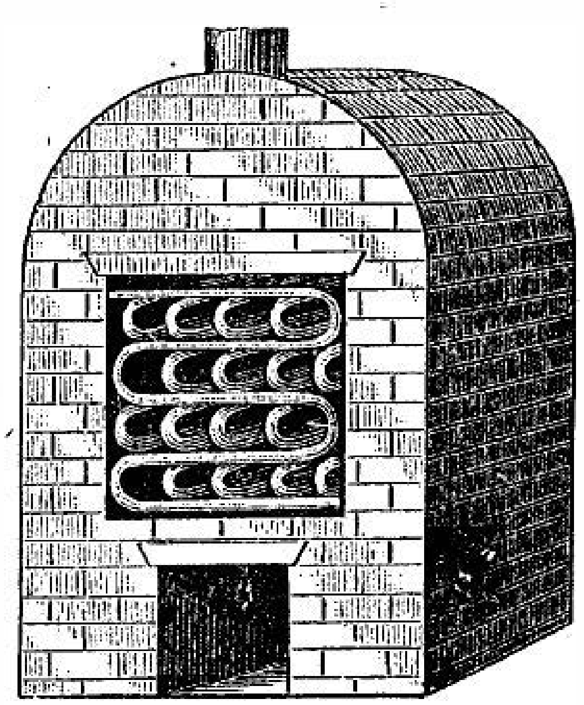

FIG. 68.—Fitch and Voight's Boiler, 1787.

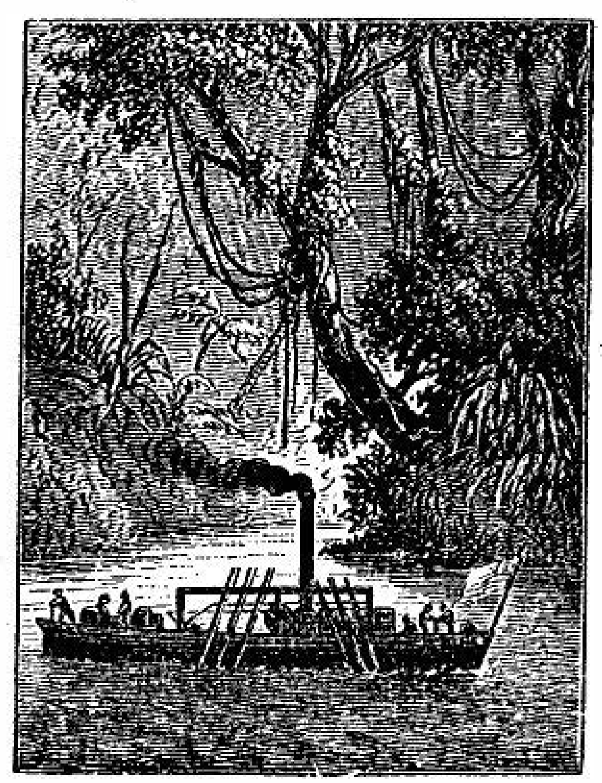

FIG. 69.—Fitch's First Boat, 1787.

claimed that this boiler was copied from his designs. Fitch brought evidence to prove that Rumsey had not built such a boiler until after his own.

Fitch's first boat-engine had a steam-cylinder 12 inches in diameter. A second engine was now built (1788) with a cylinder 18 inches in diameter, and a new boat. The first vessel wase45 feet long and 12 feet wide; the new boat was 60 feet long and of but 8 feet breadth of beam. The first boat (Fig. 69) had paddles worked at the sides, with the motion given the Indian paddle in propelling a canoee; in

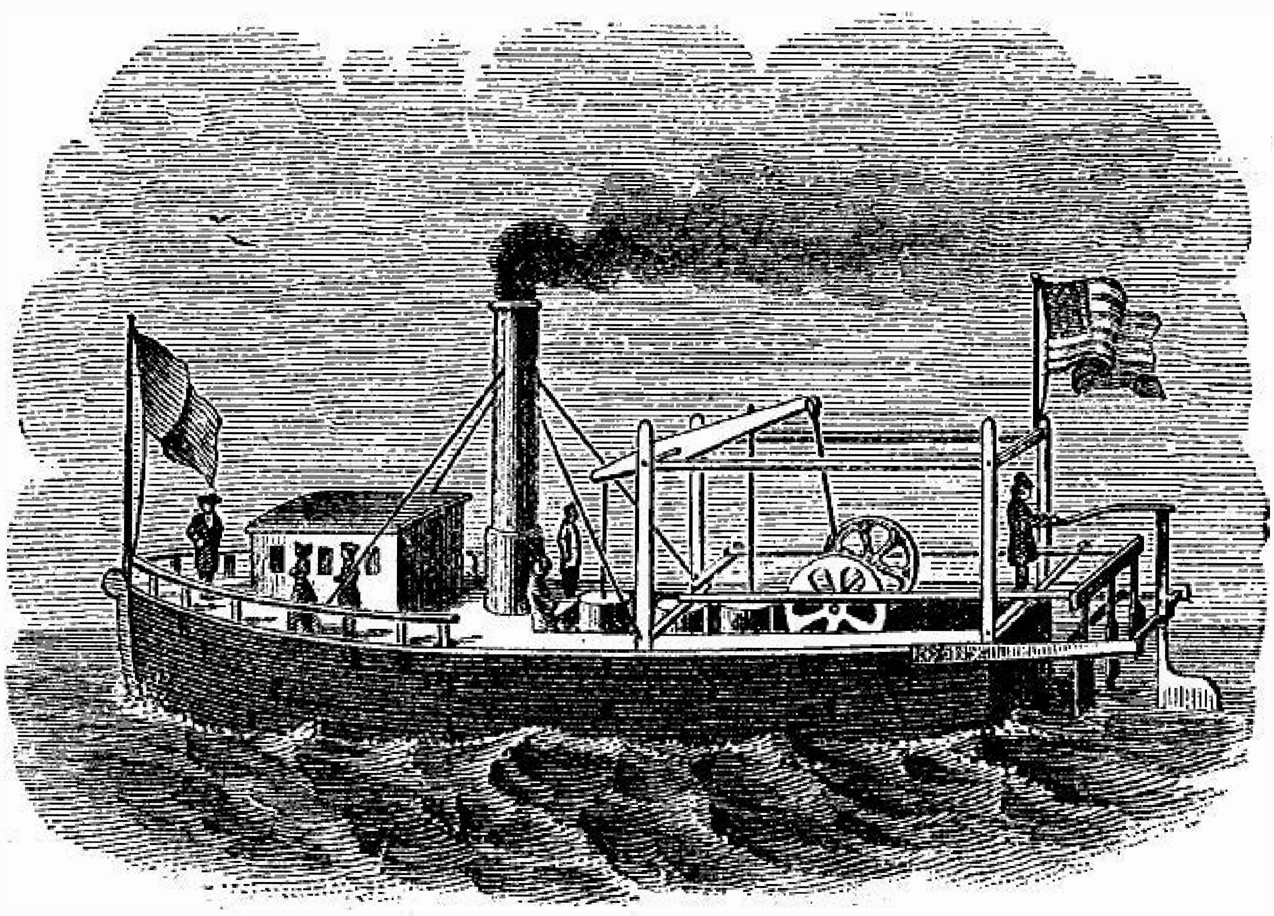

Fig. 70.—John Fitch, 1788.

theesecond boat (Fig. 70) they were similarly worked, but were placed at the stern. There were three of these paddles. The boat was finally finished in July, 1788, and made a trip to Burlington, 20 miles from Philadelphia. When just reaching their destination, their boiler gave out, and they made their return-trip to Philadelphia floating with the tide. Subsequently, the boat made a number of excursions on the Delaware River, making three or four miles an hour.

Another of Fitch's boats, in April, 1790, made seven miles an hour. Fitch, writing of this boat, says that "on the 16th of April we got our work completed, and tried our boat again; and, although the wind blew very fresh at the east, we reigned lord high admirals of the Delaware, and no boatnon the river could hold way with us." In June of that year it was placed as a passenger-boat on a line from Philadelphia to Burlington, Bristol, Bordentown, and Trenton, occasionally leaving that route to take excursions to Wilmington and Chester. During this period, the boat probably ran between 2,000 and 3,000 miles,[1] and with no serious accident. During the winter of 1790–'91, Fitch commenced another steamboat, the "Perseverance," and gave considerable time to the prosecution of his claim for a

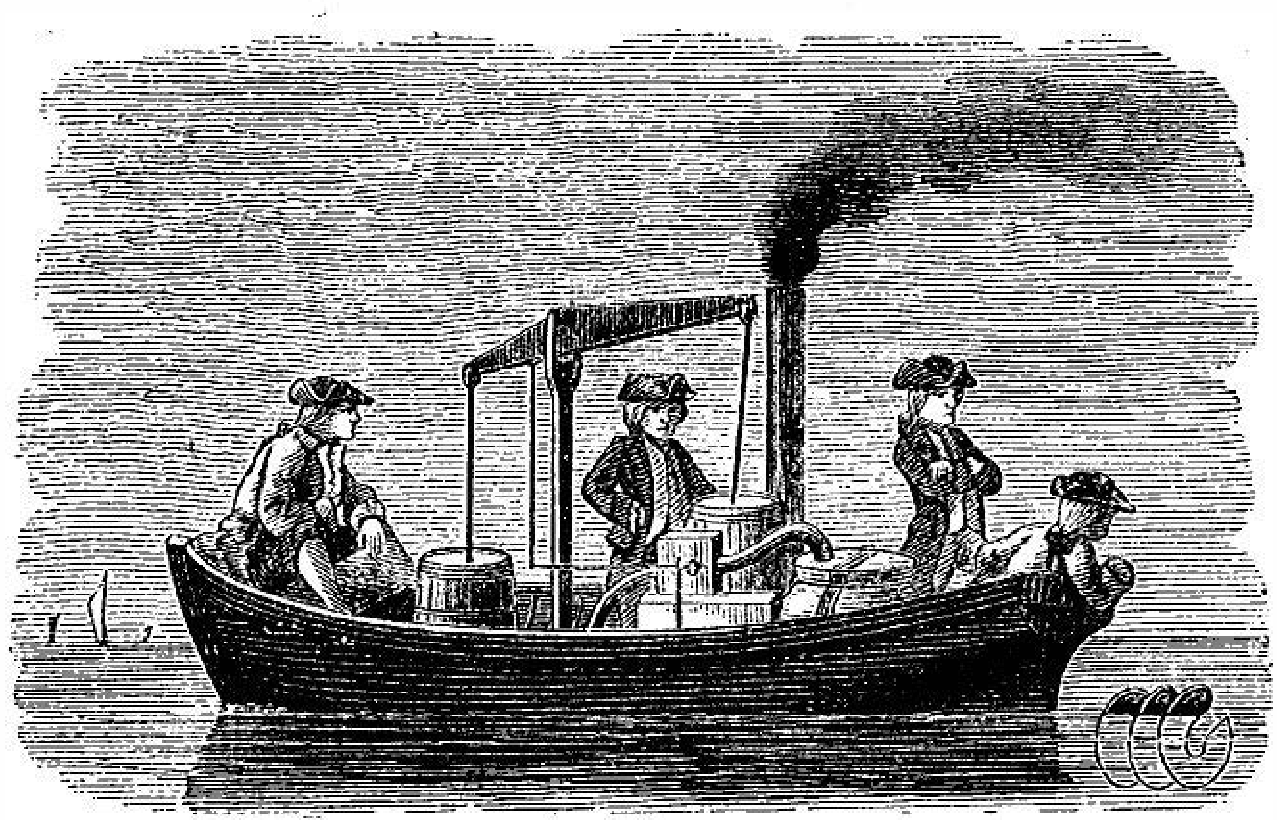

FIG. 71.—John Fitch, 1796.

patent from the United States. The boat was never completed, although he received his patent, after a long and spirited contest with other claimants, on the 26th of August, 1791, and Fitch lost all hope of success. He went to France in 1793, hoping to obtain the privilege of building steam-vessels there, but was again disappointed, and worked his passage home in the following year.

In the year 1796, Fitch was again in New York City, experimenting with a little *screw* steamboat on the "Collect" Pond, which then covered that part of the city now

[1] "Life of John Fitch," Westcott.

occupied by the "Tombs," the city prison. This little boat was a ship's yawl fitted with a screw, like that adopted later by Woodcroft, and driven by a rudely-made engine.

Fitch, while in the city of Philadelphia at about this time, met Oliver Evans, and discussed with him the probable future of steam-navigation, and proposed to form a company in the West, to promote the introduction of steam on the great rivers of that part of the country. He settled at last in Kentucky, on his land-grant, and there amused himself with a model steamboat, which he placed in a small stream near Bardstown. His death occurred there in July, 1798, and his body still lies in the village cemetery, with only a rough stone to mark the spot.

Both Rumsey and Fitch endeavored to introduce their methods in Great Britain, and Fitch, while urging the importance and the advantages of his plan, confidently stated his belief that the ocean would soon be crossed by steam-vessels, and that the navigation of the Mississippi would also become exclusively a steam-navigation. His reiterated assertion, "The day will come when some more powerful man will get fame and riches from my invention; but no one will believe that poor John Fitch can do anything worthy of attention," now almost sounds like a prophecy.

During this period, an interest which had never diminished in Great Britain had led to the introduction of experimental steamboats in that country. PATRICK MILLER, of Dalswinton, had commenced experimenting, in 1786–'87, with boats having double or triple hulls, and propelled by paddle-wheels placed between the parts of the compound vessel. James Taylor, a young man who had been engaged as tutor for Mr. Miller's sons, suggested, in 1787, the substitution of steam for the manual power which had been, up to that time, relied upon in their propulsion. Mr. Miller, in 1787, printed a description of his plan of propelling apparatus, and in it stated that he had "reason to believe that the power of the Steam-Engine may be applied to work the wheels."

In the winter of 1787–'88, William Symmington, who had planned a new form of steam-engine, and made a successful working-model, was employed by Mr. Miller to construct an engine for a new boat. This was built; the little engine, having two cylinders of but four inches in diameter, was placed on board, and a trial was made October 14, 1788. The vessel (Fig. 72) was 25 feet long, of 7 feet beam, and made 5 miles an hour.

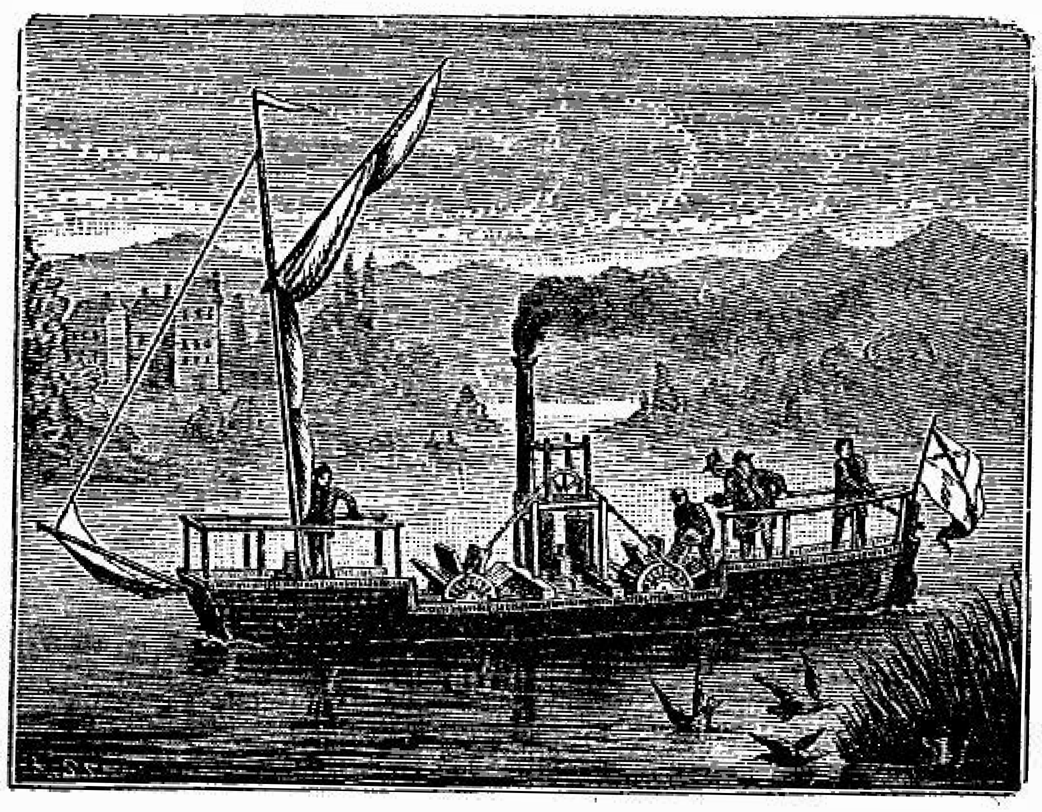

FIG. 72.—Miller, Taylor, and Symmington, 1788.

In the year 1789, a large vessel was built, with an engine having a steam-cylinder 18 inches in diameter, and this vessel was ready for trial in November of that year. On the first trial, the paddle-wheels proved too slight, and broke down; they were replaced by stronger wheels, and, in December, the boat, on trial, made seven miles an hour.

Miller, like many other inventors, seems to have lost his interest in the matter as soon as success seemed assured, and dropped it to take up other incomplete plans. More than a quarter of a century later, the British Government gave Taylor a pension of £50 per annum, and, in 1837, his four daughters were each given a similar annuity. Mr. Miller received no reward, although he is said to have expended over £30,000. The engine of Symmington was condemned by Miller as "the most improper of all steam-engines for giving motion to a vessel." Nothing more was done in Great Britain until early in the succeeding century.

In the United States, several mechanics were now at work besides Fitch. Samuel Morey and Nathan Read were among these. Nicholas Roosevelt was another. It had just been found that American mechanics were able to do the required shop-work. The first experimental steam-engine built in America is stated to have been made in 1773 by Christopher Colles, a lecturer before the American Philosophical Society at Philadelphia. The first steam-cylinder of any considerable size is said[1] to have been made by Sharpe & Curtenius, of New York City.

Samuel Morey wasnthe son of one of the first settlers of Orford, N. H. He was naturally fond of science and mechanics, and became something of an inventor. He began experimenting with the steamboat in 1790 or earlier, building a small vessel, and fitting it with paddle-wheels driven by a steam-engine of his own design, and constructed by himself.[2] He made a trial-trip one Sunday morning in the summer of 1790, a friend to accompany him, from Oxford, up the Connecticut River, to Fairlee, Vt., a distance of several miles, and returned safely. He then went to New York, and spent the summer of each year until 1793 in experimenting with his boat and modifications of his engine. In 1793 he made a trip to Hartford, returning to New York the next summer. His boat was a "stern-wheeler," and is stated to have been capable of steaming five miles an hour. He next went to Bordentown, N. J., where he built a larger boat, which is said to have been a

[1] *Rivington's Gazette*, February 16, 1775.

