titanium carbide bonded with nickel or cobalt, in which the creep resistance of the material had proved to be adequate; but failure had resulted from insufficient resistance to the stress concentrations in the blade root. Confidence in this type of material has not yet been established, and its future seems to depend on the achievement of sufficient plasticity without loss of creep resistance.

The alternative way of achieving high inlet gas temperature is to cool the critical metal parts. The problem then is to secure the greatest effective cooling with the least loss of heat and energy in the cooling agent. There is little doubt that the most effective device is to interpose a stable blanket of cool gas between the hot gases and the surface to be cooled. Mr. P. Grootenhuis and Mr. N. P. W. Moore described how this can be done by leading a small quantity of liquid continuously to the surface through fine pores provided in the component. This is known as 'sweat cooling'. It can be readily applied to lightly stressed components, but not so easily to severely stressed components. It is possible that in view of the need for conserving scarce metals, and the improbability of a large and swift improvement of the available alloys, the correct policy for the next few years will be to stabilize the main types of creep-resisting alloy and concentrate upon the efficient use of cooling.

The second problem of the gas turbine is to increase the useful life of the engine from the thousand or so hours demanded of the aircraft engine to the ten thousand or hundred thousand hours required for most industrial applications, while at the same time adopting a cheap fuel, such as heavy fuel oil or pulverized coal. The need for more data on the behaviour of the new alloys over extended periods of time was repeatedly stressed. The difficulty of providing this information while the alloys themselves are being modified continuously has already been mentioned, and furnishes an additional argument for standardizing the alloys as soon as it becomes possible to do so. It was mentioned, however, that the performance of the gas turbine will be seriously diminished if unnecessarily long service lives are insisted upon. The use of cheap fuel introduces the danger of corrosion of the engine by the mineral constituents of the fuel, particularly by the fusible vanadium salts that are present in many fuel oils. Metallurgists could hold out no hope of finding a serviceable alloy that would resist contact with partially molten fuel ash, and looked to the oil technologists to remove, or render harmless, the objectionable constituents of the oil; but the oil technologists could suggest no method cheaper than distillation. It is to be hoped that the last word has not yet been said on this subject. Gas turbines have run successfully for short periods on vanadium-containing fuel oils without serious effects. Much can be done to minimize the danger of corrosion, and it may be that the importance of the problem is exaggerated; but it undoubtedly gives rise to much anxiety.

The immediate future appears to demand the detailed improvement of the existing types of alloy, as a result of which a gradual rise of the strength and reliability of components of all kinds will no doubt take place. The shortage of many essential metals overshadows the situation, and it will be necessary to ensure that the strongest alloys are not used where weaker ones would do, and that no excessive amounts of scarce elements are employed even to meet the most onerous conditions. A prolonged struggle between the more advanced ferritic alloys and the less developed austenitic alloys for use at temperatures between 550° C. and 650° C. is to be expected, with the austenitic alloys gradually yielding place. In view of the complexity of the alloys, all this work will call for a vast amount of metallurgical experiment and mechanical testing. How much improvement is to be expected? The opinion was expressed that the possibilities of the austenitic solid solution alloys based on iron, nickel, chromium and cobalt are approaching exhaustion; and although a somewhat similar opinion was expressed in 1924, it now seems rather unlikely that the temperatures to which these alloys will maintain their strength can be much increased. Improvements of the reliability with which the best properties can be secured are more probable. Some major discovery seems to be required before the service temperatures of gas turbine materials can be greatly increased: it will no doubt be made, but how and where cannot yet be foreseen.

N. P. Allen

OBITUARIES

Prof. V. F. K. Bjerknes, For.Mem.R.S.

Prof. Vilhelm F. K. Bjerknes, foreign member of the Royal Society, honorary member and Symons Medallist of the Royal Meteorological Society, who died at Oslo on April 9, 1951, was the doyen of meteorologists. V. Bjerknes, as he was generally known, was born on March 14, 1862, the son of C. A. Bjerknes, professor of mathematics at Christiania, himself a pioneer in the investigation, theoretical and experimental, of fluid motion. V. Bjerknes, during his education at Christiania, assisted in his father's investigations and afterwards worked in Germany under Hertz. He became specially interested in the (apparent) action at a distance of solids moving in a circulating fluid and the analogies with electrodynamics. After his appointment in 1893 as professor of mechanics and mathematical physics at Stockholm, he prepared his first important work, lectures on "Hydrodynamische Fernkräfte", issued in two volumes during 1900–2. He was later to indicate in a lecture at the Royal Institution in May 1924 the analogy between the forces on a rotating cylinder moving through a fluid and the forces on an aeroplane due to the circulation induced by the asymmetry of the wing. The forces, lifting the cylinder, at quite moderate speeds are substantial and can be exactly controlled by adjusting the speed of rotation.

In 1898 Bjerknes introduced into dynamical meteorology the concept of 'solenoids', the tubes formed by the intersection of a system of isobaric surfaces at unit intervals with a system of isosteric (equal specific volume) surfaces also at unit intervals. He showed that if C is the circulation around any closed circuit, $dC/dt = N$, the number of solenoids intersecting the circuit. He deduced that, for a fluid in equilibrium, N must be zero, and that if N is not zero, the induced circulation is in the direction which will bring the isobaric and isosteric surfaces into coincidence (or parallelism). Bjerknes thought at first that this would have very wide meteorological uses and he applied it to the sea breeze and the Indian monsoon. But he soon realized that the effect of the rotation of the earth, though small in the initial development of motion from rest, became of great importance in the major movements of the atmosphere, and that he must include with N a term $-2\omega \frac{dS}{dt}$, where S is the area of the projection of the circuit on the equatorial plane and ω is the angular velocity of rotation. He did this in 1901, and pointed out the fundamental deduction that a circuit acquires cyclonic or anticyclonic circulation according as it contracts or expands.

