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JAMES B. EADS

BY

LOUIS HOW



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PREFACE

I must mention with particular gratitude several books that were invaluable in preparing this sketch, in supplementing the usual biographical dictionaries and naval histories. These are: Captain Mahan's "The Gulf and Inland Waters;" Boynton's picturesque "History of the American Navy during the Great Rebellion;" Mr. Fiske's "Mississippi Valley in the Civil War;"

Snead's "The Fight for Missouri;" Mr. C. M. Woodward's "History of the St. Louis Bridge;" Mr. Estill McHenry's edition of Eads's "Papers and Addresses," with a biography; two memoirs by Señores Francisco de Garay and Ignacio Garfias, of the Mexican Association of Civil Engineers; and, above all, several memoirs and addresses and the history of the Jetties by Mr. Elmer L. Corthell, C. E., without which I could scarcely have written this Life.

I must also cordially thank for kind personal aid and advice Chancellor Chaplin (of Washington University), Dr. William Taussig, Mr. Albert Bushnell Hart, Major George Montague Wheeler of the Engineer Corps (retired), Messrs. Winston Churchill, William L. Wright, C. Donovan, E. L. Corthell (who was as obliging as he was helpful), Estill McHenry and John A. Ubsdell, Mrs. Susan F. Stevens, and especially my mother—to whose help and encouragement this Life of her father is due.

L. H.

ROCKPORT, MASS., July 30, 1900.

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JAMES B. EADS

I

EARLY TRAINING

James Buchanan Eads was born in Lawrenceburg, Indiana, May 23, 1820. Both the Eads family, who came from Maryland, and his mother's people, the Buchanans, who were originally Irish, were gentleness; but James's father never was very prosperous. The son, however, went to school, and he showed early a very special love for machinery, observing with great interest everything of that kind that he came upon. For a while the family lived in Cincinnati; from there they removed in 1829 to Louisville. In those days, when steamboats were the best of conveyances, the Ohio River formed a natural highway between the two towns. On the trip the small boy of nine hung around the engine of the boat, considering it with so much wonder and admiration that finally the engineer, who found him an apt pupil, explained the various parts of the mechanism to him.

He really had understood his lesson well, for two years later, in the little workshop that his father had fitted up for him, he made a small engine which ran by steam. Besides he made models of sawmills, fire-engines, steamboats, and electrotyping machines. Except such chance instruction as that which he found on the boat, he had had no teaching in mechanics, but worked with the ingenuity of many a bright boy; for he is by no means the only one who ever took apart and put together the family clock, or even a lever-watch, with no other tool than a penknife. One of his inventions, which shows not so much his talent as his true boyishness, was a small box-wagon, open only underneath and with a hole in front, which, suddenly produced before his mother and sisters, ran mysteriously across the room. The motive power concealed within this agreeable toy was found to be a live rat.

So much is often said of the precocity of youthful geniuses, that it is good to know that young Eads was after all a real flesh-and-blood boy, a boy so mischievous that, as he was the only son, his father hired a neighbor boy to come and play with him. Certainly he was very clever; but that he had even better qualities than cleverness is shown by his first actions on his arrival at Saint Louis.

His father, deciding to move farther west, had sent ahead the mother, the two daughters just grown, and the lad of thirteen, intending to follow with supplies for opening a shop. Again the route was by river. Arrived at Saint Louis, the boat caught fire; and early on a cold morning the family set foot, scarcely clothed, not only in the city of which the young boy was to be one day the leading citizen, but on the very spot, it is said, where he was afterwards to base one pier of his great bridge. On that bleak morning, however, none of them foresaw a bright future, or indeed anything but a distressful present. Some ladies of the old French families of the town were very kind to the forlorn women; and once on her feet Mrs. Eads set about supporting herself and her children. In those days, when sometimes a letter took a week to go a couple of hundred miles, she was not the one to wait for help from her husband; so she immediately rented a house and took boarders. The boy, as resourceful and self-reliant as his mother, now showed his energy as well as his devotion by doing the first thing he found to help her. In going along the street he saw some apples for sale, and, buying as many of them as he could afford, he peddled them to the passers-by.

That, of course, was no permanent occupation for a well-bred boy, whose associations and abilities were both high. Nevertheless his family could no longer afford to have him at school, and it was necessary for him to do some sort of work. One of his mother's boarders, a Mr. Barrett Williams, offered him a position in his mercantile house. Before long this gentleman discovered his young employee's aptitude and overwhelming love for mechanics, and kindly allowed the lad the use of his own library. Studying at night the scientific books which he found there, Eads acquired his first theoretical knowledge of engineering. In this way, without teachers, he began, in a time when there was no free higher education, to educate himself; and both then and ever after he was a constant reader not only of scientific works, but of all kinds of books. This practical experience in helping to support his family and in getting his own education, while he was still so young a lad, was the school in which he learned self-reliance. It is pleasant to know that the earnestness of life did not take all of his boyishness away from him, for it must have been while he was hard at work that he built a real steamboat, six feet long, and navigated it on Chouteau's Pond.

For five years he was a clerk in the dry-goods house. At the end of that time, probably because he was in poor health, he left that position for one that would take him more into the open air. Though his health was not strong, he was by no means an invalid; for at nineteen his muscles were solid and his fund of nervous energy was inexhaustible. So, with the natural taste of a boy for a more exciting life, he took a position as clerk on a Mississippi River steamboat. While he had nothing to do with actually running the boat, he certainly kept his eyes open to everything going on both on board and in the river; and began then to make an acquaintance with the stream which was later to be the scene of his greatest labors. If ever Nature played a prominent part in the life of a man, the Mississippi did in that of Eads; for it became the opportunity for three of his chief works, and from it he learned perhaps more of the laws of science than from all the books he ever read. To understand his life, one must have some idea of the huge river, which seems to flow sluggishly or rapidly through his whole career.

The Mississippi River, with its branches, drains the larger part of the whole United States,—that is, from the Alleghanies on the east to the Rockies on the west. The main stream, 4200 miles long, and in some places over a mile wide, flows along with tremendous force, ceaselessly eating away its yellow clay banks. The water, full of sediment, is of a thick dull brown color. The clay that it washes off in the bends it deposits on the juts of land, thus forming greater and greater curves; so that often the distance between two points is very much less by land than by water. Sometimes there are only a few yards across the neck of a peninsula, around which the channel distance is many miles; and on one side the level of the river is several feet higher than on the other. Gradually the water keeps eating its way, until it forces a passage through the neck, and then the torrent rushes through in a cascade, with a roar that can be heard for miles. The banks dissolve like sugar, and the next day steamboats can cross where the day before were fields and may be houses. Besides this, the current is constantly washing away and building up not only hidden bars on the river bottom, but even islands above its surface. In the fall and in the spring it rises with such terrifying rapidity that some years it quickly overflows its banks in certain reaches till it is sixty miles wide. Houses and trees torn from their places, and wrecks of boats, float or protrude from the bottom of this brown lake. And when the flood subsides, the current often chooses a new and changed channel. Amid the ever-varying dangers of such a river the only safety for steamboats is in a race of pilots so learned and so alert as to have the shifting bars and courses always in their minds. In 1839, when steamboats were the only means of rapid transit in the West, when there were more of them in the harbor of the little town of Saint Louis than to-day when it is a great city, this class of pilots was a large and a very

respectable one. Much of their knowledge of the river was what young Eads learned while he was a clerk among them; and as time went on, he came to realize that although the Mississippi seems so capricious in its terrible games that one would think them the result of chance, yet in truth, they "are controlled by laws as immutable as the Creator."

Despite all care that could be used, steamboats were every week sunk and wrecked, and with their valuable engines, boilers, and cargoes were often left where they lay in the ceaseless brown current. After he had been for three years on the river, Eads gave up his clerkship to go into the business of raising these boats, their machinery, and their freight. In 1842, at the age of twenty-two, he formed a partnership with Case & Nelson, boat-builders. His first appearance in the new business was an experience that well shows his quick inventive genius, his persistency, and his courage. While his diving-bell boat was building, a barge loaded with pig-lead sank in the rapids at Keokuk, 212 miles from Saint Louis. A contract having been made with its owners, Eads hurried up there to rescue the freight from fifteen feet of water. He had no knowledge himself of diving-armor; but he had engaged a skilled diver from the Great Lakes, who brought his own apparatus. They set out in a barge and anchored over the wreck; but, once there, they soon discovered that the current was so exceedingly rapid that the diver could do nothing in it. Eads at once returned to Keokuk, and, buying a forty-gallon whiskey hogshead, took it out to the wreck; and having knocked out one head, he slung pigs of lead round his improvised diving-bell, made a seat inside it, rigged it to his derrick and air-pumps, and then asked the diver to go down in it. The diver having very naturally refused, Eads on the spot set himself a precedent which, during his after life, he never broke,—saying that he would not ask an employee to go where he would not trust himself, he got inside his hogshead and was lowered into the river. His assistants were unused to managing diving-bells, and when they came to haul him up the derrick got out of order. By main force they were able to raise the hogshead to the surface, but not above it. As the air-pump continued to work all the while, Eads, though wondering what was amiss, sat patiently in his place, till finally he saw a hand appear under the rim of the hogshead. Seizing this, he ducked under and got out. Although the rough diving-bell worked thus awkwardly at first, it served well enough, and finally all of the lost freight was saved.

A young man so fearless, so energetic, and so able to invent mechanical devices at sudden need, was bound to succeed in a business like this. And young Eads did succeed. "Fortune," he believed, "favors the brave;" and his motto was, "Drive on!"

The insurance companies were willing to give the wreckers a large interest, sometimes as much as a half, of the rescued cargoes; and there was a law by which a vessel or freight that had been wrecked for five years belonged to whoever could get it up. Eads and his partners worked up and down the river for hundreds of miles. The first diving-bell boat was followed by a larger one, provided with machinery for pumping out sand, and for raising whole hulls. While in this hazardous business Eads invented many new appliances for use in its various branches. Because he was in charge of a boat people began to call the young wrecker Captain Eads, and that was the only reason for a title which clung to him always. He grew now to know the river as few have ever known it,—his operations extended from Galena, Illinois, to the Balize at the river's very mouth, and even into the tributaries of the Mississippi,—and he used to say that there was not a stretch of fifty miles in the twelve hundred between Saint Louis and New Orleans in which he had not stood on the bottom under his diving-bell.

With the same devotion to his parents as when he peddled the apples in the street, Eads now bought them a farm in Iowa, and provided in every way he could for their comfort. But beyond the ordinary desire of making a fortune for them, for himself, and for a new interest that was coming into his life, it does not appear that there were in his mind any unusual ambitions, any of the dreams of genius. As yet he was only a hard-working, earnest young man, extraordinarily clever to be sure, but founding on that cleverness no visions of great renown in the future. Perhaps this was because he had enough to dream of in the present, enough hopes of purely domestic happiness to look towards. For he had fallen in love with a Miss Martha Dillon, a young lady of about his own age, daughter of a rich man in Saint Louis. The father disapproved of the match, not only because he thought the suitor too young, too poor, too unknown, but because he wished to keep his daughter with him, and for other less reasonable causes.

The letters between the engaged couple show Eads at twenty-five as a keen, experienced, and yet an unsophisticated young man; generous, proud, brave, and courteous; a lover of Nature, of poetry, of people, and of good books; an inveterate early riser; reverend in religion, and yet, while nominally a Catholic, really a free-thinker; sentimental in his feelings almost as if he had lived a century sooner, and at the same time controlling his true and deep emotions, and showing his strong love only to those he loved.