[2] *Providence Journal*, May 7, 1874. Coll., N. H. Antiquar. Soc., No. 1; "Who invented the Steamboat?" William A. Mowry, 1874.

side-wheel boat, and to have worked satisfactorily. His funds finally gave out, and he gave up his project after having, in 1797, made a trip to Philadelphia. Fulton, Livingston, and Stevens met Morey at New York, inspected his boat, and made an excursion to Greenwich with him.[1] Livingston is said[2] to have offered to assist Morey if he should succeed in attaining a speed of eight miles an hour.

Morey's experiments seem to have been conducted very quietly, however, and almost nothing is known of them. The author has not been able to learn any particulars of the engines used by him, and nothing definite is known of the dimensions of either boat or machinery. Morey never, like Fitch and Rumsey, sought publicity for his plans or notoriety for himself.

Nathan Read, who has already been mentioned, a native of Warren, Mass., where he was born in the year 1759, and a graduate of Harvard College, was a student of medicine, and subsequently a manufacturer of chain-cables and other iron-work for ships. He invented, and in 1798 patented, a nail-making machine. He was at one time (1800–1803) a Member of Congress, and, later, a Justice of the Court of Common Pleas, and Chief Justice in Hancock County, Me., after his removal to that State in 1807. He died in Belfast, Me., in 1849, at the age of ninety years.

In the year 1788 he became interested in the problem of steam-navigation, and learned something of the work of Fitch. He first attempted to design a boiler that should be strong, light, and compact, as well as safe. His first plan was that of the "Portable Furnace-Boiler," as he called it; it was patented August 26, 1791. As designed, it consisted, as seen in Figs. 73 and 74, which are reduced from his patent drawings, of a shell of cylindrical form, like the now common vertical tubular boiler. *A* is the furnace-door, *B* a heater and feed-water reservoir, *D* a pipe leading

[1] Rev. Cyrus Mann, in the *Boston Recorder*, 1858. [2] Westcott.

the feed-water into the boiler,[1] *E* the smoke-pipe, and *F* the steam-pipe leading to the engine. *G* is the "shell" of the boiler, and *H* the fire-box. The crown-sheet, *I I*, has depending from it, in the furnace, a set of water-tubes, *b b*,

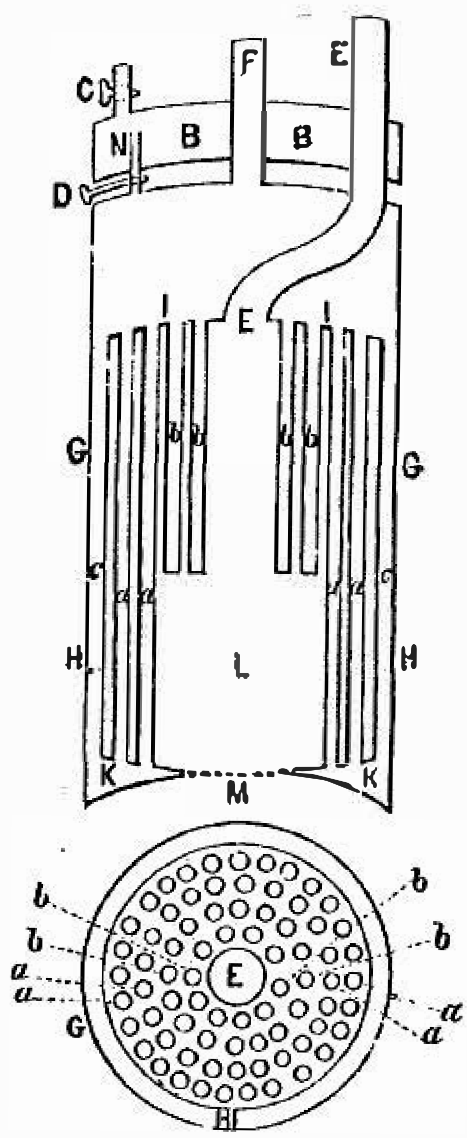

FIG. 73.—Read's Boiler in Section, 1788.

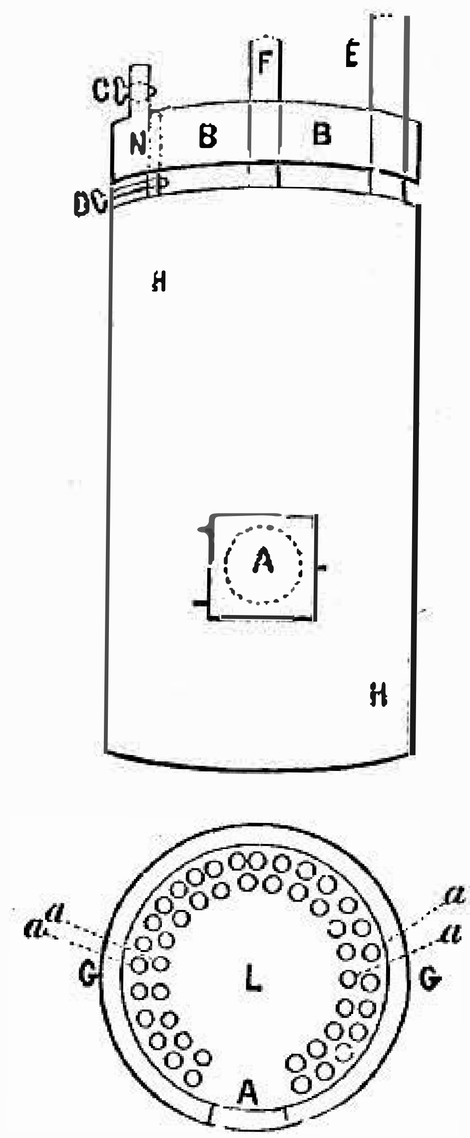

FIG. 74.—Read's Multi-Tubular Boiler, 1788.

closed at their lower ends, and another set, *a a*, which connect the water-space above the furnace with the water-bottom, *K K*. *L* is the furnace, and *M* the draught-space between the boiler and the ash-pit, in which the grates are set.

This boiler was intended to be used in both steamboats and steam-carriages. The first drawings were made in 1788 or 1789, as were those of a peculiar form of steam-engine which also resembled very closely that afterward constructed in Great Britain by Trevithick.[2] He built a

[1] This is substantially an arrangement that has recently become common. It has been repatented by later inventors.

[2] "Nathan Read and the Steam-Engine."

boat in 1789, which he fitted with paddle-wheels and a crank, which was turned by hand, and, by trial, satisfied himself that the system would work satisfactorily.

He then applied for his patent, and spent the greater part of the winter of 1789–'90 in New York, where Congress then met, endeavoring to secure it. In January, 1791, Read withdrew his petitions for patents, proposing to incorporate accounts of new devices, and renewed them a few months later. His patents were finally issued, dated August 26, 1791. John Fitch, James Rumsey, and John Stevens, also, all received patents at the same date, for various methods of applying steam to the propulsion of vessels.

Read appears to have never succeeded in even experimentally making his plans successful. He deserves credit for his early and intelligent perception of the importance of the subject, and for the ingenuity of his devices. As the inventor of the vertical multi-tubular fire-box boiler, he has also entitled himself to great distinction. This boiler is now in very general use, and is a standard form.

In 1792, Elijah Ormsbee, a Rhode Island mechanic, assisted pecuniarily by David Wilkinson, built a small steamboat at Winsor's Cove, Narragansett Bay, and made a successful trial-trip on the Seekonk River. Ormsbee used an "atmospheric engine" and "duck's-foot" paddles. His boat attained a speed of from three to four miles an hour.

In Great Britain, Lord Dundas and William Symmington, the former as the purveyor of funds and the latter as engineer, followed by Henry Bell, were the first to make the introduction of the steam-engine for the propulsion of ships so completely successful that no interruption subsequently took place in the growth of the new system of water-transportation.

Thomas, Lord Dundas, of Kerse, had taken great interest in the experiments of Miller, and had hoped to be able to apply the new motor on the Forth and Clyde Canal, in which he held a large interest. After the failure of the earlier experiments, he did not forget the matter; but subsequently, meeting with Symmington, who had been Miller's constructing engineer, he engaged him to continue the experiments, and furnished all required capital, about £7,000. This was ten years after Miller had abandoned his scheme.

Symmington commenced work in 1801. The first boat built for Lord Dundas, which has been claimed to have been the "first practical steamboat," was finished ready for trial early in 1802. The vessel was called the "Charlotte Dundas," in honor of a daughter of Lord Dundas, who became Lady Milton.

The vessel (Fig. 75) was driven by a Watt double-acting engine, turning a crank on the paddle-wheel shaft. The sectional sketch below exhibits the arrangement of the

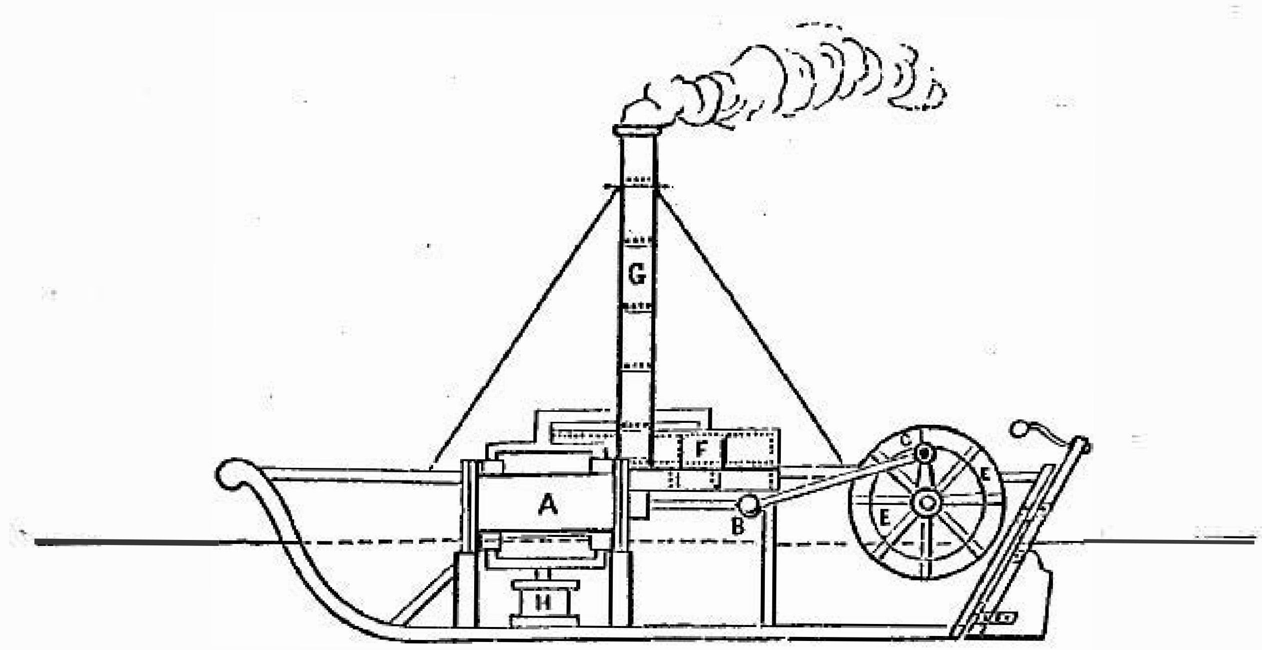

FIG. 75.—The "Charlotte Dundas," 1801.

machinery. *A* is the steam-cylinder, driving, by means of the connecting-rod, *B C*, a stern-wheel, *E E*. *F* is the boiler, and *G* the tall smoke-pipe. An air-pump and condenser, *H*, is seen under the steam-cylinder.

In March, 1802, the boat was brought to Lock No. 20 on the Forth and Clyde Canal, and two vessels of 70 tons burden each taken in tow. Lord Dundas, William Symmington, and a party of invited guests, were taken on board, and the boat steamed down to Port Glasgow, a distance of about 20 miles, against a strong head-wind, in six hours.

The proprietors of the canal were now urged to adopt the new plan of towing; but, fearing injury to the banks of the canal, they declined to do so. Lord Dundas then laid the matter before the Duke of Bridgewater, who gave Symmington an order for eight boats like the Charlotte Dundas, to be used on his canal. The death of the Duke, however, prevented the contract from being carried into effect, and Symmington again gave up the project in despair. A quarter of a century later, Symmington received from the British Government £100, and, a little later, £50 additional, as an acknowledgment of his services. The Charlotte Dundas was laid up, and we hear nothing more of that vessel.

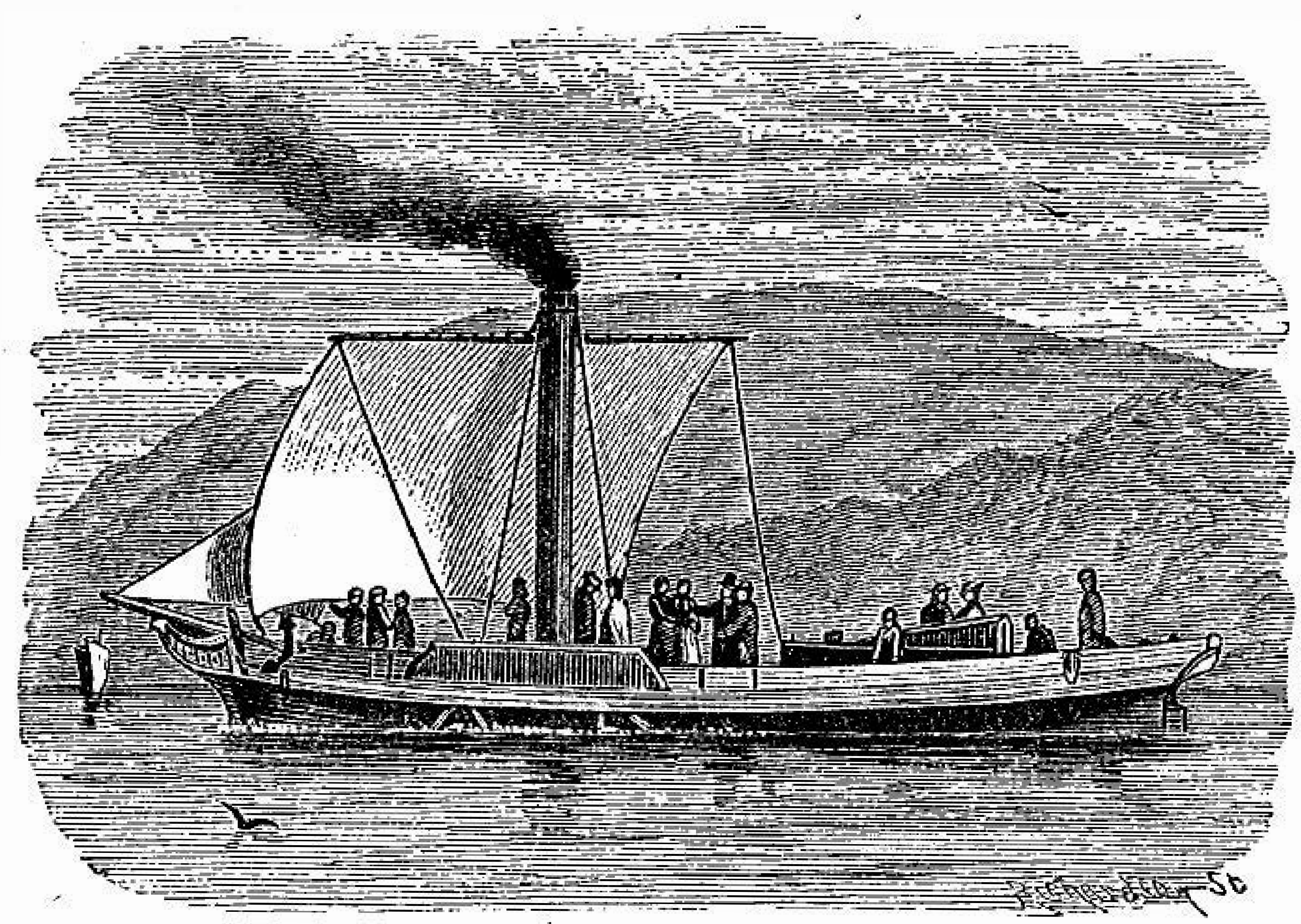

FIG. 76.—The "Comet," 1812.

Among those who saw the Charlotte Dundas, and who appreciated the importance of the success achieved by Symmington, was HENRY BELL, who, 10 years afterward, constructed the Comet (Fig. 76), the first passenger-vessel built in Europe. This vessel was built in 1811, and completed January 18, 1812. The craft was of 30 tons burden, 40 feet in length, and 10½ feet breadth of beam. There were *two* paddle-wheels on each side, driven by engines rated at three horse-power.

Bell had, it is said, been an enthusiastic believer in the advantages to be secured by this application of steam, from about 1786. In 1800, and again in 1803, he applied to the British Admiralty for aid in securing those advantages by experimentally determining the proper form and proportions of machinery and vessel; but was not able to convince the Admiralty of "the practicability and great utility of applying steam to the propelling of vessels against winds and tides, and every obstruction on rivers and seas where there was depth of water." He also wrote to the United States Government, urging his views in a similar strain.

Bell's boat was, when finished, advertised as a passenger-boat, to leave Greenock, where the vessel was built, on Mondays, Wednesdays, and Fridays, for Glasgow, 24 miles distant, returning Tuesdays, Thursdays, and Saturdays. The fare was made "four shillings for the best cabin, and three shillings for the second." It was some months before the vessel became considered a trustworthy means of conveyance. Bell, on the whole, was at first a heavy loser by his venture, although his boat proved itself a safe, stanch vessel.

Bell constructed several other boats in 1815, and with his success steam-navigation in Great Britain was fairly inaugurated. In 1814 there were five steamers, all Scotch, regularly working in British waters; in 1820 there were 34, one-half of which were in England, 14 in Scotland, and the remainder in Ireland. Twenty years later, at the close of the period to which this chapter is especially devoted, there were about 1,325 steam-vessels in that kingdom, of which 1,000 were English and 250 Scotch.

But we must return to America, to witness the first and most complete success, commercially, in the introduction of the steamboat.

The Messrs. Stevens, Livingston, Fulton, and Roosevelt were there the most successful pioneers. The latter is said to have built the "Polacca," a small steamboat launched on the Passaic River in 1798. The vessel was 60 feet long, and had an engine of 20 inches diameter of cylinder and 2 feet stroke, which drove the boat 8 miles an hour, carrying a party of invited guests, which included the Spanish Minister. Livingston and John Stevens had induced Roosevelt to try their plans still earlier,[1] paying the expense of the experiments. The former adopted the plan of Bernouilli and Rumsey, using a centrifugal pump to force a jet of water from the stern; the latter used the screw. Livingston going to France as United States Minister, Barlow carried over the plans of the "Polacca," and Roosevelt's friends state that a boat built by them, in conjunction with Fulton, was a "sister-ship" to that vessel. In 1798, Roosevelt patented a double engine, having cranks set at right angles. As late as 1814 he received a patent for a steam-vessel, fitted with paddle-wheels having adjustable floats. His boat of 1798 is stated by some writers to have been made by him on joint account of himself, Livingston, and Stevens. Roosevelt, some years later, was again at work, associating himself with Fulton in the introduction of steam-navigation of the rivers of the West.[2]

In 1798, the Legislature of New York passed a law giving Chancellor Livingston the exclusive right to steam-navigation in the waters of the State for a period of 20 years, *provided* that he should succeed, within a twelvemonth, in producing a boat that should steam four miles an hour.

