PART FIVE

Scientific and Technological Development

1

SCIENCE IN VICTORIA

INTRODUCTION

Science is universal and international but at the same time it can have highly specialised features or be concerned with localised phenomena. At the present time, Victoria, as every other advanced state or country, is actively contributing to many fields of basic and applied science. For most of these fields, Victorian work is a significant segment of the Australian contribution to world knowledge with no special character relating it to this particular State. Throughout Victoria's history, however, special investigations have been needed to deal with natural calamities, epidemics in man or domestic animals, invasion by weeds and animal pests, or with the requirements for such necessary local developments as the siting of roads and railways, drainage of swamps, and provision of water for town supply or irrigation.

Again, as in every other area of the modern world, science in Victoria has a history which involves both the application of science from elsewhere in its development, and the growth of indigenous scientific activity and achievement within the State.

The pattern of early settlement in Victoria had little to do with science. The first comers were looking for new pastures for their sheep and, until the discovery of gold, wool was the only significant export. With the gold discoveries of the early 1850s a flood of immigrants swept into Victoria, including every kind and condition of men. There were professional and other well-educated men among them who were ambitious that science, art, and letters should find a place in the infant colony. It was a measure of the enthusiasm and optimism brought by the gold discoveries that the University of Melbourne, the National Museum and Art Gallery, and two organisations to foster science, the Victorian Institute for the Advancement of Science, and the Philosophical Society of Victoria, were all founded in the years 1853 and 1854. The latter two amalgamated in 1855 and became the Royal Society of Victoria in 1859.

It is natural that most early scientific work was largely descriptive in the fields of botany, zoology, and geology. Frederick McCoy, who was appointed Professor of Natural Science when the University of Melbourne was founded, was prominent in all these fields but pre-eminently in palaeontology. Significant work in the experimental sciences began when Masson, Baldwin Spencer, and Lyle were appointed in 1887 and 1888 to chairs at the University of Melbourne. Baldwin Spencer's work on the cultural anthropology of the Central Australian Aboriginals was probably the most significant scientific contribution from Australia before the First World War.

Medical research in Victoria began when Professor G. B. Halford, the first Professor of Medicine (from 1863 to 1903), began experimenting with snake venoms. Although of uncertain scientific worth, his work may have stimulated his successor, C. J. Martin, to an interest in the same field. At around the turn of the century, Martin and Cherry in Melbourne did important work on the neutralisation of snake venom by antivenene; this added significantly to the world's understanding of immunity. Just before the First World War, H. B. Allen, Professor of Pathology, was interested in bringing laboratory science into the Melbourne Hospital. He succeeded in interesting the Walter and Eliza Hall Trust; the Walter and Eliza Hall Institute of Research in Pathology and Medicine was established and began to function in 1920 as an independent research institute attached to the Melbourne Hospital. This was the first move of this type in Australia, and was followed by the development of similar institutes for medical research in other teaching hospitals in Victoria and in the other States with medical schools. The Walter and Eliza Hall Institute has remained, however, one of the most distinguished in Australia. Another very important development was the foundation of the Commonwealth Serum Laboratories in Melbourne in 1916, initially in the buildings which had been built for the Walter and Eliza Hall Institute. This has not only been the most important source of vaccines, sera, and the like for Australia, but has also played a major part in research. Two achievements which were of importance to medicine in Australia were the production of antivenene against Australian snake venoms and the preparation of influenza virus vaccines. Even more important for the Australian economy was the production of vaccines against a number of bacterial diseases of stock.

During the years since the end of the Second World War, medical research has burgeoned in the university medical schools. Clinical sciences buildings have been erected at the hospitals and research activity in the pre-clinical departments has steadily increased. This, of course, has been a world-wide development, and medical research in Victoria ranks in quantity and quality with what is being done anywhere else in the advanced countries of the world.

Veterinary science has necessarily been of special interest to Australia, and a veterinary school was founded at the University of Melbourne in 1908 with J. A. Gilruth as the first Professor. A steady stream of valuable work came from the school. Then in 1935 the Council for Scientific and Industrial Research (C.S.I.R.) Animal Health Laboratories were built in nearby Parkville. Under the direction of L. B. Bull these in turn provided major discoveries of great economic importance; black disease, bovine pleuro-pneumonia, complex plant poisonings associated with disturbed copper metabolism, contagious abortion, and the early studies on rabbit myxomatosis were some of the important areas of study. Finally, in 1962 the University's Veterinary School, which had lapsed since 1927, was re-established.

As in the rest of Australia, a large proportion of scientific work in Victoria is carried out in the laboratories and field stations of the Commonwealth Scientific and Industrial Research Organization. This and its precursors, the Council for Scientific and Industrial Research (1926 to 1949), the Commonwealth Institute of Science and Industry (1920 to 1926), and the Advisory Council of Science and Industry (1916 to 1920), all represent Commonwealth-wide activities. The beginnings were, however, mainly forged in Melbourne, then the seat of the Commonwealth Government. Many men were concerned but three of the key figures came from the University of Melbourne. Professor W. A. Osborne was one of the originators in promoting the earliest discussions. Professor (later Sir) David Orme Masson was probably mainly responsible for insisting that the C.S.I.R. should be actively concerned with research under its own direction and not merely serve as a co-ordinating body. Professor (later Sir) David Rivett, who had recently succeeded Masson as Professor of Chemistry, became the first director of the C.S.I.R.

Since 1926 there has been a steady expansion in all States and in an ever-widening range of fields. In Victoria the first two divisions to establish laboratories were Forest Products and Animal Health. A Division of Industrial Chemistry set up in 1939 at Fishermens Bend has since expanded into a number of new divisions of which the Division of Chemical Physics is perhaps the best known. Three other divisions based in Melbourne are Tribophysics, Building Research, and Atmospheric Physics.

Although the C.S.I.R.O. was devised primarily to apply scientific methods to the problems of primary and secondary industry, it has also sponsored a great deal of wholly basic research with no direct economic application, for example, in radio-astronomy. In the more "applied" divisions, the tendency has been to concentrate on the elucidation of principles leaving more immediate practical problems to the research and extension activities of State Government departments and the research and development sections of industrial firms. Both groups have expanded over the years, each organisation arising in response to some practical need, enlarging with prosperity or being held back in depression. It does not seem possible to make any general statements about their history and it will be best to refer the reader directly to their specific contributions in this volume.

EARLY BEGINNINGS

Scientific activities in Victoria were notable not only for the early date at which they commenced and for their virility and scope, but also for the high scientific stature of the participants. In 1852, following the first gold discoveries, A. R. C. Selwyn was appointed to initiate the Geological Survey of the Colony, to be followed by other geologists including R. Brough Smyth, later Secretary of Mines. In 1853 an astronomical observatory was established at Williamstown under R. L. J. Ellery, and it made notable observations. The Meteorological and Magnetic Observatory, under the direction of Professor G. Neumayer, was established in the Flagstaff Gardens in 1858. In 1863 both observatories were transferred to the Domain.

In order to study the strange vegetation of the Colony, Dr Mueller (later Baron Sir Ferdinand von Mueller) established in 1857 what is now the National Herbarium, a short time after he became director of the Melbourne

Botanic Garden (now the Royal Botanic Gardens). Mueller had carried out notable pioneering expeditions for botanical collecting purposes in 1853 and 1854, including expeditions through north-eastern Victoria, the Grampians through to Albury, and southern and eastern Gippsland. In 1855 he had accompanied Gregory's expedition from Perth to the Northern Territory, and had acquired a further valuable botanical collection.

In 1854 the National Museum was established, largely through the efforts of Captain Andrew Clarke, R.E., the Surveyor-General of the Colony, and some of the new Museum's specimens were displayed at the Melbourne Exhibition of that year. The first official appointment to the Museum staff was the zoologist William Blandowski, who conducted a scientific expedition in 1854 to collect material for the Museum. In the same year the University of Melbourne was founded, Professor (later Sir) Frederick McCoy being appointed to the Chair of Natural History, at the same time becoming the first Director of the Museum.

Two important scientific societies were founded in 1854 : the Victorian Institute for the Advancement of Science with a constitution and by-laws based on those of its British counterpart, and the Philosophical Society of Victoria. The Institute owed its origin to W. S. Gibbons, an analytical chemist and lecturer at the Mechanics Institute, and aimed to encourage communication between people with interests in the natural sciences, to provide a centre for the collection of observations and specimens, and to assist in developing the resources of the Colony. It was due to Captain Clarke, who had been largely instrumental in establishing the National Museum, that the Philosophical Society of Victoria (modelled on the Royal Society of Britain) was founded. The Society had as its objects the study of the whole field of natural science, and the provision of assistance in the development of the natural resources of the Colony.

Clarke, Selwyn, and Mueller served on the governing bodies of both societies which, in 1855, combined to form the Philosophical Institute of Victoria, a practicable arrangement in view of the limitations of the Colony's resources at that time. The Institute actively studied the natural resources of the Colony and the possible beneficial introduction of exotic animals and plants. It was also interested in the formation of an astronomical society, and sponsored the organisation of a geographical expedition: the pioneering Burke and Wills expedition of 1860. In 1859 the Institute obtained Royal assent to assume the title of the Royal Society of Victoria. Sir Henry Barkly, the Governor of Victoria and President of the Institute at that time, continued as President of the Society, in which he took a very active part; subsequent Governors of Victoria have accepted the position of patron. The Royal Society of Victoria has continued to fluorish, encouraging and carrying out scientific work.

Founded in 1857, the Zoological Society of Victoria was incorporated into the Acclimatization Society of Victoria in 1861; this became the Zoological and Acclimatization Society in 1872, and finally in 1910, the Royal Zoological and Acclimatization Society. McCoy, Mueller, and other leading scientists were actively interested in the work of the Society. The aim of the Society was the introduction and acclimatisation of animals, birds, fishes, and plants, both useful and ornamental. The first collections were housed in the Richmond Paddock opposite the Melbourne Botanic Garden, the animals being removed in 1862 to the present Zoological Gardens site at Royal Park, and the plant specimens being transferred to the Botanic Garden.

As the sciences of genetics and ecology were as yet comparatively undeveloped, many failures occurred, such as the attempts to introduce nightingales, partridges, canaries, and pheasants into the local bird populations, and Murray Cod and " Murray " lobsters into the Yarra. Another failure was the project to introduce oysters and crayfish into Lake Corangamite on the assumption that the fact that the lake had a similar salinity to ocean waters would ensure the success of the project. On the other hand the Society had many " successes ", including the introduction of the blackberry, rabbit, starling, thrush, and sparrow. Trials were also made of Brahmin cows and Aden, Bengal, and Russian sheep, foreshadowing modern experiments. By the 1930s the Society was facing financial and other difficulties, and requested the Victorian Government to assume responsibility for the Zoological Gardens and the extensive collections housed therein. As a result the *Zoological Gardens Act* 1936 appointed the Zoological Board of Victoria, on which the Society was represented until its final disbandment in the 1950s.

Other important societies founded in the early years of the Colony included the Field Naturalists' Club of Victoria, the Geographical Society of Victoria, and the Royal Victorian Horticultural Society. A branch of the British Astronomical Association functioned between 1897 and 1963, being superseded by the Astronomical Society of Victoria which had been established in 1922.

AUSTRALIAN AND NEW ZEALAND ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The Australasian Association for the Advancement of Science was formed in Sydney in 1886, holding its inaugural congress in 1888, and acting through congresses held at two year intervals in the capital cities of Australia, with New Zealand included once in each rotation. In 1930 the name was changed to Australian and New Zealand Association for the Advancement of Science, the first A.N.Z.A.A.S. congress being held in 1932. After the first congress in Sydney in 1888, the University of Melbourne was the venue in 1890, 1900, 1915, 1921, 1935, 1955, and 1967. The announced intention, following the lead of the British Association for the Advancement of Science, was to " promote science among the interested public ". The term " science " was used to include history, education, and economics. Until the 1950s interstate travel for scientific discussion was not common, and these congresses were outstanding among the scholarly gatherings. They were more an occasion for scientific discussion than for enlightening the public. With the development of specialist societies since about 1950, and with easier travel, A.N.Z.A.A.S. began to work towards a more popular and less specialised type of science and to concentrate on symposia between different interests, leaving special topics to the specialist societies ; restructuring of the Association in this direction occurred in 1970. By 1967 attendances in Melbourne had already reached 3,600.

While Melbourne has often been the venue for international meetings, the meeting of the British Association for the Advancement of Science in 1914 was the one occasion when this parent body met in Australia. Many distinguished overseas guests arrived for this meeting which, unfortunately, was interrupted by the outbreak of war.

FELLOWS OF THE ROYAL SOCIETY, LONDON

During the 140 years of Victoria's history since the first settlement, many learned persons have contributed to the advancement of knowledge. Some of these have been honoured for their efforts in their respective fields by being elected as Fellows of the Royal Society in London. The following list, verified by the Royal Society, London, is of those Fellows who at some stage in their lives have lived and worked in Victoria ; many of these have attained international status in their own fields ; all have contributed greatly to the advancement of knowledge in Victoria.

KAY, Captain Joseph Henry, R.N. (1814–1875).
F.R.S. 1846.
Entered Royal Navy 1827; resident in Melbourne, *c.* 1854–1875. At one time (dates not known) Director of H.M. Magnetic Observatory at Hobart Town, Tasmania.

STRZELECKI, Sir Paul Edmund de, K.C.M.G. (1797–1873).
F.R.S. 1853.
Explorer and geologist; came to Australia in 1839. In February 1840 ascended Mt Kosciusko which he named, and later that year explored Gippsland region of Victoria. In 1846 was awarded the Founder's Medal of the Royal Geographic Society.

MUELLER, Baron Sir Ferdinand Jakob Heinrich von, K.C.M.G. (1825–1896).
F.R.S. 1861.
Botanist, explorer and geographer ; Government Botanist to the Colony of Victoria. Director of the Melbourne Botanic Gardens, 1857–1873.

VERDON, Sir George Frederic, K.C.M.G., C.B. (1834–1896).
F.R.S. 1870.
Lawyer ; came to Melbourne in 1851. Called to the Victorian Bar 1863. Treasurer for Victoria, 1860–1861 and 1863–1868.
Agent-General in London, 1868–1872.

ELLERY, Robert Lewis John, C.M.G. (1827–1908).
F.R.S. 1873.
Physician and astronomer ; came to Melbourne in 1851. Trained for the medical profession, but took up astronomy. Founded Observatory at Williamstown in 1853. Director Geodetic Survey of Victoria, 1858–1874. Government Astronomer, Melbourne, 1863–1895.

McCOY, Sir Frederick, K.C.M.G. (1823–1899).
F.R.S. 1880.
Physician ; came to Melbourne from Dublin. Educated for the medical profession. Appointed (*c.* 1854) Professor of Natural Science in the University of Melbourne. Founded the National Museum of Natural History in Melbourne.

CLARKE, Sir George Sydenham, G.C.M.G., later Lord Sydenham of Coombe (1848–1933).
F.R.S. 1896.
Soldier ; Governor of Victoria, 1901–1904.

SPENCER, Sir Walter Baldwin, K.C.M.G. (1860–1929).
F.R.S. 1900.
Zoologist and ethnologist ; Professor of Biology in the University of Melbourne, 1887–1919. Trustee of Public Library, National Gallery, and National Museum of Victoria, 1895–1928.

GREGORY, John Walter (1864–1932).
F.R.S. 1901.
Geologist ; Director of the Geological Survey, Mines Department, Victoria, 1902–1904. Professor of Geology in the University of Melbourne, 1900–1904.

MARTIN, Sir Charles James, C.M.G. (1866–1955).
F.R.S. 1901.
Physiologist ; Lecturer in Physiology in the University of Melbourne, 1897. Professor of Physiology in the University of Melbourne, 1901–1904. Chief of Division of Animal Nutrition, C.S.I.R., 1931–1933.

MICHELL, John Henry (1863–1940).
F.R.S. 1902.
Mathematician; Professor of Mathematics in the University of Melbourne, 1923–1929.

MASSON, Sir David Orme, K.B.E. (1858–1937).
F.R.S. 1903.
Chemist; Professor of Chemistry in the University of Melbourne, 1886–1923. Participated in organisation of Mawson's Antarctic expedition, 1911–1914. President of Australasian Association for the Advancement of Science, 1911–1913. Chairman of organisation for meeting of British Association for the Advancement of Science in Australia in 1914. First President of Australian Chemical Institute, 1917–1920. Associated with formation of Australian National Research Council, President, 1922–1923.

LYLE, Sir Thomas Ranken (1860–1944).
F.R.S. 1912.
Mathematician and physicist; Professor of Natural Philosophy in the University of Melbourne, 1889–1915. Chairman of Board of Visitors of Melbourne Observatory and Member of State Electricity Commission of Victoria, 1917–1937.

AGAR, Wilfred Eade (1882–1951).
F.R.S. 1921.
Zoologist; Professor of Zoology in the University of Melbourne, 1919–1948.

EWART, Alfred James (1872–1937).
F.R.S. 1922.
Botanist; Government Botanist to the State of Victoria, 1906–1921. Professor of Botany in the University of Melbourne, 1906–1937.

JONES, Frederic Wood (1879–1954).
F.R.S. 1925.
Anatomist; Professor of Anatomy in the University of Melbourne, 1930–1937.

LABY, Thomas Howell (1880–1946).
F.R.S. 1931.
Physicist; Professor of Natural Philosophy in the University of Melbourne, 1915–1944.

MICHELL, Anthony George Maldon (1870–1959).
F.R.S. 1934.
Consulting engineer; graduate of the University of Melbourne. Consulting engineer in Melbourne, 1903–1959.

VERNEY, Ernest Basil (1894–1967).
F.R.S. 1936.
Pharmacologist; Research Professor in Physiology in the University of Melbourne, 1961–1964.

KELLAWAY, Charles Halliley, M.C. (1889–1952).
F.R.S. 1940.
Pathologist; graduate of the University of Melbourne. Resident Medical Officer and later Registrar, Melbourne Hospital, 1912–1914. Director of the Walter and Eliza Hall Institute of Research in Pathology and Medicine, Melbourne, 1923–1944. Specialist physician, Royal Melbourne Hospital, 1925–1943.

ECCLES, Sir John Carew, F.A.A.
F.R.S. 1941.
Physiologist; Professor of Physiology, University of Otago, New Zealand, 1944–1951. Professor of Physiology, Australian National University, 1951–1966. President, Australian Academy of Science, 1957–1961.

RIVETT, Sir Albert Cherbury David, K.C.M.G., F.A.A. (1885–1961).
F.R.S. 1941.
Chemist; graduate of the University of Melbourne. Associate Professor, 1920. Professor, 1924–1927. Deputy Chairman and Chief Executive Officer, C.S.I.R., 1927–1945, Chairman, 1946–1949.

BURNET, Sir Frank Macfarlane, O.M., K.B.E., F.A.A.
F.R.S. 1942.
Biologist (immunologist); graduate of the University of Melbourne. Resident pathologist, Melbourne Hospital, 1923–1924. Assistant Director of the Walter and Eliza Hall Institute of Research in Pathology and Medicine, 1928–1931 and 1934–1944. Director of the Institute and Professor of Experimental Medicine in the University of Melbourne, 1944–1965, and Emeritus Professor from 1965. Nobel Laureate (Physiology and Medicine), 1960. President of Australian Academy of Science, 1965–1969.

FAIRLEY, Sir Neil Hamilton, K.B.E. (1891–1966).
F.R.S. 1942.
Physician; Assistant Director, Walter and Eliza Hall Institute of Research in Pathology and Medicine, 1920–1922. Director, L.H.Q. Medical Research Unit, Cairns (where experiments led to control of malaria in jungle warfare), and consulting physician for tropical diseases to Australian and United States of America Armed Forces, 1942–1945. Tata Professor of Tropical Medicine, Bombay. Wellcome Professor of Tropical Medicine, University of London. Honorary consultant to British Army, 1950–1956. Buchanan Medal of Royal Society, 1957.

TIEGS, Oscar Werner, F.A.A. (1897–1956).
F.R.S. 1944.
Zoologist; Associate Professor of Zoology in the University of Melbourne, 1933–1951. Professor and Head of the Department, 1951–1956.

BRUCE, of Melbourne, The Rt Hon. Viscount Stanley Melbourne, P.C., C.H. (1883–1967).
F.R.S. 1944.
Statesman; Prime Minister of Australia, 1923–1929. High Commissioner for Australia in Great Britain, 1933–1945. First Chancellor of Australian National University, Canberra, 1952–1961.

CAMERON, Sir Gordon Roy (1899–1966).
F.R.S. 1946.
Pathologist; Assistant Director, Walter and Eliza Hall Institute of Research in Pathology and Medicine, 1925–1927. Professor of Morbid Anatomy, University College Hospital Medical School, London, 1937–1964, and Emeritus Professor, 1964–1966.

FELDBERG, Wilhelm Siegmund, C.B.E.
F.R.S. 1947.
Neuropharmacologist; at Walter and Eliza Hall Institute of Research in Pathology and Medicine, 1936–1938. Honorary lecturer, University of London, since 1950. Head of Laboratory of Neuropharmacology, National Institute for Medical Research, London, since 1966. Professor Emeritus.

BULLEN, Keith Edward, F.A.A.
F.R.S. 1949.
Mathematician and geophysicist; Senior Lecturer in Mathematics at the University of Melbourne, 1940–1945. Professor of Applied Mathematics, University of Sydney since 1946.

ANDERSON, John Stuart, F.A.A.
F.R.S. 1953.
Chemist; Professor of Inorganic and Physical Chemistry and Head of the Department of Chemistry in the University of Melbourne, 1954–1959.

CHERRY, Sir Thomas Macfarland, F.A.A. (1898–1966).
F.R.S. 1954.
Mathematician; Professor of Mathematics in the University of Melbourne, 1929–1963. President of the Australian Academy of Science, 1961–1965.

HILLS, Edwin Sherbon, C.B.E., F.A.A.
F.R.S. 1954.
Geologist; graduate of the University of Melbourne. Professor of Geology and Mineralogy, University of Melbourne, 1944–1963. Deputy Vice-Chancellor of the University of Melbourne, 1962–1970, and Research Professor of Geology in the University since 1964. Chairman of Trustees, National Museum of Victoria, 1961–1968.

MARTIN, Sir Leslie Harold, C.B.E., F.A.A.
F.R.S. 1957.
Physicist; appointed to Natural Philosophy Department of the University of Melbourne, 1927. Professor of Physics in the University of Melbourne, 1945–1959 and Emeritus Professor in 1960. Chairman of the Australian Universities Commission, 1959–1966. Professor of Physics and Dean of Faculty of Military Studies (University of N.S.W.), Royal Military College, Duntroon, since 1967.

FENNER, Frank John, M.B.E., F.A.A.
F.R.S. 1958.
Biologist; Francis Haley Research Fellow, Walter and Eliza Hall Institute of Medical Research, Melbourne, 1946–1948. Professor of Microbiology, John Curtin School of Medical Research, Australian National University, Canberra, 1949–1967, and Director of the School since 1967.

ROBERTSON, Sir Rutherford Ness, C.M.G., F.A.A.
F.R.S. 1961.
Botanist; Member of the Executive of the C.S.I.R.O., Melbourne, 1959–1962. Professor of Botany, University of Adelaide, 1960–1969. President, Australian Academy of Science, 1970. Chairman, Australian Research Grants Committee, 1965–1969. President, A.N.Z.A.A.S., 1965. Master of University House, Australian National University, Canberra, since 1969.

WHITE, Michael James Denham, F.A.A.
F.R.S. 1961.
Zoologist; Professor of Zoology in the University of Melbourne, 1958–1964. Professor of Genetics in the University of Melbourne since 1964.

MENZIES, Rt Hon. Sir Robert Gordon, K.T., C.H., F.A.A.
F.R.S. 1965.
Lawyer and statesman; practised as a barrister at the Victorian Bar. Entered Victorian Parliament 1928. Attorney-General, Minister of Railways and Deputy Premier of Victoria, 1932–1934. Prime Minister of Australia, 1939–1941 and 1949–1966.

ISAACS, Alick (1921–1967).
F.R.S. 1966.
Virologist: Rockefeller Travelling Fellow at Walter and Eliza Hall Institute of Medical Research, 1948–1950. Head of Division of Bacteriology and Virus Research, National Institute of Medical Research, London, 1961–1967.

WHITE, Sir Frederick William George, K.B.E., F.A.A.
F.R.S. 1966.
Physicist; educated Victoria University College, New Zealand. Served in C.S.I.R., Melbourne, 1941–1946. Chief Executive Officer, C.S.I.R.O., 1949–1957, Deputy Chairman, 1957–1959, and Chairman, 1959–1970.

PRIESTLEY, Charles Henry Brian, F.A.A.
F.R.S. 1967.
Physicist; Chief of the Division of Meteorological Physics of the C.S.I.R.O., Aspendale, Victoria, since 1946.

WALSH, Alan, F.A.A.
F.R.S. 1969.
Physicist; Assistant Chief, Division of Chemical Physics, C.S.I.R.O., Victoria, since 1961. Introduced atomic absorption spectrometry.

MILLER, Jacques Francis Albert Pierre, F.A.A.
F.R.S. 1970.
Pathologist; Head, Experimental Pathology Unit, Walter and Eliza Hall Institute of Medical Research since 1967. First to demonstrate immunological importance of thymus gland.

2

UNIVERSITIES AND INSTITUTES OF ADVANCED EDUCATION

UNIVERSITY OF MELBOURNE

The *Faculty of Agriculture,* established in 1905, remained strictly a teaching organisation until 1928 when funds for research were provided under the Agricultural Education Acts Amendment Act of that year. These funds were used by the Dean, Professor (later Sir Samuel) Wadham, to support surveys of the soils and land use practices in four Victorian districts, and sociological studies of farmers through the wheat belt and of irrigators in the Mildura area. These surveys all contributed to his writings and his recommendations as a member of the Rural Reconstruction Commission in the 1940s. A later survey was concerned with the wool industry of the Western District. In recent years the research programme has greatly increased with the provision of additional funds from governments, primary industry research funds, banks, and industrial sources. A large part of the Faculty's field research work is conducted at Mt Derrimut.

Work in agricultural chemistry has been concerned with trace elements in soils, especially the essential elements manganese and molybdenum. A unit of the C.S.I.R.O. was connected with this work and also investigated silicon in plants. Work in agricultural biochemistry has covered fatty acid and amino acid metabolism in sheep tissues, proteins and polysaccharides in relation to the quality of wheat, the utilisation of the rumen bacteria as a source of nutrients by sheep, and biochemical changes during the maturation of the sheep blowfly.

Workers in the plant sciences have been concerned basically with the developmental physiology of crop plants, in particular the reactions of varieties to temperature and length of day in relation to flowering and maturity. Other studies have concerned the effects of nitrogen fertilisers, weed competition in crops, the invasion of permanent pastures by annuals, and plant breeding problems. The research programme in animal production has dealt with nutrition, the growth and body composition of animals, and genetic improvement. Meat studies have shown how nutrition, breed, sex, age, and weight influence the quality of cattle and sheep carcasses. A performance recording scheme for cattle breeders has been recommended.

Sociological studies have been made in selected districts with particular reference to agricultural extension needs and problems. The agricultural economics research has been on farm management aspects of the grazing and wheat industries and on the marketing of wool, beef, and dairy products.

Recently work has been concentrated on problems of rural reconstruction.

In the *Faculty of Dental Science* organised research began with the appointment of the first professor, Dr F. C. Wilkinson, in 1924. However, as early as 1886 papers had been presented on numerous subjects to the Odontological Society of Victoria, which had been formed two years earlier by a group of Melbourne dentists. It was instrumental in establishing the Dental Hospital of Melbourne, as well as the Australian College of Dentistry, the first dental school in Australia, in 1897. Some organised research was carried out there, notably on dental caries, and members published the *Australian Journal of Dentistry,* a precursor of the present *Australian Dental Journal.*

During the early part of this century, when research facilities were not readily available, work was carried out in close association with university departments. One project in 1913 investigated the relationship of saliva to dental decay. Dr Wilkinson, when appointed to the Chair of Dental Science in the University of Melbourne, became the first professor at the Australian College of Dentistry. He obtained funds from the college for a clinical research laboratory and an annual grant was devoted to dental research. In 1929 legislation enabled the University Council to act as trustees for the Dental Research Department's funds; the F. A. Kernot Bequest, also made at that time, still assists dental research considerably. Some of the earlier projects concerned the absorption of alveolar bone in Aboriginal skulls, a new method of root canal treatment, and the pathology of pyorrhoea.

In co-operation with the University's Metallurgy Department, a special laboratory was set up in 1934 for the study of metallography including the fundamental properties of dental amalgams. In 1947 this laboratory was taken over by the Commonwealth Department of Health and became known as the Commonwealth Bureau of Dental Standards; during the Second World War it tested materials for the Armed Services. After the war, with the increase of students, clinical teaching had to be carried out in accommodation previously reserved for research, which therefore suffered even though some university departments, notably Physiology and Pathology, gave considerable research assistance to the Faculty. Funds were more readily available after the appointment of professors to the Chairs of Dental Prosthetics and Conservative Dentistry in 1949, and suitably equipped research laboratories were available when the School of Dental Science moved to new buildings in 1963.

Early research workers were mainly concerned with establishing facilities and encouraging those interested in projects, but some aspects of research have received continuous attention. Under the first professor the main interests were in anatomy and pathology, and a materials research laboratory was developed. His successor, Professor (later Sir) Arthur Amies, extended research in the field of dental materials, until the laboratory was taken over by the Bureau of Dental Standards, and interest in dental pathology continued. Latterly, research has covered the prevention and cure of dental disease, the role of fluoride in dental health, bone development, the physiology of speech and mastication, and immunological studies.

Considerable sums have been provided for research by private sources, the University itself, the State and Commonwealth Governments, the Australian Research Grants Committee, and the National Health and Medical

Research Council. Between 1970 and 1971 $105,000, which included a capital grant of $50,000 for an electron microscope, was available for research, and 22 members of staff were engaged in research activities.

Although *Faculty of Engineering* courses were introduced in 1861 research was, at first, limited and sporadic. The earliest work seems to have been on tests of model bridges begun about 1870 by the first Professor of Engineering, W. C. Kernot, whose research on local timbers and wind pressures on buildings was also significant. Later wind pressure studies were carried out on models in the wind tunnel which was installed soon after the First World War, and other important work was done on electrical measuring equipment, and on metal creep in lead and aluminium alloys. There were no research scholarships in engineering until after 1920, and other finance came first from the Science and Industry Fund; it was used between 1930 and 1935 for research on the strength of welds. After the Second World War separate Chairs were created in Civil, Mechanical, and Electrical Engineering, and the staff in each department was increased. More research scholarships became available; laboratories and equipment were improved; and industry sponsored several projects. In 1971 over one hundred members of staff and postgraduate students were engaged in research and teaching activities. The annual university research grant to the Faculty was about $86,000 exclusive of scholarships, but about $250,000 came from outside sponsors, mainly for specific projects.

In metallurgy, studies of cavitation (the development of very small holes) at grain boundaries in deformed metals have become widely known. This was the result of combined research done by the university staff and a C.S.I.R.O. group within the Metallurgy Department, as was also the study of the electrolytic production of titanium metal from titanium chlorides. Since 1948 a unit has been studying methods of converting brown coal to fuel of high calorific value, and one of these, high-temperature carbonised char, has shown promise as a competitor to metallurgical coke from New South Wales. Recent studies have shown that raw brown coal as well as the char may have considerable potential in metal extraction, removing pollution from water, and collecting oil slicks. In mining, close links have been maintained with the C.S.I.R.O., especially in work on methods of mineral separation and processing. Studies on rotary drag drilling are among the University's own projects.

Civil engineering studies on rock fill dams, in which some of the overflow passes through the dam itself, rather than over a costly spillway, have received recognition. Studies have also been concerned with the carrying capacity of long slender piles, driven through soft soil to rock at depth; in fact, the foundations of the first stage of the Arts Centre, built between 1966 and 1968, were designed on the basis of this research. The failure of King's Bridge in 1962 prompted research on the brittle fracture of the broken girders, and since 1956 the difficult problem of highway foundation design has progressed.

In mechanical engineering, boundary layer fluid flow has been studied on building structures, ships' hulls (including aspects of the design of an Australian entry for the America's Cup yacht race), water turbines, and aircraft wings. Investigations have also centred on the mechanics and economics of milling and turning. The human engineering group has been assessing the strains on the car driver; the interaction of the vehicle, driver, and roadway; and the design of motor cars.

For nearly twenty years electrical engineers have investigated the stability of electric power systems where sudden overload or other failure can cause widespread breakdowns. Originally the work was experimental, but a computer programme now predicts the performance of electrical machines in large interconnected systems. Research on electronic circuits has important applications in the design of amplifiers used in telecommunications. A third major project has been on the noise performance of semi-conductor devices.

Between 1960 and 1964 a group of chemical engineers conducted experimental work on packed catalytic tubular reactors and fluidised bed reactors. Since 1964 heat and mass transfer processes have been studied : improved gas heat transfer is an example which it is hoped will result in improved designs for gas heated equipment.

Since 1954 the Agricultural Engineering Department has operated the Australian Tractor Testing Station. Research has also been conducted on run-off from catchments and infiltration of water in bay irrigation. The Survey Department has investigated transition curves and astronomy, the mathematics of adjustments of surveys as used in the 1966 adjustment of the Australian Geodetic Survey, and the adjustment of aerial photographs in photogrammetry.

In the *Faculty of Medicine* of the University of Melbourne, the first Medical School in Australia, was established in 1862, and the first Professor, G. B. Halford, began teaching in 1863, being responsible for courses in Anatomy, Physiology, and Pathology. By 1885 it became necessary to accommodate Pathology and Anatomy in a separate building, and in 1900 Bacteriology and a lecture theatre block were added. Anatomy was transferred to a new building in 1923.

Medical School development in the early years involved consolidation rather than expansion. The number of students was relatively small, the medical course was designed for general practitioners who were greatly in demand in a rapidly growing community, and medical science was in its infancy. Staff in the departments was inadequate, equipment deficient, and facilities for research limited. A typical department might consist of a professor and one or two other members, but teaching commitments permitted little time for research, which the School was thus unable to support on a continuing basis. The only exceptions to this were the Hall and the Baker Institutes.

During the Second World War the importance of research in solving complex medical problems was recognised, and the resulting impetus continued into the post-war period. New departments, additional staff, and greatly improved facilities were necessary. In 1947 the Royal Children's Hospital established a Clinical Research Unit which was incorporated in the Royal Children's Hospital Research Foundation in 1960. Since the mid-1950s all departments of the Medical School have been enlarged, and are now accommodated in new buildings in the south-west corner of the University. Many new departments have also been created, and clinical professorial units with well equipped research laboratories have been established in all the teaching hospitals associated with the University. Modern teaching and research facilities are now under construction at St Vincent's Hospital, the Royal Victorian Eye and Ear Hospital, and in the new clinical schools at the Austin and Mercy hospitals.

When the Medical School was founded there was one professor responsible for courses in Anatomy, Physiology, and Pathology; it was twenty years before another chair was established. By the outbreak of the Second World War the professorial staff numbered only 6; in 1971 it was 28. Five of these chairs, as well as the Florey Laboratories, were established through substantial contributions from private benefactors and the community. Sub-professorial staff numbers have increased from 5 in 1866 to about 145 in 1971.

By 1931 endowments to the University for medical research had reached a level which justified the creation of a Medical Research Funds Committee; three years later this became the Medical Research Committee. The funds remained small, however, and in 1942 the sum of only $9,206 was available. The following approximate figures illustrate the gradual development of internal funds: 1950, $22,000; 1952, $46,000; 1955, $50,000; 1962, $106,000; 1965, $196,000; 1969, $173,000; and in 1970, $225,000. The substantial growth in research which has occurred since 1945 has been largely due to external funds provided by Australian and overseas foundations and various government and non-government bodies in Australia. These include the National Health and Medical Research Council, the Australian Research Grants Committee, the National Heart Foundation of Australia, the Anti-Cancer Council of Victoria, and the Life Insurance Medical Research Fund of Australia. With the growing international reputation of the School, overseas aid has greatly increased in recent years. As a result of this support, the total expenditure on medical research had grown to $800,000 in 1964, and in 1971 was approximately $1.25m.

Outstanding among the large number of research programmes undertaken over the years have been Sir Macfarlane Burnet's contributions to virology and immunology, culminating in the award of a joint Nobel Prize in 1960; studies on snake venoms; work on the comparative physiology of monotremes; the nature of the toxin antitoxin reaction; nerve repair studies; the elucidation of the nature of chloroform death; studies on the comparative anatomy of the Australian Aboriginal and Australian mammals; pioneer studies on surgical pathology and thoracic surgery; work on prophylaxis against tetanus, the problems of hospital asepsis, and on barbiturate and morphine antagonists; studies on peripheral nerves and nerve repair; and the work of the Florey Laboratories and the Department of Physiology on salt and water biology, renal hypertension, and cell differentiation.

The *Walter and Eliza Hall Institute of Medical Research* owes its foundation to Sir Harry Allen, then Professor of Pathology in the University of Melbourne, who in 1915 urged the Walter and Eliza Hall Trust of Sydney to provide the Melbourne Hospital with diagnostic laboratories. Early in 1915 the first director, Dr G. C. Matheson, was appointed and building on the hospital site began. It was completed in 1916, but as Matheson was killed at Gallipoli, the Institute was not inaugurated until January 1920 as the Walter and Eliza Hall Institute of Research in Pathology and Medicine, acquiring its present title in 1947. Since then it has had an unbroken record of work in the medical sciences under its successive directors. By 1939 the hospital laboratories had become independent of the Institute, and in 1946 the clinical research unit of the Institute was established with its own ward in the Royal Melbourne Hospital. This re-established a close but specifically limited relationship with the Hospital. Several of the Institute's scientists have become Fellows of the Royal Society and Fellows of the Australian Academy of Science. Since 1944 the Director has also held a Chair in the University of Melbourne. This was at first styled the Chair of Experimental Medicine, but is now the Chair of Medical Biology.

A wide range of topics has been studied, depending both on the special interests of individual workers and on the need for the investigation of epidemics or of war-time contingencies. The first major study was of hydatid disease (between 1920 and 1924), followed by a long series of investigations on Australian snake venoms between 1927 and 1938, leading to the production of an anti-venene by the Commonwealth Serum Laboratories. Arising from these studies important work was carried out between 1935 and 1939 on the action of toxic substances in provoking the liberation of active pharmacological agents from cells. In 1934 the Rockefeller Foundation began to support extensive and significant virus research, which was carried out in the following years under Sir Macfarlane Burnet who was Director of the Institute from 1944 to 1965. This included work between 1935 and 1941 on psittacosis, herpes virus, and poliomyelitis. During the Second World War a major segment of the Institute's activities was concerned with influenza and methods of producing vaccines from virus grown in the chick embryo, a technique initiated in the Institute between 1935 and 1945. Influenza virus remained a central theme for the Institute until about 1957 and the two most important fields to be developed were the progressive clarification of the function of sialic acid and neuraminidase, and the development of techniques for genetic recombination between influenza viruses. Interest in immunological topics has grown during the last twenty years, and since 1957 these have become the main activity of the Institute. Sir Macfarlane Burnet, O.M., F.R.S. shared a Nobel Prize with P. B. Medawar in 1960 for his part in the discovery of immunological tolerance, and from 1957 to 1959 had developed his clonal selection theory of immunity. Since 1960 the Institute has developed into one of the world's main centres of immunological research.

In 1971 there were 53 research workers at the Institute, in addition to supporting staff and postgraduate students, and the total research expenditure in 1970–71 was $948,000.