At last Eads and Miss Dillon were married, he being over twenty-five at the time, she nearly twenty-four. Eads then sold out his wrecking business and left the river. He probably made this change because he hoped thereby not only to be more with his wife, but also to support her in the comfort she had been used to, and to show her father that he could do so. The

new enterprise, into which at least one of his old partners entered with him, and into which he put all his money, was the manufacture of glass; and they built the first glass factory west of the Ohio River. He had to go to Pittsburg—then a long journey by boat, stage, and rail—to get trained workmen and to learn the process himself. Almost all of the necessary ingredients and apparatus had to be sent for to Pittsburg, to Cleveland, or to New York; and they were often slow in arriving and thereby made matters drag considerably. Still there was always something to do, and Eads, the only one of the partners who understood the trade, was forced to work extraordinarily hard. With his usual persistence he stuck to it pluckily, often staying up late into the night and rising the next day before dawn to oversee operations. He was also indispensable for his faculty of managing men; and a letter to his wife written on his twenty-seventh birthday (1847) shows how strong the man already was in that power of getting the most from a workman, which was afterwards to count for so much in his best work. An employer, he says, must "have constant control of his temper, and be able to speak pleasantly to one man the next moment after having spoken in the harshest manner to another, and even to give the same man a pleasant reply a few minutes after having corrected him. Self must be left out of the matter entirely, and a man or boy spoken to only as concerns his conduct; and the authority which the controller has over the controlled, used only when absolutely necessary, and then with the utmost promptness."

However, despite all his firmness and perseverance, the difficulties of the glassworks became greater and greater; and at last, after having been run two years, they were shut down. Eads was left with debts of \$25,000. The very unusual action of his creditors in this crisis shows what confidence they had in his integrity and in his ability; for they advanced him \$1500 with which to go back into the wrecking business, and he at once rejoined his former partners. He now worked harder, if possible, than ever; for he felt, as he wrote to his wife, that "with a man in debt it cannot be said that his time is his own." Powerful as he was physically, his health was not good, but even in sickness he scarcely ceased to toil during the first year or two; and at the end of ten years, not only had all his debts been long since paid, but his firm was worth half a million dollars.

Work, however, was to him only a means to an end. The real dignity of character he knew to lie in culture. To a small boy he sends, in one of his letters, the message that he should "be a good boy and study hard, as that is the only way to be respected when he is grown." Even in his amusements his mind sought occupation: we find him at night on the diving-bell boat playing chess, and in later years he had become unusually adept at that game.

The wrecking business was full of life and action. Here and there, up and down the river, and into its branches, wherever a boat was wrecked or burned or run aground, the Submarine hurried off to reach the spot before other wreckers. Under their bell the divers got at the engines, boilers, and freight, while the pumps, worked from above, cleared away the sand; and sometimes by means of great chains and derricks the very hull itself would be lifted and towed ashore. But on that huge river, which at times would suddenly rise three feet in a single night, and whose strong current played such giant pranks as turning over a wreck in the chains that were raising it, there was need of eternal vigilance and agility. However, Eads was more on his own ground on the river than on the shore, and his business so increased that he was soon running four diving-bell boats. In 1849 twenty-nine boats were burned at the levee in Saint Louis in one big fire, and most of their remains were removed by him. Winter as well as summer the work went on; and the task of cutting out a vessel wrecked in an ice-gorge, or of raising one from beneath the ice, must have been as trying as walking the river bottom in search of a wreck. Eads himself, years later, thus describes one of his many experiences: "Five miles below Cairo, I searched the river bottom for the wreck of the Neptune, for more than sixty days, and in a distance of three miles. My boat was held by a long anchor line, and was swung from side to side of the channel, over a distance of 500 feet, by side anchor lines, while I walked on the river bottom under the bell across the channel. The boat was then dropped twenty feet farther down stream, and I then walked back again as she was hauled towards the other shore. In this way I walked on the bottom four hours at least, every day (Sundays excepted) during that time." For a day's work the city of Saint Louis gave him \$80, out of which he paid his own workmen. He was so prosperous that, as he wrote to his wife, there was no need for him to join the rush to California to get gold; and his success caused much envy among his rivals. He began to clear the channel of the Mississippi from some of its obstructions and to improve the harbor of Saint Louis.

In 1856 he knew his work so well that he went to Washington and proposed to Congress to remove all the snags and wrecks from the Western rivers,—the Mississippi, the Missouri, the Arkansas, and the Ohio,—and to keep their channels open for a term of years. A bill to that purpose passed the House, but in the Senate it was defeated by Jefferson Davis and others. The next year, on account of poor health, Eads retired from business, but he carried with him a fortune. He had not succeeded in his purpose at Washington, but his name was known there and remembered.

Meanwhile his wife had died, and two years later he had married the widow of a first cousin.

With his second wife he made his first trip to Europe,—the first of very many he was destined to make. In 1857, being thirty-seven years old, he retired, as I have said, from business.

His youthful hopes, the ordinary ambitions of men, were realized. He had been a poor boy: at only thirty-seven he was rich,—very rich for the times and for the place. From his proposals to the government, we may imagine that he now had broader dreams of usefulness. But his first proposition toward river improvement had been checked. He had bought a large house and grounds. He made for himself a rose-arbor, and for four years he was as much unoccupied as his lively mind permitted. He was at any rate what is called a man of leisure.

Then, four years being passed, he received from Washington, from his friend Attorney-General Bates, a letter written three days after the surrender of Fort Sumter, which said: "Be not surprised if you are called here suddenly by telegram. If called, come instantly. In a certain contingency it will be necessary to have the aid of the most thorough knowledge of our Western rivers, and the use of steam on them, and in that event I advised that you should be consulted."

The government was thinking of placing gunboats to occupy and to defend the Western waters.

II

THE GUNBOATS

At the beginning of the Civil War the State of Missouri and the city of Saint Louis were in a very confused condition. A border slave State, Missouri contained a great many persons of Southern birth and Southern sympathies; and besides a good many strong Northern men, Saint Louis had also a considerable German population, all staunch Unionists. But excepting the Germans and one or two dauntless clear-seeing men, who read the future, few persons in either party wished to fight if fighting could possibly be avoided. The governor, a Southern man, while hesitating at actual secession, wished and tried to control the power of the State so that at need it might help the South; and while professing loyalty, he did all he could to prove his disloyalty to the Union. The legislature, however, would not pass a bill to arm the State, thereby, says an historian, causing the South to sustain "a defeat more disastrous to its independence than any which thereafter befell its arms, down to the fall of Vicksburg." In response to Lincoln's call for troops, the governor refused to send any from Missouri. An extraordinary state convention, called in this crisis, voted against secession. Seeing that the governor, notwithstanding this, was covertly aiming at throwing himself and the State, so far as he could, in with the Confederacy, young Frank Blair and General Nathaniel Lyon, carrying things with a high hand, seized and dispersed the state militia encamped in Saint Louis, got control of almost all the Federal arms in the State, and with outside aid and help from the regular army, chased the governor from the capital, and held him at bay long enough for the convention to depose him and the General Assembly, and to establish a state government loyal to the Union.

During all these lively events Saint Louis was in confusion. There were many minds in the town—secessionists, conditional and unconditional unionists, submissionists: some who wanted war, some who wanted only to preserve peace so that they might keep their homes and fortunes safe, even on condition of abandoning slavery.

James B. Eads did not own a slave, nor did he approve of slavery, but among his friends and associates there were many who did own them, and many secessionists. It is curious to observe how little a difference of opinion on these points, that had become so vital, was able to put personal enmity among men who were true friends. Of course, among mere acquaintances there were many instances of bitterness and taunting. Through it all, Eads, with his rare tact and his exquisite manners, steered without collision, offending none of those who were not on his side. And yet we are presently to see what a deep interest his side had for him, and how much he was able and willing to do for it.

Between the election and the inauguration of Lincoln, Eads and three other prominent citizens of Saint Louis wrote a letter to him, expressing their fears that an attempt at secession would be made, and urging the policy of having a secretary of state from one of the slave States. And they recommended, for "purity of character, stern integrity, exalted

patriotism, and enlightened statesmanship," Edward Bates, born in Virginia, married into a South Carolina family, and long resident in Missouri. A first draught of this letter is in Eads's handwriting. When the new cabinet was formed, Bates, a personal friend of Lincoln's as well as of Eads's, was given a position in it, that of attorney-general. It was he who, three days after Sumter was fired on, wrote the letter, already quoted, telling Eads to expect a telegram calling him to Washington for consultation on the best method of defending and occupying the Western rivers. Eads himself was by this time no believer in a defensive policy for the government. After Sumter he had already written to Bates advocating determined and vigorous measures. So, when the telegram soon followed the letter, he was glad to hasten to Washington in order to be of use. There he was introduced to the Secretary and to the Assistant Secretary of the Navy.

The importance of controlling the Mississippi River was well seen by the great strategist, Lincoln, who called it "the backbone of the rebellion"—"the key to the whole situation." If it could be held by the government, the Confederacy could neither move its troops up and down it, nor—thus cut in half—could it bring over from Texas and Arkansas the many men and the quantities of food greatly needed by its armies east of the river. Realizing this, the Confederacy was already beginning to fortify the Mississippi and the Ohio with its branches. To dislodge the rebels Bates proposed a fleet of gunboats. The Secretary of War, however, thinking this idea of gunboats either useless or impracticable, showed at first no interest in the plan. But at the request of the Secretary of the Navy, who realized the importance of the subject, Eads prepared a statement of his views, embodying Bates's project. In it he also suggested, besides the best kind of boats for the service, batteries, to be erected at several points. Commodore Paulding, on reading this statement, at once reported in favor of it. Suddenly, the Secretary of War, when he saw that the scheme was coming to something, claimed jurisdiction over the whole matter, but finally he agreed to order the same officer already appointed for the purpose by the Navy to go west with Eads and purchase vessels to be armed. All necessary approvals having been made, the two went to Cairo, where they examined the Benton, one of the former snag-boat fleet. Afterwards Eads proposed the strong and swift Missouri River steamboats. But neither of these suited his colleague, who at last went to Cincinnati, and buying three boats there, armed them himself: and very useful boats they were.

The gunboat scheme had been first proposed in April; it was now June, and excepting these three wooden boats, nothing seemed to have come of it. So in July the quartermaster-general advertised for bids for ironclad gunboats. In 1861 ironclads were a rather new thing. France and England had a few of them, but at the time the Merrimac was begun no ironclad had been finished in America. On August 5, when the bids were opened, that of Eads was found not only to be the lowest, but to promise the quickest work. On August 7 the contract was signed for seven gunboats to be delivered at Cairo on October 10,—sixty-four days later. This contract, it has been said, would under ordinary circumstances have been thought by most men impossible to fulfill. And the circumstances then were anything but ordinary: it was a time of great financial distress; in the border slave States the pursuits of peace were interrupted; all was in turmoil and confusion; rolling-mills, machine-shops, foundries, forges, and sawmills were all idle, and many of the mechanics had gone to the war. The timber for the boats was still growing in the forests; the iron was not yet manufactured. And so short was the time that two or three factories alone, no matter how well equipped they might be, were not to be depended upon. Yet Eads had undertaken to start up the factories, to gather the materials, and to build his boats in two months. Never were the self-reliance and the energy of the man better exhibited; but his keen business sense might have hesitated, had not his patriotism shown him that the Union needed the boats quickly.

