The Bicentenary of Thomas Newcomen.

AMONG the vast number of ingenious inventors whose work is the heritage of to-day, a prominent place must be accorded to Thomas Newcomen, who invented the atmospheric steam engine. Newcomen died in London on Aug. 5, 1729, two hundred years ago. Steam power, which is now of universal application, drives our factories, propels our ships, transports our trains, and waters, drains and lights our cities, raises our minerals, ventilates our mines, irrigates our fields, and ministers to our needs in a thousand ways. If for certain purposes oil and gas have displaced steam, it should be remembered that the first airship, the first aeroplane, and the first self-propelled carriages were driven by steam, and the internal combustion engine itself owes much to the steam engine.

Newcomen's first engine, that near Dudley Castle, was erected in 1712. Fifty years later, similar engines were to be found all over Europe, and a hundred years after that the total horse-power of the steam engines of the world amounted to some twenty millions, while to-day this total runs into hundreds of millions. Whether we contemplate the crude constructions of Newcomen, the stately beam engines of a later day, the whirling high-speed engines which drove some of our first dynamos, or the magnificent machinery found in our ships and power houses to-day, we cannot but admire the skill, ingenuity, and resource which has given man so adaptable and so powerful a means of multiplying his efforts. The steam engine, indeed, has changed the character of our civilisation, and among all the hundreds of men who have applied their minds to the problem of steam power, none deserves recognition more than Thomas Newcomen.

"The engineer", it has been said, "pre-empts and conveys to society the benefits of the experiments and discoveries of the scientist. This contribution is vital; for he finds practical and economic obstacles that tax his ingenuity to the utmost; and the joy of solution, coupled with the satisfaction of achievement, is his reward. For success he needs all the knowledge the pure scientist has acquired and all the experience the man of practical arts has accumulated." This interdependence of abstract science and engineering progress is nowhere more clearly manifest than in the history of the steam engine. The engine of Newcomen was the outcome of the application of the physical discoveries of the seventeenth century; the greatest improvement in the engine during the eighteenth century was due to the discovery of the theory of latent heat by Black and Watt, while the appearance of Rankine's treatise on the steam engine in 1859, in which for the first time a sketch of the new science of thermodynamics was incorporated, marks another epoch in its progress.

The discussions of the present time on the properties of steam and the refined investigations on its pressure and temperature which are being made in a score of laboratories, have their seeds in the studies of the natural philosophers of Italy three hundred years ago, from which came the first thermometers and pressure gauges. Speaking of the applications of the forces of Nature to the promotion of human welfare, Simon Newcomb wrote: "The superficial observer who sees the oak but forgets the acorn, may tell us that the special qualities which have brought out such great results are expert scientific knowledge and rare ingenuity, directed to the application of the powers of steam and electricity. From this point of view the great inventors and the great captains of industry were the first agents in bringing about the modern era. But the more careful inquirer will see that the work of these men was possible only through a knowledge of the laws of Nature which had been gained by men whose work took precedence of theirs in logical order, and that success in invention has been measured by the completeness of such knowledge. While giving all due honour to the great inventors, let us remember that the first place is that of the great investigators, whose forceful intellects opened the way to secrets previously hidden from men." In doing honour to Newcomen, we therefore pay homage not only to a great inventor, but also to those students of science through whose work the steam engine became possible.

Of the Newcomen steam engine we know a great deal; of Newcomen's life very little. Born at Dartmouth and baptized in St. Saviour's Church on Feb. 28, 1663, he was the son of an Elias Newcomen and great-grandson of another Elias, who graduated at Cambridge in 1568–69, and for many years was rector of the pleasant parish of Stoke Fleming, near Dartmouth. Newcomen himself learned the trade of an ironmonger at Exeter, and afterwards had a business of his own in his native town. But no particulars from which we can form an estimate of his character have come down to us. His fellow-countryman, Thomas Savery, was his senior by about ten or a dozen years, and it was these two Devonshire worthies who first attempted to use fire and steam for pumping water for mines.

Savery's patent was obtained in 1698, and this included the plan of obtaining a vacuum by the condensation of steam. But prior to Savery's patent had come the invention of the barometer, the measurement of the pressure of the air, the invention of the air-pump, and the work of Torricelli, Pascal, and von Guericke had been succeeded by that of Boyle, Mariotte, and Hooke. Then, too, Huygens had made a piston descend by the weight of the atmosphere after he had obtained a vacuum beneath it by the explosion of gunpowder, and Denis Papin had afterwards suggested the use of steam instead of gunpowder.

