Commonwealth Scientific and Industrial Research Organization, Australia

CSIRO Twenty-ninth Annual Report 1976/77

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This report of the work of CSIRO
for the year ending 30 June 1977 has been
prepared as required by Section 30
of the Science and Industry Research
Act 1949.

The Executive gratefully acknowledges the
valuable help received from Commonwealth and State
government departments and instrumentalities,
universities and other research bodies, represen-
tatives of primary and secondary industries,
private individuals, and overseas institutions.

The Executive also wishes to thank those who
have made their knowledge and experience freely
available to the Organization by serving on
its Committees or by personal advice.

V. D. Burgmann (*Chairman*)
N. K. Boardman
M. E. Holman
V. E. Jennings
A. E. Pierce
W. J. Vines
F. M. Wiltshire
H. W. Worner

CSIRO was established by the Science and Industry Research Act of 1949. Under the Act, CSIRO replaced the former Council for Scientific and Industrial Research established in 1926.

The powers and functions of CSIRO are:

the carrying out of scientific research in connection with Australian primary and secondary industries or any other matter referred to it by the Minister

the training of scientific research workers and the awarding of studentships

the making of grants in aid of scientific research

the recognition and support of research associations

the maintenance of the national standards of measurement

the dissemination of scientific and technical information

the publication of scientific and technical reports

liaison with other countries in matters of scientific research.

Contents

Cover

In March 1977, Interscan—Australia's proposed aircraft landing system for the next generation—was recommended for worldwide adoption by an expert evaluation committee set up by the International Civil Aviation Organization. The photograph shows the part of the system used for azimuth guidance undergoing night-time adjustments by a Department of Transport engineer.

This electronically scanned microwave aerial was designed and constructed at the DIVISION OF RADIOPHYSICS. It is located beyond the end of a runway at Melbourne Airport and has been used for flight testing the system as part of the international evaluation.

Photograph: John Masterson
David Whillas

Acknowledgment

The Executive wishes to acknowledge the assistance of Miss Heulwen M. Ridgway in writing and compiling this report.

Research

Research in brief

Introduction

The year 1976/77, which is the subject of this report has been a significant one for CSIRO. In 1976 the Organization celebrated the 50-year Jubilee of CSIRO and its predecessor CSIR; 1977 is thus the commencement of our second half-century. In the last two years more attention than usual has been devoted to reviewing the past and, more particularly, to considering the future of the Organization. The existence of a committee appointed by the Government to inquire into and advise on the role of CSIRO has heightened and assisted this approach. It would appear timely, therefore, to set out the views that I, as Chairman of the Executive, hold on the role of CSIRO and the importance of that role to the Australian community.

The work with which the Organization is most strongly identified and to which it has devoted most effort is the carrying out of scientific research, assisting in the application of the results of research and providing scientific and technological information. The full range of the powers and functions of CSIRO are described in Section 9 of our Act and are summarised on page 3 of this report. The wording reflects the intention of Parliament in 1949 that CSIRO's research should be directed to assisting primary and secondary industry.

Although research associated with industry has remained CSIRO's major objective, an increasing proportion of our work, which has been undertaken with the approval of successive Ministers, is of importance to the community in general. Examples are research into the use and management of natural resources and environmental problems.

Nowadays I think the community expects CSIRO to have this wider responsibility and hence to undertake research and development aimed at achieving identifiable national or community benefits. These benefits may be economic and industrial, as emphasised in the Act; they may be related to 'quality of life' issues such as work on land use, nutrition or smog; or they may be the more intangible kind that flow from scientific work which adds to national prestige or fulfils a national obligation such as oceanography or radio astronomy.

The benefits from Australian research or from advances in science and technology made elsewhere in the world do not flow to the community without a great deal of effort beyond that which a research organisation can provide. Advances in science and technology are often important in meeting national needs, but in many cases the benefits of such advances can only be achieved by the efforts of Government Departments as in the case of Interscan; by further research, development and investment by industry as with the self-twist spinner; or by new community attitudes being expressed by Governments in legislation as in the case of new flammability standards for certain clothing. CSIRO, of necessity, is deeply involved with the effective use of science and technology and must continue to demonstrate the feasibility of new applications and to provide technical support to those bodies responsible for achieving such applications.

In the past CSIRO has displayed foresight in identifying areas in which research should be undertaken in the national interest and has taken the necessary initiatives. It is vital to Australia that CSIRO should continue in this role and receive the necessary support. It has also developed, as a consequence of past support, a manpower resource of scientists of world class. These scientists, with wide ranging expertise in science and technology, are an important national resource. They are the source of advice which CSIRO gives on the practical needs and day-to-day problems of the nation. Nevertheless CSIRO should be seen as a research organisation and not be regarded as having the potential for regulatory or executive functions of government which are the proper role of Departments of State and other bodies established for these purposes.

I believe there are six elements essential to CSIRO fulfilling its research role successfully:

- a governing body with sufficient independence and consistency of support from Government to initiate and pursue both short- and long-term research in response to existing needs and in anticipation of future needs
- adequate lines of communication with Government and sectors of the community for the Organization to be aware at all times of national priorities and conversely for the Government and the community to be informed of CSIRO activities
- research leaders of outstanding calibre who are sensitive to national needs in the areas for which they have responsibility
- management arrangements which foster an environment in which creative and imaginative work can be done
- a broad base of expertise covering a wide spectrum of scientific disciplines and subject areas in order to be able to investigate highly complex problems and to regroup personnel and programs as needs change
- continual improvement of the means whereby knowledge gained from research is fostered and applied for the benefit of the Australian people.

Thus I see the primary role of the Organization as undertaking research to enhance the capability of Australian science and technology and encouraging applications of that capability for the benefit of the Australian community. The complexity of our society is such that a substantial resource in science and technology, of the kind that exists in CSIRO, is essential to our national development.

V. D. BURGMANN
Chairman

General

Sir Robert Price

Sir Robert Price, K.B.E., D.Phil., D.Sc., F.A.A., the Chairman of CSIRO for nearly seven years, retired on 24 March 1977. He joined the Organization in 1945 and served as a Member of the Executive from 1966.

In 1933 Sir Robert graduated B.Sc. with honours from the University of Adelaide and M.Sc. from the same University in 1935. He then left for Britain where he obtained the degree of D.Phil. from the University of Oxford in 1937. The same year, he became head of the Chemistry Section of the John Innes Horticultural Institute. During the second world war he spent four years working on propellants and explosives for the Ministry of Supply.

Returning to Australia in 1945, Sir Robert joined CSIR's DIVISION OF INDUSTRIAL CHEMISTRY. In 1960 he was appointed Officer-in-Charge of the Organic Chemistry Section and when the Section became a Division the following year, he was appointed Chief.

He was awarded a D.Sc. by the University of Adelaide in 1954, the H. G. Smith Memorial Medal of the Royal Australian Chemical Institute in 1956 and the Institute's Leighton Memorial Medal in 1959. Also in 1959 he was elected a Fellow of the Australian Academy of Science. In 1976 he was created a Knight Commander of the Order of the British Empire in recognition of his services to science and government.

Mr V. D. Bürgmann

The Commonwealth Government decided that it would not proceed with the appointment of a Chairman for the usual term to succeed Sir Robert Price,

pending the outcome of, or at least substantial progress with, the inquiry into CSIRO. In these circumstances, the Governor-General's approval was given to the appointment of Mr V. D. Burgmann, C.B.E., B.Sc., B.E., as Chairman of the Executive for a period of 12 months as from 25 March 1977.

Mr Burgmann graduated B.Sc. from the University of Sydney in 1936 and B.E. (Hons) from the same University in 1939. After a further short period with the University, he joined CSIRO's DIVISION OF RADIOPHYSICS later in 1939. With the outbreak of war, he became particularly involved in the development of radar. He spent several years first in London, then in Washington investigating developments in radar.

Returning to the Division after the war, Mr Burgmann led a team which developed navigational aids for aircraft. In 1949 he was appointed Officer-in-Charge of a new CSIRO Unit, the PHYSICS AND ENGINEERING UNIT of the WOOL TEXTILE RESEARCH LABORATORIES. When the Unit achieved Divisional status in 1959, he was appointed Chief of the new DIVISION OF TEXTILE PHYSICS.

In 1969 Mr Burgmann served as an Associate Member of the Executive and the following year was appointed a full-time Member.

He was awarded the Prize of The Institution of Engineers Australia in 1939 and the Bronze Medal of the British Institute of Navigation in 1951. In January 1977 he was created a Companion of the Order of the British Empire.

Executive and senior appointments

In March 1977, Dr N. K. Boardman was appointed a full-time Member of the Executive for a 12-month term. Dr Boardman's appointment fills a vacancy that has existed on the Executive for some time. Dr Boardman, formerly a Chief Research Scientist with the DIVISION OF PLANT INDUSTRY, has had a distinguished research career in biochemistry, biophysics and the plant sciences.

Mr V. E. Jennings, Chairman of Jennings Industries Ltd, has been re-appointed as a part-time Member of the Executive for a further three years.

In September 1976, Sir William Vines, who is Chairman of Dalgety Australia Ltd and a Director of Conzinc Riotinto of Australia Ltd, was re-appointed as a part-time Member of the Executive for a further year.

In November 1976, Dr K. A. Ferguson was appointed an Associate Member of the Executive for a period of up to 12 months. During his term of office, he is continuing as Chairman of the ANIMAL RESEARCH LABORATORIES.

Dr R. J. Millington, Chief of the DIVISION OF LAND USE RESEARCH, was appointed an Associate Member of the Executive for a period of up to 12 months as from November 1976. Mr J. J. Basinski has been appointed Acting Chief during Dr Millington's absence from the Division.

Dr J. P. Wild, Chief of the DIVISION OF RADIOPHYSICS, is serving as an Associate Member of the Executive for a period of 12 months as from March 1977. During Dr Wild's term of office, Mr H. C. Minnett has been appointed Acting Chief of the Division.

In March 1977, Dr E. F. Henzell was appointed Chief of the DIVISION OF TROPICAL CROPS AND PASTURES, following the retirement of Dr E. M. Hutton.

Dr G. N. Lance relinquished his post as Chief of the DIVISION OF COMPUTING RESEARCH in June 1977. He is succeeded by Dr P. J. Claringbold, previously Assistant Chief, who has been appointed Chief of the Division for a five-year term. During Dr Claringbold's term of office, Dr Lance is serving as an Assistant Chief.

Dr H. D. Barrs was appointed Acting Chief of the DIVISION OF IRRIGATION RESEARCH in April 1977, following the retirement of Mr E. R. Hoare.

Chemical Technology

On 8 July 1976, the AGRO-INDUSTRIAL RESEARCH UNIT was amalgamated with the DIVISION OF CHEMICAL TECHNOLOGY and is now termed the Agroindustrial Systems Program of that Division. Mr G. A. Stewart, formerly Officer-in-Charge of the Unit, became Coordinator of the Program.

Marine Biochemistry Unit

Following a review of the Marine Biochemistry Unit, the Unit was disbanded on 30 June 1977. The former Officer-in-Charge of the Unit, Dr G. F. Humphrey, was seconded to the School of Biological Sciences at the University of Sydney as a Research Associate. The other professional staff of the Unit was transferred to the DIVISION OF FISHERIES AND OCEANOGRAPHY.

Overseas liaison

Dr R. M. Moore, formerly in charge of the Woodland Ecology Group of the DIVISION OF LAND USE RESEARCH, has succeeded Dr F. G. Lennox as Minister (Scientific) in the Australian High Commission in London. He took up his appointment in October 1976.

In July 1976, Mr J. H. Whittem succeeded Dr E. G. Bowen as Counsellor (Scientific) in Washington.

Jubilee presentation

On 6 October 1976, the Prime Minister, the Rt Hon. Malcolm Fraser, C.H., M.P., unveiled a plaque presented to CSIRO by Australia's primary and secondary industries in recognition of its 50 years of scientific service to the nation. The plaque, which was designed by Gordon Andrew, is mounted in the entrance foyer at the Organization's Head Office in Canberra.

Reviewing research programs

Research programs are continuously under review in that research scientists and Chiefs of Divisions constantly reassess their programs in the light of results obtained from research, reactions and advice from various sources, and changes in the resources available.

In addition to this, regular reviews are conducted at Executive level. These reviews take three main forms:

- *Subject reviews* which are concerned with a subject area or discipline as a whole and which frequently span research activities in a number of different Divisions. In these reviews, special emphasis is given to identifying areas where research might alleviate current or anticipated problems of the next two decades. Most members of subject review committees are drawn from outside CSIRO.

- *Divisional reviews* which involve a critical examination of the relevance of the research programs of a particular Division to the industry or sector it serves and to the needs of the community. The review committee also examines such matters as research leadership and performance, finance, staff and buildings. Divisional review committees usually comprise members of the Executive, but where appropriate, specialists from outside the Organization may also be included. The Executive aims to conduct a review of each Division once every five to seven years. However, the Executive maintains contact with Divisional programs through less formal visits which take place at least every three years.

• *Pre-budget consultations.* Budgeting forms an essential part of program review procedures since the allocation of resources is an important avenue through which the Executive develops its research priorities for the Organization as a whole. Program budgets are devised so that allocations of resources are related directly to specific programs. An opportunity is provided each year for each Chief to discuss with members of the Executive at an early stage in the preparation of the budget, current research programs and proposals for expanding or contracting them, or commencing new programs.

During 1976–77 two subject reviews were initiated and the following committees established:

Wool Industry Review Committee:
Professor K. J. Whitely (Chairman), University of New South Wales; Dr R. H. Watson, Retired (Victorian Department of Agriculture); Mr V. G. Cole, GRAZCOS; Dr A. J. Farnworth, Australian Wool Corporation; Dr A. H. Hayman, BAE; Mr G. O. Cleveland, textile consultant; Mr J. W. Shepherd, stud sheep breeder;

Energy Review Committee:
Professor Emeritus H. W. Worner (Chairman), member of CSIRO Executive; Mr P. H. Barratt, Department of National Resources; Mr. J. J. Hurley, Electricity Commission of New South Wales; Mr D. G. McGarry, Australian Oil and Gas Corporation; Professor C. N. Watson-Munro, Sydney University Energy Research Centre.

In addition, reviews of the following Divisions and Units were conducted:

Applied Geomechanics, Applied Organic Chemistry, Atmospheric Physics, Cloud Physics, Environmental Mechanics, Australian Numerical Meteorology Research Centre, Irrigation Research, Plant Industry, Marine Biochemistry Unit.

The Committee reviewing the Divisions of Plant Industry and Irrigation Research consisted entirely of external members, namely:

Dr L. Fowden (Chairman) Rothamstead Experiment Station, U.K.; Professor J. S. Pate, Botany Department, University of Western Australia; Professor I. A. Watson, Botany Department, University of Sydney; Dr F. C. Butler, Deputy Director-General, New South Wales Department of Agriculture.

Two other review committees included external members in addition to members of the Executive. The external members for the Review of the Environmental Physics Research Laboratories were Professor N. H. Fletcher, University of New England, and Professor B. R. Morton, Monash University. Dr J. Nixon, Australian Mining Industry Research Association, served on the committee that reviewed the Division of Applied Geomechanics.

The Organization is indebted to the external members of these various committees for their assistance in the reviews.

Reviews were also made of two sections of the Organization's Head Office—the Central Information, Library and Editorial Section, and the Central Communication Unit.

Staff development

The staff training program has undergone considerable development during the past three years. It is now very diverse and approximately 3000 of the Organization's staff have received some form of in-house training during this period. The subject matter covered ranges from psychological and sociological aspects of management for senior and middle management staff, to basic procedural courses for clerical, technical and trades staff. When appropriate, use is also made of external training courses. Generally, however, the training program is oriented towards the particular requirements of CSIRO and consequently most training is developed and operated internally.

The Organization currently has three full-time training officers. They develop new courses to meet new needs which are arising on a continuing basis, manage residential courses, and provide advice and assistance to staff groups involved in training on a part-time basis. Self-help is a strong feature of the program and its continued success depends substantially on the cooperation and interest of Chiefs, staff and staff associations.

Staff relations

More than 25 unions and staff associations provide coverage of virtually all categories of staff employed by CSIRO. Of the total staff of the Organization, it is estimated that about three-quarters are members of one or more of these unions or associations.

Over many years, regular but separate programs of meetings and contact have developed between the Organization and five associations in particular. These are the Administrative and Clerical Officers' Association, Commonwealth Public Service; the Australian Public Service Association (Fourth Division Officers); the CSIRO Laboratory Craftsmen Association; the Association of Officers of CSIRO; and the CSIRO Technical Association. The last three of these associations are registered organisations whose membership is exclusive to CSIRO.

In 1975 the Executive proposed to these five associations that joint meetings should be convened annually to provide a wider forum for the discussion of matters of common interest to the associations. The proposal suggested that the joint meetings could be viewed as an experiment and the situation reviewed after an appropriate interval.