Most of the machine-shops and foundries of Saint Louis were at once set to work night and day; and for hours at a time the telegraph wires to Pittsburg and to Cincinnati were in use. Twenty-one steam-engines and thirty-five boilers were needed. Prepared timber was brought from eight different States, and the first iron plating used in the war was rolled not only in Saint Louis and Cincinnati, but in small towns in Ohio and Kentucky. Within two weeks 4000 men were at work in places miles apart,—working by night and seven days a week. To the workmen on the hulls who should stick to the task till it was done Eads promised a "handsome bonus;" and in this way gratuitously paid out thousands of dollars. The building of this little fleet has been called "a triumph of sagacity, pluck, and executive ability unsurpassed by any exploit in the military or civil history of the times."

To be sure, the seven boats were not finished at the time called for. That they were all launched within a hundred days of the signing of the contract is amazing enough, but if they had been built after designs of Eads's own, so that he would not have been delayed by sudden changes necessitated when he found weaknesses in the plans furnished him, or when the designer changed the specifications, and if the government, harassed and driven as it then was, had been able to pay him according to its part of the contract, there is little doubt that he would have had the vessels finished in time according to his agreement. Even as it was, it was legally decided later that he was not at fault. When he entered into the

contract he was a rich man; and as he was not to receive his first payment from the government for twenty days, probably only a rich man could have had the credit necessary to put so much machinery into motion. As it proved subsequently, the government was so lax in its payment, and demanded work so much more expensive than the specifications called for, that before the work was finished Eads was in a hard way financially. He had been much worried and distracted in obtaining funds: after exhausting his own fortune he had sought the aid of patriotic friends, and it was principally in order to pay them back that he made his appeal to the government. By the terms of his contract he might have delayed the work until his payments were received, and might thus have saved himself great distress and worry, but, as I have said, he realized how much the Union needed the boats. He himself said that it was "of the utmost importance that these boats should be made as effective as possible, without reference to how I was to be affected by delays, ... and that their completion should be pushed with the utmost energy, whether the government failed in its part of the bargain or not." Their rapid completion then was a proof not only of Eads's masterful energy, but of his self-sacrificing patriotism as well. Ultimately he was paid most of the money for the gunboats, and as a result of his patriotism won back the fortune he had risked; but at the time of course it hampered him intolerably to be without funds. He had, besides, other difficulties to contend with. At least one of his sub-contractors or head-workmen was a disappointed bidder for the gunboat contract, and was on a salary which ran till the boats were finished; and while Eads would not mention such a suspicion in public, he suggested in a private letter that this had been an additional cause of delay.

After all, the seven boats had been launched and were ready to be put into commission by Flag-Officer Foote, before he had more than one third of the necessary crews ready for them.

These seven, the Saint Louis (afterwards De Kalb), the Cairo, Carondelet, Cincinnati, Louisville, Mound City, and Pittsburg, were all alike. The Saint Louis, as Eads wrote to Lincoln, when he sent him a photograph of her, "was the first ironclad built in America.... She was the first armored vessel against which the *fire of a hostile battery* was directed on this continent; and, so far as I can ascertain, she was the first ironclad that ever *engaged a naval force* in the world." In reading the descriptions of them, and in reading in the naval histories of their undeniable faults, it must be remembered that Eads "had no part in the modeling of these boats, and is therefore relieved of all responsibility as to their imperfections." They were 175 feet long, 51½ feet beam. Their flat sides sloped upward and inward at an angle of about 35°, and the front and rear casemates corresponded with the sides, the stern-wheel being entirely covered by the rear casemate. It was a large paddle-wheel, placed forward of the stern so as to be protected. The whole thing was like a tremendous uncovered box, with its sides sloping up and in, and containing the battery, the machinery, and the paddle-wheel, while the smoke-stacks and the conical pilot-house stuck up out of the top. Captain Mahan says that they looked like gigantic turtles. Underneath the water, they were simply like flat-bottomed scows. As they were intended always to fight bows on, they were built with that in view. In front they were accordingly armored two and a half inches over two feet of solid oak. The only other armor they carried was abreast of the boiler and engines. The stern, therefore, and the greater part of the sides were decidedly vulnerable. Their armament consisted of three guns forward, four on each broadside, and two at the stern.

When Eads was given a chance to alter a boat from his own designs, he made it a much better one than these. It was a boat ordered by General Fremont in September, 1861, in excess of the government appropriation for the river fleet. This was the same snag-boat which three months before had been suggested for alteration by Eads, and refused by the army's agent. In this case, as in so many afterwards when Eads knew himself to be right, he stuck persistently to his own opinion; and out of the heavy old boat, despised and objected to by so many persons, he fashioned the "old war-horse," the Benton, which, slow as she was, Spears, the naval historian, calls the most powerful warship afloat at that date. As a snag-boat, formerly used by Eads, she had "had two hulls so joined and strengthened that she could get the largest kind of a cottonwood tree between them, hoist it out of the mud, and drag it clear of the channel." These hulls were now joined together; and while the boat was armored on the same general plan as the seven contract gunboats, she was so much more completely iron clad as to avoid the danger that they were exposed to of having their boilers burst and great damage and death caused thereby. Her tonnage was twice that of the others; her size about 200 by 75 feet. She was entirely iron clad. In her gun-deck casemate the twenty inches of timber under the plating had "its grain running up from the water instead of horizontally, by which means [wrote Eads] a ball will strike, as it were, *with the grain*, and then be more readily deflected. On the same principle that a minie ball will penetrate five inches of oak, crossing the grain, while it will not enter one inch if fired at the end of the timber." This detail illustrates the care and interest with which Eads built his boats.

The eight of them, Captain Mahan says, "formed the backbone of the river fleet throughout the war," and "may be fairly called the ships of the line of battle on the Western waters." He

speaks also of their "very important services." This is milder praise than has been given them. Commander Stembel said that he had heard them called equal to 5000 men each; Boynton, the naval historian, goes so far as to say that the permanent occupation of the South was rendered possible by the ironclad navy of the Western waters. Though the naval battles in the Atlantic were perhaps more brilliant, he says, none, unless that between the Merrimac and the Monitor, had more important results. Eads has been called as potent as a great general in clearing the upper Mississippi. He did not, to be sure, build the entire gunboat fleet, but he did build, as Captain Mahan says, the backbone of it; and that the praises for that fleet, which I have quoted, are not altogether extravagant, is further shown by the comments of Mr. John Fiske. He says, "While it was seldom that they ["these formidable gunboats"] could capture fortified places without the aid of a land force, at the same time this combination of strength with speed made them an auxiliary without which the greater operations of the war could hardly have been undertaken."

These eight boats figured in many a fight on the great river and its branches. They "were ever where danger was." A month and more before the Merrimac and the Monitor were finished, the important capture of Fort Henry "was a victory exclusively for the gunboats." It was the Carondelet that ran the gauntlet past Island Number 10, a feat as full of romance and daring as any that the Civil War tells us of. And these things were done with vessels still unpaid for and the personal property of their builder. Their usefulness was a great satisfaction to Eads, and he rejoiced, as he wrote to Foote, with "the prideful pleasure of the poor armorer who forged the sword that in gallant hands struck down the foe."

When the Benton left her dock for Cairo, Foote requested Eads to see her there in safety. Eads, who was so deeply interested in his boats that on another occasion he was narrowly prevented from going into action with one of them, gladly agreed. Before long the Benton grounded. As Eads was merely a guest, and as there were naval officers aboard, he did not feel called upon to interfere with any suggestions. But after the officers and crew had labored all night trying to float her, then with his aptitude for emergencies he used his scientific knowledge to suggest another scheme. The captain at once gave him leave to command the entire crew, and by means of hawsers tied to trees ashore and then strongly tightened, the vessel was floated. In this case the old river man knew more than the naval officers.

In April, 1862, the Navy Department called Eads to Washington to make designs for more ironclads,—or rather boats made wholly of iron. These were to be of very light draught and turreted. He submitted plans for boats drawing five feet. The department insisted on lighter draught, but still on heavy plating. So he revised his designs once, and then once more. Finally the draught was reduced to only three and a half feet. Eads has himself described his going back to his room in the hotel, and in a few hours making over his designs. When these boats were finished they were found to draw even less than had been contracted for, so that extra armor was ordered for them, and three of them exceeded the contract speed. At first two boats were ordered, later four others. For the turrets Eads submitted designs of his own, but as it was then only a month after the Monitor's fight, Ericsson's turrets were insisted on for the first two boats, although modifications were allowed. As the other four had two turrets each, Eads was allowed on two of them to try one turret of his own, with the guns worked by steam, on condition of replacing them at his own cost with Ericsson's in case of failure. This was the first manipulation of heavy artillery by steam. The guns were fired every forty-five seconds, or seven times as fast as in Ericsson's turrets.

In addition to the fourteen gunboats, Eads also converted seven transports into musket-proof "tinclads," and built four mortarboats. "Such men," says Boynton, "deserve a place in history by the side of those who fought our battles."

The career of some of the gunboats subsequent to the war is interesting. In 1880 the Chickasaw and the Winnebago, which were two of the six iron boats, and both of which took part in the naval campaign at Mobile, had come into the hands of Peru; and old as they were, they were used very effectively against some of the larger and more modern boats of the Chileans.

During those trying war times all of Eads's tremendous energy had by no means been exhausted by the gunboats. In more ways than one he had been showing himself a good citizen and a kind-hearted man. Much as his fortune had been drained by the boats, he still found money to give to the sufferers in the war. Out of a belated partial payment on the Benton he at once sent money to Foote for use in relief work, and with characteristic persistence he sent several letters and telegrams to make sure of the money's arriving. A month or so later he sent a check from Washington to Saint Louis to the Sanitary Commission, asking that its receipt might not be made public. In the letter sent with this he speaks of the war as "an accursed contest between brothers," but adds that the "cause is most worthy of the sacrifice." From the niece of the Secretary of the Navy we also find a letter of acknowledgment of money to be used in relief. But it was not only to the soldiers that he showed his tenderness: to Foote, the gallant "Christian commander" of his fleet, he sent various friendly gifts when that brave man lay dying,—grapes from his own vines, a

portrait he had had painted of his friend. And even to those on the other side he showed an unusual consideration. Towards the end of the war there seemed to be no means of feeding the many refugees in Saint Louis but by levying a tax upon Southern sympathizers. Eads, who foresaw what bitterness such a course would produce, offered, in the name of a bank in which he was a director, \$1000 to start a subscription to be used instead, and the invidious assessment was never levied again.

To his personal friends he was always generous and thoughtful, sending them many presents, defending them from misrepresentation, and helping them in their chosen careers. By means of his influence and tact he procured the release of an indiscreet person who had talked himself into McDowell's College prison as a suspected enemy to the government. Giving to others seemed a trait in Eads's character which afforded him an intense pleasure; and though a man of great dignity, he used with his intimate friends a charming playfulness and affection. He could be extremely mild in correcting faults; and while he was inclined to bear with others, he could be stern. His manners were rather those one expects in a European gentleman of leisure and high breeding, than in a former steamboat clerk and a man who had worked hard most of his life. His hospitality was princely. In his large house in the suburbs of Saint Louis he received not only the young friends of his five daughters and his own friends, but also officers of the river fleet and of the army, officers sent west on inspection duty, and foreign officers following the course of the war and of the improvements in gunboat building.

