Broach, and Baroda, to Ahmedabad, leaving the remainder of the scheme for future decision, and the work to be commenced at Bombay. The Home Government, however, decided that the work should be commenced at Surat. The main line from Bombay to Ahmedabad is 308 miles in length, and crosses several large rivers and inlets of the sea. It runs through a flat, alluvial district, and the only difficulty to be encountered in its construction was the erection of the necessary bridges. So great did this appear, that some engineers connected with the Bombay Presidency stated that these arms of the sea and large rivers could not be bridged, except at such a cost as would render the construction of the railway unjustifiable. Knowing that masonry structures would be extremely expensive, Lieutenant-Colonel Kennedy had the foresight to turn to practical account the late Mr. Mitchell's invention of the screw-pile, and the rivers were bridged by Mitchell's screw-piles and Warren girders. He was a strong opponent to the break of railway gauge, and did all in his power to dissuade the Indian Government from adopting it.

He wrote many pamphlets on Indian subjects. The following extract is from the report of the Bombay, Baroda, and Central India Railway Company, of the 20th of June, 1879 : " The Directors announce, with deep regret, that failing health has obliged Colonel John Pitt Kennedy, the consulting engineer, and one of the original founders of the Company, to resign his appointment. The Directors cannot express in more fitting terms their sense of Colonel Kennedy's high qualities, than by adopting the following resolution of the Bombay Government : 'In resigning the post of consulting engineer to the Baroda Railway Company, Colonel Pitt Kennedy terminates a long career of public usefulness, during which his ability, integrity, and courtesy, have gained him the respect and esteem of all with whom he has been brought in contact. Government desire to take this opportunity of placing on record their sense of his personal worth, and of the value of the services he has rendered to the State.' "

He was elected a Member of the Institution of Civil Engineers on the 3rd of March, 1868, and occasionally took part in the discussions at the evening meetings.

MR. JOHN PENN was born at Greenwich in 1805, and died at the Cedars, Lee, in 1878. He thus lived during the most important part of the nineteenth century. How much he accomplished

during his lifetime, the following memoir will very briefly show.

He was emphatically well born. His father was a man of great mechanical genius; industrious, persevering, and always working his way upwards and to the front. Beginning as apprentice to a millwright at Bridgewater, the elder Penn was made foreman of an important work at Bristol when he was only twenty-two years of age. He became celebrated for his theoretical and practical knowledge of the teeth of wheels,—a branch of construction which was then imperfectly understood by mechanicians. Leaving Bristol in 1793, he made his way to London, where he remained ever after. He began business on his own account at Greenwich in 1799, where he soon became known as a millwright. It may be noted that many of the principal civil engineers began life as millwrights,—such as Brindley, Rennie, Sir William Fairbairn, Sir William Cubitt, and others. The treadmill for prisons, designed by Cubitt in 1818, was first executed at Mr. Penn's works. But his greatest attention was devoted to flour mills, in which he made many improvements, particularly in the substitution of metal for wood framing. In consequence of a strike amongst the millwrights, who then constituted a powerful society, Mr. Penn was induced to adopt self-acting tools, which greatly improved the uniformity of the work turned out, and also led to the employment of another class of workmen. Steam-engine making was introduced to the factory; and in his hands, and especially in those of his son, the marine engine was subjected to many important improvements.

Under such a father was the late Mr. John Penn brought up. He received the usual education, but his most important school was the workshop. He learnt the use of his hands, and he worked steadily and perseveringly. He learnt to handle the file; and the use of the file, before self-acting tools were in general use, was a great mechanical accomplishment. He worked at the forge, and could handle the hammer with any man in the smithy. He worked at the lathe, and turned out beautiful work. In short, he was a thoroughly skilled workman, and a master who is becoming very rare in these days; for he could take the tools out of any man's hands, and deftly show how the work should be done—the true method of securing the workman's respect and admiration.

He was very intimate with Joseph Clement, a man of great mechanical merit. Clement improved the lathe, which he made

self-regulating; and he established a mechanical practice with regard to the pitch of the screw, which has now become universal. He also invented the headless tap, which, in the opinion of Nasmyth, "ought to immortalise him among mechanics." His planing machine was also one of the wonders of the time. He modified it so as to present a complete union of the lathe with the planing machine and dividing engine, by which turning of the most complicated kind was readily executed. Mr. Penn carefully studied the work going on in Clement's workshops, and he afterwards became one of his best customers. To the day of his death, he always spoke of Clement as one of the most ingenious mechanics whom he had ever known.