The first joint meeting was held in October 1975 and the second in October 1976. This latter meeting was attended by the Minister for Science, Senator the Hon. J. J. Webster. The Executive believes that the success of these meetings augurs well for the possible development of a more formal and regular joint consultative process with appropriate staff associations and unions. The Executive sees considerable merit in establishing such a consultative process and will be pursuing this objective in the coming year.

Staff ceilings and redeployment

During the year, along with Commonwealth departments and other authorities, the Organization has been required to operate within a reduced ceiling of staff funded from Appropriation sources. It was therefore necessary for the Executive to introduce a number of measures to ensure that the Organization's staff ceiling was not exceeded.

Reductions to the staff ceiling, totalling 97 since 30 June 1976, have made it increasingly difficult for the Organization to maintain the viability of all its current research programs and, at the same time, to respond to perceived needs to develop new research programs of national importance. Consequently, greater internal redeployment of staff to programs urgently in need of increased resources has been encouraged. All vacancies within the Organization are advertised internally in order to explore the availability of existing staff for redeployment. Also, Chiefs of Divisions have cooperated in promoting both inter- and intra-Divisional redeployment of staff. During the year, some 70 staff were redeployed to research programs in another Division or Unit. In addition to this, many members of staff were redeployed within Divisions.

Research

In a report of this size it is not possible to give a full account of all of CSIRO's current investigations. The items in this section have been chosen, therefore, to show something of the wide range of CSIRO's activities and their relevance to the needs of the Australian community. The items also illustrate that many research programs involve the collaboration of scientists from different disciplines and different Divisions. More comprehensive information on the Organization's current research activities can be obtained from the separate annual reports published by each Division. A brief description of the fields of research engaged in by each Division is given on pages 95–101 of this report.

Energy research in CSIRO

Research is focussed on locating new reserves of fossil fuels and ensuring that they are extracted and used efficiently and effectively; developing methods for converting coal into liquid and gaseous fuels; exploiting alternative sources of energy with the major emphasis on utilising solar energy; storing energy; conserving energy; reducing pollution arising from the extraction and use of various forms of energy.

Introduction

CSIRO has had a long-standing involvement in energy research, stemming from an awareness of national needs, an acknowledgment of the key role of energy in the economy and a recognition of the limited life expectancy of our fossil fuel reserves. Since 1948 the Organization has maintained an uninterrupted program of research into the utilisation of coal, Australia's main source of energy. The scope of the research has diversified with time, and the experience and skill obtained in coal science are now being applied over a wider field of endeavour. Research on solar energy began a few years later in 1953. The early research identified the generation of heat as the most effective way of converting the sun's energy into a usable form and led to the commercial manufacture of solar water heaters, chiefly for use in dwellings. Again, the scope of the research has diversified, particularly in the past few years in response to the need to conserve fossil fuels by developing alternative methods of energy production, especially for industrial usage.

Energy considerations have always entered into the development by CSIRO of new and improved processes and inventions for primary and secondary industry. Reduction of energy consumption is often one of the major factors determining the most economic route.

In 1973, embargoes on supplies of crude oil, coupled with substantial price increases, highlighted the political and financial implications of an increasing dependence on overseas supplies of crude oil. Since then, the Organization has informed itself on all aspects of the energy situation in order to bring the full weight of its considerable background of experience and expertise to bear on the problem of determining sources of energy and developing their potential.

The Organization maintains a close watch on outside opinions and developments, both nationally and internationally, through many channels such as CSIRO representation on outside energy committees, formal and informal contact with institutions undertaking energy research, and through regular reports from CSIRO's scientific representatives overseas.

In April 1976 the Executive decided to commission a review of the nation's needs in the realm of energy research, with a view to reassessing the Organization's objectives and identifying the areas which warranted increased support. The Energy Review Committee is discussed further in the General section of this report.

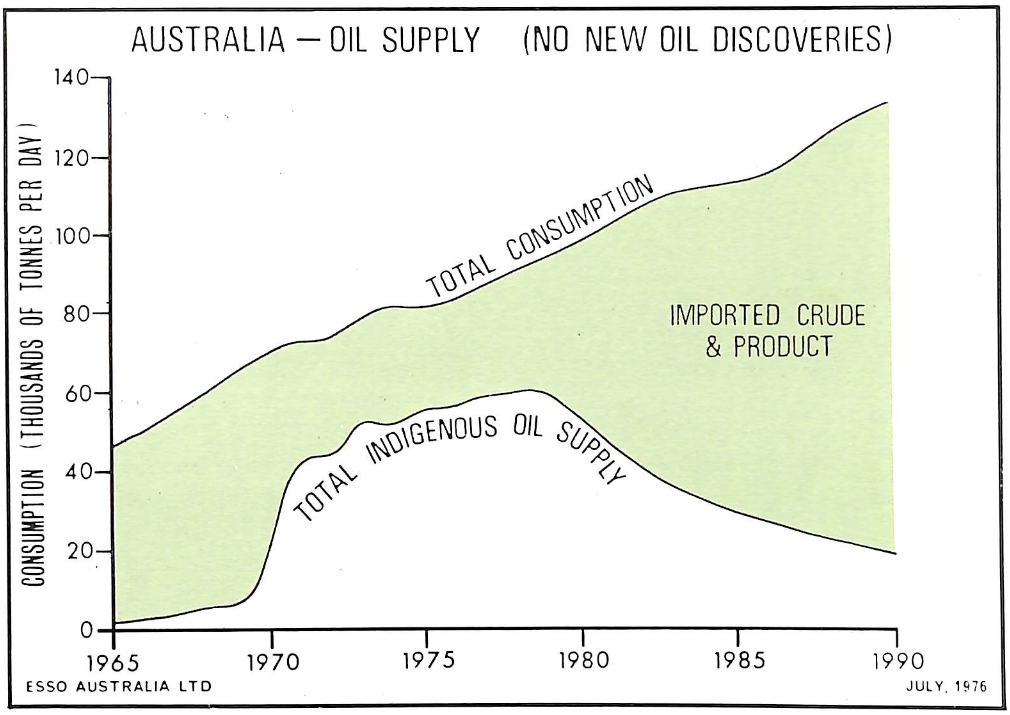
The major energy problem facing Australia today is the waning ability to supply a significant proportion of our liquid fuel requirements from our own reserves. While the nation has impressive reserves of coal and uranium, our petroleum deposits will be approaching depletion within 10 years unless new oil fields are discovered. Natural gas, although relatively plentiful, cannot be expected to last far into the next century.

At present, demands for oil are already outstripping local production by about 30%. However, our crude oils do not provide the heavy fractions which are used for industrial furnace heating and for bunker fuel. Even if Australia's production of crude oil were to increase appreciably, we would still need to import a considerable tonnage of heavy crude.

In the face of rapidly vanishing and hence increasingly expensive reserves of

This diagram indicates Australia's increasing dependence on imported crude oil and refinery product.

Reproduced from A. M. Schirrman, *Australian Energy Outlook and Policy, Implication for Petroleum Supply and Consumption (1976)* by permission of Esso Australia Ltd.



fluid fuels, energy consumption is currently increasing by about 6% each year. Using the latest figures of Australia's known petroleum reserves, it is estimated that Australian crude, which in 1975 supplied 68% of our domestic requirements, will meet only 30% of our requirements by 1985 and 5% in 2000. Spiralling costs, increasing consumption and the growing dependency on imported crude, will combine to rocket our oil import bill, which currently exceeds $700 million a year, to around $2,500 million in 1985. The upward spiral will continue relentlessly unless alternative sources of energy are brought into use.

As liquid fuels are of vital importance to industry, to our way of life and particularly to transportation which is likely to be heavily dependent on liquid fuels for many years, CSIRO is placing increasing emphasis on research relating to the exploration for and development of further oil resources, on research aimed at conserving and supplementing fossil fuels, and on establishing the technology and facilities for the production of fuels which will be effective substitutes for petroleum products. Specifically, research is being concentrated on:

- advanced techniques for prospecting for fuels,
- improved mining technology,
- the more efficient utilisation of fossil fuels,
- the conversion of coal into liquid fuels,
- utilisation of solar energy,
- the development of alternative sources of energy production,
- energy storage,
- conservation of energy, and
- control of environmental pollution resulting from the extraction or use of forms of energy.

The major aspects of this research are described in this article.

Prospecting

Although responsibility for research on fossil fuels as a source of energy is centred in the five Divisions of the MINERALS RESEARCH LABORATORIES—the DIVISIONS OF PROCESS TECHNOLOGY, MINERAL PHYSICS, MINERALOGY, MINERAL CHEMISTRY and CHEMICAL ENGINEERING—the particular expertise of the DIVISIONS OF APPLIED GEOMECHANICS, APPLIED ORGANIC CHEMISTRY and MATHEMATICS AND STATISTICS has become a feature of the program. The research is directed towards locating and assessing reserves of oil, natural gas and coal, and ensuring that they are extracted efficiently and used effectively.

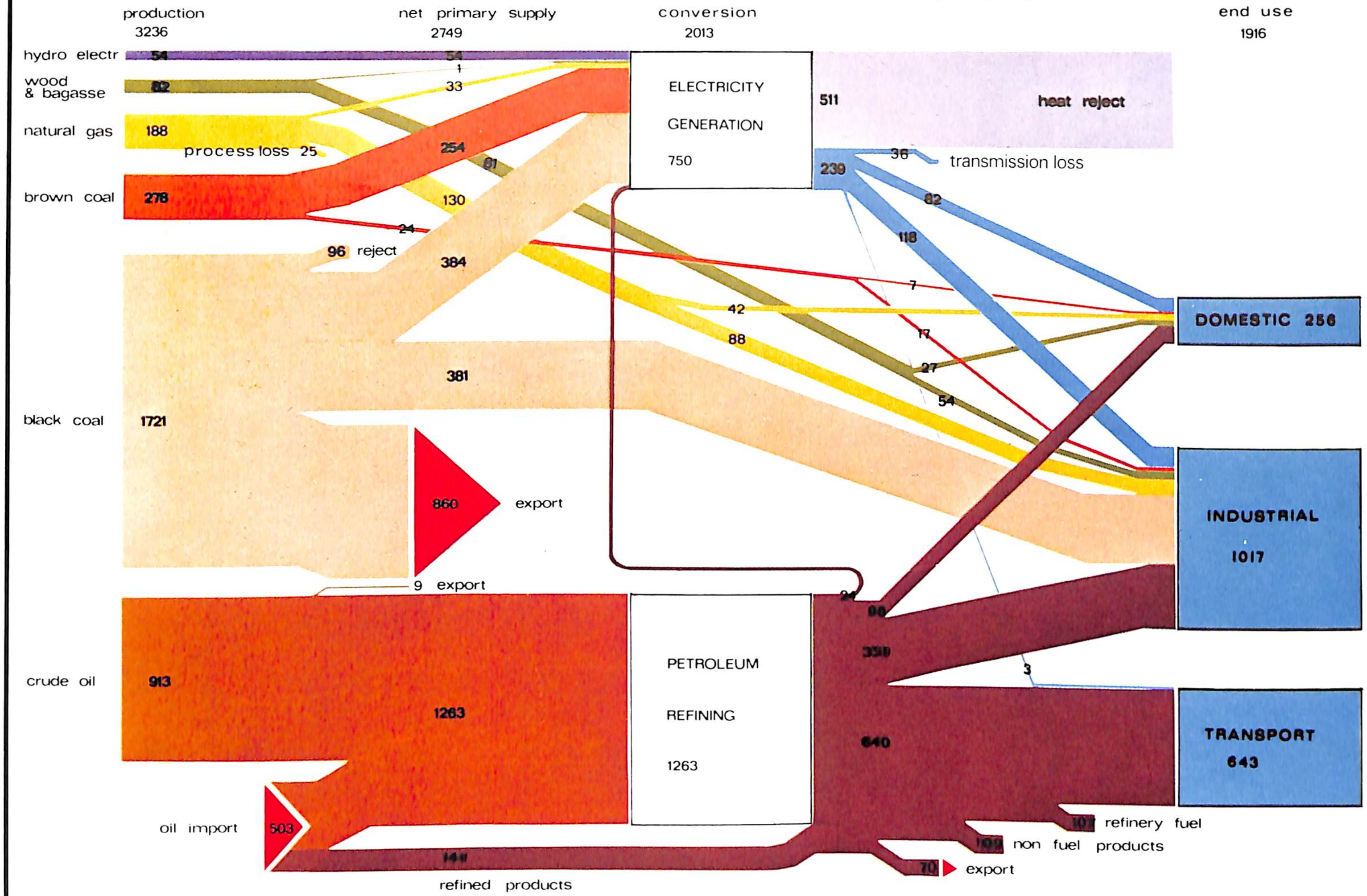
The establishment of an inventory of national resources, including fossil fuel is, of course, the responsibility of the Department of National Resources. In the field of exploration for fossil fuels, the Department's Bureau of Mineral Resources, Geology and Geophysics is making a major contribution through the publication of maps, regional memoirs, sedimentary basin studies and collation of field data from exploration companies.

As the discovery of new oil fields would give a major boost to the country's energy prospects, the DIVISION OF MINERALOGY is investigating the characteristics of Australian oil fields that could help in exploration. From an economic point of view, improved methods of prospecting are also vital—a single drill-hole can cost up to $5 million.*

Oil and natural gas are generated from solid organic material in the earth's crust. The Division is studying the way in which they are generated, and is identifying the types of organic material from which they originate.

* The Division does not undertake any drilling operations. Rock samples and much additional information are supplied by commercial companies.

ENERGY SUPPLY / DEMAND IN AUSTRALIA 1974 / 1975



The information is leading to improved guidelines for locating reserves of oil and natural gas.

The chemical components which form oil and natural gas filter up through the earth's crust when the temperature at depths is sufficiently high to release them from the rocks in which they are trapped. They migrate upwards until they reach a layer of impermeable rock and are trapped beneath it. If they are not trapped, they continue to filter upwards until they are lost to the atmosphere.

Through studies of surface rocks and rock samples obtained during drilling operations, the Division is able to estimate the amount of oil and gas-forming substances which are present in rocks and to determine whether or not the rocks have already liberated their oil and gas content. From these calculations, Divisional scientists are able to predict the depth at which the oil and gas components are being generated. The next step is to search for reservoirs of trapped oil and gas by examining the permeability of the rocks above the level of generation. Studies of surface rocks and geophysical methods often provide a good guide to the composition of strata well beneath the surface.

It is becoming increasingly clear that the alkane component of oils (alkane is the general name of chemicals of the methane series) can be degraded by bacteria, resulting in alkane-depleted oils. At Barrow Island, for instance, both alkane-rich and alkane-deficient oils are found. Gas formed by the bacteria during the breakdown process can react with dissolved calcium to form a characteristic type of calcite. The presence of this form of calcite indicates that bio-degraded oil is present or was present in the past. Even if oil is not found at a particular locality, the presence of this calcite indicates that a horizon of oil-bearing potential has been located and further investigation at this stratigraphic level may be warranted.

The DIVISION OF APPLIED GEOMECHANICS has started an investigation of the problems of the stability of offshore platforms with a view to improving safety and decreasing the cost of drilling operations. Overseas technology is not directly transferable to the Australian scene because the structures here are subjected to different patterns of wind and waves, and the seabed sediments are more calcareous than in other areas of offshore development and so offer a different degree of support to the platform piles.

MINING

As Australia is richly endowed with coal, there is no immediate problem in maintaining our self-sufficiency in solid fuels. However, it is important to increase the proportion of coal extracted from mines. In the absence

This diagram, prepared by the DIVISION OF CHEMICAL ENGINEERING, is based on data from 'Oil and Australia 1975' (Australian Institute of Petroleum Ltd), the Electricity Supply Association of Australia—Annual Report 1974/75 and 'End Use Analysis of Primary Fuels Forecast, 1971–72 to 1984–85', Petroleum Branch, Department of National Resources (formerly Department of Minerals and Energy). The energy unit used is the petajoule (10^{15} joules).

Note: The petroleum component of the industrial end use block includes 95 petajoules associated with industrial transport and shipping.

Artwork: Department of Construction

of discoveries of substantial new oil-fields—for which the prognosis is not particularly encouraging at present—it is important to investigate the potential for producing synthetic liquid fuel from coal, a process which, on a commercial scale, would require enormous amounts of coal. Also, it is necessary for the supply of coal to keep pace with the increasing demand for electricity. Moreover, Australia, as one of the world's major exporters of coal, should continue to take heed of the needs of other countries which are deficient in coal.

In general, the capital costs in underground coal mining are high and the percentage of coal extracted is low. With some techniques, as little as one-third of the coal is extracted and recovery of the remainder is virtually impossible due to high costs. Surface coal mining is more efficient and will continue to be of major importance, but, in the long term, the bulk of Australia's requirements will have to be won from underground deposits. The potential cost-benefits from underground mining research are high, and thus warrant a greater emphasis being placed in this area. The thrust of research must be to develop geological, geomechanical and mining engineering techniques that will allow safer, economic operations.

The DIVISIONS OF APPLIED GEOMECHANICS and MINERAL PHYSICS are examining ways of increasing the percentage of coal extracted and of improving safety in underground coal mines in the Sydney basin, N.S.W., and the Bowen Basin, Qld. There are several rapidly developing coalfields in both regions that offer special opportunity for innovation. Investigations may be different at each site, but it is envisaged that application of the results to other sites will be possible.