His mind was as active as his heart was generous, and the course of his life mirrored that activity. Now he was at home, now in Washington, now at Cairo visiting the gunboats to see how they worked under fire. In Washington he was busy with plans and projects. An intimate associate said of him in his later life that he was always inventing some new gun or gun-carriage; and we may be sure that if he ever was doing so, he was in those war times. Besides inventing his own, he was also busy examining Ericsson's inventions, in making improvements on them, in applying steam in novel ways to the working of artillery and to the rotating and raising of turrets; in sending models of his inventions here and there, at home and abroad, to Germany, where the Prussian minister, a friend with whom he often dined, "wished they could get some of his boats on the Rhine;" having his turrets explained at a Russian dinner in New York or Washington; and receiving from the Navy Department an appointment as special agent to visit the navy yards in Europe. At home he was just as busy. With his house so full of company, he nevertheless found time somewhere for solid reading apart from his work—the Attorney-General sent him Cicero's letters, and he lent the Attorney-General King Alfred's works. There is a curious interest in knowing what two men so engrossed, and upon such necessary duties, were reading at such a time. While he was building the second batch of gunboats, he wrote to Bates in a personal letter that he believed he had the most complete and convenient works in the country for iron boat-building; that there and in other places he had as many as seventy blacksmith fires at work for him, and that his men were all sheltered from sun and rain. After those boats were finished, he went on planning others, and we have a letter from Farragut in which the admiral asks if some of them are not for his use at Mobile.

Eads, by this period in his strenuous life, knew a great many men, all of whom he treated with a uniform dignity and courtesy, even when they were unfriendly, and a few of whom he was on the most intimate terms with. Among all of them he was admired; perhaps already he was as prominent a citizen as there was in Saint Louis, and as it was still in the good old times when the mayoralty there was a high honor to the best men, it was suggested to him that he hold the office. Nor was this the first honor offered to be thrust upon him; early in the war Bates had wanted him appointed commissary of subsistence at Saint Louis, and though it was unusual to appoint a civilian to that position, Lincoln had been willing to do it to oblige Bates,—but Eads had not wished it. More than a year later he was given a commission of lieutenant-colonel by the governor, but he was never sworn in. Like all men in those troublous times, he took a peculiar interest in politics; and on being asked privately in a joint letter from the editors of three Saint Louis papers (two of them German) exactly what his politics were, he replied that he was as strongly in favor of emancipation as he was opposed to slavery, and that he believed in no "kid-glove policy;" but he remarked incidentally that if he were to be offered the mayoralty he should refuse it.

His work was for the whole country. While he was still too much engrossed with his turrets and his plans for new boats, he fell very ill. Indeed there can be no question that he sacrificed his health to build the gunboats. Never very robust, he was now so ill that eight doctors gave him up. His indomitable spirit pulled him through, but he was ordered away from his workshop to Europe, he and his family. His overburden of labor had crushed him,—before this his eyes had been tired out. Bates charged him to take care of himself; "the country can't spare you," he said "and I can't spare you."

Unless Bates was a prophet, we may well think the first of these statements unduly strong. To be sure, when in a crucial moment the gunboats were needed, and needed quickly, Eads's unparalleled haste in building them certainly did an inestimable service to the

country. But so far in his career,—and he was over forty,—while he had shown a marked inventive talent, he had not as yet made clear his signal genius for engineering. And although he had exhibited wonderful executive ability and such true patriotism as made him a valued citizen, he had still to render himself indispensable to the development of the nation.

III

THE BRIDGE

Eads was bred to the Mississippi. He had mastered its secrets by hard experience; he had worked in successful opposition to its great wayward forces. But he was not to be content till he had tamed it, till he had saddled it, and, wild as it will always be, had made it nevertheless subservient to him. To his quietly stubborn spirit there was a delightful invigoration in using his brain to conquer the brute force of this capricious monster. For the river is the grandest power between our two oceans. Niagara is more sublime; but Niagara is constant, and therefore its immense strength has been easily set to a task. The Mississippi is so irregular that one tends unconsciously to personify it by calling it tricky. To find the causes of its sudden changes one must go back hundreds of miles to the mountains east and west. Seeming to delight in destruction, it tears down or eats away the checks that are put upon it. Only a mind never discouraged, a mind capable of discovering and comprehending the laws that after all underlie the apparently blind and brutal jests of this untiring giant, can, by the use of those very laws, tame it. And such a mind Eads had. "That everlasting brain of yours will wear out three bodies," said one friend.

Though indeed his body was strong, with iron muscles and a fierce nervous energy, yet it was not a big body, and his health was weak. Again and again he worked beyond his strength, and only on the absolute order of his doctors would he go away from his work and rest. But he could not entirely rest. His brain would work. In his health tours to Europe he was always open to new ideas, always studying new methods to carry back to his task. "Your recreation," some one wrote him, "is Monitor discussions with Captain Ericsson." Another recreation was chess. Had he not elected to be the leading engineer of his day, he might have been the chess champion. This game, never one for the slothful and unthinking, he made even more exacting than usual. He would play several games at the same time; or, without seeing the board which his opponent used, he would carry the game in his head. Though it was his nature not to like to be beaten, yet he was as kindly as he was set in his purpose; and it was also his nature to take defeat gracefully: defeat seldom came. "Never let even a pawn be taken," he gave me, a small boy, as a rule for the game. Even in little things he liked thoroughness,—a capacity for painstaking which is, I think, characteristic of the "thoroughbred."

His appearance showed his traits. Not tall, and rather slight, he was always dignified. His wide and thin-lipped mouth shut so emphatically that it made plain his intention to do, in spite of all, what he believed could and should be done. Some one said that it was a hundred horse-power mouth. It admitted no trifling. When it spoke seriously, it spoke finally. But his eyes, with their merry twinkle, showed that he could also speak humorously. He was indeed a famous story-teller, fond of all sorts of riddles and jests, and remembering all of them he heard. He used often to point his arguments with an anecdote, always a fresh one. Believing with Lamb that a man should enjoy his own stories, he would laugh at his in a most infectious way, till he was red in the face. Indeed, he was the larger half of his stories. His face was thoughtful and stern. Though he seldom found fault, he never did more than once; but he was by no means violent. His mildness was more forcible than anger. He wore a full beard, but no mustache, thus exhibiting his long, determined lip. At forty he was already bald, and after he was sixty he always wore indoors a black skull-cap. Scrupulously cleanly, in his dress he was point-device. Without the least ostentation, his clothes were invariably faultless. From young manhood he had thought that it is due to one's self and to one's friends to look one's best; and he had also realized the practical value of a good appearance. Often impressing this on his wife and daughters, he would have them at all times well dressed. Really he seems to have been a point too precise. He was just the opposite to those geniuses whose great brain shows itself by a sloppy exterior. Eads was never sloppy, even at home.

His great brain showed itself in its restless activity, in its grasp of laws and of details, in its fight to help and to better the country and the world. For it was not only the lusty pleasure

of battling with Nature that made him long for another struggle with the Mississippi: he saw the value there was in it to commerce and to civilization. Before the war he had long contended with stubborn currents, and with ice, and by his energy and his talent for inventing new devices he had become the most successful wrecker on the river. Abandoning the peaceful but lively triumphs of snatching hulls and cargoes from the maw of the stream, he had offered the government to cleanse its course and thereby to increase its safety and usefulness. In war times, owing to his knowledge of the waterways and of science, he had been able to build, with a speed fairly romantic, a gunboat fleet to patrol the Mississippi. Already now greater schemes for improving this central highway of our country were in his mind, but as yet the fullness of the time was not come. Still, he was no longer merely the careful son and father striving to protect his beloved ones and with no dreams of broader duties; he was no longer contented with rose-arbors for an occupation. The grim war had roused him; his years of rest were over; he was the well-known boat-builder,—engineer, perhaps some persons already called him,—and his mind was teeming with schemes of helpfulness. Yet his ambition was not for fame, but to do in the perfect way the work that only he could do.

In 1867 a grand convention for the improvement of the Mississippi and its tributaries met in Saint Louis. Even then people were beginning to see vaguely that the Mississippi Valley is destined to be the ruling section of the country. Eads in his speech showed that he foresaw it plainly. He urged the convention to persuade the government to take steps to improve the river; showing that for less money than was paid by the river boats in three years for insurance against obstructions, those obstructions could be removed. There was not one of them, he said, that engineering skill and cunning could not master.

Two years later he urged upon the commercial convention at New Orleans by letter the importance of introducing iron boats on the Mississippi; saying that it was the fault of the tariff on iron that the saving they would effect was not taken note of. Thirty years later this scheme has again been brought up. Perhaps Eads was before his time in advocating it. But it shows how he had the interests of commerce at heart.

His convention speech is a good sample of his style. He was so painstaking that even in private letters he would insert words and change sentences and sometimes rewrite. There are first draughts with excisions of whole half pages, for he sought conciseness. He sought also a certain rhythm or grace or forcefulness, it is hard to tell exactly what, since in his letters it often resulted in a rather self-conscious formality or a stiff playfulness, and in his speeches in a prettiness or a floweriness of style. He sought too carefully. Probably in delivery the speeches sounded better than we should imagine. In reading them, they seem florid. That was, however, the favorite style of the time. And while, by overdoing it, he often seems to lose force, he is almost always clear and always entirely logical. In contrast to his speeches his professional reports are models: simple and complete, written not faultlessly perhaps, but with a limpidity which makes one interested even in dry technical details. One of his most marked talents, often noted, was the ability to explain an abstruse subject so that it would be quite clear to anybody. And this he did nearly as well in writing as by word of mouth.

He thus made clear his remarkable plans for the bridge; for in 1867 the long talked of bridge at Saint Louis was at last begun.

In 1833, when Eads had arrived at the town, it had about 10,000 inhabitants. Though already seventy years old, it had not advanced very far beyond its original state of a French trading-post. With the introduction of steam and the waking up of the country, the growth of Saint Louis was rapid. In 1867 it had about 100,000 people. Despite a commanding situation, it could be seen that a struggle would have to be made for it to maintain the leadership among the river towns. As early as 1839 there had been a project for a highway bridge; and we are told that "the city fathers stood aghast" at an estimated cost of \$736,600. In the following years there were several more abortive schemes for bridging, one of which, it is even said, would have been carried out, had not its projector died. Perhaps it is as well that he never lived to try it, for until Eads no one seems to have realized how enormous the undertaking was. Probably few others, realizing it, would have dared to go on.

In the winter of 1865-66 a bill was brought up in Congress to authorize the bridging of the Mississippi at Saint Louis. Dependence on ferries had become intolerable to the people, and often when the river was frozen even the ferries were blocked. A bridge was felt to be absolutely indispensable. However, the antagonism of rival commercial routes was so powerful that the bill was allowed to pass only after it had been so amended that it was supposed to require an impracticability. It declared that the central span of the contemplated bridge must be no less than 500 feet long, nor its elevation above the city directrix less than fifty feet. It was said at the time "that the genius did not exist in the country capable of erecting such a structure."

Still, a span of over 500 feet had been built in Holland; and the fact that there was not a total doubt as to the practicability of doing as well in the Mississippi Valley is shown by the

inauguration of two rival bridge companies about a year after the passage of the bill. One of these, which was located in Illinois, after calling a convention of engineers, who considered the question for ten days, without an examination of Eads's plans, adopted a plan for a truss bridge. The other, the Saint Louis company, from the first had Eads as its chief engineer. For another year there was a sharp contest carried on between these two companies, confined, however, principally to the courts and the newspapers, until finally the Illinois company sold out to the Saint Louis company. Had the truss bridge been built, there is no knowing how long it might have stood, for the engineer who designed it did not arrange to base the foundations on the bed-rock of the river. Afterwards it was shown how necessary it was to do this; but at the time many people thought it quite superfluous, and on that, as well as on many other points, Eads met with opposition.