[1] "Encyclopædia Americana."

[2] "A Lost Chapter in the History of the Steamboat," J. H. B. Latrobe, 1871.

Livingston did not succeed in complying with the terms of the act, but, in 1803, he procured the reënactment of the law in favor of himself and Robert Fulton, who was then experimenting in France, after having, in England, watched the progress of steam-navigation there, and then taken a patent in this country.

Robert Fulton.

ROBERT FULTON was a native of Little Britain, Lancaster County, Pa., born 1765. He commenced experimenting with paddle-wheels when a mere boy, in 1779, visiting an aunt living on the bank of the Conestoga.[1] During his youth he spent much of his time in the workshops of his neighborhood, and learned the trade of a watchmaker; but he adopted, finally, the profession of an artist, and exhibited great skill in portrait-painting. While his tastes were

[1] *Vide* "Life of Fulton," Reigart.

at this time taking a decided bent, he is said to have visited frequently the house of William Henry, already mentioned, to see the paintings of Benjamin West, who in his youth had been a kind of protégé of Mr. Henry; and he may probably have seen there the model steamboats which Mr. Henry exhibited, in 1783 or 1784, to the German traveler Schöpff. In later years, Thomas Paine, the author of "Common Sense," at one time lived with Mr. Henry, and afterward, in 1788, proposed that Congress take up the subject for the benefit of the country.

Fulton went to England when he came of age, and studied painting with Benjamin West. He afterward spent two years in Devonshire, where he met the Duke of Bridgewater, who afterward so promptly took advantage of the success of the "Charlotte Dundas."

While in England and in France—where he went in 1797, and resided some time—he may have seen something of the attempts which were beginning to be made to introduce steam-navigation in both of those countries.

At about this time—perhaps in 1793—Fulton gave up painting as a profession, and became a civil engineer. In 1797 he went to Paris, and commenced experimenting with submarine torpedoes and torpedo-boats. In 1801 he had succeeded so well with them as to create much anxiety in the minds of the English, then at war with France.

He had, as early as 1793, proposed plans for steam-vessels, both to the United States and the British Governments, and seems never entirely to have lost sight of the subject.[1] While in France he lived with Joel Barlow, who subsequently became known as a poet, and as Embassador to France from the United States, but who was then engaged in business in Paris.

When about leaving the country, Fulton met Robert Livingston (Chancellor Livingston, as he is often called),

[1] *Vide* "Life of Fulton," Colden.

who was then (1801) Embassador of the United States at the court of France. Together they discussed the project of applying steam to navigation, and determined to attempt the construction of a steamboat on the Seine; and in the early spring of the year 1802, Fulton having attended Mrs. Barlow to Plombières, where she had been sent by her physician, he there made drawings and models, which were sent or described to Livingston. In the following winter Fulton completed a model side-wheel boat.

January 24, 1803, he delivered this model to MM. Molar, Bordel, and Montgolfier, with a descriptive memoir, in which he stated that he had, by experiment, proven that side-wheels were better than the "chapletn" (paddle-floats set on an endless chain).[1] These gentlemen were then

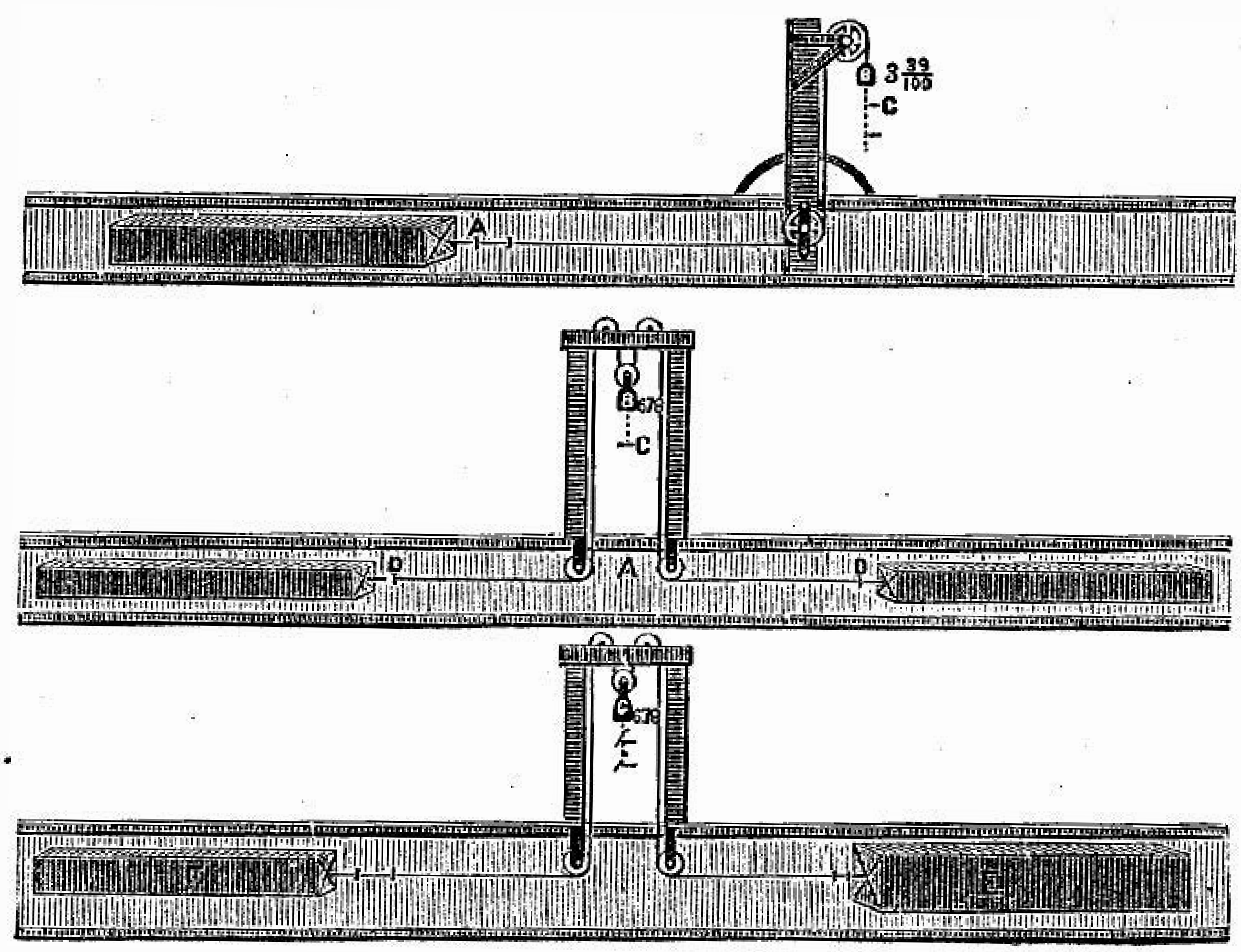

FIG. 77.—Fulton's Experiments.

building for Fulton and Livingston their first boat, on L'Isle des Cygnes, in the Seine. In planning this boat, Ful-

[1] A French inventor, a watchmaker of Trévoux, named Desblancs, had already deposited at the Conservatoire a model fitted with "chaplets."

ton had devised many different methods of applying steam to its propulsion, and had made some experiments to determine the resistance of fluids. He therefore had been able to calculate, more accurately than had any earlier inventor, the relative size and proportions of boat and machinery.

The author has examined a large collection of Fulton's drawings, among which are sketches, very neatly executed, of many of these plans, including the chaplet, side-wheel, and stern-wheel boats, driven by various forms of steam-engine, some working direct, and some geared to the paddle-wheel shaft. Figs. 77 and 78 are engraved from two of these sheets. The first represents the method adopted by Fulton to determine the resistance of masses of wood of various forms and proportions, when towed through water. The other is "A Table of the resistance of bodies moved through water, taken from experiments made in England by a society for improving Naval architecture, between the years 1793 and 1798" (Fig. 78). This latter is

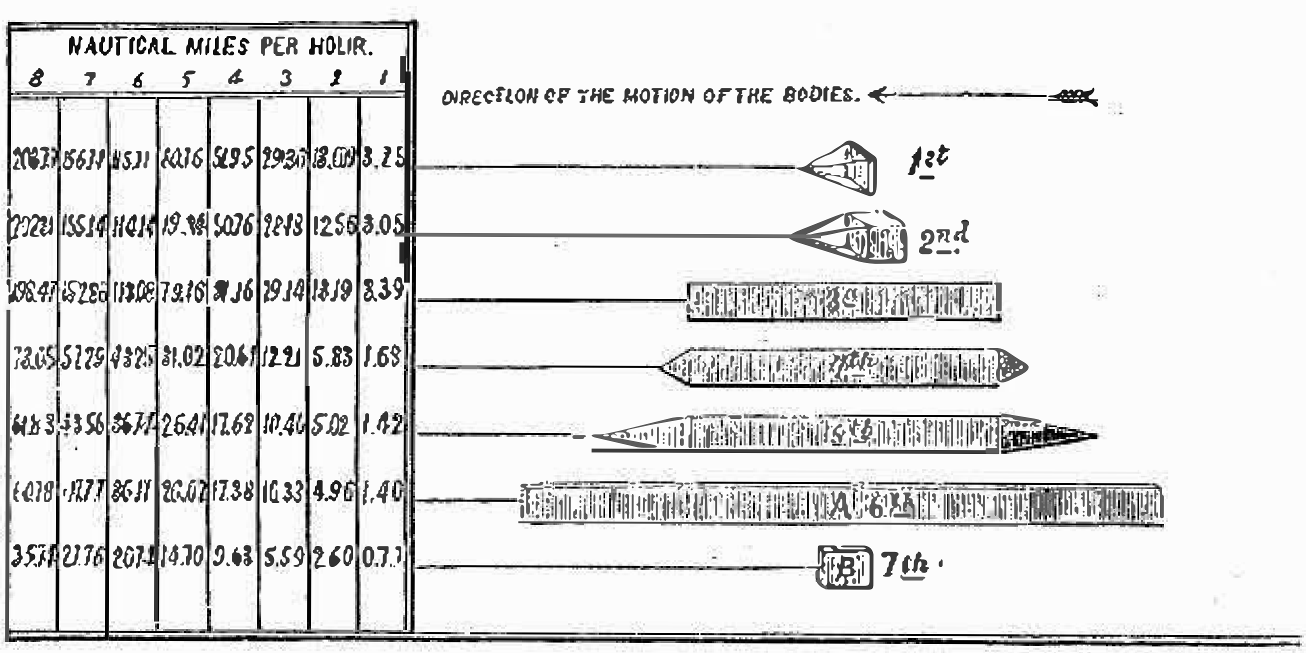

FIG. 78.—Fulton's Table of Resistances.

from a certified copy of "The Original Drawing on file in the Office of the Clerk of the New York District, making a part of the Demonstration of the patent granted to Robert Fulton, Esqr., on the 11th day of February, 1809. Dated this 3rd March, 1814," and is signed by Theron Rudd, Clerk of the New York District. Resistances are given in pounds per square foot.

Guided by these experiments and calculations, therefore, Fulton directed the construction of his vessel. It was completed inthe spring of 1803. But, unfortunately, the hull of the little vessel was too weak for its heavy machinery, and it broke in two and sank to the bottom of the Seine. Undiscouraged, Fulton at once set about repairing damages. He was compelled to direct the rebuilding of the hull. The machinery was little injured. In June, 1803, the reconstruction was completed, and the vessel was set afloat in July. The hull was 66 feet long, of 8 feet beam, and of light draught.

August 9, 1803, this boat was cast loose, and steamed up the Seine, in presence of an immense concourse of spectators. A committee of the National Academy, consisting of Bougainville, Bossuet, Carnot, and Périer, were present to witness thenexperiment. The boat moved but slowly, making only between 3 and 4 miles an hour against the current, the speed through the water being about 4½ miles; but this was, all things considered, a great success.

The experiment was successful, but it attracted little attention, notwithstanding the fact that its success had been witnessed by the committee of the Academy and by many well-known savants and mechanics, and by officers on Napoleon's staff. The boat remained a long time on the Seine, near the palace. The water-tube boiler of this vessel (Fig. 79) is still preserved at the Conservatoire des Arts et Métiers at Paris, where it is known as Barlow's boiler. Barlow patented it in France as early as 1793, as a steamboat-boiler, and states that the object of his construction was to obtain the greatest possible extent of heating-surface.

Fulton endeavored to secure the pecuniary aid and the countenance of the First Consul, but in vain.

Livingston wrote home, describing the trial of this steamboat and its results, and procured the passage of an act by the Legislature of the State of New York, extending a monopoly granted him in 1798 for the term of 20 years from April 5, 1803, the date of the new law, and extending

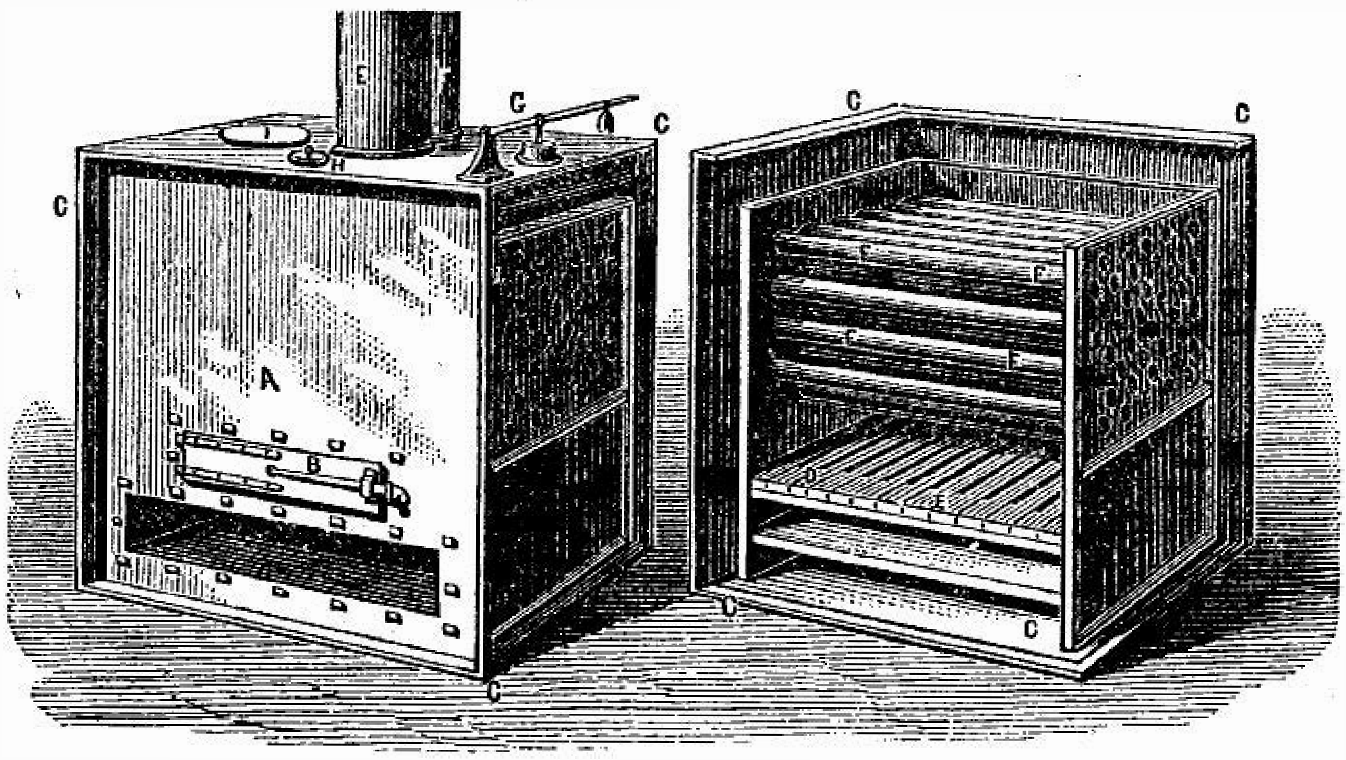

FIG. 79.—Barlow's Water-Tube Boiler, 1793.

the time allowed for proving the practicability of driving a boat four miles an hour by steam to two years from the same date. A later act further extended the time to April, 1807.

In May, 1804, Fulton went to England, giving up all hope of success in France with either his steamboats or his torpedoes. Fulton had already written to Boulton & Watt, ordering an engine to be built from plans which he furnished them; but he had not informed them of the purpose to which it was to be applied. This engine was to have a steam-cylinder 2 feet in diameter and of 4 feet stroke. The engine of the Charlotte Dundas was of very nearly the same size; and this fact, and the visit of Fulton to Symmington in 1801, as described by the latter, have been made the basis of a claim that Fulton was a copyist of the plans of others. The general accordance of the dimensions of his boat on the Seine with those of the "Polacca" of Roosevelt is also made the basis of similar claims by the friends of the latter. It would appear, however, that Symmington's statement is incorrect, as Fulton was in France, experimenting with torpedoes, at the time (July, 1801[1]) when he is accused of having obtained from the English engineer the dimensions and a statement of the performance of his vessel. Yet a fireman employed by Symmington has made an affidavit to the same statement. It is evident, however, from what has preceded, that those inventors and builders who were at that time working with the object of introducing the steamboat were usually well acquainted with what had been done by others, and with what was being done by their contemporaries; and it is undoubtedly the fact that each profited, so far as he was able, by the experience of others.

While in England, however, Fulton was certainly not so entirely absorbed in the torpedo experiments with which he was occupied in the years 1804–'6 as to forget his plans for a steamboat, and he saw the engine ordered by him in 1804 completed in the latter year, and preceded it to New York, sailing from Falmouth in October, 1806, and reaching the United States December 13, 1806.

The engine was soon received, and Fulton immediately contracted for a hull in which to set it up. Meantime, Livingston had also returned to the United States, and the two enthusiasts worked together on a larger steamer than any which had yet been constructed.

In the spring of 1807, the "Clermont" (Fig. 80), as the new boat was christened, was launched from the ship-yard of Charles Brown, on the East River, New York. In August the machinery was on board and in successful operation. The hull of this boat was 133 feet long, 18 wide, and 9 deep. The boat soon made a trip to Albany, running the distance of 150 miles in 32 hours running time, and returning in 30 hours. The sails were not used on either occasion.

[1] Woodcroft, p. 64.

