

at the Tidnish end, where the converse operations would be effected to enable the vessel to resume her ocean voyage. Messrs. Easton and Anderson constructed the lifts and Messrs. Handyside and Co. the cradles.

While still fighting against adverse circumstances and—the financial difficulties having been overcome—seeking an extension of time from the Canadian Government to complete the work which had occupied so many years of his life, Mr. Ketchum, who had been in indifferent health for some months, died suddenly at Amherst, Nova Scotia, on the 8th September, 1896. His enthusiasm and confidence in the ultimate completion and success of this great undertaking never wavered. With persistent, earnest effort he devoted himself for fifteen years to the promotion of the enterprise with which his name is identified, and, although baffled when the work was within sight of completion, he never lost hope and was ready to stake all in support of his opinions. Some months before his death he had selected the spot, on the site of the great work of his life, where he now rests.

Mr. Ketchum was elected an Associate on the 1st May, 1866, and was transferred to the class of Members on the 30th April, 1878.

DAVID KIRKALDY was born at Mayfield, near Dundee, on the 4th April, 1820. As a boy his health was very precarious, and the nervous and highly sensitive disposition which this engendered remained a characteristic throughout life. He was educated under Dr. Low of Dundee, and at Merchiston Castle, Edinburgh, where he studied for some years, attending lectures also at the University. An interesting recollection was his discovery that his bedroom in the Castle had been the study of Napier, the celebrated mathematician and author of the system of logarithms. Kirkaldy had already developed a taste for experimenting (in those days it took the shape of chemistry) and was devoting a Saturday afternoon to laboratory work. Happening to burst a retort, or some vessel, and splashing the wall, he attempted to dry it, but in doing so removed the distemper, when he found traces of geometric figures and diagrams on the wall. The principal, Dr. Chalmers, had the walls carefully cleaned down, bringing to light many interesting souvenirs of the mathematician's work.

On leaving Merchiston, Kirkaldy returned to Dundee and worked in the office of his father, a merchant and shipper. But mercantile work was sorely against his inclinations, although, to please his

father, he honestly tried to like it. His career might have been confined to this sphere, but owing to the kindness and foresight of Mr. Erskine, of Linlathen, he was entered in 1843 as an apprentice in the works of Mr. Robert Napier,¹ the shipbuilder, at Glasgow. All through life Kirkaldy remembered this act of kindness and spoke often of it. He gave himself up entirely to engineering and, besides working all day, devoted his evenings to special studies. His capacity for work, and his faculty for devoting himself to minute details, were prominently shown at this time, and before he had completed his apprenticeship he was promoted to responsible positions in his employer's works. Having a strong artistic bent, he took up drawing with keenness and, striking out a new line, astonished engineers with his productions of highly finished and artistically coloured drawings. He was awarded a medal for a series of five drawings at the Paris Exhibition in 1855, and in 1861 his beautiful coloured drawing of the steamship "Persia" was exhibited at the Royal Academy, the only instance, it is said, in which this honour has been accorded to an engineering drawing.

The strong bent of his mind for experimental work and research took the direction, while at Mr. Napier's, of investigating the best lines and forms of ships, and systematically recording the details of each ship and set of engines during construction and of their performances during trial-trips. His earnestness and enthusiasm in this pursuit brought him into much trouble. The foremen were mostly prejudiced, while others higher in authority were jealous of his advanced ideas and perhaps resented many improvements in details which he gradually introduced. The prejudice and undercurrent of feeling at last became so bitter that his employer was approached, and even induced to dispense with the trial-trip performances, to the regret of Kirkaldy, who saw plainly that the time was coming when shipbuilders would require to estimate for and to build and engine ships to rigorously defined requirements as to capacity, speed, draught, and, not least, low consumption of fuel. It had been his earnest desire to serve his master to the utmost of his power in this direction, by faithfully collecting in good time a vast accumulation of data and experience upon which to act in future, and with the confident hope that thereby the firm would be able to more than hold its own against rival competition. The evenings of more than ten years had been devoted, without fee or reward, to the collection and classification

¹ Minutes of Proceedings Inst. C.E., vol. xlv. p. 246.

of data and details in an accessible form of all the vessels and engines constructed at the works.

