the retorts in return for a small extra capital expenditure and the cost required to drive the fan on the outlet boilers. The author points out in this connection what is so frequently ignored by the less informed advocates of low-temperature carbonisation, that in the continuous vertical retort a really fractional distillation can be attained. "The products of distillation are driven away as made, and have to pass through no higher temperature than that at which they are evolved, whilst if water-gas is made at the same time in the retort by steaming, this process protects the hydrocarbons and gives a greater quantity of a lighter quality tar." The weakness of gasworks practice, from the author's point of view, is that the coal has to be conveyed to the gasworks and the coke removed from it.

In dealing with coke-ovens it is argued that they meet a definite but limited demand for a specific article, namely, hard coke for blast-furnace work, and that on this account the erection of coke-ovens for supplying gas- and tar-oils to meet national needs is not feasible.

The author turns aside for a moment to indicate the possibility of using much more coke-oven gas for town supply, and points out that the chief difficulty in the way at present is the variation in its quality. That difficulty is not, however, insuperable.

He expresses, too, a belief that gas will in the future be used instead of coke in the smelting of iron-ore, but it is possible that in coming to that conclusion the high output and efficiency of a modern blast-furnace plant have not been taken sufficiently into account.

Sir Arthur does not regard gas-producers very favourably, though he admits their power of giving a large supply of heat-units in the form of gas at a low cost. His main criticism is that the tar-oils recovered are not valuable. "The condition in which they come from the plant makes them difficult to work up, and, according to the tar distillers, the final products do not compare at all favourably in value with the final products from other methods of destructive distillation of coal." In justice to the gas-producer it may be pointed out, however, that most of the criticisms under this head might be applied equally well to products of other processes of low-temperature distillation, and often mean simply that the tar is very poor in aromatic constituents, different from gasworks tar, and cannot be worked conveniently along with it.

In speaking of low-temperature carbonisation the author makes the pertinent observation that its advantages are too obvious. He goes on to indicate that the difficulties it presents are very real, and, of course, it cannot attain his ideal because so much of the fuel is finally left in the solid form.

The whole of these considerations and criticisms of the shortcomings of different processes have been leading up to a proposal of something different—total gasification in some form of plant which differs from a gas-producer in that air is not used for gasification of the fixed carbon, and, therefore, nitrogen in quantity is not present in the gas. "The principle of this process is the partial carbonisation of coal in a vertical retort superimposed on a water-gas generator, the retort being heated externally by means of the products of combustion of the producer during the blow period, and internally by the passing of the water-gas made up through the charge in the retort."

This comprehensive survey ends with the formulation of an ideal system of manufacture to meet the demands for liquid and gaseous fuels. It is to gasify coal completely, preferably in one vessel, recovering in a liquid form the maximum amount of volatiles in the coal (working with any coal) and preserving the resulting ammonia. It would be of the combined vertical retort water-gas-producer type, with recuperators, waste-heat boilers, and mechanical arrangements making for labour-saving and for high thermal and chemical efficiency. It is to the treatment in some such plant as this that the author looks for increasing our home-produced oil-fuel supplies, and no doubt he is willing to take his share in the skilful design and careful experimental work involved.

Sheep Panics.

A SHEEP panic on the night of December 10–11, in which the sheep broke their folds in twenty parishes in an area extending some twenty miles in the highest part of Cambridgeshire, has been attracting attention. These panics have often occurred, for sheep are notoriously timid and nervous animals. On November 3, 1888—an intensely dark night, with occasional flashes of lightning—tens of thousands of folded sheep jumped the hurdles and were found scattered the next morning. Every large farm from Wallingford to Twyford was affected, and those on the hill country north of the Thames most so. Again, on the night of December 4, 1893, another very remarkable panic among sheep occurred in the northern and middle parts of Oxfordshire, extending into adjoining parts of the counties of Warwick, Gloucester, and Berks.

Various causes for these panics have been suggested, but only one reasonable explanation has been satisfactorily adduced. The 1893 panic was, at the time, fully investigated by Mr. O. V. Aplin, who published in the Journal of the Royal Agricultural Society the result of his inquiries and the conclusions he drew from the extensive evidence collected. The conclusion arrived at was that the cause of the panic was simply thick darkness. Very few people, probably, have ever been out in a really dark night, and it is impossible for anyone who has not had this experience to imagine what it is like and the sense of helplessness it causes. That a thick darkness of this kind was experienced in the early part of the night of the recent panic (at a time agreeing with that at which, so far as was known, the sheep stampeded) was proved by abundant evidence. One report said that it was between 8 and 9 p.m. when such a thick and heavy darkness came on that a man could not see his own hand. Another witness wrote that a little before 8 o'clock there was an extraordinary black cloud travelling from north-west to south-east, which appeared to be rolling along the ground. The darkness lasted for thirty or forty minutes, and during that time it was like being shut up in a dark room. Later in the night—long after the panics—there were several flashes of lightning.