This was the first voyage of considerable length ever made by a steam-vessel, and Fulton, though not to be classed with James Watt as an inventor, is entitled to the

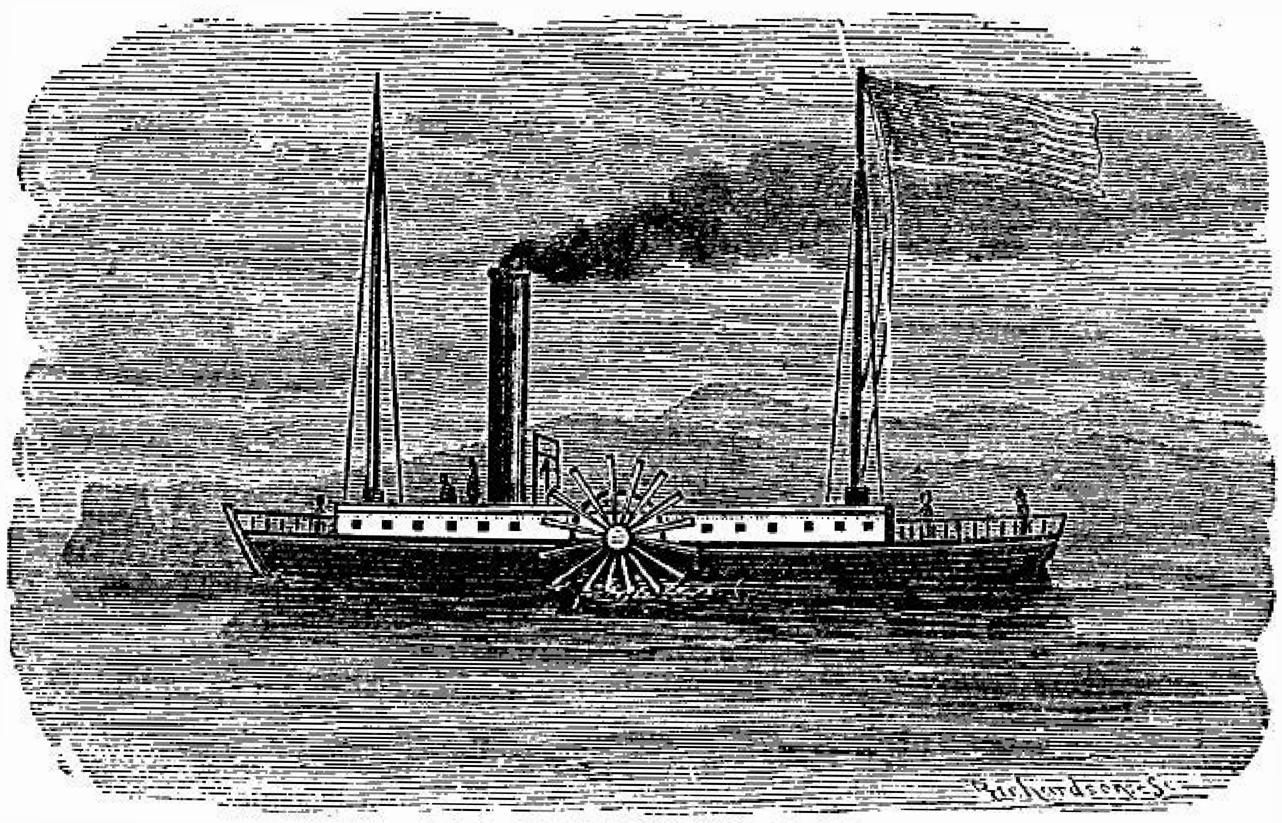

FIG. 80.—The Clermont, 1807.

great honor of having been the first to make steam-navigation an every-day commercial success, and of having thus made the first application of the steam-engine to ship-propulsion, which was not followed by the retirement of the

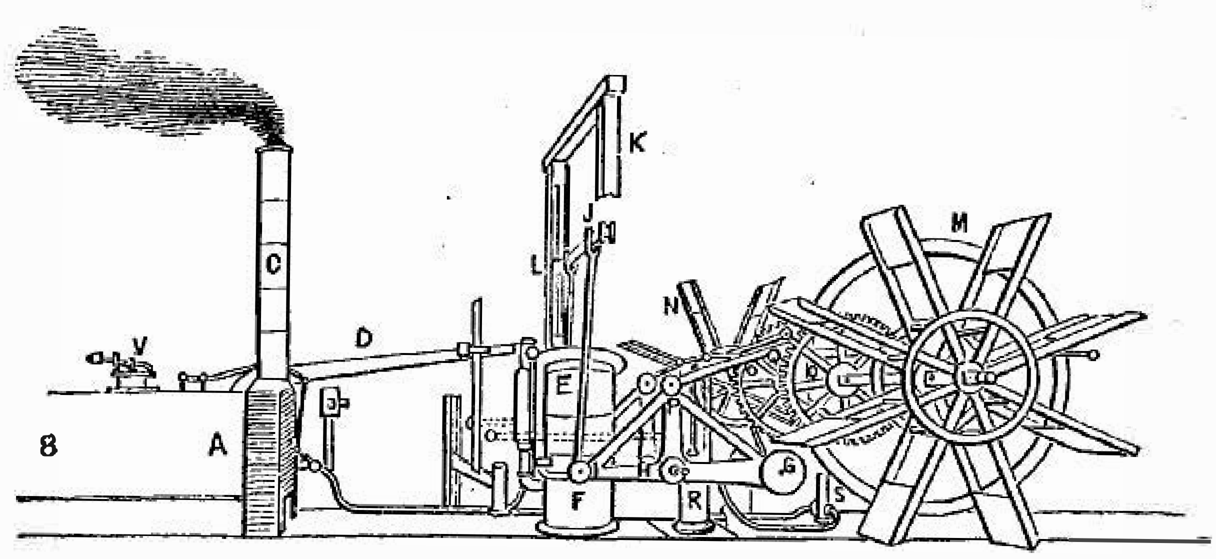

FIG. 81.—Engine of the Clermont, 1808.

experimenter from the field of his labors before success was permanently insured.

The engine of the Clermont (Fig. 81) was of rather peculiar form, the piston, *E*, being coupled to the crank-shaft, *O*, by a bell-crank, *I H P*, and a connecting-rod, *P Q*, the paddle-wheel shaft, *M N*, being separate from the crank-shaft, and connected with the latter by gearing, *O O*. The cylinders were 24 inches in diameter by 4 feet stroke. The paddle-wheels had buckets 4 feet long, with a dip of 2 feet. Old drawings, made by Fulton's own hand, and showing the engine as it was in 1808, and the engine of a later steamer, the Chancellor Livingston, are in the lecture-room of Prof. Wood at the Stevens Institute of Technology.

The voyage of the Clermont to Albany was attended by some ludicrous incidents, which found their counterparts wherever, subsequently, steamers were for the first time introduced. Mr. Colden, the biographer of Fulton, says that she was described, by persons who had seen her passing by night, "as a monster moving on the waters, defying wind and tide, and breathing flames and smoke."

This first steamboat used dry pine wood for fuel, and the flames rose to a considerable distance above the smoke-pipe. When the fires were disturbed, mingled smoke and sparks would rise high in the air. "This uncommon light," says Colden, "first attracted the attention of the crews of other vessels. Notwithstanding the wind and tide were averse to its approach, they saw with astonishment that it was rapidly coming toward them; and when it came so near that the noise of the machinery and paddles was heard, the crews (if what was said in the newspapers of the time be true), in some instances, shrank beneath their decks from the terrific sight, and left their vessels to go on shore, while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster which was marching on the tides, and lighting its path by the fires which it vomited."

In the Clermont, Fulton used several of the now characteristic features of the American river steamboat, and subsequently introduced others. His most important and creditable work, aside from that of the introduction of the steamboat into every-day use, was the experimental determination of the magnitude and the laws of ship-resistance, and the systematic proportioning of vessel and machinery to the work to be done by them.

The success of the Clermont on the trial-trip was such that Fulton soon after advertised the vessel as a regular passenger-boat between New York and Albany.[1]

During the next winter the Clermont was repaired and enlarged, and in the summer of 1808 was again on the route to Albany ; and, meantime, two new steamboats—the Raritan and the Car of Neptune—had been built by Fulton. In the year 1811 he built the Paragon. Both of the

[1] A newspaper-slip in the scrap-book of the author has the following :

"The traveler of to day, as he goes on board the great steamboats St. John or Drew, can scarcely imagine the difference between such floating palaces and the wee-bit punts on which our fathers were wafted 60 years ago. We may, however, get some idea of the sort of thing then in use by a perusal of the steamboat announcements of that time, two of which are as follows:

[" *Copy of an Advertisement taken from the Albany Gazette, dated September*, 1807.]

"The North River Steamboat will leave Pauler's Hook Ferry [now Jersey City] on Friday, the 4th of September, at 9 in the morning, and arrive at Albany on Saturday, at 9 in the afternoon. Provisions, good berths, and accommodations are provided.

"The charge to each passenger is as follows :

"To Newburg........................	dols. 3,	time 14 hours.
" Poughkeepsie......................	" 4,	" 17 "
" Esopus..........................	" 5,	" 20 "
" Hudson..........................	" 5½,	" 30 "
" Albany..........................	" 7,	" 36 "

"For places, apply to William Vandervoort, No. 48 Courtlandt Street, on the corner of Greenwich Street.

" *September* 2, 1807.

[" *Extract from the New York Evening Post, dated October* 2, 1807.]

" Mr. Fulton's new-invented *Steamboat*, which is fitted up in a neat style for passengers, and is intended to run from New York to Albany as a Packet, left here this morning with 90 passengers, against a strong head-wind. Notwithstanding which, it was judged she moved through the waters at the rate of six miles an hour."

two vessels last named were of nearly double the size of the Clermont. A steam ferry-boat was built to ply between New York and Jersey City in 1812, and the next year two others, to connect the metropolis with Brooklyn. These were "twin-boats," the two parallel hulls being connected by a "bridge" or deck common to both. The Jersey ferry was crossed in fifteen minutes, the distance being a mile and a half. To-day, the time occupied at the same ferry is about ten minutes. Fulton's ferry-boat carried, at one load, 8 carriages, and about 30 horses, and still had room for 300 or 400 foot-passengers. Fulton also designed steam-vessels for use on the Western rivers, and, in 1815, some of his boats were started as "packets" on the line between New York and Providence, R. I.

Meantime, the War of 1812 was in progress, and Fulton designed a steam vessel-of-war, which was then considered a wonderfully formidable craft. His plans were submitted to a commission of experienced naval officers, among whom were Commodores Decatur and Perry, Captain John Paul Jones, Captain Evans, and others whose names are still familiar, and were favorably commended. Fulton proposed to build a steam-vessel capable of carrying a heavy battery, and of steaming four miles an hour. The ship was to be fitted with furnaces for red-hot shot. Some of her guns were to be discharged below the water-line. The estimated cost was $320,000.

The construction of the vessel was authorized by Congress in March, 1814; the keel was laid June 20, 1814, and the vessel was launched October 29th of the same year.

The "Fulton the First," as she was called, was considered an enormous vessel at that time. The hull was double, 156 feet long, 56 feet wide, and 20 feet deep, measuring 2,475 tons. In the following May the ship was ready for her engine, and in July was so far completed as to steam, on a trial-trip, to the ocean at Sandy Hook and back—53 miles—in 8 hours and 20 minutes. In September of the same year, with armament and stores on board, the same route was traversed again, the vessel making $5\frac{1}{2}$ miles an hour. The vessel, as thus completed, had a double hull, each about 20 feet longer than the Clermont, and separated by a space 15 feet across. Her engine, having a steam-cylinder

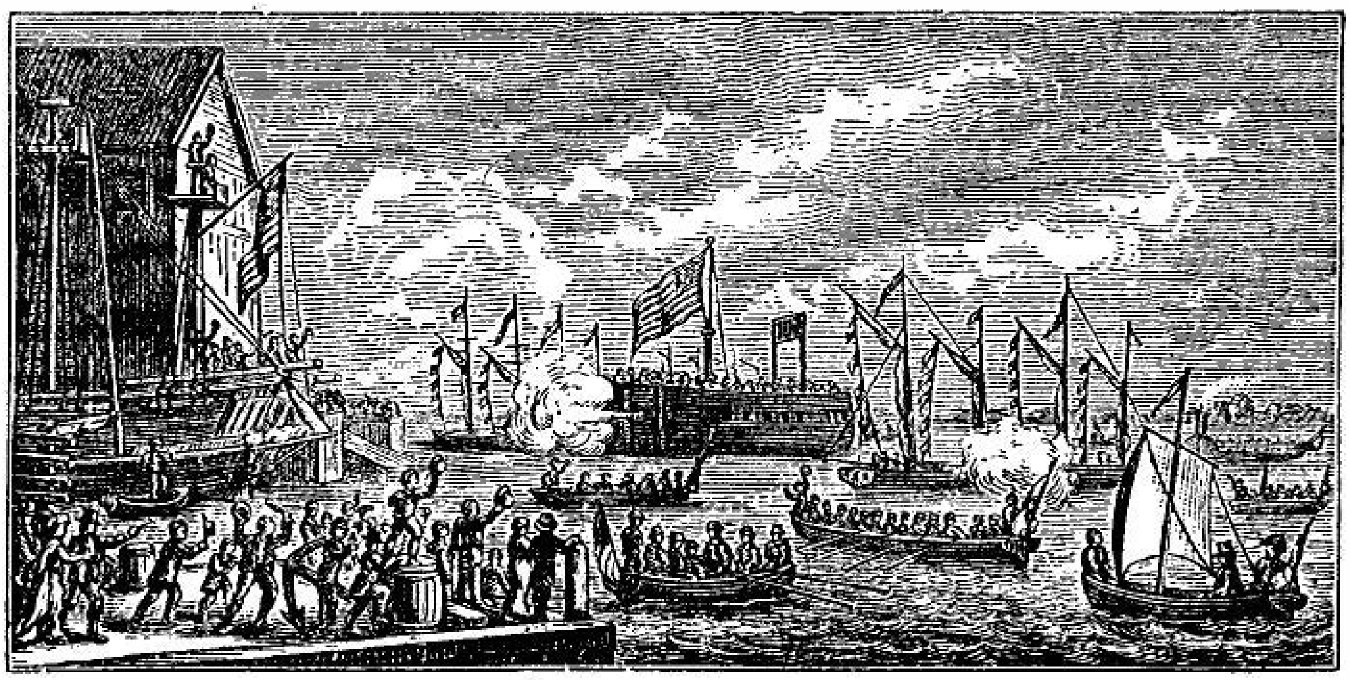

FIG. 82.—Launch of the Fulton the First, 1804.

48 inches in diameter and of 5 feet stroke of piston, was furnished with steam by a copper boiler 22 feet long, 12 feet wide, and 8 feet high, and turned a wheel between the two hulls which was 16 feetnin diameter, and carried "floats" or "buckets" 14 feet long, and with a dip of 4 feet. The engine was in one of the two hulls, and the boiler in the other. The sides, at the gun-deck, were 4 feet 10 inches thick, and her spar-deck was surrounded by heavy musket-proof bulwarks. The armament consisted of 30 32-pounders, which were intended to discharge red-hot shot. There was one heavy mast for each hull, fitted with large latteen sails. Each end of each hull was fitted with a rudder. Large pumps were carried, which were intended to throw heavy streams of water upon the decks of the enemy, with a view to disabling the foe by wetting his ordnance and ammunition. A submarine gun was to have been carried at each bow, to discharge shot weighing 100 pounds, at a depth of 10 feet below the water-line.

This was the first application of the steam-engine to naval purposes, and, for the time, it was an exceedingly creditable one. Fulton, however, did not live to see the ship completed. He was engaged in a contest with Livingston, who was then endeavoring to obtain permission from the State of New Jersey to operate a line of steamboats in the waters of the Hudson River and New York Bay, and, while returning from attending a session of the Legislature at Trenton, in January, 1815, was exposed to the weather on the bay at a time when he was ill prepared to withstand it. He was taken ill, and died February 24th of that year. His death was mourned as a national calamity.

From the above brief sketch of this distinguished man and his work, it is seen that, although Robert Fulton is not entitled to distinction as an inventor, he was one of the ablest, most persistent, and most successful of those who have done so much for the world by the introduction of the inventions of others. He was an intelligent engineer and an enterprising business-man, whose skill, acuteness, and energy have given the world the fruits of the inventive genius of all who preceded him, and have thus justly earned for him a fame that can never be lost.

Fulton had some active and enterprising rivals.

Oliver Evans had, in 1801 or 1802, sent one of his engines, of about 150 horse-power, to New Orleans, for the purpose of using it to propel a vessel owned by Messrs. McKeever and Valcourt, which was there awaiting it. The engine was actually set up in the boat, but at a low stage of the river, and no trial could be made until the river should again rise, some months later. Having no funds to carry them through so long a period, Evans's agents were induced to remove the engine again, and to set it up in a saw-mill, where it created great astonishment by its extraordinary performance in sawing lumber.

Livingston and Roosevelt were also engaged in experiments quite as early as Fulton, and perhaps earlier.

The prize gained by Fulton was, however, most closely contested by Colonel JOHN STEVENS, of Hoboken, who has been already mentioned in connection with the early history of railroads, and who had been since 1791 engaged in similar experiments. In 1789 he had petitioned the Legislature of the State of New York for a grant similar to that accorded to Livingston, and he then stated that his plans were complete, and on paper.

In 1804, while Fulton was in Europe, Stevens had completed a steamboat, 68 feet long and of 14 feet beam, which combined novelties and merits of design in a manner that exhibited the best possible evidence of remarkable inventive talent, as well as of the most perfect appreciation of the nature of the problem which he had proposed to himself to solve. Its boiler (Fig. 83) was of what is now known as the water-tubular variety. It was quite similar to some now

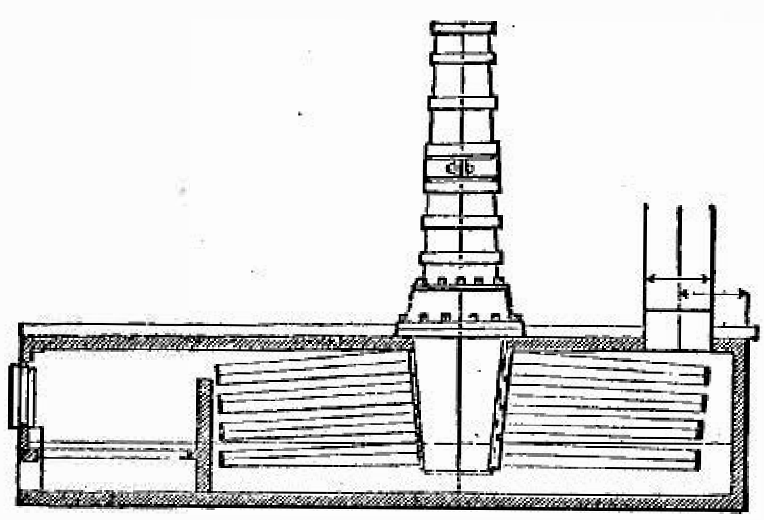

FIG. 83.—Section of Steam-Boiler, 1804.

known as sectional boilers, and contained 100 tubes 2 inches in diameter and 18 inches long, each fastened at one end to a central water-leg and steam-drum, and plugged at the other end. The flames from the furnace passed around and among the tubes, the water being inside them. The engine (Fig. 84) was a *direct-acting high-pressure* condensing engine, having a 10-inch cylinder, 2 feet stroke of piston, and drove a *screw* having four blades, and of a form which, even to-day, appears quite good. The whole is a most remarkable piece of early engineering.