This was the pregnant suggestion which was employed in very different ways by Savery and Newcomen—by the former unsuccessfully; by Newcomen with far-reaching effects. Newcomen's engine was like a gigantic balance. At one end of a great beam hung the pump rods ; at the other hung a piston working in a cylinder, the cylinder being closed at the bottom and open at the top. The action of the engine was simple in the extreme. The cylinder having been filled with steam from a boiler beneath it, a spray of water was admitted to condense the steam and to form a partial vacuum. When this had been accomplished, the atmospheric pressure caused the piston to descend, thus raising the pump rods.

After the erection of the Dudley Castle engine in 1712, others were set up in Cornwall, Flintshire, the Newcastle-upon-Tyne area, London, Königsberg, Cassel, Paris, and in Sweden. No patent was ever taken out by Newcomen, but Savery's patent was considered to cover Newcomen's plan. The method of working naturally resulted in a great expenditure of fuel—about 25 lb. per horse-power per hour—but engines of the type were made until the beginning of the nineteenth century, and one or two were at work within the last twenty years.

The first great improvement in the engine came with Watt's experiment with the Newcomen engine model, still preserved at the University of Glasgow, which led to the invention of the separate condenser in conjunction with an air pump, a system which, as is well known, is still used in all condensing engines.

For a very long time Newcomen's merits were but little recognised. The Dartmouth antiquary, Thomas Lidstone, in 1857, and again in 1873, advocated the erection of a memorial to him at Dartmouth, and the project was at last carried out in 1921, the memorial consisting of a block of Dartmoor granite on which is a bronze plate with a line drawing of Newcomen's engine and an inscription.

Some Problems of Cosmical Physics, Solved and Unsolved.[1]

By Lord RAYLEIGH, F.R.S.

THE NEBULAR AND AURORAL SPECTRA.

AFTER the first period of success in identifying the origin of the spectral lines of the sun and stars with terrestrial materials, certain outstanding cases remained which were obviously important, but in which the identification could not readily be made. The first of these cases to yield was that of helium, which was unravelled while some of the pioneers in astronomical spectroscopy were still active.

Kindred to the hypothesis of helium, so triumphantly vindicated by terrestrial experience, were the hypotheses of nebulium, geocoronium and coronium. The problems epitomised by the two former words have now been solved, though the solution has taken quite a different turn from what was expected by the older generation of astrophysicists.

In the nebulæ are spectrum lines which have never been observed terrestrially. These are not faint members of otherwise complex spectra, such, for example, as we have in nearly all remaining unidentified lines of the solar spectrum, but they stand out, bold and challenging, on a dark background, presenting a puzzle that was the more intriguing from its apparent simplicity. According to spectroscopic experience, now made precise and rational, simple spectra are due to light elements. This, taken with the fact that lines known to be due to hydrogen and helium accompanied the nebular lines, strongly suggested that they too were due to light elements of the class which terrestrially are known as permanent gases. But the fact remained that no one had succeeded in observing them in the laboratory, and as time went on the originally convenient resource of relegating them to an unknown element had become less convenient. For the scheme of the elements became definite, and there was no room in it for new light elements.

More systematic knowledge of spectra in general, and of the spectra of the light elements in particular, was wanted before the question could be resolved. The clue was afforded by the circumstance that important nebular lines occur in pairs, obviously associated by their closeness and their constant relative intensity in different nebulæ and in different parts of the same nebula.

It is found, then, that the frequency difference of the green pair of lines originally discovered by Huggins, and known as N_1 and N_2, is 193 waves per centimetre. I. S. Bowen, to whom we owe the final elucidation of this enigma, sought for an equal interval in the spectrum of doubly ionised oxygen which he was analysing, and found it in the interval between the low-lying levels designated as P_2 and P_1. The lines were attributed to intercombination between one singlet upper level and two lower levels belonging to a triplet, the third being excluded by the rule of inner quantum numbers. To fix the differences of the terms concerned, it was necessary to connect the singlet and triplet levels by an intercombination line observed in the laboratory spectrum of doubly ionised oxygen. This was done by A. Fowler, who, combining Bowen's laboratory data with his own, was able to get a fairly satisfactory check on the observed position of the nebular pair. Practically no doubt remains, in view of the fact that other less well-known nebular lines can be similarly explained as due to singly ionised nitrogen and singly ionised oxygen.

The identification of these lines was made by ignoring so far as convenient the rules of the quantum theory. These rules forbid certain lines which might occur according to the combination principle. When a state of excitation of the atom is such that it cannot directly pass to a lower state without breaking one of these rules, that state is called metastable ; and this is the case which we have in the nebular lines.

The next cosmical problem I wish to refer to is the long outstanding one of the green line of the

[1] From the presidential address to Section A (Mathematical and Physical Sciences) of the British Association, delivered at Cape Town on July 24.