Although disheartened at this treatment, his energy soon found vent in another channel, which eventually was to prove his life-work and bring him wide reputation. In 1858 Napier received orders for some high-pressure boilers and marine machinery in which lightness combined with strength was an important factor. It was proposed to use homogeneous metal for the one, and puddled steel for the other, instead of wrought-iron as ordinarily employed. In connection with this order, Kirkaldy was selected by the firm to devise apparatus for, and to make experiments to ascertain the relative merits of, those at that time new materials. The original intention was only to make a few experiments upon each variety, but the investigation proved so interesting in itself, and so likely to lead to important results, that he was induced to extend the experiments considerably; and he obtained the sanction of Messrs. Napier for doing so as opportunity offered. For the purpose of carrying out these operations he designed and erected a testing machine; the testing was commenced by him on the 13th April, 1858, and terminated on the 18th September, 1861. He entered into the work with characteristic earnestness, and during that period carried out a large number of experiments of an interesting and important nature. He also tested the iron plates and angle-bars used in the construction of H.M. armour-cased ships "Black Prince" and "Hector." The Scottish Shipbuilders' Association, having obtained the sanction of Messrs. Napier for the results to be laid before it, Kirkaldy forthwith prepared a Paper. The reception given to this effort led to the publication, in 1862, of the tests in a more extended form as a book, entitled "Results of an Experimental Inquiry into the Tensile Strength and other Properties of various kinds of Wrought Iron and Steel."¹ Some of the investigations recorded in that work are worthy of particular mention on account of the far-reaching consequences which they were the means of inaugurating. The most important was the service David Kirkaldy rendered in discovering, and placing on record therein, the effects of oil-hardening upon the properties and behaviour of steel. It had not previously been imagined that by heating steel and cooling it in oil its strength would be greatly enhanced without sacrificing its toughness. Knowing the importance of this process of oil-hardening, he took out a provisional patent for its application.

¹ This book is in the Library of the Institution.

In 1864 the Institution of Engineers in Scotland awarded him a gold medal for his communication "Experiments on Iron and Steel."¹ It may be mentioned that in 1857 Kirkaldy had a share with several others in the inception of that Institution. Another service was rendered to engineering knowledge by the publication of the results of his researches as to the "effects of shape" on the behaviour of metals, one outcome of these results being the adoption of an improved form of bolt for securing the armour plates of ships.

The experience thus gained, coupled with the success of his book, encouraged Kirkaldy to study the question of testing more deeply. After anxious consideration, he determined to erect a special testing-machine at his own cost, and to devote all his energy to the investigation of the mechanical properties of materials used in the constructive arts. He had resigned his post at Messrs. Napier's towards the close of 1861, after being in their service nineteen years, and had devoted two and a half years to the study first of the nature of the tests which would be required for the various materials, and then of the mechanical difficulties to be overcome in a machine which would be suitable for the full range of such tests, and at the same time very accurate and delicate in its action. The construction of his testing-machine was commenced in June, 1864, but was not finished until September, 1865, the long delay in making it causing him great anxiety and considerable pecuniary loss. The machine was erected in premises in The Grove, off Southwark Street, London, and public testing operations were commenced on the 1st January, 1866.

For many years Kirkaldy experienced great difficulties; his testing work was opposed by interested parties and prejudice had to be overcome. Although essentially a man of peace, he found himself on several occasions driven to defend himself against unjust attacks. Working quietly for many years, he carried out a vast number of experiments, and was the means of introducing many useful and important improvements; for example, in the form and proportions of bridge-link eyes, tie-rod ends, the true relations of welding, the shape of railway axles, and also in a great many details of engines of different kinds, the form of coupling gear, and hooks and screws for railway work, in which he was able to increase the strength considerably while reducing the weight. His experiments on riveted joints led gradually to great modifications and consequent improvement in the style of riveting for bridge-work. In the face of severe opposition he

¹ Transactions of the Institution of Engineers in Scotland, vol. vi. p. 27.

proved the importance of drilling holes in steel in preference to punching, fearlessly pointing out the detrimental effect and the risk of punching holes.