A model of this little steamer, built in 1804, is preserved in the lecture-room of the Department of Mechanical Engineering at the Stevens Institute of Technology; and the machinery itself, consisting of the high-pressure "sectional"

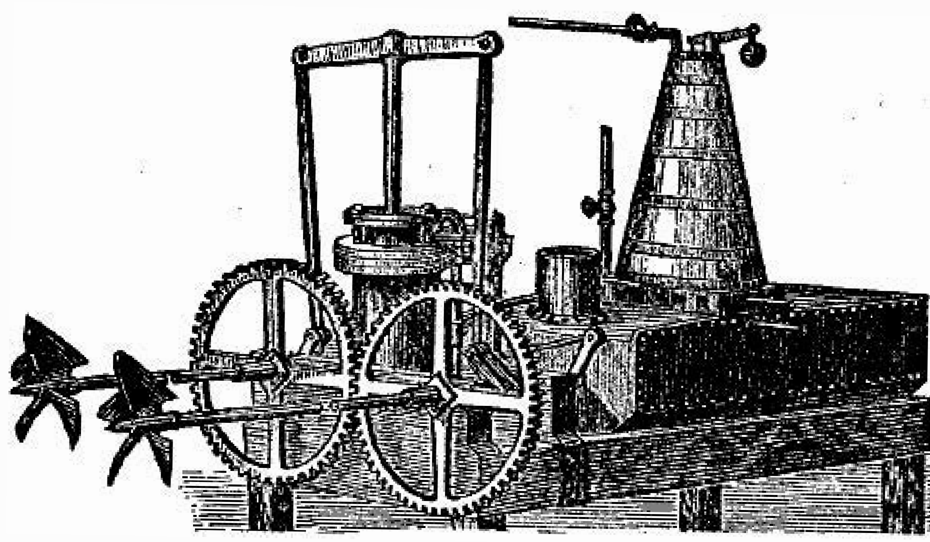

FIG. 84.—Engine, Boiler, and Screw-Propellers used by Stevens, 1804.

or "safety" tubular boiler, as it would be called to-day, the high-pressure condensing engine, with rotating valves, and twin screw-propellers, as just described, is given a place of honor in the model-room, or museum, where it contrasts

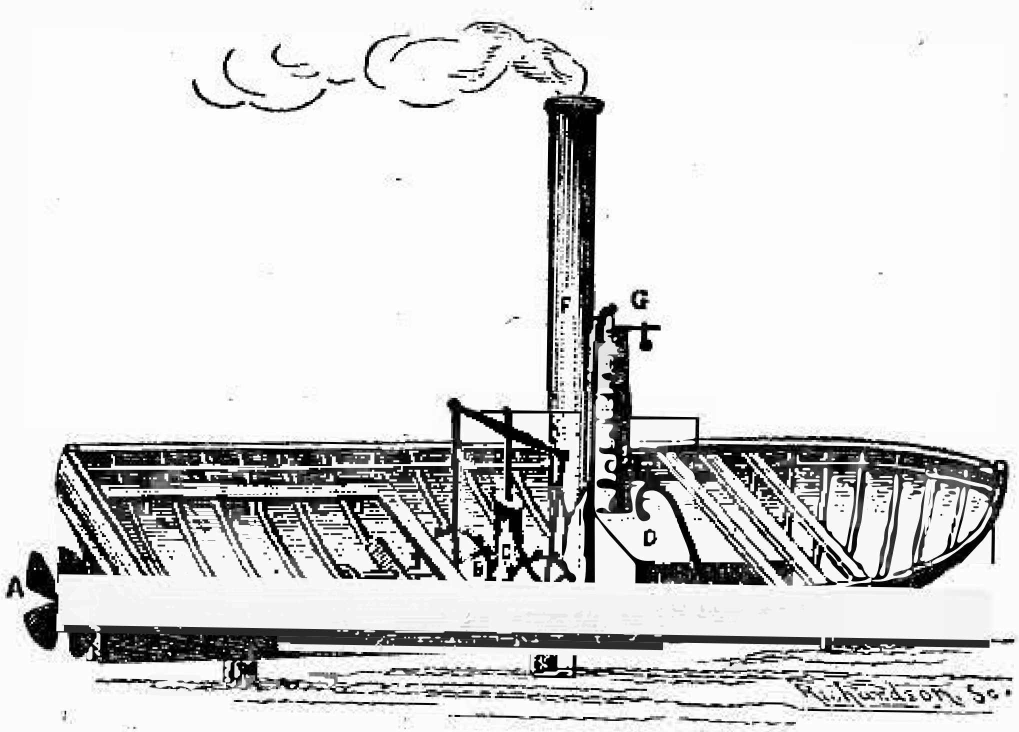

FIG. 85.—Stevens's Screw Steamer, 1804.

singularly with the mechanism contributed to the collection by manufacturers and inventors of our own time. The hub and blade of a single screw, also used with the same machinery, is likewise to be seen there.

Stevens seems to have been the first to fully recognize the importance of the principle involved in the construction of the sectional steam-boiler. His eldest son, John Cox Stevens, was in Great Britain in the year 1805, and, while there, patented another modification of this type of boiler. In his specification, he details both the method of construction and the principles which determine its form. He says that he describes this invention as it was made known to him by his father, and adds:

"From a series of experiments made in France, in 1790, by M. Belamour, under the auspices of the Royal Academy of Sciences, it has been found that, within a certain range, the elasticity of steam is nearly doubled by every addition of temperature equal to 30° of Fahrenheit's thermometer. These experiments were carried no higher than 280°, at which temperature the elasticity of steam was found equal to about four times the pressure of the atmosphere. By experiments which have lately been made by myself, the elasticity of steam at the temperature of boiling oil, which has been estimated at about 600°, was found to equal 40 times the pressure of the atmosphere.

"To the discovery of this principle or law, which obtains when water assumes a state of vapor, I certainly can lay no claim; but to the application of it, upon certain principles, to the improvement of the steam-engine, I do claim exclusive right.

"It is obvious that, to derive advantage from an application of this principle, it is absolutely necessary that the vessel or vessels for generating steam should have strength sufficient to withstand the great pressure from an increase of elasticity in the steam; but this pressure is increased or diminished in proportion to the capacity of the containing vessel. The principle, then, of this invention consists in forming a boiler by means of a system, or combination of a number of small vessels, instead of using, as in the usual mode, one large one; the relative strength of the materials of which these vessels are composed increasing in proportion to the diminution of capacity. It will readily occur that there are an infinite variety of possible modes of effecting such combinations; but, from the nature of the case, there are certain limits beyond which it becomes impracticable to carry on improvement. In the boiler I am about to describe, I apprehend that the improvement is carried to the utmost extent of which the principle is capable. Suppose a plate of brass of one foot square, in which a number of holes are perforated; into each of which holes is fixed one end of a copper tube, of about an inch in diameter and two feet long; and the other ends of these tubes inserted in like manner into a similar piece of brass; the tubes, to insure their tightness, to be cas in the platese; these plates are to be inclosed at each end of the pipes by a strong cap of cast-iron or brass, so as to leave a space of an inch or two between the plates or ends of the pipes and the cast-iron cap at each end; the caps at each end are to be fastened by screw-bolts passing through them into the plates; the necessary supply of water is to be injected by means of a forcing-pump into the cap at one end, and through a tube inserted into the cap at the other end the steam is to be conveyed to the cylinder of the steam-engine; the whole is then to be encircled in brick-work or masonry in the usual manner, placed either horizontally or perpendicularly, at option.

"I conceive that the boiler above described embraces the most eligible mode of applying the principle before mentioned, and that it is unnecessary to give descriptions of the variations in form and construction that may be adopted, especially as these forms may be diversified in many different modes."

Boilers of the character of those described in the specification given above were used on the locomotive built by John Stevens in 1824–'25, and one of them remains in the collections of the Stevens Institute of Technology.

The use of such a boiler 70 years ago is even more remarkable than the adoption of the screw-propeller, in such excellent proportions, 30 years before the labors of Smith and of Ericsson brought the screw into general use; and we have, in this strikingly originalncombination, as good evidence of the existence of unusual engineering talent in this great engineer as we found of his political and statesmanlike ability in his efforts to forward the introduction of railways.

Colonel John Stevens designed a peculiar form of iron-clad in the year 1812, which has been since reproduced by no less distinguished and successful an engineer than the late John Elder, of Glasgow, Scotland. It consisted of a saucer-shaped hull, carrying a heavy battery, and plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was secured to a swivel, and was anchored in the channel to be defended. A set of screw-propellers, driven by steam-engines, and situated beneath the vessel, where they were safe against injury by shot, were so arranged as to permit the vessel to be rapidly revolved about its centre. As each gun was brought into line of fire, it was discharged, and was then reloaded before coming around again. This was probably the earliest embodiment of the now well-established "Monitor" principle. It was probably the first iron-clad ever designed. It has recently been again brought out and introduced into the Russian navy, and is there called the "Popoffka."

The first of Stevens's boats performed so well, that he immediately built another one, using the same engine as before, but employing a larger boiler, and propelling the vessel by *twin screws*, the latter being another instance of his use of a device brought forward long afterward as new, and frequently adopted. This boat was sufficiently successful to prove the practicability of making steam-navigation a commercial success; and Stevens, assisted by his sons, built a boat which he named the "Phœnix," and made the first trial in 1807, but just too late to anticipate Fulton. This boat was driven by paddle-wheels.

The Phœnix, being shut out of the waters of the State of New York by the monopoly held by Fulton and Liv-

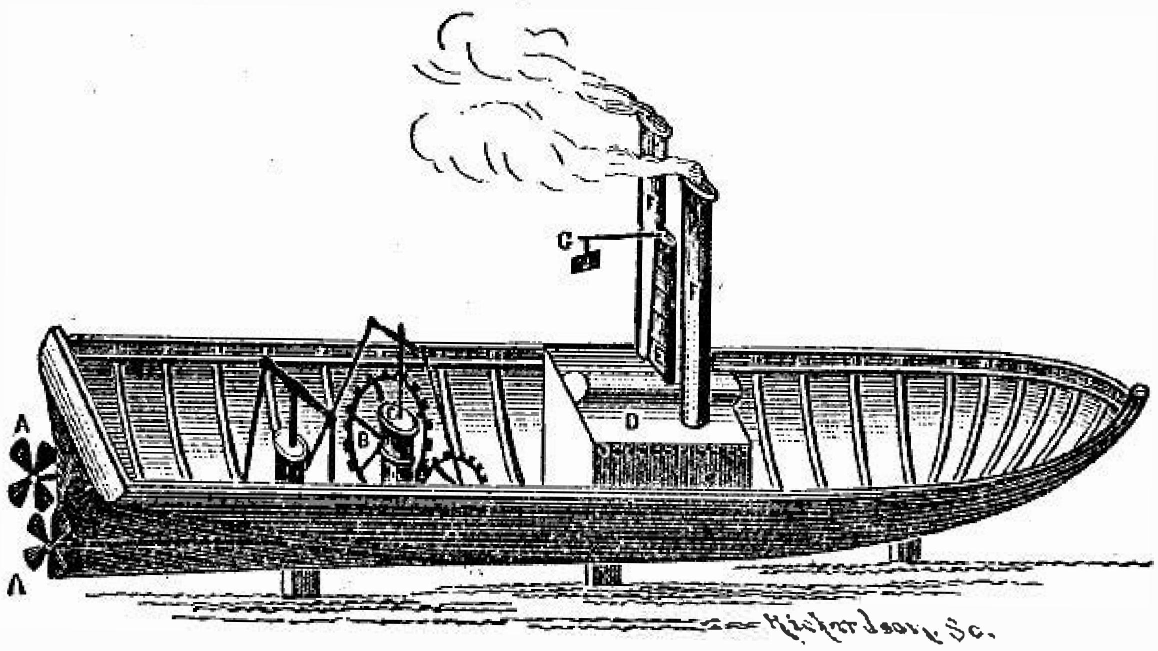

FIG. 86.—Stevens's Twin-Screw Steamer, 1805.

ingston, was used for a time between New York and New Brunswick, and then, anticipating a better pecuniary return, it was concluded to send her to Philadelphia, to ply on the Delaware.

At that time no canal offered the opportunity to make an inland passage; and in June, 1808, Robert L. Stevens, a son of John, started with her to make the passage by sea. Although meeting a gale of wind, he arrived at Philadelphia safely, having been the first to trust himself on the open sea in a vessel relying entirely upon steam-power.

From this time forward the Stevenses, father and sons, continued to construct steam-vessels; and, after the breaking down of the Fulton monopoly by the courts, they built the most successful steamboats that ran on the Hudson River.

After Fulton and Stevens had thus led the way, steam-navigation was introduced very rapidly on both sides of the ocean; and on the Mississippi the number of boats set afloat was soon large enough to fulfill Evans's prediction that the navigation of that river would ultimately be effected by steam-vessels.

The changes and improvements which, during the 20 years succeeding the time of Fulton and of John Stevens, gradually led to the adoption of the now recognized type of "American river-boat" and its steam-engine, were principally made by that son of the senior Stevens, who has already been mentioned—ROBERT L. STEVENS—and who became known later as the designer and builder of the first well-planned iron-clad ever constructed, the Stevens Battery. Much of his best work was done during his father's lifetime.

Robert L. Stevens.

He made many extended and most valuable, as well as interesting, experiments on ship-propulsion, expending much time and large sums of money upon them ; and many years before they became generally understood, he had arrived at a knowledge not only of the laws governing the variation of resistance at excessive speeds, but he had determined, and had introduced into his practice, those forms of least resistance and those graceful water-lines which have only recently distinguished the practice of other successful naval architects.

Referring to his invaluable services, President King, who seems to have been the first to thoroughly appreciate the immense amount of original invention and the surprising excellence of the engineering of this family, in a lecture delivered in New York in 1851, gave, for the first time, a connected and probably accurate description of their work, upon which nearly all later accounts have been based.

Young Stevens began working in his father's machine-shop in 1804 or 1805, when a mere boy, and thus acquired at a very early age that familiarity with practical details of work and of business which is essential to perfect success. It was he who introduced the now common "hollow water-lines" in the Phœnix, and thus anticipated the claims of the builders of the once famous "Baltimore clippers," and of the inventors of the "wave-lines" form of vessels. In the same vessel he adopted a feathering paddle-wheel and the guard-beam now universally seen in our river steamboats.

As usually constructed, this arrangement of float is as shown in Fig. 87. The rods, *F F*, connect the eccentrically-set collar, *G*, carried on *H*, a pin mounted on the paddle-beam outside the wheel, or an eccentric secured to the vessel, with the short arms, *D D*, by which the paddles are turned upon the pins, *E E*. *A* is the centre of the paddle-wheel, and *C C* are arms. Circular hoops, or bands, connect all of the arms, each of which carries a float. They are all thus tied together, forming a very firm and powerful combination to resist external forces.

The steamboat Philadelphia was built in the year 1813, and the young naval architect took advantage of the opportunity to introduce several new devices, including screw-bolts in place of tree-nails, and diagonal knees of wood and of iron. Two years later he altered the engines of this boat, and arranged them to work steam expansively. A little later he commenced using anthracite coal, which had been discovered in 1791 by Philip Ginter, and introduced at Wilkesbarre, Pa., in the smith-shops, some years before the Revolution. It had been used in a peculiar grate devised by Judge Fell, of that town, in 1808. Oliver Evans also had used it in stoves even earlier than the latter date, and at

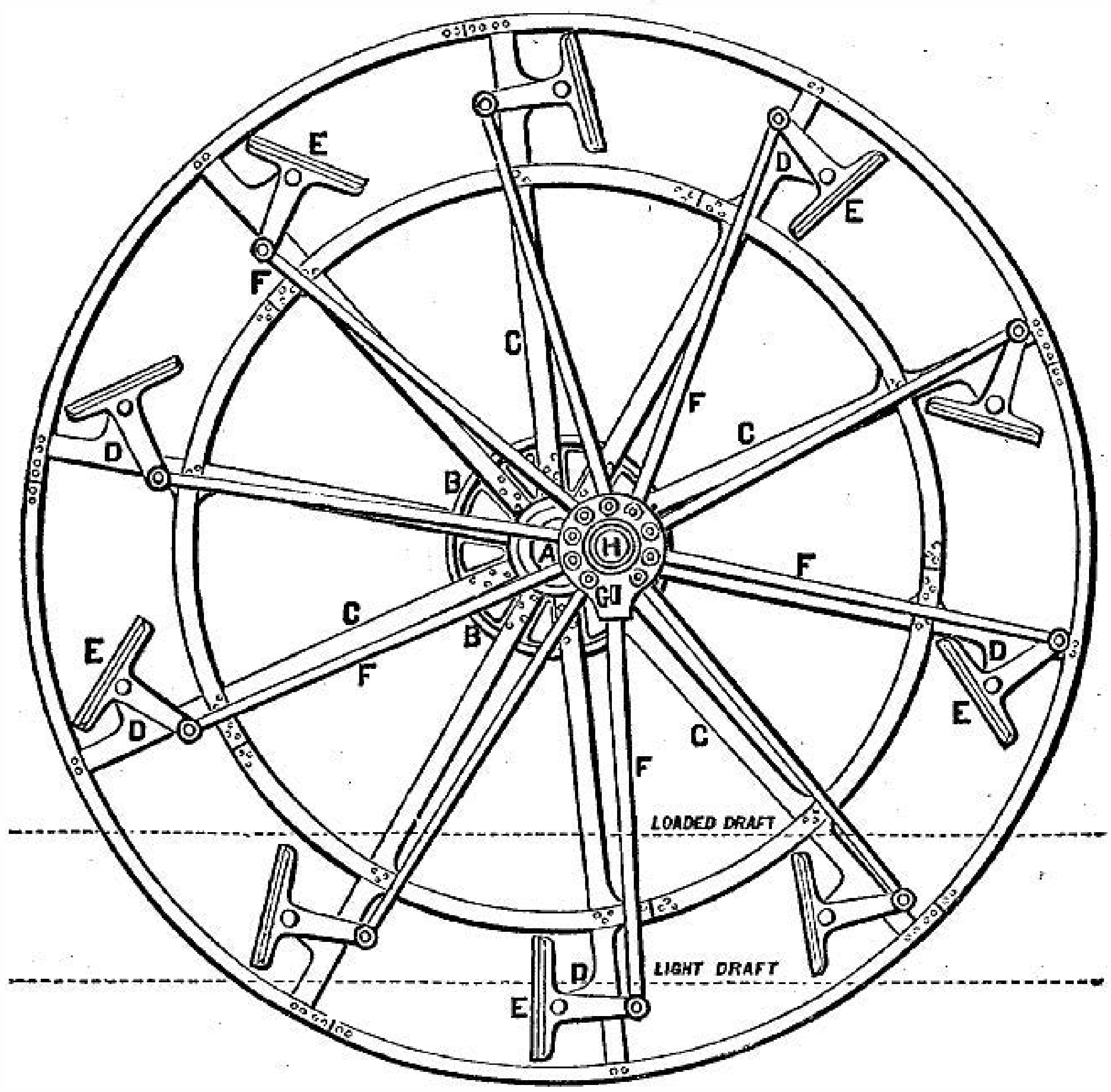

FIG. 87.—The Feathering Paddle-Wheel.

about the same time it had been used in the blast-furnace at Kingston. Stevens was the first of whom we have record who was thoroughly successful in using, as a steam-coal, the new and almost unmanageable fuel. He fitted up the

[1] Bishop.

boiler of the steamboat Passaic for it in 1818, and adopted anthracite as a steaming-coal. He used it in a cupola-furnace in the same year, and its use then rapidly became general in the Eastern States.