The *Faculty of Science* gained its reputation for scientific research following the appointments of Professor (later Sir) David Orme Masson (Chemistry), Professor (later Sir) Baldwin Spencer (Biology), and Professor (later Sir) Thomas Lyle (Natural Philosophy). With Professor (later Sir) Frederick McCoy, who was appointed Professor of Natural Science in 1855, they became the first four of the sixteen members of the Faculty elected as Fellows of the Royal Society, London. Twelve were later elected Fellows of the Australian Academy of Science. McCoy pioneered Australian palaeontology; Masson determined atomic volumes and worked on the theory of solutions; Spencer made the first scientific studies of the Australian Aboriginal and was the founder of Australian anthropology; and Lyle studied fundamental problems of electro-technology and the theory of the alternating current generator. A number of notable successors also encouraged the development of research. J. H. Michell, a Fellow of the Royal Society who became Professor of Mathematics in 1923, made important contributions to hydrodynamics and elasticity. The value of his work on the wave resistance of a ship, published in 1898, was only recognised by overseas authorities some thirty years later.

By 1930 there were five departments in the Faculty, each with a small research staff and some postgraduate students working for the M.Sc. degree. They were supported by the Department of Mathematics in the Faculty of Arts, and by the Bacteriology, Biochemistry, and Physiology Departments in the Faculty of Medicine.

Scientific research and training for industry, teaching, and government service have been important since the earliest days. McCoy was responsible for the establishment of the National Museum of Victoria. Masson played an important part in public health work, in organising Antarctic exploration, and in the formation of the Australasian Association for the Advancement of Science (later A.N.Z.A.A.S.) ; he was also first Chairman of the Committee which eventually became the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.), as well as first President of the Royal Australian Chemical Institute. In later years members of the Faculty made important research contributions in nuclear science; gave advice to the Council for Scientific and Industrial Research (C.S.I.R.) and the defence and service departments; set up the Radium Laboratory and the X-ray Laboratory which later came under Commonwealth control; formed the Optical Munitions Panel during the Second World War; advised the paper industry; and explored various mathematical aspects of engineering and aerodynamics. Professor Ewart produced handbooks on Victorian weeds, poisonous plants, and forest trees, and the authoritative *Flora of Victoria* in 1930.

Until the end of the Second World War many students with the M.Sc. degree from Melbourne went overseas for further research training. In 1946 the degree of Ph.D. was introduced, candidates for which have typically worked in Melbourne as research students before taking staff positions or going overseas with post-doctoral fellowships. Even so, the growth of the C.S.I.R.O. and the lack of finance for the universities tended to limit scientific research in universities.

The 1957 Murray Report noted that Australian honours and postgraduate research schools were generally weak, despite the high quality of postgraduate students. As a result of this report, the Australian Universities Commission was constituted. Since then increased financial aid has assisted the growth of the original Departments—Chemistry, Physics, Botany, Zoology, and Geology ; increased the size of research schools ; and assisted the development of many newer Departments—Anthropology, Computation, Forestry, Genetics, Mathematics (transferred from Arts), Meteorology, Statistics, and the Science Departments linked with the R.A.A.F. Academy. In 1970 the staff in all these departments numbered 181, with 136 on the technical side; and there were 6 research fellows, 255 M.Sc. students, and 237 Ph.D. students, many of whom were also engaged in part-time teaching. In 1969 alone, the members of the Faculty published 380 scientific papers, and at the end of that year, 58 M.Sc. degrees and 49 Doctorates were awarded. The increasing size of the research schools would not have been possible without industrial support, private benefactions, and subsidies from government instrumentalities. From 1966 to 1970 the Australian Research Grants Committee provided $1.2m to the Science Faculty for various projects.

Research contributions by the Faculty have been widely spread and have included :

Physics : The accurate determination of the mechanical equivalent of heat ; measurements of thermal conductivity ; studies of long-wave X-rays, the Auger effect, cosmic rays, and the Mossbauer effect ; advances in the theory of electron diffraction.

Chemistry : The invention of the Steel-Grant microbalance and its use in the study of the photographic process ; the origination of new synthetic methods in heterocyclic organic chemistry; the characterisation of many plant products and of organo-metallic compounds ; studies of magnetochemistry and the electronic structure of compounds ; kinetic studies of the mechanism of chemical reactions, including those on surfaces and of solids ; and the development of new techniques for the study of the chemistry of reacting solids.

Geology : Advances in stratigraphy and palaeontology, especially in Tertiary sediments and in the relationships of the Palaeozoic igneous and sedimentary rocks, and geochemical investigations.

Zoology and Genetics : The structure and evolution of insects, a long-term test of the theory of Lamarckian inheritance ; the cytology, genetics, and evolution of Morabine grasshoppers ; the ecology of marsupials and of amphibians ; the social organisation of Australian Aboriginal tribes ; and the electrophysiology of muscle and nerve in man and the lower animals.

Botany : Studies of plant respiration, photosynthesis, and hormones; of plant pathology; of alpine ecology in relation to soil conservation; of the plant microfossils of brown coal ; of marine botany, forest ecology, and conservation ; and electron microscopy of virus, phloem, and leaf surfaces.

Forestry : The ecology and silviculture of *Eucalyptus* and of *Pinus radiata* ; photo-interpretation and remote sensing.

Meteorology : Glacial meteorology and glaciation ; agricultural and aeronautical meteorology.

Biochemistry and Physiology : The study of respiratory pigments and amino acid metabolism ; the chemistry of polysaccharides and proteins ; and the salt metabolism of sheep.

Computation : Advances in computer techniques.

The *Faculty of Veterinary Science* began with the first Veterinary School of the University of Melbourne about 1908. This was the University's first official association with veterinary education and research, and the School replaced the Melbourne Veterinary College. The Melbourne Veterinary College was a privately owned institution established by W. T. Kendall in 1888, and was gradually absorbed by the University between 1905 and 1910. Although research records of the Melbourne Veterinary College are incomplete, it is known that Kendall and others conducted studies covering tuberculosis in cattle, the production and use of subcutaneous tissue exudate for vaccination against bovine pleuropneumonia, " bone chewing " in cattle, the toxicity of various poisonous plants, possible antidotes against snake venom, and stringhalt and osteoporosis in horses. Kendall was also interested in the study of professional history and published a number of papers.

The first Veterinary School at the University completed and published significant research work. An extensive survey was conducted of the beef nodule forming worm, *Onchocerca gibsoni,* and the School also continued diagnostic tests for pleuropneumonia in cattle while developing a reasonably satisfactory complement fixation test by the use of tissue exudate. Subsequently this test was improved and standardised by the C.S.I.R.O. by using organisms grown in an artificial medium. Studies of " bone chewing " in cattle continued, and it was shown that the paralysis which sometimes accompanied this activity was a form of botulism. A series of experiments was also conducted on the bionomics of the sheep ked (a wingless lousefly), *Melophagus ovinus.* In the early 1920s a special laboratory was set up to study the bacteriological status of the metropolitan milk supply, and extensive surveys were conducted on *Mycobacterium tuberculosis* and other pathogens, as well as on the various factors leading to high bacterial counts in commercial milk.

The Act of Parliament which authorised the absorption of the Melbourne Veterinary College into the University of Melbourne also stipulated that a Veterinary Research Institute should be established to perpetuate the veterinary laboratory diagnostic service initiated by Kendall. Research projects conducted by this Veterinary Research Institute, which was established in 1928, included studies of a peculiar type of actinomycosis of the mammary glands of cattle and of other mammals ; the epidemiology of Newcastle disease in Australia in the 1930s ; Johne's disease in cattle and the development of a complement fixation test for its diagnosis ; ovine brucellosis in sheep and the development of a complement fixation test for diagnosis and control ; infectious pneumonia in pigs ; botulism in wild birds; copper poisoning in domesticated birds ; parasitism in dogs and foxes, particularly in relation to the significance of the foxes in the distribution of the sheep measle parasite *Taenia ovis,* and the tongue worm *Linguatula serrata ;* leptospirosis in domestic and wild animals ; low grade swine fever under Australian conditions ; facial eczema in sheep ; eperythrozoonoses and other anaemias in domesticated animals ; colibacillosis in birds and animals ; mycobacterial infections and interference with the tuberculin test ; and hypomagnesaemia in cattle.

In 1963 undergraduate classes, which had been discontinued since 1927, recommended in the School of Veterinary Science at Parkville and subsequently at the School's Veterinary Clinical Centre at Werribee. The first class graduated in December 1967. Postgraduate students were enrolled almost immediately, and most of the research projects have provided postgraduate training in research for the degrees of M.V.Sc. and Ph.D.

In anatomy the main recent research interest has been in the reproductive tract, particularly in the development and structure of the male system. This is balanced, in the field of animal production, by concentration on diseases of the reproductive system of males and the measurement of their effect on fertility in herds and flocks. In physiology, pharmacology, and biochemistry the principal interest has been in the physico-chemical effects of physical effort, particularly in relation to horse racing. Parasitological research has included basic work, such as the effect of hormones on infestation by worms, and applied studies on the epidemiology of internal parasites in sheep and cattle. Microbiological studies have related to the viruses causing abortion in mares and the immunological aspects of nasal granuloma of cattle. Much of the research in pathology has been directed to the nutritional deficiency diseases which affect the growth of bone. Interest has also developed in the causes of liver diseases in animals and in poultry diseases which severely limit the production of chicken meat and eggs. Research surgery has covered various aspects, including the causes of infection of the kidneys and of degenerative diseases of bones and joints. Preventive medicine has become the chief research interest in medical investigations and projects have covered the economic assessment of disease control and prevention programmes, the development of alternative programmes when existing ones do not achieve maximum economic efficiency, and the testing of new programmes in terms of practical feasibility in normal farm conditions.

Much research has been supported financially by funds from the animal industries, but there have also been significant contributions from private endowments and from a research trust set up for the re-establishment of the Veterinary School. The amount available for research in 1971 was $154,000, and 21 staff were employed in research projects.

MONASH UNIVERSITY

The *Faculty of Engineering* has engaged in research since its foundation in 1960. Facilities have increased and academic staff, of whom there were only five early in 1961, numbered about 70 in 1971. By 1971 special contributions had supported and assisted 79 projects, in addition to other research. Sixty-nine Masters Degrees and Doctorates had been awarded, and about 120 scholars were enrolled as higher degree candidates. In 1970, $1m was paid in salaries to the staff of the Faculty and $295,000 on maintenance and equipment. Of these sums a significant proportion can be related directly to research activities. In addition, and apart from the specific outside research grants mentioned above, over $125,000 was disbursed in salaries to personnel engaged purely on research, and there were about another twelve research students who were not supported financially by the University.

Work in the Faculty covers the broad fields of chemical, civil, electrical, materials, and mechanical engineering. The use of computers in research has given a new dimension to analytical techniques, for example, through their use as a link in the control of many production processes. Examples of engineering research which receive stimulus from the practice of technology include structural engineering, materials engineering, production science, noise problems, electric power transmission, and mineral and chemical processing.

All departments in the Faculty are also engaged in some form of " bio-engineering " : work in electrical engineering has included research in neuro-physiology, while electrical techniques and statistical methods have combined with neurosurgery in the context of communications in the nervous system, demonstrating a link between electrical communications and the impulses conducted along nerves. Studies are also being made of the behaviour of animal tissue (whether flexible structures such as blood vessels or the brain) to predict behaviour under extreme conditions of accident or applied forces, and in circumstances where artificial substitute components are required. A growing field of research has covered the effects on animal and vegetable life of pollution in the atmosphere and water, and studies have been undertaken on the biochemistry of food processing as well as of other materials. Transport, urban development, water supply, and irrigation are all related to other civil engineering activities. Other research is undertaken in the more conventional engineering fields such as electronics, control systems, electrical machines, power conversion, processes in chemical reactors (including distillation, crystallisation, and fluidisation), heat and mass transfer, fluid mechanics, flows in estuaries, vibrations, dynamics, and mechanisms. Many projects necessarily interact with one another; " control systems " link almost all branches of engineering, and studies on the wind-loading on large buildings bring both civil and mechanical engineers into close contact with the meteorologists.

The *Faculty of Medicine* was founded at the opening of the University in 1961, and now includes the Departments of Anatomy, Biochemistry, Physiology, Pathology, Microbiology, Medicine, Surgery, Paediatrics, Obstetrics and Gynaecology, Social and Preventive Medicine, and Psychological Medicine. As these cover a large segment of the biological sciences, a free interchange of research and teaching staff continually takes place with the Faculty of Science. In 1971, for example, there were 301 science students and 331 medical students working in the Department of Biochemistry.

Research has proceeded in all departments since their establishment. The university staff, almost without exception, is engaged in research, as is a number of the visiting staff attached to the affiliated hospitals. The full-time academic staff now numbers 160, the visiting staff 200, and the supporting staff 200. The budget for salaries for the Faculty was $2.4m in 1971, and for maintenance and equipment, $465,000. A significant proportion of this is devoted to research. Since the Faculty was established, $8m has been spent on buildings for the Medical School at the University and at the affiliated hospitals (Alfred, Prince Henry's, Queen Victoria, Royal Park, Larundel, and Fairfield), providing a net area of 270,000 sq ft. A total of $3m has also been spent on furniture and equipment for these buildings. In addition, the sum of $2.3m has been spent specifically from research grants and donations to the Faculty during the years 1962 to 1970, including $593,000 in 1970, in which year 342 papers were published by the Faculty.

The Anatomy Department directs its main research to studies of the very fine structures in cells by the use of the electron microscope with particular reference to the intestines, glands, and lungs.

The Biochemistry Department studies *diabetes mellitus* and the importance of the new substance A.C.G., discovered in this Department, in controlling this disease. Arthritis and the ageing process and the various inherited and chemical factors which influence all cells form a large part of the research.

The Physiology Department studies include the transmission of messages along nerves, and the detailed study of nerve and muscle structure by the electron microscope form other research fields. Work is also being conducted on marsupials, particularly in relation to kidney function.

In the Department of Medicine much of the research activity centres on the control of body functions by hormones ; to this end radio-isotopes are used. High blood pressure, stomach ulcers, coronary disease, and the breathing mechanisms of the new-born child are also intensively studied.

The Department of Surgery carries out research on injury in its broadest sense—of tissues and the whole man. Work at a basic and practical level has been done in the areas of gastric and nutritional investigations and of organ transplantation, particularly of the liver, and on the treatment of severe burns.

In the Department of Obstetrics and Gynaecology a special study of the physiology of the unborn child and methods of diagnosing danger signals before and during birth has proceeded for a number of years. Social factors related to contraception, unmarried mothers, and sexual behaviour are all being actively researched.

The Paediatrics Department conducts research on blood, respiratory, and intestinal diseases in the new-born child. Fundamental studies on the production of red blood corpuscles, anaemias, and leukaemia have been undertaken, and the importance of minute amounts of minerals in the body is being examined.

The Social and Preventive Medicine Department deals with traffic accidents ; student health, particularly psycho-social aspects ; suicide ; and the effect on the family of sick members in hospital.

The Psychological Medicine Department's main areas include the mother's care of her baby and how this influences its development ; the causes of excessive crying and problems of insomnia and food upsets in infants ; and the effect of emotion on heart and blood pressure.

The Pathology Department directs a very large part of its research towards cancer. Investigations proceed into protective mechanisms, with the aid of radioactive substances.

The Microbiology Department's research includes studies on the organism which causes infectious jaundice as well as rapid means of identification of various bacteria.

The *Thomas Baker, Alice Baker and Eleanor Shaw Medical Research Institute* was established in 1926 to provide laboratory services for the Alfred Hospital and to conduct medical research. It is situated in the hospital grounds. In 1949 the Hospital created a clinical research unit which was functionally joined with the Institute and this, together with expanding activities, necessitated a complete re-building and re-equipping programme from 1966 to 1968. The founders had created a Trust, which assumed responsibility for the major portion of maintenance work, and which also bore the costs of this re-building project, about $1.5m, in contrast with only $6,000 for the original building. Similarly the annual maintenance costs have increased from $6,000 in 1926 to approximately $350,000 (including the Clinical Research Unit) in 1971, while the number of graduate staff has grown from seven to twenty-five.

At first, work was largely concerned with improving the routine medical services of the hospital, but by 1949 these activities had all been transferred to the hospital and members of the Institute were free to engage in medical research and postgraduate teaching. Developments now sponsored by the Institute help to establish new service departments in the Hospital ; the clinical pathology services, the cardiovascular diagnostic service, and the diabetic and metabolic unit of the Alfred Hospital all arose from Institute activities. Facilities are provided for medical students, and postgraduate training is available in both medicine and science. The Institute was formally affiliated with Monash University in 1965.

During the first twenty years, practical research covered a wide field, including the introduction to Victoria of insulin treatment for diabetes, the study of beef measles as a public health hazard, and the treatment of detached retina of the eye. During the Second World War studies were associated with chemical warfare. More recently the Institute's research has led to considerable improvement in the treatment of haemophilia and to extensions of cardiovascular surgery ; pure research now represents the major portion of its activities. The fact that various fields of interest must be related when any biological problem is studied in all its ramifications is illustrated by the linking of research at cellular component level with problems of the cardiovascular system (embracing heart, blood vessels, and blood), the production of some forms of cancer by the action of chemicals, the disturbances of the air passages of the lungs producing asthma, and the mobility of parts of the alimentary canal.

The international reputation gained by the Institute has sprung from the contributions of many workers. Especially important has been work on the clotting of blood and the resultant improvement in the treatment of haemophilia and excessive clotting. Investigations covering the behaviour of cardiac muscle cells, together with the roles of calcium and of drugs which react to it, have established a basis for research in other countries. Studies on the control of body fluids in relation to heart failure, and on the identification and study of kinekard, have also been carried out.

Research in the *Faculty of Science* at Monash University began with the appointment of its first professors in 1960, the year before undergraduate teaching began, with the intention of establishing research programmes which would attract workers from other parts of Australia and from overseas. It is carried on in all departments with practically every member of the academic staff, numbering 190 in 1971, involved. These are supported by 26 research staff ranging from technical assistants to research fellows. The annual salaries for academic and research staff amount to almost $1.8m and the annual expenditure on maintenance and equipment, directly attributable to research, to $299,000. Research was first undertaken in the Department of Chemistry in theoretical chemistry and spectroscopy, using both an infra-red and a nuclear-magnetic-resonance spectrometer. In the Department of Physics the fields chosen were low-temperature and solid-state physics, and the basic equipment included a helium liquefier and a large electro-magnet. In the Department of Zoology, emphasis was placed on the behaviour and physiology of Australian fauna, and in the Department of Mathematics the research interests were directed towards theoretical radio astronomy.

Departments of Botany and Psychology were established in 1965. In Botany the principal areas of research were translocation in plants, the mapping of the distribution of plant species in Victoria, Quaternary ecology, and the cell biology of grasses. In the Department of Psychology, research has been carried out by a group working in physiological psychology, where the neurophysiological bases of attention, habituation, and learning have been studied. Other work covers human cognitive processes such as memory, complex skills, and information processing, while some workers have studied problems in perceptual constancy, illusion, and instability. Since 1965 new departments in the Faculty have included Genetics, Information Science, and Earth Sciences. Research projects have been set up in the fields of the genetic control of enzyme synthesis and DNA specificity, and in numerical taxonomy and computer simulation.

An important adjunct to both research and teaching activities has been the availability of adequate computing facilities. At the end of 1961 the University had acquired its first computer, a Sirius, around which grew an independent computer centre offering a service to all departments in the University. This has grown rapidly and in 1971 operated two Burroughs B5500 computers and one Control Data 3200 which also served some Victorian hospitals and other affiliated organisations.

Research in the foundation departments has increased steadily with staff numbers. In 1964 a Professor was appointed to a Chair of Inorganic Chemistry to direct a programme in organo-metallic and co-ordination chemistry, and in 1965 a Chair of Organic Chemistry was established to carry out studies in synthetic organic chemistry, especially organophosphorus compounds, heterocyclic compounds, and compounds of biological significance. Meanwhile, a microwave spectroscopy group has also developed. Among various spectrometers, the group operates some special instruments designed to study very unstable compounds and compounds in high density magnetic fields.

In Physics one project has done much to establish the magnetic properties of chromium in a highly purified state, and another has shown that grain boundaries in certain alloys have a marked effect on the magnetic behaviour of superconductors. The Department also performed the first Australian photon-counting experiments on light coherence and constructed a refrigerator which regularly attains the lowest temperature reached in Australia, one twentieth of a degree above absolute zero, for the purpose of studying the atomic structure of magnetic solids.

The University's Jock Marshall Reserve with its near-natural conditions has been used in zoology research. Besides their scientific interest, the Department's arid-zone and fresh-water biology projects have immediate application to the development of water resources and to increasing the productivity of dry environments in the north-west of the State. The Department has instituted a programme in vertebrate palaeontology, and fish fossils about 400 million years old have been discovered.

Monash was the first Australian university to build up a large multiprofessorial Department of Mathematics. A second Chair, for Pure Mathematics, was filled in 1963, and was followed by a Chair in Mathematical Statistics in 1964. By 1965 two other Professors of Pure Mathematics had been appointed, and two Chairs of Applied Mathematics were established in 1965 and 1967. By this time the research activities of the Department had expanded to cover the fields of functional analysis, groups, semigroups, lattices, genetics, operational research, astrophysics, and geophysical fluid dynamics.

LA TROBE UNIVERSITY

Research in the Science Schools at La Trobe University began in 1966 with both the School of Biological Sciences and the School of Physical Sciences being housed temporarily, partly in the basement of the Library and partly in Glenn College. Some research work was also carried out in laboratory space provided by Monash University, the University of Melbourne, and the C.S.I.R.O. until the completion of the Physics, Chemistry, and Biological Sciences buildings in 1969. In 1971 the School of Agriculture lacked the necessary space to embark on a full scale research programme.

In the *School of Agriculture* the main lines of investigation stem from the often fatal disease, " grass tetany ", in cattle and sheep, characterised by a temporary lack of magnesium in the blood at particular times of the year. The role of magnesium in the animal's metabolism is being studied ; regular analyses of pastures from affected areas are being carried out.

Research by the *School of Biological Sciences* has included the following :

Botany. Research in this department concerns the structure and development of plants and factors governing their distribution and relation to the environment. Detailed studies are concerned with the ultrastructure of cells ; biochemical aspects of cell differentiation ; the physiological growth of algae ; factors governing the entry of parasites into plants ; the form and growth of members of the Liliaceae with an arborescent habit of growth ; and studies on the distribution of eucalypts in arid zones of Australia.

Genetics and Human Variation. Research is carried out on a broad range of topics, including behavioural, ecological, radiation, and biochemical genetics. Organisms being studied include micro-organisms, insects, plants, marsupials, and man. The interaction of genetic type and environment is being stressed with respect to local population of insects and plants. Other interests include physical anthropology of Australian Aboriginals, immunology, and cell biology.

Zoology. Studies include a zoo-geographic survey of the south-east Australian reptile fauna ; patterns of reproduction in dasyurid marsupials including *Dasyuroides byrnei, Dasycercus cristicauda :* pathology of dasyurid marsupials ; speciation of endemic psocopteran insects of the Galapagos Archipelago ; studies on the origin and distribution of the psocopteran insect fauna of the Melanesian arc of islands , taxonomy and ecology of psocopteran insects of Australia and South America and of neuropteran insects and their hymenopterous parasites ; ecology of wasps causing galls on *Acacia,* and insects causing foliage damage to eucalypts ; insect physiology and ultrastructure ; population ecology of the Light Brown Apple Moth, *Epiphyas postvittana ;* bionomics and ecology of the Pear Slug, *Caliroa cerasi ;* ecology of the Diamond Black Moth, *Plutella maculipennis ;* comparative endocrinology of vertebrates with particular reference to salt and water metabolism in birds.

The *School of Physical Sciences* has carried out research in the fields of chemistry, mathematics, and physics.

Chemistry—Inorganic and Analytical. Of the 92 elements which are naturally occurring, inorganic chemistry is interested in and concerned with 91 of them, in the general sense. Of particular interest and significance are the so-called transitional elements which comprise many of the elements important to industry and metallurgy (iron, chromium, nickel, etc.) Ions of these metals react with organic compounds forming co-ordination compounds, and a study of their preparation, chemical behaviour, and other properties provides valuable theoretical information which can produce compounds of value in industry, medicine, and agriculture. This type of work and study is classified as the " preparation and study of co-ordination and organo-metallic compounds ". Often the organic moiety used has to have certain characteristics, and must be designed and synthesised (design and synthesis of multi-dentate chelating agents). In the modern chemical industry the ability to analyse or determine the constituents present in a compound is of great importance. This is true in the Australian mineral industry, the pharmaceutical industry, and in agriculture. Advanced methods are required and these are usually instrumental, so interest centres in spectroscopic techniques such as ultra-violet and visible spectrophotometry, infra-red spectroscopy, and atomic absorption spectroscopy, in which properties of the metallic atom, which are based on the emission or absorption of radiant energy, are exploited. Electro-chemical studies, such as polarography, chronopotentiometry, and chronoamperometry, by which the reducing or oxidising properties of the metal atom in the compound can be characterised, are also of interest, and can lead to valuable information on the compounds as a whole. Thermal methods (thermogravimetry and differential thermal analysis) are also used and the weight losses associated with particular entities examined ; these methods are based on the behaviour of the chelate (co-ordination) compounds when heated in a controlled manner.

Chemistry—Organic. The Organic Division studies certain theoretical, physical, and synthetic aspects. Work is in progress on understanding and predicting the properties and reaction of organic molecules, both by theoretical calculations and by more empirical relationships with other known features ; particular use is made of modern instrumentation, allowing important properties to be measured. Relationships between structure and biological activity are also being studied ; much synthetic work is involved in these studies. Work on pollution, particularly by insecticides, is also being carried out.

Chemistry—Physical. Mass spectrometers, controlled by the University's PDP 9 computer, are being used in the analysis of complex organic mixtures (e.g., flavours), the determination of isotope abundances in minerals, and the study of energy states of molecules. Energy states are also being investigated by using high energy radiation to displace electrons from the molecules, and related theoretical calculations of the bonding in polyatomic molecules are being made. The rates of reactions of gaseous free radicals, crystal structures of organic and co-ordination compounds, levels of chemical contamination in the local environment, and the geochemistry of ores are also being studied.

Mathematics. Among the areas of research are : application of mathematics and statistics to biology with special emphasis on population genetics, maximising the use of limited resources subject to physical or economic constraints, obtaining approximate solutions to mathematical problems where exact solutions cannot be obtained, and utilising a computer for language translation.

Physics—Electron. Studies are made of the interaction of electrons with gases and solids. Some effects of X-rays on solids are being examined. Lasers are used to study the surfaces of solids.

Physics—Space. The composition and movements of the earth's atmosphere above 60 miles altitude are being studied theoretically and experimentally. Studies are also proceeding on the theory of liquids and of elementary particles.

SCHOOL OF MINES AND INDUSTRIES, BALLARAT

When the School of Mines and Industries was established at Ballarat in 1870, it was the first institute of technical education in Australia. Its original object was to provide two types of training, one of a scientific type in the various branches of mining technology for mining engineers, surveyors, and assayers, and the other a training for managerial and sub-professional mining employees. Chemistry and metallurgy laboratories were erected during 1871 and 1872, and from the 1880s trade and secondary courses were established to provide an adequate technical and educational basis for persons desiring to undertake professional and sub-professional courses. It was soon found necessary to broaden the scope of courses to cater for additional technical professions such as the various other branches of engineering, applied science, and geology. The School awarded the first diploma in Victoria (metallurgy) in 1896, and the first engineering diploma (mining engineering) in 1897.

During its early years the School depended heavily on funds from local private sources, government grants, and revenue from the public assaying and smelting of gold. Although by 1881 financial difficulties necessitated a reduction in lecturing staff, the School Council established Chairs of Chemistry and Geology to which professors were appointed. From 1887 to 1893 the School was an affiliated college of the University of Melbourne.

In 1881 the School had anticipated the advent of university extension courses by introducing a series of popular science lectures by prominent scientists, including the Government Botanist, F. J. H. Mueller, and the Government Astronomer, R. L. J. Ellery. An astronomical observatory was established by the School on nearby Mount Pleasant in the 1880s; its 12½ inch Newtonian telescope was later removed to the Commonwealth Observatory on Mount Stromlo in the Australian Capital Territory. For some years meteorological observations were published in the School's annual report, which also contained scientific papers, chiefly on geological matters. In 1896 an X-ray plant was installed and used for both clinical and experimental purposes; this was only seven months after Roentgen's demonstration of his discovery.

By 1890 the School was conducting courses in many fields other than mining, including natural philosophy (physics), electricity, telegraphy, biology, botany, and materia medica. Progressively these courses became broader and more advanced until the present diploma courses evolved: art; business studies; applied chemistry; mechanical, electrical, electronic, civil and mining engineering; applied geology; metallurgy; and applied physics. In 1971 a degree course for B.App.Sc. (Chemistry) and a postgraduate diploma course in malting and brewing were introduced. The latter course is the only one of its kind in Australia. From this expansion of the tertiary division has evolved the present Institute of Advanced Education which is being progressively transferred to a new 240 acre site at Mount Helen near Ballarat.

BENDIGO INSTITUTE OF TECHNOLOGY

The Bendigo Institute of Technology was established in 1873 as the Bendigo School of Mines and Industries to meet the scientific and technical needs of the local gold mining industry by providing instruction in subjects related to mining, chemistry, geology, and metallurgy, the first diploma (metallurgy) being awarded in 1902. The tertiary section of the Institute is affiliated with the Victoria Institute of Colleges and is being progressively transferred to a new site at Flora Hill with a modern campus and buildings. Fifteen diploma and post-diploma courses are now provided in the fields of applied science, art and design, business studies, engineering, general studies, mathematics, and information science. Degree courses in metallurgy and in civil engineering were due to commence in 1973.

The Institute operates a regional computer centre which has developed a new computer programming language used by secondary schools in the central and northern areas of the State. Other educational research and development has included theoretical and practical approaches to the improvement of tertiary level study skills. Testing services for industry are provided by the Institute, the Soil and Concrete Laboratory being approved by the National Association of Testing Authorities to undertake compression testing of concrete between 50,000 lb and 300,000 lb per square inch. It makes available a full range of concrete testing services to contractors and builders in northern Victoria.

ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY

The Royal Melbourne Institute of Technology was founded in 1882 as the Working Men's College. It has been the Institute's policy since its inception to develop courses to meet the demands of the State's technological and industrial growth, and during its ninety years the Institute has continued to offer an increasing range of vocationally oriented courses.

Traditionally, the Institute has also made staff and facilities available to both government authorities and industry for technological problem-solving and testing. Initially, testing and allied services were carried out by individual staff members. This led to the establishment of a testing department in 1935. Although this department had permanent staff and its own equipment, it still relied on, and utilised, staff and equipment from the teaching departments for particular services to industry.

It was not until late in the 1960s that the Royal Melbourne Institute of Technology was able to develop an industrially oriented research programme. In 1968 the Institute undertook its first major research project. A grant of $10,000 from the Commonwealth Advisory Committee on Advanced Education enabled two research fellows to undertake a study of the information service provided by colleges of advanced education. Over 7,000 firms were invited to participate in a survey of practices and needs, and the study was completed in 1969.

Although extensive use is made of the Institute's facilities and personnel by outside organisations, the potential for investigation and research has only been partly developed. The growth in demand, both in volume and complexity, has indicated the need for a co-ordinated and comprehensive approach to testing services and research. In 1971 the Institute announced the registration of Technisearch Ltd, a company limited by guarantee and owned by the Institute. Technisearch aims to promote the development and practical application of science and technology to industry and commerce, and to undertake applied research and investigations in collaboration with industry.

TEXTILE COLLEGE, GORDON INSTITUTE OF TECHNOLOGY

The Textile College, Gordon Institute of Technology, was opened in 1946, although research and public testing in textiles at the Institute dates from 1938. The College teaches textile technology and textile science at postgraduate, undergraduate, and diploma levels, and also engages in public testing for the woolgrower (including a fleece measurement service to aid stud breeders), and in research into the physical and chemical properties of the Australian wool fibre for manufacturing. It conducts refresher courses, conferences, and seminars, and has participated in overseas conferences. In 1971 the staff consisted of ten lecturers and four demonstrators. An annual research grant of $30,000 is received from the Australian Wool Board, which, together with major industrial firms and manufacturers' associations, contributes about $38,000 annually in special student scholarships.

The Textile College has carried out pioneer research on the dimensions of wool staples and bulks (fibre diameter, length, crimp frequency, shape of cross-section, etc.) and their inter-relationships ; the efficacy of woolclassing and wool-sorting techniques ; the relationship between fibre properties in the flock or manufacturing bulks and their manufacturing importance in tops, yarn, and fabric ; the effects of woven fabric parameters on the subjective and objective assessments of cloth; the causes of certain processing effects of special wools, such as lambs' wool, carpet wool, and stained wool ; and the modifying effects of finishing and dyeing on the woven fabric. Ninety scientific papers were written between 1945 and 1971 for overseas and local publication.

The Australian Wool Board's Experimental Unit is housed in the College under a collaborative agreement and acts as a practical liaison or technical service between research and industry. Modern textile machinery, valued at $1m, was supplied mainly by the Commonwealth, with some help from the State, and includes woollen, worsted, and cotton-type machinery, together with weaving and knitting plant. The textile testing section is being rapidly developed.

The following organisations, which have no formal university affiliations, are engaged in, or sponsor, medical research :

ST VINCENT'S SCHOOL OF MEDICAL RESEARCH

The St Vincent's School of Medical Research was established in 1952 as a result of a bequest made by the late John Holt. The research activities of the School fall broadly within the field of molecular biology, the science which seeks to explain the biological phenomena from the chemical and physical properties of the bio-molecules, examples of which are proteins and nucleic acids. Studies of this type have already shed much light on such fundamental biological mechanisms as immunity and heredity.

The study of the structure of proteins has been the main interest of the School, and some notable contributions have been made. Among these are the internationally used advanced technique of determining protein structures, and the invention and introduction in 1967 of the protein sequenator instrument to quicken the task.

Research on the mechanism of blood clotting has led to an understanding of changes in the structure of fibrinogen, a protein in the blood. For the first time an overall picture of the fibrinogen molecule has been gained, opening up possibilities for the study of inherited and acquired defects in the blood clotting mechanism.

More recently investigations have been directed towards the molecular basis of the immune reaction, and important aspects of the mechanism by which antibodies are synthesised in the body have been clarified.

In 1971 the staff of the School comprised five research workers and six technical officers. There is also a variable number of visiting research workers from Australia and overseas. The main source of finance for the School is the interest on the John Holt foundation bequest, but supporting grants have been obtained from the National Health and Medical Research Council and from the Australian Research Grants Committee. The expenditure of the School for the financial year 1971–72 was $73,534.

NATIONAL HEART FOUNDATION OF AUSTRALIA

The National Heart Foundation was established by public subscription in June 1961 for the study, diagnosis, and treatment of diseases of the heart and the circulatory system, for the rehabilitation of sufferers of these diseases, and for promulgating information on the prevention, treatment, and control of heart disease. In Victoria the Foundation supports experimental and clinical research on the cardiovascular system, notably in such fields as the mechanism and pharmacology of drugs affecting cardiovascular function and coronary circulation, and specialised studies on hypertension and thrombosis. As a voluntary organisation, most staff are honorary, although the work is co-ordinated by a small team of salaried workers.

The Foundation's research programme, which accounts for two thirds of all its expenditure, has advanced cardiovascular work in Australia, and between 1963 and 1969 about $400,000 was spent annually on supporting various projects, about one third of this being awarded for work in Victoria. Aid given to fundamental research has enabled Australia to make important contributions to world knowledge in the electro-physiology of nerve and muscle cells, and in the analysis of heat production in contracting heart muscles. Clinical and applied research work has included the development of new X-ray and other practical techniques in diagnosing early heart failure, in surgery techniques, and in the development of intensive coronary care wards. Rehabilitation units are also maintained and staffed by the Foundation in all capital cities and other major population centres. A Work Assessment Centre specialising in the rehabilitation of patients has been operating in Melbourne for some years, assisting an increasing number of patients to lead productive and rewarding lives. The total number of patients per year increased from 27 in 1961 to over 1,200 in 1971.

As heart diseases are now responsible for more than 34 per cent of all Australian deaths the Foundation has established a public information and education programme so that risks may be recognised and minimised. Over sixty publications for lay and professional readers have been published, and material has also been prepared for the news media. The Foundation finances a continuing education programme to help keep doctors informed of the latest developments, and it supports the recruitment and training of research workers through its Undergraduate Medical Research Scholarships and by grants for fellowships and specific research projects.

By 1971 the Foundation had awarded a total of over \$1.4m for research in Victoria, had supported 82 research grants in the State, and was currently supporting 27 research projects, fourteen vacation scholars, and six undergraduate research students, representing approximately one third of the Foundation's total awards in Australia.

3

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

HISTORICAL OUTLINE

At the commencement of the First World War Germany had well-established chemical and precision machine industries, and held a near monopoly in the manufacture of such commodities as dyestuffs and optical instruments. Other countries came to realise the importance of providing scientific help to industry ; the British Government quickly created the Department of Scientific and Industrial Research. Convinced that a similar organisation was needed in Australia, the Prime Minister, the Rt Hon. W. M. Hughes, called a meeting in Melbourne of prominent scientists and industrialists, as a result of which a temporary body, the Advisory Council of Science and Industry, was established in 1916. By 1917 a scheme for a permanent Institute of Science and Industry had been drafted, but political support failed. The Advisory Council struggled on ; its financial resources were extremely limited, and it had neither laboratories, research staff, nor apparatus of its own. Nevertheless, it appointed a number of expert committees which did valuable work in co-ordinating and stimulating research in existing laboratories. In 1920 the Government, due largely to the advocacy of Professor (later Sir) David Orme Masson, the first Professor of Chemistry at the University of Melbourne, established a permanent Institute. Sir George Knibbs, who was then the Commonwealth Statistician, was appointed Director in 1921.

In 1925 the Commonwealth Government convened a conference of scientific and industrial leaders in Melbourne to advise how the Institute might best be re-organised and its activities extended, and the Prime Minister, the Rt Hon. S. M. Bruce, invited a leading British science administrator, Sir Frank Heath, to advise on the reorganisation of national scientific research in Australia. Resulting from the ensuing recommendations the Science and Industry Research Act in 1926 established the Council for Scientific and Industrial Research, which in its early days was guided by an Executive Committee comprising Mr G. A. (later Sir George) Julius, Professor A.C.D. (later Sir David) Rivett, and Professor A.E.V. Richardson. Rivett, who was the only full-time member of the Committee, was Professor of Chemistry at the University of Melbourne from 1924 to 1927.

The Council organised its work into a number of Divisions. No attempt was made to centralise the organisation ; laboratories and field stations were set up wherever in Australia was most appropriate for the work concerned.

The emphasis was on primary production problems, plant and animal diseases, insect pests, food preservation and transport, irrigation problems, and utilisation of forest products; within a few years the Council had established the Divisions of Animal Health, Animal Nutrition, Entomology, Food Preservation, Forest Products, Plant Industry, and Soils.

In 1936 the Commonwealth Government decided to extend the activities of the C.S.I.R. to embrace the problems of Australia's secondary industries, and this led to the establishment of the National Standards Laboratory, the Division of Aeronautics, and the Division of Industrial Chemistry. At the outbreak of the Second World War most of the long-range research programmes of the C.S.I.R. were suspended and the Council concentrated on work of immediate bearing on the war effort; further research groups such as the Division of Radiophysics and the Lubricants and Bearings Section (later the Division of Tribophysics) were formed.