In every case it turned out that he had been right. No one else knew so well as he the immense power and the waywardness of the Mississippi. Good engineers supposed that the greatest imaginable scour at the river bottom in extreme high water would not remove over twenty-two feet of sand, and it was believed that there were perhaps one hundred feet of it along the east shore. But Eads had been sixty-five feet below the river's surface at Cairo, and there he had found the river bottom to be a moving mass at least three feet deep; and in cutting through the frozen river to liberate his diving-bell boats, he had found that the floating ice which goes underneath solid ice, as well as the rising or "backing-up" of the water above ice-gorges, forces the undercurrents lower than even a flood does; and he had found on cutting a wreck out of the ice that she had been held up by the gorged ice underneath her, which must therefore have been packed to the bottom. Knowing all this and much more about what goes on under the turbid surface of the river, he did not doubt that even beneath 100 feet of sand the bed-rock might at times be laid bare, and he was absolutely convinced that his bridge must be founded on it.

Moreover, he saw that on account of the exceptional force of the current in its rather narrow bed at Saint Louis, the masonry piers of his bridge must be made unusually big and strong to withstand it. Since they must be so big and sunk so very deep, it was evident that they would be so costly that the fewer there need be of them the better. The central span was required to be 500 feet; with three spans about that length the river could be crossed, and three spans would require only four piers. Steel trusses 500 feet long would have to be made extremely heavy; but Eads showed that a steel arch the same length, while quite as strong, would be lighter and consequently much cheaper. When his opponents objected that there was no engineering precedent for such spans, while he pointed out their mistake, at the same time he expressed his conviction that engineering precedents had nothing to do with the question of length of span; that it was altogether a money question. Therefore, since the cheapest method was to be carefully sought, he determined upon arches,—two abutment piers, two river piers, and three arches of respectively 502, 520, and 502 feet long.

There were many opponents to this plan; some of them people who would have opposed any bridge, as, for example, the ferry and the transfer companies. To his own company he explained away every objection that came up, as he was bound to do, in view of their confidence in him. He made the clearest of explanations of the theories involved; and even such absurd predictions as that his superstructure would crush his huge stone piers, he took the trouble to blast sarcastically. To an engineering journal he wrote three letters correcting mistakes in its accounts of his work. But he seems to have wasted little of his energy in arguing with the newspaper public. It was a question only of time till everybody should be convinced.

The most extraordinary care and pains were expended in every direction. The stone, granite, and steel were both hunted up and tested by experts, and by machines specially devised in the bridge works, though not by Eads himself. For his assistants he chose men who were of real ability and well trained, and to them he invariably gave great credit for their part in the work. The plans, after being figured out in detail by them, were gone over by the mathematician Chauvenet, then chancellor of Washington University, who found not one single error in them. Most of the big work, such as the masonry and steel, was given out on contract; and, as was natural, delays by the contractors often greatly delayed the progress of the bridge. The whole work occupied seven years.

While Eads had promised the company to prove by careful experiment, so far as was possible, everything connected with the bridge that had not already been fully demonstrated in practice, he did not pretend that in his main outlines he was without some examples. It was in his development of known ideas and his expedients for simplification that his genius perhaps most strikingly showed itself. Again and again he contrived some device so simple that, like a great many strokes of genius, it seemed that anybody should have thought of it. The massive piers were sunk to the bed-rock by means of metal caissons. These were adapted in design from some he had seen in use in France, and had examined during a trip his doctors ordered him to make in 1868. Eads himself compared them to inverted pans. They were open at the bottom, but perfectly air-tight everywhere else. They had several important features which were entirely original. Such caissons, sunk to the bottom, have the

masonry of the pier built on top of them even while they are sinking; and workmen inside them keep removing the sand from underneath, and throwing it under the mouths of pipes which suck it up to the surface of the river. Evidently the caissons must be filled with compressed air to equalize the external pressure, which is constantly increasing as ever deeper water is reached; they must also have an opening connecting with the surface; and to admit of passing from the ordinary atmosphere to the denser one, there must be an air-lock. Before this bridge was built, the air-lock had always been placed at the top of the entrance shaft, where, as the caisson sank and the shaft was lengthened, it had to be constantly moved up. Eads placed it in the air-chamber of the caisson itself, where it never had to be moved; and thus, as the shaft was not filled with compressed air, less was needed, and there was less danger of leaks. Another of his useful innovations was to build his shaft of wood, and another was to put a spiral stairway into it. Indeed, in the last pier he put an elevator into the shaft. Moreover, he was the first person to run his pipes for discharging the sand, not through the shaft, but through the masonry itself; and he invented a very simple and effectual new sand-pump, which was worked by natural forces without machinery. All these improvements and various others seem to have been thought of so easily, that we are inclined to wonder why clumsier methods had ever been in use. He described them all in his reports and his letters about the bridge in a style which is not only clear but actually fascinating even to a person who has scant scientific knowledge or taste.

One of the piers was sunk 110 feet below the surface of the river, through ninety feet of gravel and sand. Eads's theories were justified by finding the bed-rock so smooth and water-worn as to show that at times it had been uncovered. This was the deepest submarine work that had ever been done, and Eads tells us in his reports many interesting experiments he made in the air-chambers. In their dense atmosphere a candle when blown out would at once light again. This was before the days of electric lighting; otherwise we may be sure that that would have been used, as so many other modern inventions were. For the first time in any such work, the last pier sunk had telegraphic communications with the offices on shore; which must have been comforting to workmen starting out to their labor in the dead of winter with two weeks' provisions. The dense air of the chambers caused not only discomfort to the ears, but also in the case of some of the workmen a partial paralysis. There was no previous experience to go by, but every precaution seen to be necessary was taken; the hours of work were made very short, the elevator was provided, medical attendance and hospital care were given free. After the first disasters no man was allowed to work in the air-chambers without a doctor's permit. And it is known that in helping the sufferers with his private means, Eads was as charitable as ever. Out of 352 men employed in the various air-chambers, 12 died. Eads, with his wonted generosity of praise, printed in his yearly report the names of all the men who worked in the deepest pier from its beginning till it touched bed-rock. It is interesting to note in passing that of all the workmen in the blacksmith's yard only the head smith himself could lift a greater weight than the designer of the bridge.

The superstructure consisted mainly of three steel arches, by far the longest that had ever been constructed; the first to dispense with spandrel bracing; and the first to be built of cast-steel. The "Encyclopædia Britannica" called them "the finest example of a metal arch yet erected." They were built out from the piers from both ends to meet in the middle; and were put into place entirely without staging from below,—once again, the first instance of such a proceeding. All the necessary working platforms and machinery were suspended from temporary towers built on the piers; and thus while the arches were being put up, navigation below was not interfered with. This throwing across of the 500-foot arches without the use of false works has been ranked with the sinking of the piers "through a hundred feet of shifting quicksands," as producing "some of the most difficult problems ever attempted by an engineer." One problem, caused by the fault of the contractors, presented itself when they came to insert the central tubes to close the arches. The tubes were found to be two and a half inches too long to go in, although they would be only the required length when they were in. It was left for Eads to insert them. Shortening them would of course have lowered the arch. Eads, who was just starting for London on financial business of the bridge, cut the tubes in half, joining them by a plug with a right and left screw. Then he cut off their ends, for the plug would make them any required length by inserting or withdrawing the screws a little. Then he went away. As it would have been much cheaper not to use this device, his assistants tried for hours to shrink the tubing by ice applications, and thus to get the arches closed; and there is a popular tradition in Saint Louis that they succeeded; but it was excessively hot weather, and they did not succeed. The screw-plug tubes, of course, were easily put in. Any part of this steel work can be at any time safely removed and replaced,—another structural feature original in this bridge.

Although Eads took care to protect his special innovations by patent, he was most willing to explain them with care to other engineers and to have others profit by his improvements; and several of the mechanical novelties of his bridge are now in the commonest use, and have been taken advantage of even in such famous structures as the Brooklyn Bridge.

During the building of the bridge Eads spent many months in enforced absence, but while in Europe he always had his labor in mind, and, as I have said, brought home from France one

of his most useful appliances. During his absence he left absolutely trustworthy and efficient engineers in charge of the work, and before leaving home he provided for accidents that might occur. So much work was done in the winter that great barriers had to be built to keep it clear of floating ice. One curious detail connected with the bridge is that the Milwaukee, one of the double-turreted gunboats which Eads had built from his own plans, and which had been with Farragut at Mobile, was bought now from a wrecking company, and her iron hull used in making the caissons; so that her usefulness still continued in peace as in war.

It has been said of Eads that he grappled with great problems in engineering, and solved them as easily as a boy subtracts two from six. While this is true, it must not be forgotten that he had not the school-training of an engineer. Nothing is more untrue than the statement that he was, like de Lesseps, only a contractor. He was a very unusually brilliant engineer, and his ignorance of the higher mathematics served to show his brilliancy the more clearly. Some persons have said that his chief talent was in explaining abstruse reasonings simply; but an engineer has told me that he thought Eads's chief talent was his ability to arrive by some rough means at a certain conclusion to a given problem, which conclusion would in every instance be approximately the same that better trained mathematicians would reach by mathematics.

By the time the bridge was finished, indeed from the time (1868) when his first report for it made a decided stir in the scientific world, both at home and abroad, Eads was a very well-known engineer. In that same year a visit to Europe for his health's sake gave him the opportunity to interview a French steel company, through whom he met a famous bridge-builder, and was led to examine the piers of the bridge then being constructed at Vichy; and it was there that he found his new ideas for caissons. Going home, by way of England, he explained his plans to the engineers there, and was by them proposed as a member of the Royal Society. Even at home, in his own adopted State, he was not without recognition; for in 1872 the University of Missouri conferred upon him the honorary degree of LL.D. From the general of engineers he received a request for suggestions for improvements in guns; and from his work on the subject of Naval Defenses it is plain that his mind still found time to run on this favorite topic.

In 1874 the bridge was finished. After it had satisfactorily stood the severe tests put upon it, it was formally opened on the 4th of July. The celebrations of that day were the first public outburst of approval given to Eads's work. And to-day the strong and graceful bridge stands as his most beautiful and lasting monument. And as even the great tornado of 1896 was unable to do the piers any serious damage, they are likely to last indefinitely, and thus make the bridge "endure," as its builder said, "as long as it is useful to man."

To Saint Louis it has been so useful that while on the one hand the growth of the city was the cause of its being built, on the other it has been one great cause of the continued growth and prosperity of the city. But it had even broader results than that. "It made a radical change in the conditions of transportation East and West, and it made possible the Memphis bridge and the future New Orleans bridge."

And in another direction yet it is peculiarly important. In bridge-building it marks an era, not only because of its strength and beauty and the daring of its design, but also because of its many labor-saving devices, the inventions of a thoroughly practical mind. A distinguished engineer calls it "a great pioneer in the art of sinking deep foundations and building spans over wide stretches of space, that astonished in its construction the entire civilized world." London "Engineering" chose it, while building, as preëminently the "most highly developed type of bridge;" and says, "In that work the alliance between the theorist and the practical man is complete." In Eads it finds its long-sighed-for dream, combining the highest powers of modern analysis with the ingenuity of the builder.