Stevens continued his work of improving the beam-engine for many years. He designed the now universally-used "skeleton-beam," which is one of the characteristic features of the American engine, and placed the first example of this light and elegant, yet strong, construction on the steamer Hoboken in the year 1822. He built the Trenton, which was then considered an extraordinarily powerful, fast, and handsome vessel, two years afterward, and placed the two boilers on the guards—a custom which is still general on the river steamboats of the Eastern States. In this vessel he also adopted the plan of making the paddle-wheel floats in two parts, placing one above the other, and securing the upper half on the forward and the lower half on the after side of the arm, thus obtaining a smoother action of the wheel, and less loss by oblique pressures.

In 1827 he built the North America (Fig. 88), one of his largest and most successful steamers, a vessel fitted with a pair of engines each 44½ inches in diameter of cylinder and 8 feet stroke of piston, making 24 revolutions per minute, driving the boat 15 to 16 miles an hour. Anticipating difficulty in keeping the long, light, shallow vessel in shape when irregularly laden, and when steaming at the high speed expected to be obtained when her powerful engine was exerting its maximum effort, he adopted the expedient of stiffening the hull by means of a truss of simple form. This proved thoroughly satisfactory, and the "hog-frame," as it has since been inelegantly but universally called, is still one of the peculiar features of every American river-steamer of any considerable size. It was in the North America, also, that he first introduced the artificial blast for forcing the fires, which is still another detail of now usual practice.

Steven's next turned his attention to the engine again, and adopted spring bearings under the paddle-shaft of the

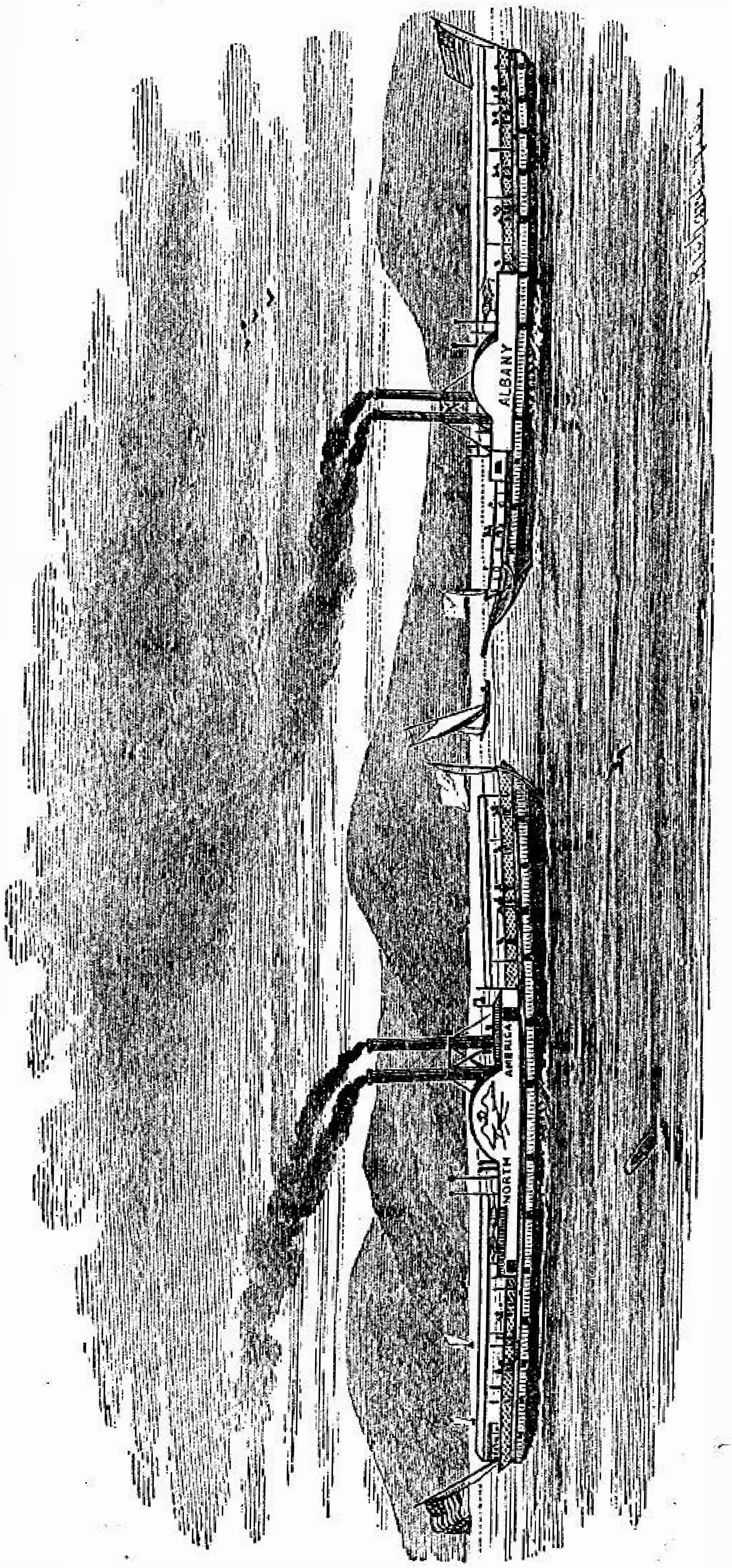

FIG. 88.—The North America and Albany, 1827-'30.

New Philadelphia in 1828, and fitted the steam-cylinder with the "double-poppet" valve, which is now universally used on beam-engines. This consists of two disk-valves, connected by the valve-spindle. The disks are of unequal sizes, the smaller passing through the seat of the larger. When seated, the pressure of the steam is, in the steam-valve, taken on the upper side of the larger and the lower side of the smaller disk, thus producing a partial balancing of the valve, and rendering it easy to work the heaviest engine by the hand-gear. The two valve-seats are formed in the top and the bottom, respectively, of the steam-passage leading to the cylinder; and when the valve is raised, the steam enters at the top and the bottom at the same time, and the two currents, uniting, flow together into the steam-cylinder. The same form of valve is used as an exhaust-valve.

At about the same time he built the now standard form of return tubular boilers for moderate pressures. In the figure, *S* is the steam and *W* the water space, and *F* the furnace. The direction of the currents of smoke and gas are shown by the arrows.

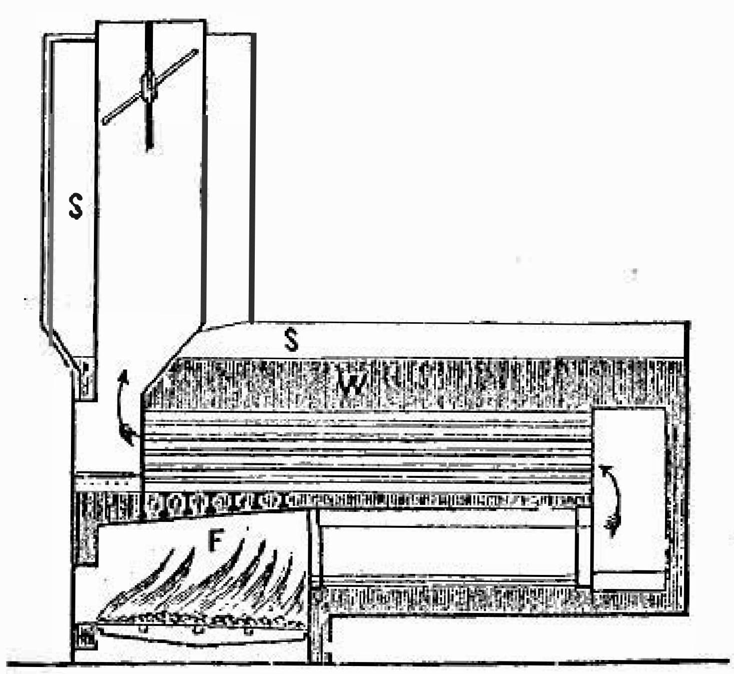

Fig. 89.—Stevens's Return Tubular Boiler, 1832.

Some years later (1840), Stevens commenced using steam-packed pistons on the Trenton, in which steam was admitted by self-adjusting valves behind the metallic packing-rings, setting them out more effectively than did the steel springs then (and still) usually employed.

His pistons, thus fitted, worked well for many years. A set of the small brass check-valves used in a piston of this kind, built by Stevens, and preserved in the cabinets of the Stevens Institute of Technology, are good evidence of the ingenuity and excellent workmanship which distinguished the machinery constructed under the direction of this great engineer.

The now familiar "Stevens cut-off," a peculiar device for securing the expansion of steam in the steam-cylinder, was the invention (1841) of Robert L. Stevens and a nephew, who inherited the same constructive talent which distinguished the first of these great men—Mr. Francis B. Stevens. In this form of valve-gear, the steam and exhaust valves are independently worked by separate eccentrics, the latter being set in the usual manner, opening and closing the exhaust-passages just before the crank passes its centre. The steam-eccentric is so placed that the steam-valve is opened as usual, but closed when but about one-half the stroke has been made. This result is accomplished by giving the eccentric a greater throw than is required by the motion of the valve, and permitting it to move through a portion of its path without moving the valve. Thus, in Fig. 90, if $A\ B$ be the direction of motion of the eccentric-rod, the valve would ordinarily open the steam-port when the eccentric assumes the position $O\ C$, closing when the eccentric has passed around to $O\ D$. With the Stevens valve-gear, the valve is opened when the eccentric reaches $O\ E$, and closes when it arrives at $O\ F$. The steam-valve of the opposite end of the cylinder is open while the eccentric is moving from $O\ M$ to $O\ K$. Between K and E, and

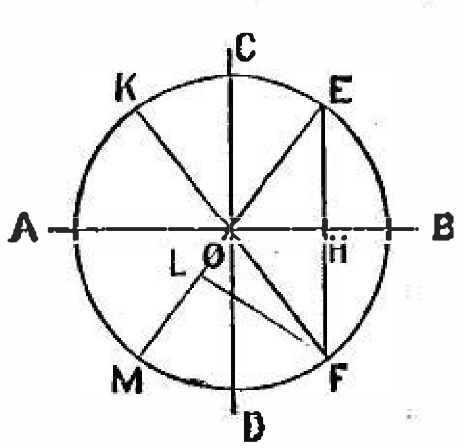

FIG. 90.—Stevens's Valve-Motion.

between F and M, both valves are seated. $H B$ is proportional to the lift of the valve, and $O H$ to the motion of the valve-gear when out of contact with the valve-lifters. While the crank is moving through an arc, EF, steam is entering the cylinderi; from F to M the steam is expanding. At M the stroke is completed, and the other steam-valve opens. The ratio $\frac{EM}{EL}$ is the ratio of expansion.

This form of cut-off motion is still a very usual one, and can be seen in nearly all steamers in the United States not using the device of Sickles. It was at about this time, also, that Stevens, having succeeded his father in the business of introducing the steam-engine in land-transportation, as well as on the water, adopted the use of steam expansively on the locomotives of the Camden & Amboy Railroad, which was controlled and built by capital furnished principally by the Messrs. Stevens. He at the same time constructed eight-wheeled engines for heavy work, and adopted anthracite coal as fuel. In the latter change he was thoroughly successful, and the same improvement was made with engines built for fast traffic in 1848.

The most remarkable of all the applications of steam-power proposed by Robert L. Stevens was that known as the Stevens Steam Iron-Clad Battery. As has already been stated, Colonel John Stevens had proposed, as early as 1812, to build a circular or saucer-shaped iron-clad, like those built 60 years later for the Russian Navy. Nothing was done, however, although the son revived the idea in a modified form 20 years afterward. In the years 1813–'14, the war with England being then in progress, he invented, after numerous and hazardous experiments, an *elongated shell*, to be fired from ordinary smooth-bored cannon. Having perfected this invention, he sold the secret to the United States, after making experiments to prove their destructiveness so decisive as to leave no doubt of the efficacy of such projectiles.

As early as 1837 he had perfected a plan of an iron-clad war-vessel, and in August, 1841, his brothers, James C. and Edwin A. Stevens, representing Robert L., addressed a letter to the Secretary of the Navy, proposing to build an iron-clad vessel of high speed, with all its machinery below the water-line, and having submerged screw-propellers. The armament was to consist of the most powerful rifled guns, loading at the breech, and provided with elongated shot and shell. In the year 1842, having contracted to build for the United States Government a large war-steamer on this plan, which should be shot and shell proof, Robert L. Stevens built a steamboat at Bordentown, for the sole purpose of experimenting on the forms and curves of propeller-blades, as compared with side-wheels, and continued his experiments for many months. After some delay, during which Mr. Stevens and his brothers were engaged with their experiments and in perfecting their plans, the keel of an iron-clad was laid down in a dry-dock which had been constructed for the purpose at great cost. This vessel was to have been 250 feet long, of 40 feet beam, and 28 feet deep. The machinery was designed to furnish 700 indicated horse-power. The plating was proposed to be 4½ inches thick—the same thickness of armor as was adopted 10 years later by the French for their comparatively rude constructions.

In 1854, such marked progress had been made in the construction of ordnance that Mr. Stevens was no longer willing to proceed with the original plans, fearing that, were the ship completed, it might prove not invulnerable, and might throw some discredit upon its designer, as well as upon the navy of which it was to form a part. The work, which had, in those years of peace, progressed very slowly and intermittently, was therefore stopped entirely, the vessel given up, and in 1854 the keel of a ship of vastly greater size and power was laid down. The new design was 415 feet long, of 45 feet beam, and of something over 5,000 tons displacement. The thickness of armor proposed was 6¾ inches—2¼ inches thicker than that of the first French and British iron-clads—and the machinery was designed by Mr. Stevens to be of 8,624 indicated horse-power, driving twin-screws, and propelling the vessel 20 miles or more an hour. As with the preceding design, the progress of construction was intermittent and very slow. Government advanced funds, and then refused to continue the work; successive administrations alternately encouraged and discouraged the engineer; and he finally, cutting loose entirely from all official connections, went on with the work at his own expense.

The remarkable genius of the elder Stevens was well reflected in the character of his son, and is in no way better exemplified than by the accuracy with which, in this great ship, those forms and proportions, both of hull and machinery, were adopted which are now, twenty-five years later, recognized as most correct under similar conditions. The lines of the vessel are beautifully fair and fine, and are what J. Scott Russell has called "wave-lines," or trochoidal lines, such as Rankine has shown to be the best possible for easy propulsion. The proportion of length to midship dimensions is such as to secure the speed proposed with a minimum resistance, and to accord closely with the proportions arrived at and adopted by common consent in present transoceanic navigation by the best—not to say radical—builders.

The death of Robert L. Stevens occurred in April, 1856, when this larger vessel had advanced so far toward completion that the hull and machinery were practically finished, and it only remained to add the armor-plating, and to decide upon the form of fighting-house and upon the number and size of guns. The construction of the vessel, which had proceeded slowly and intermittently during the years of peace, as successive administrations had considered it necessary to continue the payment of appropriations, or had stopped temporarily in the absence of any apparent immediate necessity for continuance of the work, was again interrupted by his death.

The name of Robert L. Stevens will be long remembered as that of one of the greatest of American mechanics, the most intelligent of naval architects, and as the first, and one of the greatest, of those to whom we are indebted for the commencement of the mightiest of revolutions in the methods and implements of modern naval warfare. American mechanical genius and engineering skill have rarely been too promptly recognized, and no excuse will be required for an attempt (which it is hoped may yet be made) to place such splendid work as that of the Messrs. Stevens in a light which shall reveal both its variety and extent and its immense importance.

While Fulton was introducing the steamboat upon the waters of New York Bay and the Hudson River, and while the Stevenses, father and sons, were rapidly bringing out a fleet of steamers on the Delaware River and Bay, other mechanics were preparing to contest the field with them as opportunity offered, and as legislative acts authorizing monopoly expired by limitation or were repealed.

About 1821, Robert L. Thurston, John Babcock, and Captain Stephen T. Northam, of Newport, R. I., commenced building steamboats, beginning with a small craft intended for use at Slade's Ferry, on an arm of Narragansett Bay, near Fall River. They afterward built vessels to ply on Long Island Sound. One of their earliest boats was the Babcock, built at Newport in 1826. The engine was built by Thurston and Babcock, at Portsmouth, R. I. They were assisted in their work by Richard Sanford, and with funds by Northam. The engine was of 10 or 12 inches diameter of cylinder, and 3 or 4 feet stroke of piston. The boiler was a form of "pipe-boiler," subsequently (1824) patented by Babcock. The water used was injected into the hot boiler as fast as required to furnish steam, no water being retained in the steam-generator. This boat was succeeded, in 1827–'28, by a larger vessel, the Rushlight, for which the engine was built by James P. Allaire, at New York, while the boat was built at Newport. The boilers of both vessels had tubes of cast-iron. The smaller of these boats was of 80 tons burden; it steamed from Newport to Providence, 30 miles, in 3½ hours, and to New York, a distance of 175 miles, in 25 hours, using 1¾ cord of wood.[1] Thurston and Babcock subsequently removed to Providence, where the latter soon died. Thurston continued to build steam-engines at this place until nearly a half-century later, dying in 1874.[2] The establishment founded by him, after various changes, became the Providence Steam-Engine Works.

James P. Allaire, of New York, the West Point Iron Foundery, at West Point, on the Hudson River, and Daniel Copeland and his son, Charles W. Copeland, on the Connecticut River, were also early builders of engines for steam-vessels. Daniel Copeland was probably the first (1850) to adopt a slide-valve working with a lap to secure the expansion of steam. His steamboats were then usually stern-wheel vessels, and were built to ply on several routes on the Connecticut River and Long Island Sound. The son, Charles W. Copeland, went to West Point, and while there designed some heavy marine steam-machinery, and subsequently designed several steam vessels-of-war for the United States Navy. He was the earliest designer of iron steamers in the United States, building the Siamese in 1838. This steamer was intended for use on Lake Pontchartrain and the canal to New Orleans. It had two hulls, was 110 feet long, and drew but 22 inches of water, loaded. The two horizontal non-condensing engines turned a single paddle-wheel placed between the two hulls, driving the boat 10 miles an hour. The hull was constructed of plates

[1] *American Journal of Science*, March, 1827; *London Mechanics' Magazine*, June 16, 1827.