After the war the Council was able to give its full attention to problems of primary and secondary industry. New Divisions and Sections extended the work into building research, meteorological physics, physical metallurgy, wool textiles, coal, and other fields. In 1949 the Council was re-constituted by Act of Parliament as the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.). It ceased all secret or classified work, the Division of Aeronautics becoming the Aeronautical Research Laboratories of the Department of Supply. The first Chairman of C.S.I.R.O. was Professor (later Sir) Ian Clunies-Ross. He was succeeded by Dr (later Sir) Frederick White in 1959, who was followed by Dr J. R. Price in 1970.

The first annual report of the C.S.I.R. in June 1927 listed 41 scientific officers. The Council had a small chemical laboratory in rented accommodation. By 1971 C.S.I.R.O. had over one hundred laboratories and field stations throughout the Commonwealth and a total staff of 6,400 including more than 1,800 scientists. In 1970–71 C.S.I.R.O. spent some $65m on research; about three quarters of these funds were provided directly by the Commonwealth Government, the remainder being contributed by primary industry, individual companies, Australian and overseas government instrumentalities, and private foundations. The Head Office of C.S.I.R.O. (and of its predecessor, C.S.I.R.) was located in East Melbourne until 1971, when it was transferred to Canberra.

C.S.I.R.O. IN VICTORIA

As a Commonwealth organisation charged with undertaking research for the benefit of Australian rural and industrial activity, most of C.S.I.R.O.'s research is directed towards problems common to more than one State. Thus, while work on physics is concentrated in Sydney, on soils in Adelaide, on building research in Melbourne, and on insect control in Canberra, the results of this research find application in many parts of Australia, not merely in the State where the research is carried out.

Today about one third of the organisation's research is conducted in Victoria and the section which follows traces the history up to 1971 of those C.S.I.R.O. Divisions and Sections which are, or have been, based in Victoria, giving a brief account of their activities and achievements.

Protein chemistry

In 1949 the Biochemistry Section of the Division of Industrial Chemistry was separated from the Division to become the Biochemistry Unit of the newly established Wool Research Laboratories. In 1952 the Unit moved to Parkville, and in 1958 it became the Division of Protein Chemistry, mainly conducting research on the structure and physical properties of the wool fibre ; since 1965 some research has been undertaken on hides and leather.

The Division has made a major contribution to the elucidation of the detailed structure of the wool fibre at the cellular and molecular levels, and has developed biochemical techniques for wool and protein research workers in general. Studies of the distribution and reactivities of amino acid side-chain groups in wool proteins have helped provide a strong basis for understanding many of the physical and chemical properties of the wool fibre. Research on the biochemical mechanisms involved in linking protein molecules to one another during the permanent pleating of woollen garments and the flat setting of suitings had led to a search for new types of chemical cross-links which could be exploited in more rapid setting processes. The demonstration that some oxidative shrink-resist treatments do not completely split disulphide bonds unless a second chemical reagent is employed has also guided further research on these processes. Studies have shown that the sunlight yellowing and bleaching of wool are caused by ultra-violet and blue light, respectively ; tryptophan in wool appears to be the major source of discolouration. A process developed by the Division for whitening wool and retarding sunlight yellowing is being used by industry.

Research has also led to a method adopted by the fellmongering industry of recovering wool from sheepskins, and to the use of tanned sheepskins in hospitals for the prevention of bedsores. Work on hospital blankets has shown that with appropriate detergents, shrinkproofed hospital blankets can be boiled without discolouration or damage. The Division has successfully developed a vacuum pressing method of baling wool, a method for protecting wool during carbonising, and a fluorocarbon treatment which prevents the accumulation of wool wax on shearing combs during shearing.

Textile industry

A Textile Research Laboratory was established at Geelong in 1949 as one of the three C.S.I.R.O. Wool Research Laboratories ; it became the Division of Textile Industry in 1958.

Research in the Division has been concentrated on problems and improvements in wool textile processing, and on the development of new and better consumer products from wool. Chemical treatments have been devised which make woollen fabrics shrinkproof, mothproof, resistant to " balling " or " pilling ", and which confer permanent press properties, perhaps the best known being the " Si-Ro-Set " process for permanent creasing or pleating, which has been used by clothing manufacturers in Australia and overseas.

Notable achievements in textile processing have also been made in the Division. The introduction of a sheep branding fluid, removable during normal processing, has overcome the problem of " tar " in the Australian clip. A scouring process has been developed for cleaning greasy wool by passing it under a series of jets which spray it with either an organic solvent or a detergent solution ; jet scouring plants are now operating in Australia and in overseas countries. A control instrument developed for the Noble comb is widely used by the wool combing industry, and improved methods of dyeing have been devised which enable wool " top " to be dyed rapidly and on a continuous basis instead of in batches. An entirely new concept of spinning invented at the Division is known as the self-twist system. Self-twist spinning machines are extremely compact and can produce two-ply worsted yarns at twelve to fifteen times the speed of conventional machines. They are manufactured under licence in Australia and distributed overseas.

Chemistry and minerals

A Division of Industrial Chemistry was set up in 1940 and was located in the Chemistry Department of the University of Melbourne until 1941 when it moved to Fishermens Bend. In 1958 the Division was divided into the Divisions of Chemical Physics, Mineral Chemistry, and Physical Chemistry, and into several smaller sections which later became the Divisions of Organic Chemistry, Applied Mineralogy, and Chemical Engineering. The Division of Chemical Physics transferred to Clayton and the Division of Mineral Chemistry to Port Melbourne in 1965.

In 1966 the Divisions of Physical Chemistry and Organic Chemistry combined to form the Division of Applied Chemistry, while the Mineragraphic Investigations Section, formed at the University of Melbourne in 1927 to study ore materials by microscopic, spectrographic, X-ray, and other techniques, became part of the Division of Applied Mineralogy. In 1967 the Division of Coal Research, Sydney, became part of the Division of Mineral Chemistry, and in 1969 the Division of Chemical Engineering moved to Clayton. In 1971 those Divisions concerned with research for the mineral industries were re-organised and grouped together as the C.S.I.R.O. Minerals Research Laboratories, a complex which has its headquarters in Melbourne and which comprises the Divisions of Chemical Engineering, Mineral Chemistry, and Mineralogy. The latter Division, which has its headquarters in Perth, was formed from parts of the Divisions of Mineral Chemistry and Applied Mineralogy. The remaining staff of the Division of Applied Mineralogy was transferred to research groups in the Divisions of Tribophysics and Building Research. Later in 1971 the Mineral Physics Section of the Division of Mineral Chemistry became an independent section within the Minerals Research Laboratories.

During the Second World War the Division of Industrial Chemistry spent much of its time on the immediate problems imposed by the war, such as extracting uncommon metal derivatives from local minerals. Titanium tetrachloride, for example, was needed for smokescreens, and cerium oxide was needed as a polishing powder for optical lenses. The Division worked on many chemical problems, including the construction of laminated aircraft propellers, prevention of " crazing " of plastic aircraft windows, concentration and drying of foodstuffs, and the preservation of leather boots in hot and humid climates.

Many of the discoveries made during the wartime investigations of ores of the less common metals were subsequently developed into industrial processes ; typical examples include the use of butyl titanate as a heat-resistant paint medium, the manufacture of glass polishing powder, the separation of hafnium from zirconium, and the production of compounds of aluminium, chromium, and zirconium.

Following the formation of the Division of Mineral Chemistry in 1958, research was extended to cover the industrial extraction of gold, copper, aluminium, and the base metals. Research has since been initiated in the fields of mineral exploration, mining, mineral dressing, and extraction metallurgy.

A Cement Section, supported by manufacturers, was formed in the Division in 1941 to carry out research into the problems of cement production and utilisation. At that time there had been some spectacular failures of overseas concrete structures which had been attributed to a chemical reaction between the cement and the aggregates. The group was able to show how failures could be avoided by proper selection of the aggregate. After the war, the Section entered the field of ceramics and demonstrated the suitability of Australian clays for whiteware manufacture. Subsequently work in the field of industrial minerals led to major projects on refractories for use in kilns, furnaces, and gas plants ; contaminants in Victorian brown coal seams ; boiler fouling ; and the solution of problems in Lurgi gas plant operation. The Section became the Division of Applied Mineralogy in 1962.

In 1944 a group equipped with modern physical facilities for the investigation of chemical problems was set up in the Division of Industrial Chemistry. This group later became the Division of Chemical Physics. It is concerned primarily with basic researches ; these have yielded results of great practical importance. For example, spectroscopic studies led to two new techniques, one for producing light of high spectral purity, the other for carrying out chemical analysis by means of atomic absorption measurements. Instruments based on these techniques are now manufactured under licence to C.S.I.R.O. by Australian and overseas instrument manufacturers and are widely used throughout the world.

Studies in the diffraction of light and of electrons have led to a major advance in physical optics, while X-ray methods have been used to determine the structures of several large organic molecules of biological significance. Electron microscopy applied to studies of such materials as muscle, plant chloroplasts, protein crystals, and wool has yielded important new biological knowledge. A knowledge of the solid state is of basic importance in many industrial processes, and as a contribution to this knowledge, investigations have been made of some of the electronic processes involved in diffusion, oxidation, luminescence, and the chemical reactions of solids. In addition to its research programme, the Division of Chemical Physics has stimulated and assisted in the production of scientific instruments in Australia.

The Division of Applied Chemistry is concerned with the application of chemistry to problems of particular importance to Australian industry. Considerable effort is being devoted to the synthesis of new chemicals and the isolation of naturally occurring ones ; some of these are of potential value as insecticides, and others have pronounced pharmacological effects, anti-tumour activity, and activity in plant growth control. Research in the area of organo-metallic chemistry is aimed at developing new compounds of some of Australia's basic metals such as zirconium, titanium, and aluminium. It has potential value to the chemical industry in providing specific catalysts for certain kinds of reactions. Significant advances have been made in developing a method for reducing evaporation from reservoirs and in devising processes for purifying water. Studies of ice nucleation and crystallisation are contributing towards understanding the basic mechanisms of cloud-seeding methods of inducing rainfall.

The Division has developed infra-red aerial methods for detecting bush fires, and has devised a system for economically starting large control fires by dropping incendiary capsules in a grid pattern from aircraft. It is also working on problems in chemical thermodynamics and theoretical physical chemistry, and on the chemical effects of very high pressures. Techniques of separation and analysis are studied and used widely in the Division's research. In conjunction with the University of Melbourne, the Division operates the Microanalytical Laboratory which conducts analyses for research groups and private industry.

The Division of Chemical Engineering is concerned with the development of processes for industrial use and with research into the more fundamental aspects of chemical engineering operations. Development projects have included a study of economic methods for the desalination of sea water and bore waters, and the production of gas of high calorific value by the direct combination of hydrogen with brown coal. The Division also studies the separate operations common to many industrial processes which make up chemical engineering processes, such as fluidisation and mixing, grinding, and the separation of fine particles according to their size. Studies are also carried out in the more basic fields of fluid mechanics and transport properties, and of chemical reactions fundamental to chemical engineering operations.

An Ore Dressing Investigations Section was established at the University of Melbourne in 1934 to study the recovery of minerals from ores by different methods, including cyanidation, amalgamation, flotation, leaching and pressure leaching, and by gravity, electrostatic, and magnetic methods. In 1969 it was closed down, some of its research being transferred to the Division of Mineral Chemistry but most to the Division of Chemical Engineering.

Tribophysics

In 1939 C.S.I.R established the Lubricants and Bearings Section at the University of Melbourne to study wartime problems associated with friction and lubrication. Replacements for aircraft engines were unavailable in Australia, so the section developed methods of manufacture and testing of bearings, and some were actually produced at the University under the supervision of C.S.I.R. officers. Concurrently, ideas were developed which still form the basis of the understanding of frictional behaviour. At the end of the war, the study of lubricants and bearings was extended to cover all aspects of the study of metal surfaces and in 1948 the Section became the Division of Tribophysics ("rubbing physics").

The Division has contributed to the knowledge of the structure of metals and the properties of metal surfaces ; experimental techniques have increased scientific knowledge of the relation of crystal defects to the strength, deformation, "working", and annealing of metals ; studies of the physics and chemistry of solid surfaces have led to better understanding of friction and of surface catalysis and adsorption. In particular, the detailed geometry of surfaces and the arrangement of atoms at the surfaces is now known. The Division's activities have become increasingly diversified, particularly in the direction of ceramic-type materials, and it now works over a wide range of materials science and technology, with heavy, but not exclusive, emphasis on surfaces.

Physical metallurgy

A Physical Metallurgy Section was founded in the Metallurgy Department of the University of Melbourne in 1946.

The Section has conducted research on the physical properties and oxidation of titanium and its alloys, and on the slow deformation of metals at elevated temperatures (known as "creep"). Much of this work has been concerned with the actual mechanisms of creep and of creep fracture, and with developing and using microscope techniques for this type of investigation. In 1971 the Section was amalgamated with the Division of Tribophysics.

Dairy research

A Dairy Research Section was established in 1939. During the war the Section worked with the Industrial Chemistry Division on problems of transport and storage of dairy products. One achievement was the development of a butterfat spread known as butter concentrate which kept well at tropical temperatures. In the immediate post-war years projects included the elimination of the washing step in butter making, the development of a milk powder suitable for use in bread, the manufacture of egg substitutes from milk, and the study of the chemistry of weed taints in butter. In 1955 the Section moved to new laboratories at Highett, and in 1962 it became the Division of Dairy Research. In 1971 the Division became the Dairy Research Laboratory of a new Division of Food Research which has other laboratories in Sydney and Brisbane.

The Laboratory carries out fundamental and applied research on milk and its constituents, the manufacture of dairy products, and the development of new foods designed to increase the demand for dairy products. A major project over the last 15 years has been the mechanisation of Cheddar cheese manufacture; plant developed in the Laboratory is now used widely in Australia and has been exported to the United States, Britain, New Zealand, and Holland. The Laboratory has also helped the cheese industry overcome problems associated with the maturation of rindless Cheddar in plastic film wrappers, and with the manufacture of non-Cheddar varieties of cheese, and it now supplies the industry with freeze-dried starter cultures. New methods have been developed for the manufacture of casein, for the production of entire milk proteins or co-precipitates, and for the manufacture of various recombined milk products, particularly recombined sweetened condensed milk. The Laboratory has shown that contamination of butter with copper can seriously affect its keeping quality, and that prevention of this contamination can lead to a substantial reduction of butterfat losses during churning. New products such as butter powder, ice-cream for dietetic uses, and a milk biscuit comparable in nutritive value to whole milk solids have been developed in the Laboratory to expand the use of milk solids. Fundamental research is carried out on the structure of milk proteins, the microstructure of dairy products, the action of rennin on casein, and the chemistry of those substances which give dairy products their characteristic flavour and of those which cause abnormal flavours.

Building research

Towards the end of the Second World War the Australian building industry faced many problems, and in 1944 a C.S.I.R. section began research into building materials. Its work was complementary to that of the Commonwealth Experimental Building Station (now a part of the Commonwealth Department of Works), established in 1944 to experiment with new ideas in building construction. In 1950 the Building Research Section became the Division of Building Research ; its functions were broadened and it became responsible for long-term research on all aspects of building and its related engineering.

The Division has built up a programme of research into the properties, uses, and manufacture of concrete, clay products, stone, bituminous products, gypsum and gypsum products, glass, and organic materials such as paint and plastics. It devised processes for producing lightweight aggregate from Australian clays and shales ; concrete made from this is much lighter than ordinary concrete but of equal strength and durability and is now widely used in construction. Fundamental and applied research on gypsum resulted in a great improvement in the properties of fibrous plaster. Early work on the manufacture of clay products led to the establishment of large, highly mechanised plants throughout Australia. A number of new ceramic products, many of them based on basalt, have been developed by the Division. One of the most promising of these is a low temperature coloured ceramic glass which can be applied to the exposed surfaces of concrete products.

The Division has made a study of architectural acoustics and this has led to the successful design of sound reinforcement systems in large halls and in open spaces such as the Sidney Myer Music Bowl in Melbourne. With the recent erection of special acoustical chambers, it has become possible to work on the many problems arising from the present trend to lightweight and open planned buildings. Basic work on the heating and cooling of buildings is also being undertaken.

In the structural field the Division has given attention to the behaviour of concrete flat plates and other concrete structures, resulting in greatly improved methods of design. In a number of cases the study of these structures has involved the construction of large models to enable the determination of such problems as the deflection of the structure or its resonant frequency and vibration under moving loads. The application of electronic computers to the design of structures is being studied with the ultimate aim of completely mechanising the process.

During the 1960s the Division extended its activities into the field of building operations and economics to study important problems relating to the management, organisation, and economics of the building industry. The Division has also entered the field of systems research to develop and apply systems techniques to the design and planning of civil engineering building projects.

Mechanical engineering

In 1945 a small group was set up in Head Office to provide an engineering service to Divisions. The group gained special expertise in environmental control as a research tool for both plant and animal studies and developed its own research programme on environmental control. This extended later into new fields such as the utilisation of solar energy. In 1955 the group became the Engineering Section and in 1963 the Division of Mechanical Engineering.

The Division now operates mainly in the fields of engineering, thermodynamics, and fluid dynamics. Its interests include controlled environment engineering, with emphasis on comfort cooling in tropical areas, heat and mass transfer processes, solar energy and thermal radiation, aerodynamics of fans and ducting, electronics and telemetering, and some aspects of agricultural engineering.

The controlled environment engineering projects cover studies of thermal design for air conditioning, the conditions required for human thermal comfort, the development of novel cooling systems for hot climates, and sponsored investigations for industry. The solar energy research programme includes water heating for domestic and industrial installations, solar distillation of salt water, and heating of air for industrial and low temperature drying processes. Aerodynamics research and development is being applied to the manufacture of fans, both large and small, and to mine ventilation.

Two aspects of agricultural engineering receive attention in the Division : the development of agricultural machinery and techniques, and the protection of stored wheat and similar commodities from insect and mould attack, particularly by the use of aeration to cool bulk grain.

Forest products

The Division of Forest Products was founded in 1928 to carry out research into the more effective use of Australia's timber resources. To do this, it has been necessary to study not only the applied problems which affect the industry, but also the fundamental aspects of the growth structure, chemistry, and properties of wood.

During the Second World War the Division worked on various defence projects involving timber. The Division's war effort included the testing of timber and plywood for use in aircraft construction, and work on tropic proofing, ammunition boxes, wood identification (particularly of New Guinea timbers), glue lamination, and standards.

The Division's work has made a notable impact on the Australian timber industry. Assistance to the sawmilling industry has helped to improve production rates, recovery, and quality of sawn timber. Large-scale production of high grade kiln-dried hardwood has followed improvements to kiln design and drying methods. Work on timber preservation has enabled the life of wood in contact with the ground, such as poles and posts, to be greatly extended. Studies of the peeling, drying, and gluing of veneers have enabled the plywood industry to produce a high quality product from a wide variety of local timbers. In addition, determinations of the mechanical properties of timber and the provision of design data have played an important part in promoting the efficient use of timber as a structural material.

In 1971 that part of the Division concerned with wood as a structural material was integrated with the Division of Building Research. The remaining part of the Division of Forest Products, which was concerned with research for the pulp and paper industries, was integrated with the Division of Applied Chemistry.

Applied geomechanics

In 1955 a Soil Mechanics Section was established in Melbourne as a component section of the Division of Soils which has its headquarters in Adelaide. It became an independent Section within C.S.I.R.O. in 1958 and in 1967 it became the Division of Soil Mechanics. Its name was changed to the Division of Applied Geomechanics in 1970.

The Division undertakes basic and applied studies of the physical, chemical, mineralogical, and engineering properties of Australian soils and rocks. A major part of the research programme is concerned with design of road pavements; the mechanisms of moisture transfer beneath road pavements; and the design of openings in rock in relation to mining engineering. The Division is also concerned with the properties of soils as foundations for buildings, bridges, and other engineering structures. An instrument designed by the Division has provided foundation engineers with an improved technique for determining moisture potential in foundation soils. This enables the engineer to predict more accurately the effect of moisture changes on the ability of soils to support their loads.

New testing and design techniques for building foundations on troublesome expansive clays have been devised by the Division and are used by the Foundations Advisory Service of the South Australian Department of Mines. The factors contributing to the failure of earth dams have been studied and recommendations drawn up for construction methods which will prevent such failure from occurring. New methods developed by the Division for the quantitative definition of particle arrangements and structure of soils and rocks are leading to a better understanding of the influence of structure on the physical properties of soils and rocks. The Division has also developed a system for classifying, describing, mapping, and evaluating country as an aid to planning the design and construction of roads and other engineering structures.

Atmospheric physics

In 1945 the C.S.I.R. established a Meteorological Physics Section in Melbourne which became the Division of Meteorological Physics in 1955. In 1969 the Division's activities were strengthened by the formation in Melbourne of the Commonwealth Meteorology Research Centre, a joint venture operated by the Commonwealth Bureau of Meteorology and the Division. Following the incorporation of the Cloud Physics Section of the Division of Radiophysics, Sydney, into the Division of Meteorological Physics in 1971, the Division was re-named the Division of Atmospheric Physics and was grouped with the Division of Environmental Mechanics, Canberra, to constitute the C.S.I.R.O. Environmental Physics Research Laboratories.

The Division of Atmospheric Physics is concerned with the physical properties of the atmosphere, including those influencing weather and climate, such as turbulence in the lower layers of the earth's atmosphere and radiation from sun and sky. Other important studies in this field include the connection between sea surface temperature and rainfall, the measurement of evaporation from all types of natural surfaces, and the use of tracers to map wind patterns at high levels. Special instruments for use in connection with these studies have been developed by the Division, including a long-term recorder for making various measurements such as wind velocity and water level, which can operate unattended for up to six months at a time and thus facilitate observations from remote areas.

The Division is the centre for radiation work in the World Meteorological Organisation's Region V (the south-west Pacific) and makes, on a continuous basis, measurements of various radiation quantities, including ultra-violet.

Animal health

Between 1925 and 1930 the Institute of Science and Industry appointed several veterinarians to work at the University of Melbourne's Veterinary Research Institute at Parkville on contagious bovine pleuropneumonia, tuberculosis in cattle, and black disease of sheep. In 1930 the C.S.I.R. created the Division of Animal Health with headquarters at Parkville. Apart from the research group working at Parkville, the Division had a team of scientists at the McMaster Laboratory, Sydney, and another group at a field station near Townsville. At the end of the war, the Division's interests were widened to include problems of animal husbandry, and the Division was renamed the Division of Animal Health and Production. In 1959 the Division was divided into three. Much of the work on genetics and physiology which was being carried out by the Division in New South Wales and Queensland passed to new Divisions—the Division of Animal Genetics and the Division of Animal Physiology. The Division of Animal Health retained the Animal Health Research Laboratory at Parkville, the McMaster Laboratory, Sydney, and the Veterinary Parasitology Laboratory, Brisbane.

One of the early achievements of the Division's Parkville Laboratory was the discovery that black disease of sheep was due to a bacillus which was stimulated into growth and invasions by lesions in the liver caused by the entry of young liver flukes ; this work led to the development of an effective vaccine.

Pleuropneumonia in cattle was produced experimentally by workers at the Laboratory in the late 1930s. Subsequently a vaccine was developed which conferred a high degree of immunity on the cattle inoculated with it. The complement fixation test which was developed for detecting pleuropneumonia in " carrier " animals is now accepted internationally as the standard method of diagnosis. The Laboratory has now moved into research aimed at developing a more rapid and more specific test for tuberculosis in cattle.

Another important achievement was the discovery that toxaemic jaundice, a disease of sheep characterised by the occurrence of jaundice before death, was two separate diseases. Initially it was found that toxaemic jaundice was a manifestation of chronic copper poisoning caused by excessive copper intake. Subsequently it was shown that toxaemic jaundice could also be caused by the consumption of heliotrope, an annual summer-growing weed which was found to contain liver-damaging alkaloids. Further research revealed that sheep which were grazed on pastures with a low molybdenum and low inorganic sulphate content tended to store higher levels of copper in their livers and were more liable to chronic copper poisoning. Work on another disease of sheep, enterotoxaemia, led to the development of a satisfactory vaccine.

In 1958 a Virology Section was established at Parkville. The Section isolated several livestock viruses which, although known overseas, had not been isolated in Australia before. They included infectious bovine rhinotracheitis, mucosal disease, sporadic bovine encephalomyelitis, a strain of Newcastle disease of low virulence, and a myxo virus—para influenza type III.

Horticultural research

In 1919 a Viticultural Research Station was established at Merbein, Victoria. The Station was financed by a levy based on acreage and imposed by the Vineyards Protection Board, by the sale of fruit, and by a grant from the Commonwealth Institute of Science and Industry. Investigations in the early years included fertiliser trials with currants, sultanas, and gordos; studies of insect pests and fungus diseases and their control; studies of the development and growth of the vine; and appraisals of routine vineyard practices in the district.

In 1927 the Station was taken over by the C.S.I.R. and became the Commonwealth Research Station. The work was expanded and investigations were conducted in New South Wales and South Australia. The main problem of the 1930s was soil salinity which was studied in all Murray River districts. The Station's findings in the fields of irrigation and drainage are the basis of current practice in virtually all the Murray irrigation areas. All phases of dried vine fruit production including processing were also investigated.

In the 1950s research was undertaken on vine nutrition, grape drying and processing, and fruitfulness and pruning effects in the sultana. Studies in field hydrology were expanded to cover the region from Kerang in Victoria to Renmark in South Australia. Research was commenced into the effect of plant parasitic nematodes on vines. In 1964 a new laboratory and headquarters were built in Adelaide and, together with the Merbein Station, were designated the Horticultural Research Section of the C.S.I.R.O. In 1967 the Section became the Division of Horticultural Research.

The emphasis of the work is now directed towards understanding and improving the performance of woody perennial fruit crops such as vines and fruit trees. Advances have included the selection of high yielding clones of the sultana vine, the development of vine pruning procedures to increase yield, the release of vine rootstocks which are resistant to nematode attack, and the development of improved quality control methods for the dried grape industry. Basic long range research is being conducted in the fields of vine and tree physiology, grape biochemistry, and nematology. Investigations are also being made into methods of mechanising grape harvesting.

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COMMONWEALTH RESEARCH FACILITIES*

AUSTRALIAN ROAD RESEARCH BOARD

The increase of motor vehicles in the first three decades of this century led to a vigorous growth in road building. Specialised road authorities were set up in each State before the Second World War to ensure that the most suitable and economical procedures would be employed in construction work. The particular characteristics of the Australian climate, terrain, and resources made local investigations essential, and the State authorities met as a national association to share their findings. However, urgent construction and maintenance work often had to be completed at the expense of sustained research, even while the fields for study broadened. Besides the traditional study of the physical ingredients, research included traffic engineering, which involved road layout, signals, vehicle characteristics, accident reduction, and human behaviour patterns. Changing land uses and new road networks also called for basic planning formulae to determine the patterns of transport and road expansion.

In 1960 the association founded the Australian Road Research Board. The Director in Melbourne had a total staff of ninety in 1971, while the members of the Board are the heads of the six State road authorities and the Director-General of the Commonwealth Department of Works, the Board being financed jointly by the Commonwealth and State Governments. The budget for 1970–71 was approximately $1.1m. To give the Board a broad perspective an Advisory Council was appointed to consider when and how research projects should be undertaken, and to recommend additional investigations. The Board also has eight specialist committees which may co-opt staff from various university faculties if considered necessary. Thus the Human Factors Committee includes persons versed in traffic and mechanical engineering, traffic control, psychology, aviation medicine, pathology, statistics, and law. Other committees deal with traffic engineering, road transport planning, bituminous materials, soil stabilisation, pavement design and performance, the brittle fracture of bridge steel, and other bridge problems.

About twenty research fellows and their assistants in the universities are sponsored wholly or partly by the Board, which, before approving any research project, requires a detailed statement of objectives, the proposed line of investigation, and an estimate of cost; the Director may authorise smaller projects.

* Excluding C.S.I.R.O

The Board's library contains details of research already done and in progress elsewhere. The Board has sponsored five National Road Research Conferences, the papers submitted having been published as " Proceedings ". It also publishes the journal *Australian Road Research* for local and overseas circulation. This gives details of results from sponsored research studies and other Australian investigations which have helped to ensure economic road construction and to decrease the possible causes of accidents. A major example of the Board's work has been a two year " on the spot " determination of how far urban accidents are the result of road layout, vehicle design, and human behaviour, with an analysis of the types of fatality and casualty. Special bulletins have included research findings on the performance of various types of road rollers in compaction of pavement and underlying materials; a review of the functions of State road authorities and of the Board in national road planning and road works; an analysis of comparative national contributions and use of resources by the various transport media, with a discussion of relevant forms of taxation and finance for road purposes; and research data applicable to the design of road and street intersections.

AUSTRALIAN WOOL TESTING AUTHORITY

The Australian Wool Testing Authority was established in September 1957 by the Commonwealth Government at the request of the Australian wool industry. In July 1963 the Authority was reconstituted as part of the Australian Wool Board, but it functions independently to provide facilities for the testing of raw wool, processed wool, and manufactured wool products. Initial funds provided for testing purposes were $36,000, with a professional and technical staff of four. The Authority consists of eight members appointed by the Board, of whom six represent major sections of the wool industry : the Australian Council of Wool Buyers ; the Wool Scourers, Carbonizers and Fellmongers Federation of Australia; the Wool Textile Manufacturers of Australia; the National Council of Wool Selling Brokers of Australia; the Australian Wool Board; and the Commonwealth Scientific and Industrial Research Organization ; there are also two members who are not directly connected with the wool industry. The Australian Wool Board contributes the capital funds although the Authority charges for its services and operates on a commercially self-supporting basis. Income is used entirely to offset capital and operational costs and to improve services. Testing laboratories and wool sampling offices have been established throughout Australia, and the textile testing facilities are located at North Melbourne.

The *Wool Industry Act* 1962 defines the Authority's functions, which are to carry out tests of wool and wool products and to issue certificates and make reports on these tests. The Authority's operations can be considered under three general divisions, namely, the testing of greasy wool, the testing of semi-processed wool, and textile testing.

Core sampling and testing greasy wool to determine clean fibre yields is the main activity. Since 1968 greasy wool transactions have been based on fibre diameter measurements in addition to yield testing. Woolbuyers who purchase auction lots and assemble them into shipping consignments engage the Authority to sample and test wool, and to issue certificates which have been increasingly used as the basis for commercial transactions instead of the more traditional basis of invoicing on visually assessed yields. Fibre diameter, and to a lesser extent, fibre length and strength testing are being used to describe wool consignments more accurately, and increasing numbers of bales are being tested to provide guidance to buyers for their subsequent yield appraisals. The yield of each lot of greasy wool comprising a delivery on the Sydney Greasy Wool Futures Exchange is established by the Authority, and all wool currently being supplied to India under the Colombo Plan is also tested. Certificates issued by the Authority are accepted throughout the world, and meet the standards of accuracy laid down by the International Wool Textile Organization, the British Wool Federation, and the American Society for Testing and Materials.

The condition testing of scoured and carbonised wools was the earliest of the Authority's operations and this remains the second largest activity. In testing, the moisture content of a consignment is determined, and from this information a correct invoice weight is established. Certificates issued are used as the basis for sale. The Authority was first approved for listing as a Public Conditioning House by the International Wool Textile Organization in 1962, and is now also the Australian calibrating laboratory for Airflow fibre diameter testing instruments.

The Authority provides facilities for a wide range of textile tests to assist manufacturers of tops, yarns, fabrics, and garments. Quality control testing for the Wool Mark programme is carried out, and fibre fineness, length, and strength testing have been incorporated into the textile section's activities.

The Authority is a member of the appropriate committees of the International Wool Textile Organization and the Standards Association of Australia, and maintains close collaboration with the International Wool Secretariat and with Australian and overseas research and testing organisations. The Authority's research into the determination of commercial yields of greasy wool has made a significant contribution to the formulation of the International Wool Textile Organization's Method of Test and Core Testing Regulations. In 1971 the research and testing budget was \$1.1m, with a professional and technical staff of 200.

COMMONWEALTH BUREAU OF CENSUS AND STATISTICS

In 1959, a year after the integration of State and Commonwealth statistical services, the Victorian Office of the Commonwealth Bureau of Census and Statistics installed ICT mechanical data processing equipment comprising one tabulator, two sorters, and one reproducer summary punch. Supported by card punching and verifying machines, this equipment processed data covering a wide range of economic and social statistics, until increased statistical activity necessitated more processing plant and the Office acquired an additional tabulator in 1962. About this time, the Bureau began feasibility studies to examine the potential of modern computer equipment as a possible replacement for the mechanical data processing plant. Tenders were called in 1962 for the supply of equipment comprising a central system located in Canberra with, initially, satellite systems in the five mainland State capitals; subsequently this was expanded to include Tasmania. The equipment was to be used to process the economic and social statistical data collected by the Bureau, as well as some accounting and administrative records of other government departments. The installation of this Australia-wide high speed digital computer complex took place over two years, beginning in June 1964 in Canberra, where Control Data 3600 and 3300 computers were located; 3200 and 160A computers were installed in Sydney and in Melbourne, and 3200 computers in each of the other three mainland States. As a result of rapid expansion and the conversion to computer processing, the Bureau purchased additional equipment in 1967, and in Melbourne this included a Control Data 3300 computer system. All three Melbourne computers are now backed by a full range of peripheral devices, including mass storage and interrogation devices supported by a data preparation pool containing over fifty card and paper tape punching and verifying machines and a magnetic tape encoder.

As part of the Australia-wide network, the Bureau's Melbourne Computer Service Centre fulfils two main functions: the applications section offers a systems analysis, design, and programming facility to service the Bureau's own data processing requirements; and the operations section provides an advanced computer processing facility, operating as a service bureau on a continuing basis, both for the Bureau and other government departments. By 1971 the Centre had a staff establishment of 140.

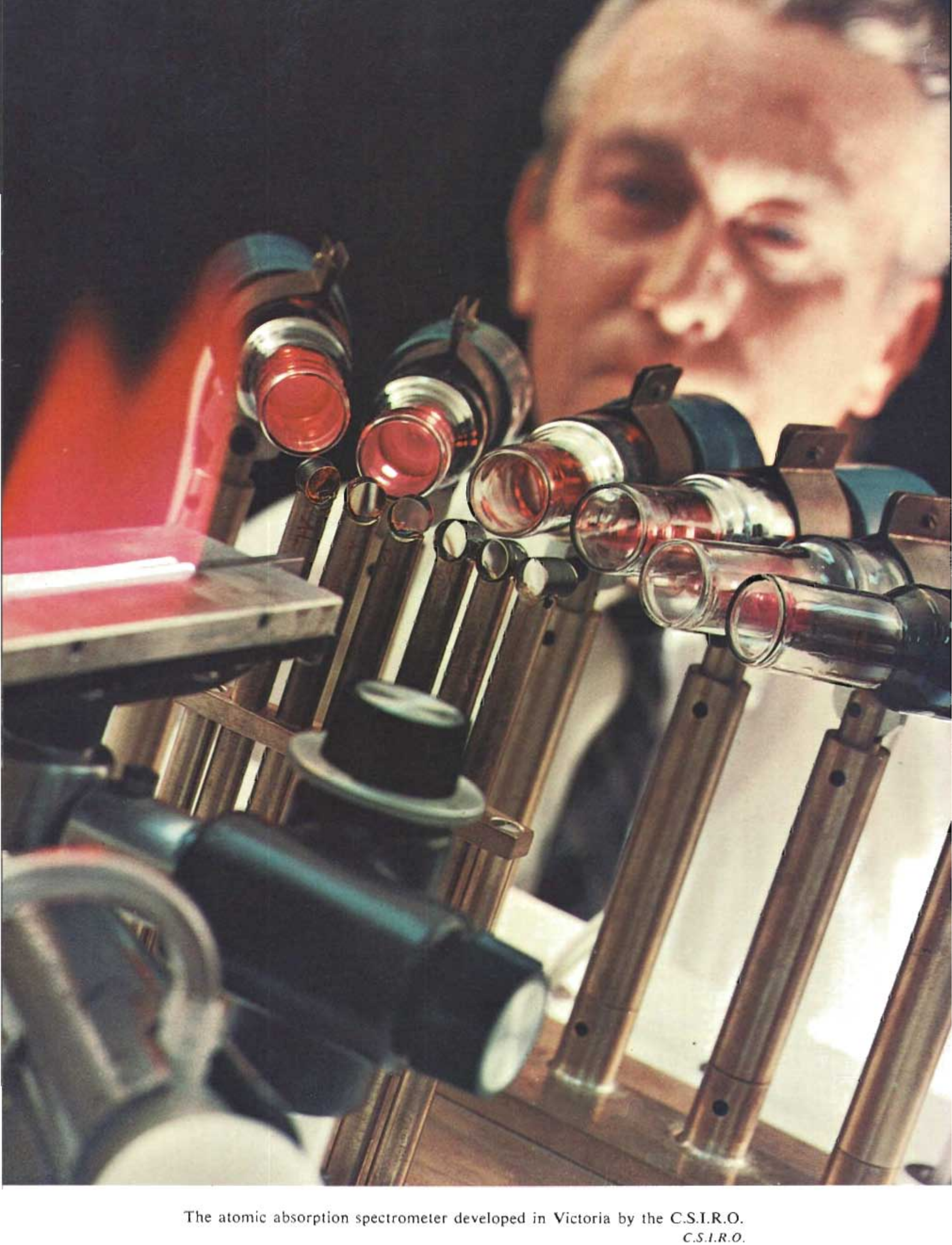
COMMONWEALTH BUREAU OF DENTAL STANDARDS

Australian research in dental materials began in 1934 at the University of Melbourne in association with the Dental School, work being concerned initially with the metallurgy of dental amalgams, and later also covering other materials and instruments used in dental practice. Financial assistance came from a variety of local sources until the National Health and Medical Research Council subsidised the work from 1939.

The value of the Materials Testing Laboratory was demonstrated by the research and testing carried out during the Second World War for the Armed Services and various government departments. As a result, it was considered highly desirable to establish the Laboratory officially on a national basis, a view which was reinforced by the increasingly widening scope of investigations in the fields of dental materials and instrumentation. Accordingly, the Bureau of Dental Standards was established in 1947 within the Commonwealth Department of Health, with a professional and technical staff of six; it is one of the few establishments devoted to the study of dental materials. Although now formally dissociated from it, the Bureau was accommodated by the University of Melbourne as a temporary measure until a suitable site was found.

Because of the diverse nature of dental materials, a wide range of scientific knowledge is required, and the disciplines of chemistry, physics, and metallurgy are represented (in 1971) in the professional and technical staff of eight persons. The Bureau provides consultative and testing services to the dental profession and associated trades, and to hospitals and other public instrumentalities. This involves considerable research work on new products and techniques as well as on improvements in existing ones.

The Bureau also conducts original research on dental and allied materials, instruments, techniques, and processes; develops, in collabora-



The atomic absorption spectrometer developed in Victoria by the C.S.I.R.O.
C.S.I.R.O.

The prototype Nomad aircraft, designed and produced in Melbourne, on a test flight.

Department of Supply

The Australian designed and developed Ikara missile leaving the launcher of an R.A.N. vessel

Department of Supply

Surveyor from the Victorian-based Antarctic Division of the Department of Supply at Mawson Station, Antarctica.

Department of Supply

Accelerated weathering tests on plastics, dyestuffs, and pigments are carried out at research laboratories at Ascot Vale.

I C I Australia Ltd

Setting up a disc brake assembly on a heavy duty inertia brake dynamometer for a high speed test.