The DIVISION OF APPLIED GEOMECHANICS is developing engineering techniques which will enable potentially stable or unstable areas to be identified before mining begins, is investigating ways of recognising and controlling the outbursts that may result from a combination of stress and gas pressure and is studying the effect of different mining methods and the mining sequence and direction on operating conditions. Mathematical studies of new techniques designed to overcome the special problems of mining thick or multiple seams will be followed by field investigations. The DIVISION OF MATHEMATICS AND STATISTICS is actively participating in some aspects of this research.

At Goonyella, in the Bowen Basin, the coal seam is 10 m thick and ideally suited to an open strip mining operation. The overlying soil and rock is removed—or stripped—and dumped in spoil piles on one side of the exposed coal, leaving a high wall now exceeding 50 m in height on the other. The operating company wishes to strip to high wall heights of 120–150 m but technology for stripping to such heights has not yet been developed in Australia. The DIVISION OF APPLIED GEOMECHANICS is examining the stability of the high walls and spoil piles with a view to minimising the risk of the material in them slipping down, and subsequently endangering human life, covering the coal and interrupting production. The mechanisms of the various ways in which the high walls and spoil piles collapse are being studied so that a mining method can be developed that will allow maximum extraction of coal with a minimum loss of operating time due to failure.

The DIVISIONS OF MINERAL PHYSICS and MATHEMATICS AND STATISTICS are studying the geological factors that impair the extraction of coal. They

This photograph shows a major dome fall in a coal mine. The downward sag of the coal seam can be seen above the normal roof level. The width of the heading showing broken timber supports is 6·5 metres. The MINERALS RESEARCH LABORATORIES are studying ways of predicting such dome failures in advance of mining.

Photograph: Dr John Shepherd
Dr R. Britten (Joint Coal Board)

have shown that there is a direct link between certain types of geological faults, and roof failure. These results suggest that it may be possible to predict roof conditions ahead of the working face.

Aerial and satellite photography can assist colliery development in virgin areas. The DIVISION OF MINERAL PHYSICS has shown that fractures identified on space photography continue downwards to the level of the coal seams, and contribute to poor mining conditions.

The DIVISIONS OF MINERAL PHYSICS and APPLIED GEOMECHANICS are collaborating in a study of hazardous roof conditions which result from a combination of geological faults and underground stress. Areas of roof instability, when encountered in the past, have been responsible for the abandonment of large volumes of coal. Methods are being developed to predict where roof failure might occur so that appropriate mining techniques can be used.

LIQUID FUEL FROM COAL

Research on the conversion of coal into synthetic liquid fuels is centred at the MINERALS RESEARCH LABORATORIES and the DIVISION OF APPLIED ORGANIC CHEMISTRY. Australian coals vary widely in their characteristics, only certain coals being suitable for direct conversion to liquid fuels. Studies in the DIVISION OF MINERALOGY on the distribution and properties of different coals are providing the information needed to select for conversion suitable coals which are in sufficiently abundant supply.

Basically there are three approaches to producing liquid fuels from coal—pyrolysis, hydrogenation and gasification. Although oil can already be produced by all three methods, further studies are needed to establish technically reliable and economically viable processes that can readily be adapted to different Australian coals. These studies are based on the long background of experience in coal research mentioned earlier.

At present, CSIRO's investigations are concentrated primarily on the simplest of the three methods, pyrolysis, in which coal is heated in the absence of air. The research is focussed on a process of very rapid heating known as flash pyrolysis which shows promise of providing the heavy oils that tend to be lacking in our indigenous crude oils. Several variations to the basic concept of producing liquid fuels from the flash pyrolysis of coal are being developed overseas. Although the Organization is taking account of overseas developments, its research is aimed specifically at developing a method of flash pyrolysis suited to the low sulphur coals found in Australia and which will fulfil the particular energy requirements of this country.

Flash pyrolysis involves heating pulverised coal very rapidly in a furnace which has been pre-heated to a steady temperature. The small size of the pulverised coal particles ensures rapid penetration of the heat. The end products of the process are char, tar and gas, which can all be upgraded into liquid fuels by chemical treatment but the overall promise of the process depends on the amount of tar obtained.

Four Divisions are collaborating in the flash pyrolysis project in order to assess the potential for producing liquid fuels. Ways of using the residual char, in the first instance as a fuel for the generation of electricity and, in the longer term, to produce gaseous fuels, synthesis gas and hydrogen are also being developed. In particular, the project is aimed at determining the combinations of temperature and duration of heating that will give the greatest amount of high quality tar.

The DIVISION OF PROCESS TECHNOLOGY, assisted by the DIVISION OF MINERALOGY, is studying the pyrolysis process to determine the conditions of the reaction and the influence of the characteristics of coal which can be exploited to improve the yield of high quality tar. In general, rapid rates of heating, followed by speedy removal of the product gases and tar from the reactor, give increased amounts of tar. In certain circumstances, though, it may be desirable to sacrifice the yield somewhat in favour of obtaining a tar of lower viscosity. The physical and chemical properties of different coals vary widely and hence the response of coal to pyrolysis depends largely on the type of coal used.

The DIVISION OF CHEMICAL ENGINEERING is examining the design features of the reactors which will allow adequate heating times for the solid material, while providing for rapid removal of the liquid and gaseous products. The Division is also developing computer techniques for evaluating the merits of the various options available for pyrolysis and refining of the tar and for integrating the best options with the choices available for utilising the char.

The tars are converted into synthetic crude oil by chemical reaction with hydrogen gas, a process known as hydrogenation. The areas of interest of the DIVISION OF APPLIED ORGANIC CHEMISTRY are the study of the composition of the tars, the chemistry of the hydrogenation process and the characteristics of the product oils. The composition of the tars may influence the choice of catalyst for the hydrogenation process and probably directs the course of the reaction. The product oils are subjected to standard tests for crude oils to ensure that the synthetic oils will be adequate substitutes for the naturally occurring oils.

For the initial investigations into flash pyrolysis, scientists at the DIVISION OF PROCESS TECHNOLOGY used a small entrainment reactor in which small pieces of coal are carried along in a flow of hot gas, and a fluidised bed reactor where the pieces are suspended in a hot inert gas. The outcome of these experiments emphasised the importance of the different characteristics of coal in obtaining satisfactory results. The observations also confirmed that rapid heating combined with the small size of the pulverised coal particles significantly increases the quantity of tar obtained. For all the coals studied so far, the yield of tar reaches a maximum at temperatures of 550–600°C.

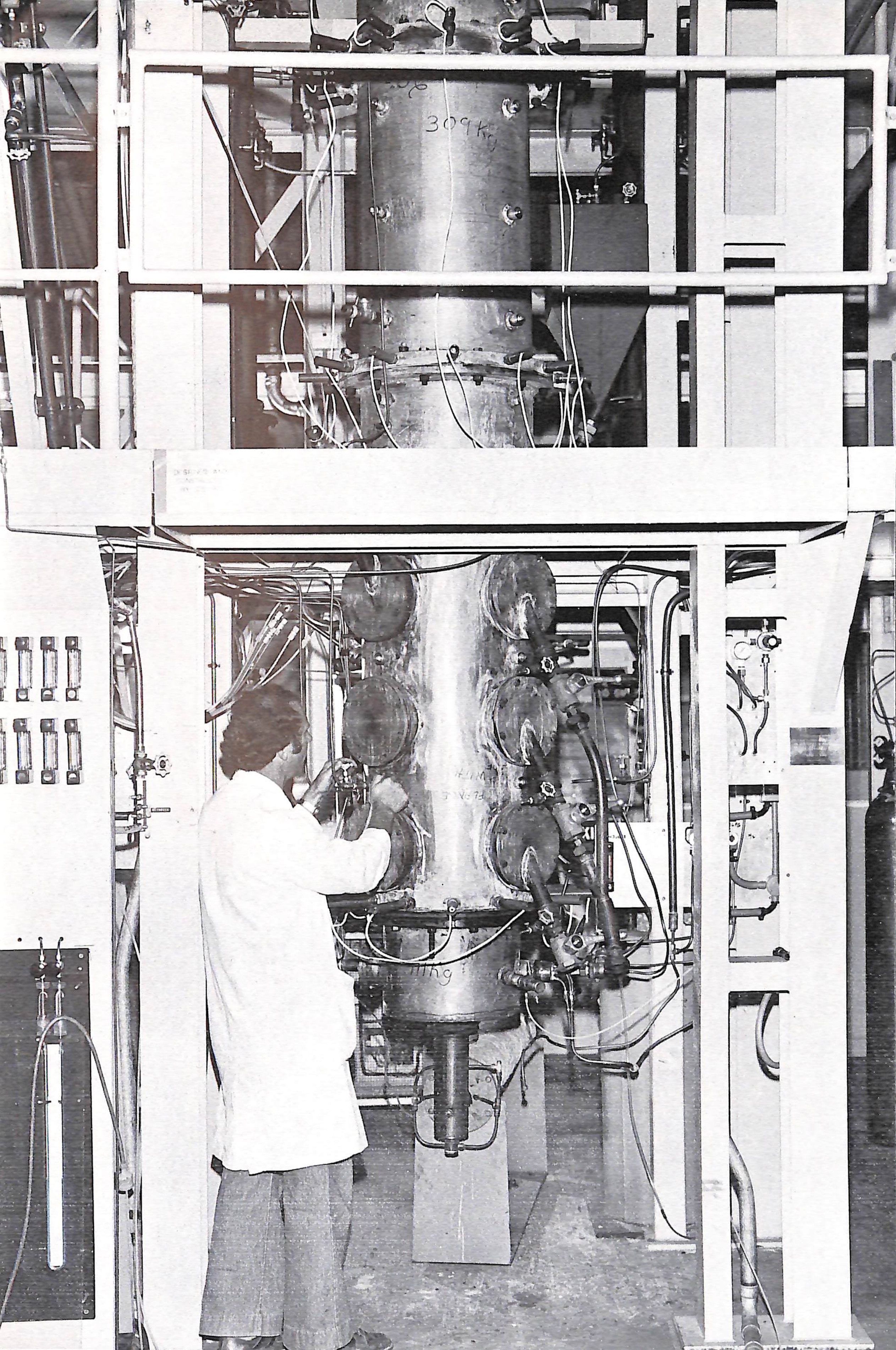
The best method of heating the pulverised coal is by bringing the particles into contact with pre-heated solid material. For instance, hot char can be used to heat the incoming particles. An important aspect of the reaction is the rather delicate balance needed to provide adequate time in the reactor to heat the coal particles thoroughly and allow decomposition of the coal, but minimal time to prevent secondary breakdown reactions from occurring.

Satisfying all these requirements presents a considerable challenge in designing a suitable reactor. Computer models of the flash pyrolysis process are helping in the evolution of design concepts.

The flash pyrolysis tars are complex in chemical make-up, but experiments have shown that they can easily be hydrogenated to produce a range of oils. The oils are low in nitrogen and sulphur, a highly desirable characteristic with respect to control of atmospheric pollution during use.

As the results obtained on a small scale were promising, a large-scale experimental pyrolysis rig with a capacity for treating 20 kilograms of coal an hour has been constructed. The rig, commissioned in February 1977, will provide information on the effect of scaling-up the pyrolysis process and offer the opportunity of testing new design features. Tar and char will also be obtained in sufficient quantities to assess their potential more fully.

The tars can then be converted into liquid fuels by hydrogenation; the DIVISION OF APPLIED ORGANIC CHEMISTRY is studying the hydrogenation stage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using a continuous reactor constructed in the Division. Tar is fed into this reactor and hydrogenated on a continuous basis, while the product oil is also removed continously. The information obtained from this reactor and a second reactor which is being assembled, will be used to design and operate a hydrogenation unit which will be incorporated in the flash pyrolysis rig. So far, the work has been carried out on tars from brown coals obtained as a by-product of an industrial carbonisation process. The technology will be adapted to black coal tars when the new experimental rig is fully operational.

In addition to the pyrolysis approach to the production of liquid fuels from coal, studies have also been initiated into the direct hydrogenation approach. In this case, the coal is heated under pressure in the presence of hydrogen, and the liquid obtained is again treated with hydrogen to convert it into synthetic crude oil. Investigations are being undertaken at present on a laboratory scale. The DIVISIONS OF MINERALOGY and PROCESS TECHNOLOGY are studying the effects that the different characteristics of coal have on the hydrogenation process. They are also investigating the physical and chemical processes that occur during hydrogenation. The DIVISION OF APPLIED ORGANIC CHEMISTRY is developing improved and cheaper catalysts for the process.

Technical scale flash pyrolysis rig at the DIVISION OF PROCESS TECHNOLOGY.

Photograph: Gordon Shrubb

The Organization's work on the conversion of coal into liquid fuels, particularly the research on flash pyrolysis, is attracting the interest of overseas research agencies such as the Energy Research and Development Administration in the United States where a massive investment is being made in coal liquefaction research. The results of the Organization's research could lead to an international exchange of information in a field of vital importance where research and development costs are extremely high.

Research aimed at using biological processes to obtain liquid fuels from living matter such as trees, plants and algae is also being undertaken and will be described in the context of solar energy research.

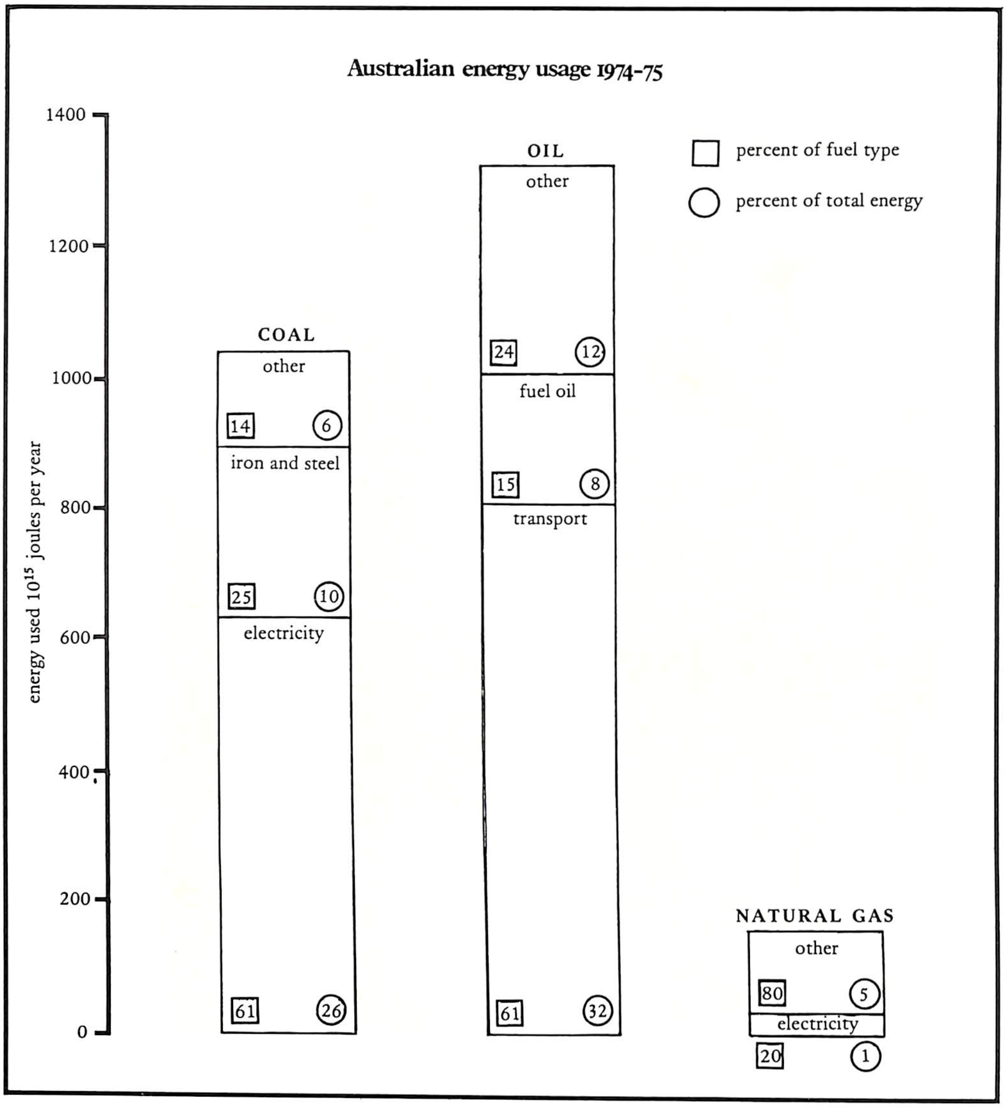
ALTERNATIVE SOURCES OF ENERGY

Crucial to the aim of conserving supplies of oil and petroleum products is the development of alternative sources of energy which are independent of fossil fuels. Australia is rich in two alternative sources—uranium and solar energy.