From this time, for the next twenty years, Bjerknes devoted his energies to the problem of approximate integration of the equations of motion of the atmosphere (and the ocean) as a necessary preliminary to a practical scientific method of forecasting weather. In this he had the assistance first of J. W. Sandström and then of many other collaborators, notably Th. Hesselberg, and from 1906 he received financial assistance for his investigations from the Carnegie Institution of Washington. There resulted "Dynamical Meteorology and Hydrography", a treatise designed to present in an ordered and rational form the principles and the practical aids to the development of meteorology and hydrography from the point of view of a mathematical physicist. The treatise was planned in three volumes; but only two were completed and issued, in 1910 and 1912. It emphasized the importance of a universal co-ordinated system of units and included the proposal, first put forward in 1906, to use absolute units of pressure, and introduced the terms 'bar' (megadyne per cm.^{2}) and 'millibar' as the practical units for hydrography and meteorology respectively. The millibar has now become established throughout the world in meteorology and aviation, though not yet in physical laboratories, still wedded to the mercury inch and mercury millimetre. The treatise included also the first explicit statement of the important result that the distance between contour lines on an isobaric surface in the atmosphere is an inverse measure of the geostrophic wind, independent of the density of the air. This has been the main factor in influencing meteorological services to use contours on isobaric surfaces instead of isobars on geopotential surfaces in the practical application of upper air observations.

Bjerknes had left Stockholm for Christiania in 1907, and five years later he went to direct the new Geophysical Institute at Leipzig. He gathered around him a band of workers and initiated two series of publications; one of actual synoptic situations and the other of special researches, notably those by Hesselberg and Sverdrup, and, in later years, of Bergeron and Swoboda. The First World War took away his ten German assistants—half of them were killed—and in 1917 he left Leipzig for Bergen. He had already, in a lecture in London in 1910, emphasized the value of charts of stream lines in revealing lines of convergence. Their further application, begun at Leipzig and continued at Bergen, led to the development of frontal and air-mass meteorology, including the polar front and the structure of cyclones. These have played an outstanding part in meteorology in the past thirty years. Bjerknes freely acknowledged the contribution of Bergeron, Solberg, and his son, J. Bjerknes, to this development; but he was himself the architect of the building and the inspirer of the workmen. In 1920 he and Helland Hansen arranged a meeting in Bergen with British meteorologists, including Sir Napier Shaw and Dr. L. F. Richardson, and the discussions were renewed in 1921 at a meeting of the International Upper Air Commission, of which Bjerknes was president. The enthusiasm of the 'Bergen' School was infectious and inspiring.

In 1926 Bjerknes left Bergen, where the work was continued by his pupils and whither meteorologists from all over the world were drawn. He returned to his former chair at Christiania (now Oslo), and with the collaboration of Solberg, J. Bjerknes, Bergeron and Godske completed and published the three-volume treatise on "Hydrodynamics and the Applications to Meteorology", issued in 1933–34, which stands as his permanent memorial. He retired in 1932, but continued to take an active part in international meteorology. He presided over the fruitful meetings of the Association of Meteorology of the International Union of Geodesy and Geophysics at Edinburgh in 1936. He lived in Oslo during the German occupation, sad but courageous. In 1946 he paid his last visit to England, when he and Prof. C. Størmer were the two delegates from Norway to the Newton Tercentenary Celebrations of the Royal Society. In the summer of 1948 he was looking forward cheerfully to his winter ski-ing.

Bjerknes was dignified in manner, in appearance and in his presentation of his scientific work; but with his dignity he combined a certain modesty and an unfailing attraction and stimulus to younger men. Through them his influence on meteorological development has been outstanding in the meteorological services of all nations.

Bjerknes married, in 1893, S. H. Bonnevie, whose gracious and warm-hearted hospitality at the Bergen meetings of 1920 and 1921 was a fitting, well-remembered counterpart to the scientific enthusiasm of Bjerknes and their son, Prof. J. Bjerknes, to whom meteorologists throughout the world will wish to tender their respectful sympathy in his loss.

E. GOLD

Mr. H. St. J. K. Donisthorpe

HORACE ST. JOHN KELLY DONISTHORPE, who died on April 22, was the sole survivor of the 'great five' of myrmecology. In the period between 1850 and 1950 immense advances were made in the study of ants. These embraced practically every field: the re-organization of their taxonomy, the study of their distribution, their life-history, polymorphism, and behaviour. Thousands of papers were produced and more than ten thousand new species were described during this period. The inspiration behind all this work was the existence of five great students of ants, Auguste Forel in Switzerland, Wasman in Holland, Wheeler in America, Emery in Germany, and Donisthorpe in Britain. Each one was an amateur.

Donisthorpe published his first paper on ants in 1908. Since then he has published more than three hundred papers reporting his studies on ants. His book, "British Ants", first published at his own expense in 1915 and re-published considerably enlarged and amended in 1927, is still the book to which anyone seeking knowledge about the ants of Britain must turn.

To-day, Donisthorpe is remembered chiefly as a taxonomist. He always sought to encourage people to study ants, and he would go to any lengths to help them to make their studies more accurate and worth while. In his early days, he spent much time studying the behaviour of ants, especially their slave-making and the way in which the queen ants (females) found new colonies.