Mr. Aplin states that animals probably see perfectly well on ordinary dark nights, and we can imagine a bewilderment coming over them when they find themselves overtaken by a thick darkness in which they can see nothing. Folded sheep (and it was the small folds that the sheep broke most) in moving about would knock against their feeding-troughs and one another, and the first one that got a fright from this and made a little rush would probably come into collision with one or two others, and it would need nothing more to imbue the whole pen with the idea that there was some cause for fear. Then they would all make a rush, and their terror and the momentarily recurring incentives to, and aggravations of, it in the shape of collisions would only subside when the sheep had broken out and were in the open, clear of one another and of their troughs and hurdles.

If this is the explanation of the panic, then it is easy to understand why folded sheep are so much more likely to suffer than those lying in open fields. The heavy, oppressive atmosphere accompanying the thick darkness, the susceptibility of sheep to atmospheric disturbance, and their nervous and timid dispositions would all tend to increase the fright the sheep experienced. The cause of the panic being a cloud rolling along so low down as (apparently) to touch the ground, the tops of the hills and the high-lying ground would naturally be most affected; and this is observed to be the case, although locally the usual direction followed by thunderstorms has indicated a line along which sheep stampeded on nearly every farm.

The Work and Discoveries of Joule.[1]

By SIR DUGALD CLERK, K.B.E., F.R.S.

THE greatest generalisation in the early history of physical science was made late in the seventeenth century by Sir Isaac Newton when he enunciated the laws of motion and deduced from them the existence in space of attraction between planets and the sun. Mechanical science has been built up on Newton's fundamental propositions and discoveries. The discovery by Joule in the middle of the nineteenth century of the mechanical equivalent of heat and his suggestion and determination of the existence of an absolute zero, together with the adaptation of Carnot's cycle of 1824 to the theory of heat as a mode of motion, provide generalisations of equal importance to Newton's law of gravitation, and from them fundamental thermodynamic laws are deduced: the equivalence of energy in different forms, conservation of energy and dissipation of energy. Joule's discovery, in fact, called the modern science of thermodynamics into existence.

Manchester has been the home of many highly distinguished men—great scientific men, great inventors, and great masters of industry and business—but it is fortunate indeed in its connection with two of the greatest discoverers in the history of the world, Dalton and Joule. Joule read his first paper before the Manchester Literary and Philosophical Society in the year 1841 upon the subject of "The Electric Origin of the Heat of Combustion." He contributed a long series of papers from that year until 1879, a period of thirty-eight years, and he dealt with a great variety of subjects, including experimental investigations on the phenomena of the voltaic current, the determination of the specific heat of bodies, heat and constitution of elastic fluids, mirage, freezing point of thermometers, galvanometers, dip circle, solar photographs, duty of electro-magnetic engines, magnetic storms, polarisation of platinum plates, mercurial air-pumps, and telescopic oscillations.

The debt of the practical engineer to Joule and his great associates is very real, but the science of thermodynamics did not supply the fundamental laws from which heat-engines were invented and developed. The steam-engine had been developed by Newcomen, Smeaton, and James Watt long before the birth of the science of thermodynamics. What is true of the steam-engine is true also of the hot-air engine and the internal-combustion engine; all the known types of heat-engine at present in use were invented before the year 1850, and practical experimental examples of both hot-air and internal-combustion engines were then in operative existence. Thermodynamics supplied the laws of the conversion of heat into mechanical work by which these engines are governed; it explained the relative perfection of engines already in existence, but it did not create these engines. It performed the very important service of dispelling the errors of thought which hindered the future advance of heat-engines Such errors as to the theory of the regenerator and the theory of compression and expansion in all steam and internal-combustion engines, held by the most eminent engineers and scientific men so late as from 1845 to 1853, were rendered impossible by the splendid work of Joule, Kelvin, Rankine, and their Continental colleagues. The knowledge of thermodynamics has thus an increasing effect upon instructed engineers of the present generation. It is quite obvious that although the origin of heat-engines cannot be ascribed to Joule's work, yet the improvement and final development towards a maximum conversion of heat into mechanical work are rendered possible to the engineer of to-day by his great discoveries. Engineers and engine-designers are most grateful to Joule, and look back on his achievements as those of the utmost intellectual and practical importance.

Giant and Dwarf Stars.[2]

THE amount of light received from a star determines its *apparent magnitude* (m), the ratio for two stars differing by one magnitude being 2·512. The *absolute magnitude* (M) is what the apparent magnitude would be if the star were at the standard distance of 10 parsecs, which corresponds to a parallax of 0·1″. If π is the parallax of a star in seconds of arc,

$$M = m + 5 + 5 \log \pi.$$

In this equation m is not difficult to measure, and hence if π or M is determined the other can be found.

Russell took all stars for which fairly accurate values of π were available, and from the above equation computed M. Then, plotting M as ordinate and type of spectrum as abscissa, he found that (1) all white stars are far brighter than the sun; (2) range of brightness increases with redness; (3) all faint stars are red; and (4) all red stars are very bright or very faint.

Adams and Kohlschütter found that the relative intensity of selected lines in the spectrum of a star depended on the absolute magnitude from measurements on the spectrum. M being determined, the

[1] Abstract of the first Joule Memorial Lecture delivered on Tuesday, December 14, 1920, to the Manchester Literary and Philosophical Society.

[2] Abstract of a lecture delivered before the Royal Society of Victoria, Melbourne, on October 14, 1920, by Dr. J. M. Baldwin, Government Astronomer.