The Australian Atomic Energy Commission is responsible for research into all aspects of atomic energy; however, certain facets of the exploration for uranium deposits and subsequent grading into valuable and non-valuable fractions are being investigated by the MINERALS RESEARCH LABORATORIES as part of the total program of research relating to exploration and assessment of minerals.

In the short term, solar energy research in CSIRO is aimed at developing heating systems which save scarce fossil fuels, especially the oil used in domestic, commercial and industrial processes. In the longer term, research is directed towards producing fuels from solar energy sources. Research now centres on applications in industry as this is the area where large-scale use of solar heating systems could make the greatest contribution towards reducing Australia's dependence on imported oil. Solar air heaters for domestic, commercial and industrial uses are also being investigated. Other areas where solar energy could be used as an alternative to fossil fuels are being explored. Also the biological and chemical conversion of solar energy to fuels which can be stored and transported are being studied.

Solar energy research in the DIVISION OF MECHANICAL ENGINEERING spans almost a quarter of a century. The early work, carried out on a very modest scale, led to the commercial manufacture of solar water heaters for both Australian and overseas markets. A number of Divisions are now



contributing to the research effort and in 1974, the SOLAR ENERGY STUDIES UNIT was formed to assist the Executive in planning solar energy research.

The SOLAR ENERGY STUDIES UNIT undertakes feasibility studies, analyses and provides data, maintains contact with research workers in Australia and overseas, and has prepared reports in collaboration with the DIVISIONS OF CHEMICAL ENGINEERING and MECHANICAL ENGINEERING and the Capricornia Institute of Advanced Education.

The Unit has suggested a strategy for solar energy research which could enable Australia to be self-sufficient in fuel by about the turn of the century. The strategy is based on the careful utilisation of reserves of coal and natural gas, together with the development of solar energy systems for those processes where the consumption of fossil fuels is highest.

Although more oil is used for transport than for any other activity, large amounts are also used to provide heating for industrial processes. Much of this heating is at temperatures for which solar technology is already available. For example, in the food processing industry, 60% of the process heating is at temperatures below 80°C—temperatures well within the scope of solar collectors. The Unit has indicated that solar heat-generating systems, installed progressively in industry over the next two or three decades, could provide one-eighth of the estimated Australian requirements of primary energy by the end of the century. This would release large amounts of oil for use in transport.

To facilitate the transfer of the solar energy technology which is available in CSIRO to industry, a series of demonstration systems is being installed at selected factories. The first of these is now operating in a soft drink factory in Queanbeyan, N.S.W. These will provide data on capital and running costs and savings of liquid fuel, as well as building up the expertise in designing and constructing collectors which will be needed if the systems are to be used widely in industry.

One of the most effective ways of reducing the consumption of natural gas, oil and electricity is by the

Usage of coal, oil and natural gas for various purposes. This histogram was compiled from data published by a number of State and Commonwealth Government departments and from the Petroleum Information Bureau.

increasing use of solar energy for heating homes and buildings and providing hot water. Fortunately, Australian coal is plentiful enough to provide electricity for at least 100 years, so that hopefully, there is time to solve the difficult problem of using solar or nuclear power to generate electricity. Even so, electricity accounts for 13% of the total energy consumption, and the wide use of electrically boosted solar water heaters would help to minimise the rise in the consumption of electricity.

At present, the solar equipment industry is primarily oriented towards supplying hot water systems for homes, hotels and hostels, where flat-plate collectors can be used to heat water up to about 50 or 60°C. However, the long-term savings in energy could be substantially greater in industry than in domestic applications. In addition, the use of solar energy in industry would represent a major saving in oil. For these reasons, a new experimental facility was commissioned at the Organization's Highett complex during 1976 which will enable the relatively higher temperatures required in industry to be studied.

The designers of solar energy equipment need data on the amount of solar radiation available as well as other climatic data. Solar radiation is monitored at points around Australia by the DIVISIONS OF ATMOSPHERIC PHYSICS and MECHANICAL ENGINEERING, and considerable data are also available from the Bureau of Meteorology. The DIVISION OF ATMOSPHERIC PHYSICS has mapped the distribution of solar radiation over the continent and developed a method of using cloud cover observations to predict the amounts of solar radiation available at various locations. The DIVISION OF BUILDING RESEARCH has produced tables for each of the capital cities and some other localities showing the amounts of solar radiation incident on surfaces of various orientations on clear days during each month of the year.

Not all solar radiation falling on a collector actually strikes the absorber plate. The radiation must first penetrate the sheet of glass above the plate. This sheet insulates the plate and reduces losses of heat to the atmosphere. The properties of the glass and the absorber plate, together with the amount of insulation incorporated, largely determine how much of the incident radiation is utilised. The DIVISION OF MECHANICAL ENGINEERING is examining by both theoretical and experimental means, the characteristics of collectors in order to predict their performance. The measurements on prototype collectors, carried out by the Division, have been used by the SOLAR ENERGY STUDIES UNIT together with meteorological data to predict the month-by-month performance of collectors mounted directly on roofs, oriented in any direction and set at any angle.

Mainly in response to requests from industry and government departments, the DIVISION OF MECHANICAL ENGINEERING has undertaken related studies to assess the radiation properties of a wide range of materials such as curtain materials, shading films on glass, and paint and other surface coatings.

The Division is also installing a solar simulator which will enable collectors of up to two square metres in area to be tested indoors. The simulator, with an energy and light output similar to that of sunlight, will eliminate the problem of varying weather conditions and will greatly improve the effectiveness of the Division's testing and development programs.

As a result of some of the earlier work of the DIVISION OF MECHANICAL ENGINEERING, the surfaces of the collector plates of some water heaters manufactured in Australia have been specially treated since 1965 with chemicals which improve the absorption of solar heat. The Division continues to evaluate the performance of new selective surfaces. In 1974, the DIVISION OF MINERAL CHEMISTRY began a program aimed at developing better selective surfaces. A commonly used copper oxide surface, although adequate for collectors used for heating domestic water, is chemically unstable at the higher temperatures needed for industrial processes. Treatment with a suitable chromate solution has improved both the stability of the surface and the performance of the collectors. The technique is now being used commercially.

A range of electro-deposited surfaces has also been examined, especially black chrome, black nickel and the black film formed on treating zinc electrochemically. Most of the work has been concentrated on black chrome surfaces. When used on the flat-plate collectors that are currently being developed, black chrome surfaces have given better results than had been possible previously. They can be used as a surface on a wide range of materials, provided a nickel undercoat is deposited first. Development work in collaboration with industry has commenced. The black chrome surfaces appear to be stable at temperatures of up to 200°C in air, or 300°C in a vacuum. In order to use the selective surfaces at the higher temperatures, the DIVISION OF MINERAL CHEMISTRY has designed and is constructing tubular collectors in which the absorbing surface is enclosed in a vacuum.

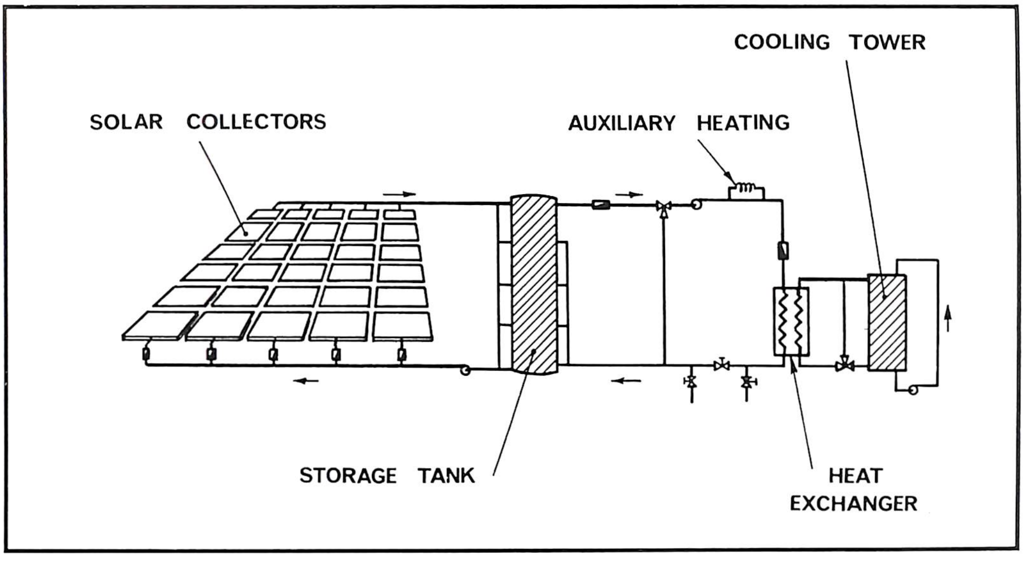
Solar water heaters have now reached the stage where a good factory-built collector, incorporating the design features developed by CSIRO, should convert into heat 45% of the annual radiation reaching it. Australian-made collectors have established an international reputation for efficiency and durability, and are being exported widely. Licence agreements have been granted for manufacturing Australian-designed collectors in Japan, New Zealand and Fiji.

The DIVISION OF MECHANICAL ENGINEERING is continuing to investigate other applications of solar energy. For instance, solar air heaters can be used to heat domestic and commercial premises, and to provide hot air for certain industrial processes such as the kiln drying of timber.

About 12 years ago, the Division installed a prototype solar air heating system combined with a rock thermal storage unit in one of its laboratory buildings. Hot air from the solar collectors can either be used immediately for space heating or ducted to the storage unit where it is used to warm the rock piles in the unit. The stored heat can be drawn off and used as required. The system provides efficient heating in winter for 100 square metres of laboratory and office space.

In summer, the rock storage unit is used to store coolness obtained from a low cost, evaporative cooling system. This combination provides efficient cooling which, although not powered by solar energy, represents a substantial saving in fossil fuels.

Recently, considerable interest has been shown by architects and building services consultants in using solar collectors for domestic space heating. Solar air heating could prove particularly economical if the solar


COOLING TOWER
SOLAR COLLECTORS
AUXILIARY HEATING
STORAGE TANK
HEAT EXCHANGER

collectors are incorporated into the building structure. The Division is constructing an experimental rig which will enable various types of solar air heaters to be built into and tested in wall and roof structures.

The investigations into using solar heated air for drying timber in pre-fabricated kilns have reached the stage where about 20 species of hard and soft woods have been dried successfully, and the Division is now able to assess the relative merits of various designs and operating techniques. This work has been carried out in collaboration with the James Cook University of North Queensland.

Above: This test facility at the DIVISION OF MECHANICAL ENGINEERING is being used to develop solar heating for industrial processes. It is a typical, industrial type of roof installation with storage and auxilliary equipment under the roof. The collectors can heat water up to 90°C.

Below: Schematic lay-out of the facility. The heat exchanger and the cooling tower on the right are used to control the heating demand.

Photograph: Neil Hamilton
Artwork: Ian Lane

The use of solar heating for swimming pools is an application which is stimulating considerable interest from the general public and also from municipal and commercial enterprises. At the Organization's Highett complex, the DIVISION OF MECHANICAL ENGINEERING is testing solar collectors and pool covers, both separately and in combination, using two small (approximately five metres diameter) swimming pools. The first pool is used as a control for obtaining reference data for any increase in temperature in the second pool. Results show that pools can be heated effectively using solar collectors combined with pool covers. A collector which is three-quarters of the area of the pool, used in conjunction with a cover, can increase the temperature of the water by up to 10°C. The number of manufacturers interested in heating pools by solar means is increasing, and it is anticipated that this form of heating will be used extensively in the future.

Since natural variations in sunlight due to locality, weather and the seasons place certain constraints on the use of solar energy, any large-scale exploitation would have to be accompanied by the development of techniques for converting it into forms—such as fuels—which can be stored and transported. Both biological and chemical methods of obtaining liquid fuels, such as ethanol, and gaseous fuels, such as methane and hydrogen, are being studied.

Ethanol, produced from cellulose, sugars or starches, which are end products of photosynthesis and can be regarded as solar energy stored in plants, could provide a replenishable liquid fuel. Ethanol can be mixed with petrol or used by itself in internal combustion engines and could therefore

CSIRO expenditure ($m) on energy research in 1976/77 (including overheads)

Solar energy		**1·27**
Fossil fuel exploration		**0·41**
Coal		
Mining	0·32	
Combustion and pollution control	0·40	
Liquefaction and gasification	1·05	
Other	0·24	
		2·01
Uranium exploration		**0·32**
Energy utilisation and conservation		
Residential/commercial	0·62	
Industrial/agricultural	0·87	
Energy from wastes	0·63	
		2·12
Other		**0·13**
		6·26

(Note: Figures have been rounded off.)

be readily phased into the existing energy economy. Carbon dioxide and water, the products of combustion, are recycled in the process of photosynthesis.

Various aspects of producing ethanol or other similar replenishable liquid fuels from crops and forests are being studied by the DIVISIONS OF PLANT INDUSTRY, FOREST RESEARCH, CHEMICAL TECHNOLOGY and TROPICAL CROPS AND PASTURES. The DIVISION OF TROPICAL CROPS AND PASTURES is examining high-yielding crops which produce large amounts of cellulose. The DIVISION OF CHEMICAL TECHNOLOGY is also examining the relative costs of obtaining fuels from different plant sources. For example, at 1974 prices it was cheaper to produce ethanol from cereal grains or sugar than from woodchips. A conflict could arise here over allocating raw materials for either the production of fuels or for use as foods.

For sufficient liquid fuels to be obtained from plantations of fuel crops, large areas of productive land would be needed. For the net gain in energy to be acceptable, energy expenditure, in the form of fertilisers and the fuel requirements of mechanical harvesting and irrigation, would have to be kept at low levels. Also, non-replenishable fertilisers, particularly phosphate, would need to be recycled. Studies could show that liquid fuels cannot be produced in sufficient quantities, or that the fuel crops would have to occupy unacceptably large areas of land. This aspect of liquid fuel production is of particular interest to the DIVISIONS OF LAND USE RESEARCH, PLANT INDUSTRY and TROPICAL CROPS AND PASTURES.

The DIVISION OF CHEMICAL TECHNOLOGY is investigating ways of converting certain agricultural wastes, such as cereal straw, into replenishable fuels. Work is in progress to improve the technology for separating plant materials into various fibrous and nutrient components with a view to producing both fuels and other useful products. For instance, methane can be produced by the bacterial fermentation of cereal straw or the residues from the leaf proteins of lucerne. The Division is also investigating the production of methane from manure.

The DIVISION OF FOOD RESEARCH and the DIVISION OF CHEMICAL ENGINEERING are also investigating the production of methane from biological wastes. For several years, the DIVISION OF FOOD RESEARCH has been investigating the feasibility of converting solid or concentrated liquid wastes from food-processing factories into methane. Yields of methane from these sources are high, and would probably be economical where factories operate the year round. Since the process also reduces the cost of treating effluent and disposing of solid wastes, it may prove of overall benefit even if the methane itself is not produced at a profit. The DIVISION OF CHEMICAL ENGINEERING is studying the conversion of brewery waste into methane and is looking in particular at the design of equipment for this purpose.

The DIVISION OF CHEMICAL TECHNOLOGY is examining the feasibility of extracting hydrocarbons and vegetable oils from particular types of algae for use as fuels or as substitutes for mineral oils. Also, under specific conditions, certain algae produce hydrogen gas. This aspect is being examined by scientists at the DIVISION OF PLANT INDUSTRY. As algae can multiply in brackish water or in sea water, these methods do not necessarily make demands on arable land or supplies of fresh water.

A basic process in photosynthesis is the splitting of water into hydrogen and oxygen, and research in the DIVISION OF PLANT INDUSTRY on photosynthesis may lead to the development of new processes for splitting water and hence of obtaining hydrogen for use as a fuel.

The DIVISION OF APPLIED ORGANIC CHEMISTRY is investigating chemical methods for obtaining hydrogen from water. The Division has developed specialised catalysts which, when immersed in water and exposed to sunlight, release hydrogen from the water. The catalysts are not altered in any way and can be recycled indefinitely. Similar methods for obtaining methane and methanol for use as fuels are also being investigated.

In a different approach, scientists at the Division have developed a number of chemical substances in which solar energy can be trapped and stored indefinitely. These substances, when exposed to sunlight, are changed in structure and the solar energy is thus 'locked' into the chemical structure. When the chemicals are heated, they revert to the original structure while the trapped energy is released for use. Once again, the chemicals can be recycled repeatedly.

An advantage of these chemical methods is that they would not encroach on arable land. Indeed, the chemical collectors could be set in areas which are presently regarded as waste land.

In a related program, the DIVISION OF MINERAL CHEMISTRY is examining the composition and use of solid catalysts in electrochemical cells. When exposed to light, the catalysts can split water to generate hydrogen. If various chemicals are added to the water, the additives can be split to generate electricity rather than hydrogen. At present, generation of electricity seems the more viable approach. If successful, this research could provide the basis for developing small-scale generation of electricity of about 5–10 kilowatts capacity for use in remote areas.