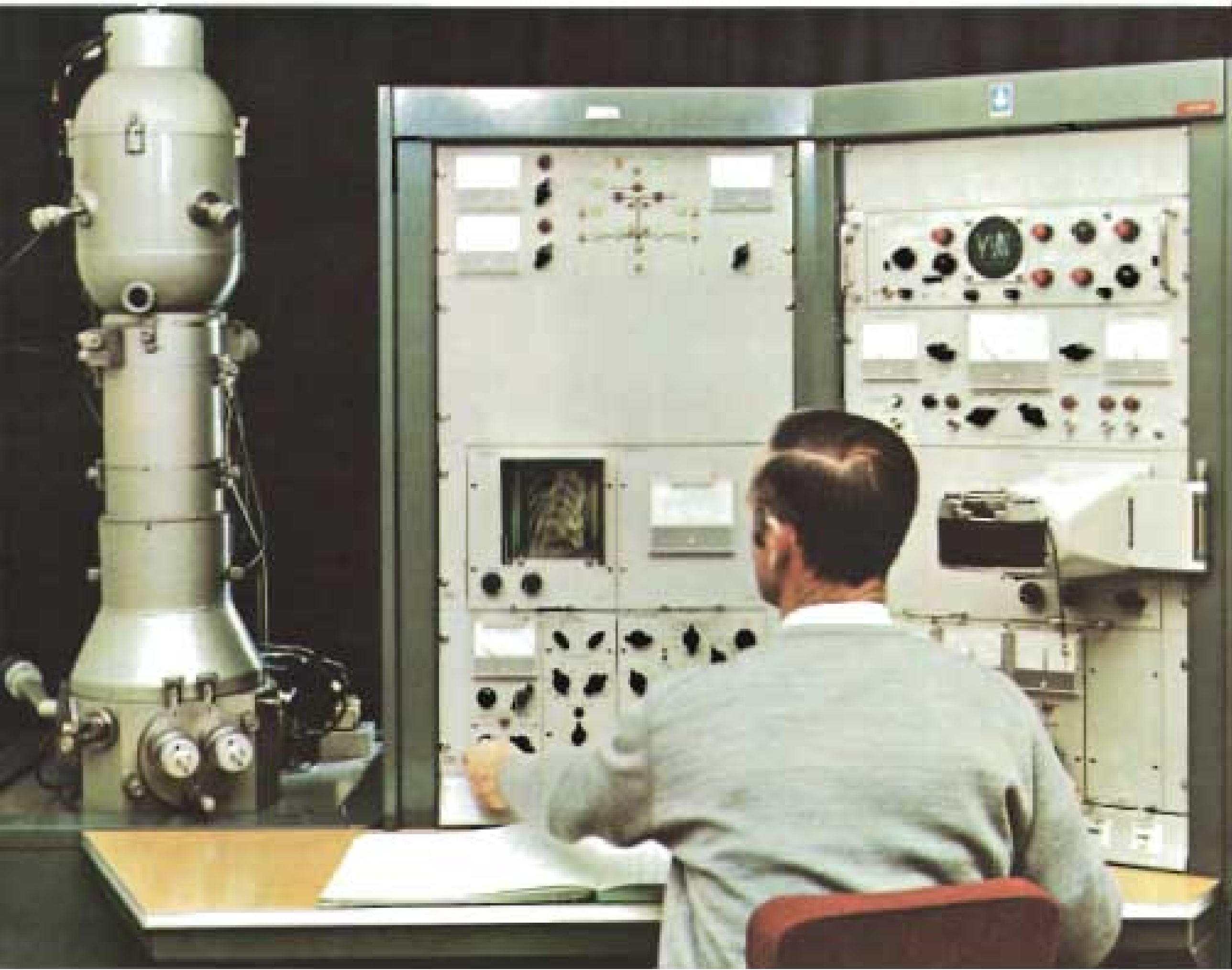
Repco Ltd

Preparation of pigment dye emulsion for experimental application to wool fabrics.

C.S.I.R.O.

This stereoscan electron microscope is used to study the effects of shrink-proofing treatments and mechanical processing on wool fibres.

C.S.I.R.O.



tion with the Standards Association of Australia and the Australian Dental Association, specifications on dental materials and instruments; makes regular systematic surveys on dental materials on sale to the profession; and provides a consultative service and testing facilities for manufacturers and distributors of dental products to assist them in improving materials. The Bureau has also made investigations and tests of medical and surgical supplies and equipment.

The major fields of investigation and publication have covered gypsum products including casting investment materials, orthodontic wires, dental amalgam alloys, cements, impression materials, and synthetic resins. The Bureau has also assisted in the preparation of over thirty Australian Standards which are used for assessing the quality of local dental products. They are also the basis of the accreditation programme conducted by the Australian Dental Association to ensure that dental products consistently meeting the requirements of the relevant standard can be accepted as Certified Products. Lists of these are made available to the dental profession. The Bureau also participates in the preparation of international standards for dental products, through both the Fédération Dentaire Internationale and the International Organization for Standardization, and it assists in the training of dental students, nurses, and technicians. It also provides facilities for postgraduate training and research.

COMMONWEALTH BUREAU OF METEOROLOGY

The climate of a locality can be defined only by means of accurate observation, with standard instruments, over a long period of time. Meteorological observations began in Melbourne in 1840, and were published in the Government Gazette of New South Wales, but as the exact type of instruments used, and their exposure, are not known, the results are not accepted as part of the official record. Following Separation in 1851 observations ceased, but were resumed in 1855 under the Lands Department. Stations were established in Melbourne and at about twenty places in different districts of the Colony. In 1858 Professor Neumayer began five years of hourly observations in Melbourne, and in 1859 all meteorological stations in the Colony were placed under his control. By 1863 regular observations were made at eight stations, at Melbourne, Ararat, Ballarat, Bendigo, Cape Otway, Gabo Island, Port Albert, and Portland, and there were twenty-four other stations where rainfall alone was measured.

Following Professor G. Neumayer's return to Europe, control of meteorological observations passed to the Astronomical Observatory in Melbourne which continued with this work until 1907, by which time the number of observing stations in Victoria had increased to 940, of which 86 measured temperature as well as rainfall. On 1 January 1908 all meteorological services in the various States were placed under the control of a Commonwealth Meteorologist. In Victoria, the initial professional and technical staff numbered twelve. Although there was little addition to the number of observing stations in the following sixty years, a greater variety of elements was measured, including sunshine, evaporation, and radiation. Many self-recording instruments have also been installed for the continuous measurement of rainfall, temperature, humidity, and air pressure. Since 1957 meteorological data has been processed and tabulated by mechanical and electronic equipment.

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Before forecasts of future weather can be prepared, it is necessary to know the current state of the atmosphere over a wide area. In 1875 the Melbourne Observatory began issuing a daily bulletin of telegraphic reports about the existing weather over the Colony. The first Australian Meteorological Conference was held in Sydney in 1879, followed by a second in Melbourne in 1881, where the heads of the colonial weather departments of Victoria, New South Wales, South Australia, and New Zealand agreed upon the interchange of daily weather information. The other Colonies joined the scheme, and from 1881 a weather chart was prepared by the Melbourne Observatory each day, Sundays excepted, copies being posted at a number of public places in the city. Synopses of the weather over Australia and forecasts for Victoria accompanied the chart, and newspapers commenced the daily publication of forecasts.

As radio communication developed, ships were able to receive the latest weather forecasts, and eventually in the 1920s broadcasting brought forecasts and warnings to the general public. Until 1939 forecasts in Australia were prepared on the basis of daily reports received at 9 a.m. only, with a very limited network of observations at 3 p.m. In April of that year daily reporting networks were established for 6 a.m. and noon. Further extension in the following years led to the present system of reports every three hours, except at midnight, on every day of the year, while forecasts are prepared for the public four times a day and for shipping twice a day. The development of aviation necessitated detailed forecasts for flights. A meteorological office was opened at Essendon Airport in 1937, and offices were established during the Second World War at Laverton, East Sale, and Mildura, the first two of the latter three being at Royal Australian Air Force bases. The increase in light aircraft led to another office being opened at Moorabbin Airport in 1968. A meteorological office was opened at Tullamarine (Melbourne Airport) in 1970, and in 1971 this became the Bureau's main aeronautical office in Victoria.

Winds in the upper atmosphere can be measured by a free hydrogen balloon tracked by a theodolite. Hydrogen balloon flights began in Melbourne in 1921, and at Mildura and East Sale during the Second World War. The measurement of temperature in the upper air proved more difficult. In the 1930s a plane flew daily from Point Cook to measure the temperature and humidity at each thousand feet of altitude. However, it was not until the development of the radio-sonde, which automatically transmitted the observations to a ground station, that satisfactory operational measurements could be made. The first regular radio-sonde flights in Victoria began at Laverton in 1943. The use of radar has enabled balloons to be tracked in all conditions, whereas visual tracking by theodolites is limited by cloud ; radar can also detect falling rain. Windfinding radar was installed at Laverton in 1949 and at Mildura in 1963, while a large radar capable of measuring rainfall intensity was installed in the Melbourne office in 1964 ; it has both dual control and display at the University of Melbourne. The first weather satellite was placed in orbit in 1960 by the United States of America. The first satellites were experimental, but since 1964 operational satellites using visual and infra-red techniques for both day and night observation have been launched. Cloud pictures are obtained directly from the satellite by a station at Werribee for interpretation by meteorologists.

The Bureau's functions as defined by the Commonwealth *Meteorology*

Act 1955 are to take and record meteorological observations, to forecast weather, to issue warnings and supply meteorological information, to advance meteorological science by research, and to furnish advice on meteorological matters.

In recent years staff have been employed as consulting meteorologists in investigations (frequently in co-operation with other authorities) in such fields of applied meteorology as hydrometeorology (the development of flood forecasting schemes and the estimation of maximum rainfall), agrometeorology (effects of weather on productive plants and animals), and the meteorological aspects of bush fires. A standards laboratory for meteorological instruments is maintained in the Central Office in Melbourne for the use of the Bureau throughout Australia. The Central Office carries out meteorological research and has worked on the development of forecasting techniques, the problems of clear-air turbulence, extended range forecasts, and mathematical models of the atmosphere suited to the Australian region for use by computer. A computer was installed in Melbourne in 1968, and this is used to prepare analyses and prognoses of weather in the southern hemisphere. It will eventually be linked with computers in Washington and Moscow as part of World Weather Watch, as ultimate understanding of the processes at work in the earth's atmosphere will only come with continued international co-operation. In 1971 the Bureau's professional and technical staff stationed in Victoria numbered 382.

A Department of Meteorology was established at the University of Melbourne in 1936 and the C.S.I.R.O. established a Division of Meteorological Physics in Melbourne in 1948. The Commonwealth Meteorology Research Centre commenced operation in 1969, jointly operated by the Bureau and the C.S.I.R.O. Division of Atmospheric Physics. The Centre studies the detailed structure of the atmosphere and its changes as they affect the surface level weather patterns, and in its first year of operation it produced 24 hour experimental forecasts for the whole of the southern hemisphere. In 1971 the Centre's staff comprised seven research scientists, fourteen other professional officers, and two technical staff.

COMMONWEALTH RADIATION LABORATORY

In 1925 the Commonwealth Department of Health made a statistical study of the incidence of cancer mortality in Australia. An Advisory Committee set up in 1927 recommended that ten grams of radium should be purchased at a cost of about £100,000, and in 1929 the Commonwealth Department of Health established a Radium Laboratory at the University of Melbourne to act as custodian of the radium purchased, to ensure its safe and equitable use, to provide a radon service, and to advise on physical aspects such as dosimetry and the precautions necessary in handling radium and radon.

In 1935 it was renamed the Commonwealth X-ray and Radium Laboratory and extended its activities to include all physical aspects of the use of X-rays in treatment of cancer, and an X-ray section was established in the University's Department of Natural Philosophy. Portable clinical X-ray dosemeters were calibrated in terms of an established standard, so establishing uniformity of dosage to patients in radiotherapy centres in Australia. As the work of the Laboratory increased, new accommodation became essential and a specially designed building was erected in the University grounds. By 1972 it was used as one of six occupied by the Laboratory.

The activities of the Laboratory were further extended in 1939 to include investigations into the physical aspects of diagnostic radiology, and again in 1946 to include the procurement and distribution of all radioactive isotopes for use in Australia in medicine, industry, and research. The responsibilities for those isotopes to be used in industry and research were relinquished in 1961, but the Laboratory still retained the responsibility for the supply of isotopes used in medical diagnosis, treatment, and research. In 1969 it became possible for users of isotopes for medical research to purchase directly from the Australian Atomic Energy Commission or through the Australian representatives of overseas suppliers. Radiochemical and low-level measurement sections were established in 1961 for the collection and analysis of data on radioactive materials present in the environment, including radioactive fall-out from the testing of nuclear weapons. In 1968 this work was supplemented by the installation of a whole-body monitor at the Laboratory.

In 1965 the Director of the Laboratory was appointed under the Commonwealth *Weights and Measures (National Standards) Act* 1960–1964 as an agent authorised to establish and maintain national standards for the measurement of X-rays, gamma rays, and radionuclides. The Laboratory has maintained a Commonwealth Standard of Exposure to X-rays since 1968, and is working to create other standards and improve existing ones. An advisory service on all aspects of radiological protection (including a film-badge service) to ensure that exposure to ionising radiations is kept below the acceptable maximum, has always been an important part of its work. By 1971 the professional and technical staff had increased to 43, with a budget of over $1m. In 1972 it became the Commonwealth Radiation Laboratory.

COMMONWEALTH SERUM LABORATORIES COMMISSION

Serious wartime shortages in supply of vaccines and antitoxins led the Commonwealth Government in 1916 to establish a central Australian institute to produce these drugs of standardised quality and at low cost. This institute, the Commonwealth Serum Laboratories, operated for about 1½ years in temporary quarters in the original building of the Walter and Eliza Hall Institute of Medical Research, Melbourne, but in 1918 it transferred to new, specially designed buildings erected on a site at Royal Park where smallpox vaccine had been continuously produced from 1881, originally under direction from the Victorian Government. From earliest days senior staff performed some tertiary teaching functions for outside bodies in the newer disciplines involved, and a substantial amount of research under local conditions was necessary. By August 1918 capital expenditure on the new laboratory buildings, stables, and animal houses at Royal Park was found to have greatly exceeded the original estimate of £15,000.

The Commonwealth Serum Laboratories was originally under the control of the Quarantine Service which, until its transfer to the newly established Commonwealth Department of Health in 1921, was part of the Department of Trade and Customs. The Laboratories continued as a division of the Department of Health until the Commonwealth *Serum Laboratories Act* 1961 established the Commonwealth Serum Laboratories Commission.

Many important overseas discoveries in medicine, biology, and biochemistry have affected laboratory activity. The discovery of insulin by Banting and Best in 1922, of penicillin by Fleming and Florey in 1943, and of poliomyelitis vaccine by Salk in 1954 are outstanding examples. There have also been many other important although less spectacular achievements for preventing, diagnosing, and treating disease, and as a result some diseases which were common fifty years ago are now virtually non-existent in Australia : in 1932 there were over 7,000 cases of diphtheria in Victoria, with 166 deaths ; there are practically no deaths today from this cause.

Rapid developments in pathology and public health have increased the demand for new biologicals ; this has resulted in continuous expansion, often accelerated by sudden demands. For instance, during the influenza epidemic of 1918–1919 the original staff of thirty was more than trebled, and again during the Second World War the Laboratories produced greatly increased quantities of vaccines, antitoxins, and blood products. From 1939 to 1945 the staff increased from 240 to 620, substantial additions being needed for the production of penicillin from 1944 and for influenza virus vaccine from 1945. In 1971, 950 persons were employed, and the scientific staff included about 130 professionally qualified persons, among whom are fellows and members of about forty different learned professional societies and associations. Members of the staff are serving on thirty national and international expert committees.

One of the products of the first year of operation was tuberculin for the testing of animals, and shortly afterwards antitoxins and vaccines for veterinary use were produced. The Laboratories now carry out extensive veterinary research and prepare a wide range of products including antitoxins, vaccines, antibiotics, and diagnostic agents for veterinary use.

The products of the Commonwealth Serum Laboratories fall under the following headings : antisera for therapeutic and prophylactic use—antitoxins, antivenenes, and other antisera ; vaccines—bacterial, viral, and toxoid ; hormones—insulin, human growth hormone, and follicle stimulating hormone ; blood products—albumins, gamma globulins, clotting factors (human blood products are prepared in collaboration with the Australian Red Cross Society); antibiotics—a wide range of penicillins and other antibiotics ; clinical and laboratory diagnostic agents—agglutinating and precipitating sera, blood grouping sera, bacterial antigens and suspensions, C.F. (" complement fixing ") agents, etc. ; bacteriological and tissue culture media ; allergen extracts ; bacterial cultures, tissue cultures, and living virus preparations ; products made to special requirements of doctors and veterinarians, and special products for the Commonwealth Department of Health for immunisation purposes. Veterinary products are also produced in most of these categories. Several of these products, including influenza virus (sub-unit) vaccine, and snake, spider, tick, stonefish, and sea wasp antivenenes have resulted directly from original research at the Laboratories, and many others have been adapted and developed to meet local requirements.

The Laboratories are also responsible for preparing, holding, and distributing a wide range of low volume products in the interests of public health. On several occasions the Laboratories have been called on to deal with outbreaks of infectious diseases such as cholera, typhoid, and plague in

Asian countries, and have also supplied products on a large scale to Britain and the United States of America.

In 1970–71, $964,000 was spent on research. The Laboratories now occupy 27 acres of land at Royal Park, about one third of which is under cover, and 1,527 acres at Woodend, where the larger animals are kept.

DEPARTMENT OF SUPPLY

The Commonwealth Department of Supply's primary responsibility is for the supply of war material, including aircraft, from both government establishments and private industry, and for related research and development. In 1971 in Victorian establishments 11,000 persons, including 800 professional scientists, engineers, chemists, and metallurgists, were employed, with more than 3,800 qualified technicians, draftsmen, and tradesmen. Defence projects and tasks allocated by the Department to private industry engage additional professional and skilled resources.

Aeronautical Research Laboratories

Aeronautical research in Australia began with Lawrence Hargrave's work in the 1880s, but for fifty years it was mainly exploratory. The necessity for aeronautical research was recognised, however, after the establishment of the government aircraft factories in the 1930s, and in January 1939 the first laboratory was established in Melbourne as a division of the Council for Scientific and Industrial Research (C.S.I.R.). The first group of buildings was completed at Fishermens Bend in April 1940, and work began with nine professional officers and seven supporting staff. Work was carried out on aircraft design, including aerodynamics, structures, materials, and power plants, and a wind tunnel was brought into use in December 1941.

During the Second World War important research covered structural and aerodynamic assistance in the design of aircraft such as the Boomerang, Wackett Trainer, and CA.15 ; the use of Australian timbers for aircraft structures ; the testing and evaluation of captured Japanese engines ; the organisation and control of the R.A.A.F. Flight Research and Development Unit ; the simplification of aircraft materials specifications ; and the evaluation of Australian aircraft steels, then being produced for the first time. Important pioneer work was also carried out on fatigue and the life of aircraft structures.

By the end of the war the Laboratories were clearly committed to defence projects, and in February 1949 were transferred from the C.S.I.R.O. to the Department of Supply and named the Aeronautical Research Laboratories. The number of staff had risen to 245, of whom 65 were professional officers, and the annual budget for 1948–49 was $3.9m. The terms of reference were to undertake research and development work on specific defence projects ; to act as consultants and make investigations for the Armed Services, government departments, and industries engaged on defence work ; and to join with the Australian Aeronautical Research Committee to promote and review the progress of aeronautical research in Australia, and to keep abreast of international advances in aeronautical and guided weapons research.

Since the war the Laboratories have carried out significant work on fatigue and the life of aircraft structures, and have developed special methods for testing the magnitude and frequency of wing and structural loads. Crash safety has also been investigated, and studies have been made of the heating of supersonic aircraft, and of their engine problems. The facilities for aerodynamic research include three major wind tunnels operating, respectively, at subsonic, transonic, and supersonic speeds. These are used for work in problems of air flow, as research support for new aircraft and missile designs, and in the solution of air operating problems. Basic and applied research has included the practical application of chromium alloys for turbine blades; turbine blades have also been developed for high temperature operation, while a turbine has been designed to operate on types of readily obtainable coal. High-strength aluminium alloys have also been developed for air frames, and the dangerous brittle fracture phenomenon in metals is now better understood.

The Laboratories have developed combustors to burn fuels such as high ash coal, heavy residual oils, distillates, and other special fuels, including silver iodide in acetone for cloud seeding operations. They have also contributed to elucidating various human engineering problems, and have been concerned with operations research on the effective deployment of weapons, transport, supplies, and other resources for the three Armed Services. Research and development associated with guided weapons has included mathematical modelling and dynamic studies, and a major contribution has been the Ikara anti-submarine weapons project, a joint activity of the Department of Supply and the Royal Australian Navy. The Laboratories were responsible for co-ordinating the work on the missile and overall system performance. The Laboratories consist of five research and development divisions: Structures, Aerodynamics, Materials, Mechanical Engineering, and Systems, together with their engineering support facilities. The Laboratories are recognised internationally as a leading aeronautical research establishment.

In 1971–72 expenditure at the Laboratories was $5.5m and the staff totalled 590 including 440 professional and technical personnel.

Defence Standards Laboratories

The origin of the Defence Standards Laboratories can be traced to the establishment of a Chemical Adviser's Branch of the Defence Department at Victoria Barracks in 1910. In 1916 it was reorganised and enlarged to include physics and metallurgy, and renamed the Central Research Laboratories. Six years later the Laboratories moved to Maribyrnong and in 1925 the title Munitions Supply Laboratories was adopted; the present name dates from 1950.

An important early task was to provide adequate standards of measurement for the munitions industry, involving work in the field of metrology. These standards, developed and verified at the National Physical Laboratory in England, became the first official Commonwealth Standards of Measurement, and the Laboratories remained their custodian until 1938 when responsibility was assumed by the National Standards Laboratory. At this time development was slow, but during the next twenty years activities increased, and a scientific consultative and testing service was provided for the Armed Services, munitions production establishments, and industries manufacturing defence requirements, while specifications were tested for Service Inspection Authorities. These activities increased during the Second World War, as did work to maintain the accuracy of metrological and pyrometric instruments, and the number of employees rose to more than 900. By September 1944 the Laboratories were able to offer assistance to secondary industries changing from munition to civil production.

Post-war projects included the design and manufacture of optical components for student microscopes. With the experience acquired in making and testing optical munitions the Laboratories were able to produce objectives, eyepieces, and sub-stage condensers, and in 1967 assisted an Indian establishment in this field. Studies have also been made of new and improved materials, methods, processes, and equipment of known or potential defence interest, while collaboration continues with industry in technological matters. Other major fields of research include abrasion, chromium alloys, electrophotography, explosives, the fracture of metals and fragmentation of projectiles, the metallurgy of welds, the microbiological contamination in aircraft fuels, the physics of high-energy lasers, plastics and elastomers, the precise measurement of physical quantities (mass, length, time, force, temperature, and electrical quantities), the structure of organic compounds, thermocouple alloys, and the underwater protection of naval vessels from corrosion and fouling.

In 1971–72 expenditure at the Laboratories was $6.5m and staff totalled 750 including 500 professional and technical personnel.

Antarctic Division, Melbourne

The Division, which was formed in 1948 within the Department of External Affairs, is responsible for the management, co-ordination, and logistic support of the Australian National Antarctic Research Expeditions. Until 1954 operations were confined mainly to maintaining scientific stations at Heard Island (established 1947), and Macquarie Island (established 1948), and expeditions were supervised by scientists from other Commonwealth departments and the universities. A major phase of exploration, settlement, and scientific investigation followed the charter of the vessel *Kista Dan* in 1953, and within a decade explorations, surveys, and traverses, involving ship-borne and land-based aircraft, had covered the coastline and the main features of the Australian-claimed section of Antarctica. Stations were established at Mawson (1954), Davis (1957), and Casey (1969), while between 1959 and 1969 Australia also operated an American station at Wilkes. A Scientific Branch responsible for programmes in upper atmospheric physics, cosmic ray physics, glaciology, biology, and medical science was also established, and other research programmes conducted in Antarctica include meteorology, topography, earth sciences, and cartography. In 1968 the Division was transferred to the Department of Supply.

In 1971–72 expenditure by the Division was $3.3m and staff totalled 170 including 80 stationed in Antarctica and at Macquarie Island.

Production establishments

The Department's defence production establishments in Victoria, indeed defence production in Australia, date from the Victorian Government's acceptance in 1888 of an offer from the Colonial Ammunition Company to establish a factory for the supply of small arms ammunition. The firm was established at Footscray and initially manufactured ·45 inch Martini–Henry ammunition but by 1900 had changed over to ·303 inch Lee–Enfield ammunition for supply to colonial governments in Australia. The firm continued to operate after Federation in 1901 until it was taken over by the Commonwealth Government in 1921. Other establishments were set up progressively by the Commonwealth Government: ordnance factories at Bendigo and Maribyrnong, explosives and filling factories at Albion and Maribyrnong, marine engine works at Port Melbourne, the clothing factory at Coburg, and aircraft factories at Fishermens Bend and Avalon. The Department is responsible for the supply of a wide range of munitions, aircraft, guided missiles, clothing, vehicles, etc., to the Armed Services. Supply is arranged either from the government factories or from private industry.

The Ammunition Factory produces complete rounds of small arms ammunition and components for larger calibre gun ammunition including cartridge cases, fuses, and primers. The Factory has introduced statistical quality control procedures and precision screw thread grinding for tools and gauges. The Explosives and Filling Factories produce the various types of explosive compositions and propellants required for gun ammunition, rockets, and guided missiles. The Ordnance Factories are equipped to produce heavy ordnance equipment, such as naval guns and gun mountings ; large turbine gears ; shells ; rocket motors for guided missiles ; trailers and tank transporters ; and other items requiring heavy engineering capacity. As well as work for the Armed Services, the Bendigo factory produces large heavy engineering items for the coal, cement, and steel industries. A factory established at Echuca during the Second World War to manufacture ball bearings was later sold to private industry.

The Engine Works at Port Melbourne provides an engine repair, testing, and consultant service for certain classes of ships in Australian waters, and heavy machining capacity for maintenance tasks, in addition to the manufacture of certain types of reciprocating steam and marine diesel engines. The Aircraft Factory produces aircraft and guided weapons. These included Beaufort and Beaufighter aircraft during the Second World War, and Lincoln, Canberra, and Mirage aircraft during the post-war period. Design of the Jindivik target aircraft for use in connection with missile development was a notable achievement. Since the first fully operational Jindivik in 1952, more than 400 have been produced for Australia, the United Kingdom, the United States, and Sweden. The Avalon establishment, which contains airfield facilities, is responsible for final assembly and preparation for flight of aircraft manufactured at Fishermens Bend, either by the Government Aircraft Factory or the Commonwealth Aircraft Corporation Pty Ltd. A major contribution has also been made in the development and production of the Malkara anti-tank and Ikara anti-submarine guided missile systems. The introduction of several aspects of advanced technology has been pioneered in Australia, including the use of metal bonding in aircraft and missile structures. Facilities include numerical control path machining centres. Major activities cover the manufacture of airframe and engine spare parts ; the overhaul, repair and modification of military aircraft and engines for the R.A.A.F., R.A.N., and the Army ; and the reconditioning and servicing of aircraft instruments and other ancillary equipment.

The Clothing Factory makes uniforms and clothing for the Armed Services, the Postmaster-General's Department, and for some other Commonwealth authorities at its premises at Coburg ; these replaced earlier factories at South Melbourne and Brunswick.

In 1971–72 the Supply production establishments employed 7,500 persons, including 3,000 professional and technical staff ; the production from the establishments for the year exceeded $50m.

FORESTRY AND TIMBER BUREAU

Forestry activity on a national scale began in 1907 when the Commonwealth Department of Health prepared an extensive list of harmful insects to be kept out of Australia by quarantine, and in general these precautions have proved reasonably successful. In 1922 several pioneer surveys, including reconnaissance of the forest resources of Papua and New Guinea, of the Australian Capital Territory, and of Norfolk Island were carried out, and in 1924 it was decided to establish a Commonwealth Forestry Bureau and an Australian Forestry School.

During the Second World War the Controller of Timber managed the supply of timber and Australian species replaced imports which were no longer available. The Commonwealth *Forestry Bureau Act* 1930 was replaced by the Forestry and Timber Act in 1946 which established the headquarters of the Forestry and Timber Bureau in Melbourne. It took over the functions of the former Commonwealth Forestry Bureau and of the Controller of Timber, and was transferred to Canberra in 1953, although until 1967 the Timber Control functions continued to be exercised in Melbourne by the Timber Supply Economics Branch. It regularly produced a summary of timber supply and consumption data for industry, helped to improve safety precautions, and established a Logging Research Section to reduce logging costs. In 1958 the Forestry and Timber Bureau established a Research Station at Traralgon in co-operation with A.P.M. Forests Pty Ltd to work on tree breeding and the genetics of *Pinus radiata* and Gippsland eucalypts. By 1971 professional and technical staff numbered seven, with a research budget of $50,000.

In 1961 the wood wasp, *Sirex noctilio,* a pest greatly feared by Australian foresters, was found in a plantation of *Pinus radiata* in the Melbourne area. Meetings were held in Melbourne early in 1962 to prepare for a National Sirex Fund which was approved by a Premiers' Conference in that year. Since then much important work to contain this insect has been done, and time has been gained for the introduction of parasites, which promise to reduce the significance of the wood wasp in softwood plantations.

POSTMASTER-GENERAL'S DEPARTMENT

The Research Laboratories of the Postmaster-General's Department, established in 1923 to study and advise on the use of new equipment following the development of the thermionic valve, first worked on trunk line communication and voice frequency repeaters. Efficient communication between the main centres of population was then the prime requirement of the P.M.G.'s Department. This work eventually incorporated carrier equipment, at first three-channel and later twelve-channel, and culminated in the provision in 1935 of the multi-channel submarine cable facilities from Apollo Bay in Victoria to Tasmania ; this completed the interconnection by telephone of all the States.

From 1928 to 1935 the Laboratories were involved in planning and establishing the national broadcasting service; the introduction of new antenna designs and new fabrication techniques provided a much greater area of non-fading reception than had been available with the conventional antennae of that time. The Mont Park short wave reception centre, developed by the Laboratories, enabled the Australian Broadcasting Commission by 1936 to incorporate items from the Empire station at Daventry, England, as regular features of the national programmes. The Laboratories participated in the development of the short wave complexes at Lyndhurst, and later at Shepparton.

In the late 1930s research activities were expanded to aid the engineering division of the Department; this dealt with factors such as corrosion, equipment deterioration, and materials selection and analysis.

During the Second World War research facilities were oriented towards military needs, including the investigation of substitutes for scarce materials, the development of materials for tropical conditions, and the refinement of radar techniques. During this period the Laboratories were also concerned with the establishment of the short wave complex, Radio Australia, at Shepparton and with the provision of a VHF radio link between the mainland and Tasmania. In 1945 they provided the Victorian time service, previously the responsibility of the Melbourne Observatory, and expanded it to provide standard frequency and time services to major centres throughout Australia.

Immediately after the war the staff of 130 used its capacities to overcome war-caused arrears of development in the Postmaster-General's Department. Advances in techniques had resulted in the telecommunication frequency spectrum being increased by a factor of 300 ; the introduction of broadband radio links allowed the Laboratories to continue work in the fields of radio propagation and radio meteorological phenomena, facilitating such projects as the microwave radio link from Adelaide to Perth ; and the increase in capacity and capability of Australian industry stimulated the manufacture of electronic equipment in Australia, necessitating advice from the Laboratories on the standards required.

In the early 1950s the Laboratories, through research on television transmission techniques and coaxial cable transmission systems, prepared standards applicable to the introduction of television in 1956 and for coaxial cables in the early 1960s. The Laboratories also investigated the characteristics and uses of new materials such as plastics for insulation and sheathing, and of new equipment such as crossbar switching equipment, as well as techniques and standards to ensure reliability. Projects in 1971 related to the introduction of digital transmission systems, electronic switching techniques, the use of satellite communication in the remote areas of

Australia, and the use of solid state amplifiers for economy in subscriber line networks.

Because of the importance of telecommunications research the Laboratories maintain close liaison with relevant faculties in universities ; the publication of reports on the scientific and technical work of the staff and the organisation of conferences and symposia are two means of facilitating this aim. The organisation in 1971 consisted of 36 divisions with a staff of 423 including 117 engineers and 28 scientists ; it occupied about 142,000 sq ft of floorspace in eight buildings in and around Melbourne, with equipment valued at over $6m and a research budget of $4m.

TOOLANGI GEOPHYSICAL OBSERVATORY

The Toolangi Geophysical Observatory operated by the Bureau of Mineral Resources, Geology, and Geophysics, comprises two separate sections, the Magnetic Observatory and the Seismological Observatory.

On 1 May 1858 Professor G. Neumayer began the first regular geomagnetic observations in Victoria at a site in Melbourne's Flagstaff Gardens. Since then magnetic observations or recordings have been continued with few interruptions. The three elements—declination, horizontal intensity, and inclination—were observed visually every hour for five years, but the site became unsuitable because of nearby blasting and building activities, and in 1862 the variometers were transferred to the Botanic Gardens. In 1866 the Magnetic Observatory received a photographic recording magnetograph and new control instruments from England, and operations began in 1867 under the direction of the Government Astronomer, R.L.J. Ellery. The magnetograph was transferred in 1877 to the basement of a building which still exists in the grounds of the former Melbourne Observatory, where recordings were continued until 1919.

After 1913 the records became very disturbed during the daytime because of electric trams, and when Dr J. Baldwin took over the Observatory in 1915, he began intensive surveys for an alternative site. Eventually the present site at Toolangi, about 40 miles north-east of Melbourne, was chosen, and installations were completed in 1919 when recordings began. In January 1939 bushfires destroyed the magnetograph building and the instruments. The buildings were replaced by the present underground vault and a new set of instruments was installed ; these are still operating continuously. The Commonwealth acquired the Observatory from the Victorian Government in 1943 and the Commonwealth Solar Observatory, Mount Stromlo, administered the station. The Bureau of Mineral Resources took over the Observatory in 1946 and has operated it since then. Under the Bureau's jurisdiction, several improvements have been made in equipment, buildings, and methods. The old instruments have been replaced and new buildings have been erected, while data are now being reduced with the aid of electronic computers.

Earthquake recordings in Victoria began in 1902 when a Milne seismograph, recording on a strip of photographic paper 22 inches by 3.5 inches, was installed in a basement of the original Melbourne Observatory; this was used until December 1927 when a new Milne-Shaw seismograph, which is still recording, replaced it. In 1951 the Seismological Observatory added Wood-Anderson instruments, and these operated, together with the

Milne-Shaw, until 1956 when a 3-component short period Benioff seismograph was received. This high sensitivity instrument is still in use at Toolangi, where it can be operated at its maximum magnification of about 180,000. A set of long period instruments was installed in October 1963 to supplement the short period ones, so that a complete set of instruments is in continuous operation. Auxiliary equipment, such as precise timing and crystal controlled power supplies, is included in the installation. About 1,400 tremors are recorded annually. The staff establishment for 1970–71 comprised two geophysicists, two technical officers, and a computing assistant, together with a supporting budget of $9,000.

5

STATE RESEARCH FACILITIES

CANCER INSTITUTE

Following a report from an Interim Committee, the Cancer Institute was created by Act of Parliament in 1948. The Act also provided for an agreement with Tasmania, and clinics at the Royal Hobart and Launceston General Hospitals were placed under Institute control. The Institute seeks to carry out research into the causation, prevention, diagnosis, and treatment of cancer ; provide outpatient and inpatient hospital treatment at the Institute ; and provide for the teaching of undergraduate and postgraduate medical students, medical practitioners, nurses, technicians, and physicists.

The Institute is governed by a Board consisting of *ex officio* members, namely the Medical Director, Manager, and Assistant Medical Director of the Institute, as well as the Director of the Commonwealth Radiation Laboratory and representatives of the Ministers of Health in Victoria and Tasmania, the Anti-Cancer Council of Victoria, the University of Melbourne, and the general teaching hospitals in Melbourne. The Board delegates wide administrative powers to an Executive Committee. The Peter MacCallum Clinic of the Institute is an approved public hospital under the National Health Act.

The Institute began within the Radiotherapy Department of the Royal Melbourne Hospital, but because it lacked accommodation and facilities, one of its first developments was the Visiting Nursing Service, which began in 1950. Accommodation was subsequently provided in what was previously the Queen Victoria Hospital building in William Street.

One of the first tasks of the Institute was to assemble staff and equipment for a complete radiotherapy service ; the greatest demand at that time was for patient treatment facilities. In 1950 the total number of staff was five, but by 1970 it had reached 748. The rapid overall growth of these facilities, especially from 1958 to 1968, is illustrated by increasing expenditure and patient admissions. In 1958 expenditure was $990,000, 2,440 new patients were seen, and 64,648 treatments were given. By 1968 the respective figures were $2.42m, 5,857, and 90,914.

Activities now include a complete hospital service to both outpatients and inpatients suffering from cancer ; consultative and treatment service for all general and special hospitals in the metropolitan area ; a consulting service for regional base hospitals in the country ; and superficial therapy service in either remote or densely populated areas of Victoria. Fully supportive diagnostic services, including pathology, biochemistry, medical physics, diagnostic X-ray, radio-isotopes, and clinical investigation are provided. The Institute maintains an outpatient transport service for those unable, on medical grounds, to use public transport, and a Visiting Nursing Service for cancer patients in the metropolitan area. Country patients can also avail themselves of hostel accommodation.

Together with the Royal Melbourne Institute of Technology, the Institute trains therapy radiographers and medical nucleographers, and there is a postgraduate school for radiotherapeutic nursing. Undergraduate and postgraduate medical education is carried on as a clinical school of the University of Melbourne.

Major developments have included improved treatment techniques using radioactive substances and radiation equipment ; the introduction of four megavoltage units in the 4-10 MeV range and the investigation of super voltage units in the 35-50 MeV range ; and the association of the scientific departments and research activities for higher degrees with the University of Melbourne. An airborne consulting service has also been made available to country hospitals.

Research activities have covered many fields. Biological research includes the histological and ultra-structural studies in auto-radiography and radiation effects, cell culture studies, cytology, and biochemistry studies in measurement and growth rate. Endocrine research has also been carried out, and includes the analysis of cortico steroids and keto steroids, associated with the " discriminant factor " in breast cancer, while in the field of medical physics, investigations have covered the pure and applied sciences including activation analysis, tumour localisation and measurement, dosimetry, scanning and diagnostic techniques, and computer planning. Barotherapy (high oxygen tension studies), is another activity, and clinical research, including the use of radio-isotopes and haematological studies, is being undertaken. It is estimated that the Institute will ultimately provide inpatient accommodation of 600 beds, together with fully supporting services at both the clinical and research level. In 1971 the Institute's professional and technical research staff numbered 35, with a research budget of $186,000.

COUNTRY ROADS BOARD

When the Country Roads Board was established in 1913, the existing system of roads and bridges was inadequate. However, the development of improved and economical methods of construction was accelerated in the early 1920s when a laboratory was set up in conjunction with the University of Melbourne to carry out tests on stone and bitumen. This was not entirely satisfactory, and in 1928 the Board set up its own laboratory in the Exhibition Buildings with a staff of two. For the next ten years, activity was confined to elementary control testing of gravel and bitumen, and to research on the local application of soil and gravel testing methods then being developed in the United States of America. During the same period the Board's engineers developed methods of low cost road construction, as well as techniques and plant for bituminous surface treatment of roads. During the Second World War the staff gained experience of pavement design for airfield construction, and in 1948 the California Bearing Ratio method of pavement design was adopted with modifications for local conditions ; it is still used.