The elder Penn died in 1843; but, for several years before that event, his son had had the entire management of the works. The first engine introduced by him was the well-known "grasshopper." A 6 HP. engine of that type drove the machinery of his workshop. It was a small beginning, but it led to many greater things. Some time after, Mr. Penn designed a table engine with a 10-inch vertical cylinder, which answered admirably; and it is still in use at the Greenwich works.

To improve himself in the knowledge of machinery, Mr. Penn visited by turns all the more important establishments in England and in Scotland. He also determined to see what the foreigners were doing; and he made special journeys into Belgium, Holland, Germany, France, Switzerland, and Italy, for this particular purpose. He brought back many "wrinkles," which he embodied in his own works. Mr. Penn was bent on having the best of everything, no matter where it came from. He required to have perfect tools and perfect machinery. Thus his success was not the result of chance, but of faithful and persevering work. He had the seeing eye and the observant mind. He shirked nothing—labour, pains, nor application. He would have no shoddy work. Everything must be turned out in the best manner. He would trust to no underhand information. He trusted himself—his own eyes, his own hands, his own faculties. His great undertaking centred in himself.

When Mr. Jacob Perkins invented the steam-gun, the work was sent to Greenwich to be executed. John Penn was then only twenty-one; but he undertook to make the gun. It had a wrought-iron rifled barrel of 3 inches calibre. The steam-gun was finished, and answered admirably. Although it had been made to the order of the French Government, it was taken to a piece of

waste ground in Westminster to exhibit its wonderful powers, in sight of many military men who were invited to inspect it. One day the Duke of Wellington came to inspect the steam-gun. Great things were expected from the Duke's visit. John Penn was there to show it off. Everything was done in order; the gun, by the aid of steam, shot off its 3-inch bullets with inconceivable rapidity, penetrating an iron plate 100 yards off. Then the Duke began to put his questions to Penn. "Now, my young man," he said, "what weight is the boiler?" "About 5 tons," said Penn. The Duke shook his head. "Ah!" he said, "if we had been fighting with steam-guns till now, what a grand thing we should have thought the invention of gunpowder!" The Duke departed, with the same grave wag of his head. Penn immediately went to Perkins, and said, "It's all up with us now." He told him what the Duke had said. The result was, that the Duke made an unfavourable report on the gun—not so much as regarded its performances, but as to its unwieldy weight while travelling across country or in the field. The Duke thought better of Penn than of the gun which he had exhibited. He formed a favourable opinion of him, and afterwards found many opportunities of testifying his high admiration of the young engineer. After the trial in London, the gun was sent to France, and Mr. Penn went with it. He remained in Paris for about three months, to erect it and put it in operation. Nothing came of the invention. The revolution of 1830 swept away Charles X. and his steam-gun. It was afterwards brought back to England, and exhibited at the Adelaide Gallery, until the Exhibition was dispersed. It was probably afterwards sold as old iron.

Mr. Penn devoted the principal part of his life to the manufacture and improvement of marine engines. As early as 1823, he repaired the engines of a vessel called the "Nero," and fitted her up with new boilers in the following year. The first marine engines which he made at Greenwich were for the steamer "Ipswich," in 1825. He was then only in his twentieth year. This vessel gave such satisfaction that it was followed by the "Suffolk," employed in the same trade. These vessels ran from London to Ipswich along the east coast, and up the river Orwell. They were fitted with beam engines of 40 HP.

Steam-boats were by this time regularly running on the Thames, and Mr. Penn had his fair share of the trade of fitting them with engines. Whatever he undertook he endeavoured to improve; and in this he was greatly helped by the workmen in his estab-

lishment. He himself took a special interest in training the boys, so that they might become first-class workmen. He gave a great deal of time to them; showed them how they should handle the file, how they should use the hammer, how they should work at the lathe. He did this in so kindly, and yet in so masterful a manner, that they never forgot his instructions. Mr. Penn was particularly proud of the excellent work obtained from his boy workmen.

By the year 1845, four passenger steamboats, running between London and Greenwich, were fitted by him with beam engines of 45 HP. In 1838, he began to make marine engines with oscillating cylinders. The oscillating engine was invented by that gifted mechanic, William Murdoch, in 1785. It was afterwards patented by Aaron Manby in 1816. The oscillating system was at first regarded with prejudice; until Mr. Penn, feeling convinced that there was a good principle involved in the idea, grappled with the difficulties, and eventually brought the engine into favour. The first paddle-boats with machinery of this construction plied between London and Richmond. They had engines of 24 HP. and tubular boilers, and the results were extremely satisfactory.