In another approach to developing alternatives to fossil fuels, the DIVISION OF MINERAL CHEMISTRY is investigating the use of battery power for cars and other traction engines. More oil is consumed in transport by road, rail and air than in industry and domestic usage combined. Consequently, with no immediate alternative to the oil-dependent internal combustion engine yet in sight, our way of life and the needs of commerce and industry stand in jeopardy.

Electric vehicles are used both in Australia and overseas but the major drawbacks are the excessive weight and low power output of the only commercially available traction battery, the lead-acid battery. As a short-term measure, the Division has collaborated with Flinders University and with industry in studying certain aspects of using lead-acid batteries for vehicles.

As a longer term solution, the Division is now beginning a program of collaborative research with Imperial College, London, to develop lighter batteries with a higher output of energy. For instance, changing from lead-acid to chemical systems of higher reactivity per unit weight may provide a superior battery.

Harnessing the energy of winds, waves and tides provides further alternative sources of power. CSIRO is not undertaking research in these areas at present but is maintaining a close watch on developments overseas and is reviewing the potential in Australia for exploiting these sources of energy.

Conserving energy, reducing pollution

Much of the Organization's work is directed towards the efficient use of resources, an approach which usually leads to conservation of energy. The energy savings resulting from more efficient methods of producing pulp for paper are discussed in the article in this report entitled 'Updating pulp and paper making.' Energy usage in mining beneficiation, melting and refining operations are being studied in the MINERALS RESEARCH LABORATORIES where new methods are being explored for decreasing the energy required in the production of aluminium and the treatment of base metal sulphides. The article entitled 'Disposing of coal washery waste' describes the way in which energy can be won from coal waste while at the same time providing a solution to a major source of environmental pollution.

Two CSIRO Divisions have been effecting novel adaptations of certain ceramics which can be employed to measure concentrations of oxygen in the products of combustion of fuels used in many types of industrial furnaces. Use of these ceramics provides a basis for reducing the consumption of fuel; it also serves to minimise the deterioration and wastage of the materials heated in the furnaces. Ceramic probes developed in the DIVISION OF TRIBOPHYSICS over the past several years have shown considerable promise during trials in a wide range of furnaces used in the metallurgical, glass-making, and mineral-processing industries. In more recent work, a technique of reaction bonding of ceramics to metals, developed collaboratively by the DIVISION OF CHEMICAL PHYSICS and Flinders University, has been adapted to the construction of ceramic sensors which provide the means of reducing the substantial losses of metal and energy which sometimes occur in furnaces employed in the production of heavy tonnage steels.

Studies directed towards reducing the energy consumed in agricultural activities have resulted in such developments as the 'reduced tillage' method of crop production. (See the article 'Cutting down on cultivation'.)

Savings in energy in commercial and industrial premises by the use of thermal insulation, new concepts in air conditioning and improved building design are discussed in the article entitled 'Comfort—at less cost'. Also, large savings in the energy consumed by large reverse-cycle air conditioning units could result from the use of a new style reverse-cycle valve developed by the DIVISION OF CHEMICAL PHYSICS. This type of air conditioning unit is being used increasingly in Australia, indeed usage is increasing at the rate of 84,000 kilowatts capacity a year. With the valves that are generally used in these units, large drops in pressure and temperature occur which result in considerable losses of energy. The new valve, in addition to substantially decreasing these energy losses, will enable central plant systems to be replaced by smaller and more reliable reverse-cycle units.

CSIRO is aware of the effects on the environment resulting from the use of various forms of energy. The ENVIRONMENTAL PHYSICS RESEARCH LABORATORIES (DIVISIONS OF ATMOSPHERIC PHYSICS, CLOUD PHYSICS, ENVIRONMENTAL MECHANICS and the AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE), PROCESS TECHNOLOGY and the LAND RESOURCES LABORATORIES (DIVISIONS OF LAND RESOURCES MANAGEMENT, LAND USE RESEARCH and SOILS) are investigating both the short- and long-term effects of the various uses of non-replenishable fuels on the environment. CSIRO also undertakes research aimed at alleviating some of the more objectionable sources of pollution. As mentioned, one such study relates to the utilisation of coal washery wastes. In another project, work at the DIVISION OF PROCESS TECHNOLOGY has led to the use of an additive to power station emissions which increases the separation of fly ash.

Selecting plants for Australian environments

Plant-collecting expeditions provide the opportunity of introducing into Australian agriculture or into plant-breeding programs, plants that are adapted to different soil and climatic conditions.

Efficient agriculture depends not only on sound management, but also on the availability of well-adapted, productive varieties of crop and pasture plants. Apart from the macadamia nut and plants harvested for food by Aborigines, Australia had no native crop plants and the first European settlers had to bring their own crop varieties with them. Many more crops were introduced during the 19th Century; many more are needed.

Realising that new crops and more productive varieties of traditional crops could be introduced, the DIVISION OF PLANT INDUSTRY established a Plant Introduction Section as one of its first research groups in the late 1920s. As well as obtaining new plants by exchange with foreign institutes and collectors, the Division sent plant explorers to Mediterranean, African and South American countries.

The search for new plants is being continued by the DIVISIONS OF PLANT INDUSTRY and HORTICULTURAL RESEARCH, and by the DIVISION OF TROPICAL CROPS AND PASTURES in association with the DIVISION OF SOILS. The DIVISION OF PLANT INDUSTRY also plays a key role as a registration centre and clearing house for introductions made by both CSIRO and the State Departments of Agriculture. For instance, over the last five years, the Division has handled over 180 introductions of temperate and tropical fruit trees and approximately 200 grapevine varieties from all over the world on behalf of the DIVISION OF HORTICULTURAL RESEARCH.

The Divisions undertake collecting expeditions for several reasons. One reason is that they are a means of obtaining new types of plants. Sometimes these are suitable for immediate agricultural use, but others are tailored by plant breeding to improve their adaptation to the local environment. Also, the diversity of plants collected allows the researchers to study those characteristics which assist plants to thrive in particular environments. If agricultural efficiency is to be increased, more scientific knowledge of the factors that contribute to production and ecological balance is needed to ensure that research is focussed on the key issues.

In recent years, the search for new plants has become a matter of urgency from another aspect. As the world population increases, vast tracts of land, particularly in tropical countries, are being cleared for agriculture. There is a danger that, as the natural vegetation is destroyed, the habitats could become so altered that varieties or even whole species could be lost. The plants affected are often the wild relatives of existing crop and forage plants, which constitute a pool of genetic material that is invaluable in breeding improved varieties, or they may be wild species which could be used as new agricultural plants. In this situation, collecting expeditions are vital if a world resource of genetic material is to be saved.

The Divisions have made a number of plant-collecting trips in the past few years. For instance, three years ago, the DIVISION OF PLANT INDUSTRY made a joint expedition to the U.S.S.R., along with the New South Wales and South Australian Departments of Agriculture, to search for pasture legumes. Early in 1977, the Division mounted a joint Australia–U.S.S.R. expedition to northern Australia in search of wild relatives of crop plants, and also made collections in south-east Asia of the winged bean and wild relatives of the soybean. The collections were made with a view to incorporating them in future plant-breeding programs in the Division.

The DIVISION OF TROPICAL CROPS AND PASTURES has built up a substantial collection of forage plants, mainly in the form of seeds, which represents an agricultural resource of world standing. For a number of species, the collections are the world's largest and the Division's contribution as part of an international network of genetic resource centres is recognised by the International Board for Plant Genetic Resources. Similarly, the DIVISION OF HORTICULTURAL RESEARCH INDUSTRY and HORTICULTURAL RESEARCH, maintains working collections of several perennial species, including a world-class collection of grapevines which is used in the Division's vine-breeding program. The Division also cooperates with State Governments in establishing and maintaining sites for testing a number of new varieties and species of fruit trees.

Studies of plants collected during recent explorations in Africa and Central and South America, together with the data gathered on soils and climates, have revealed that with many tropical plants there is a wide diversity of characteristics available within a single species. This diversity may give a wide range of tolerances not only to climatic factors but also to soil characteristics and to levels of plant nutrients in the soil. This offers the opportunity of bringing in from overseas, or of introducing into breeding programs, pasture plants that are adapted to different levels of soil fertility. Hopefully, this will mean that fertilisers can be used more effectively and pasture improvement technology modified to suit changing economic circumstances.

Plant and soils experts from the DIVISIONS OF TROPICAL CROPS AND PASTURES and SOILS work in close collaboration, collecting seeds from suitable plant varieties, taking soil samples at the collection sites and gathering as much additional information about the climate and habitat as possible. On arrival in Australia, the seeds are registered at the DIVISION OF PLANT INDUSTRY, and are then grown in quarantine glasshouses at the DIVISION OF TROPICAL CROPS AND PASTURES to ensure that they are free from seed-borne diseases. Sometimes, a few soil samples from collection sites are brought into Australia and are treated to conform with quarantine regulations before testing. Assessments of these samples help to predict where the plants will grow best in Australia. Soil data also aid studies of how plants adapt to their environment.

The seeds from the glasshouse plants are then planted out at a number of sites with different soils and climates. It is not possible to test every introduction in detailed experiments, so the DIVISION OF TROPICAL CROPS AND PASTURES uses pattern analysis to streamline the testing procedure. This is a computerised system for identifying groups of plants with similar morphological features, growth characteristics and reactions to soil and climate. From these groupings and the results of tests carried out at a few key sites, it is possible to select groups of plants warranting detailed study in particular combinations of soil and climate. At an early stage the plants are also tested to ensure that they are not toxic to stock or native animals.

Plants which show promise at this stage are then grown in small plots. The plots are retained for several years to assess the longer term merits of the plants. Legumes are planted out with grasses to discover how they compete with grass, the plots are cut from time to time to calculate yields and they are grazed by animals to estimate their ability to withstand grazing.

The most promising plants are then planted out in fields at several locations. The production of animals grazing these fields is compared with production on fields of well-tried varieties of pasture plants. If the introduction is judged at this stage to be worthwhile, its release is recommended to the appropriate State Herbage Plant Liaison Committee.

Once release is approved, this Committee is responsible for organising the multiplication of seed stocks for release to the market. Where material is promising, but no varieties suitable for release are available from the introduction program, breeding may be undertaken to adapt species to particular environments or to overcome susceptibility to disease.

In the last 50 years, more than 70 of the pasture plants introduced by CSIRO have proved to be directly useful, while many others have been used in plant-breeding programs both in CSIRO and in the State Departments of Agriculture. For example, plant introduction research in the DIVISION OF TROPICAL CROPS AND PASTURES has led to the development of perennial varieties in the legume family Stylosanthes. Although Townsville stylo, *Stylosanthes humilis*, has been an extremely useful pasture plant since the end of the last century, it has limitations. For instance, in some parts of northern Australia it has failed to compete successfully with weed grasses. Also, as an annual, it regenerates every year from seed, which gives it a slow start at the beginning of each summer growing season. New varieties of Stylosanthes such as *Stylosanthes hamata* cv. Verano (Caribbean stylo), which is a semi-perennial variety, and *Stylosanthes scabra* cv. Seca, which is a true perennial, compete with grasses better than Townsville stylo, give higher yields under dry conditions and provide better feed through the winter period. Both these cultivars have been released; Seca is still in the seed multiplication stage but some seed of Verano is available for commercial sowing.

The DIVISION OF PLANT INDUSTRY is presently using introduced plant material in a number of breeding programs. For example, lupin varieties selected in Western Australia do not perform well in the eastern States. Lines introduced from Portugal, Italy, Czechoslovakia, Bulgaria, the U.S.S.R. and West Germany, have been crossed and selected at Canberra and Wagga to produce 30–40% greater yield than the two Western Australian varieties. A phalaris cultivar to replace Sirocco, which sheds seed and is occasionally toxic, is being developed from crosses between the cultivars Sirocco, Australian and

Seedmaster and 12 Mediterranean introductions, which are sources of genes for good seed retention, low alkaloid content, persistence, more competitive seedlings and high winter yield.

With the recent invasion of Australia by both the spotted alfalfa aphid and the blue-green aphid, plant breeders in the DIVISION OF PLANT INDUSTRY are actively engaged in introducing aphid-resistant lucerne lines from the U.S.A. with the aim of developing resistant varieties adapted to Australian conditions. The possible need for such varieties was anticipated in the late 1960s, when material was introduced which has since resulted in the recent registration of the cultivar Falkiner, a variety with moderate resistance to the spotted alfalfa aphid.*

* This approach to controlling the aphids is being complemented by an active program in the DIVISION OF ENTOMOLOGY of introducing and testing biological control agents.

Cutting down on cultivation

New methods of cultivation which save time, labour and fuel are being tested for Australian agriculture.

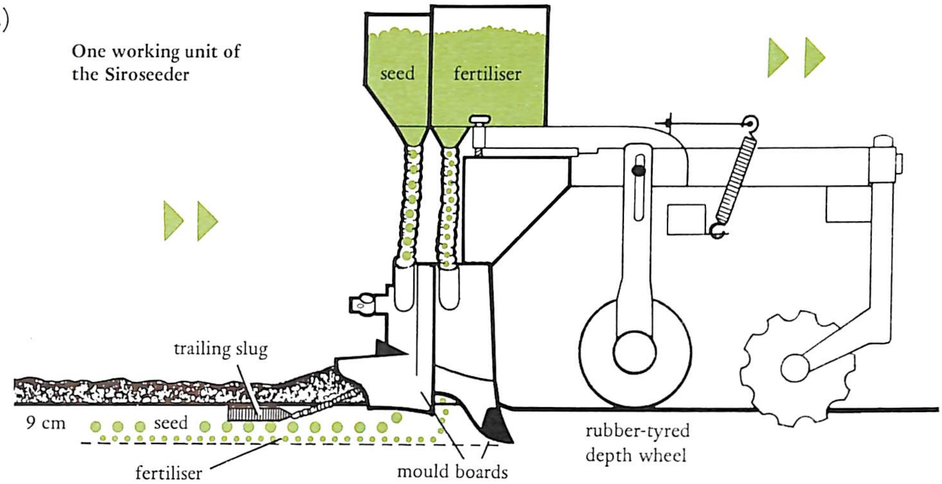
Tillage has long been regarded as an essential step in preparing the soil as a seedbed for crops since it removes weeds and provides a tilth. However, despite the increasing mechanisation of modern agriculture, seedbed tillage is becoming a major expense. In a resource-conscious world, it has also become a significant consumer of non-renewable resources: increasing mechanisation has increased the consumption of fossil fuels.

Advances in the chemistry of herbicides in recent years have provided alternatives to seedbed tillage and opened the way for new techniques for establishing crops. Primary tillage to destroy weeds can now be replaced by an application of herbicides, and further tillage can be reduced to the minimum needed to actually plant the crops and place the fertiliser. In this way, time, labour and fuel are saved and the soil is still maintained in a suitable condition. With less tillage needed, flexibility in planting times is increased, resulting in economic savings.

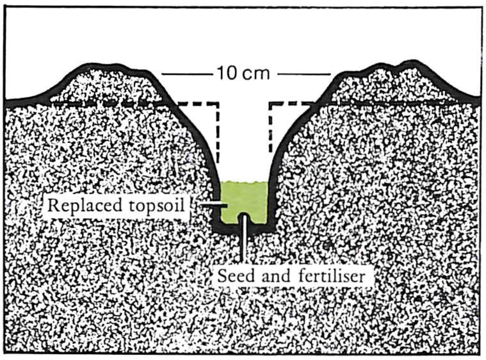
The Siroseeder for reduced tillage.

Photograph: Colin Totterdell

(a)



(b)



Diagrams: (a) one working unit of the Siroseeder; (b) cross-section of a furrow. The double mouldboards remove surface trash, and topsoil falls back into the furrow, burying the seed and fertiliser. The trailing slug consolidates this soil.

Artwork: David Marshall

The DIVISION OF PLANT INDUSTRY is investigating two techniques of reduced tillage, known as minimum tillage and zero tillage, which could be used to replace conventional methods of tillage for certain crops.

With minimum tillage, unwanted vegetation is destroyed by a primary cultivation, sometimes coupled with an application of herbicide. In contrast with conventional methods, secondary cultivation is confined to the rows where the crop will be planted, leaving the areas between rows untouched. If the implements needed for minimum tillage are linked together, the whole process of cultivation involves only a single passage of the tractor over each stretch of land. If not, a separate passage is needed for each implement.

Zero tillage confines the area of cultivation to continuous slots or 'micro-seedbeds' which are formed by a specially designed drill. Generally, a herbicide is used first to eliminate unwanted vegetation, and a single passage of the tractor and drill is then all that is needed to complete the operation.

In recent years, these techniques have been used both experimentally and commercially in a wide range of cropping systems. Generally, yields compare favourably with conventional fallow systems. Savings in fuel range between 30 and 50% for minimum tillage and vary between 50 and 80% for zero tillage. In addition, erosion caused by exposing soil to wind and water is reduced by some 10 to 15 fold in intensive cropping systems.

Reduced tillage demands new skills in the use of herbicides and implements for cultivation, as well as requiring effective machinery for sowing a wide range of crops directly. The DIVISION OF PLANT INDUSTRY has developed the Siroseeder, which is an experimental prototype of a precision drill for investigating reduced tillage under Australian conditions, and is now building a prototype suitable for commercial production.