As time went on Kirkaldy found that it was desirable to obtain larger premises, and, in order to have works adapted for his requirements, he decided to build. Selecting a site in Southwark Street (No. 99), he erected the present premises; the machinery was moved and re-erected there, and testing operations were renewed on the 1st January, 1874. No expense nor trouble was spared to render every department as perfect as possible, and from a merely business point of view he invested too much in apparatus and tools; but his enthusiasm for experimental research remained so keen that even during the last year of his life he cheerfully laid out a considerable amount on new machinery and tools in order to be able to carry out work more promptly. Among his more recent work mention may be made of an interesting series of experiments on the condition of steel rails after long-continued service, for which he received the thanks of several leading railway engineers.

In December, 1888, Kirkaldy was deeply gratified by a notification from the Court of the Worshipful Company of Turners that it had been resolved to confer upon him the Honorary Freedom and Livery of the Company in recognition of his life-work. The Freedom of the City of London also accompanied this honour. In all his trials he was cheered by the friendship of those who valued his labours and appreciated the sterling honesty of the man. Imbued with a lofty sense of truth and honour, ardently striving to carry out his work impartially, he was almost recklessly regardless of consequences. He would unflinchingly act up to what he considered right, often seeing clearly in advance that it would entail serious pecuniary loss and also tend to increase prejudice against him and his work. Realizing this, as he did, it is the more to his credit that he would not turn or prevaricate in order to gain support. His sensitive nervous system rendered it specially hard to bear the many worries inseparable from the position he had devoted himself to fill. In Kirkaldy's case the office of judge, ever considered a difficult one, was rendered more arduous not only by his staking everything he possessed in providing apparatus and premises, as an additional guarantee of responsibility, and by carrying out tests personally, but also by his being dependent for his livelihood upon the support of the persons who came to him often to settle very important issues. He fearlessly and consistently acted up to what appeared to

him to be right, and he lived long enough to see his work widely acknowledged. While unflinching in his professional life, privately he always retained his genial and lovable nature. Probably many misunderstood him simply through not knowing him. He was so scrupulous, even jealous, in maintaining the line of action which he had marked out for himself that he could not easily brook dictation or thwarting. One of his strong points was a desire for, and adherence to, Standards. When inaugurating his elaborately complete system of testing materials, the ground was clear, and every minute detail was carefully considered by him before adopting his standards. He was an ardent advocate of the adoption by engineers of definite, carefully-sifted, standard specifications, standard sections for rails, and uniform requirements for steel axles, locomotive and carriage tires, &c., all of which he considered would prove of immense advantage to British manufacturers, as they could then readily work up their productions to a given uniform standard. He had always looked forward to publishing a summary of his experimental work, so as to render it accessible to the profession. The opposition he had to contend against delayed the fulfilment of this intention, and ultimately he was glad to leave the work to his son, Mr. William G. Kirkaldy, whom he assisted in its compilation. The book, entitled "Strength and Properties of Materials, with description of the System of Testing," was published in 1891.¹

During the last year or two his health failed considerably; but he was cheerful and genial to the last, and took pleasure in knowing details of experiments, although for several months he was physically unable to carry out tests personally. From about September, 1896, he gradually became weaker, but his mental faculties remained wonderfully clear. He passed away peacefully in the early morning of the 25th January, 1897.

Mr. Kirkaldy was elected a Member on the 3rd March, 1885.

ALFRED RUMBALL, born in London on the 10th August, 1831, was the youngest son of Mr. Thomas Rumball, of Epping, and the stepson of Captain A. Vere Drury, R.N. He was privately educated at Mortlake and at an early age became a pupil of his brother, Mr. Thomas Rumball. Subsequently he was for seven years in the office of Mr. Thomas Bartlett,² who was then engaged on the construction of the London section of the Great Northern Railway for

¹ This work is in the library of the Institution

² Minutes of Proceedings Inst. C.E., vol. xxiv. p. 526.