At length, the Lords of the Admiralty took up the application of steam power to ships of war. Naval officers, who had grown old in the tactics of sailing ships, could not brook the idea of employing the artificial power. But at length they began to try steam power, first hiring tugs belonging to private owners, and then using a small tug of their own. "The Comet" was built in 1822, after the designs of the late Mr. Oliver Lang. Yet this vessel was only employed in towing ships of war from one naval seaport to another.

But when they saw the steamers fitted with Mr. Penn's engines scudding up and down the Thames, and more especially when they found the French anticipating them in the use of the new motor in ships of war, their antipathy abated. In 1844, the Admiralty employed Mr. Penn to remodel the engines on board the "Black Eagle." The ship had been formerly provided with beam engines of 131 HP. It was a slow and lumbering ship—so slow and lumbering that, in 1838, a paddle-boat steamer from Rotterdam passed her rapidly at the mouth of the Thames, and soon left her far in the distance. But when Mr. Penn's oscillating engines replaced the old steam gear in 1844, the "Black Eagle" became a handy, steady, and rapid ship. He introduced in the same space oscillating engines of double the power, with tubular boilers;

thus securing the more rapid production of steam, a much greater speed, and a large saving in coal. Mr. Penn made a voyage in this ship, and carefully watched the action of the engines. He was satisfied that he had already made a great stride in the working of ships of war.

This was the beginning of Mr. Penn's employment by the Admiralty; and it led to numerous orders for marine engines. Among the most celebrated ships with oscillating engines may be mentioned, Her Majesty's yacht "Victoria and Albert," the Emperor of Austria's yacht "Miramai," the Sultan's yacht "Taliah," the "Mahrousseh" of Egyptian fame, with a speed of 18½ knots; as well as a large number of fast passenger steamers plying between England and the continent.

But it was only when the paddle was supplemented by the screw that Mr. Penn began to supply the greater part of his engines to the Royal Navy. In 1843, he was commissioned to make oscillating engines for the "Phœnix," of 260 HP.; and in the following year for the royal yacht "The Fairy," of 120 HP., which was employed as a tender to the "Victoria and Albert," which lay off Woolwich. The "Phœnix" and "Fairy" were modelled after the "Archimedes," the vessel which first embodied Sir Francis Pettit Smith's invention of the screw propeller. The "Archimedes" had steamed round the British Islands, and made a voyage across the Bay of Biscay to Oporto. The results were so satisfactory that Mr. Brunel obtained the loan of the vessel, and made various experiments upon her with screws of different pitches.

Mr. Brunel had originally designed the "Great Britain" to be worked by paddles, and the wheels were actually in course of construction. But when he ascertained the results of the screw system, he altered his designs for the purpose of adopting that propeller. The "Great Britain" was launched in 1843, but it was not until some years later that Mr. Penn constructed her engines of 500 HP. on the oscillating principle. The screw, however, was not as yet driven direct, but through gearing. This proved entirely satisfactory as regards speed; indeed too satisfactory, as the vessel was run on shore in Dundrum Bay on the North of Ireland, the accident being due in some measure to her excessive speed as compared with the steam vessels of those days.

The screw had been adopted in many merchant vessels. The reports of the Admiralty surveyors were entirely in favour of this method of propelling ships; and at length the Admiralty resolved upon its general adoption. This again put Mr. Penn on his mettle.

Although his success had been great with the oscillating engine, he found it necessary to compress his engine into as small a space as possible, and to place it low down in the vessel, so as to be under the water line and practically below the line of shot penetration. He consequently adopted the "trunk" engine, for which a patent was taken out in 1845.

In October, 1845, he was commissioned to supply direct-acting engines on the horizontal trunk system, for the "Arrogant" and "Encounter," each of 360 nominal HP. The engines were so admirably executed, so compact, so finished in every respect, that fresh orders flowed in upon Mr. Penn continuously, and up to the day of his death, he had fitted 735 vessels with engines having an aggregate actual power of more than 500,000 horses. Among the first ships he supplied with trunk engines, were the "Agamemnon," the "Impérieuse," the "Royal George," the "St. Jean d'Acre," the "Cæsar," the "Colossus" (or the "Goloshes," as the seamen call it), the "Conqueror," and the "Orion." These ships were engined in 1853–4–6. Though the "Conqueror" for instance, was fitted for 800 HP., it actually indicated on trial 2,812 HP. These vessels were followed by others of larger size and greater steam power, especially after ironclads came into existence. The application of defensive armour to ships of war was not at first considered safe, but Napoleon III., when Emperor of the French, had the sagacity to see its importance. In 1855, four vessels were covered from stem to stern with iron armour-plates. It was the use of one of these ships that led to the successful assault of Kinburn at the mouth of the Dnieper; while our wooden ships at Sebastopol were unable to resist the attack of the enemy's shot and shells.