Biological control of weeds

Biological control measures are providing effective, long-lasting methods of controlling weeds. Intensive studies in the native ranges of weeds have increased the success of recent control programs.

In Australia, many of the plant species recognised as weeds are of foreign origin, having been brought into the country either intentionally or accidentally by man. Plants that have been introduced in this way from other continents often spread out of control because they are no longer subject to attack by their natural enemies. So they crowd out useful pasture and crop plants, or otherwise affect man's interests adversely.

The best known example of a plant invasion is the spread of the prickly pear early in this century throughout some 20 million hectares of eastern Australia. The land was rendered virtually useless for any form of primary production and the Commonwealth Prickly Pear Board was established to attack the problem. The Board carried out studies in tropical America, where the cactus originated, and imported a variety of its natural enemies. One of these in particular, the moth *Cactoblastis cactorum*, brought about such an astounding change that by the early 1930s, only a few years after the moth had been established, most of the land formerly alienated by prickly pear was back in full production. So it remains to this day. *Cactoblastis* still persists in low numbers, soon attacking any local build-up of prickly pear and reducing it to a few small scattered plants.

The success of *Cactoblastis* provided a classic demonstration of the advantages of weed control by natural enemies. The research program was relatively inexpensive, no harm has ever been done to any other plant, there have been no undesirable side effects, and the advantages will apparently continue indefinitely without further input by man.

The DIVISION OF ENTOMOLOGY began research into the biological control of weeds soon after the Division was established, but early experiments did not result in sweeping successes like that of the campaign against prickly pear. It is now realised that the staggering impact of *Cactoblastis cactorum* was rather exceptional. Generally, the great advantages that are to be won from the biological control of weeds call for specialised studies of all the types of natural enemies that occur throughout the native range of the plant, and also for detailed investigations into the genetic variation and climatic tolerances of both the weed and its natural enemies.

The relative success of the Division's weed control programs has improved with time, reflecting to some extent an increasing understanding of the general principles of biological control. For instance, the Division achieved only partial success from an attempt in the late 1930s to control St John's wort, because it was not realised that the insects imported to control it were subject to climatic limitations which would seriously reduce their effectiveness in some parts of Australia.

The Division has also achieved progressively increasing levels of success in its efforts to control lantana over the past few decades. The earliest attempts, in the mid 1930s, involved importing small stocks of lacebug from a population that had been established in Fiji. These insects, which are of restricted genetic diversity, were liberated in the field onto an unstudied flora of lantana plants which is now known to be of considerable genetic complexity. Consequently, the lacebugs had little impact.

More recently, special studies by the Division and also by the Queensland Department of Lands have been carried out over a wide area of the natural range of lantana in tropical America to find insect species or strains that are adapted to the wide range of climates in which the weed grows in Australia. At the same time, the taxonomy, biochemistry and natural distribution of the many strains of *Lantana camara* have been studied. This work, in which the overseas posting of research workers has played an important part, has resulted in a collection of insects that are adapted to a variety of climatic and ecological conditions, and in many areas the weed is now receding quite markedly.

The Division's most successful biological control program has been the campaign against skeleton weed. In this work, the DIVISION OF PLANT INDUSTRY and several State Departments of Agriculture have carried out complementary studies on the taxonomy, ecology and control of the weed.

Skeleton weed is native to southern Russia and Asia Minor, but there and in neighbouring areas, it is of little consequence as a weed. On the other hand, when it gained a foothold in Australia, it spread rapidly and became a major problem to wheatgrowers in eastern Australia where losses were estimated at about $30 million a year in terms of reduced yields and the cost of control measures.

The rise of this weed as a pest in Australia was attributed to the fact that none of its natural enemies had been 'transplanted' with it, so the DIVISION OF ENTOMOLOGY began a search in Europe and the Middle East for organisms that damaged the plant. A number were found that either confined their attack to it or, at most, infested only close relatives which were of no economic significance. Several of these, in particular a rust fungus, were established in Australia. The result has been a spectacular reduction in the infestation of skeleton weed in an astonishingly short space of time. Consequently, there has also been a great reduction in the use of herbicides to control it. It has been conservatively estimated that savings of the order of $60 million have been effected over the past five years.

The skeleton weed project illustrates a number of important principles of biological control which are being employed to advantage in current programs. For instance, it demonstrates the importance of studying the many different forms of each weed, since control organisms tend to attack only certain types. Indeed, an organism may be specific to one particular form as is the case with the rust fungus that was used to combat the Australian infestation of skeleton weed. With some 40 forms of skeleton weed occurring in Russia and the Middle East, three of which are found in Australia, the rust fungus attacks only one form—the narrow-leafed form which predominated in Australia. The highly specific nature, rapid spread and impressive impact of this rust fungus illustrate the potential in this field of biological control.

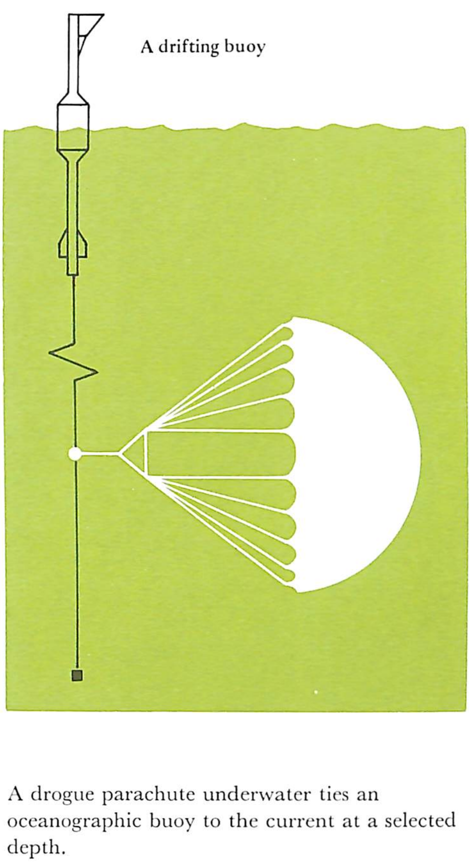
The skeleton weed campaign also illustrates the value of undertaking intensive studies in the weed's native range. Without such studies, the rust fungus that was used would probably have been dismissed out of hand as being unlikely to produce any worth while impact. Like the prickly pear campaign, the program also demonstrates the freedom from undesirable side effects that is inherent in biological control, and it is also expected to demonstrate once again the long-lasting effects of such control. True, it is only six years since the rust fungus became widespread, but in this time there has been no sign of a resurgence of the narrow-leafed form in areas where the infestation has been reduced, nor any emergence of rust-resistant forms of this variety.

The DIVISION OF ENTOMOLOGY is confident that many more successes would result from biological control among the hundreds of species of exotic weeds that infest Australia. At present, the Division is paying particular attention to aquatic weeds, several of which are becoming troublesome. Water hyacinth, *Salvinia* and alligator weed, the three which are currently giving most cause for concern, all appear to be amenable to biological control.

Studying the oceans with drifting buoys

Over the last five years the DIVISION OF FISHERIES AND OCEANOGRAPHY has developed a new tool in oceanography—a free-drifting, satellite-tracked buoy. It is a spar buoy, floats upright, and is tied to the current at a selected depth by means of an underwater drogue parachute. A solar panel is used to power the various sensors and transmitters.

The buoy program is aimed at investigating large scale circulations in the ocean, and studying the dynamics of ocean eddies and the interchange of waters between the ocean and the continental shelf. Buoys off the west coast of Australia have enabled scientists to correlate the oceanic migrations of the larval stages of the economically important western rock lobster with the circulation of the Indian Ocean (see article in this report entitled 'Weather eye on lobster larvae'). Off the east coast, buoys will provide information on the eddies and general structure of the East Australian current. This work will establish a background for investigations into pelagic fisheries, aid navigation and increase knowledge of the link between the current and weather patterns over eastern Australia.



A drogue parachute underwater ties an oceanographic buoy to the current at a selected depth.

Fifty buoys of basically the same design will be released by the Bureau of Meteorology as Australia's contribution to the first experiment of the Global Atmospheric Research Program, in which a total of 300 satellite-tracked buoys will be released between 20°S. and 65°S. in 1978–79. The DIVISIONS OF FISHERIES AND OCEANOGRAPHY and ATMOSPHERIC PHYSICS are participating in this program in an advisory capacity.

At the DIVISION OF ATMOSPHERIC PHYSICS, research workers are developing a long spar buoy to measure interactions between the sea and air up to a height of three metres above the surface of the sea.

Establishing disease-free poultry flocks

Specific Pathogen Free poultry flocks are essential for studying diseases of birds and for producing vaccines against poultry diseases.

In recent years there has been a growing demand within Australia for the establishment of Specific Pathogen Free (SPF) poultry flocks, i.e. flocks which are bred in conditions that keep them free from a specified number of those viruses, bacteria and parasites known to cause poultry diseases.

SPF poultry are essential for studying the diseases of poultry since only when other disease-producing micro-organisms are excluded can both single diseases and mixed infections be studied satisfactorily. Another important area in which SPF poultry are needed is in the production of vaccines. Many of the virus vaccines used to counter poultry diseases and the human disease, influenza, are produced by growing the viruses in fertile eggs. However, a number of poultry diseases are transmitted through the eggs. If a vaccine were produced from infected eggs there would be a grave risk of a new disease actually being introduced by vaccination. In order to minimise this risk, all poultry vaccines manufactured and used in Australia will be required by 1 January 1978 to be produced from eggs laid by SPF poultry.

Most State Departments of Agriculture, several universities, the National Biological Standards Laboratory and all the major vaccine manufacturers have already begun moves to establish or obtain access to SPF poultry flocks. The role of the DIVISION OF ANIMAL HEALTH is to build up a national reserve of SPF poultry, and to develop the tests which will be required to maintain the pathogen-free status of SPF flocks. The Division will also use its SPF flocks to study diseases of birds.

The Division's first SPF flock was established in 1973 from birds obtained from the School of Veterinary Science at the University of Melbourne and housed in small isolation buildings at its Maribyrnong field station. In April 1977 the Division's new SPF poultry building at Maribyrnong was commissioned. It will house 36 Multibird Isolator units made of moulded fibreglass, each of which will be able to accommodate a small flock of about 12 hens and one or two roosters.

The isolators are supplied with sterile air, and food and water are specially treated to reduce the risk of introducing disease. Staff has no direct contact with the birds, except through gloves which are permanently fixed to the gloveports of the isolators. To avoid the possibility of introducing disease into the SPF Unit, no research directly involving the use of any micro-organism responsible for an avian disease is being carried out at Maribyrnong.

Birds are hatched in isolation and transferred to the isolators when they are one day old. Fertile eggs, produced by natural mating of birds in the isolators, will be available to other institutions to enable them to establish their own SPF flocks. Some of the fertile eggs are also dispatched to the Division's Parkville laboratory where they are used for research on avian diseases.

The SPF flocks are monitored continuously by the SPF Unit's staff at Maribyrnong, and at Parkville facilities have been established for rapidly diagnosing 14 avian diseases, including all the major avian pathogens known to exist in Australia. Methods of detecting two of these pathogens, reovirus and bursal disease virus, in the blood of poultry have recently been developed at the Division and have been integrated into the regular test program. Research is also being undertaken to improve existing tests and to develop tests for micro-organisms such as the reticuloendotheliosis virus for which there is no reliable test available.

Other future programs include developing new strains of SPF poultry, particularly those that will have higher productivity and longevity under SPF conditions.

Keeping a watch on range condition

Australia's arid lands have been grazed for over a hundred years but until recently, pastoralists and land administrators have had no way of judging how the land is reacting to the pressures of grazing unless severe deterioration and erosion make it obvious. Once severe effects become apparent, remedial management is both difficult and costly. The DIVISION OF LAND RESOURCES MANAGEMENT has been seeking an early warning system that will allow deterioration to be identified before the more serious and possibly irreversible impact of erosion sets in. Such a system would enable land-management strategies to be modified accordingly.

Researchers at the Division have introduced from America the concepts of rangeland 'condition' (the state of health of an area of land) and 'trend' (whether the land is improving, remaining stable or deteriorating). Management policies aimed at maintaining or improving the long-term productivity of rangelands must be based on the condition and trend of the land resources, rather than on the condition of stock or short-term profitability.

Range condition—like health—involves many factors and is therefore difficult to assess absolutely. After some years of careful experimentation under Australian conditions, the Division has endorsed the conclusion of United States scientists working under American conditions that the best way of spotting changes brought about by grazing is by monitoring changes from the original botanical composition of an area. Monitoring nearby tracts of similar, but ungrazed, land ensures that changes in the vegetation due to the vagaries of the climate are excluded.

The Division, in collaboration with the Department of the Northern Territory, has adapted the method to suit the particular needs of central Australia. The method is simple, rapid and repeatable and can be used regardless of the prevailing climatic conditions. In western New South Wales, the N.S.W. Conservation Service Range Assessment Committee is also adapting the method for use.

Weather eye on lobster larvae

Studies of the movements and behaviour of the western rock lobster larvae are part of a collaborative project aimed at stabilising the rock lobster industry.

The western rock lobster industry is mainly an export industry, with exports valued at $32 million annually. Large fluctuations occur from time to time in the numbers of lobsters available. Possible causes of these fluctuations could be excessive exploitation of the breeding stock or variations in the numbers of larvae returning to the coast after drifting for nine to eleven months in the Indian Ocean.

The DIVISION OF FISHERIES & OCEANOGRAPHY is collaborating with the Western Australian Department of Fisheries and Wildlife in a program of research aimed at determining the cause of the yearly fluctuations, with a view to stabilising the rock lobster population and hence the rock lobster industry. The Division is studying the larval and juvenile stages while the Department of Fisheries and Wildlife is investigating the later stages of development. The Western Australian Museum has also assisted with the project.

Over the last four years, the Division has used a chartered ship, the 43-metre research vessel *Sprightly*, to investigate the oceanic phase of larval development. The seagoing phase of the investigations was completed in January 1977, but the biological and water movement data are still being analysed and correlated.

Earlier research showed that the larvae, at this stage called phyllosoma, hatch mainly in November, December and January from eggs held under the female's tail. This occurs on the continental shelf. The phyllosoma concentrate in the upper layers of water and are carried offshore. The main objective of the Division's recent investigations was to determine the movements and behaviour of the phyllosoma, with a view to understanding the environmental and biological factors necessary for their successful return to the coast.

During their oceanic journey, the phyllosoma larvae go through a large number of moults and at least nine identifiable stages. During the first stage, the larvae are less than two millimetres in length and, because they are almost transparent, are only just visible to the human eye; by the last stage they are about 35 millimetres long. On returning to the coastal region, the phyllosoma then moult into another almost transparent stage, the puerulus, which secretes itself in the inshore weedbed nursery areas; this is the first stage at which the larvae resemble the adult lobster.

The phyllosoma larvae were followed by the *Sprightly* to a distance of 1500 kilometres west of Perth. They were found to make daily vertical migrations, rising towards the surface of the water at night and then descending again during the day. Since layers of oceanic water at different depths move in different directions, and since the larvae are found at different depths depending on the time of day, a detailed study of these migrations was essential if the larvae were to be tracked.

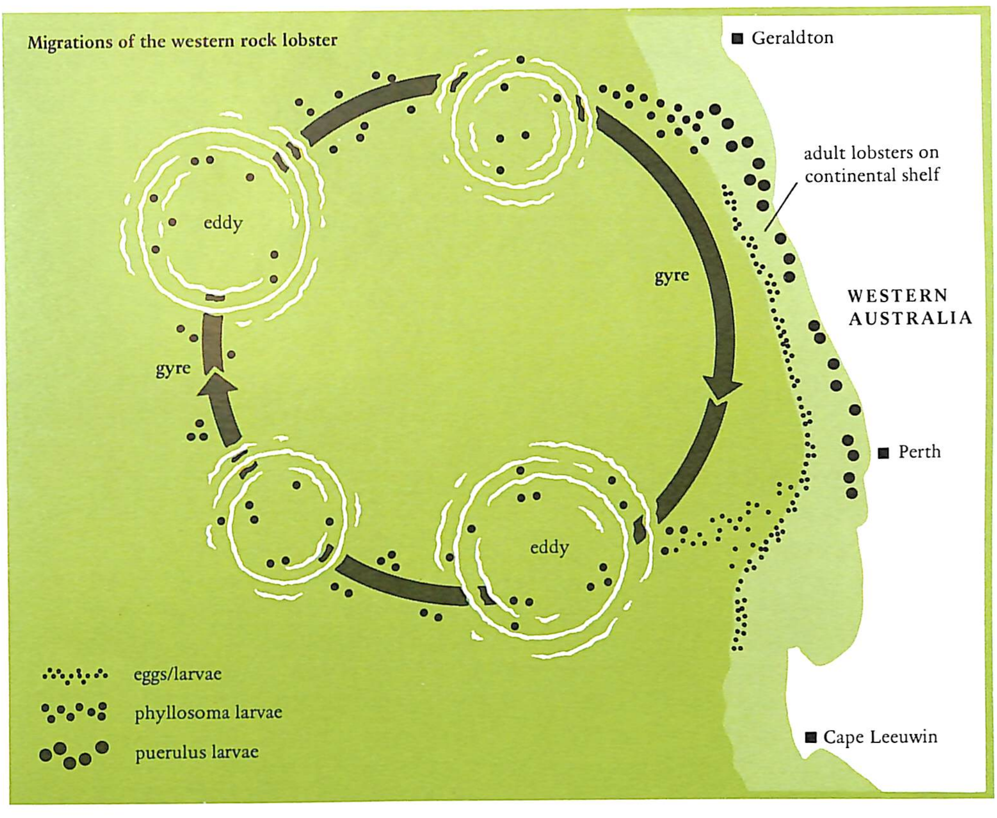
Light appears to be a key factor in these migrations. The newly hatched larvae appear less sensitive to light than later larval stages and are usually found within the upper 50 metres of water. At night they rise to the surface, regardless of the intensity of the moonlight. In rough weather they are unable to concentrate at the surface at night as the turbulence causes mixing of the upper layers of water and the larvae become randomly distributed through the mixed water. However, the later stages, seeking lower levels of illumination, are usually found at depths of 100 to 200 metres during daylight; on moonlit nights they avoid the surface. They can swim strongly enough to overcome the effects of turbulence and attain the desired depth despite the weather.