[2] "New Universal Cyclopædia," vol. iv., 1878.

of iron 10 feet long, formed on blocks after having been heated in a furnace constructed especially for the purpose. The frames were of T-iron, which was probably here used for the first time. The same engineer, associated with Samuel Hart, a well-known naval constructor, built, in 1841, for the United States Navy, the iron steamer Michigan, a war-vessel intended for service on the great northern lakes. This vessel is still in service, and in good order. The hull is $162\frac{1}{2}$ feet in length, 27 feet in breadth, and $12\frac{1}{2}$ feet in depth, measuring 500 tons. The frames were made of T-iron, stiffened by reverse bars of L-iron. The keel-plate was $\frac{5}{8}$ inch thick, the bottom plates $\frac{3}{8}$, and the sides $\frac{3}{16}$ inch. The deck-beams were of iron, and the vessel, as a whole, was a good specimen of iron-ship building.

During the period from 1830 to 1840, a considerable number of the now standard details of steam-engine and steamboat construction were devised or introduced by Copeland. He was probably the first to use (on the Fulton, 1840) an independent engine to drive the blowing-fans where an artificial draught was required. He made a practice of fitting his steamers with a "bilge-injection," by means of which the vessel could be freed of water, through the condenser and air-pump, when leaking seriously ; the condensing-water is, in such a case, taken from inside the vessel, instead of from the sea. This is probably an American device. It was in use in the United States previously to 1835, as was the use of anthracite coal on steamers, which was continued by Copeland in manufacturing and in air-furnaces, as well as on steamboats. He also modified the form of Stevens's double-poppet valve, giving it such shape that it was comparatively easy to grind it tight and to keep it in order.

In 1825, James P. Allaire, of New York, built compound engines for the Henry Eckford, and subsequently constructed similar engines for several other steamers, one of which, the Sun, made the trip from New York to Albany in 12 hours 18 minutes. He used steam at 100 pounds pressure. Erastus W. Smith afterward introduced this form of engine on the Great Lakes, and still later they were introduced into British steamers. The machinery of the steamer Buckeye State was constructed at the Allaire Works, New York, in 1850, from the designs of John Baird and Erastus W. Smith, the latter being the designing and constructing engineer. The steamer was placed on the route between Buffalo, Cleveland, and Detroit, in 1851, and gave most satisfactory results, consuming less than two-thirds the fuel required by a similar vessel of the same line fitted with the single-cylinder engine. The steam-cylinders of this engine were placed one within the other, the low-pressure exterior cylinder being annular. They were 37 and 80 inches in diameter respectively, and the stroke was 11 feet. Both pistons were connected to one cross-head, and the general arrangement of the engine was similar to that of the common form of beam-engine. The steam-pressure was from 70 to 75 pounds—about the maximum pressure adopted a quarter of a century later on trans-atlantic lines. This steamer was of high speed, as well as economical of fuel.

In the year 1830, there were 86 steamers on the Hudson River and in Long Island Sound.

During the early part of the nineteenth century, the introduction of the steamboat upon the waters of the great rivers of the interior of the United States was one of the most notable details of its history. Inaugurated by the unsuccessful experiment of Evans, the building of steamboats on those waters, once commenced, never ceased ; and a generation after Fitch's burial on the shore of the Ohio, his last wish—that he might lie "where the song of the boatman would enliven the stillness of his resting-place, and the music of the steam-engine soothe his spirit"—was fulfilled day by day unceasingly.

Nicholas J. Roosevelt was, as has been already stated, the first to take a steamboat down the great rivers. His boat was built at Pittsburgh in 1811, under an arrangement with Fulton and Livingston, from Fulton's plans. It was called the "New Orleans," was of about 200 tons burden, and was propelled by a stern-wheel, assisted, when the winds were favorable, by sails carried on two masts. The hull was 138 feet long, 30 feet beam, and the cost of the whole, including engines, was about $40,000. The builder, with his family, an engineer, a pilot, and six "deck-hands," left Pittsburgh in October, 1811, reaching Louisville in 70 hours (steaming about 10 miles an hour), and New Orleans in 14 days, steaming from Natchez.

The next steamers built on Western waters were probably the Comet and the Vesuvius, both of which were in service some time. The Comet was finally laid aside, and the engine used to drive a mill, and the Vesuvius was destroyed by the explosion of her boilers. As early as 1813 there were two shops at Pittsburgh building steam-engines. Steamboat-building now became an important and lucrative business in the Westn, and it is stated that as early as 1840 there were a thousand steamers on the Mississippi and its tributaries.

In the Washington, built at Wheeling, Va., in 1816, under the direction of Captain Henry M. Shreve, the boilers, which had previously been placed in the hold, were carried on the main-deck, and a "hurricane-deck" was built over them. Shreve substituted two horizontal direct-acting engines for the single upright engine used by Fulton, drove them by high-pressure steam without condensation, and attached them, one on each side the boat, to cranks placed at right angles. He adopted a cam cut-off expanding the steam considerably, and the flue-boiler of Evans. At that time the voyage from New Orleans to Louisville occupied three weeks, and Shreve was made the subject of many witticisms when he predicted that the time would ultimately be shortened to ten days. It is now made in four days. The Washington was seized at New Orleans, in 1817, by order of Livingston, who claimed that his rights included the monopoly of the navigation of the Mississippi and its tributaries. The courts decided adversely on this claim, and the release of the Washington was the act which removed every obstacle to the introduction of steam-navigation throughout the United States.

The first steamer on the Great Lakes was the Ontario, built in 1816, at Sackett's Harbor. Fifteen years later, Western steamboats had taken the peculiar form which has since usually distinguished them.

The use of the steam-engine for ocean-navigation kept pace with its introduction on inland waters. Begun by Robert L. Stevens in the United States, in the year 1808, and by his contemporaries, Bell and Dodd, in Great Britain, it steadily and rapidly advanced in effectiveness and importance, and has now nearly driven the sailing fleet from the ocean. Transatlantic steam-navigation began with the voyage of the American steamer Savannah from Savannah, Ga., to St. Petersburg, Russia, *via* Great Britain and the North-European ports, in the year 1819. Fulton, not long before his death, planned a vessel, which it was proposed to place in service in the Baltic Sea; but circumstances compelled a change of plan finally, and the steamer was placed on a line between Newport, R. I., and the city of New York; and the Savannah, several years later, made the voyage then proposed for Fulton's ship. The Savannah measured 350 tons, and was constructed by Crocker & Fickett, at Corlears Hook, N. Y. She was purchased by Mr. Scarborough, of Savannah, who placed Captain Moses Rogers, previously in command of the Clermont and of Stevens's boat, the Phœnix, in charge. The ship was fitted with steam-machinery and paddle-wheels, and sailed for Savannah April 27, 1819, making the voyage successfully in seven days. From Savannah, the vessel sailed for Liverpool May 26th, and arrived at that port June 20th. During this trip the engines were used 18 days, and the remainder of the voyage was made under sail. From Liverpool the Savannah sailed, July 23d, for the Baltic, touching at Copenhagen, Stockholm, St. Petersburg, and other ports. At St. Petersburg, Lord Lyndock, who had been a passenger, was landed ; and, on taking leave of the commander of the steamer, the distinguished guest presented him with a silver tea-kettle, suitably inscribed with a legend referring to the importance of the event which afforded him the opportunity. The Savannah left St. Petersburg in November, passing New York December 9th, and reaching Savannah in 50 days from the date of departure, stopping four days at Copenhagen, Denmark, and an equal length of time at Arundel, Norway. Several severe gales were met in the Atlantic, but no serious injury was done to the ship.

The Savannah was a full-rigged ship. The wheels were turned by an inclined direct-acting low-pressure engine, having a steam-cylinder 40 inches in diameter and 6 feet stroke of piston. The paddle-wheels were of wrought-iron, and were so attached that they could be detached and hoisted on board when it was desired. After the return of the ship to the United States, the machinery was removed and was sold to the Allaire Works, of New York. The steam-cylinder was exhibited by the purchasers at the "World's Faire" at New York thirty years later. The vessel was employed, as a sailing-vessel, on a line between New York and Savannah, and was finally lost in the year 1822. Under sail, with a moderate breeze, this ship is said to have sailed about three knots, and to have steamed five knots. Pine-wood was used as the fuel, which fact accounts for the necessity of making the transatlantic voyage partly under sail.

Renwick states that another vessel, ship-rigged and fitted with a steam-engine, was built at New York in 1819, to ply between New York and Charleston, and to New Orleans and Havana, and that it proved perfectly successful as a steamer, having good speed, and proving an excellent sea-boat. The enterprise was, however, pecuniarily a failure, and the vessel was sold to the Brazilian Government after the removal of the engine. In 1825 the steamer Enterprise made a voyage to India, sailing and steaming as the weather and the supply of fuel permitted. The voyage occupied 47 days.

Notwithstanding these successful passages across the ocean, and the complete success of the steamboat in rivers and harbors, it was asserted, as late as 1838, by many who were regarded as authority, that the passage of the ocean by steamers was quite impracticable, unless possibly they could steam from the coasts of Europe to Newfoundland or to the Azores, and, replenishing their coal-bunkers, resume their voyages to the larger American ports. The voyage was, however, actually accomplished by two steamers in the year just mentioned. These were the Sirius, a ship of 700 tons and of 250 horse-power, and the Great Western, of 1,340 tons and 450 horse-power. The latter was built for this service, and was a large ship for that time, measuring 236 feet in length. Her wheels were 28 feet in diameter, and 10 feet in breadth of face. The Sirius sailed from Cork April 4, 1838, and the Great Western from Bristol April 8th, both arriving at New York on the same day—April 23d—the Sirius in the morning, and the Great Western in the afternoon.

The Great Western carried out of Bristol 660 tons of coal. Seven passengers chose to take advantage of the opportunity, and made the voyage in one-half the time usually occupied by the sailing-packets of that day. Throughout the voyage the wind and sea were nearly ahead, and the two vessels pursued the same course, under very similar conditions. Arriving at New York, they were received with the greatest possible enthusiasm. They were saluted by the forts and the men-of-war in the harbor, the merchant-vessels dipped their flags, and the citizens assembled on the Battery, and, coming to meet them in boats of all kinds and sizes, cheered heartily. The newspapers of the time were filled with the story of the voyage and with descriptions of the steamers themselves and of their machinery.

A few days later the two steamers started on their return to Great Britain, the Sirius reaching Falmouth safely in 18 days, and the Great Western making the voyage to Bristol in 15 days, the latter meeting with head-winds and working, during a part of the time, against a heavy gale and in a high sea, at the rate of but two knots an hour. The Sirius was thought too small for this long and boisterous route, and was withdrawn and replaced on the line between London and Cork, where the ship had previously been employed. The Great Western continued several years in the transatlantic trade.

Thus these two voyages inaugurated a transoceanic steam-service, which has steadily grown in extent and in importance. The use of steam-power for this work of extended ocean-transportation has never since been interrupted. During the succeeding six years the Great Western made 70 passages across the Atlantic, occupying on the voyages to the westward an average of 15½ days, and eastward 13½. The quickest passage to New York was made in May, 1843, in 12 days and 18 hours, and the fastest steaming was logged 12 months earlier, when the voyage from New York was made in 12 days and 7 hours.

Meantime, several other steamers were built and placed in the transatlantic trade. Among these were the Royal William, the British Queen, the President, the Liverpool, and the Great Britain. The latter, the finest of the fleet, was launched in 1843. This steamer was 300 feet long, 50 feet beam, and of 1,000 horse-power. The hull was of iron, and the whole ship was an example of the very best work of that time. After several voyages, this vessel went ashore on the coast of Ireland, and there remained several weeks, but was finally got off, without having suffered serious injury—a remarkable illustration of the stanchness of an iron hull when well built and of good material. The vessel was repaired, and many years afterward was still afloat, and engaged in the transportation of passengers and merchandise to Australia.

The "Cunard Line" of transatlantic steamers was established in the year 1840. The first of the line—the Britannia—sailed from Liverpool for New York, July 4th of that year, and was followed, on regular sailing-days, by the other three of the four ships with which the company commenced business. These four vessels had an aggregate tonnage of 4,600 tons, and their speed was less than eight knots. To-day, the tonnage of a single vessel of the fleet exceeds that of the four; the total tonnage has risen to many times that above given. There are 80 steamers in the line, aggregating nearly 100,000 horse-power. The speed of the steamships of the present time is double that of the vessels of that date, and passages are not infrequently made in eight days.

The form of steam-engine in most general use at this time, on transatlantic steamers, was that known as the "side-lever engine." It was first given the standard form by Messrs. Maudsley & Co., of London, about 1835, and was built by them for steamers supplied to the British Government for general mail service.

The steam-vessels of the time are well represented in the accompanying engraving (Fig. 91) of the steamship Atlantic—a vessel which was shortly afterward (1851) built as the pioneer steamer of the American "Collins Line." This steamship was one of several which formed the earliest of American steamship-lines, and is one of the finest examples of the type of paddle-steamers which was finally superseded by the later screw-fleets. The "Collins Line" existed but a very few years, and its failure was probably determined as much by the evident and inevitable success of screw-propulsion as by the difficulty of securing ample capital, complete organization, and efficient general management. This steamer was built at New York—the hull by William Brown, and the machinery by the Novelty Iron-Works. The length of the hull was 276 feet, its breadth 45 feet, and the depth of hold 31½ feet. The

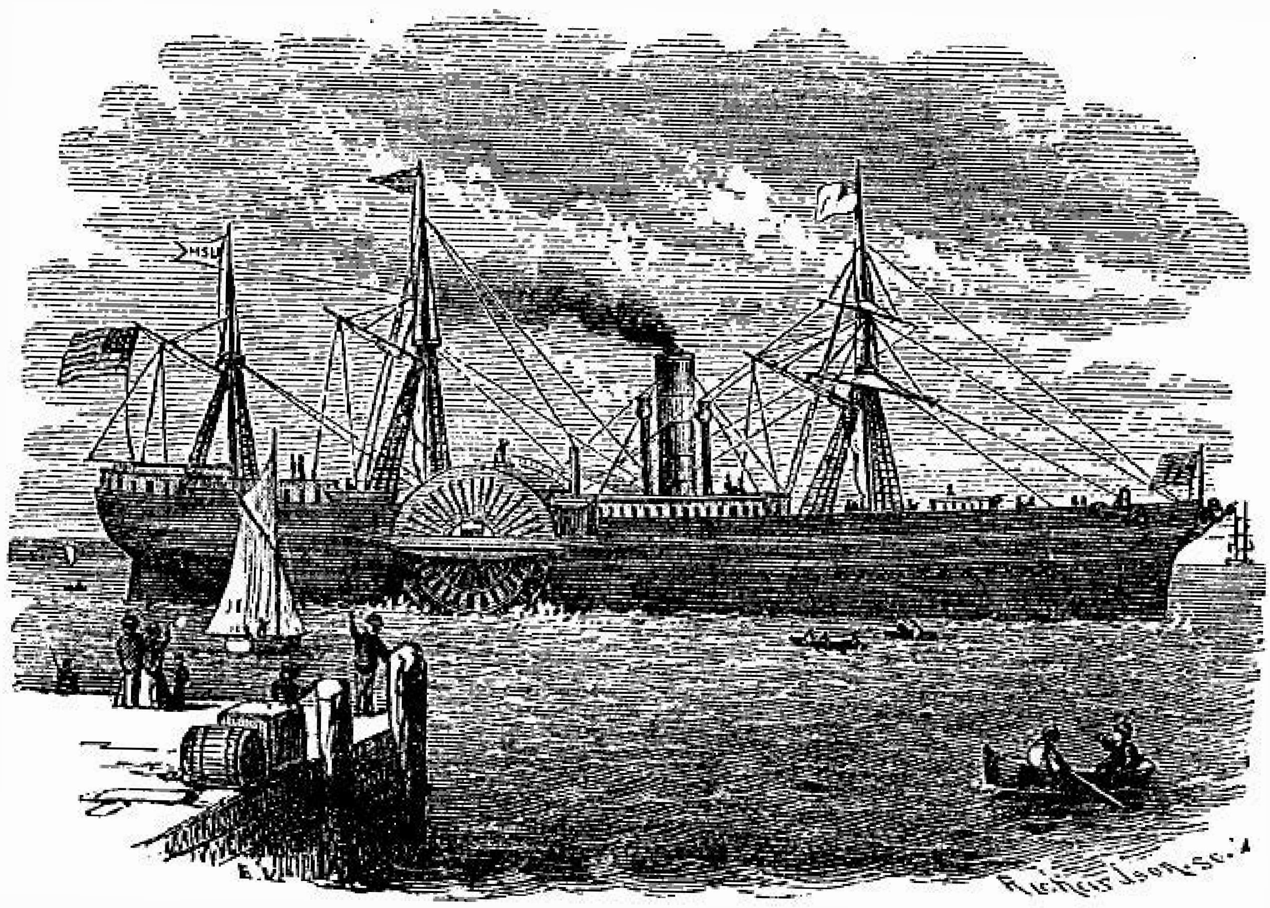

FIG. 91.—The Atlantic, 1851.

width over the paddle-boxes was 75 feet. The ship measured 2,860 tons. The form of the hull was then peculiar in the fineness of its lines; the bow was sharp, and the stern fine and smooth, and the general outline such as best adapted the ship for high speed. The main saloon was about 70 feet long, and the dining-room was 60 feet in length and 20 feet wide. The state-rooms were arranged on each side the dining-“saloon,” and accommodated 150 passengers. These vessels were beautifully fitted up, and with them was inaugurated that wonderful system of passenger-transportation which has since always been distinguished by those comforts and conveniences which the American traveler has learned to consider his by right.

The machinery of these ships was, for that time, remarkably powerful and efficient. The engines were of the side-lever type, as illustrated in Fig. 92, which represents the engine of the Pacific, designed by Mr. Charles W. Copeland, and built by the Allaire Works.