While the Crimean war was raging in 1854, the admirals found themselves at a great loss for want of gunboats for sounding the way for the larger ships in ascending rivers, and for other purposes of attack or defence. The Government at once ordered one hundred and twenty of them, with 60 HP. engines, to be ready at the beginning of next spring. It was at first thought difficult to accomplish so large an amount of shipbuilding in so short a time. But the result showed what an immense number of warships the workshops of England can turn out in the event of war. Mr. Penn solved the difficulty. He called to his assistance the best workshops of the country; he provided them with patterns, from which duplicate parts were executed and forwarded to Greenwich; and by the admirable resources of his own establishments at Greenwich

and at Deptford, he was able to supply ninety-seven gunboats for the spring of 1855. In all, one hundred and twenty-one engines were fitted by Mr. Penn for the British Government during the Crimean war. The lesson which it taught will not soon be forgotten either at home or abroad, though a great deal more can be done now.

Towards the end of 1858, the Admiralty were induced to take into consideration the construction of iron-clad ships of war. The subject was one of great difficulty. An enormous burden of armour had to be added to the weights hitherto carried; at the same time greater speed was demanded, and this involved an increased weight and power of engines, and a larger supply of fuel.

The "Warrior" was the first of these iron-clad ships. She was launched on the 31st of December, 1860. She is a splendid ship, constructed on beautiful lines, but as she was iron-cased in the strongest parts only 4½ inches thick, she is now comparatively helpless in consequence of the increased penetrative power of steel shot. The engines, constructed by Mr. Penn, were of 1,250 nominal HP., but might be worked to upwards of 5,000 indicated HP. The weight of the engines was 950 tons, and that of the whole armament from 9,000 to 10,000 tons. The five thousand pieces of which the engines were composed were fitted together with such precision, that when the steam was let into the cylinders, the immense machine began to breathe and move like a living creature, stretching its huge arms like a new-born giant, and then, after practising its strength and proving its soundness in body and limb, it started off with the power of over five thousand horses to try its strength in breasting the billows of the North Sea.

The "Black Prince" was the next of the ironclads. It was also engined by Mr. Penn, and proved equally satisfactory with the "Warrior." It would be unnecessary to mention all the numerous ironclads and other ships for which Mr. Penn provided the engines, but the following may be cited: the "Orlando," "Howe," "Bellerophon," "Inconstant," "Devastation," "Northampton," "Hercules," "Achilles," "Minotaur," "Neptune," and "Northumberland." The "Sultan" gave an indicated power of 8,629 horses, and the "Neptune" (formerly "Independencia") upwards of 8,800 indicated HP., about the highest hitherto realised by one pair of engines.

Another invention of Mr. Penn's remains to be mentioned. It may be remembered that at the beginning of screw-propulsion, a

difficulty was experienced in the heating and wearing of the screw gear. Hence there was a great prejudice against high-speed engines of every kind. Brass, cast iron, and soft metal were tried; but no material could be found to stand the strain and wear. The bearings were rapidly worn away, there was an intolerable noise, and danger to the ship from fracture to the stern tube, besides the loosening of the stern framing, and the wear and tear of the screw shaft under water. The difficulty was so great that at one time screw-propulsion seemed in danger of abandonment, and a return to paddle ships was supposed to be necessary. At this juncture Mr. Penn instituted an exhaustive series of experiments with various kinds of metal and wood, and the result was the application of lignum-vitæ bearings to the screw shafts of steamers. He patented the invention in 1854, and, as usual, his patent was infringed by many shipbuilders. He proceeded against them by law, and in every case his rights were upheld. The first vessel fitted with the lignum-vitæ bearings was the "Malacca." It had previously given serious trouble with her outer screw-shaft bearings, wearing the metal away at the rate of $3\frac{1}{2}$ ounces per hour. The wood bearings introduced by Mr. Penn proved a thorough success, and after 15,000 miles steaming were found to have become worn to the extent of only $\frac{1}{32}$ of an inch. By this means the practicability of screw-propulsion was thoroughly established.