In 1963 the laboratory, now the Materials Research Division, was moved from Carlton to a modern building at the new head office at Kew. The greater space and improved facilities not only permitted a substantial increase in control testing, but also original research. The finding of deposits of road making material has long been an important function of the laboratory. Since 1961 seismic methods of checking the depth and hardness of rock in road cuttings and in bridge foundations have been widely used, and since 1963 electrical resistivity techniques have been used in the search for suitable road making sands. Modern sampling and testing equipment is used in foundation engineering studies on undisturbed soil samples to ascertain the possible amount of settlement of embankments. While facilities for routine strength tests on steel have been available for many years, the metallurgical laboratory established in 1965 now provides for the complete metallurgical investigation of steel used in bridges or in failed parts of mechanical plant. It also carries out research on the welding characteristics of new types of steel.

To provide objective methods for measuring surface characteristics of pavements, instruments which measure unevenness in road surfaces have been modified and fitted with electronic recording equipment. Slipperiness, or the tendency of certain stones to polish, is measured according to British Standard methods, while the strength of pavements is assessed by measuring the deflection of the surface when it is loaded by a wheel carrying the maximum legal load. The Division has co-operated with the Standards Association of Australia in developmental work such as the preparation of specifications and test methods for traffic line paints, materials for reflective signs and markings, bituminous products, cement concrete, and related materials.

The number of persons employed on materials research in 1971 averaged twelve and the annual research and development budget was approximately $100,000.

DEPARTMENT OF AGRICULTURE

In 1872 the Department of Agriculture replaced the Board of Agriculture, and soon afterwards took over a stock inspection branch comprising a chief inspector and district sheep inspectors. As disastrous losses were then common in the plant industries as well as in the Colony's flocks and herds, the earliest activities were directed towards disease control. A chemist and an agricultural chemist were appointed in 1873 and 1886, respectively, the latter beginning field experimentation ; in the early years the Department's work was primarily inspectorial and experimental. However, phylloxera, rusts, grasshoppers, and codling moth continued to take a heavy toll ; this resulted in the establishment of a Royal Commission on Vegetable Products in 1891. Subsequently, the Department appointed an entomologist and a vegetable pathologist, the first plant pathologist in Australia. Between them they produced five books, five handbooks, 48 articles, and 188 papers. Superphosphate came into use later, and by 1901, 370 field trials were being conducted. Further developments included experimental farms at such places as Wyuna and Whitfield, and the establishment of Government Cool Stores at East Burwood, Ringwood, Diamond Creek, Tyabb and, subsequently, Victoria Dock. Research into primary industries increased with the establishment of the Rutherglen Research Station, and the State Research Farm at Werribee in 1912. The Department has progressively used new equipment, including electron microscopes, automatic analysers, gas chromatographs, spectrophotometers, and computers.

In 1911 the Department's staff numbered 362, and between 1872 and 1911 the total expenditure on research was about £182,500; from 1912 to 1946 the Department spent about £600,000 on research, while between 1947 and 1968 the total amount rose to $14.7m. The total number of staff was 750 in 1947, and was over 2,000 in 1971.

Pasture improvement studies began with permanent topdressing experiments at Rutherglen Research Station in 1912, and these have continued at a steady rate, particularly since the 1920s. By 1971 over one quarter of the State consisted of improved pastures. Since 1930 an underlying feature of Victoria's development has been the scientific improvement of its native pastures by the introduction of new species, notably subterranean clover and ryegrass, by topdressing with fertilisers (mainly superphosphate), and by general developments in grazing management.

Associated with this development has been the clover-ley system of farming, i.e., a period during which a paddock is under clover pasture rather than fallow or crop. This restores and improves soil fertility, and heavy yielding cereal crops with higher grain quality can be grown more efficiently. Following the adoption of this system in the higher rainfall cropping districts, further research indicated that barrel medic and other legumes could extend similar benefits to areas which were too dry for subterranean clover.

Improved pastures have been the most important contribution to Victoria's higher animal production since the Second World War. During the 1960s research work in this sphere has largely aimed at increasing yields of meat and wool to the acre. Experiments at the Pastoral Research Station at Hamilton and elsewhere indicate that there is still great potential for increased stock numbers in Victoria. Complementary research includes the utilisation of pastures and conserved fodder by stock, the survival of lambs and other young animals, and improved breeding methods. In recent years there has been a great increase in the amount of research work with cattle and with the possibilities of dairy-beef production. Artificial insemination, especially in the dairying industry, is being used widely in conjunction with herd recording to build up a State population of high-producing cows. With reference to animal health, the Department of Agriculture's TB eradication scheme has reduced the incidence of tuberculosis in dairy cattle, and the HYPAR process, with its hysterectomy-produced piglets, has been used for producing pneumonia-free herds. In the poultry industry the random sample laying test has continued to improve the efficiency of egg-layer performance.

Plant breeding research has considerably improved crop yields. The breeding programme for cereals, initiated at Dookie Agricultural College about 1890 and continued at the State Research Farm, Werribee, has produced several outstanding cereal varieties which have added to the yield and quality of grain produced in the State; for many years more than 95 per cent of Victoria's wheat acreage has been sown to varieties bred at Werribee. The additional yield from these varieties is valued at several million dollars a year. Insignia, released to farmers in 1946, was for many years the most popular wheat variety in Australia and is still sown in some areas. The Department's geneticists have also bred high yielding varieties of other crops including oats, barley, linseed, tomatoes, and stone fruits. Associated with this breeding programme has been the introduction and testing of plants from other countries ; varieties of tobacco and potatoes now grown are examples. The testing of new plant varieties on research stations and farmers' properties has always been a major part of the Department's applied research work.

Scientific research work into other features of plant production, such as nutrition, has also contributed to Victoria's productivity. Outstanding results following the general introduction of superphosphate early in the century were followed later by the favourable response of plants to small amounts of zinc during the early 1930s, mainly on the dark Wimmera soils, and later to small amounts of molybdenum, mainly in areas of the central highlands. Favourable responses to cobalt and copper have been recorded in some of the light sands. Research has also contributed to the more intensive high cost horticultural industries. Modern investigations in this field began in the mid-1920s. The Department pioneered fruit cool storage studies and established horticultural research stations at Tatura in 1937, Scoresby in 1946, Mildura in 1954, and Frankston in 1962. Experiments have also sought to determine the best root stocks and soil management practices to increase productivity of fruit trees, and to investigate improved methods of pruning, mechanical harvesting, the selection of optimum harvesting dates, and pre-cooling of fresh produce. Other important results of horticultural research have included the appropriate applications of nitrogen and phosphate to produce a 30 per cent increase in canning-peach yields ; the critical irrigation times to improve watering efficiency and increase fruit yields ; the virtual elimination of pre-harvest drop of fruit in apples and pears ; and the selection and breeding of new tomato varieties.

Progress in the control of plant diseases, pests, and weeds has also contributed to improvement in quality and increasing production. An outstanding example is the control of viruses, especially those in strawberries, whose average yields, as the result of virus-free clones, have been raised from some 15 cwt to nearly four tons to the acre during recent years. Another is the virtual elimination of seed borne diseases from the lettuce crop. The Department has also worked on the control by new chemicals of weeds, pests, and diseases. With the increasing use of new chemicals, advanced analytical techniques have been developed to analyse minute residues in food products. Other methods of pest control include the genetic control of the field cricket and of rust in wheat, the biological control of red scale in citrus, and the agronomic control of skeleton weed.

Pioneer work in irrigation research has included some early experiments with irrigated pasture at the State Research Farm, Werribee, in the 1920s. Subsequently, notable work was done in reclaiming land in northern Victoria in areas which had been rendered valueless by salt. An Irrigation Research Station was established at Kyabram in 1959.

DEPARTMENT OF CROWN LANDS AND SURVEY

Since the Second World War, there have been rapid developments in surveying instruments and techniques, largely due to the development of electronics, but before this time, even though survey instruments had been improved and refined, the fundamental methods had remained unchanged for over two centuries. The Department of Crown Lands and Survey, which was originally the sole survey authority in the State, still remains the largest surveying establishment, with approximately 45 licensed surveyors on its staff.

Although the accuracy of the early surveys came under criticism, the surveyors must be credited for the speed with which the country was opened up under the most difficult conditions. In this period, although theodolites had been developed for more than 100 years, their use was rare. Surveyors preferred the circumferenter, which permitted more rapid work but was subject to greater inaccuracies than was the theodolite. The circumferenter consisted simply of a sighting vane over a graduated circle which could be oriented by a compass needle. Distances were also subject to large inaccuracies, being measured with a Gunters chain, which was nominally 66 ft long, and consisted of 100 links of iron wire interconnected by small rings for flexibility.

Theodolites of the period were very cumbersome with horizontal circles of up to 24 inches in diameter, and were generally reserved for triangulation surveys, which consisted of a precisely measured base line on to which was built a network of triangles whose angles were observed by theodolite. The positions of all stations could then be computed. The system required the position of at least one station to be fixed by astronomical observations. This classical method of triangulation was developed over 100 years previously and continued until after the Second World War. Although techniques for angular observations using theodolites had been perfected to give relatively high precision, accurate base line measurements presented many difficulties. One of the early triangulation surveys in Victoria, carried out to co-ordinate the surveys in the Melbourne district, used pine measuring rods to establish the base. For the geodetic triangulation of Victoria, begun in 1858, a five mile base line was measured using 10 ft iron measuring bars, previously standardised in England. Elaborate precautions were taken to protect the bars from direct sunlight, and the techniques employed resulted in a highly precise base measurement. The actual base line measurement, not including clearing, took four months to complete. A repeat measurement over a two mile section of the line gave agreement to better than half an inch or a relative agreement of approximately four parts in a million.

Gradually, the linear accuracy of ordinary surveys was improved. First the 66 ft long broad steel band by Chesterman replaced the Gunters chain, to be followed in the 1870s by thin steel bands of up to 300 ft length. The major achievement in precise distance measurement was the development of a tape of low coefficient of thermal expansion composed of a steel alloy called Invar. This tape was developed overseas in 1896 and was being used in Victoria by some Departmental surveyors by about 1910. By this time the Army had taken over the topographic mapping and triangulation, and its Survey Section employed the new Invar tapes to establish base lines. Accuracy of 1 part in 500,000 was achieved, but this still involved considerable time and labour.

Between the two world wars the major achievement in Europe came from Heinrich Wild, who revolutionised theodolite design with the introduction of the glass arc. Theodolites designed by Wild in the early 1920s were well ahead of their time, and remain today among the world's leading theodolites of their type, both in design and precision. Generally, however, there was lack of communication between countries and progress was limited. Certainly in Victoria it was a very static period, although this could also partly be accounted for by the depression of the 1930s.

In the early 1950s the first electronic distance measuring (E.D.M.) instruments for surveying purposes were produced overseas. The Geodimeter, based on a light wave principle, could measure a distance of more than 20 miles to an accuracy of better than six inches; the Tellurometer, an instrument based on a radio wave principle, is capable of measuring lines up to 100 miles in length with a comparable accuracy. The Victorian Department of Crown Lands and Survey was among the first organisations in Australia to enter the E.D.M. field and to apply the electronic computer to surveying computations. By 1971 the Department was equipped with eight Tellurometer units and two electro-optical distance measuring units, and its techniques were virtually completely computer oriented.

Both world wars have contributed greatly to the development of photogrammetry for mapping. It was shortly before the Second World War that elementary photogrammetric techniques were introduced to Victoria through the Australian Survey Corps. After the war a mapping section was established in the Department, Wild stereoplotters were purchased, and more advanced techniques introduced. These instruments, which had been developed in 1937, made possible the plotting and contouring of maps direct from aerial photographs. The Department has since followed overseas trends and by 1971 was equipped with modern photogrammetric instruments valued at more than $500,000 and employed the latest techniques of analytical photogrammetry. Overseas research is moving more and more towards complete automation, not only in photogrammetry but in the complete mapping process. The first automatic equipment from overseas has now arrived in Australia, and the next decade could see significant advances in mapping.

EPIDEMIOLOGICAL RESEARCH UNIT, FAIRFIELD HOSPITAL

As the exotic diseases hospital of the Victorian Health Department, Fairfield Hospital provides a centre for treatment of severe manifestations of infectious diseases with the best available medical knowledge, and offers ideal opportunities for the study of the agents responsible for infectious disease and its spread in the community (epidemiology).

Proposals for an Epidemiological Research Unit were first made in 1954. Part-time research workers were to be employed, so that only a minimum number of additional staff and new buildings would be necessary, with key personnel carrying out both routine diagnostic work and research. However, grants from the National Health and Medical Research Council and from private individuals made possible the purchase of special equipment and the employment of additional trained staff. The total number of laboratory staff was therefore increased, as well as the proportion of those with special technical skills. In 1969 there were eight research workers. The unit ceased operations in June 1970.

The initial activities of the unit were concerned solely with bacteriological problems such as streptococcal disease, brucellosis, and leptospirosis. The occurrence of leptospirosis as an important human and animal disease in Victoria was first recognised when investigations were carried out with the assistance of a district veterinary officer in Gippsland. An extension of microbiological activity into virology did, however, become necessary during 1954 and 1955 as a result of rapid developments in diagnostic techniques, many of which were applied for the first time in Australia by the laboratory. Since then, research activities have tended to be virological rather than bacteriological with special emphasis on clinical medicine. Papers describing epidemiological studies of diseases such as poliomyelitis, virus meningitis, influenza, croup, bronchiolitis, hepatitis, gastroenteritis, and rubella have been published, and in 1965 the unit was appointed as the World Health Organization reference laboratory for virus diseases in the southern Pacific area, thus providing international exchange of epidemiological information.

FISHERIES AND WILDLIFE DEPARTMENT

The development of the Fisheries and Wildlife Department as a research and management organisation effectively began in the 1940s. Before Federation the responsibility for fisheries and wildlife was vested in the Department of Trade and Customs and from 1901 in the Department of Public Works ; in 1909 these activities were transferred to the Department of Agriculture. Until then there was little more than limited enforcement work and stream stocking. A separate office for the Fisheries and Game Branch (as it was then called) was established in 1913 when the group came under the control of the Chief Secretary, and until 1940 activities were mainly centred on the acclimatisation programme which had begun in the 1870s. Trout were distributed from hatcheries at Ballarat and Geelong, a small government hatchery, and a number of small hatcheries operated by local angling clubs throughout the State. In 1933 a trout licence was introduced at a cost of 5s per season. In 1940 the branch consisted of eleven persons and the total budget was £10,500.

The appointment of the first biologist in 1941 resulted in bream fishery research at the Gippsland lakes, leading to the first Victorian fisheries management regulations based on scientific observations. Information on trout food and growth was also collected and plans were formulated for a large trout hatchery and research station near Eildon ; in 1946 the first temporary buildings of the Snobs Creek Freshwater Fishery Research Station and Hatchery were erected. In 1947 the Port Phillip Bay fisheries were studied extensively with particular reference to snapper, and these studies foreshadowed a relatively short term but lucrative scallop fishing industry. In 1948 research was expanded to cover mammals and birds, resulting in more knowledge and better management of quail, water-rats, koalas, and fish-eating birds. Enforcement was also increased by the appointment of six new inspectors in that year. By 1950 the staff of the branch had increased to 40 and the annual budget had reached a figure of \$82,000 of which about \$5,000 was spent on research. From 1950 to 1952 research was conducted into Murray fishes, trout, and pond culture, and in 1953 the need for research into game was recognised by the appointment of a Biologist (Game Birds). Research into ducks resulted in the game licence being introduced in 1959, and in that year 34,863 shooters took out the \$2 licences, a wildlife reserves system was established, and the programme was expanded with the appointment of the State Wildlife Reserves Investigation Committee.

Following the appointment of a Scientific Superintendent at the Snobs Creek Station in 1952 several basic problems relating to the culture of trout under Australian conditions were overcome, and by 1956 large numbers of trout were being produced and released into streams and lakes. Further additions to the research staff, particularly on other wildlife, resulted in a new research wing being opened in 1959. By 1960 the total number of staff had risen to 121 and the annual budget was slightly in excess of \$500,000 of which approximately \$100,000 was devoted to research.

Since 1959 the Serendip Wildlife Research Station near Lara has been developed to demonstrate that farming and wildlife are not incompatible; research work at the Station includes the rehabilitation of declining species of birds, including water fowl. In a report by the State Development Committee on the fishing industry in Victoria, major recommendations were aimed at securing development of the fishing industry and led to the creation of the Commercial Fisheries Council in 1961.

There has been increasing interest in studies of the total environment since 1962, and this broad ecological approach provided the basis for the beginning of the Port Phillip Bay study in 1968. This programme, undertaken in co-operation with the Melbourne and Metropolitan Board of Works and the universities, aims to establish the environmental *status quo* of Port Phillip Bay, so that any changes produced by the discharge of effluents into the Bay can be assessed.

At the beginning of 1971 the total staff was over 200, and approximately one half of the annual operating budget, which exceeded \$1.2m, was devoted to research. A new and spacious research facility, the Arthur Rylah Institute for Environmental Research, was opened at Heidelberg in 1970.

The Fisheries Act, amended in 1967 and re-enacted in 1968, increased licence fees for some commercial fisheries and created a Fisheries Research Fund into which these fees are paid. The 1968 Act further provided that these funds should be applied towards research, management, and development of commercial fisheries, including extension services and education for fishermen.

FORESTS COMMISSION

Transport changes have had far reaching and lasting effects on forest industries. Logs from the mountain and foothill forests were once moved to the sawmill by bullock team, and along the Murray River they were carried by barge. This primitive transport gave way to steam-powered traction engines and winches, and then to trucks and tractors. The construction of a network of roads over most forest regions of the State has brought all Victorian forests within economic range of the Melbourne market, and provides quick access to areas for fire protection and recreation.

Trial pulpings of eucalypt wood for paper making were made very early in this century, but were unsuccessful as they used the technology developed in the northern hemisphere for long fibred softwood species. The first economic pulping process for short fibred eucalypt wood was developed in the 1930s. In 1937 the first commercial sulphate pulp mill was established on a pilot scale at Maryvale ; it proved so successful that operations were rapidly expanded. This process used wood material which previously had no market at all and was merely left in the forest to hinder the growth of new stands. The market for pulp products has increased to such an extent that 30 per cent of Victoria's wood harvest is now pulped and five mills are engaged in the manufacture of paper pulp, hardboards, and particle boards.

A major technological advance in Victorian forestry during the last century was the selection of *Pinus radiata* for extensive planting. This species was introduced into Victoria in 1857, and the Forestry Department began experimental plantings at Macedon in 1873. By 1910 the ability of *Pinus radiata* to outgrow other exotic species over a wide range of sites was apparent, and several plantations had been started. These developed into large-scale projects in the 1960s and by 1971 annual plantings approached 17,000 acres. This has been made possible by the use of planting machines which were introduced in 1950; one machine can plant eight times as many trees as one man in a day.

In 1958 a long-term research project to breed improved strains of *Pinus radiata* was begun. Trees which appeared to be superior were selected and are still being tested for their ability to pass on their desirable qualities. The seed from orchards of selected parent trees will be used for future Forests Commission plantations.

The disastrous bushfires of 1939 stimulated improved fire control methods. In the early days isolated fire fighters worked with rakes and beaters, but modern fire fighters are now equipped with tankers and bulldozers and are in contact with fire headquarters by two-way radio, using a State-wide radio network controlled from a central radio station in Melbourne. Helicopters are used to ferry men and equipment as well as to observe fires. Aerial bombing of small fires with fire retardant chemicals has brought speedy control measures to rough country.

Major research into the regeneration of eucalypt forests began in the mid-1950s. Scientific studies of the flowering and seeding habits of native species, their seed germination, and seed bed requirements are now well documented. Unreliable methods of natural seeding are being replaced by controlled artificial seeding from light planes or helicopters, and fire and bulldozers are being used to help prepare suitable seed beds.

The Commission has used computers since 1958 to process forest survey data. Volumes of wood of suitable qualities are quickly calculated, allowing more field work to be carried out by the Commission. Computers are also used to analyse the results of experimental work and to plan the management of forests. Aerial photographs now help the forest assessor with the location and estimation of timber volumes. Mathematical models to simulate forest growth provide forest managers with better estimates of the produce which will be available, thus leading to greatly improved forest planning.

Supplies of naturally durable hardwoods of pole quality for telephone and electricity transmission lines are declining, but research by the C.S.I.R.O.'s Division of Forest Products established that the less durable timber of other eucalypts was suitable for poles if treated with preservative. Two treatment plants were established in the 1950s to treat poles of less durable hardwood species such as messmate and stringybark, and many smaller plants have been established in Victoria to treat pine wood for various end uses, particularly for farm fence construction and poles.

Forests Commission research activities during 1971–72 involved 21 professional officers and ten support staff at a budgeted expenditure of $290,000 including wages and salaries. The principal research activity areas cover forest management, silviculture, biology, pathology, entomology, hydrology, and fire research.

GAS AND FUEL CORPORATION

The Victorian gas industry was established in 1857 with the commissioning of a bench of hand-stoked horizontal retorts on the site of the present Gas and Fuel Corporation's West Melbourne works. Until 1929 gas was produced by the carbonisation of bituminous coal using an English process developed in 1808, and developments were primarily associated with the improvement of retort design and the introduction of mechanical handling. In 1929 the carburetted water gas process was introduced, but the advancement of the industry up to this time was based mainly on overseas research and development. In 1927 Dr R. S. Andrews began research and development work ; investigations made to improve tar for road making led to the important Bitural process being developed. From 1930 until 1936, when imported bitumen prices were lowered, making local production uneconomic, this process made a valuable contribution to the supply of road making materials. Investigations also resulted in the development and construction of cyclic plant to gasify black coal completely at atmospheric pressure, using a three generator system (the 3G process); the first 3G plant began to operate in 1939, to be followed by a second, larger plant in 1942. In Melbourne the newly formed National Gas Association (now the Australian Gas Association) first formulated an Australian standard in 1932 for the design and performance of gas appliances, these codes providing a basis for the national scheme now in operation.

During the early 1930s Dr Andrews began investigations into the use of Victorian brown coal resources for town gas production, examining characteristics of the brown coal and analysing overseas developments for possible application in Victoria. This research led to the establishment in 1956 of the Lurgi Pressure Gasification Plant at Morwell, the first of its type outside eastern Europe. Extensive investigation on the carbonisation of Victorian brown coal was carried out in co-operation with the University of Melbourne, culminating in the production of a high-grade char.

During the Second World War the Victorian gas industry plants extracted motor fuel from syphon liquor, produced sodium formate and sodium oxalate, extracted sodium ferrocyanide and sodium thiosulphate from spent oxide, and produced ammonium thiocyanate from gas works liquor.

In the post-war years there was considerable expansion in gas utilisation research. Projects included the investigations of kitchen ventilation, the development and exploitation of the power flueing technique, the development of a direct flame contact heater giving considerably improved paper machine output, and the development of equipment to allow the use of tempered refinery gases as a fuel in glass works.

In 1966 the Corporation concentrated its research and testing facilities in a new laboratory at Port Melbourne. Staff in the laboratory undertook studies into the practical problems of combustion of natural gas and prepared the way for the conversion of gas appliances. Since conversion, research and development has aimed at improving appliance designs and techniques for installation, and at ensuring that the most efficient procedures and materials are available for the distribution of natural gas.

INSTITUTE OF MENTAL HEALTH RESEARCH AND POSTGRADUATE TRAINING

The Mental Health Research Institute of Victoria was established in 1955 within the Mental Health Authority. With an initial professional and technical staff of five and an undefined research budget the Research Institute has developed as an autonomous unit, as well as acting in catalytic and supportive roles for research developments through individual researchers within the Authority as a whole. At any one time there are 30 to 40 research projects in progress. In order to carry out a mental health education programme, the Institute's buildings are linked with the Mental Health Authority Library and with a mental health museum.

The Parkville Psychiatric Unit of the Institute operates with the University of Melbourne to provide undergraduate and postgraduate teaching, and the Institute's activities are linked with the University of Melbourne's Department of Psychiatry and other university departments, and with such organisations as the Victorian Marriage Guidance Council and the Family Council of Victoria. Specific research activities are also supported by organisations such as the National Health and Medical Research Council, the Social Sciences Research Council, and by private sources.

The Institute has been concerned mainly with compiling data relative to psychiatric morbidity in Victoria, and has been operating a cumulative case register since the Population Census in 1961. Data on psychiatric and mental hospital admissions, discharges, and deaths are processed, and bulletins are published analysing various aspects of specific psychiatric disorders and their treatment. The Commonwealth Bureau of Census and Statistics has assisted with these analyses by providing computer facilities. In 1969, to recognise the growing educational activities, the name of the Institute was changed to the Institute of Mental Health Research and Postgraduate Training, Victoria.

Major areas of research have included the epidemiology of mongolism (Down's syndrome) and other congenital anomalies of the central nervous system, and the occurrence of mongolism has been linked with the epidemiology of infectious hepatitis. The hypothesis of virus-chromosome interaction as a cause of congenital anomalies has been formulated, and immunological studies are being developed to test this theory. In addition to the potential of the mongolism studies, two new methods of treatment in psychiatry have been originated through the medical staff of the Mental Health Authority:

the lithium treatment of mania, and the treatment of enuresis with imipramine.

Altogether, some 400 research projects were processed and 750 papers published by Mental Health Authority personnel before 1970. Total health and social surveys in a rural town and in a Melbourne suburban area, carried out in association with the three Victorian universities, have provided data on the prevalence of specific mental and physical disorders in the community and their relation to social and familial factors. Other studies have been carried out on alcoholism, the mental ill-health of immigrants, Aboriginal adolescents, deserted mothers, and other mentally vulnerable groups. Suicides and attempted suicides have been the subject of a number of studies, as well as the social causes and consequences of schizophrenia in Victoria, prevalence patterns of mental retardation, community attitudes to mental illness, and many other topics in the field of mental health research.

The Institute has aimed to establish links between medical research and the biological, behavioural, and social sciences. In 1971 the Institute had a professional staff of seventeen and its budget was financed through the Mental Health Authority and other sources mentioned above.

MELBOURNE AND METROPOLITAN BOARD OF WORKS

The Melbourne and Metropolitan Board of Works has about 850 miles of large diameter underground steel water mains transferring water from the catchment areas and distributing it in the metropolis. These mains are exposed to attack by stray electric current from the traction systems, and evidence from recording instruments shows that these hazards are very widespread and extend as far as Mt Little Joe near Warburton, but it is difficult to assess the actual damage on the mains. The Board adopts two major practices to minimise electrolytic attack. Steel mains are coated with coal-tar enamel and wrapped with asbestos felt, providing an insulating coating against stray current. In addition, a system of electric drains is installed between the Board's pipes and the traction system to conduct the stray current back to its point of origin, instead of allowing it to casually escape and so corrode the main.

The Board, in order to meet its own requirements, began the manufacture of coal-tar enamel for pipe coating and lining in 1934. Since then the Board's staff, by plasticising the enamel, by using inert wrapping materials in and over the coating, and by using granular backfills such as sand and dusty toppings, has overcome coating-distortion due to soil stresses, and cracking and splintering due to cold conditions, two defects which were earlier apparent. Investigations now centre on various combinations of wrapping material and degrees of plasticising in relation to resistance of the coating to soil stress damage. Overhardening and unpleasant fumes associated with the hot application of the material have been substantially reduced due to elimination of the more volatile constituents in currently produced enamel. Application of enamel has always been more cumbersome and difficult for joints of the smaller diameter new mains, and for perforation repairs of old mains. To overcome both of these difficulties, heavy plastic materials which can be applied more easily as either adherent coatings or sleeves are being investigated. Research is also being carried out into the contamination of water due to leaking of materials from pipe linings.

The Board has conducted hydrological experiments for some years in three small forestry areas at Coranderrk near Healesville. Overseas research in hydrology shows that substantial gains in water yield may be obtained, without detriment to the water quality, by correct manipulation of the catchment forest cover, but the Board wishes to be certain that similar results can be obtained locally before departing from present established catchment management policies. In its experiments, weirs have been established on three perennial streams. Designs were based on installations used successfully at the major American hydrology station at Coweeta, North Carolina. Catchment information, including streamflow, silt load, rainfall, water quality, and soil moisture has been obtained to establish correlation between the three catchments before any disturbance of the catchment growth is undertaken. The catchments will be treated experimentally; one area will be logged in accordance with normal forest practice, followed by the establishment of a mass regeneration crop of young eucalypts; the second will be logged on a more selective basis, with natural regeneration only; and the third will be retained as a control area. This should furnish information on the water economy in relation to a mature forest catchment, and the effect of a young regenerated forest on catchment yield.

Studies on the dissipation of energy in a high-velocity jet to determine a system suitable for feeding service reservoirs in residential areas have demonstrated that a fixed-cone jet-dispersion valve, discharging to the atmosphere, can be used under controlled conditions without causing excessive vibration, noise, spray, or cavitation problems.

Over the years the Board has extensively studied the corrosive effects of hydrogen sulphide in sewerage systems, with particular reference to its action on concrete. Slime growth in main sewers is a major source of sulphide generation, and a detailed examination is being made of the influence of hydraulic shear stress on the slimes at the conduit wall.

Investigations have also covered the service behaviour of 4 inch diameter vitrified clay sewers by using an experimental trench box, pipes being laid under various conditions of bedding, depth, trench width, and superimposed loading. From this the Board has determined the most suitable bedding material and laying procedure to minimise the beam loads applied to the pipes and ascertained the shear load which has to be carried by a flexible joint. This work, combined with additional information obtained from the study of various flexible jointing systems, provided the rational basis for the design of a rubber ring joint for 4 inch vitrified clay pipes; the joint specifications have been incorporated in the relevant Australian Standard Specification. The work is being extended to include the behaviour of 9 inch diameter pipes, and this will enable the rational design of joints for vitrified clay pipes of up to 12 inch diameter.

An environmental study was begun in 1968 with the Fisheries and Wildlife Department on the ecology of Port Phillip Bay. The programme includes a mathematical model study of the Bay's tides, currents and water movements, the meteorological effects, and the exchange of waters with the ocean. Current and tidal measurements were used to verify the model's simulations, and dispersals and concentrations were investigated by means of dyes and chemical sampling.

In conjunction with the Board, the Fisheries and Wildlife Department is studying the marine ecology, requiring extensive sampling and laboratory identification, and the Botany School of the University of Melbourne and the Department of Zoology at Monash University have conducted research into the incidence, distribution, and growth of specific plants and animals within the Bay. The study was co-ordinated by a Committee of representatives of the Board, the Fisheries and Wildlife Department, and the Port Phillip Authority, with the Health Department participating as an observer.

The Board, in co-operation with the State Rivers and Water Supply Commission, is investigating the possible uses of the reconditioned water to be discharged from the South-eastern Purification Plant. The work covers industrial use, agricultural use, and use for groundwater recharge.

NATIONAL MUSEUM OF VICTORIA

The National Museum of Victoria carries out research in zoology, geology, and anthropology; ensures the progress and preservation of collections which are the basis of this research; and by means of an educational programme of exhibits and publications, publicises the results of research. The National Museum, so named because Victoria was then an independent Colony, began on 1 March 1854, and its first field research expedition set out four months later. In 1856 the Museum was moved from the La Trobe Street Assay Office to the University of Melbourne, where it came under the control of Professor (later Sir) Frederick McCoy, who in 1858 was formally appointed Director and who carried out notable research on the natural history of both the present (*Prodromus of the zoology of Victoria*) and the past (*Prodromus of the palaeontology of Victoria*).

Professor (later Sir) Baldwin Spencer, who became Director in 1899, devoted much attention to anthropology. His classic Aboriginal research and his collections of artefacts made by fully tribalised Aboriginals are exceptionally valuable. He was apparently the first anthropologist to use the two new instruments, the kinematograph and the phonograph, for recording data. Spencer realised the need for conservation, and in 1907 he suggested a committee for advising the Government on fauna protection and national parks. The active collecting programme has resulted in the preservation of many species and localities. The many thousands of scientific type specimens are the control points of the nomenclature of the animals of the present and the past. In succeeding years the number of museum curators was increased, and the research work extended ; by 1968 eighteen scientific workers were employed. In 1906 the first *Memoir* was issued, and it is now an annual publication.

In 1967 the Trustees established a scientific fund to supplement the government expenditure on research. The Annual Report for 1967–68 listed thirty-five scientific papers published by members of the staff both in Australia and overseas. Much has been done to increase knowledge of marsupials, rodents, and bats, while the herpetologists have increased the understanding of snakes and lizards. Bird research has included the study of wrens, thornbills, and bush larks, and terns and other sea birds, while recently new lines of investigation have included the osteology and the ecology of birds. The extensive research collection is used by workers in many other institutions.

The investigation of invertebrates has made a major contribution to the field of molluscs. Macpherson and Gabriel published a book entitled *Marine molluscs of Victoria,* and this is a complete and authoritative study. Many contributions to research have been made by honorary associates of the Museum, especially in the department of invertebrates, where large collections of polyzoa, hydroids, sponges, and molluscs, have been brought together. A notable research project was the Port Phillip Survey of physical and biological features, the first volume of reports being published in 1966 and the second in 1971. Some of the basic work on Australian termites was carried out in the National Museum which also worked on ants and forecast problems associated with Argentine ants. The Museum has studied butterflies, cicadas, stone flies, caddis flies, and click beetles, while two honorary workers have elucidated the taxonomy and habits of Victorian spiders. Another significant contribution has been a study of freshwater crayfish and yabbies.

In geology, palaeontological research has been notable, both by curators and honoraries. The development of the knowledge of the stratigraphy of Victoria once depended largely on the palaeontological work done in the National Museum which has published *Foraminifera, Australasian fossils, The book of fossils, Open air studies in Australia,* and over 300 scientific papers on fossils and associated subjects. Fossil man was also studied following the discovery of the Keilor cranium in 1940 and the Green Gully human remains in 1965. In mineralogy and petrology, important research has been carried out on Holocene marine sediments and on beach sands.

Anthropologists have investigated the wide range of Aboriginal artefacts, and assisted in their classification. Aboriginal camping sites, cave art, and history have received considerable attention; the collection of Aboriginal skeletal remains is extensive, and has been the basis of research by physical anthropologists.

The Museum Library contains many rare publications and is an essential research tool.

ROYAL BOTANIC GARDENS AND NATIONAL HERBARIUM OF VICTORIA

The primary function of a botanic garden is to provide a source of material for scientists studying genetics, cytology, and the evolution of plants. Other attractions, such as recreation and enjoyment, are necessarily secondary. Healthy plant specimens, representative of world-wide horticultural areas, are introduced, together with fresh species and cultivar material from climatic areas similar to the native environment. These provide new research and horticultural materials, as well as economic plants of some value. The presentation of this plant material in landscaped form gives the garden scientific, educational, and recreational value.

The Royal Botanic Gardens in Melbourne was founded in 1845 to provide a collection of trees and shrubs largely imported from overseas. The early settlers of Victoria had no information on the possible value and use of native trees, and it was natural to introduce familiar species, the use of which was at least partly understood.

Apart from early plantings of deciduous trees by the early curators, the first scientific contributions were acquired during the directorship of Dr (later Baron Sir Ferdinand) von Mueller. Trees which he considered might be suitable for industrial culture or acclimatisation were planted in a " pinetum ", a term which is common on early plans of the Gardens. Many hundreds of conifers from all parts of the world were planted in the early 1860s, and many of the large trees still there remain from these early plantings. Among the species introduced about this time was *Pinus radiata* from California, a tree which quickly adapted itself to local conditions, and which has since become the major Australian softwood tree. An excellent specimen of the Monterey Cypress, *Cupressus macrocarpa,* was also introduced, originally as a shelter for the coastline, on well-drained sandy soils. There is a well known specimen of the Cedar of Lebanon, *Cedrus libani,* now a well matured veteran of the Gardens. It has not, however, generally proved to be as successful here as in its native land, where it is a useful building timber. The Swamp or Bald Cypress, *Taxodium distichum,* is the tallest tree in the Gardens, having reached a height of 120 ft in approximately eighty years. This is a short time when compared with its estimated life span of over 1,000 years in its native home in the eastern United States of America, but its importance depends upon rapid growth in wet conditions, thus providing an economic timber for building. These are but a very few of the large number of species of trees with a potential commercial value.

The century-old principle of plant introduction from overseas has continued over the years. In 1967–68 approximately 800 trees and shrubs were added to the collections of the Gardens, many of them quite new to the local environment, and it will be many years before their potential becomes apparent. Two groups of medicinal plants numbering several hundred specimens were also planted over 50 years ago, and are now a source of instruction and research for pharmacy students. In the wider field of chemistry, the native plant section of the Gardens is of particular interest to industrial chemists as a source of new drug and chemical compounds.

The National Herbarium, established in 1853, is situated within the grounds of the Royal Botanic Gardens, of which it is a vital part in providing service to the public and to government authorities. It is basically a collection of dried plants, systematically named and arranged for research purposes and for the identification of plant specimens submitted by the community. The science of systematic botany always requires reference to old plant material as well as library information, so that the correct storage and maintenance of plant specimens collected by early explorers and scientists is most important. The National Herbarium communicates the results of the scientific study of any plant problem by reference to the correct botanical name. At the present time the Herbarium houses over one and a half million sheets of specimens collected from all parts of the world. About one half consists of Australian plant species, a collection which is unequalled anywhere else.

The original Herbarium, which stood in the Domain about halfway between the Shrine of Remembrance site and the present Herbarium building, was built in 1857 to accommodate the botanical collections of Mueller, the Government Botanist, and to house his private collection formed from 1840 onwards. Mueller later presented this collection to the State. Through exchanges overseas, and by collecting within Australia, Mueller rapidly built up the collection until it became, and still is, the basis of the most scientifically important herbarium in Australia.

Over 95 per cent of the non-Australian collection was laid down before 1900, and some specimens were collected before the beginning of the eighteenth century. This material, and many of the pre-1900 specimens, are not merely of great historic value but are also of considerable scientific importance, containing as they do much type material, so that the Herbarium is the ultimate source of reference for nomenclature of a very considerable number of overseas as well as Australian species. There is a large suite of duplicate types of original Australian collectors : Preiss' suites of Western Australian material are virtually complete and are of great scientific significance. Of the overseas material the famous Sonder collection is the most important. Purchased in 1887 by the Victorian Government on the recommendation of Mueller, it consists of more than 200,000 sheets of specimens, and contains numerous overseas types or duplicate types. Some of these duplicate types, owing to war damage to European herbaria, now form the master material for world nomenclature. The sheets of type specimens in the non-Australian section of the collection number more than 10,000, and could well be about 30,000 when the whole collection is thoroughly investigated and named. One of the major problems confronting botanists with this overseas collection is that about 20 per cent of the labels need to be deciphered for the name of the collector and place of origin. To assist in this, photocopies of the labels, and specimens of the handwriting of over 700 overseas collectors, mostly of the eighteenth century, have recently been obtained.

The library of the Herbarium complements its collections. It is very rich in works published before 1900, and these are now of great intrinsic and scientific value. Many of these were a gift from Mueller.

Realising the inadequacy of the old building in the Domain, Sir Macpherson Robertson presented the present Herbarium building in 1934. It is situated on Birdwood Avenue, at the south-west corner of the Botanic Gardens, and the Government has made a special appropriation for housing the material.

