the radial velocities of the individual stars in star-clusters in the extra-galactic nebulæ, and a wide variety of other uses is foreshadowed for which the lens is peculiarly fitted owing to its extreme rapidity.

Dr. Hale, in a letter describing some of the results already obtained, refers to the lens as "a great success optically", and expresses his congratulations on "a truly remarkable achievement". It reflects great credit on the optical industry of Great Britain to have produced a lens having such outstanding possibilities.

Matthew Boulton as Scientific Industrialist

THE commemoration in January last of the bicentenary of the birth of James Watt naturally directed attention to the notable part taken in the development and application of the steam engine by his partner Matthew Boulton, and in his "James Watt, Craftsman and Engineer", Mr. H. W. Dickinson expresses regret that hitherto no separate biography of Boulton has been written (see NATURE of January 25, p. 129).

The career of Boulton, of course, has not escaped the writers on Watt and the steam engine, and Smiles in particular dealt at considerable length with many of his activities. But the life of Boulton, relating to which we imagine there is much unexplored material, deserves still closer study, for in the history of the industrial progress of Great Britain during the latter half of the eighteenth century, there is no more engaging figure. He was a man of admirable character, broad-minded, generous, energetic and far-sighted, displaying many of the attributes of a statesman. Unlike many of his contemporaries in the field of industry, he started life with social advantages, and early in life was a man of means. But if, as he himself declared, he loved money-getting projects, he was still more concerned that nothing but the highest standard should be aimed at, whether it was in connexion with his own affairs or those of the nation. As a captain of industry he had no equal, and was alike at home whether dealing with his employees, his partners, privy councillors or prime ministers.

Boulton was the senior of Watt by more than seven years, having been born in Birmingham in September 1728. The two first met when he was nearly forty years of age, and was the head of the largest manufacturing concern in the country. His father had begun as a silver stamper and piercer, and when he died in 1759 he left his son a well-established business for the manufacture of trinkets, steel buttons, buckles and the like. In 1762, Boulton married Ann Robinson of Lichfield and with her came a fortune of £28,000. This accession of wealth, instead of diminishing his interest in trade, enabled him to launch out on new ventures and he proceeded at once to erect the famous Soho Manufactory about two miles north of Birmingham, having for his partner John Fothergill. When completed, the Manufactory could house six hundred workpeople, and by 1767 the firm had a turnover of £30,000. No mean inventor himself, versed in the science of his day and possessing artistic tastes, Boulton introduced new machinery and processes, and was at as great pains as Wedgwood to apply art to industrial products. He had agents in many foreign capitals, his showroom in London was visited by dukes and lords, and at his house at Soho he dispensed a princely hospitality.

Like other manufacturers, one of the problems Boulton had to face was that of power supply, and one of the reasons for placing the factory at Soho was that water-power could be obtained from the Hockley Brook. The supply, however, was unreliable, and even before Watt first visited Birmingham, Boulton had already considered the proposal to instal a 'fire engine' for pumping the tail race water from the water wheels back to a reservoir. When Watt went to Soho in August 1768, Boulton was, therefore, ready to seize on any project which would effectively overcome his difficulties, and it is a remarkable tribute to his judgment of men and to his insight into the future of the steam engine that, although no patent had yet been secured and no full-sized engine erected embodying Watt's principle of the separate condenser, Boulton was ready at once to stake his all on the success of the new engine.

The patent was secured in January 1769 and a month later Boulton wrote to Watt that his "idea was to settle a manufactory near to my own by the side of our canal where I would erect all the conveniences necessary for the completion of engines, and from which manufactory we would serve all the world with engines of all sizes". Though in his short intercourse with Boulton he had conceived a great liking for him, to the nervous, desponding and impecunious Watt such a scheme might well have appeared rash, almost to madness, and as a matter of fact five valuable

years were allowed to slip by before Boulton saw his way clear to carry his plans into effect.