Thus Mr. Penn's success was the result of a constant study of his profession. He devoted his whole life to his work. He was alike great as a mechanic, as an engineer, and as a man of business. He had a keen insight into men. He rapidly took the gauge of character. Hence his knowledge of the men best fitted to help him in his work. His partners, Mr. Hartree and Mr. Matthew, once his apprentices, were his devoted friends and helpers. The patent for the trunk engine was taken out in the names of the three partners. While never allowing the absolute control of the business to pass from him, Mr. Penn found in them such true friends that he was enabled to take at intervals considerable periods of rest, so necessary to one whose activity and powers of work were so large. Mr. Hartree and Mr. Matthew, now sometime deceased, were both Members of the Institution of Civil Engineers.

Superiority in every respect was his chief aim. "I cannot afford," he said, "to turn out second-rate work. I must have the best workmen and the best materials." The engines con-

structed by him were distinguished for their elegance and their symmetry. They were skilfully designed, and were so artistically finished that they might have graced a drawing-room. At the Paris Exhibition of 1867 he exhibited a pair of marine engines, which, though they were of no great size, left other competitors far behind. Their finish and their simplicity attracted the admiration of all competent observers. Mr. Penn was there at the time, and it was observed that his merit was only excelled by his modesty.

Mr. Penn was elected an Associate of the Institution of Civil Engineers in 1826, and was transferred to the class of Member in 1845. He served on the Council from 1853 to 1856. He was elected a Member of the Institution of Mechanical Engineers in 1848, and occupied the Chair as President in 1858–9. He was a second time elected to that position in 1867–8. He read several Papers before that Institution. In 1859 he was elected a Fellow of the Royal Society, and in 1869 he was elected an Honorary Member of the Society of Engineers.

Early in 1847 Mr. Penn married Ellen, daughter of the late Mr. William English, of Enfield, and leaves four sons and two daughters. In 1872 he took his two elder sons into partnership, and retired from the more active duties of the business. In 1875 he retired absolutely from the firm, his two sons becoming the heads of the establishment, which employs upwards of 2,000 men.

Mr. Penn was endowed by nature with rare social qualities, and was of a most hospitable disposition. For many years he assembled large numbers of guests at the Cedars, Lee. There might be seen men of the highest distinction in art, science, and literature—the best engineers, the best painters, the best philosophers. The summer-evening gatherings were looked forward to with pleasure; they were enjoyed with delight, and left many happy remembrances.

Towards the end of his life Mr. Penn became paralysed in his lower limbs, and later he became blind. Though he felt most keenly the gradual loss of his best sense, nothing could exceed his patience and his gentleness. He was most resigned and cheerful. His wife and family were always about him, and did all that they could to cheer and amuse him in his affliction.

When old friends called he amused them with his infinite fund of anecdote, for he had a wonderful memory. He was pleased to

speak of the early engineers, and of those who had helped him on in his successful journey through life.

Although to a certain extent bedridden, when the summer-time came, he was carried on board his beautiful yacht the "Pandora." He remained in the covered cabin, and visited the Loire, or the Seine, or the coast of France. In like manner he visited Belgium and Holland, sailing along the great canals. One of his last visits was to the coast of Italy. When the steam yacht stopped at a seaport town visitors flocked on board to see the ship. Mr. Penn was always glad to chat with them in their own language, whether it were French, German, or Italian.

He died on the 23rd of September, 1878, at the age of seventy-three; and thus passed away a great man, one of the most distinguished workers of this age and country.

Mr. WILLIAM WEST, the second son of a family of fifteen, was born in 1801 at Dolcoath, near Camborne. He was one of the many men born in that district who have raised themselves to prominent positions in the world by their industry and talents, and who have left their mark on their day and generation. Mr. West's father was connected with the famous old mine of Dolcoath, for which he managed the mine farm, and was also accustomed to buy the horses required by the adventurers. His son William received but a scanty education at a dame school. While still very young he was put to work on the mine, first at the surface, and then underground with his brother-in-law, Thomas Opie. His health failing, he stopped work for a time, but afterwards resumed it for a while, working on tribute with a young fellow of his own age, named John Rabling, who afterwards became manager of some important silver mines in Mexico. Mr. West and Mr. Rabling remained fast friends all their lives. Renewed ill-health at the age of seventeen compelled young West finally to abandon mine work, and it was not long before an opportunity arose for carrying out a long-cherished wish of becoming an engineer. This was at the time when great improvements were being made in the steam engine, by a notable band of Cornish engineers, of whom Trevithick, Woolf, Andrew Vivian, and Hornblower were among the chief. Trevithick was engaged on his Cornish boilers, his high-pressure "puffer" engines, and his locomotive. Mr. West always