IV

THE JETTIES

The Mississippi River is a great antimonopolist. As more and more railways have been built it has been less and less used. And yet, because it drains almost every corner of a valley which comprises over one third of the whole United States, it affords means of transportation to an immense area; and since it cannot be controlled by any one company or group of companies, its freight rates can hardly be arbitrarily fixed. Still, so long as there

are impediments to its free navigation in the shape of floods and bars, it cannot be depended on for shipping, and the magnificent opportunities it should offer to commerce are lessened. The vastest river system in the world, it shows in its various parts great contrasts. One large tributary flowing from the Alleghanies, one from the Rockies, one from the north, others from the southwestern plains, are each able to contribute their various products of grain, lumber, cattle, cotton, fruits, and so on. Some branches freeze every winter; others never do. Some are clear, others silt-bearing. From about Cairo it flows southward through the greater delta, or land built up by its own action in ages past, and in all this part of its course both banks and bottom are of yielding alluvion. For some hundreds of miles "the crookedest of great rivers," it varies frequently in width and velocity and is full of shoals; then for hundreds more, though uniform in width, it often rises higher than its shores, and is confined in artificial levees, which it continually breaks down. Finally, below New Orleans, growing more sluggish, and dividing into several mouths, or "passes," it wanders through tracts of waste marsh-lands into the gulf, which it colors brown for miles around. Blocking the end of each shallow mouth there was formerly a sand-bar; and these obstructions to navigation were the despair of the river commerce, and no less the despair of the government in its attempts to remove them.

Every one interested in trade or shipping realized what a very serious hindrance to the usefulness of the Mississippi these choked-up mouths were, but no one realized it better than Eads. Understanding that the great valley is capable of supporting 400,000,000 people, and intent on doing all in his power for good, even before he had completed the bridge he was studying the problem of opening the river. Its improvement and the welfare of its millions of people were cherished objects of his life. For some men one great undertaking at a time is enough, but Eads's energies were such that his works overlapped one another. It is hard to see how one man can have time, even if he has brains, to do all he did. But apparently he never lived an idle day. The bridge, with its many extraordinary solutions of new problems, made its builder's permanent reputation. At the particular request of West Point he had supplied that institution with writings, diagrams, and models. And so far afield had his fame spread that on one of his many trips abroad, he made plans, at the request of the Sultan's grand vizier, for an iron bridge over the Bosphorus. A change in viziers, however, prevented its being built.

It seems as if the river-mouth problem had not always been so difficult. Still, Eads showed that the bars were inevitable; and it is probably only because, with the growing population and trade of the central States, the need for an outlet was greater, that the problem seemed more complicated. Moreover, ocean vessels were increasing in size and draught, which also made an adequate channel more desirable. Although the blockade had forced the construction of several expensive lines of railway, yet it was impossible to carry all the products of the valley by rail. Millions of dollars' worth of merchandise were delayed at the bars. As early as 1726 attempts had been made to deepen the channels through the river's mouths by harrowing. But the first government effort was in 1837, when an appropriation was made for a survey and for dredging with buckets. Again in 1852 another appropriation was made; and a board, appointed by the War Department, recommended,—

1. Stirring up the bottom.
2. Dredging.
3. If both these methods failed, the construction of parallel jetties "five miles in length, at the mouth of the South West Pass, to be extended into the gulf annually, as experience should show to be necessary."
4. "Should it then be needed, the lateral outlets should be closed."
5. Should all these fail, a ship canal might be made.

Dredging by stirring the bottom was tried, and produced a depth of eighteen feet. Three years later this depth had entirely disappeared. In 1856 an appropriation was entered into, but the jetties were never completed. Later than that dredging was tried again. Up to 1875 more than eighteen feet of depth had never been obtained, and even that could not be steadily preserved. Channels, opened in low water, were quickly filled up with sediment in high water, and sometimes a severe storm would wash in enough sand from the gulf to undo the result of months of dredging.

As early as 1832 a ship canal near Fort Saint Philip, which should cut through the river bank out to the gulf, had been planned, and this solution had been approved of by the Louisiana legislature. That idea had been revived from time to time. And there had also more than once been new recommendations made for jetties, which by narrowing the channel should deepen it. Finally Congress ordered surveys and plans for the canal, and then appointed a board not only to report on them, but also to ascertain the feasibility of improving the channel of one of the natural outlets of the river. In 1874 this board reported in favor of the canal, and against the idea of jetties, which, in its opinion, could hardly be built, could not be maintained, and would be excessively costly.

This, then, was the situation when Eads appeared on the scene: "scratching and scraping" were going on in South West Pass, but were doing little real and no lasting good; the government engineers had declared themselves in favor of a canal; and though in some quarters jetties had been advocated, scarcely any one thought they could be built, or that if they were they would last, or that they would do any good. Eads, however, understood the river like a book, and he had studied this particular subject. He now came forward publicly, offering not only to build and to maintain jetties which would insure a twenty-eight foot channel, but to do all this for less than half the cost the board had estimated, and on a contract which should provide for his being paid only in case he succeeded. From this remarkable offer his own confidence in his plans may be inferred. A purpose which he had reasoned out as practical became an inspiration to him which nothing could shake, for his courage equaled his convictions.

But so bold was his proposition that he was considered a wild enthusiast. Never at a loss to solve any problem, again, as when he planned the bridge, he undertook to do what was commonly held to be impossible. Of course, all the backers of the canal scheme opposed him bitterly. New Orleans was of that faction. Saint Louis, on the other hand, upheld him because of his personal popularity and his signal success with the bridge. The army engineers were against him as a civil engineer. Thus the controversy was sectional, personal, and professional. Up to this time the government had invariably intrusted all works of river and harbor improvement to the military engineers; and to hand over the most important one it had ever undertaken to a private citizen, and to permit him to apply a method that had just been condemned in a report signed by six out of seven of the most distinguished army engineers, met with decided opposition. So the government hesitated. Certainly this was a proposal to make them consider, promising, as it did, an open river mouth, at a cost much lower than that of the canal, and in case of failure leaving the total loss to fall upon the contractor. Besides, several eminent civil engineers supported Eads's theory. The House, nevertheless, passed the canal bill; but the Senate, more thorough, after calling Eads and two of his principal opponents to state their views before a committee, passed a bill appointing a commission to reconsider the entire subject once more. The discussion before the Senate committee was one of the crises in Eads's life. The fate of the jetty enterprise hung on the outcome of it. Fortunately for himself and for the good of the country, he was a most magnetic and persuasive man. His theories and arguments were sound and logical, his experience of the river was vast; and beyond his aptitude for making technical reasoning simple and clear, his skill as a diplomatist was equal to his ability as an engineer.

So the commission was appointed; and, ultimately, on account of the far-reaching importance of the question of river-mouth improvement, its members decided to go to Europe to inquire into the matter. About the same time, and for the same purpose, Eads also went abroad, and while there he made a careful study of the works at the mouths of the Danube, the Rhone, and several other European rivers. What he saw there served only to strengthen his confidence in his own plans. When he returned home, there had been a noteworthy change in public sentiment. Though there still remained many either prejudiced or honest enemies to his plan, and although the newspapers were still noisy with their cheap and ignorant opposition, the country at large and Congress were inclined to accept the offer, which promised them so much at no risk at all.

The commission, returning too from Europe, where it had made as careful investigations as those of Eads, reported, by a majority of six to one, in favor of trying jetties in the South Pass. This pass, the smallest of the three mouths, had a depth of only eight feet on its bar, and had besides a shoal at its head. The South West Pass, the one which Eads had proposed to use, is not only two or three times as big, both in width and in volume of water, but it had fourteen feet on the bar, and no shoal at its head. Eads argued and implored with all his strength to be allowed to use the larger pass, as the only one adequate to the demands of commerce; and so convincing were his reasons that the House passed a bill which called for jetties in the larger pass. But the Senate, again more conservative, was cautious in this experiment, and insisted on the small pass. Finally, the bill went through, and the grant was made for the improvement of South Pass. And notwithstanding the considerable difference in size, as well as preliminary conditions altogether less promising than in the pass Eads had asked for, still, the depth of thirty feet was to be obtained,—the same result under harder circumstances. The payment promised, however, was not increased with the difficulty; but on the contrary was to be a good deal less than the estimate of the commission. The terms, which required certain specified depths and widths of channel to be obtained and then maintained during twenty years, were so arranged that Eads should not receive any part of his payment till after the work covered by that part had been finished and approved.

Hard as these conditions were, they were based on his own proposal, and he was glad even on such terms to undertake the great work he had longed to do. He at once busied himself in raising money for beginning the Jetties, and here again his peculiar talents helped him. One of his friends has said, "His powers of persuasion, his charm of address, and the magnetism of his personality opened the hearts and purses of whomever he pleaded with in support of

his engineering devices. He was a most lovable man." Moreover, he was an excellent business man. He had indeed a marvelous faculty for obtaining funds with which to carry on his works; and in that time of financial distress such a faculty was very necessary.

The theory on which he based his jetties was really extremely simple. He said that, other things being equal, the amount of sediment which a river can carry is in direct proportion to its velocity. When, for any reason, the current becomes slower at any special place, it drops part of its burden of sediment at that place, and when it becomes faster again it picks up more. Now, one thing that makes a river slower is an increase of its width, because then there is more frictional surface; and contrariwise, one of the things that make it faster is a narrowing of its width. Narrow the Mississippi then, at its mouth, said Eads, and it will become swifter there, and consequently it will remove its soft bottom by picking up the sediment (of which it will then hold much more), and by carrying it out to the gulf, to be lost in deep water and swept away by currents; and thus, he said, you will have your deep channel. In other words, if you give the river some assistance by keeping its current together, it will do all the necessary labor and scour out its own bottom.

Today, since this theory has been proved, it seems as simple as A B C. And it is almost impossible to believe what opposition it then aroused. People were not only set on blocking the undertaking, but they were actually ignorant enough to deny that the velocity of water had any connection with its sediment-carrying power. Even if the narrowing process should happen to give a channel through the present bar, they said, a new one would presently form beyond, and so the jetties would have to be extended every year.

However, Eads had his contract and his backers and his ideas and his faith in them; and he set to work on the little pass. The actual delta of the Mississippi consists of nothing but water, marsh, and some sandy soil bearing willows. At the sea end of South Pass Eads extended the low banks out over the bar, by driving rows of guide-piles and sinking willow mattresses close alongside them on the riverside. The mattresses were sunk in tiers, and each tier was weighted well with rock, put in as soon as each mattress was in position. As usual he invented many of the requisite mechanical appliances and contrivances himself, and generally such good ones that his methods came to take the place of earlier ones. The South Pass was not only the smallest and shallowest of the mouths, but it was besides more difficult than the other two in having a bar at its head as well as at its sea end. And although by his contract Eads was not required to remove that bar, by the exigencies of the case he was. Like the other it had to be attacked with water, guided by dikes and dams, which were similar in construction to the two parallel banks, the jetties proper. The scheme was always to force the river itself to do all the real work; and though there was, to be sure, a good deal of planning and building, the main idea, as already explained, is exceedingly simple. Eads never pretended to have originated this idea. He had studied many jetties in Europe. He had had the eye to see that they could be adapted to the Mississippi, and the skill to adapt them. For simple as the bald theory is, there was need of the nicest appreciation of laws and forces in applying it, and the result has been called the greatest engineering feat ever accomplished. The problem of making the quantity of water needed run *up* into the smallest pass "through a narrow, artificially contracted channel, located immediately between two great natural outlets,"—this problem being complicated by many "occult conditions,"—has been called, by no mean engineer, perhaps the most difficult problem ever dealt with successfully. "There is no instance, indeed, in the world where such a vast volume of water is placed under such absolute and permanent control of the engineer, through methods so economic and simple."