SCIENCE MUSEUM OF VICTORIA

In 1869 the Governor of Victoria appointed a commission to investigate the promotion of technological and industrial instruction in the Colony. In its report the Commission criticised the stagnation of the mechanics institutes, of which there were about eighty, deplored the virtual absence of any scientific teaching in schools, and recommended that an Industrial and Technological Museum be established to provide scientific aid to industry as well as a lecture centre for science and technology training. The administrations of the Public Library, the National Gallery, the National Museum, and the new Museum were then fused under one corporate body of trustees. The Museum was located in the Great Hall, built for the 1866 Exhibition at the rear of the Public Library, and J. Cosmo Newbery headed the staff. Lecture courses in applied chemistry and physics, astronomy, physiology, food preservation, botany, and geology were instituted and the first enrolments totalled 2,216. Practical classes were also held in telegraphy, chemistry, metallurgy, and assaying, and by 1876 a new lecture hall and laboratories had been provided.

During this time a significant amount of scientific research was carried out in the Museum. In 1891 the Scientific Superintendent visited Germany to arrange the testing and evaluation of the La Trobe valley brown coal. He reported favourably on its qualities, notably its property of cohesion which permitted the manufacture of briquettes without a binding agent, but it was not until 1912 that his advocacy of exploitation was heeded.

The Museum also conducted a campaign against food adulteration and contamination in the late 1870s. Routine analyses were made of foods on sale, and cases of fraudulent adulteration or the presence of poisons, both of which were common, were publicised. As there were no pure food laws before John Ashburton Thompson's Australia-wide campaign in the 1890s, this work was far-seeing and important.

Towards 1900 there was a temporary lull in development. The lecture programme had ended in 1887 following the establishment of the Working Men's College, and the Museum's existence was endangered by the financial crisis of 1892 with the consequent curb on public spending. As a result of these economies, plans to expand the National Museum's accommodation at the University of Melbourne were abandoned, and that Museum was transferred to the large Russell Street gallery, built for and housing the Industrial and Technological Museum, whose collections with the exception of the mining exhibits were placed in storage.

However, efforts were made to re-establish the Museum, and in 1912 the trustees agreed to allocate the Queen's Hall to the Museum as soon as the new large domed building was occupied by the Public Library. From 1915 onwards the new Industrial and Technological Museum developed steadily under R.H. Walcott, a mineralogist who had been appointed curator in 1899 and who was particularly interested in the economic minerals section; his interests also included other aspects of applied science, such as the motor car, powered flight, radio transmission and reception, X-rays, and plant breeding. He also accepted for the Museum the historic Duigan aeroplane and other important items. In the late 1930s the Museum increased its professional staff from two to five. The *Catalogue of Firearms,* now a collector's item, was produced, and the *Thermopylae* model was purchased for £100. The astronomical observatory service to the public began in 1947.

At the end of the Second World War the trustees and Government realised that museum management would need to be changed in response to scientific developments. Parliamentary Acts of 1944 and 1949 separated the single trust into four component bodies, and several distinguished scientists were appointed as trustees. The name Museum of Applied Science was adopted. During the 1950s the exhibits were expanded, a radiocarbon dating laboratory was established, a lecturer (foreshadowing the present education service) was appointed, and the north-west wing was built. By 1960 there were nine professional staff, and the Museum had become the Institute of Applied Science. In 1971 it became the Science Museum of Victoria, with a staff including nine

An experiment with a video test pattern at the P.M.G. Research Laboratories.

Postmaster-General's Department

Megavoltage radiotherapy unit in use at the Cancer Institute.

Cancer Institute

Early X-ray research equipment at the Ballarat School of Mines and Industries.

Ballarat Institute of Advanced Education

The protein sequenator — a machine developed in Melbourne to determine protein structures.

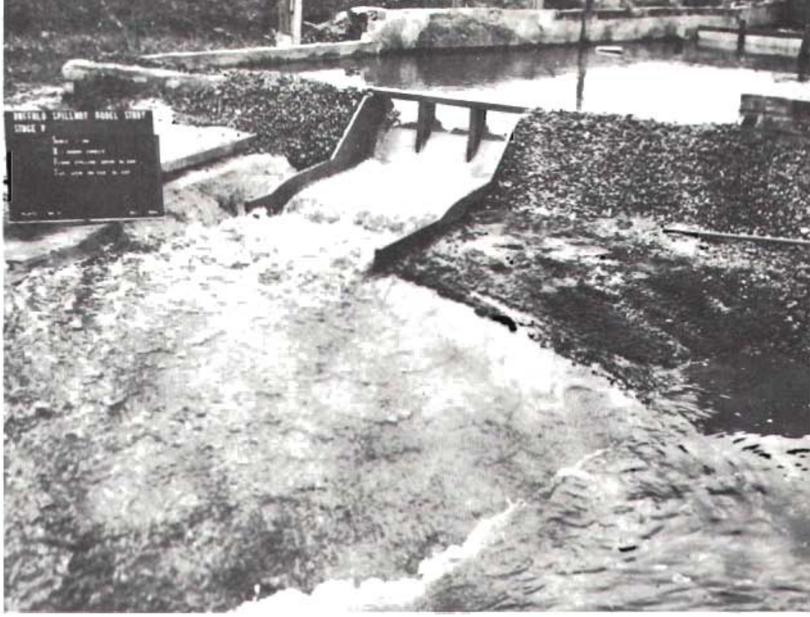
St Vincent's School of Medical Research

Research workers preparing pathological specimens for microscopic examination.

Walter and Eliza Hall Institute of Medical Research

Impact testing of the protective frame on a tractor at the University of Melbourne's tractor testing station at Werribee.

University of Melbourne



A test model of the Lake Buffalo spillway.

State Rivers and Water Supply Commission

Scientists conducting research on vine fungus infestation at the C.S.I.R.O. Horticultural Research Station, Merbein.

Gordon De'Lisle

Pine seedling lifting unit operating at the Longford nursery of A.P.M.
Australian Paper Manufacturers Ltd

professional, nine technical, and seven education officers, and a display budget, excluding salaries, of $22,000. The education service, initiated in 1962 with the seconding of the first teacher from the Education Department, has developed, and the H. V. McKay Planetarium, established in 1965, has become a prominent Museum activity. Most important has been the expansion of the Museum's area from 35,000 sq ft to 62,000 sq ft as a result of the National Gallery's move to new premises in 1968 ; this has enabled the Museum to develop displays and service facilities. Further detailed information for the period 1870 to 1970 is to be found in W. Perry's *The Science Museum of Victoria,* a history published by the Museum in 1972.

SOIL CONSERVATION AUTHORITY

From its inception in 1950 the Soil Conservation Authority has directed its resources towards the solution of ecological problems basic to the achievement of soil conservation. Appropriate systems of land use and management are necessary to ensure that soil is conserved, and that deterioration will not occur, even if the chosen use is sustained indefinitely. Land studies are made, therefore, to ascertain how various kinds of erosion have occurred, to determine what preventive adjustments must be made, and to provide better methods for erosion control. For reclamation of badly eroded land, an understanding of the modified environment produced by erosion is necessary so that appropriate plants and fertilisers can be selected for revegetation.

By developing and using special methods for classifying, mapping, and describing Victorian land resources, the interrelation is shown of the various features which determine the characteristics of an area such as climate, topography, parent materials, soils, hydrology, and vegetation. From this information it is possible to assess the potential productivity and the capability of the land, and the likely hazards of various forms of land use. The Authority has already studied more than 50 per cent of the State, and the information is being made available in published reports. Areas which have been covered include the Mallee, the Grampians, western Victoria and the Otways, and the catchments of the Hume, Goulburn, Broken, Kiewa, and Campaspe Rivers and Glenmaggie Creek.

The determination of land use in proclaimed water supply catchments to ensure their continued value is an important function of the Authority, providing information to decide whether particular forms of land use could lead to soil erosion and to the subsequent deterioration of water quality. Further information to formulate management procedures which will ensure the best possible water yield, and its annual distribution, is obtained from long term hydrological experiments to determine the effects which different forms of land use and management will have on water use and water yield in relation to rainfall. Hydrological experiments have been carried out at Reefton in the Upper Yarra catchment, at Stewarts Creek near Daylesford, at Parwan near Bacchus Marsh, and at Long Corner Creek near Myrtleford. The Authority is investigating the relative effects of different kinds of vegetative cover such as pine and eucalypt forest and grass, and of different timber harvesting methods in a high rainfall forest.

Many plants have been tested for providing vegetative cover for the reclamation of eroded areas, for covering bare soil which occurs on embankments and batters as a result of engineering construction, and for areas damaged by the extraction of road making materials.

There have also been studies into the effect of grazing on the potentially unstable vegetation of alpine areas, and on the dry forest areas in the north central part of the State to determine whether certain areas of unalienated Crown land could support useful pasture cover if cleared and developed. The Authority has also conducted pasture establishment trials.

Areas where dry land salting is a problem are parts of the Mallee and the Western District, and of central Victoria. Investigations show that increasing salinity of soils in the lower parts of certain kinds of catchments is also becoming more widespread, and that it occurs because the best use is not being made of the rain falling on the land. Faulty utilisation causes excessive seepage flow to particular parts of the catchment, and salting occurs unless grazing is controlled to maintain plant cover. If plant cover is not maintained, the excess water evaporates, leaving small amounts of salt in the soil. This gradually accumulates, so providing undesirable conditions. Research workers are studying systems of land use which make better use of water and prevent seepage, and have tested useful salt-tolerant pasture species. Some of these are now being used to reclaim affected areas for productive use.

Tunnel erosion is associated with certain kinds of soils such as exist at Navarre, at Heathcote, and at Parwan near Bacchus Marsh. The factors which cause tunnel erosion, a peculiar form of subsoil erosion, have now been sufficiently identified for economic reclamation, and where the areas are not too badly affected, desirable systems of land use and management to prevent its occurrence can be introduced. For instance, the investigation of earthworks such as diversion banks or farm dams on soils which are prone to tunnelling has led to methods of preventing, or at least effectively reducing, their chance of failure. Other investigations have helped to overcome the problem of leaking dams, where the soils normally do not lend themselves to water storage. Current investigations into the mechanical processes involved in the erosion of gully heads promise to provide a sound basis for developing improved methods of control. Similarly, gully morphology (the study of the relationship between gully dimensions and the frequency and magnitude of flood flows) will provide information about methods of preventing soil erosion. This work has been supported by laboratory investigations into the physical and chemical properties of soils. In addition to the Authority's investigation of physical problems, economic studies have been made to give landowners a better understanding of erosion and its effect on land values.

About fifteen persons have been responsible for the Authority's research work, which has been valuable in solving practical problems.

STATE ELECTRICITY COMMISSION

The State Electricity Commission of Victoria was constituted in 1919, but its scientific connections had begun earlier. In 1917 a Committee under the chairmanship of the late Dr Herman (then Director of the Geological Survey of Victoria) recommended the development of Victoria's brown coal resources for power production. While he was in charge of the Commission's briquetting and research functions, Dr Herman pioneered many developments in brown coal briquetting, preparation, and utilisation. The problems associated with brown coal also attracted attention outside the organisation, and significant contributions were made by consultants from the C.S.I.R.O. in defining coal properties and characteristics, and in solving operational problems. Before a centralised research facility was established in 1962, small scientific groups had worked in various locations such as the laboratory at the first "temporary" power station at Yallourn, the Fuel Research Laboratory at Richmond, and a section within the Production Department. In 1962 the Commission appointed a Chief Scientific Officer, and the dispersed scientific effort was brought together into a Scientific Division at the Herman Central Scientific Laboratory, Richmond. The laboratory building, which contains over 30,000 sq ft of laboratory and office space, was occupied in 1964 by sections performing chemical, metallurgical, fuel technological, and engineering investigations. At 30 June 1971 the personnel in the Scientific Division comprised 52 professional, 27 technical, and 28 supporting workers. The accumulated capital investment at that date was over $1.5m, and the annual operating expenses were almost $1.1m. The present range of facilities at the Herman Laboratory includes work in X-ray emission and diffraction spectroscopy, electron and optical microscopy, high speed photography, and electronics.

The Scientific Division has connections with other units inside and outside the Commission, is associated with long term planning of power and fuel projects, and supplies background information for assessing alternative developmental programmes. It provides functional direction for laboratories in operating units such as power stations, and uses facilities such as electronic data processing services and operational plant in the field for experimental purposes. There is also liaison with local, national, and overseas organisations. Work on methods for expressing quality factors, used as a tool in the assessment of brown coal resources in Victoria, has resulted in procedures which have been of considerable interest to other brown coal or lignite users in America, Germany, and the U.S.S.R.

The brown coal assessment programme has stimulated the development of instrumental (and to a large extent, automated) methods of analysis. In particular, pioneering work on the application of X-ray emission spectrography to the measurement of chemical elements directly on samples of the coal itself was performed in the Laboratory. Also, in collaboration with the inventors of the method in the C.S.I.R.O., the range of applicability of atomic absorption spectrophotometry has been greatly extended. Instruments, both analytical and metrological, have been developed for operational use, resulting in novel applications of optical, sonic, and thermometric principles.

A study of fundamental aspects of the aerodynamics of combustion systems and of elements of plant associated with them is increasingly producing new information and methods of improvement. One invention, an aerodynamic device for concentrating solid particles in a gas stream, could find wide industrial application. These studies, in conjunction with others on heat transfer characteristics in brown coal fired boilers, are contributing internationally to the theory and practice of combustion.

A growing field of research is in the relationship between operational activities and the environment in which they are conducted, including air pollution control, micro-meteorological studies, and the disposal of waste products (heat, coal ash, chimney emissions) from power stations. Metallurgical research with original aspects is conducted into the properties of materials used under high temperature conditions in boilers and turbines in power plants.

In science and technology generally, as distinct from organised scientific research, the Commission has undertaken a wide range of activities. The need for an original approach dates back to the first plant installations at Yallourn, when modifications to combustion equipment were required at a late stage to deal with coal which was found to have a very high moisture content. Other properties of coals have required special provisions to be made in design and operations. Geological studies of the brown coal deposits have led to the assessment of reserves, stratigraphic correlations between seams (this latter also being assisted by petrological and palynological observations), and the development of mining strategies.

STATE RIVERS AND WATER SUPPLY COMMISSION

After the separation of Victoria from New South Wales in 1851, land settlement expanded considerably, especially as a result of the 1869 Land Act. The 1881 and 1883 Water Conservation Acts expressly provided for irrigation works, but the 1886 Act, which vested in the Crown the right to the use and control of all surface waters in the Colony, was the most far-reaching. It enabled public works to be commenced under its authority, and elected trusts could now carry out works with government money; these trusts made considerable progress until 1900 when many of them failed because revenue could not be collected. In 1905 the Water Act established water conservation and distribution on a continuing and stable basis. This Act constituted the State Rivers and Water Supply Commission, and abolished all irrigation trusts with the exception of the First Mildura Irrigation Trust. The Commission thus became responsible for the management of nearly all the State's rural water resources.

A particular facet of the Commission's operations has been the laboratory and field investigations of methods, materials, and equipment. These are basically grouped under general engineering research, the operations of the Engineering Laboratories and the Werribee Hydraulic Experimental Station, and the work which, since 1952, has been done by the Irrigation Research Branch.

Research has been a major aspect of the Commission's engineering activities for many years, the most noteworthy developments having been in the areas of soil mechanics, water testing, statistical hydrology for estimating maximum flood discharges for use in dam design, and hydraulic research. Investigations have also included problems associated with the installation and use of asbestos cement and plastic pipes, metal corrosion in hydraulic structures, design and operation of channel structures, and design and calibration of water measuring devices.

The testing of materials and manufactured components used in water conservation works and distribution systems has always been important. The Commission's original facilities, then known as the Testing Branch, were enlarged in 1921 when additional staff were appointed to hasten the testing of pipes and fittings, cement, and concrete, and to carry out systematic analyses of State waters. In 1924 the Commission acquired its first large concrete testing machine which subsequently carried out tests for many construction authorities. One interesting project in those early years was the study of algal growths in reservoirs, particularly those in Lake Hume in 1929. The investigation of soil mechanics for earth dam design and construction dates from 1939, and was particularly important for these purposes. In 1942 the Testing Branch became the Engineering Laboratories.

The present laboratory building at the Commission's Head Office was first used in 1962. Extensive facilities are provided for the testing of soils, rocks, cement, and concrete, as well as a wide range of other materials and manufactured articles. Comprehensive water testing facilities, including chemical and bacteriological laboratories, are also provided.

The scope of the Laboratories' work can be gauged by the range of activities during 1970–71. These included the bacteriological testing of 4,400 water samples (including samples from supplies to 230 Victorian towns); biology and limnology studies on water storages ; chemical analyses of 4,000 water samples from storages, rivers, and distribution systems ; 450 concrete tests ; inspection of 200,000 ft of cast iron, concrete, and steel pipes, 130,000 ft of asbestos cement pipes, and 200,000 ft of plastic pipes ; and soil tests from 64 localities for dam sites for the Commission, waterworks trusts, and farms. Another major activity is participation in the preparation of Australian standards for water supply materials.

The complex hydraulics of water in dams and distribution channels is not always subject to complete resolution by computation and it is frequently necessary to make tests for this purpose by using scale or functional models. For many years this was done by individual officers of the Commission, but in 1935 models were made at the University of Melbourne of the Yarrawonga Weir spillways and a little later at a temporary Commission testing station at Bacchus Marsh.

In 1948 the Commission's present Hydraulic Experimental Station was established at Werribee for developing and calibrating hydraulic measuring devices, and for the testing of scale and functional models of dam components (especially spillways and outlets), channel layouts, and channel structures of many types. The station was built around an unused reservoir and water tower in an area of about 10 acres, and was provided with 6,000 sq ft of covered testing space, a pump house, workshops, a store, and offices. This station has been gradually extended and its total pump capacity has now reached 16 cu ft per second. Research is carried out into peculiar flow problems and the development of new types of structures and equipment for special purposes ; recent activities also included testing for other organisations. Past work has included studies of flow through rockfill dams for the Commonwealth Government (Sirinumu Dam, Papua), the Queensland Government (Borumba Dam), and harbour and river models for Victorian authorities. The Werribee Experimental Station is officially registered with the National Association of Testing Authorities. As examples of the station's work, in recent years discharge ratings were obtained for standard Dethridge meters and proposed new models, major pipelines were calibrated, flow tests were made of the Nillahcootie spillway, and model studies were made of major culverts on the Mokoan project. A model of Dandenong Creek was constructed for use in flood studies for the Dandenong Valley Authority.

The Commission's irrigation research and advisory programme began in 1950. It has worked towards finding ways of reducing water wastage either in the supply systems or on the farm itself, and there has been a significant increase in water delivery efficiencies in irrigation areas. In the Goulburn system, for example, loss of water in distribution has been reduced from 55 to 30 per cent over a 15 year period.

Significant improvements have included better channel maintenance through use of chemical weedicides, control of leakage through channel gates with neoprene sealing strips, more accurate measurement of water to farmers, better irrigation equipment (including improved water control structures and completely automatic irrigation systems) and better drainage of irrigated lands through water table control. The success of these research developments has caused a marked change in emphasis from research to application, and as a result, advisory activities have been extended for irrigation farmers.

VERMIN AND NOXIOUS WEEDS DESTRUCTION BOARD

In 1951 a scientist was appointed to undertake the first research work in the Department of Crown Lands and Survey on vermin (bird and animal pests) and noxious weeds (plant pests). By 30 June 1958 six research workers were employed. Annual research budgets increased from $5,000 in 1951 to about $175,000 between 1962 and 1968. In 1959 the Vermin and Noxious Weeds Destruction Board was established, and in 1962 it established the Keith Turnbull Research Station at Frankston as its research headquarters. Modern research facilities had been provided at a cost of $1m to 30 June 1968, and by 30 June 1973 approximately $1.2m will have been expended on these facilities. The annual budget for research at 30 June 1971 was about $275,000. A research staff of fourteen scientists, assisted by technical assistants, was employed at that date.

Between 1951 and 1968 a major research project was the study of myxomatosis for rabbit control. This work grew particularly after 1957 when it concentrated on genetic resistance, the virulence of myxoma strains, and after 1968 on the rabbit flea. The results have yielded considerable knowledge of the insect vectors which spread myxomatosis, and of the biology and ecology of the main mosquitoes involved in spreading this disease.

From 1954 to 1968 studies into the use of the poison 1080 for vermin control increased, particularly in district or group poisonings, aerial baiting of rabbits and dingoes, trials in control of sparrows and starlings, and the use of grain-based pellets for rabbit control. The results of this work on the compound 1080, together with myxomatosis, contributed to the high death rate of the rabbit (approximately 90 per cent) during the early 1950s. A significant contribution was also made between 1960 and 1964 to the control of sparrows and starlings. These had both been proclaimed vermin birds and were causing economic losses to the poultry industry. Another significant contribution has been the research on the food habits and parasites of the fox and dingo.

Research on noxious weeds has been directed to such plants as the blackberry, ragwort, Cape tulip, artichoke thistle, St John's wort, furze, golden thistle, prairie ground cherry, African feather grass, wild garlic, and Paterson's curse ; to the persistence of herbicides in soils ; and to noxious weeds of concern to cereal growers. Skeleton weed and amsinckia, for instance, are being controlled, and the cost of dealing with skeleton weed is being reduced each year. Glasshouse studies and a project on the ecology of blackberry species have also been initiated.

Chemical weedicides have helped to control noxious weeds. Susceptible varieties of blackberries have been controlled by means of 2,4,5-T and picloram, and ragwort control has advanced with the use of hormone weedicides. Aerial spraying has been adopted as a means of speedily covering large areas.

6

INDUSTRIAL RESEARCH AND DEVELOPMENT FACILITIES

INTRODUCTION

Scientific and technological development by industrial organisations in Victoria includes research and its technical application to various processes.

The organisations mentioned in this chapter do not completely cover such work in Victoria, but illustrate the various types of activity carried out in many industrial fields. Some industrial projects in other States are derived from organisations whose head offices are located in Victoria ; similarly, many industrial techniques used in Victoria are based on research work done in other States and overseas but which, nevertheless, is adapted to local conditions.

As this chapter is wide in scope and coverage, its treatment is brief. For this reason the length of sections is not related to the importance of research and development undertaken by the organisations described, nor can the various headings do more than indicate their general characteristics.

COMPUTERS

In 1949 the C.S.I.R.O. commenced the design and construction of the CSIRAC, Victoria's first computer. It began operating in 1951, and was installed at the University of Melbourne in 1955 for the processing of scientific data. Since 1950 the attraction of potential benefits expected to be gained by the application of computers in commerce and industry has provided much of the impetus which has resulted in the proliferation of computing equipment, computer manufacturers, and the extensive use to which computers are now committed. Today, directly or indirectly, computers permeate most aspects of everyday life, having been accepted as a necessary tool by most government authorities, universities, research and educational institutions, and hospitals, as well as by many branches of private enterprise throughout the business community.

The growth of computer usage in Victoria is illustrated by the increase in the number of digital computers in operation, from eleven in December 1960 to 381 by 30 June 1971.

Computer technology, through its ability to increase the capacity of high speed core storage at a decreasing cost per unit, its development of high capacity random access storage devices such as magnetic discs, its marked improvement in the performance of magnetic tape and of peripheral devices for input and output operations, and its ability to link remote terminals direct to a central computer, has enabled computer processing to be introduced into many new areas. An early example of this technology in Victoria was provided in 1967 by the centralised Totalizator Agency Board system for continuous processing of betting transactions from its agencies throughout the State. The growing use of data transmission has now made possible computer-to-computer links between computing equipment located in Victorian provincial centres and Melbourne as well as with other capital cities. An example of the many alternatives which this development offers is seen in the ability of a computer user, linked by a remote terminal located in a Melbourne suburb to a computer in Melbourne, to have access to a further computer linked to that in Melbourne but itself located in, say, Canberra or Sydney.

Increasing use is being made of computers in the field of education and information services generally, at universities, colleges of advanced education, high schools, and libraries. Computerised information storage and retrieval systems have been in use for a number of years in the libraries of establishments of the Commonwealth Department of Supply, such as at the Aeronautical Research Laboratories at Fishermens Bend and the Defence Standards Laboratories at Maribyrnong. Since the 1960s there has been an increasing use of computers in medical and biological research. Recent developments in the field of " health screening " techniques have assisted in reducing routine decision-making by physicians by producing a " biomedical profile " of the patient; the method varies from the use of automated diagnostic equipment linked to a computer to computer processing of questionnaires completed by patients.

Until 1970 most computing equipment was imported into Australia, but recently a movement to manufacture in Australia small and " mini " computers has begun. This development has been further enhanced by the decision of some computer manufacturers to manufacture certain peripheral equipment in Australia. Figures from surveys indicate that while the majority of computer users have preferred to lease rather than purchase their computer equipment outright, a growing number has begun to use computer and associated automatic data processing facilities offered by computer service bureaux. These organisations have increased both in number and in the range and variety of the service facilities offered.

The increasing use of computers in Victoria, as elsewhere, has brought not only great benefits but also new problems. Among these have been the possible adverse social effects resulting from certain fears, for example, invasion of privacy and retrenchment of staff. Within the computer industry attention has been focussed on ways of overcoming such fears by attempting to draw up an industry code of ethics and lay down professional standards, by achieving greater productivity through more effective managerial control, and by defining and establishing the educational facilities necessary to train and equip persons with the skills needed in this industry.

The introduction of computers has resulted in the creation and rapid expansion of new occupations in systems analysis, programming, computer operating, and data processing. The Department of Labour and National Service estimates that some 8,000 people will be employed in automatic data processing operations in Victoria in 1973 compared with over 5,000 who were employed in that field in 1969. Surveys by that Department indicated that some displacement of staff has occurred as a result of computer facilities but that most of those affected transferred to other positions in the same organisation; less than 4 per cent of those displaced were actually retrenched.

The increase in the number of computers initially resulted in a shortage of automatic data processing staff, especially systems analysts and programmers. While much has already been done in providing courses to overcome this problem, continued involvement by educational institutions, computer suppliers, and computer users is necessary to determine the most appropriate type of training for automatic data processing occupations.

In Victoria, installations in the fields of government, commerce, and industry include large computers for the Victorian Government and the Victorian Office of the Commonwealth Bureau of Census and Statistics; a complex, commenced in 1970, for the State Savings Bank of Victoria, then judged to be the largest "real time" network banking system in Australia; computerised reservations systems for the major airlines; and the first fully-automated hump shunting system in Australia which was installed for the Victorian Railways in 1970. The Postmaster-General's Department has operated a small research computer and a large general purpose computer in Melbourne for some years, and a nation-wide common-user data transmission network is planned, with Melbourne as one of the two major centres. That Department also uses a computerised cable-testing system. The Commonwealth Bureau of Meteorology in Melbourne makes extensive use of computer techniques in connection with the World Weather Watch, and at the Commonwealth Meteorology Research Centre produces 24 hour experimental forecasts for the whole southern hemisphere; it also hopes to improve the accuracy of short-range forecasts by the use of computers. In 1971 the State Electricity Commission of Victoria installed the first industrial process computer designed and built in Australia to monitor two 350 megawatt turbines at the Yallourn "W" Power Station.

GLASS AND CONSTRUCTION MATERIALS

The origins of *Australian Consolidated Industries Ltd* date back to the beginnings of the glass industry in Victoria, which was established in 1872 when Alfred Felton and Frederick Grimwade founded The Melbourne Bottle Works Company (which became Australian Glass Manufacturers in 1915, then part of another company of the same name formed in 1922, and renamed Australian Consolidated Industries Ltd in 1939). There were thirty-two employees in South Melbourne, mainly to provide bottles for the pharmaceutical products which they handled. Production was at first manual, and skilled tradesmen were brought from Europe. Lines were limited and as most bottled beer was then imported, the main products were medicine bottles and marble-stoppered aerated water bottles. Seamless wine and brandy bottles were produced later by turning the bottles in moulds during blowing operations. Pale green and amber were the only colours manufactured. The industry at first depended on imported supplies of some of the necessary materials, notably soda ash; sand, the bulk ingredient of glass, was available locally, but the bottle stoppers had to be imported. In 1890 operations were transferred to a larger site at Spotswood where rail access and wharf loading facilities were available.

Improvements were gradually introduced and clear white glass was produced ; in 1908 crown seals replaced corks for the first time in Australia. Increasing mechanisation helped to satisfy new demands for food and beverage containers, especially during the First World War when imports ceased. Between the wars, glass production for the food, drink, medical, and cosmetics industries developed, while specialised support became more readily available from engineering and chemical services. With minor exceptions all local requirements were supplied, even during the Second World War when engineering and allied facilities were diverted into munitions production. Dependence on overseas sources has diminished in recent years as raw materials and plant items have become available in Australia. South Australia now supplies soda ash, while sand, lime, fuel, industrial gases, and other goods and services are provided locally.

Sheet glass production to supplement New South Wales supplies began near Dandenong in 1962 in conjunction with British interests. Materials and other manufacturing facilities were then available, and a significant market was already constituted in Victoria, which now also supplies other States. Principal consumers include the construction, automotive, and furniture industries. In 1971 plans were announced for the construction of a plant at Dandenong to produce clear flat glass by the new float process invented by British technologists. Sheet glass production in Victoria will then be phased out.

In conjunction with American interests, a factory was established near Dandenong in 1960 to produce fibreglass. Although the industry had already been established in New South Wales, within three years all Australian manufacturing was being carried out at this new plant. Fibreglass is manufactured in two basic forms : wool and textile filaments. Wool, produced for thermal insulation and noise suppression, is used in home and industrial building, household appliances, industrial piping, motor vehicles, and air-conditioning. Textile filaments are used in the production of yarns for weaving into industrial and decorative fabrics. In industrial grades, fibreglass is used as the reinforcing material in plastics, as in large containers, boats, motor car bodies, and other articles where strength and dimensional stability are required.

Australian Gypsum Ltd has operated quality control laboratories and carried out developmental studies since it was formed in 1930. The central laboratory, built in 1962, concentrated on quality problems ; fundamental as well as applied research did not begin until 1965. Earlier research was of an applied type dealing with quality variables and their correction, and development work was concerned mainly with satisfying market requirements for fire-rated constructions and partition systems. There are now three groups within the company working on research and development problems and employing a large number of technicians, namely, a basic research section, a product development division, and a process development section. The company has a technical exchange agreement with the United States Gypsum Company of Chicago.

Most of the basic research is concerned with the chemistry and physics of the gypsum crystal, its conversion to hemi-hydrate, and the re-hydration to gypsum. Photomicrographic, gas absorption, differential thermal analysis, and exothermic and conductimetric techniques have been developed to assist these investigations. Recent research, and process and product development, has centred on mineral and glass wool fibres. Work is also carried out on teaching equipment such as chalk and plasticine.

To keep pace with present building trends, a completely new range of plasterboard jointing cements, plasterboard adhesives, trowelling plasters, and pottery plasters has been formulated and marketed since 1963. The increased demand for complete and reliable technical data on new products and systems led to the construction of a pilot fire test furnace (a duplicate of the unit of the Commonwealth Experimental Building Station), the construction of sound test rooms to American Society for Testing and Materials Standards, and the purchase of an Instrom unit. Since 1959 the company has designed and built several plaster mills and plasterboard plants incorporating innovations and improvements developed and implemented by the process development section. This section also examines new methods for the production of plaster, plasterboard, and cast plaster products, and carries out pilot plant studies to evaluate and perfect these processes.

As a result of research and development a wide range of building products is now manufactured. The compressed strength of casting plaster has been increased, and other characteristics improved in quality. Plasterboard is now lighter but stronger than in 1959. In 1960 one jointing system but no adhesive systems were available; there are now many jointing and adhesive systems in use. A wide variety of dry-wall construction and cementitious plaster spray systems have fire ratings from 1 to 3 hours. Dry-wall constructions can achieve sound isolations ranging from 28 to 56 decibels. Most of these systems have been developed since 1964.

Humes Ltd began as a small private company which first manufactured concrete pipes in Adelaide in 1910, and at Maribyrnong, Victoria, in 1915. As the result of several original innovations the "Hume Process" for centrifugal manufacture of concrete pipes was developed and led to the formation of the Hume Pipe Co. (Aust.) Ltd in 1920. The process rapidly became established in Australia and overseas. In 1923 the group began the manufacture of steel pipes, and a new company, Hume Steel Ltd, was established in Melbourne for the formation and welding of steel pipes and tubes. In 1952 these two companies merged to form Humes Ltd, with activities embracing most aspects of concrete and steel pipes, and structural work. In October 1970 the company structure changed and its steel pipe making activities were amalgamated with those of Tubemakers Ltd with the formation of a separate associated company, Steel Mains Pty Ltd. In early 1971 a part of the organisation, the Vitrified Clay Division, became part of another associated company, Vitclay Pipes Pty Ltd, formed in conjunction with other clay pipe manufacturers.

The company, with its associates and subsidiaries, has developed vitrified clay pipes and products, plastic pipes and products, structural steel work, reinforcement manufacture, and asbestos cement sheeting and pipes. The resulting application of original work has included improvements and developments arising from the original spun pipe patents; the combination of low frequency vibration with centrifugal spinning of concrete products; the use of linings of various materials, as well as the incorporation of plastic sheeting in spun concrete pipes; plant and equipment for the manufacture of concrete pipes and for the automatic manufacture of welded steel reinforcement for pipes ; development of processes, plant, and equipment for the continuous and intermittent manufacture of steel pipes ; developments in automatic and semi-automatic welding processes and equipment from the pioneering work of the 1920s to the most recent processes ; the lining, by centrifugal processes, of steel pipes with a variety of materials for protective purposes; the application of rubber ring jointing to steel pipe lines ; and the design, manufacture, and construction of large scale penstocks for hydro-electric installations.

In the earlier years, technical developments were a function of the company's operative divisions, but in 1955 a special experimental section was established to work on various aspects of concrete technology. In 1968 the research and development department was created, embracing the earlier concrete experimental section and extending into steel research and development in conjuction with the steel division, and some aspects of plastics and plastic pipes in conjunction with subsidiaries in those fields.

There are about 4,700 employees in the parent and subsidiary companies, of whom some 42 are engaged in research and development. Research expenditure for the year ending June 1971 was approximately $380,000. These figures do not include the associated companies.

Rocla Concrete Pipes Ltd was founded at Sunshine, Victoria, in 1920. Early this century, as Australia did not have ready supplies of cast iron, wrought iron, or steel (the traditional pipe making materials), new concrete pipe making methods were developed, including a centrifugal or " spinning " process. Thus Victoria, now a world leader in concrete pipe technology, has been the centre of significant developments for the past fifty years. Manufacturing methods developed in Victoria are now used in about thirty overseas countries.

Soon after the Second World War the company improved the manufacture of high quality concrete pipes with the introduction of the roller suspension process. This is a refinement of the centrifugal process and utilises a high quality steel mould containing a reinforcement cage suspended on a horizontal spindle and slowly rotated, while concrete with a low water/cement ratio is fed into the mould mechanically. The spindle is rotated at speeds much slower than in the centrifugal process, the concrete being compacted against the internal surface of the mould by the spindle, thus combining the effects of compression, vibration, and centrifugal force. As the durability of concrete pipes is improved by the use of low water/cement ratio concrete, the process has certain inherent advantages and is usually used with water/cement mixes around 0.3, among the lowest in any type of concrete production.

Compaction of concrete within the pipe wall is only one of two basic requirements for the manufacture of reinforced concrete pipe. The other is the making of steel reinforcing cages, which are placed within the mould before the introduction of the concrete, and are usually fabricated from high tensile steel within accurate limits. The first cage welding equipment was patented by the company in 1945. The latest such equipment enables reinforcing cages to be fabricated up to 130 inches in diameter. Since the Second World War pre-stressed concrete pipes have also been produced by a process in which a dense high quality core pipe is made, then wrapped with high tensile steel wire and coated with concrete.

The Rocla processes for roller suspension pipe making, cage reinforcement welding, and pre-stressing are in use in 22 countries under licence agreements. Agreements have also been made with various countries for the supply of pipe-making machines, for fabricating reinforcements, and for incidental subsidiary operations. The company has six concrete pipe factories in Victoria : two are in Melbourne ; the others are at Traralgon, Heywood, Stratford, and Wodonga. About 400 persons are now employed, of whom eight are concerned with research work. In 1970–71 expenditure on research projects was $220,000.

Bricks were among the earliest imports into Victoria but by 1837 were produced locally. At this time brickmaking was a simple manual process. Alluvial clay was won and prepared by hand, shaped into bricks in wooden moulds, dried in the open air, and fired in clamps or earth kilns consisting of unfired bricks mixed with fuel ; horse-powered mixers and simple extrusion machines were introduced later. The main sources of raw materials were the pockets of alluvial clay found in the valleys of the Yarra and its tributary streams. By 1856 brickmaking machines powered by stationary steam engines had been introduced, and in 1870 steam power for milling the clay and shaping the bricks was combined with firing in a Hoffman kiln. The increase in power brought about by the steam engine made it possible to mill and shape harder shales and clays, while the flexibility and efficiency of the Hoffmann kiln improved the uniformity and economics of the firing process. This type of kiln, invented in 1858, was chamberless and was constructed in the form of a ring with a chimney in the middle. High thermal efficiency resulted from its system of flues and dampers, which allowed combustion gases from the firing zone to be drawn through the freshly set green bricks and so dry them off.

This pattern of brickmaking continued until 1960, although the process was adapted from time to time to take advantage of technological advances in other fields : electric motors began to replace steam engines between 1900 and 1905, and motor transport facilitated the cartage of raw materials and finished products. The greatest technical advance came with the introduction of stoker firing with oil or coal and the mechanical handling of bricks in the Hoffmann kilns. First introduced at Ballarat in 1953, these improvements were introduced later in Melbourne, with the result that labour problems eased due to better working conditions, and output increased by at least 50 per cent. Technical modifications of the existing processes probably delayed the widespread adoption of the modern extrusion and tunnel kiln plants, the first of which appeared at Colac in 1951. By 1965 extruded bricks accounted for about half the total production in Victoria and the percentage has risen since. The extrusion method of brickmaking gives much higher output per man hour than the press method, and the bricks can be given a wide variety of surface finishes. The tunnel kiln, although not as efficient thermally as the Hoffmann kiln, gives more even firing throughout the setting, allows more efficient use of mechanical handling methods in the works, and provides better working conditions.

Until about 1900, bricks were the major structural building material, and although they now occupy a less dominant place, they are still a sensitive indicator of social and economic conditions. A peak of brick consumption was reached in the late 1880s, when brickyards produced up to 278 million bricks annually for a population of about 1.1 million. Production then fell rapidly to 48 million in 1894, and although it rose as economic conditions improved, it was not until 1962 that the 1890 figure for gross production was reached again. The increase in brick production was accompanied by an extension of the range and variety of colours and finishes. The earliest Melbourne bricks, made from surface clays, were pink through brown to black, often with black slag pits where iron bearing minerals had fused during firing. Later, the machine-pressed bricks produced from the weathered shales were predominantly red, or if overburnt, dark red to black. Small numbers of white or light-coloured bricks were produced as early as the 1850s, probably with Campbellfield clay which was also used for the cream bricks so popular after 1950. In the modern extrusion plants, the equipment used for grinding and mixing the raw material also allows accurate batching of additives, notably manganese dioxide, giving a range of grey and brown colours when mixed with clays which burn naturally to creams, pinks, and reds. There have also been changes in the use of bricks. Thick walls laid in English, Flemish, or Colonial bond have given way to much thinner walls, usually laid in stretcher bond. In buildings above three storeys, and in houses, bricks are now seldom used as the sole structural support, but where brick load-bearing walls are used, or where brick walls are used to stiffen framed buildings, the stresses in the brickwork are generally higher than was the case in the earlier, more massive, form of construction.