The mechanism by which the larvae return to the coast has been a puzzle for many years, but recent oceanographic studies by the Division suggest that the eastern Indian Ocean is dominated by an

A large clockwise gyre of water in the Indian Ocean sweeps newly hatched larvae out to sea and returns them to the edge of the continental shelf about 10 months later. They metamorphose into puerulus larvae and swim inshore where they develop for four to six years. The adults migrate back to the edge of the shelf, the females lay eggs and the cycle is repeated.

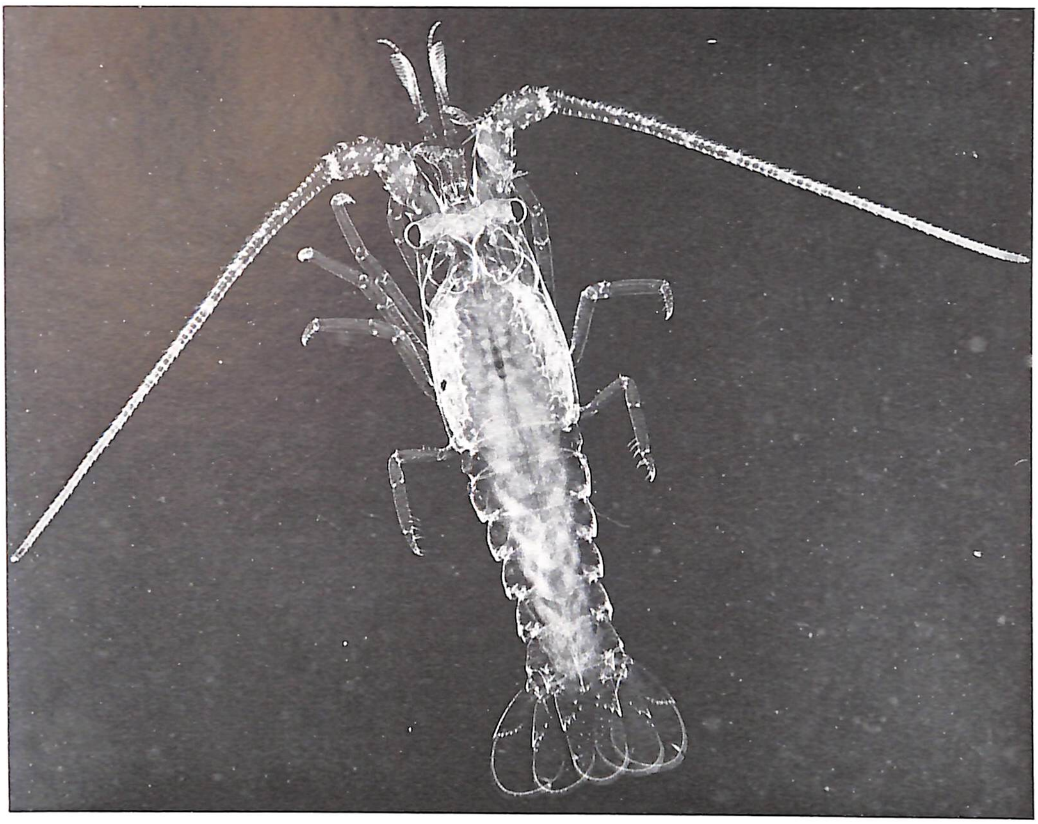
The photograph (opposite) shows a puerulus larva. At this stage, the larvae resemble the adult lobsters.

Artwork: David Marshall
Photograph: A. C. Heron



immense clockwise movement of water—a gyre—about 1000 kilometres across, with its centre some 500 kilometres west of Perth. This picture is confused somewhat by smaller scale movements of water. Many small eddies occur, and at the outer edges of the gyre, water 'peels off' and is lost from the main circulation. Oceanic waters also frequently mix with the waters along the outer portion of the continental shelf, while nearer to the shore, the waters mainly run along the shelf, parallel to the coast.

Within this framework of moving waters, the larvae are carried first southward down the coast of Western Australia, then westward out into the oceanic waters. Many are also swept out beyond the gyre and are probably lost in the oceanic waters. Some 10 months later, the late stage phyllosoma in the gyre are carried back towards the edge of the continental shelf where they undergo metamorphosis into the last larval stage, the puerulus. The puerulus are able to swim fast, and complete their oceanic odyssey by swimming perhaps 40 kilometres across the currents to the shelter of the shallow reef areas close to the shore. There they remain and grow for a further four to six years before migrating to the outer areas of the continental shelf, thus entering the commercial fishing waters.



Immunising sheep against worms

The development of vaccines to immunise sheep against worm infections could offer an improved method of worm control.

Worm infections in sheep can seriously reduce wool production or even cause heavy mortality. Young sheep are particularly at risk as they are far more susceptible to infection than older sheep. Drenching with anthelmintic drugs has been the normal method of worm control but frequent use of the more effective drenches is now giving rise to drug-resistant worms. This is a serious development, particularly since resistance to a single drug produces cross-resistance to other anthelmintic drugs, and emphasises the need for alternative methods of worm control.

Some years ago, the DIVISION OF ANIMAL HEALTH found that mature sheep, which graze on worm-infested pastures and survive the initial infection, gain a natural immunity to further infection. This phenomenon, the 'self cure' phenomenon, can be used to immunise lambs provided various techniques of pasture management are used to keep the numbers of worms at a low level. In this way, the young animals are exposed only to limited numbers of infected larvae so that they gain immunity without losses in productivity.

Following studies on the 'self cure' phenomenon, the Division intensified its research into the mechanisms associated with the development of immunity to worm infections. Immunologists in the Division discovered that the complex mechanism of immunity involves two separate components. By combining this finding with the knowledge gained from the 'self cure' work, an alternative approach of immunising sheep by vaccination emerged. The development of vaccines could provide not only a superior means of worm control, but also a cheaper and less labour intensive method than chemical drenching.

Initial attempts to immunise animals with purified worm extracts were unsuccessful, but a later method using live worm larvae whose virulence has been reduced by exposure to gamma radiation is giving encouraging results. Field and pen trials showed that almost all sheep older than six months respond to a vaccine of irradiated larvae of the black scour worm, *Trichostrongylus colubriformis*, but if they are dosed at under six months only about half respond. There is some evidence that the age at which the animals respond is inherited and genetic studies are now in progress with the objective of breeding sheep that respond immunologically at an earlier age.

In a recent experiment, sheep were vaccinated with live irradiated larvae of the black scour worm. When groups of these sheep were then exposed to infection separately with either the same species, a related species or an unrelated species, it was found that there was good protection against the same species, some protection against the related species, but no cross-protection against the unrelated species. However, in a further experiment, vaccinated sheep were exposed to infection simultaneously with the same species, a related species and an unrelated species. It was then found that there was total protection against both the vaccine species and the related species. Surprisingly, the protection against the unrelated species was also 100%. This is a most important finding because, under field conditions, animals are exposed to mixed rather than pure infections.

The results of these experiments can be explained in the light of the two components of the immune response, known as the specific and non-specific components. When a vaccinated sheep is later challenged with the same species, in this case black scour worm larvae, the specific component is activated and the immune response is triggered. However, the final rejection of the infection involves the non-specific component, resulting in a total rejection of, and hence immunity to, not only related, but also unrelated species.

These findings have encouraged further investigations to determine whether a relatively harmless parasite, *Cysticercus tenuicollis*, which migrates from the bowel into the liver and other tissues, could be used to give protection against the liver fluke, *Fasciola hepatica*. The liver fluke is an unrelated species which is of great economic importance because it causes extensive losses in production as a result of damage to the liver.

Marketing wool in larger lines

A series of trials is in progress to demonstrate a method which enables wool to be marketed in larger lines by grouping together wools of similar fineness.

In traditional classing procedures, a wool classer sorts wool into lines—a line being a group of bales of the same kind of wool intended to be sold as one lot. Fineness, length, colour, handle, presence of vegetable matter and so forth are taken into account. The wool classer has customarily referred to the fineness of wool by a series of 'quality numbers' ranging from 80's and above for the very finest wool down to 40's and below for coarser wool. 64's is a typical quality number for Merino wool. In classing, the assessment of the fineness of the wool is made by considering the crimp frequency and handle of the wool and not by fibre diameter as such. However, these two factors are related to fibre diameter.

A classer would normally class, for example, 64's, 60's and 58's as separate lines. In recent years, evidence has been accumulated that Australian wools are often overclassed and that classing of 64's, 60's and 58's, into separate lines is not warranted by differences in processing performance. A system which enables marketing of larger lines would have beneficial effects in both the buying and selling of the wool. Such a system is that known as Objective Clip Preparation (OCP) which was introduced in 1972 as a result of cooperation between a number of organisations including CSIRO.

OCP is a classing method which allows the wool classer to group together three adjacent quality numbers instead of creating three lines. For example, the 64's, 60's and 58's referred to above would now constitute one line instead of three. Thus OCP assists the classer to increase the size of lines. One requirement of OCP is that the wool is all from the same mob of sheep, that is, the sheep have a common background of breeding and have run together under similar conditions since the previous shearing. The standards of presentation, for instance skirting or separation of inferior wool around a shorn fleece, are identical with those for traditional classing. The Australian Wool Corporation's (AWC) classing standards were revised in 1972 to permit the use of OCP at the wool grower's discretion.

At present about 6% of the Australian clip is prepared by OCP and it is a feature of OCP that wool classed in this way must be offered for sale with a pre-sale test certificate showing the objectively measured fineness, yield and vegetable matter content.

From the point of view of wool buyers and wool processors, both in Australia and overseas, OCP represents a considerable departure from what has been traditionally considered as 'best practice'. In order to foster confidence in wools classed by OCP, a project commenced in 1974 and is now coming to fruition for a worldwide series of multiple purpose trials to collect independent experimental results on OCP wools and to make these known as widely as possible to the wool trade.

The project was initiated jointly by the AWC and CSIRO, and involves the DIVISION OF TEXTILE INDUSTRY at Geelong and overseas collaborators based in Belgium, Germany, Poland, Japan and England. The objective of the trials is to enable key overseas wool centres to become familiar with the details of OCP, the reasons for its introduction and the results arising from its use.

The DIVISION OF TEXTILE PHYSICS at Ryde is the coordinating centre for the project. Wools are selected, tested and dispatched from Ryde, and the results ultimately collected there for analysis.

The results obtained show that there are no drawbacks attributable to OCP, the extent of processing losses and the properties of the top and yarn being the same as those from traditionally prepared lines.

Mechanised tree pruning

The costly and hazardous procedure of pruning trees by hand to obtain knot-free timber is now being mechanised.

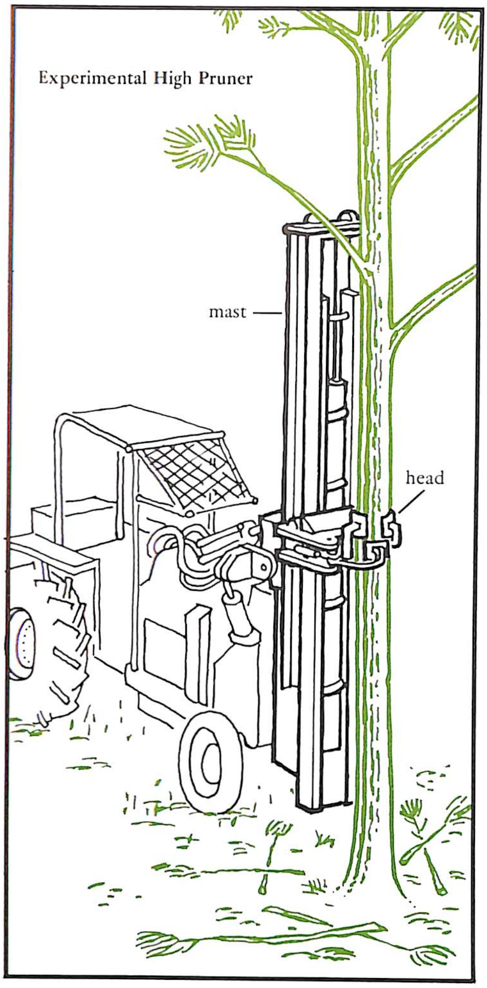
Knots occur in wood wherever the branch of a tree joins the trunk. Both the structure and visual appearance of wood are affected by the presence of knots. In particular, knots caused by the inclusion of dead or decayed wood in the growing stem reduce the value of plantation stands of timber. Such knots tend to chip or drop out when the timber is being finished, and also spoil the finish of many types of furniture. In plywood, knots may drop out or cause imperfections to the surface finish, so a veneer of clear wood is often sought for the surface layer. In addition, the presence of knots prevents the even distribution of stress along a section of timber.

However, if the branches are pruned close to the trunk, wood which grows beyond the stumps of the branches as the tree grows in diameter is knot-free. The closer the branch is pruned to the trunk, and consequently the shorter the stump, the greater the yield of knot-free timber.

Until now, the only way to obtain knot-free timber has been to prune by hand, a procedure which is very labour intensive and often dangerous. Consequently, only the most productive softwood plantations are pruned, and indeed many of the trees in these plantations are only low-pruned, since the cost increases with height. The need for mechanised high pruning has been apparent for some time. Current developments in silviculture, which not only increase the yield of timber per tree but also increase the size of branches and hence of knots, are expected to increase this need.

The mechanised high pruning device enables trees to be pruned to a selected height. As the pruning head, bearing an array of knives, moves up the mast, branches are pruned flush with the trunk.

Artwork: David Marshall



For the purpose of determining the technical feasibility of mechanising this operation, scientists at the DIVISION OF FOREST RESEARCH in association with the engineering firm R. L. Windsor and Son, designed and built a prototype mechanised high pruning device that prunes branches flush with the trunk. The device is mounted on a tractor and consists of a pruning head bearing an array of six knives, which is attached to a vertical mast. The mast is carried on a pivotal mounting and aligned with the tree trunk by means of a pair of hydraulic cylinders. The knives in the head are kept in close contact with the trunk and the branches are pruned as the head is moved up the mast.

Field tests run in conjunction with the Queensland Department of Forestry in plantations of a softwood species, *Pinus elliottii*, were extremely encouraging. Pruning to a height of six metres, the machine averaged between 57 and 88 trees per hour, the rate varying with the condition of the ground.

The machine is now being manufactured commercially and should be in use before the end of 1977. The Division is also adapting it for pruning other species of pine, including *P. pinaster* and *P. radiata*. Although the stem and branch structure of *P. radiata* make it more difficult to prune than *P. elliottii*, initial attempts have been promising.

Updating pulp and paper making

Two new techniques for obtaining pulp for paper making are being developed.

The Organization's interest in pulp and paper research dates back 50 years to the inception of CSIR, the predecessor of CSIRO. During this time the Organization has helped to adapt existing pulping and paper making processes to Australian hardwoods. However, some of the conventional methods of pulping do not make the best use of the raw material, are time consuming and are a source of industrial pollution. Also, certain high-yield processes consume large quantities of energy. Worldwide increases in the demand for paper and paper products are placing an increasing strain on forest resources, highlighting the need for pulping processes that make efficient use of the available resources.

The DIVISION OF CHEMICAL TECHNOLOGY is undertaking research aimed at developing methods of obtaining pulp from new or recycled material that will be more efficient, less polluting and consume less energy than conventional processes.

Basically, the whole process of pulping and paper making involves isolating the fibrous components of wood or other plant material and reconstituting them into sheets. The art of paper making was developed in China in about 105 A.D. but wood pulping was not introduced until the 19th Century, when mechanical grinding (the groundwood process) and three chemical processes (soda, sulphite and kraft) were developed.