To the non-mechanical mind the control of such a multitude of abstruse, minute, and exact details as combine in the making of a bridge seems perhaps more marvelous than the mere bending of nature's forces to serve the ends of man. In Eads the power to do both existed.

On piles in the marsh houses were built for the engineers and the workmen, and the Jetties were begun. Eads was not able to be there in person all the time, but as usual his choice of competent and faithful lieutenants was noteworthy. His plans were approved by an advisory board of very eminent engineers; and by the end of one year the value of the work began to show. As yet it was not very strong or solid, but it had deepened the water on the bar from nine to sixteen feet.

None the less the storm of detraction continued. There were enough difficulties to meet without this, but none of them was met more forcibly. It was never Eads's way to attack other people in a malicious spirit, for he was never jealous; nor did he often deign to answer purely personal attacks. But in defense of his undertakings, to protect them and the people who had put money into them, he was ready to fight. His defense commonly took the form of criticism of his critics, and in such writing his pen was decidedly trenchant. Probably no man ever incurred more foolish criticism, and probably none ever pointed out more plainly how foolish it was. Even "the ablest of his adversaries confessed themselves afraid of his pen." Besides this parrying of attack, he was continually writing and talking to show the simplicity and feasibility of his method; and one man phrased what it is likely many exemplified, that a few minutes' conversation with Eads had done more to convert him to the Jetties than any

amount of writing and of talking with other people could have done. Always modest and unassuming, he was so thoroughly in earnest that he convinced others by his own conviction.

Never was a man less afraid to work. Years before, in the diving-bell days, he had set himself the precedent of never asking an employee to do what he himself would fear to do. And, on the other hand, he did not hesitate to ask an employee to do as much work as he himself would have done. His former confidential clerk has told me that sometimes, after evenings of discussion, Eads on starting to bed, perhaps at midnight, would say to him, "Now, have that figured out for me in the morning," which meant three or four hours of scrupulous figuring or writing to be done by eight the next morning.

Undoubtedly he could not have worked so hard as he did himself had he not been able to throw aside his cares and problems when he was not actively engaged with them. A very sociable man, he liked not only to be with people, but to be making them enjoy themselves. Thus he was both generous and jovial. No one loved more to give presents; no one knew more droll stories and more poetry. Nor was his joviality by any means a descent; for not only before royalty was he dignified, but in the most democratic assembly. His was not, however, a forbidding dignity. Simple-hearted as a child, he was fond of children, and they were fond of him.

Of course, he kept up his miscellaneous reading. He was specially devoted to poetry; and loved not only to recite verse upon verse aloud, but also to read to his friends and associates. As usual, his enthusiasm spread to others. One old lady has told me that she never had thought much of poetry till she heard him read it. Burns and Edwin Arnold and Tennyson were favorites; and there is a letter written by Eads to Tennyson, apparently to send him a clipping in which the one was described reciting from the other's poems. Eads excuses himself for intruding with his tribute, and remarks that both of them have built works destined to outlive their authors. He says it quite modestly and candidly, "as equal comes to equal; throne to throne."

Yet despite the confidence of their builder, despite his cheerfulness, the Jetties were not getting along well. To be sure, they were steadily deepening the channel, and thereby proving to all ingenuous persons who were undeceived that jetties were what had long been needed, and that they should be helped along and finished. But the Jetties were situated far off in a remote marshland where few people saw them; consequently nearly everybody was either deceived or was disingenuous. People who had no business to interfere did interfere. Every hitch was shouted abroad, every success was concealed or twisted. Concrete difficulties were enormous. Sudden storms at just the wrong time delayed and undid the work. The need for more money was pressing, and it could be borrowed only at exorbitant rates of interest. The newspapers were clamoring that the rash experiment was a failure; and though, of course, it was not a failure, still it might have fallen through, when one day the Cromwell liner, Hudson, drawing over fourteen feet of water, came in through the Jetties, and they were saved.

Although the prestige of the undertaking was thus established, Eads realized that his contract with the government was too severe. Not that he asked to be paid beforehand for his work, but he did ask to be paid as the work was actually done. So evident were his energy, skill, and good faith that Congress promptly voted him an advance of a million dollars. It also sent a commission to inspect and to report on the progress and efficiency of the works. This commission, while reporting favorably, advised against any further advance payments. But Congress, nevertheless, voted him three-quarters of a million more. It is said that this is the only instance where the government has voted money to an individual in advance of the specific terms of his agreement. Moreover, his contract was re-arranged so as to be less oppressive.

It has been said that if Eads had failed with the Jetties he would not only have destroyed his reputation, but he would have been a beggar,—though, some one added, he would still have deserved everlasting gratitude for his efforts and sacrifices. And now he had already succeeded in changing the little pass into a grand channel of commerce sufficient for the largest shipping that visited New Orleans. Yet the violent opposition and the calumnies still continued. There was a wonderful persistency in the false reports which came from bitter opponents who would not be convinced. The foolishness and ignorance of their arguments are almost incredible. But however foolish, they had to be disproved; and Eads set himself patiently to work to point out the errors in logic and in physics; and in doing so he wrote what those who know call one of the greatest works on river hydraulics.

While there were so many men's hands against Eads, it is pleasant to record that there were also many for him. It was the "Scientific American" which first suggested his name for the presidency. It advocated him as a fearless, honest, and forceful man; but the peculiar compliment in it was that this was a technical paper that upheld him. The proposal was repeated in many newspapers, but Eads had no more intention now than ever of going into politics. He knew in what line he could do most for his country, and had an ambition rather

to be a supremely useful engineer than to be president.

Another of his admirers was the late Emperor of Brazil, Dom Pedro II., who, after a visit to the Jetties, first tried to persuade Eads to go to Brazil to do some very important work for him, and who then, failing that, sent him a personal letter asking him to recommend an engineer. And he engaged the one whom Eads recommended.

In 1879, a little over four years from the time the Jetties were begun, the United States inspecting officer there reported the maximum depth of thirty feet and the required width and depths throughout the channel. Thereupon all the remainder of the price agreed was paid over to Eads, excepting a million dollars, which was kept, at interest, as a guarantee, during twenty years' actual maintenance of the channel. Omitting from the count every day of deficient channel, these twenty years are now (1900) almost over; the results in the channel and in the part of the gulf just beyond the Jetties have been precisely and entirely what the projector of the works predicted when he began them. The bar has never formed again. The Jetties themselves, so far from having to be lengthened, are shorter than they were originally designed. In a word, the sole legitimate objection that can be made to them is that they do not furnish a great enough depth. Of course they furnish the required depth, and as great a depth undoubtedly as can possibly be had in the little South Pass. Ships, however, now draw more water than they did twenty-five years ago, and a still deeper channel is needed. The best proof of the success of the present one is that the government is preparing to apply the same plan to the big South West Pass, which Eads begged to open and was not allowed to. It is said that in that pass he would have produced thirty feet in one year. But nothing is more useless to discuss than what might have been. What Eads has accomplished with his Jetties is certain.

One result of his achievement was a quick improvement in prices. Every acre, mill, farmhouse in the whole of the Mississippi Valley was increased in value by the impetus which the open river-mouth gave to commerce. New Orleans rose from the eleventh to the second export city in the country. Consequently there was a great increase in the number of lines of ships going there, and in their tonnage. And as a result of that there was a rapid increase in railway facilities. In twenty years from the commencement of the Jetties there was a gain of one hundred per cent. in the total commerce of New Orleans, nearly all of it due to these works. This boom has, despite the marvelous multiplication of railways, preserved the river traffic; and the river traffic, as always, has by competition lowered freight rates. The effect has spread to remote districts; and by this reduction in rates and prices there is no doubt that the Jetties have made living cheaper on the Atlantic seaboard as well as in the Mississippi Valley.

Even more: in another way they have made living cheaper. The half-rail-and-half-water route from the Pacific coast to New York via New Orleans, which the Jetties first made possible, forced the transcontinental railways to cut down their time for shipping freight over one half. The tonnage by this newer route has increased enormously, and its competition has affected commerce by reducing all rates from the Mississippi Valley and the West and the Pacific slope to the Atlantic seaboard and to Europe. As a consequence bread has been made cheaper to all the great populations that require the food products of the central zone and the Pacific slope.

Another very different but curious change is probably largely due to the Jetties. Before their construction only very light-draught ships could safely reach New Orleans; but it was so favorite a cotton port that many owners would build vessels of unusually light draught, in order that they might make one trip a year to New Orleans with them, although the rest of the time they sailed to deeper ports. As soon as it became known over the shipping world that New Orleans was now open to deep-draught vessels, a great many new ones were built. Thus the Jetties, as much as any other cause, brought in the era of great ships.

It has been calculated from statistics, which it is not necessary to give here, that the annual saving to producers of the Mississippi Valley brought about by the fall of rates, the saving in marine insurance, and the saving in time, due to the Jetties, is \$5,000,000; and it is furthermore calculated that the annual money value of the Jetties to the people of the country at large is, by a very conservative estimate, \$25,000,000.

Even the Jetties, however, were not the end of Eads's efforts toward the improvement of the Mississippi. For several years before their completion he had been delivering addresses urging the application of the same system to the entire alluvial basin of the river from the gulf to Cairo. People were in despair as to what to do to prevent the breaking of the levees (the results of which are as "terrible to the dwellers on those flats as the avalanche to people who live on the sides of steep mountains"), and the distress and prostration created by the awful spring floods. Most people thought there were two possible remedies,—to build more and higher levees, and to drain off some of the volume of the river through the Louisiana bayous. But Eads insisted that the requisite move was to reduce the excessive width of certain stretches of the river with willow mattresses; by uniformity of width to produce uniformity of depth, and consequently uniformity of current. This would facilitate the

discharge of floods, and would tend to lessen the need of any levees, whereas drawing off any of the volume of water, he said, would increase the elevation of its surface slope, and thus necessitate higher levees.

His arguments on the question are clear and forcible; and it is likely that his plan, if carried out, would solve the important question of the Mississippi. But enough money to try it thoroughly has never been appropriated; and so little effect has patching had, that at this very day there are still advocates of the scheme of drawing off some of the water,—a scheme which Eads blasted years ago.

In 1879 the Mississippi River Commission was created, consisting of one civilian and six military and civil engineers, of whom Eads was one. But for him the government would not have undertaken, at any rate at that time, its very comprehensive system of river improvement, founded primarily on his theory. Besides giving a regular, deepened channel, and putting an end to overflows, he contended that his system would reclaim about 30,000 square miles of rich alluvial lands subject to inundation. For two years he served on this commission: for many years before he had been working and fighting for the same grand result,—grand though almost fruitless. "He had no selfish interest to subserve" in this; "no contract to execute; nothing himself to gain." But when, on returning from a trip to Europe, he found that the work was no longer being carried on as he thought it should be, he resigned from the commission. Deploring the wrong methods used, he still was most deeply interested in this great work up to the time of his death. If, some day, the Mississippi is conquered, it will doubtless be through the means he pointed out.

V

THE SHIP-RAILWAY

When the Jetties were finished and paid for, Eads found himself in a very good situation. Not only was his bold scheme proved to be a complete success, but it had in the end paid him well; and he was promised still further payment for maintaining his works twenty years longer. His reputation was world-wide. He was now fifty-nine years old. Five years later, in 1884, he went to live in New York. It is not hard to imagine why so busy a man wished to be more in the centre of things, though, for that matter, he had not for some years past spent much of his time at home. There was too much to make him travel. Besides the frequent voyages which he was ordered to take for the sake of his health,—and which, as he was a very bad sailor, he said were real medicine,—he was in demand here and there, in places miles apart, for professional services; and then, too, he visited many engineering works in various remote lands,—river improvements, docks, the Suez Canal. It was not alone that his curiosity was always healthy, but also that his education—the broad, useful education that he gave himself—was never ended.