As these changes necessitated more technical information, the *Brick Development Research Institute* was established in 1962 to provide information and to initiate research. The institute has only had a professional and technical staff of three, but annual expenditure has risen from $22,500 in the first year of operation to almost $41,000 in 1970–71, and activities have been extended beyond Victoria to include Queensland and Tasmania.

CHEMICAL PRODUCTS

Albright and Wilson (Australia) Ltd began production at Yarraville in December 1940 making phosphoric acid and sodium phosphates for use in the food industry. The phosphoric acid was initially made from phosphorus imported from Canada, but from 1942 onwards phosphorus was also produced at Yarraville by the electrothermal reduction of phosphate rock.

A novel continuous process for making phosphoric acid from phosphorus was developed at the Yarraville factory, which had a number of advantages over the conventional methods then in use, leading to its adoption in other factories of the Albright and Wilson Ltd group in Canada, and by manufacturers in the U.S.A., Mexico, and Argentina. Also at the Yarraville factory, the company later developed an improved single-stage process for making sodium tripolyphosphate, an important component of synthetic detergents. In 1971 the rights to this process were purchased by a Philippines company, who selected it in preference to other processes which had been investigated elsewhere.

In another company factory at Box Hill (then the Gardinol Chemical Company) some original work on detergents was being done at about the same time, the most notable achievement being the development, in association with the C.S.I.R.O., of a new detergent for wool, with important applications in hospital practice. The company has also pioneered the manufacture of a number of detergent raw materials in Australia, including a biodegradable detergent for wool scouring.

The company's products, phosphates, surface active agents, and surface coatings, have wide industrial application, the promotion of which requires continuous technical investigation and development. This kind of work has been prominent since the introduction of food phosphates 30 years ago, when much work had to be done to establish the best formulations to suit Australian flour, to the present day when recent developments covered by patent applications have included optical brighteners and waterproof coatings for masonry.

Berger Paints Victoria Pty Ltd is located at Coburg and has a manufacturing capacity of 2 million gallons of surface coating annually. A great deal of new equipment has been installed, including high speed pigment dispersion equipment which has practically displaced ball milling. The company manufactures a wide variety of coatings, formulated in the surface coatings laboratory, including polymers such as alkyds, epoxies, acrylics, and amines, and conducts paint tests to ensure performance in a number of areas. Some tests are long term, others are accelerated, and others are specialised to meet specific requirements or conditions. Exterior products, for instance, are subjected to long term exposure tests and panels are regularly evaluated to check performance. Years of exterior exposure testing can, however, be compressed into a few days or weeks in the weatherometer in which panels are subjected to controlled heat, water wetting, and ultra violet light exposure, simulating normal outdoor exposure. After individual requirements are formulated and instrumental controls applied, stringent tests are carried out for corrosion, blistering resistance, and adhesion, while other specialised tests determine acid and alkali resistance, marring, and discolouration. As user specifications determine the manufacture of many products, close technical links are maintained with customers such as the automobile and appliance industries, the Master Painters' Association, the Master Builders' Association, and the Timber Development Association.

The company was the first to manufacture ready mixed paint in Australia and since then has been responsible for originating many other new developments in paint technology.

The Commonwealth Industrial Gases Ltd (C.I.G.) was formed in 1935 by the union of the Australian Oxygen Company (founded in 1910 in Victoria by the late Sir Russell Grimwade) with similar companies in other States. In 1971 the company's oxygen production plant in Melbourne had a capacity of 56,000 cu ft per hour, or 50 tons per day.

Although the original purpose of oxygen production was for oxy-acetylene welding and cutting, the company has developed production of a wide range of industrial gases in addition to oxygen, the chief being acetylene, nitrogen, hydrogen, argon, and in the medical field, nitrous oxide, together with a large range of gas mixtures which can be produced to individual specifications. Industrial oxygen and nitrogen and medical oxygen are now being widely distributed in liquid form and are used very extensively in the chemical industry for food freezing, refrigerated food transport, and scientific research in the cryogenic* field. An automatic plant has been established at Altona to supply nitrogen to various components of the Altona petrochemical complex ; any failure of the plant and the reason for it is conveyed to the Preston works by a telemetering device.

In 1920 the E.M.F. Electric Company Pty Ltd (which became a part of C.I.G. in 1939) was formed. It was originally concerned only with the production of arc and resistance welding equipment, and it began producing arc welding electrodes in 1923. The first all-welded gas holder was constructed for the Melbourne Gas Company in 1920, and shortly after the first all-welded railway bridge was constructed for the Victorian Railways. Arc welding processes have now become common in the construction of buildings, bridges, pipelines, etc. In 1922 a small factory was established for the manufacture of gas welding and cutting equipment, and later added the production of spray painting equipment and medical anaesthetic and resuscitation equipment. This equipment factory, as part of the C.I.G. group, had about 1,000 employees in 1971, while the total staff of the C.I.G. organisation in Melbourne was 1,800.

The origins of *Drug Houses of Australia Ltd* (D.H.A.) include the partnership formed by Alfred Felton and Frederick Grimwade in 1867. High freight rates and delivery delays for imported drugs at that time led to the establishment in the early 1870s of chemical works at Port Melbourne, where the products included disulphide of carbon, manufactured as a rabbit poison under contract to the Victorian Government, and sulphuric acid. Felton Grimwade's activities expanded rapidly in the late 1870s, necessitating a new laboratory and drug mills in West Melbourne. To ensure regular bottle supplies, the company founded Victoria's first glass bottle works in 1872.

In 1851 Joseph Bosisto had opened a pharmacy in Richmond, which was later expanded by the addition of a laboratory to investigate the chemical and medicinal properties of Australian plants, especially the eucalypts. In this he was assisted by Mueller, the Victorian Government Botanist. From 1854 Bosisto extracted the oil at his Dandenong and Emerald distilleries, refining and bottling it at Richmond. By the 1880s eucalyptus oil had become the first distinctively Australian substance in the British Pharmacopoeia. Felton Grimwade became the chief distributor of eucalyptus oil when export to England commenced, and participated with Bosisto in the formation of a company to operate a distillery near Dimboola.

The Felton Grimwade laboratory investigations in early years included the examination of procedures to determine the composition of malt and eucalyptus oil, and work on bismuth, honey, rum, tobacco, and other substances. The late Sir Russell Grimwade was actively associated with the company's research work from 1903 until after the Second World War.

At the outbreak of the First World War " Feltons " found difficulty in maintaining supplies of essential drugs. The search for substitutes initiated work on the extraction of chemical by-products from tar, and included new processes in carbolic acid extraction. Further investigations were carried out in the field of essential oils, especially eucalyptus oil, which by the 1920s was used not only for medicinal purposes but also for industrial

* Cryogenics—the research and scientific aspect, as distinct from the commercial (refrigeration) aspect, of low temperature production.

processes, these being chiefly in mineral flotation. These investigations indicated that a wide range of compounds could be extracted from eucalypts by careful selection of species and more advanced methods of distillation. Indigenous and exotic plants were cultivated at Emerald for the extraction of essential oils and drug alkaloids, a work which was to be greatly extended during and following the Second World War.

In 1929 the company had initiated the formation of the Drug Houses of Australia (D.H.A.) group, enabling principal Australian pharmaceutical companies to survive the strong overseas competition of the 1930s and to adapt their products and procedures to match advances in pharmacology and medical science. Included in the group was the Felton Grimwade Dental Company Pty Ltd, and J. Bosisto and Company Pty Ltd was taken over in 1951. Felton Grimwade had also been associated with the precursors of such companies as Commonwealth Industrial Gases Ltd and Carba Industries Ltd.

During the Second World War, D.H.A. was able to produce many drugs in short supply, especially those of herbal origin, largely due to the cultivation of drug plants near Frankston. The project was sponsored by the Commonwealth Medical Equipment Control Committee, with aid from C.S.I.R., the State Departments of Agriculture, and the universities. Experiments carried out included drying of plant material, distillation of essential oils, and extraction of alkaloids from drug plants (including colchicine, squills, hyoscyamine, belladonna, atropine, and digitalis); the problem of extracting morphine from opium was also solved. Hyoscine, used to prevent travel sickness, was extracted from several species of a native Queensland plant, *Duboisia,* 500 million doses of hyoscine hydrobromide being air-freighted to allied countries.

Dulux Australia Ltd was originally incorporated in Victoria in 1918 and initially used naturally occurring raw materials for paint manufacture, testing their performance under practical conditions. By the late 1920s professional staff had been appointed to establish a scientific background to product uniformity and formulating practice.

Between 1930 and 1950 petroleum solvents, synthetic pigments, and synthetic resinous materials were adopted in the manufacture of rapid drying finishes used on electrical appliances, motor vehicles, pre-coated venetian blind strip, and linings for food cans. A central laboratory was established where chemists developed new processes and products and devised methods for measuring properties. Particular skills were developed in inorganic chemistry (pigments and phosphate coatings), polymer chemistry, chemical engineering, and in the measurement of viscosity and flow, the latter being essential for the scientific understanding of the application of paints and the formation of a continuous film on surfaces. The microbiology of fermentation was investigated to explain poor yields of white lead in the stack process ; this was traced to bacteria generating extremely high temperatures in the stack, thus inhibiting or killing normal fermentation micro-organisms. Although this process was replaced in 1948 by a continuous precipitation process, an interest in microbiology has been maintained for development of fungus-resistant paints using low levels of toxic additive.

Naturally occurring materials have been virtually eliminated from the widening range of industrial finishes since 1950, with new types of chemically reactive materials now being used. This has led to equipment changes for storage, reticulation, and manufacturing operations, and to further expansion of research and development. A new laboratory and practical trials annexe was erected at Clayton in 1960. Since 1965 major research studies have covered the development of coatings in which the evaporation loss in the drying process can be reduced to a small proportion of solvent, or water only, thus cutting costs and minimising atmospheric pollution. Results of this work are covered by patents which have been issued overseas and in Australia. Visual colour matching to a reference standard has posed a problem because it is time consuming and an excessive number of pigments may have to be used, depending on the skill of the colour matcher. To overcome this problem, colour measurement instruments and a computer are now being used to standardise output. Since 1969 extensive research has been carried out in the field of emulsion polymerisation, resulting in practical non-aqueous dispersion coatings for production line finishing of automobiles and the preparation of microscopic vesiculated polymer beads possessing unusual pigment properties. These developments represent significant technical changes which are expected to earn royalties from overseas licensing. There were 125 research employees in 1971, when the annual research budget reached $900,000.

ICI Australia Ltd at the time of its incorporation in 1928 as Imperial Chemical Industries (Australasia) Ltd had only a small range of manufactures. The most important production was that of blasting explosives and accessories such as safety fuses, mainly carried on at Deer Park where such operations had begun in 1875. In 1939 synthetic ammonia was manufactured there for the first time in Australia, and following the outbreak of the Second World War the company entered into many other new projects. Some of them were for the development of relatively straightforward inorganic chemicals such as bleaching powder, chlorates and perchlorates, and stannic chloride and titanium tetrachloride, while others involved an increasing complexity of organic chemistry. Plants for the manufacture of aniline and diphenylamine were installed at Yarraville to enable the production of phenothiazine for anthelmintic purposes. This and other organic chemicals, phthalic anhydride, beta-naphthol, and rubber accelerators were later produced in New South Wales. At Yarraville the company produced a number of chlorinated hydrocarbons, and at Deer Park the sulpha drug, sulphamerazine. The commercial synthesis of sulphamerazine rested almost entirely on research by the company and the University of Adelaide.

After the Second World War strong competition from new factories financed by overseas capital forced the increase of research and development facilities, and in 1954 the company established the Merrindale Biological Research Station near Croydon. Laboratories, a library, and greenhouses provided good facilities in which to study problems of plants, animals, insects, and fungi ; research investigations on the cattle tick were made in the D'Aguilar area near Brisbane. In 1956 the establishment of a large research laboratory at Ascot Vale contributed to the improvement of manufacturing and analytical techniques and the development of new products and processes. A plastics technical service and development laboratory was constructed close to the main laboratory for testing plastic materials, for adapting them to the needs of local processors, and for assisting customers in using new materials and grades of polymers. Other specialised development laboratories to deal with dye-stuffs and pigments, water treatment, and surfactants were incorporated in the main laboratory block, until such time as their growth would justify separate establishments. Pilot plant facilities were established near the explosives factory at Deer Park, and many chemicals have been made there for the first time in Australia. Development work on high explosives and explosive compositions, which necessitate special buildings and wide areas for safety, has proceeded in the explosives factory grounds since the 1930s.

Important contributions have also been made to world science. For example, the beginning of polyethylene production in Australia presented problems for the accurate determination of impurities in the ethylene feed stream. Specialists in the field of chromatography regard the invention of the flame ionisation detector, discovered in 1957 by Dewar and McWilliam during one of the company's programmes of analysis improvement, as a major advance in the field of chromatography. This device is found in practically every laboratory dealing with organic chemistry, and in many on-line analysers in the petrochemical industry, where it has conferred advantages of speed, accuracy, and sensitivity impossible before the 1960s. Research has also resulted in a commercial synthesis for an important member of the dipyridyl group, which has achieved world-wide use for weed control and as a foliage desiccant.

Animal medicines, particularly anthelmintics, have been the subject of continuous work. The discovery by Belgian chemists of tetramisole for the removal of worms from sheep and cattle initiated notable work here, both on synthetic routes to the drug and also to its resolution into two isomers, in one of which (the laevo form) all the biological activity is present. It was then possible to convert the inactive residue into the active form. This permitted the introduction of the drug in an injectable form. Within six years the dose rate of drug for deworming animals had been reduced from about 700 milligrams per kilogram of body weight (for phenothiazine) to 7 milligrams per kilogram, and with much higher biological efficiency.

Other research has covered surfactant effects, important for the formulation of paints and for the stabilisation of foam compositions, and the pioneering of a new route based on ethylene, as a starting material for polyvinyl chloride, a field in which the company holds one of the early patents. A new form of beta-phthalocyanine blue pigment was also produced.

Some long range research, in collaboration with the parent company in Britain, has been done on the synthesis of nylon intermediates. The use of radiation-induced polymerisation, using a captive cobalt source, resulted in the production of highly specialised copolymers now applied in radioimmuno assays and for making polypeptides. Other uses for radiation-formed polymers are for the manufacture of resins used in a new water desalination process. This work was done in conjunction with a medical research group from C.S.I.R.O.

In 1971 the total staff was 220, with 100 graduates, and equipment and buildings were worth \$3m. The annual research budget was \$2.4m.

Kodak (Australasia) Pty Ltd originated from the amalgamation in 1908 of Baker and Rouse Pty Ltd with the Eastman Kodak Company (Rochester, U.S.A.). Thomas Baker, who pioneered the photographic industry in

Australia, was manufacturing photographic plates in 1884 and built the Austral Works in 1886 at Abbotsford with his partner J. J. Rouse who marketed the goods. The company's research laboratory was founded in 1930 to set analytical standards and test photographic raw materials. Plant chemists were required to supervise and develop the preparation of the light-sensitive layers known technically as emulsions. Objectives in emulsion manufacturing were to increase the sensitivity of emulsions to light and thus reduce exposure time, to extend and control the sensitivity of emulsions to various colours of the spectrum by use of suitable dyes (sensitisers), to increase emulsion-keeping stability, and to improve the reproductibility of photographic characteristics. It was also necessary to investigate the processing of exposed photographic emulsions by formulating chemical components for developing, fixing, stabilising, and bleaching when designing new emulsions. Engineers and physicists designed instruments to measure the photographic characteristics of various products, controlled manufacturing standards, and provided data, using the tools of photometry, spectrophotometry, radiometry, colorimetry, and mathematical analysis.

During the 1930s the company produced a number of panchromatic films (sensitive to all colours, not just blue and green as previously). These films were many times more sensitive to light than any previous products. A new coating machine to apply accurate and even thicknesses of emulsion was built, and in 1936 colour film was first processed at Abbotsford.

During the Second World War research was directed towards maintaining photographic standards of basic requirements, and increasing the output of aerial films for reconnaissance, special films and papers for military mapping and reproduction, and X-ray films for medical services. A new system (V-mail) to microfilm letters sent by air was introduced to conserve freight space. Post-war technology was directed towards more sensitive X-ray films, new films for graphic reproduction, the manufacture of colour films and papers, new methods of document copying, and automatic techniques for rapid machine processing. In 1954 the first of a new series of very high contrast materials was introduced for reproduction in printing processes, replacing the hand coated collodion plates then in use for photo-engraving. In 1960 these products were coated on a special non-shrink dimensionally stable polyester base, virtually ending the use of glass plates. In 1959 a " chemical transfer " system had been introduced for producing single or multiple copies of typed, written, or printed originals.

The manufacture of colour reversal films in Australia began in 1952, providing colour transparencies for projection as slides or as movies. Later, a negative-positive colour system (colour film and paper) made possible the production of colour prints from colour films exposed in simple cameras. These colour products, some requiring the application of more than ten consecutive carefully controlled thin layers (with a combined thickness of less than a thousandth of an inch) represented considerable advances in chemical engineering technology, especially as these complex operations are done in darkness.

A new manufacturing plant was completed at Coburg in 1961. It included an enlarged research laboratory with a staff of about seventy scientists, technicians, and instrument makers, with some research being conducted in fields not necessarily directly connected with the photographic process. For example, a sensitive method which had been evolved for determining minute quantities of mercury has proved useful as a prospecting tool for mining operations, analysis of fungicides, air and water pollution investigations, and other non-photographic purposes. Special emulsions were formulated and processing equipment introduced for rapid automatic large-scale processing of professional and aerial films, and in 1967 a new system was developed enabling X-ray films to be processed within 90 seconds.

By 1971, 150 professionally qualified chemists, physicists, engineers, and mathematicians were employed by the company, and in order to keep abreast of domestic and export photographic needs more than $1m is spent each year on research and development in Victoria.

Monsanto Australia Ltd carries out research and development mainly directed towards the adaptation of overseas products and manufacturing processes to Australian conditions. In addition, some research of a more basic and exploratory nature is undertaken. The company first began operations at its West Footscray site in 1941, when it concentrated on the manufacture of phenol (by the sulphonation method) and salicylic acid and its derivatives, the most important of these being acetyl salicylic acid, better known as aspirin. War-time conditions brought about an extension into other pharmaceuticals, particularly in the manufacture of sulpha drugs for the Armed Forces. Sulphaguanidine, the preferred drug against dysentery, was brought rapidly into production by adapting an American process to Australian conditions. Later, sulphadiazine, and one of the well known antibiotics, chloramphenicol (chloromycetin), were also produced. However, the main work has covered industrial chemicals, plastics, raw materials, and agricultural and veterinary chemicals.

In 1943 the company acquired Excelite Resin Pty Ltd of Footscray, producers of phenolic resins and moulding powders. These operations needed formaldehyde, which was produced at a new plant at West Footscray from 1944. In 1947 the manufacture of phenolic plastics was consolidated and expanded at West Footscray.

In 1953 the company began the commercial production of polystyrene, initially based on imported styrene monomer. Shortly afterwards, plans were made for the manufacture of 2,4-D acid and its derivatives (used as weed killers), for fungicides and rubber accelerators. By 1955 important anthelmintics such as phenothiazine, polyvinyl acetate emulsions for plastic paints, and polyester resins for use in reinforced fibreglass products, were being produced. In 1958 the acquisition of two other companies added the range of amino formaldehyde resins and moulding powders to the manufacturing activities. Although this work was largely concentrated in New South Wales, Victorian operations and sales benefited, as they did when another subsidiary, located in New South Wales, began producing styrene monomer in 1961, largely for consumption in polystyrene. Another subsidiary, Australian Fluorine Chemicals Pty Ltd, in which Monsanto and Conzinc Riotinto of Australia were equal partners, was formed in 1960 for the manufacture at Rozelle, N.S.W., of fluorocarbons used as refrigerants and aerosol propellants. During the following years Monsanto's interest in chemicals for primary production was greatly expanded, and an agricultural division was established. In 1968 the company shut down its original phenol plant at West Footscray and began operations in a new plant which produces acetone in addition to phenol, using benzene and propylene as raw materials.

In 1969 and 1970 major expansions were made to manufacturing facilities for styrene polymers and phenol formaldehyde resins, and Monsanto became the first Australian manufacturer of styrene acrylonitrile (SAN) copolymers, a range of rubber anti-degradants based on acetone and polymeric plasticisers. In 1971 a subsidiary at West Footscray commenced manufacturing styrene butadiene latex used in the manufacture of non-woven carpets and paper coatings. At the present time a plant is under construction to manufacture a range of rubber anti-degradants based on paraphenylene diamine.

In 1971 the company employed 75 scientific and technical personnel in its laboratories at West Footscray, with a research and development budget of $800,000.

Nicholas Pty Ltd originated in 1915 when George R. Nicholas began experiments on the acetylation of salicylic acid. During the First World War the supply of aspirin and other urgently needed materials was cut off, so the Commonwealth Government encouraged production in Australia. Nicholas and a colleague produced pure acetyl salicylic acid, and as a result were granted a licence to manufacture. Tablets were first produced on a hand press at his pharmacy. Owing to the increasing demand for acetyl salicylic acid, Nicholas joined with Monsanto Ltd to form the Southern Cross Chemical Company, which later became Monsanto Australia Ltd.

Modern research laboratories were added to the Nicholas factory in South Melbourne in 1939, and qualified chemists were appointed in order to extend the range of products. War conditions again increased the demand for a number of pharmaceutical substances while at the same time limiting their importation. Vitamin A was among the substances for which an Australian source of supply was required. A research team at the University of Melbourne, working in conjunction with the C.S.I.R.O., had found that the Australian snapper shark had a liver rich in vitamin A. Having promoted the catching of snapper shark in Bass Strait and adjacent waters, Nicholas built a plant in Melbourne to extract vitamin A from the livers. This was the foundation of the pharmaceutical division of the company, and in 1945 the agricultural and veterinary division was formed to manufacture and market vitamin supplements for livestock.

Experiments were also undertaken to produce various synthetic drugs of which the supply had been interrupted by the war, and which were urgently needed by the Armed Forces. The company established a synthetic organic chemical factory, and considerable quantities of synthetic drugs were made. During this war-time venture it obtained much valuable experience in chemical synthetic work and special packaging techniques. More than 837 million tablets were made under defence contracts, including salt tablets, " jungle green " dye for camouflage nets, etc., atebrin, aspirin, sulphaguanidine, mepacrine, water sterilisers, and vitamins.

After the war there was further expansion and diversification and an enlarged research programme was also undertaken. The laboratories synthesised new substances which the Pharmacology Department at the University of Melbourne then tested. This led to the discovery of the analeptic substance, bemegride, which is used as a barbiturate antagonist throughout the world. In 1955 the Nicholas Institute for Medical and Veterinary Research was established at Sherbrooke to carry out chemical, pharmacological, and veterinary research. In 1962 the pharmacological research was transferred to the associate company in England, and chemical and veterinary research continued at Sherbrooke and at Chadstone, with special emphasis on the application of chemicals to the control of internal and external parasites of sheep, cattle, and poultry.

The production and chemical laboratories were moved to a new building at Chadstone in July 1957. Recent company reorganisation as Nicholas International Ltd has resulted in further extension of research activities. In 1971 at Chadstone and Sherbrooke the company had a staff of ten university graduates and twelve other technically qualified associates engaged in research, development, and quality control of pharmaceutical, household, toilet, and veterinary products.

Nylex Corporation Ltd originated as the Australian Moulding Corporation in 1927, and from 1932 to 1966 operated as Moulded Products (Australasia) Ltd. By 1971 the company had five factories in Victoria and four in other States, also overseas manufacturing subsidiaries and joint ventures. It employed approximately 2,600 persons and had a product range of more than 10,000 items, most of which were intermediates or components for other industries. The company uses most of the plastics materials in its processing methods, which include calendering, coating, extruding, winding, casting, foaming, and laminating. During the early 1930s the company gave priority to research and development work, although very little plastics research was then being carried out in Australia. Only two materials, phenol formaldehyde and urea, were in common use, but the quantities used were very small. Technical help came from overseas through materials suppliers. However, a laboratory was established with a staff of three chemists who worked with plastics materials not then in common use and developed an understanding of their possibilities.

During the Second World War the factory and its personnel were entirely devoted to defence needs. Earlier laboratory work now showed its value and the company was quickly able to supply vinyl insulated signal wire, reinforced mouldings, safety helmets, and hot dip coatings to protect arms and metallic equipment. Full-time work for the Armed Forces covered chemical investigations into such raw materials as PVC (polyvinyl chloride) resins, plastisols, adhesives, ethyl cellulose, styrene, acrylic polymers, and phenolic resins from sugar. The technique of spiderwebbing army equipment was also established, and a method for impregnating propellers with cellulose acetate was developed. Basic development work was done on clear phenolic resins, and a new fungus-resistant, match-striking surface, based on PVC, was introduced for the Armed Forces in the Pacific. The first work in Australia was done on PVC-paste resins, and original work was carried out on prosthetics. Ethyl cellulose hot dip coatings were also developed, and a PVC garden hose introduced to the Australian market.

After the war the range of power and communication cables reached proportions demanding specialisation, and the company therefore built a factory at Lilydale, together with a testing, research, and development laboratory. Special studies were undertaken, including those to determine the insulations least favoured by rats and termites. Development work on new types of heat stabilisers for PVC resin and investigations into the mechanism of thermal degradation of PVC were carried out, as well as the development of screenprinting inks and fast drying rotogravure inks for high speed printing. The corporation's first PVC coated fabrics were formulated and produced, and a laminating machine was built which transformed the vinyl coated fabrics industry in Australia ; the first Australian-made crystal film was developed, and an improved coupling for hoses and conduits was patented. A non-toxic sheet and tubing, having world-wide acceptance in blood transfusion applications, was also produced. Important developments have also been made in the production of coated fabrics for footwear and apparel. Wide thermoplastic sheet and a new sandwich type packaging board are extruded by a modern plant. Recent products for the automotive industry include crash padding and other moulded components for improved safety.

Until recently emphasis has been on quality control and performance improvement. Work since 1968 has included projects on the gas-liquid chromatographic analysis of ABS (acrylonitrile butadiene styrene) terpolymer residual volatiles comparable with world-wide standards ; a dry blend technique of processing plasticised emulsion polymers ; a flexible all-thermoplastic cable for mining applications ; a concealed hinge incorporating a self-catch mechanism ; an integral flange moulded into the ends of large bore polypipe sections : the first Australian-produced polyurethane coated fabrics ; and the first Australian-manufactured thickwalled clear non-toxic tubing. Rheological studies have led to advances in extrusion of large bore pipe and in general compounding. To cope with the technical aspects involved in originating and improving plastics products, there are three sites at which testing, research, and development take place : central quality control, testing, research, and development are carried out at Mentone ; electrical testing and development for the cables industry at Lilydale ; and fabrics testing, analysis, and development at Deer Park. In 1971 these sites employed about 80 persons, of whom 55 were engaged in specific research and development projects.

INDUSTRIAL METALS AND MACHINERY

Mineral technology

Victoria became an independent colony in 1851 just before one of the richest alluvial goldfields in the world was discovered at Ballarat. In the following fifty years over half of Australia's gold output came from Victoria. The Edwards' Pyrite and Ore Reduction Co. of Ballarat designed the original mechanical rotating furnace, leaching vat, and chlorine generator, which were acclaimed as among Victoria's major technological contributions to Australia's gold mining industry. The continuing impact of Victoria on Australian mineral development has had little to do with its gold production. In 1885 the newly formed Broken Hill Proprietary Company Ltd established its head office in Melbourne. Its directors, many of them pastoralists, ventured into mining fields which others shunned. Their outlook, shared with leaders of Melbourne's brewing industry, was responsible for new mines in Broken Hill, Cloncurry, and Mount Lyell ; their successors, many of whom are their direct descendants, have added to the tradition of mineral management so effectively that 60 per cent of Australian-based mining and exploration companies now have their headquarters in Melbourne.

Innovation has flourished in the atmosphere created by these men. In 1901 Potter's Sulphide Ore Treatment Ltd was established in Collins Street to develop C.V. Potter's answer to the problem of floating the valuable zinc sulphide away from the worthless gangue of the Broken Hill tailing dumps. In 1904 De Bavay's Treatment Company developed an alternative approach on which was founded the Amalgamated Zinc (De Bavay's) Ltd in 1909; from this grew the Electrolytic Zinc Company of Australasia Pty Ltd in 1916. Two years later this new company and the Broken Hill Associated Smelters Pty Ltd jointly established a research station in South Melbourne; in 1920 G. K. Williams, a young Melbourne mining graduate, commenced a study of the desilverising of lead in this laboratory. His work culminated in an investigation at Port Pirie which gave Australia, and the world, the first industrial process for the continuous refining of lead. Since that time Melbourne-based companies have been responsible for initiating and developing projects which have added significantly to the general technological development of the Australian mineral industry.

A professional interest in technical subjects accompanied the early development of skills and techniques in the Victorian minerals industry. In 1892 the Annual Conference of the Amalgamated Mining Managers' Association meeting at Ballarat accepted the proposal of a Broken Hill delegation that the Australasian Institute of Mining Engineers should be formed. At the 1893 inaugural meeting in Adelaide two Victorians were elected to the Council; in 1897 the Institute set up its headquarters in Melbourne where in 1919 it changed its name to the Australasian Institute of Mining and Metallurgy. Typical of its contributions to mineral development was its publication in 1938 of *Principles of flotation,* by Dr I. W. (later Sir Ian) Wark. This book, which records the results of ten years' research, sponsored by six mining companies, in the University of Melbourne, has become a classic in world metallurgical literature.

Victoria was the first recipient of a Commonwealth mineral research grant when the Advisory Council of Science and Industry sponsored work on gold at Bendigo in 1916. Practical benefits from this type of work were marginal, but in 1940 Dr Wark fostered a new approach to research when he was appointed Chief of the C.S.I.R. Division of Industrial Chemistry. Dividends from this Division include the technology for treating Australian uranium ores and the development of the atomic absorption spectrophotometer which is now widely used in geochemical prospecting; the Division has grown into a complex of Melbourne-based laboratories whose annual expenditure on mineral research exceeds $2m.

For many years Victoria's only major mineral resource besides gold seemed to be brown coal; discovered in 1857 it was first successfully exploited commercially in 1917 when the Department of Mines commenced open cut recovery from the extensive Morwell fields. In 1924 this operation was taken over by the State Electricity Commission, which in the same year commenced the production of briquettes and the generation of electricity at Yallourn.

From 1956 until the introduction of natural gas in 1970 Melbourne had been supplied with gas generated from Morwell brown coal in a Lurgi total gasifying plant. The technical foundations which led to the adoption and modification to this process were provided by the Gas and Fuel Corporation and the University of Melbourne. Investigations within the State Electricity Commission and the University of Melbourne led to the decision to form a char-making industry based on La Trobe valley brown coals. The presence of adequate reserves of brown coal at Anglesea was one of the factors responsible for the construction of an aluminium smelter at Point Henry by Alcoa of Australia Ltd in 1963. The discovery of natural gas in 1965, and of oil in 1966, off the Gippsland coastline has set the stage for Victoria's next major contribution to the development of Australia's mineral resources. This has involved the provision of production platforms at the well sites, refining facilities, pipe lines to convey the gas and crude oil, gas treatment and crude oil stabilisation facilities, and the securing of markets for the various products.

Alcoa of Australia Ltd was incorporated in Victoria in 1961 with the aim of establishing an integrated Australian aluminium production industry. A subsidiary company mines and refines bauxite in Western Australia, producing alumina (aluminium oxide). Most of the alumina is exported, and the rest is sent to the Alcoa works at Point Henry, near Geelong, where it is smelted, cast, and semi-fabricated into rolled and extruded products.

By 1964 Point Henry was producing 40,000 tons of aluminium annually ; by the end of 1969 an increase in smelting capacity had more than doubled the design capacity to 90,000 tons. This was matched with similar increases in the associated manufacture of carbon anodes, and in casting and semi-fabricating facilities. A fully mechanised 5,000 ton extrusion press was installed and adapted to meet local requirements for a wide range of alloys and products for industries including building, transport, and agriculture. Auxiliary equipment to handle sections from the press included a 400,000 lb stretching machine, and additional heat treatment furnaces. Other expansion included a new 72 inch sheet mill, a new 72 inch width foil mill, auxiliary slitting machines, and furnaces to cater for the increasing domestic demand for a wide range of high quality sheet and foil products.

To provide the necessary large quantities of low-cost electricity the company's own 150 MW generating station was built on the Anglesea brown coal field ; this has operated since 1969.

The Broken Hill Proprietary Company Ltd (B.H.P.) has had its head office in Melbourne since 1885 although most of its production activities have been located outside Victoria. Until recently, research activities have also been carried on outside Victoria in the steelmaking towns of Newcastle, Port Kembla, and Whyalla. However, as world steel competition increased in the late 1960s, it became desirable to integrate research on the properties of steel products more closely, locating forward planning at head office in Melbourne. A research laboratory was therefore established in Melbourne, and a director appointed to co-ordinate all research activities throughout Australia. In 1965 a 25 acre site was acquired in Clayton, near Monash University and the C.S.I.R.O. laboratories. Construction of the first two laboratory buildings with a total area of 76,000 sq ft (1¾ acres) was completed in late 1968, and by 1971 these laboratories employed 130 persons on an annual operating budget in excess of $1m. It is unusual in the world steel industry for laboratories to be so isolated from the nearest steelmaking centre. This has not presented any outstanding difficulties, and as Melbourne is a centre for metals research, major benefits have arisen from interaction with university and government laboratories. In addition, location in a capital city has facilitated recruitment of research staff. The B.H.P. Melbourne research laboratories are responsible for long term product research. This primarily involves research into the improvement of existing steels, the introduction of new steels, and the development of new ways of using steels. This work is closely co-ordinated with the steelmaking centres and with the marketing division in the Melbourne head office.

In 1971 the two completed laboratory buildings contained equipment valued at more than $1m, and included some of the most advanced tools available for examination of steel. A three storey air-conditioned building contains small-scale apparatus for the physical and chemical study of steels, including a high resolution electron microscope, an electron probe micro-analyser, and X-ray diffraction equipment ; there are also precision machines for measuring the strength properties of steels. This building also contains the library, administration, canteen, and computer facilities. The second building contains the heavy plant, including a workshop, pilot plant facilities, equipment for making steels, and for rolling or forging them to shape. These facilities essentially constitute a miniature steelworks, capable of melting up to one hundredweight of steel in either air or vacuum, and of transforming it into sheet, rods, and other products, suitable for further testing. Research also covers the surface properties of steel and the prevention of corrosion by alloying and surface treatment. To assist these studies the laboratory grounds contain an atmospheric corrosion testing compound in which the resistance to corrosion of steel in a light industrial environment can be assessed. This testing station is augmented by other stations in different environments throughout Australia.

The *Commonwealth Aircraft Corporation Pty Ltd* was established in 1936 to undertake the design and manufacture of aircraft and aircraft engines. During the Second World War the corporation produced 1,400 aircraft, and provided repair and engineering support facilities for Australian and American aircraft in the Pacific area. During the immediate post-war period aircraft produced included the Winjeel trainer, Avon Sabre jet fighter, and the Ceres cropduster.

The most notable change in post-war front line military aircraft has been the almost exclusive use of jet engines. To 30 June 1971 the corporation had produced 570 jet engines of four different types—Nene, Avon, Atar, and Viper—for installation in Australian-produced Vampire, Sabre, Canberra, Mirage, and Macchi aircraft. Two major local engine developments have included the production and fabrication of blades and vanes for the jet engines, and the fabrication of the highly specialised sheet metal components forming a significant proportion of modern jet engines. Engine vanes are usually precision castings produced by the " lost wax process ", but an alternative precision casting process has been developed where part size precludes wax patterns.

Almost 1.5 million compressor blades have been produced in aluminium, bronze, and stainless steel alloys, and approximately 163,000 turbine blades have been forged in heat and creep resisting alloys, the majority being of the " close forged type ", with airfoil forged precisely to finished size. Of the 87,000 turbine nozzle guide vanes manufactured, most have been cast, while the more advanced air-cooled type are produced in sheet metal involving the precision forming and welding of modern heat resisting alloys. The local manufacturing content of all jet engines produced in Australia is approximately 90 per cent, and this includes the specialised components associated with engine mounted fuel systems and burners.

The changes in airframe assembly and production techniques have been less radical, although special facilities had to be installed for the sealing of the Mirage's integral fuel tanks and for the checking of its wing section shapes. Some new sheet metal forming techniques have been developed for producing the plane's large external tanks.

The corporation at present produces the Macchi MB326H trainer for the Royal Australian Air Force with a local content of at least 90 per cent structural components. Wheels, brakes, tyres, and several hydraulic components are also locally produced. The growing importance of hydraulic services in modern aircraft has necessitated the expansion of the corporation's facilities, a very important area being the power-operated flying controls for the Mirage aircraft. All this has resulted in less dependence on overseas supply and ensures vital engineering and manufacturing support for the aircraft throughout its expected service life.

Since 1961 the corporation has been responsible for the design and manufacture of several Ikara anti-submarine missile launcher and handling systems for the Royal Australian Navy. Recently the corporation became the Australian distributor for Cessna aircraft. The number of staff engaged on research for 1970–71 was 35 ; research expenditure was approximately $230,000.

The *Cyclone* group of companies had its origin in a partnership formed in Melbourne in the early 1890s, and known as The Beekeepers' Supply Coy. In 1898 the partnership acquired the Australian rights to manufacture and market a fabricated wire fence produced by the Cyclone Fence Company of the United States of America, and the Cyclone Woven Wire Fence Company was formed, producing the first Australian fabricated fence.

The group has continued to develop varying types and specifications of fabricated fence to meet the technical and economic needs of rural industry. It has also produced and marketed a range of prefabricated rural buildings, including shearing sheds, hay sheds, and implement sheds, and fabricated structural steel for industrial and multi-storeyed buildings. In 1937 the group introduced tubular steel scaffolding to Australia. It also caters for the householder, producing a large range of car-ports, clothes hoists, playground equipment, hand and garden tools, special forgings, and metal windows. In 1926 the group pioneered the manufacture of insect screening in Australia and has since developed and manufactured insect screening and other meshes in various metals and in fibreglass. The wire cloth division also produces a wide range of meshes for industrial purposes. Victorian establishments manufacture a full range of the group's products with the exception of fabricated structural steel. Product development is a continuing process and a staff of executives seek and develop new products for both the local and export markets. During the year ended 30 June 1968 this activity was recognised by the Australian Industrial Research and Development Grants Board which made a grant of $24,000. Cyclone now employs 2,455 persons in all States of the Commonwealth and the Territory of Papua and New Guinea. During 1970–71 research and development staff in Victoria numbered seven, with a supporting budget of $68,500.

General Motors-Holden's Pty Ltd has a technical centre at Fishermens Bend, officially opened in 1964, and built at a cost of $7m. It incorporates facilities for research, product design, engineering, and testing ; it divides into two main sections, engineering and styling, each with its own workshops. Since the first Holden was produced at Fishermens Bend in 1948, the car has been fully designed in Australia.

In the rig test laboratories, tests are made to determine the endurance of the vehicle's components, including those which are produced by suppliers to the company. A more recent development has been the establishment of the research and development section of the engineering department, where studies are made of design trends, propulsion systems, and other long range developments. Work within this department has resulted in a research vehicle called the Holden Hurricane. This is an experimental aerodynamic wedge-shaped mid-engined car less than 40 inches high.