Without attempting to trace again the interesting story of the development of the engines with which the names of Boulton and Watt are inseparably connected, it may be said that if Boulton claims our admiration as a judge of men, an industrialist and an organiser, he also deserves recognition as one of the few manufacturers of his time who were devoted to scientific pursuits. Had he lived to-day, he would undoubtedly have been one of the keenest advocates of scientific research for industrial purposes. As a boy he studied mechanics and chemistry, in middle age he was one of the most prominent figures in the celebrated Lunar Society, which included among its members Watt, Priestley, Wedgwood, Withering, Erasmus Darwin, Keir and Galton; and when immersed in the difficulties of negotiations with Cornish miners could write: "chemistry has for some time been my hobby-horse . . . I am almost an adept in metallurgical moist chemistry. I have got all *that* part of Bergmann's last volume translated, and have learnt from it many new facts". Years before, in 1757, when in correspondence with Benjamin Huntsman, the pioneer of the steel industry of Sheffield, he wrote: "I hope thy Philosophic Spirit still laboureth within thee, and may it soon bring forth Fruit useful to mankind, and more particularly to thyself".

The philosophic spirit possessed Boulton all his life, and when seventy years of age and holiday-making at Cheltenham, he must needs have his chemical apparatus so that he could make careful analysis of the waters of the place, the results of which were all duly entered in minute detail in his memorandum books.

The chief activity of the later years of Boulton were connected with the improvement in coining and the coinage of the country. He improved the processes of minting out of all recognition, and at Soho laid down a plant which for many years served as a model for this and other countries. In his enterprise he showed the same thoroughness, the same power of organisation, the same appreciation of the application of science and art to a great practical need that marked his work on the steam engine.

Obituary

Sir Joseph Petavel, K.B.E., F.R.S.

BRITISH applied science suffered a grievous loss in the death of the director of the National Physical Laboratory, Sir Joseph Petavel, on March 31. Sir Joseph, who was sixty-two years of age, was second director of the Laboratory, succeeding Sir Richard Glazebrook in 1919 and surviving him by only a few months.

Sir Joseph, who was born in London on August 14, 1873, was a son of the late Rev. E. Petavel. He received his early scientific training at University College, London, under Sir Ambrose Fleming, with whom he collaborated in his first published paper, on the alternating current arc. With the aid of an 1851 Exhibition Scholarship, he then worked under Dewar for three years at the Royal Institution and Davy Faraday Laboratory, where he studied the thermal emissivity of platinum at high temperatures and pressures. In later years he had many reminiscences to tell of his experiences at the Royal Institution.

Then came Petavel's election in 1900 to the John Harling research fellowship at Owens College, Manchester, following which he became lecturer in mechanics under Schuster. He published notable contributions on very high pressures as generated, for example, by solid and gaseous explosives. In 1904 he was responsible at the St. Louis Exhibition for the management of the liquid-air plant which was shown by the British Royal Commission. Four years later, Osborne Reynolds resigned the chair of engineering, and Petavel was elected in his place as professor of engineering and director of the Whitworth Laboratories at the University of Manchester. Further outstanding papers had meanwhile been published jointly with R. S. Hutton, on electric furnace reactions under high pressures and the effect of pressure on arc spectra.

About this time Petavel was developing an interest in meteorology and aeronautics, and collaborated in an investigation on kite soundings as applied to upper-air temperatures. In 1909 he became a member of the original Advisory Committee for Aeronautics, and presently took up the study of the stability of aeroplanes. His enthusiasm led him to qualify as a pilot, an accomplishment by no means free from danger with the experimental aeroplanes of those days. It was during this period that he was the victim of a serious accident which might well have proved fatal, and indeed left its mark on him all his life. When the Aeronautical Research Committee was formed in 1917, Petavel was appointed chairman of the Aerodynamics Sub-Committee and a member of several of the other sub-committees. He also served as vice-chairman of the main Committee for many years until his death. In these various capacities he exercised a profound influence on the progress of aeronautical research in Great Britain.

From 1911 until 1916 Petavel had been a member of the General Board of the National Physical Laboratory, and when the directorship of the