We have seen how he refused to go to Brazil. He was also wanted at Jacksonville, Florida, where the citizens called him in 1878 to examine the mouth of the Saint John's River, and to report on the practicability of deepening the channel through the bar with jetties. He went there, and, after a personal examination, presented a very elaborate report. In 1880 the governor of California had requested him to act as consulting engineer of that State, and he accordingly visited the Sacramento River, and reported upon the plans for the preservation of its channel and the arrest of débris from the mines. In 1881 he was consulted by the Canadian Minister of Public Works on the improvement of the harbor of Toronto, which he also examined. This was the first instance in which the Canadian government had ever employed an American engineer. When he was in Mexico, the government there asked him for reports on the harbors of Vera Cruz and Tampico and suggestions for their improvement. Although he did not examine these two harbors personally, he drew up plans on surveys furnished by engineers whom he sent there; and the work which has since been carried out after his instructions has proved eminently satisfactory. Again, it was the people of Vicksburg who sent for him to tell them how to better their harbor; and at another time he was consulted about the Columbia River in Oregon and about Humboldt Bay. In 1885 the Brazilian Emperor made a second attempt to secure his services for an examination of the Rio Grande del Sul, but ill health and pressing business prevented his acceptance of the offer; nor was he able to undertake the examination of the harbor of Oporto requested by the Portuguese government. It seems superfluous to say that all the reports he did make "were exhaustive and eminently instructive in their treatment of the subjects discussed."

Perhaps the two most important professional cases submitted to him were those in 1884 on

the estuary and bar of the Mersey River and on Galveston Harbor. In the case of the Mersey he was called in, at the solicitation of the Mersey Docks and Harbor Board of Liverpool, to settle a dispute. Appearing before a committee of the House of Lords, he gave his testimony as to the effect which the proposed terminal works of the Manchester ship canal would have upon the estuary of the Mersey and the bar at Liverpool. "He brought to the solution of this question that same keen insight into hydraulics and the same close application that had made him so successful in this country." He showed so plainly what would inevitably be the deleterious results of the proposed plans that the committee decided against them. Subsequently they were changed to conform to his suggestions. For this report he received £3500, said to have been the largest fee ever paid to a consulting engineer.

In the Galveston case, the same year, he was requested, not only by the city but by the state legislature, to formulate a plan and to take a contract from the United States government for improving that harbor. The government had already been carrying on works there for several years and accomplishing nothing. Indeed, it was the jetty method—by this time more highly thought of than ten years before—which was being attempted, but not in proper form. Eads, after long and careful study of the situation, made a plan, which he offered to carry out on conditions very similar to those adopted in the case of the Mississippi Jetties, but Congress was not willing to grant the contract. Since then, however, the works there have been altered according to his suggestions, and have consequently been more successful.

For a good many years, owing to the weakness of his lungs and to other illness, Eads had not only had to travel much for his health, but to take special care of himself generally; and yet, to judge from the following account, in the first person, of how he had spent the year 1880, it seems that his wondrous energy had not failed: "I inspected the River Danube about 800 miles of its course; and investigated the cause and extent of the frightful inundation at Szegedin, in Hungary, which involved an examination of 150 miles of the Theiss River. I also examined the Suez Canal, to familiarize myself more thoroughly with the question of a ship canal across the American isthmus, having previously visited the Amsterdam ship canal and the one at the mouth of the River Rhone. As a member of the Mississippi River Commission I also aided in perfecting the plans for the improvement of that river, and the preparation of its report now under consideration before Congress. As consulting engineer of the State of California I made a thorough inspection of the Sacramento River, to consider the best method of repairing the injury to its navigation caused by the hydraulic mining operations there, and submitted a lengthy report upon it. On my way back I visited the wonders of the Yellowstone Park, crossing the Rocky Mountains in that excursion six different times. Within this time I have thrice visited the Jetties at the mouth of the Mississippi, besides my visit to the city of Mexico, Tehuantepec, and Yucatan.... I have also, at the request of the mayor and council of Vicksburg, twice visited that city during the last year, to examine its harbor with a view to its improvement."

In 1884 Eads received perhaps the most distinguished honor of his career—the award of the Albert Medal. As it came only two or three months after the report on the Mersey, it was undoubtedly due to that as its immediate cause, although the Jetties were almost specifically named as the reason for this honor,—and Eads had not by any means lacked even earlier appreciation in England. Three years before, at a meeting of the British Association, he had been urged, nay pressed, to deliver an impromptu address on his works, both completed and projected. Nevertheless, it was not until after the Mersey report that the Albert Medal was conferred upon him. This medal, founded in 1862 in memory of the Prince Consort, is awarded annually by the Society for the Encouragement of Arts, Manufactures, and Commerce. It was in Eads's case awarded "as a token of their appreciation of the services he had rendered to the science of engineering," to the engineer "whose works have been of such great service in improving the water communications of North America, and have thereby rendered valuable aid to the commerce of the world." He was the second American citizen and the first native-born American to receive this medal.

Of course he belonged to many scientific organizations. He was a member of the Engineers Club of Saint Louis, and for two years president of the Academy of Science there; he was also a member of the American Geographical Society, of the Institution of Civil Engineers, Great Britain, and of the British Association, and of the Society for the Encouragement of Arts, Manufactures, and Commerce; a fellow of the American Association for the Advancement of Science; and a member, fellow, and for a year vice-president of the American Society of Civil Engineers.

He was now a person whose return from Europe, with plans for river improvement, and news about a fresh engineering scheme, was an item in the small as well as the large newspapers. For, since the Jetties were finished, he had a new scheme,—a decidedly new one it seemed to most people,—though, as formerly, he made no pretense of having originated the idea. Instead of resting content, now that he was almost sixty,—rich, and honored, and frail,—instead of resting content on his laurels of the gunboats, the Bridge, the Jetties, he was as active as ever, with the hope of opening more roads to commerce and prosperity. The publication of the proceedings of De Lesseps's Interoceanic Canal Congress

in 1879 gave Eads an opportunity to propose, in a letter to the New York "Tribune," his own project for spanning the isthmus. The Tehuantepec route from the Gulf of Mexico to the Pacific would be, in the general lines of travel, about 2000 miles shorter than the Panama route, or 1500 miles shorter than the Nicaragua. And it was at Tehuantepec that Eads proposed building, not a canal, but a ship-railway. The proposition was astounding. It certainly suggested very picturesque visions of transportation; but at first sight it did not sound very practicable. However, Eads held that it presented six great and purely practical advantages: First, it could be built for much less than the cost of a canal. Secondly, it could be built in one quarter of the time. Thirdly, it could, with absolute safety, transport ships more rapidly. Fourthly, its actual cost could be more accurately foretold. Fifthly, the expense of maintaining it would be less than for a canal. Sixthly, its capacity could be easily increased to meet future requirements.

In 1880 he appeared before a committee of the House, and in reply to De Lesseps, who was advocating the Panama Canal, he stated his plan for the ship-railway. A few months later he went to Mexico, where the government gave him, besides a very valuable concession for building the ship-railway, its cordial assistance in his surveys. It was at this time that Mexico requested his aid in improving its two harbors, and when he returned home, sent him in the Mexican man-of-war, the *Independencia*. The next year he proposed to Congress to build the ship-railway at his own risk, and to give the United States special privileges, which had been arranged for in his Mexican charter, provided the government would, as he proved the practicability of his plan by actual construction and operation, guarantee part of the ship-railway's dividends. Although this arrangement would have laid as little risk on the government as the jetty arrangement had, it was not accepted.

Strange and even unnatural as the idea itself appeared, it was adapted from perfectly simple ship-railways already in existence and in satisfactory use. Science, he said, could do anything, however tremendous, if it had enough money. In the magnified form contemplated, the plan provided for a single track of a dozen parallel rails, and a car with 1500 wheels. On this car was to be a huge cradle into which any ship might be floated and carefully propped. The car having then been hauled up a very slight incline out of the water, and monster, double-headed locomotives hitched to it, by gentle grades it and the ship were to be drawn across to the other ocean a hundred miles away, where the ship could be floated again. To obviate any chance of straining the ships, all curves were to be avoided by the use of turn-tables.

Nevertheless, many people believed that such a journey would strain a ship so much that it would never float afterwards. On the other hand, there is so imposing an array of names of distinguished engineers, shipbuilders, and seamen, who declared that the plan was feasible in every particular, that it is hard to think they could all have been mistaken in thus supporting the leading engineer of the day. It may easily be supposed that every other imaginable and unimaginable objection was raised, but to one and all Eads gave an answer that sounded conclusive.

As usual he was willing to back up his ideas with money, and he had the most elaborate surveys made, and remarkable models prepared to show the working of the ship-railway. He preached this new crusade of science with his customary vigor. So many men were financially interested in the project, or were ready to be, that it would at all events have been tested, had not its leading spirit, the very life of it, died.

Even though he was at the same time engaged in investigations so important as those at the Mersey and at Galveston, Eads devoted the last six years of his life mainly to this daring and tremendous enterprise. In 1885, after obtaining from the Mexican government a modification of his concession, guaranteeing one third of the net revenue per annum, he had a bill introduced in Congress, whereby, when the ship-railway should be entirely finished and in operation, the United States was to guarantee the other two thirds. Though this bill was favorably reported, Eads finally decided to withdraw it, and to ask after all for a simple charter, which would doubtless have been granted. During those six years there was perhaps not another man in the country who was so able to persuade others of the scientific, financial, commercial soundness of his projects. If, more than any one else, he could make a scheme appeal, it was not that it was in any sinister sense a scheme, but because his tact and his address were pleasing, his reputation firmly grounded for honesty and common-sense as well as for thorough scientific knowledge, so that his enthusiasm was contagious. His enemies might call him a lobbyist, but his sole means of persuasion were the soundness of his views, the clearness of his arguments, and the fervor of his wish to benefit his country.

For this undertaking, as for his previous ones, Eads invented many devices. All in all he held nearly fifty patents from the United States and England for useful inventions in naval warfare, bridge foundations and superstructure, dredging machines, navigation, river and harbor works, and ship-railway construction.

In January, 1887, when his bill was to come up, he went to Washington. He was in such poor health that he was not able to remain there, but on his doctor's advice he went with his wife

and one daughter to Nassau. While sick there, he was still at work on improvements for his ship-railway. He was wont to say to his intimate friends, "I shall not die until I accomplish this work, and see with my own eyes great ships pass from ocean to ocean over the land." But in Nassau it was soon known that he was dying; and still he said, "I cannot die; I have not finished my work."

He died March 8, 1887, not quite sixty-seven years of age. No one has finished his work.

In any career there are three main elements of success: talent, education, work. Eads's life, like that of so many other self-made men, seems to show us that education is less important than the other two. But while it is true that he had not the formal education of an engineer, he had a certain very broad training gained in experience, and had read hard. Education, after all, is nothing but a summary method of teaching the lessons of life; therefore, while less insistent, it is often swifter than practical experience. And there is no doubt that a man like Eads would be the first to deplore a young man's failing to appreciate its value. When he himself was young, he never supposed that he was a genius; but if he had thought this, he would have striven to be the best-read and the best-equipped of geniuses; believing that though he might be mistaken about his talent he could make sure of his culture.

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