The proving ground at Lang Lang in Gippsland is a 2,167 acre test area for all products designed and engineered in the technical centre. For 24 hours each day, six days a week, prototype Holdens are driven on a specially prepared test track over bad roads, simulated outback tracks, and mud and water stretches. At the proving ground the safety design test centre incorporates advanced equipment devised for safety testing, including an impact sled, a crash barrier, and a special tyre testing machine.

Hecla Electrics Pty Ltd's electrical activities began in 1899 with the design and manufacture of Australia's first electric radiator incorporating carbon filament lamps. The work led to the development of nickel-chromium-iron alloy wires so that heating elements could be made without the use of the glass enclosures of the earlier form ; in conjunction with ceramic supports for the wires, increased wattages and a greater heat output became possible. The firm then began producing a wider range of heating appliances, such as kettles, irons, toasters, and industrial and commercial appliances. The large-scale manufacture of electric blankets commenced in the 1960s. The organisation adopted the name Hecla in 1918 and was incorporated as Hecla Electrics Pty Ltd in Melbourne in 1922. Since 1969 it has been a member of the Hecla Rowe Ltd group of companies. Research is carried out by its research and development division. In 1971 the company had six development engineers, one design engineer, and three other research and development staff.

International Harvester Company of Australia Pty Ltd was formed in 1912 with its initial activities confined to importing farm machines and selling them on the Australian market. By 1939 local testing of all imported equipment became essential, and in that year, therefore, the company purchased 47 acres at Corio, near Geelong, initially erecting a small drawing office and a workshop for engineering purposes. Five persons were employed, simple agricultural implements were designed, and prototypes were assembled in the workshop. Testing was done in the field, and to ensure that all local conditions would be taken into account, the engineering group went to central New South Wales, South Australia, and Victorian rural areas.

During the Second World War the Commonwealth Government encouraged research into the design and production of food growing and harvesting implements. At the end of the war the company's engineering group, in addition to adapting imported machinery for local use, had designed a wide range of machines for use in Australia. They covered a variety of products, ranging from cultivating to harvesting equipment and including mowers and rakes. One of the most notable local achievements was the design of a header harvester, a scarifier, and a cultivator drill. In 1949 the company's first Australian-made tractor was produced at the Geelong works, and extensions were also made at Geelong for engine testing. A motor truck testing staff was added, and other components were tested in operating conditions on the road. In 1950 work began at Dandenong on the construction of the first plant to be built exclusively for the manufacture and assembly of trucks in Australia. When the building was completed in 1952, the motor truck engineering staff moved to Dandenong, although truck testing on the road continued, and a special fleet was established for this purpose. At first, work was confined to adapting imported trucks to local conditions, but in the early 1950s a vehicle for use by the Army was designed with the assistance of the Commonwealth Government. This was the first truck to be completely designed and manufactured in Australia, and was the basis for the first commercial truck of Australian design and manufacture ; by 1971 it was available in more than thirty models.

In 1957 the company established another engineering group to carry out research on construction equipment : this group has been located at the Port Melbourne works since 1958. A proving ground of 2,556 acres was purchased in 1961 at Wormbete, near Anglesea. This automotive proving ground contains many rigorous courses, including a truck chassis twist course, a motor truck test loop, a loader test area, and a tractor test loop.

The product engineering centre was also erected at Geelong in 1961. Facilities included a testing laboratory, drawing office, workshop, and prototype assembly area, five dynamometers, a stress test laboratory, and a rig test laboratory, in addition to a hydraulic and electrical laboratory. In 1962 all engineering groups moved into the product engineering centre. The Dandenong works and Port Melbourne works used a resident engineering group, and the engineering department employed over 200 persons responsible for the development of a wide range of trucks, tractors, and farm equipment, as well as construction and industrial equipment.

Johns and Waygood Ltd was founded by Peter Johns in 1856 who imported iron sections for structural fabrication and prefabricated iron houses. In 1888 he converted his business into a public company. Peter Johns was already manufacturing hydraulic lifts when a new enterprise, Richard Waygood and Company of Great Britain, entered the field in 1888. By 1891 the Waygood business was in difficulties and Peter Johns bought their interests in Victoria, South Australia, and Tasmania, and a year later the company's name became Johns and Waygood Ltd.

Expansion continued, and in 1966, after the amalgamation with the Perry Engineering Company Limited of South Australia, the name was changed to Johns and Waygood Perry Engineering Ltd.

The company employed 6,000 people in 1971, of whom 1,670 were in Victoria, and is established throughout Australia with its head office in Melbourne. Its main products are structural steelwork, steel platework, alloy iron and steel castings, forgings, mining machinery, lifts, escalators, mechanical and hydraulic presses, hydraulic motors, storage tanks, pressure vessels, security equipment, and commercial laundry equipment.

In Victoria, research and development on structural work includes the development of equipment for use in inspecting the guys on radio and television masts, and tests on strength of socketing at the ends of such guys. The latter is related to the effect of bond, using different types of wire rope, and of varying the geometry of sockets. The company has also conducted a series of tests to investigate the effect of pickling and galvanising on steel edges cut by shearing, sawing, and oxy-cutting, and subjected to tension. Tests have also been carried out on fillet welds and butt welds containing imperfections, in order to examine the effect on strength.

The lift division has been predominant since the industry began its development in the early 1880s. Some techniques and designs developed by the company have included the introduction in 1925 of " precision control ", which ensured accurate floor registration irrespective of load or driver skill ; the installation in 1926 of the first high-speed variable-voltage gearless lifts outside the United States of America ; the erection of the first Australian lift test tower in South Melbourne in 1926 to facilitate the testing of designs for increasing speeds and heights in lift equipment ; and the introduction of a patented form of " collective control " in 1930 to " store " automatically all registered calls for answering in correct sequence. High-pressure oil-operated hydraulic lifts were developed in the early 1950s for heavy duty goods or short travel passenger applications, and in 1964 the first " demand " group control system was introduced, whereby the operation of a bank of lifts is completely monitored for optimum performance throughout the service period.

The mechanical division has been associated with the wool industry since the 1890s, and since the 1950s has been involved in continuous research into the design of dumping presses. In 1952 the high speed oil-operated dumping press was developed and introduced to the industry with marked success. In 1962 the first automatic wool dumping press was developed and supplied to the industry, followed in 1964 by the first high density automatic wool dumping press. Following the success of these presses which reduce 27 cu ft bales down to 9 cu ft, the company developed a unitising press which compresses and automatically bands five 12 cu ft bales into a unit not exceeding 84 inches by 32½ inches by 29 inches. Twenty-one of these units can be neatly loaded in a minimum of time into a standard I 50 shipping container, each container thus carrying 105 bales.

Forge-weld steel grid flooring for industrial plants, boiler rooms, and power generating centres has been marketed in Australia for some years. In 1969 the company drew up specifications and assisted a specialised manufacturer in the development of a new high capacity automatic electric forge-welding machine for the production of this type of steel grid flooring.

The machine commenced production in the Trafalgar workshops in 1970 and is operating successfully.

Research into the machining of asbestos cement pipes led to the development and manufacture, from 1947 to 1965, of a number of fully automatic pipe turning lathes for local and export use.

Over the past five decades continuous research has been carried out to develop overhead electric travelling cranes and " stiff-leg " derrick cranes in order to keep abreast of requirements and to meet industry's changing needs.

McPherson's Ltd manufacturing interests include production of a wide range of bolts and nuts and other fasteners ; machine tools and special machines ; pumps ; cast iron and non-ferrous castings ; metal-cutting tools such as twist drills, taps, and dies ; files, rasps, and cutlery ; chilled iron shot and grit ; friction brake materials ; and dust extraction equipment. The company established a Central Testing and Research Department in 1938 to provide technical and development services to its works and to those of subsidiary and associated firms in the group.

The new department consisted initially of a metallurgical and chemical laboratory, and during the Second World War these facilities were made available to many other companies working on defence contracts. The laboratory was an Approved Test House recognised by the defence services inspection authorities, and subsequently it became one of the first industrial laboratories registered by the National Association of Testing Authorities. In 1946 an engineering research laboratory was established, and later metallurgical laboratories were set up for quality control purposes in individual manufacturing plants.

Until 1948 the department directed its efforts towards improving technical control of materials and processes in the various manufacturing plants including the development of improved cast irons for machine tools, heat treatment practices for cutting tools, and heat treatment and electroplating controls for fasteners. This type of work has been continued, but since the establishment of the engineering research laboratory, development has expanded into mechanical and production engineering. Initially work was concentrated on evaluation and improvements in performance of metal cutting tools and on investigation of design features and behaviour of lathes.

Of particular interest in metallurgical and chemical investigations was the development of the practice of carbon restoration in the heat treatment of high strength bolts. This was achieved in the early 1950s, when the technique was unique in Australia and rare overseas.

Recent achievements in the engineering research field have included the development over a period of 2½ years research of the Macson Numerically Controlled Machining Centre, the first tape controlled machine tool designed in Australia, which provides control on three axes, a rotary work table, and ample power for heavy metal removal rates ; design of special purpose numerically controlled, and other, machines ; the development of formulations and manufacturing techniques for railway brake blocks, and the design of special dynamometer equipment for the study of friction characteristics ; the development of an automatic unit for assembly greasing and inspection of ball bearings on pump shafts ; the development of improved plant and equipment for chilled iron shot and grit production ; and the development of bolting practices.

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In 1970–71 the department employed nearly fifty mechanical and production engineers, metallurgists, chemists, and technical assistants, and had an annual budget of about $370,000.

Massey-Ferguson (Australia) Ltd was formed comparatively recently, but its Australian origins date back to 1884 when the development of the stripper-harvester by H. V. McKay marked the beginning of Victoria's leadership in the Australian farm machinery manufacturing industry. McKay's machine, the first to combine the functions of reaping, threshing, and winnowing grain from the standing crop, was officially credited with reducing harvesting costs by two thirds before 1900. This economic advantage paved the way for the broad acre production of grain and made possible Australia's emergence as a major wheat exporter. The first six stripper-harvesters were produced by McCalman and Garde at North Melbourne in 1885. Later McKay established a manufacturing base at Ballarat, initially converting strippers to harvesters which performed the winnowing function previously carried out separately. In 1895 McKay produced the first of the improved "Sunshine" harvesters, which were to simplify crop-gathering and eliminate the drudgery of the hand-winnowing machine. In 1902, when drought had affected the home market, 200 harvesters were dispatched to Argentina as the first known export of Australian farm machinery. More than 10,000 machines were sold there before First World War shipping difficulties forced the cessation of this trade. The inability to obtain rail freight concessions and impending labour problems were responsible for the factory's move to Braybrook Junction (now Sunshine), where McKay had purchased the Braybrook Implement Works in 1906–07. The settlement was renamed Sunshine in 1908.

Subsequent development by designers produced the one-way disc, the header which could gather storm-flattened crops previously lost, and the combined seed drill and cultivator known as the Suntyne. McKay had built a prototype self-propelled harvester with a 24 ft cut in 1909, and a tractor in 1916. An outstanding product of 1917 was the Sundercut, a stump-jump disc plough-cultivator, which opened up much of the Mallee scrub country for wheatgrowing. In 1924 the Taylor auto-header was developed. This was the forerunner of the modern self-propelled machines which have made possible speedy inexpensive harvesting with minimal manpower, and it was followed later by a binder, an original wire-tie pick-up hay baler, and a multi-float drill-cultivator with optional detachable disc or tine float units. The major contribution since 1945 to farm mechanisation has been the research, engineering development, manufacture, and commercial introduction of the sugar cane harvester, a machine which combines the base cutting, topping, chopping, and loading of sugar cane in a continuous operation. These "chopper" machines, which made a basic change in cane harvesting and virtually eliminated hand cutting, were designed expressly for the Australian small farm. The company has produced farm machinery, tractors, and construction equipment, the farm machinery being exported to many countries.

In February 1955 the family interests of H. V. McKay Pty Ltd were sold to Massey Harris-Ferguson, now Massey-Ferguson.

Repco Ltd's research and development began in 1922 when a shortage of replacement parts for motor vehicles from overseas prompted the design and manufacture of pistons and piston pins to satisfy the demands of the engine repair trade. Since 1961 the major share of the company's research and development work has been carried out at its Research Centre at Dandenong. Most of the manufacturing divisions also operate testing and research laboratories.

In the course of manufacture of a wide range of automotive components and accessories as original equipment and replacement parts for motor vehicles made in Australia and overseas, the company has developed a range of special purpose machine tools of its own design. Much of this has proved suitable for companies operating in developing countries. A recent important development has been the cold extrusion method used in producing critical engine components. The company's research teams have designed a range of high-speed, high-efficiency hydraulic machines for producing a range of small components including piston pins. The process eliminates many machining operations and material waste. A similar cold forming process has revolutionised the production of ring gears.

The company has developed a method of manufacturing clutch diaphragms for original vehicle and replacement components, and processes of production for use in Australia and overseas. The company also pioneered the development of an aluminium–tin automotive engine bearing, which is produced and used overseas. Continuous research on braking components has improved brake calipers, brake drums and discs, and a range of control valves to ensure efficient braking on heavy equipment.

Repco's range of specialised automotive engine reconditioning and engine servicing equipment, as well as hand tools, supplies motor trade requirements in Australia and overseas. Some items, such as the off-the-car wheel balancer, have higher sales in overseas markets than they do in Australia. The latest off-the-car wheel balancer developed by the company incorporates what is really a built-in computer, and it does not need highly trained personnel for its operation. Equipment for accurate wheel alignment to service the front-ends of motor cars was developed in the early 1950s for a special racing car developed by the company. A notable research project carried out by the organisation was the production of grand prix engines which won world championship honours in 1966 and 1967.

The latest significant project is the Repco–Spinner developed in Repco research laboratories from a C.S.I.R.O. concept. Utilising a revolutionary principle for the production of yarn, it is twelve to fifteen times faster than conventional equipment, and is smaller, lighter, and easier to operate and maintain. Released in 1971, it has already attracted world-wide attention and sales in many countries.

In 1970–71 the company invested $525,000 and employed 43 persons in research and development work.

Vickers Ruwolt Pty Ltd had its origin in Charles Ruwolt's windmill construction and general engineering business founded in Wangaratta in 1902. Charles Ruwolt Pty Ltd was formed in 1908, and began manufacturing bucket dredges for alluvial gold mining to replace the rather crude machines on wooden pontoons used until that time. The first dredge to be designed and built was entirely of steel, and had a total weight of 470 tons.

It was capable of digging to a 30 ft depth, and had an average capacity of 50,000 cu yd a month. This machine proved so satisfactory that better facilities became necessary and the factory moved to its present site in Victoria Street, Richmond, in 1912. Between 1908 and 1921 twenty-eight complete dredges were built, ranging from 470 to 1,800 tons in weight, with dredging capacity of 175,000 cu yd a month to a depth of 50 ft. Many of these machines were exported to the Federated Malay States, and some of them were still in operation in 1971.

To meet the demand for the rugged and hard wearing parts essential for the successful operation of a dredge, a steel foundry was opened in 1913 working on the Tropenas converter process. By 1971 the foundries had an area of 120,000 sq ft and made steel castings up to 33 tons in weight. In 1928 the first of the four electric furnaces, which is still in operation, was designed and erected.

During the Second World War the company was the co-ordinating contractor for the production of 25 lb gun howitzers, the first gun being put through its proof firing trials within nine months of the start of production. In all, over one thousand of these guns were made. In addition, production included one hundred and twenty-eight 17 lb tank attack guns, sixty-eight 200 hp diesel engines with fuel injection pumps and atomisers, several million 3-inch mortar bombs, and almost a million 2 lb armour-piercing shot. The steel foundry also supplied castings and ingots made to rigid specifications.

In 1946, to increase planing capacity, it was decided to obtain a large electrically operated planer of open-sided construction. As no overseas manufacturer had made an open-sided planer of the size required at that time, one was designed and produced by the company. The research staff has designed and produced other special machines, furnaces, and equipment which have been used by the machine shop foundries and the structural and boilermaking departments.

A large and comprehensively equipped chemical and physical laboratory has played an important part in many activities. Since 1963 more emphasis has been placed on research and development, and a programme has been instituted to contribute to technological development in mineral processing and, in particular, general engineering, such as heavy hydraulic machinery. In 1968 a research and development company was formed to evaluate industrial requirements and to carry out research in many areas, and machines have been produced for such diverse industries as mineral processing and brewing. By 1971 trade with Malaysia was continuing and sales had been made to the Philippines, South America, and to European countries. The company employed 35 professional engineers, and, in addition to its main factory in Richmond, had a machine shop at Nunawading and a non-ferrous foundry at Moorabbin. In 1970–71 seven full-time and several part-time persons were engaged in research projects, with a supporting budget of approximately $200,000.

TEXTILES AND LEATHER

Fibremakers Ltd manufacturing operations were established at Bayswater in 1958 by the parent company, British Nylon Spinners, which supplied the technological resources. Since that time the Bayswater company has grown substantially and by 1971 produced a wide range of both nylon and polyester products. This growth has stimulated increasing advances in the company's technological investigation and development work, both contributing to, and benefiting from, the association with overseas companies of the ICI group. This association is formally covered in an annual international research and development conference in which the company participates. As the Australian environment, with its severe climatic conditions, presents special problems in all textile end-uses covering apparel, domestic, industrial, and defence requirements, the company's technological efforts have been concentrated on specific Australian problems.

In 1971 the company's technical establishment, divided into two major areas, the technical services department and the development department, comprised 72 persons of whom 26 were graduates.

The technical services department is involved in quality control, and in efficiency investigation and development work on all manufacturing aspects, with the aim of ensuring high standards of quality and uniformity. It is also responsible for chemical and physical analytical work and for statistical services. Much of the modern apparatus in use has been custom built, and other items of apparatus such as the atomic absorption spectrometer have provided modern and effective analytical techniques. All its work has been co-ordinated with the overall company use of computers for recording and investigating.

The development department is concerned with the investigation and development of new processes, products, and plant, in many cases involving the development of textile uses of products. This work has ranged from processes for fine yarns suitable for ladies hosiery and flimsy articles of clothing, to high tenacity industrial yarns suitable for heavy industrial tow-rope. This work involves an understanding of polymer molecular structures and the investigation of the engineering, physics, and chemistry involved in converting amorphous polymer into oriented textile fibre. Other examples of development projects on new products have been work on yarns of differential dyeing properties and work on yarns of modified geometry. Another project has been the development of larger packages (bobbins), which involved not only an increase in size, but detailed attention to the complex tension characteristics of the yarn. The work of the department also requires a knowledge of the textile operations involved in conversion of these products into their various end-uses, involving processing, weaving, tufting, knitting, and the dyeing and finishing trades. The company is also engaged in productivity research, and this has resulted in an increase in manufacturing capacity.

Leather research in Victoria was sparse and fragmented before 1965. The only tannery with a tradition of independent research was that of *Michaelis–Hallenstein Pty Ltd* (now trading as *Michaelis Bayley Ltd*) which has maintained a small research group for the past 40 years. This group has published the results of work on fermentation in vegetable tanning liquors, on pioneering applications of ion exchange resins to the investigation of tanning liquors, and on the measurement of adhesion of finish. Particular interest was taken in the influence of the vertical fibre defect of hides on leather properties, a paper on the subject attracting world-wide recognition in 1959. Although other Victorian tanneries did not undertake research on their own account during this period most of them were subscribers to the Australian Leather Research

Association which was established in New South Wales in 1946 and carried out research over the succeeding 15 years.

Research connected with the leather industry in the C.S.I.R. and C.S.I.R.O. during this period included a small group which was established in the Division of Industrial Chemistry to carry out research on fellmongering. This group was the forerunner of the present Division of Protein Chemistry of the C.S.I.R.O., which resumed research into leather in 1965. Another group in the former Division of Forest Products has been working since 1950 on the fundamental organic chemistry of tannin extracts from different woods and has made valuable contributions to this field.

Following the cessation of the activities of the Australian Leather Research Association, a number of tanners requested C.S.I.R.O. to undertake leather research on a wider scale. As a result of this proposal the Leather Industry Research Association was incorporated in 1964 with a membership comprising all of the larger and most of the smaller tanners. The C.S.I.R.O. Division of Protein Chemistry agreed to establish a Leather Research Section with an annual budget of $88,000 for a period of five years and this came into operation early in 1965. Of the annual budget, one half was contributed by the Leather Industry Research Association and the remainder by the Commonwealth Government. The group has a research staff of six with supporting technical assistants. The initial five year agreement has been renewed for a further term.

The principal avenues of research have related to improvements in the methods of preservation and unhairing of hides; the development of new methods of utilising zirconium salts and chrome-zirconium complexes in tanning; gaining a better understanding of the binding of chromium to collagen; investigations of the mechanisms of drying of leather and of practical improvements to this process; and the development of processes by which the properties of leather may be improved by impregnation with polymers. Processes developed in the Leather Research Section have been adopted by the industry. A method for the short-term preservation of green hides without the use of salt has found wide application, and a new method of drying has proved so promising that a full-scale commercial dryer using these principles has been installed in a Melbourne tannery.

FOOD TECHNOLOGY

Carlton and United Breweries Ltd was formed by the amalgamation of the six leading breweries in Victoria in 1907. Brewing in Victoria began soon after European settlement, but imported English ales and beers were more popular. By the 1870s colonial beer was beginning to compete, and the value of imported beer decreased from £300,000 in 1860 to £75,000 in 1872. The adoption of Dr Hansen's ideas on the use of yeast cultures in the 1870s firmly established the brewing industry. Fierce competition between brewers forced many out of business, and only thirty-seven breweries were still operating in 1907, compared with 126 in 1871.

Brewing is a highly technical process demanding the use of high quality raw materials and extensive routine control, research, and development. Each stage of the company's brewing process is monitored by control panels, as well as by samples being submitted to the control laboratory.

The company employed its first laboratory worker in 1908 to give monthly reports on the quality of the beer ; in 1971, 80 persons were employed in the research and control laboratory, and the research budget was \$300,000. Early research was concerned with the setting of brewery standards. One of its by-products was the investigation into the flotation method of treating ores. From 1923 to 1956 the laboratory was responsible for developing measurement techniques for critical parameters. The development of the Clendinnen Haze Meter, which has continued in use in the company's plants, was of particular importance for the measurement of beer clarity; other techniques included those to determine the carbon dioxide content of beer, and to analyse hop resins. In 1958 the research laboratory began to investigate and identify the chemical compounds responsible for the flavour and aroma of beer, and this led to the development of the company's hop extract process. The hop extract processing plant, built at a cost of more than \$1m, received the annual award of the Society of Chemical Industry of Victoria in October 1966. The extract has been exported to south-east Asia and planned for manufacture in Europe and the United States. The company has also developed new and improved varieties of hops. Experiments since 1950 have led to the development of two varieties of the hop plant which meet the requirements of both grower and brewer, and by 1971 these represented much of the Victorian hop crop.

More recently, the laboratory has sought to define an objective flavour profile for beer and to correlate it with subjective testing. It has investigated various aspects of all raw materials and their more efficient utilisation, and close contact has been maintained with the Barley Improvement Research Scheme which is supported by the brewing and malting industries as well as by the Governments of Victoria and South Australia. The laboratory also carries out studies of the company's pure culture yeast and its behaviour under varying conditions, with particular reference to processing changes and the potential advantages of continuous processing. Research generally has led to a greater understanding of beer composition, and over 250,000 samples are checked each year in the control laboratories.

Engineering work included the development, in conjunction with Vickers Ruwolt Pty Ltd, of automatic rotary beer cask fillers which fill six to nine casks a minute (averaging 8,000 gallons an hour).

H. J. Heinz Co. Australia Ltd carried out little research in Australia on food technology before 1951 as most fundamental information was obtained from overseas affiliates. At that time there was a research staff of seven and the total budget was \$20,000. In 1970 the professional and technical staff numbered 28, all of whom were variously qualified between the levels of chemist, food technologist, and laboratory technician, and the research budget was \$220,000. Recent developments have included increasing the vitamin assay to include vitamins A, B_1, B_2, C, folic acid, niacin, and carotene, and the production of a nutritive data sheet which gives the analyses of all the company's baby foods and which can be used by the medical profession to determine children's diets. Nutritional research experiments, using microbiological growth study techniques, evaluate the protein content of ingredients in baby foods. Research methods have determined the trace metal content of foods by the use of the atomic absorption spectrophotometer developed by the C.S.I.R.O., and the measurement of residual pesticide has been determined by gas chromatography. Other work has involved the development of statistically acceptable sampling levels for the quality of raw materials, involving about 95 per cent of bulk receipts ; this has been of particular significance in can sampling using parameters established overseas which have been adapted to Australian conditions. Specifications have also been established for all incoming raw materials and one result has been the recognition and elimination of bacteriological defects associated with prepared fish.

Research into recipe formulation has made possible the bulk preparation of some basic ingredients, the use of which simplifies operations and increases efficiency. Another important development has been the industrial adoption of the steam injection method of food processing, which allows food to be cooked almost instantly by exposing individual particles to high temperature steam. Decentralised quality control laboratories check " in process " work and have accelerated production flow. Emphasis on food technology has contributed towards new products, 22 being introduced in 1970

W. S. Kimpton and Sons Pty Ltd (now trading as *KMM Pty Ltd*) was founded by W. S. Kimpton, who in 1875 was operating a steam-powered stone roller flour mill in Fitzroy. It was destroyed by fire, and in 1888 a new roller flour mill, which extracted white flour more efficiently, was built at Kensington. Although fundamental operations have not changed, roller mill machinery and ancillary equipment have become safer and more efficient. The company engaged a fully qualified chemist early in 1936 and established the first fully equipped mill laboratory in Australia for specialised flour testing and analysis, and for test baking. While quality control was the main activity, some cereal research of an *ad hoc* and long term nature was carried out, and the latter included a study of the diastatic activity of Australian wheats during the period 1937 to 1942.

In 1938 the company produced pelleted stock feeds and in 1941 began the construction of the first fully integrated continuous flow stock feed plant in Australia. Increased research work ensured that the feeds were of high nutritional standard, and a small experimental farm was purchased at Bayswater in 1939 for feeding experiments in conjunction with laboratory analysis. At the beginning of the Second World War the laboratory staff consisted of five persons, two of whom were qualified chemists. The company assisted the Nutrition Committee of the National Health and Medical Research Council in research on the nutritional value of Australian flour and bread, with special reference to vitamin B_1, for which a satisfactory assay method was established by 1943. In 1944 a research chemist was employed and a microbiological method of assaying was eventually adopted for vitamin B_2 ; surveys were made of the vitamin B_2 levels of cereals and of many of the ingredients required for foodstuffs manufacture. As quantity production of many commoner vitamins was becoming feasible, assaying became increasingly important. Nutritional evaluation has been made of stock feed ingredients, and chemical assay methods were developed for vitamin B_2, vitamin A, methionine, cystine, tryptophan, lysine, and tocopherols, and polarographic methods for trace elements such as copper, zinc, and cobalt.

By 1959 the problems of diminishing local and export markets for flour led the company to pioneer the Australian development of a new method of flour processing—air classification. This involved secondary treatment of white flour by further high speed grinding and subsequent particle size separation to produce flour fractions of much higher or much lower protein than the parent flour. Production of the high protein fraction was of particular value for Victorian bakers since flour protein levels are generally below those considered desirable for production of high quality bread. The low protein fraction provided a new flour of interest to many industrial users, and which was also suitable, after chlorination, for high-ratio cakes and sponges. In 1952 the company was the first in Victoria to carry out research on high-ratio flours and to produce them in commercial quantities.

The company established further stock feed factories at St Arnaud in 1956, Echuca in 1961, and Corowa in 1968, and during 1967 the plant at Kensington was modernised and converted to a continuous batch-weigh process in order to improve precision of blending and uniformity. In 1963 a larger experimental farm of about 40 acres was established at Lyndhurst.

Research and development has tended to be integrated with control and service work but in 1969, following a merger between W. S. Kimpton and Sons Pty Ltd, J. Minifie Pty Ltd, and McLennan and Co. Pty Ltd, a separate research and development division was formed with three major sections, animal nutrition, analytical and chemical research, and product development.

In 1970–71, fifteen persons were engaged full-time and two part-time in research and development, and the annual operating budget was about $120,000. The total number of staff engaged in research and quality control work was 31 and the annual net expenditure was about $170,000.

Kraft Foods Ltd was founded in 1908 as Fred Walker and Company. Initially research work was directed towards the maturing and processing of cheese and the development of a yeast extract by the autolysis of brewers yeast. Shortly before the Second World War, staff was appointed for investigatory work in bacteriology at Allansford and in chemistry at Melbourne, and in 1944 a separate research laboratory with a staff of five was established. Work in Melbourne at this time was in two main fields : studies on B complex vitamins, and an investigation of the action of emulsifier salts in cheese processing. The former led to a better understanding of the thermal instability of thiamine and to the establishment of microbiological methods for the assay of B vitamins and amino acids. Considerable progress was also made towards an understanding of the mode of action of emulsifier salts on cheese protein during processing. In 1939 starter failures owing to the presence of phage were occurring in cheese factories, and Australian pioneering work on bacteriophage was carried out at Allansford in the 1940s. Preventive measures were developed and work on phage relationships of starter organisms began.

By 1954 there were seventeen persons engaged in research and development, and with increasing diversification more attention was being given to product development and food technology. The new laboratories at Port Melbourne were also occupied, and these have since been extended several times. During the 1950s packaging problems and product development became important, rindless cheese was introduced into Australia, and Swiss cheese manufacture re-introduced. The development of large blocks of cheese

(400 lb and over) was a technical and economic advance. Significant advances have been made in the knowledge of phage relationships of cheese starters, the technology of cheese processing, the study of milk and cheese proteins, and the understanding of flavour problems encountered in cheese and yeast extract. A mechanical cheese making process has also been developed and patented, while technological development has taken place in instrumentation, automation, and machine design. The company's recently developed products have included cheese types not previously made (Swiss, Edam, Gouda, Cheshire, etc.) as well as jellies, conserves, refrigerated dough products, peanut butter, and new salad dressings.

In 1970–71 the total staff engaged in research and development numbered 62, of whom half were graduates or diplomates. The facilities included laboratories equipped with modern instruments specially directed towards gas chromatography, spectrography, and absorptiometry, and pilot plant equipment for technological studies.

PAPERMAKING

Papermaking was already well established in overseas countries before Victoria's settlement, but was essentially a craft industry with no significant research or development. The first paper mill in Victoria was built in 1868 on the south bank of the Yarra River near Princes Bridge. This later became the Melbourne mill of *Australian Paper Manufacturers Ltd* (A.P.M.) and continued production until it was closed in 1968. The first scientific study of native eucalyptus species for the manufacture of paper pulps was begun in 1919. The investigations were extended in the early 1920s by a group which became the nucleus of the Forest Products Division of the Council for Scientific and Industrial Research (C.S.I.R.) in 1926. Despite the opinions of overseas consultants, local interests were optimistic about the prospects of using eucalypt pulp for paper production, and in the late 1920s the company, together with other paper and some mining companies, arranged for the conduct of pilot-scale and semi-commercial trials by C.S.I.R. staff. Ultimately this led to two new and independent companies being established to manufacture printing papers (*Associated Pulp and Paper Mills Ltd*) and newsprint (*Australian Newsprint Mills Pty Ltd*) in Tasmania, and to A.P.M. establishing a mill at Maryvale, Victoria.

With established markets for strong wrapping papers and packaging materials, A.P.M. found suitable pulpwood sources in the forests of western Gippsland, and it was here that the largest pulping operation in Australia began when the Maryvale mill started production in 1939. Most early investigation of eucalypt pulping used the (acid) sulphite process, but at Maryvale the alkaline kraft process was introduced. This process produces a strong grade of pulp but requires comparatively large quantities of alkaline chemicals. Fortunately, efficient process equipment for chemical recovery was developed overseas in the early 1930s, and this proved suitable for eucalypt pulping.

In 1936 A.P.M. formed a small research department with a staff of five to develop and utilise indigenous raw materials and it occupied laboratories in the grounds of the Fairfield mill in Melbourne. This department undertook systematic and detailed studies of chemical pulping which contributed not only to the establishment of the Maryvale mill, but also to the development of a process for making paper wood cellulose and a more highly refined alpha cellulose board. These were basic requirements for production of nitro-cellulose by the Commonwealth Munitions Department and more than 10,000 tons of paper wood cellulose for explosives were produced at Maryvale during the Second World War. After the war attention was directed to the provision of softwood pulp which forms the larger part of the fibre requirement for strong grades of wrapping papers and container boards. The company initially experimented with growing New Zealand flax (*Phormium tenax*) as a perennial crop, but abandoned this approach in 1951 in favour of establishing large scale pine plantations on a long term basis. A forestry research group was established in 1957 and has conducted a continuing study into establishment techniques, soils, plant nutrition, and silviculture.

After 1950 the market for packaging materials expanded rapidly. Several new paper and board machines were installed, and between 1958 and 1968 new pulping plants were built in Tasmania, Queensland, and Victoria to meet the increased demand. In addition the company, in conjunction with Cellulose Australia Ltd, built an integrated pulp and tissue paper mill at Millicent, South Australia. These installations differ considerably in scale and process. Each was developed after extensive research for a type of pulp meeting the specific requirements of the paper to be manufactured from it, and the Tasmanian project would not be economic but for the development by A.P.M. of pulp in pelleted form for bulk handling.

A major innovation has been made in the basic method of forming multi-ply paper sheets or "paperboards". This began with the English development of a new type of paperboard making machine known as Inverform, and was the first basic departure in paper and board making equipment for over a hundred years. Although the equipment brought new problems, it did offer special advantages in productive versatility. In 1960 the first commercial machine was installed, and after further research and development three more large machines, incorporating major design improvements evolved by the company, were installed. The company became a major world producer of Inverform products, and the bulk of its board production has come from these machines.

The early years of the research department witnessed fundamental studies in lignin and cellulose chemistry. Research findings in cellulose chemistry, in paper sheet formation, and in several other fields have been published. Since 1950 research and development work has included instrumentation, paper physics and pulp processing, hydraulics, paper sheet formation, printing and packaging, new product development, and, in more recent times, operations research and systems engineering. In 1971 more than 50 graduates were employed on research and development work which is centred in the research laboratories adjacent to the Fairfield mill. The research and development budget was approximately $1m in 1971.

RUBBER

Dunlop Australia Ltd began in 1899 as a small Melbourne factory producing cycle tyres, largely by hand. J. B. Dunlop had invented the first practical pneumatic motor car tyre in Britain in 1888, and production of car tyres began in Melbourne in the early 1900s; other goods manufactured by the company before the First World War included garden hoses, diving suits for the pearling industry and other maritime products, rubber parts of various types for the automotive industry, inflatable rubber cushions, flat transmission belting, and tennis balls.

In 1926 the company made the first aircraft tyres produced in Australia. Tractor tyres and other products were gradually introduced and a self-sufficient industry developed between the two world wars. In 1934 the Dunlopillo process, a practical foamed rubber produced directly from latex without passing through the coagulation stages, was developed by Dunlop in England. During the 1930s the introduction of more advanced materials with special properties such as synthetic rubbers and textile materials made rubber technology more complex, and to deal with the problems the company established a development and research department. Rubber shortages during the Second World War led to the development of a synthetic rubber technology by the United States petroleum industry, and the company benefited from this knowledge in its manufacturing processes in Australia ; an increase in the number of graduate scientists and engineers resulted in the expansion of skills to overcome difficulties in the mixing, adhesion, and vulcanisation of this material. The development of textile and rubber combinations drew more attention to aspects of textile technology within the framework of the rubber/textile composite materials.

During the decade following the Second World War the development of batteries, tubeless tyres, collapsible rubber tanks, and industrial products, together with a wide field of footwear technology using rubber-like materials, made it necessary to extend research beyond the applied techniques used previously. In the later 1950s more advanced research laboratories were built and major areas of investigation included chemical research, the development of instrumental analytical techniques, the study of the physical characteristics of pneumatic tyres, and the study of adhesion in many different fields. The rapid growth of the automotive industry during the 1960s has led to the development of radically different types of tyres for local conditions. The development and research department has been working on new products and materials, including new techniques for making battery containers, and has undertaken studies in textile characteristics and textile bonding. In the second half of the 1960s the company concentrated on expanding the manufacture of automotive, aircraft, and industrial products, and footwear, apparel, and sports goods. Research and development expenditure throughout the group in 1971 exceeded \$2m.

The *Olympic* group of companies was founded in 1922 when F.E. (later Sir Frank) Beaurepaire opened the Beaurepaire Tyre Service Pty Ltd to retread and retail tyres. The group in 1971 comprised a holding company, Olympic Consolidated Industries Ltd, and four operating subsidiaries : The Olympic Tyre and Rubber Co. Pty Ltd, Beaurepaire Tyre Service Pty Ltd, Olympic Cables Pty Ltd, and Olympic General Products Pty Ltd. The group activities included manufacturing and marketing new and retreaded tyres and tubes ; batteries ; power, telecommunications, and control cables ; steel cord and fabric conveyor belting ; transmission belting ; vee-ropes and pulleys ; nylon extrusions, mouldings, and castings ; footwear soling ; thermal insulation materials, fabrications, constructions, and installations; flexible polyurethane foams; expanded polystyrene; acoustic ceiling tiles; rubber flooring; and other industrial rubber and plastic products.

The tyre company introduced many innovations to retreading methods and undertook special research during the Second World War on the application of synthetic rubbers. Olympic introduced the first Australian rubber inner tubes to be compounded with carbon black as a filler. These tubes were characteristically black and replaced the previous red rubber tubes which used a clay-type filler.

Rigid performance specifications for service aircraft in the Second World War stimulated research on aircraft tyres and enabled them to be manufactured in Australia. The techniques for custom retreading of aircraft tyres were greatly improved to ensure full use of scarce imported raw materials, and led to the manufacture of high quality retreadable tyres for major types of aircraft. In 1955 the introduction of tubeless tyres based on overseas designs at first increased the incidence of premature tyre failure caused by tread separation, but these failures were largely overcome by extensive development programmes designed to meet the more extreme service conditions in Australia. The commencement of the manufacture of radial ply tyres in Australia in 1964 was also based on overseas designs, but again adaptation was required to meet local conditions.

In 1967 Australian tyre manufacturers adopted general performance standards in line with overseas trends for passenger car tyres. With the growing number of cars having a capacity for sustained high speeds, tyres capable of running at speeds of over 100 mph were being developed and a maximum performance rating was specified for each type of tyre. In 1964 the tyre company installed an indoor dynamometer to test tyres at speeds of up to 180 mph under controlled conditions; this has helped to develop high speed tyres for production-line cars. To overcome the problems of hard stump residues which have led to frequent holding of tractor tyres during ploughing, the company developed a range of wire cord reinforced tractor tyres.

Recent developmental work has concentrated on the energy losses produced in tyres during running. This involves the testing of car and truck tyres and analysing their components, thus revealing factors which influence energy losses. The increasingly high horsepower output of modern automotive engines can then be fully utilised. Allied to this work has been the evaluation of the wet-skidding resistance of tyres by a highly-instrumented trailer technique. Through gradual development, results from these projects are providing increasingly higher levels of tyre performance.

The group pioneered the Australian manufacture of vulcanised rubber insulated cables in 1940, and extended its manufacturing operations to a wide range of cables during the Second World War. Since then many new methods of cable manufacture have been introduced for a wide range of power cables, overhead conductors, and telecommunications cables (including the first manufacture in Australia of a coaxial cable).

Important research work resulted in the development of a method of manufacturing steel cord reinforced conveyor belting on a continuous rotary vulcanising machine. This process, patented in 1967, has prompted overseas manufacturers to take up manufacturing rights.