In this type of engine, as is seen, the piston-rod was attached to a cross-head working vertically, from which, at each side, links, *B C*, connected with the "side-lever," *D E F*. The latter vibrated about a "main centre" at *E*, like the overhead beam of the more common form of engine; from its other end, a "connecting-rod," *H*, led to the

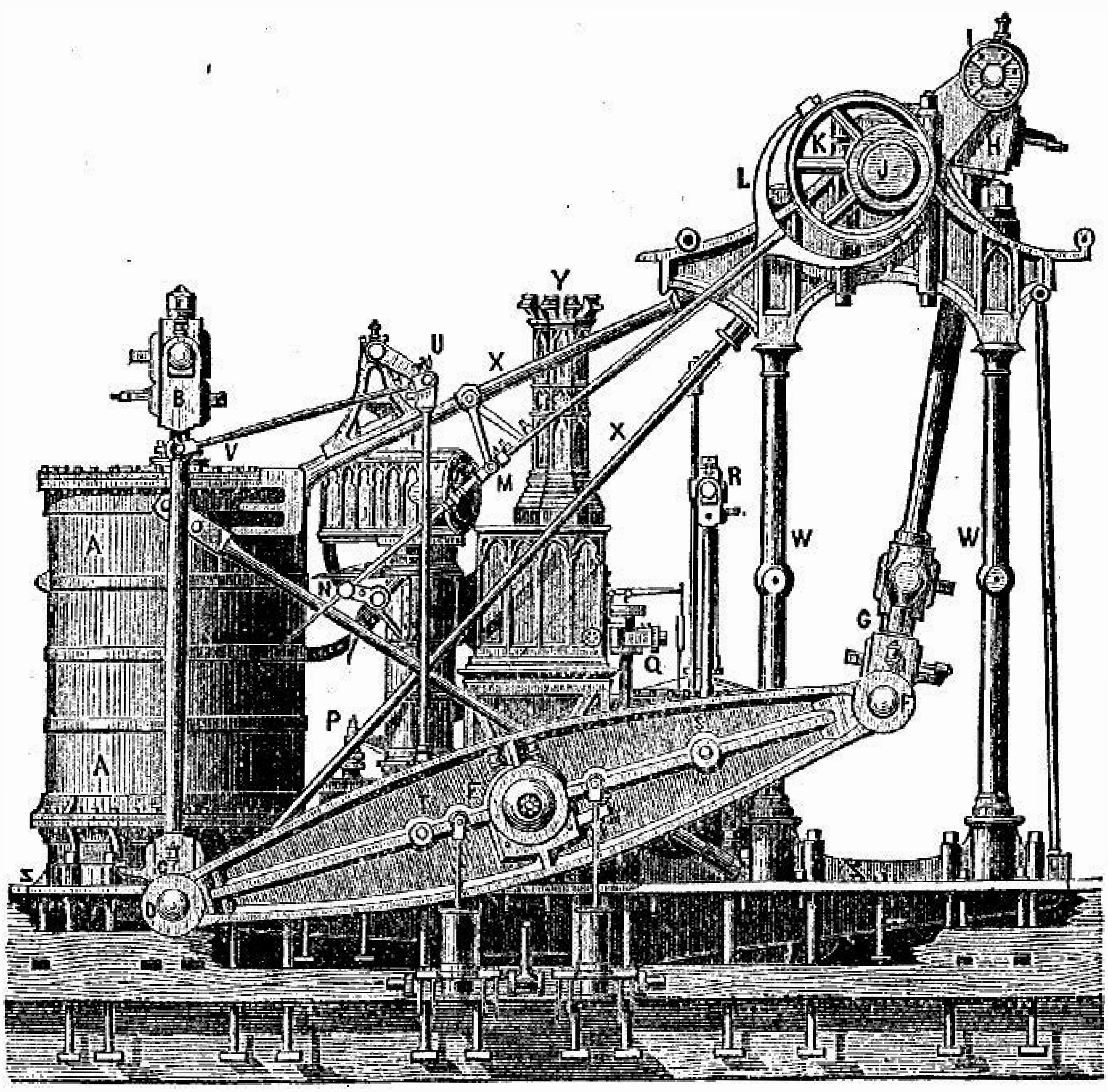

FIG. 92.—The Side-Lever Engine, 1849.

"cross-tail," *W*, which was, in turn, connected to the crank-pin, *I*. The condenser, *M*, and air-pump, *Q*, were constructed in the same manner as those of other engines, their only peculiarities being such as were incident to their location between the cylinder, *A*, and the crank, *I J*. The paddle-wheels were of the common "radial" form, covered in by paddle-boxes so strongly built that they were rarely injured by the heaviest seas.

These vessels surpassed, for a time, all other sea-going steamers in speed and comfort, and made their passages with great regularity. The minimum length of voyage of the Baltic and Pacific, of this line, was 9 days 19 hours.

During the latter part of the period the history of which has been here given, the marine steam-engine became subject to very marked changes in type and in details, and a complete revolution was effected in the method of propulsion. This change has finally resulted in the universal adoption of a new propelling instrument, and in driving the whole fleet of paddle-steamers from the ocean. The Great Britain was a screw-steamer.

The screw-propeller, which, as has been stated, was probably first proposed by Dr. Hooke in 1681, and by Dr. Bernouilli, of Groningen, at about the middle of the eighteenth century, and by Watt in 1784, was, at the end of the century, tried experimentally in the United States by David Bushnell, an ingenious American, who was then conducting the experiments with torpedoes which were the cause of the incident which originatednthat celebrated song by Francis Hopkinson, the "Battle of the Kegs," using the screw to propel one of his submarine boats, and by John Fitch, and by Dallery in France.

Joseph Bramah, of Great Britain, May 9, 1785, patented a screw-propeller identical in generalnarrangement with those used to-day. His sketch exhibits a screw, apparently of very fair shape, carried on an horizontal shaft, which passes out of the vessel through a stuffing-box, the screw being wholly submerged. Bramah does not seem to have put his plan in practice. It was patented again in England, also, by Littleton in 1794, and by Shorter in 1800.

John Stevens, however, first gave the screw a practically useful form, and used it successfully, in 1804 and 1805, on the single and the twin screw boats which he built at that time. This propelling instrument was also tried by Trevithick, who planned a vessel to be propelled by a steam-engine driving a screw, at about this time, and his scheme was laid before the Navy Board in the year 1812. His plans included an iron hull. Francis Pettit Smith tried the screw also in the year 1808, and subsequently.

Joseph Ressel, a Bohemian, proposed to use a screw in the propulsion of balloons, about 1812, and in the year 1826 proposed its use for marine propulsion. He is said to have built a screw-boat in the year 1829, at Trieste, which he named the Civetta. The little craft met with an accident on the trial-trip, and nothing more was done.

The screw was finally brought into general use through the exertions of John Ericsson, a skillful Swedish engineer, who was residing in England in the year 1836, and of Mr. F. P. Smith, an English farmer. Ericsson patented a peculiar form of screw-propeller, and designed a steamer 40 feet in length, of 8 feet beam, and drawing 3 feet of water. The screw was double, two shafts being placed the one within the other, revolving in opposite directions, and carrying the one a right-hand and the other a left-hand screw. These screws were 5¼ feet in diameter. On her trial-trip this little steamer attained a speed of 10 miles an honr. Its power as a "tug" was found to be very satisfactory; it towed a schooner of 140 tons burden at the rate of 7 miles, and the large American packet-ship Toronto was towed on the Thames at a speed of 5 miles an hour.

Ericsson endeavored to interest the British Admiralty in his improvements, and succeeded only so far as to induce the Lords of the Admiralty to make an excursion with him on the river. No interest was awakened in the new system, and nothing was done by the naval authorities. A note to the inventor from Captain Beaufort—one of the party—was received shortly afterward, in which it was stated that the excursionists had not found the performance of the little vessel to equal their hopes and expectations. All the interests of the then existing engine-building establishments were opposed to the innovation, and the proverbial conservatism of naval men and naval administrations aided in procuring the rejection of Ericsson's plans.

Fortunately for the United States, it happened, at that time, that we had in Great Britain both civil and naval representatives of greater intelligence, or of greater boldness and enterprise. The consul at Liverpool was Mr. Francis B. Ogden, of New Jersey, a gentleman who was somewhat familiar with the steam-engine and with steam-navigation. He had seen Ericsson's plans at an earlier period, and had at once seen their probable value. He was sufficiently confident of success to place capital at the disposal of the inventor. The little screw-boat just described was built with funds of which he furnished a part, and was named, in his honor, the Francis B. Ogden.

Captain Robert F. Stockton, an officer of the United States Navy, and also a resident of New Jersey, was in London at the time, and made an excursion with Ericsson on the Ogden. He was also at once convinced of the value of the new method of application of steam-power to ship-propulsion, and gave the engineer an order to build two iron screw-steamboats for use in the United States. Ericsson was induced, by Messrs. Ogden and Stockton, to take up his residence in the United States.[1] The Stockton was sent over to the United States in April, 1839, under sail, and was sold to the Delaware & Raritan Canal Company. Her name was changed, and, as the New Jersey, she remained in service many years.

The success of the boat built by Ericsson was so evident that, although the naval authorities remained inactive, a private company was formed, in 1839, to work the patents

[1] This distinguished inventor died at New York in 1889 ("Trans. A. S. M. E.," 1890).

of F. P. Smith, and this "Ship-Propeller Company" built an experimental craft called the Archimedes, and its trial-trip was made October 14th of the same year. The speed attained was 9.64 miles an hour. The result was in every respect satisfactory, and the vessel, subsequently, made many voyages from port to port, and finally circumnavigated the island of Great Britain. The proprietors of the ship were not pecuniarily successful in their venture, however, and the sale of the vessel left the company a heavy loser. The Archimedes was 125 feet long, of 21 feet 10 inches beam, and 10 feet draught, registering 232 tons. The engines were rated at 80 horse-power. Smith's earlier experiments (1837) were made with a little craft of 6 tons burden, driven by an engine having a steam-cylinder 6 inches in diameter and 15 inches stroke of piston. The funds needed were furnished by a London banker—Mr. Wright.

Bennett Woodcroft had also used the screw experimentally as early as 1832, on the Irwell, near Manchester, England, in a boat of 55 tons burden. Twin-screws were used, right and left handed respectively ; they were each two feet in diameter, and were given an expanding pitch. The boat attained a speed of four miles an hour.

Experiments made subsequently (1843) with this form of screw, and in competition with the "true" screw of Smith, brought out very distinctly the superiority of the former, and gave some knowledge of the proper proportions for maximum efficiency. In later examples of the Woodcroft screw, the blades were made detachable and adjustable—a plan which is still a usual one, and which has proved to be, in some respects, very convenient.

When Ericsson reached the United States, he was almost immediately given an opportunity to build the Princeton—a large screw-steamer—and at about the same time the English and French Governments also had screw-steamers built from his plans, or from those of his agent in England, the Count de Rosen. In these latter ships—the Amphion and the Pomona—the first horizontal direct-acting engines ever built were used, and they were fitted with double-acting air-pumps, having canvas valves and other novel features. The great advantages exhibited by these vessels over the paddle-steamers of the time did for screw-propulsion what Stephenson's locomotive—the Rocket—did for railroad locomotion ten years earlier.

Congress, in 1839, had authorized the construction of three war-vessels, and the Secretary of the Navy ordered that two be at once built in the succeeding year. Of these, one was the Princeton, the screw-steamer of which the machinery was designed by Ericsson. The length of this vessel was 164 feet, beam 30½ feet, and depth 21½ feet. The ship drew from 16½ to 18 feet of water, displacing at those draughts 950 and 1,050 tons. The hull had a broad, flat floor, with sharp entrance and fine run, and the lines were considered at that time remarkably fine.

The screw was of gun-bronze, six-bladed, and was 14 feet in diameter and of 35 feet pitch; i. e., were there no slip, the screw working as if in a solid nut, the ship would have been driven forward 35 feet at each revolution.

The engines were two in number, and very peculiar in form; the cylinder was, in fact, a *semi*-cylinder, and the place of the piston-rod, as usually built, was taken by a vibrating shaft, or "rock-shaft," which carried a piston of rectangular form, and which vibrated like a door on its hinges as the steam was alternately let into and exhausted from each side of it. The great rock-shaft carried, at the outer end, an arm from which a connecting-rod led to the crank, thus forming a "direct-acting engine."

The draught in the boilers was urged by blowers. Ericsson had adopted this method of securing an artificial draught ten years before, in one of his earlier vessels, the Corsair. The Princeton carried a XII-inch wrought-iron gun. This gun exploded after a few trials, with terribly disastrous results, causing the death of several distinguished men, including members of the President's cabinet.

The Princeton proved very successful as a screw-steamer, attaining a speed of 13 knots, and was then considered very remarkably fast. Captain Stockton, who commanded the vessel, was most enthusiastic in praise of her.

Immediately there began a revolution in both civil and naval ship-building, which progressed with great rapidity. The Princeton was the first of the screw-propelled navy which has now entirely displaced the older type of steam-vessel. The introduction of the screw now took place with great rapidity. Six steamers were fitted with Ericsson's screw in 1841, 9 in 1842, and nearly 30 in the year 1843.

In Great Britain, France, Germany, and other European countries, the revolution was also finally effected, and was equally complete. Nearly all sea-going vessels built toward the close of the period here considered were screw-steamers, fitted with direct-acting, quick-working engines. It was, however, many years before the experience of engineers in the designing and in the construction and management of this new machinery enabled them to properly proportion it for the various kinds of service to which they were called upon to adapt it. Among other modifications of earlier practice introduced by Ericsson was the surface-condenser with a circulating pump driven by a small independent engine.

The screw was found to possess many advantages over the paddle-wheel as an instrument for ship-propulsion. The cost of machinery was greatly reduced by its use; the expense of maintenance in working order was, however, somewhat increased. The latter disadvantage was, nevertheless, much more than compensated by an immense increase in the economy of ship-propulsion, which marked the substitution of the new instrument and its impelling machinery.

When a ship is propelled by paddles, the motion of the vessel creates, in consequence of the friction of the fluid against the sides and bottom, a current of water which flows in the direction in which the ship is moving, and forms a current following the ship for a time, and finally losing all motion by contact with the surrounding mass of water. All the power expended in the production of this great stream is, in the case of the paddle-steamer, entirely lost. In screw-steamers, however, the propelling instrument works in this following current, and the tendency of its action is to bring the agitated fluid to rest, taking up and thus restoring, usefully, a large part of that energy which would otherwise have been lost. The screw is also completely covered by the water, and acts with comparative efficiency in consequence of its submersion. The rotation of the screw is comparatively rapid and smooth, also, and this permits the use of small, light, fast-running engines. The latter condition leads to economy of weight and space, and consequently saves not only the cost of transportation of the excess of weight of the larger kind of engine, but, leaving so much more room for paying cargo, the gain is found to be a double one. Still further, the quick-running engine is, other things being equal, the most economical of steam ; and thus some expense is saved not only in the purchase of fuel, but in its transportation, and some still additional gain is derived from the increased amount of paying cargo which the vessel is thus enabled to carry. The change here described was thus found to be productive of enormous direct gain. Indirectly, also, some advantage was derived from the greater convenience of a deck clear from machinery and the great paddle-shaft, in the better storage of the lading, the greater facility with which the masts and sails could be fitted and used ; and directly, again, in clear sides unencumbered by great paddle-boxes which impeded the vessel by catching both sea and wind.

The screw was, for some years, generally regarded as simply auxiliary in large vessels, assisting the sails. Ultimately the screw became the essential feature, and vessels were lightly sparred and were given smaller areas of sail, the latter becoming the auxiliary power.

In November of the year 1843, the screw-steamer Midas, Captain Poor, a small schooner-rigged craft, left New York for China, on probably the first voyage of such length ever undertaken by a steamer; and in the following January the Edith, Captain Lewis, a bark-rigged screw-vessel, sailed from the same port for India and China. The Massachusetts, Captain Forbes, a screw-steamship of about 800 tons, sailed for Liverpool September 15, 1845, the first voyage of an American transatlantic passenger-steamer since the Savannah's pioneer adventure a quarter of a century before. Two years later, American enterprise had placed both screw and paddle steamers on the rivers of China—principally through the exertions of Captain R. B. Forbes—and steam-navigation was fairly established throughout the world.

On comparing the screw-steamer of the present time with the best examples of steamers propelled by paddle-wheels, the superiority of the former is so marked that it may cause some surprise that the revolution just described should have progressed no more rapidly. The reason of this slow progress, however, was probably that the introduction of the rapidly-revolving screw, in place of the slow-moving paddle-wheel, necessitated a complete revolution in the design of their steam-engines; and the unavoidable change from the heavy, long-stroked, low-speed engines previously in use, to the light engines, with small cylinders and high piston-speed, called for by the new system of propulsion, was one that necessarily occurred slowly, and was accompanied by its share of those engineering blunders and accidents that invariably take place during such periods of transition. Engineers had first to learn to design such engines as should be reliable under the then novel conditions of screw-propulsion, and their experience could only be gained through the occurrence of many mishaps and costly failures. The best proportions of engines and screws, for a given ship, were determined only by long experience, although great assistance was derived from the extensive series of experiments made with the French steamer Pelican. It also became necessary to train up a body of engine-drivers who should be capable of managing these new engines; for they required the exercise of a then unprecedented amount of care and skill. Finally, with the accomplishment of these two requisites to success must simultaneously occur the enlightenment of the public, professional as well as non-professional, in regard to their advantages. Thus it happens that it is only after a considerable time that the screw attained its proper place as an instrument of propulsion, and finally drove the paddle-wheel quite out of use, except in shoal water.

Now our large screw-steamers are of higher speed than any paddle-steamers on the ocean, and develop their power at far less cost. This increased economy is due not only to the use of a more efficient propelling instrument, and to changes already described, but also, in a great degree, to the economy which has followed as a consequence of other changes in the steam-engine driving it. The earliest days of screw-propulsion witnessed the use of steam of from 5 to 15 pounds pressure, in a geared engine using jet-condensation, and giving a horse-power at an expense of perhaps 7 to 10, or even more, pounds of coal per hour. A little later came direct-acting engines with jet-condensation and steam at 20 pounds pressure, costing about 5 or 6 pounds per horse-power per hour. The steam-pressure rose a little higher with the use of greater expansion, and the economy of fuel was further improved. The introduction of the surface-condenser, which began to be generally adopted some ten years ago, brought down the cost of power to from 3 to 4 pounds in the better class of engines. At about the same time, this change to surface-condensation helping greatly to overcome those troubles arising from boiler-incrustation which had prevented the rise of steam-pressure above about 25 pounds per square inch, and as, at the same time, it was learned by engineers that the deposit of lime-scale in the marine boiler was determined by temperature rather than by the degree of concentration, and that all the lime entering the boiler was deposited at the pressure just mentioned, a sudden advance took place. Careful design, good workmanship, and skillful management, made the surface-condenser an efficient apparatus; and, the dangers of incrustation being thus lessened, the movementi toward higher pressures recommenced, and progressed so rapidly that now 75 pounds per square inch is very usual, and more than 125 pounds has since been attained.

The close of this period was marked by the construction of the most successful types of paddle-steamers, the complete success of transoceanic steam-transportation, the introduction of the screw-propeller and the peculiar engine appropriate to it, and, finally, a general improvement, which had finally become marked both in direction and in rapidity of movement, leading toward the use of higher steam-pressure, greater expansion, lighter and more rapidly-working machinery, and decidedly better design and construction, and the use of better material. The result of these changes was seen in economy of first cost and maintenance, and the ability to attain greater speed, and to assure greater safety to passengers and less risk to cargo.

The introduction of the changes just noted finally led to the last great change in the form of the marine steam-engine, and a revolution was inaugurated, which, however, only became complete in the succeeding period. The non-success of Hornblower and of Wolff, and others who had attempted to introduce the "compoundi" or double-cylinder engine on land, had not convinced all engineers that it might not yet be made a successful rival of the then standard type; and the three or four steamers which were built for the Hudson River at the end of the first quarter of the nineteenth century are said to have been very successful vessels. Carrying 75 to 100 pounds of steam in their boilers, the Swiftsure and her contemporaries were by that circumstance well fitted to make that form of engine economically a success. This form of engine was built occasionally during the succeeding quarter of a century, but only became a recognized standard type after the close of the epoch to the history of which this chapter is devoted. That latest and greatest advance in the direction of increased efficiency in the marine steam-engine was, however, commenced very soon after Watt's death, and its completion was the work of nearly a half-century.