Methods using mainly chemical energy, such as the widely used kraft process, separate the fibres by removing lignin, a substance which binds wood fibres. The quality of such pulps is good, but the yield is poor. These methods are also slow, require high temperatures and pressures, and can be a considerable source of polluting effluent unless expensive control measures are adopted. Purely mechanical methods do not remove the lignin and although yields are high, the quality of the pulp suffers, particularly in the strength of the wet sheet and final paper.

In thermomechanical pulping, which is still only a few years old, the lignin softens above a certain transition temperature and enables the fibres to be separated more easily. Consideration of the factors influencing the transition point suggested that chemicals could be used to lower the transition temperature so that the fibres could be separated without excessive consumption of heat and so that separation of the microfibrils within the fibres, essential for developing strength, would occur.

This line of thought has led to a study in the Division of a new technique, chemithermomechanical pulping (CTMP), which uses a combination of all three forms of energy. Conventional pulping equipment is used, and the process consists essentially of soaking woodchips in a solution containing sodium hydroxide and sodium sulphite, steaming the chips at atmospheric pressure, then mechanically separating the fibres at 100°C. A further mechanical step completes the process. Soaking the chips in a mixture of sodium hydroxide and sodium sulphite gives better results than either chemical used alone.

CTMP operates at lower temperatures and pressures than chemical processes. It also uses less chemical, is faster and cheaper, needs less pollution control and produces higher yields of pulp. In comparison with conventional mechanical methods, the paper is stronger and more suitable for printing. The product could be used as a partial replacement for the expensive kraft component of newsprint which is added mainly for strength. It may also be useful as a component of writing papers, packaging papers and tissues. The process is suitable for plantation-grown timber, or young wood such as thinnings and regrowth. The method has produced promising results with young eucalypts in which the lower density of wood allows ready penetration of chemicals. Industrial trials are now in progress to test the process on a larger scale.

In contrast with existing techniques, the DIVISION OF CHEMICAL TECHNOLOGY has also developed a new method for obtaining pulp. It is a versatile unit operation which shows promise of greater efficiency in pulping new wood, and particularly in reclaiming waste paper and paper products. In this process, the raw material is heated with standard chemicals at high pressure. Rapid release of pressure by means of a special valve which can open in milliseconds, discharges the contents of the pressure vessel down a specially designed nozzle at a speed approaching sonic velocities. Defibration is achieved as the softened raw material is propelled down the length of the nozzle.

The method is a considerable departure from traditional methods. As a result of the pressure, heating times can be cut from about three hours to around 10 minutes, also chemicals penetrate faster, reducing the amounts required. In addition, less fibre damage occurs and the quality of the pulp is enhanced. Carbon dioxide and nitrogen have been used to pressurise the reaction vessel, but it is envisaged that on a larger scale, flue gas could be used, further increasing the economy of the operation. On a small scale, synthetic flue gas has given good results.

Experiments so far indicate that yields for conventional raw materials would be at least as good as those obtained by the standard chemical methods. In addition, this method of defibration offers the advantage of being applicable to a range of raw materials which cannot be satisfactorily pulped along conventional lines. For instance, many fast-growing plants with a high pith content, such as kenaf and various agricultural crops, cannot normally be used for paper making as the pith cells collapse, become enmeshed in the fibres and prevent the pulp from draining. In the defibration process, these cells disintegrate and can be washed away. By producing useful pulp from some agricultural wastes and short-rotation crops such as wheat straw, sugar cane bagasse or kenaf, the demands on our already overtaxed forest resources could be moderated. At the other end of the scale, even exceptionally hard woods can be pulped readily.

By controlling the conditions of discharge, the process can be used to separate fibres of different thicknesses. This offers the opportunity of separating fibres suited to different end uses. Also, bark, leaves and dirt can be separated from twigs, branches and roots, upgrading these normally waste materials into useful pulping materials. For recycling waste paper, conditions can again be selected which will pulp paper, leaving unwanted materials such as adhesive tapes, plastics, waxed boards or bituminised paper untouched. Ink, too, can be separated from wastepaper by treating the waste with alkali, followed by mild defibration treatment, after which the ink is flushed away.

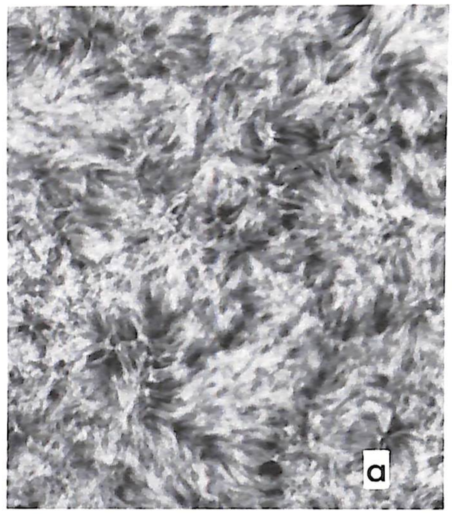
Negotiations for the commercial development of the defibration process are in progress.

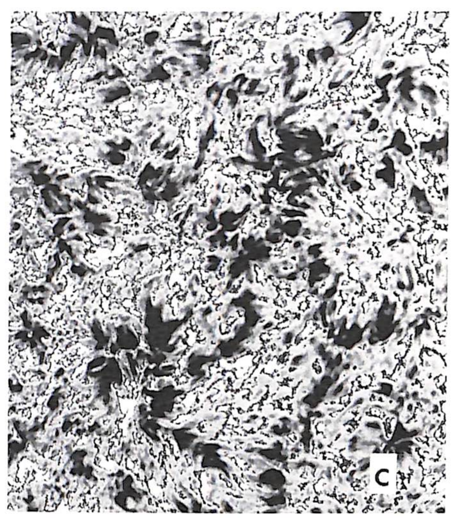
Improving technical photographs
It is often difficult to analyse technical photographs because of the large amounts of unwanted information that they contain. The NATIONAL MEASUREMENT LABORATORY has developed a technique which aids analysis by defining and separating areas in the photograph that correspond to areas of different brightness in the subject.

The method used is to copy the original photograph onto a very high contrast film, then repeatedly transfer from a negative to a positive until the image is reduced to only black and white with no middle tones. The final negative and positive, when superimposed, yield what is known as a brightness contour map. A reversed copy of the brightness contour map is then superimposed over the original photograph, and the final print is made on high contrast paper.

In this sequence of photographs, (a) shows the original photograph of a portion of the Sun's atmosphere and (b) is the brightness contour map; (c) shows the greatly improved definition obtained by superimposing the brightness contour map on the original photograph.

Photograph: Harry Gillett





Interscan—a new concept in aircraft landing systems

The basic principle of the Interscan aircraft approach and landing guidance system, which has been recommended for international use, provides a simple and economical answer to the needs of civil aviation.

In March 1977, a panel of experts, set up by the International Civil Aviation Organization (ICAO) to assess the relative merits of a number of proposals for a new aircraft approach and landing guidance system, recommended that the system concept submitted first by Australia and subsequently taken up by the United States, should be adopted for international use. The Council of ICAO has now decided that the technical recommendation should be put before a world-wide meeting of its 138 member countries. These decisions represent a major step towards international acceptance of the Interscan landing system conceived in the DIVISION OF RADIOPHYSICS and developed jointly, over the last five years, by CSIRO and the Department of Transport.

The Interscan project originated as a result of an invitation by ICAO to all member countries to submit proposals for a new international approach and landing guidance system to be used from the 1980s into the next century. It was generally acknowledged that a new system would be essential for guidance in poor or zero visibility under the increased traffic densities of the future. The system would have to handle new types of aircraft with short take-off and landing capabilities and permit approaches to airports along curved paths for terrain clearance or to minimise noise in densely populated areas. Moreover, its performance would need to be affected as little as possible by reflections from buildings and other objects.

Following discussions between the DIVISION OF RADIOPHYSICS and the Air Transport Group of the Department of Transport, the Division suggested a system in which antennas installed near the runway radiate narrow fan beams. The beams are electronically scanned to and fro at precisely controlled rates—one beam in a horizontal plane and a second in a vertical plane. Each time one of the beams intercepts the aircraft, a pulse is generated in the receiver and the time interval between the 'to' and 'fro' pulses gives the angle between the aircraft and a reference line, measured in the plane of scan. Thus, the beam scanning horizontally gives the azimuth angle of the aircraft, that is the angle measured from the runway centreline; the vertically scanning beam supplies the elevation angle measured from the horizontal plane of the runway surface. The very simple and efficient Interscan method of transmitting the angular information is now known internationally as the Time Reference Scanning Beam (TRSB) principle.

In order to convert the simple concept into a practical system, an essentially new antenna technology had to be developed at the DIVISION OF RADIOPHYSICS—economical antennas transmitting electronically scanned beams were needed. A novel form of antenna was developed comprising a cylindrical reflector fed by a circular arc of multiple feed elements, the beam being scanned by exciting the elements in sequence. Such antennas were built at the Division and tests showed that they were capable of giving guidance information with angular accuracy of about a hundredth of a degree.

In the complete system, the azimuth and elevation angles measured in the aircraft are combined in a small computer with the distance measured to a ground beacon by distance measuring equipment (DME), thus fixing the aircraft's position relative to the runway. When the pilot has selected a particular approach path, any deviation from this path can be indicated to him or fed to the aircraft's automatic guidance equipment (auto-pilot). A variety of approach paths can therefore be designed—straight, segmented or curved in three dimensions—to suit a particular airport, instead of the single straight approach path provided by the present Instrument Landing System. In addition to allowing increased operational flexibility, the new system is very much less susceptible to reflections from airport buildings and taxi-ing aircraft because of the very narrow beams used.

Following feasibility studies by the Division during 1972, the Department of Transport adopted the proposed system as the basis of an Australian submission to ICAO. To obtain the extensive test data required by ICAO for the assessment of proposals, the Department of Transport engaged Amalgamated Wireless (A/Asia) Ltd to produce equipment, based on the Division's research and development work, for installation at Melbourne Airport, Tullamarine, where the Department carried out the necessary ground and flight tests.

Other proposals to ICAO were received from the United Kingdom, West Germany, France and the U.S.A. Initially the U.S.A. developed a number of systems simultaneously as a basis for selecting its national proposal. During this phase, the Australian Government invited the U.S. Federal Aviation Administration (FAA) to send a team of experts to inspect the Interscan work in Australia. As a result of this visit, one of the U.S. systems was modified to incorporate the Interscan TRSB principle and Australia was invited to participate in the U.S. selection process. The FAA decision late in 1974 to adopt the TRSB principle meant that Australia and the U.S.A. were able to present complementary proposals to ICAO. This culminated early in 1977 with the recommendation of the ICAO assessment panel that the Interscan TRSB principle should be adopted for international use. The ICAO Air Navigation Commission has now decided that this recommendation will be put before a meeting of all ICAO member countries early in 1978.

Continuing research in the DIVISION OF RADIOPHYSICS during the past five years has resulted in a number of improved antenna designs all based on the original system of electronic scanning. A new version of the original type of antenna, smaller in size and superior in performance, has been produced as a result of the development of a more advanced electronic scanning technique. Also, a new type of antenna has been developed of even smaller dimensions and lower inherent cost by using a microwave lens to replace the reflector. The lens is of entirely novel design and is better than other known types. By these and other means, Interscan hardware is evolving into improved and more economical forms. The DIVISION OF RADIOPHYSICS is now collaborating with the Department of Productivity in investigating the commercial manufacture of the new Interscan hardware by Australian industry.

More cheese—less whey

In the manufacture of cheese, the use of ultrafilters, which separate molecules of different sizes, increases the yield of cheese and reduces the amount of whey.

In the first stages of cheese manufacture, the milk is set to a firm gel by adding rennet, an enzyme which causes the milk to clot, and a bacterial culture. The gel is then cut and exudes liquid, separating the solid curds from the liquid whey. The curds provide the basic material for making cheeses, different cheeses being obtained from different treatments of the curds.

The whey is generally regarded by the cheese industry as a waste product, although it is of high food value containing about one-fifth of all the proteins in the milk and most of the lactose or milk sugar. If whey is discharged into sewers or waterways it is a serious source of pollution owing to the noxious effects of the decomposing proteins and lactose. The Dairy Research Laboratory of the DIVISION OF FOOD RESEARCH has developed a successful method of recovering the proteins and lactose from the whey, thus reducing the pollution factor. These substances can then be used as food ingredients. However, the proteins cannot easily be returned to the curds to increase the yield of cheese.

Recent industrial developments in the technique of ultrafiltration have now made possible an alternative approach in which the proteins are retained in the curds. The water is removed from the milk by filtering it under pressure through an ultrafilter in which the pores are small enough to retain all the milk proteins but allow the water and lactose to pass through. The lactose can readily be recovered from the protein-free whey.

In France, a group of scientists at the INRA Station at Jouy-en-Josas, has developed a process for manufacturing Camembert cheese in which the milk is ultrafiltered until about 90% of the water is removed, leaving behind a semi-liquid product or 'pre-cheese'. To obtain the cheese, rennet and a bacterial culture are added, and the pre-cheese sets with virtually no separation of whey from the curds.

Cheeses made from milk treated in this way are indistinguishable at maturity from those produced conventionally and, as all the protein normally lost in the whey is retained in the cheese, the yield of cheese per litre of milk is increased by about a fifth. At the same time, effluent protein, which on decomposition generates an obnoxious smell, is almost eliminated.

Scientists at the Dairy Research Laboratory hope to adapt this technique to making Cheddar, the main type of cheese manufactured in Australia. However, Cheddar is more difficult to make than Camembert as it has a much lower water content and necessitates removing about 95% of the water. Current experiments indicate that, while it may not be possible to completely eliminate the formation of whey, it should be possible to retain the bulk of the whey proteins in the cheese.

Liaising with the meat industry

Liaison with the meat-processing industry ensures rapid dissemination of new technology and directs research towards those areas of the industry experiencing problems of immediate importance.

Most industries which process primary products have the benefit of extension and liaison services provided by either State or Commonwealth agencies. In the mid 1960s, when the DIVISION OF FOOD RESEARCH expanded its activities in the field of meat research, representatives of the meat-processing industry suggested that a group should be formed within the Division to provide such services to their industry.

The various meat industry authorities agreed that funds for the service should be collected as a levy from the owners of stock who would be required to pay 1 c per head for cattle slaughtered and 0·1 c per head for sheep and lambs. Legislation for collecting the levy for an initial period of three years came into effect at the beginning of 1969. The Act provided that the revenue from the levy would be matched by an equal amount from Commonwealth Government funds, and the Australian Meat Research Committee was empowered to administer these funds.

Thus, the financial basis for the formation of the Industry Section of the Division's Meat Research Laboratory was created. Its responsibilities can be classified broadly as follows.

- Extension—disseminating technical information to industry.
- Liaison—establishing and maintaining liaison with individual meat-processing firms, manufacturers of equipment, regulatory bodies and research groups, both within CSIRO and in other institutions.
- Service—answering queries; advising on day-to-day problems; establishing training programs for industry personnel.
- Investigations—research of a short-term nature, directed mainly towards solving urgent problems in the meat industry; field studies of techniques and equipment used in meatworks; evaluating new techniques and equipment.

To ensure a close association with the industry and other bodies, the Australian Meat Research Committee set up the Meat Research Advisory Panel. The Panel meets annually to consider the contributions that the Industry Section has made to the industry in the year just past and to estimate the budgetary requirements of the Section for the year to come. This panel comprises representatives from the Australian Meat Exporters Federal Council, the Australian Meatworks Federal Council, the Meat and Allied Trades Federation of Australia, the Council of Australian Public Abattoir Authorities, the Australian Meat Board, the Department of Primary Industry and CSIRO. A subcommittee of the Panel, the Industry Section Liaison Subcommittee, meets quarterly to advise the Officer-in-Charge of the Meat Research Laboratory on problems of immediate importance in the industry.

The personnel of the Industry Section consists of a chemist, a microbiologist, a food technologist, two engineers, an information officer and supporting technical and clerical staff located at the Meat Research Laboratory at Cannon Hill, Queensland. Extension officers at Perth, Sydney and Melbourne provide services to the meatworks outside Queensland.

The early work of the Industry Section was largely concerned with improving the standard of hygiene in meatworks and with introducing modern, quality-control procedures. The Section also collaborated with the suppliers of vacuum packaging equipment and plastic wrapping films to establish procedures for maintaining the quality of vacuum-packed chilled beef during transport to overseas markets. As this technology became available, lucrative markets opened up for Australian beef and later for vacuum-packed chilled lamb.

Current research projects include investigation of ways in which proteins for human consumption can be recovered from meat that would normally be processed into animal feedstuffs, examination of the requirements for standardising materials handling in abattoirs, and a study of methods for improving the quality and extending the shelf-life of meat and meat products.

The Section communicates technical information and gives advice to industry by personal contact of the extension officers with individual meat processors, and also to a wider audience through published material, teaching sessions and conferences.

The Meat Research Newsletter, published bimonthly, carries technical information and offers advice on technical problems, while the Meat Research Reports describe the results of experimental work undertaken by the Industry Section as well as by other groups within the Meat Research Laboratory.

As new techniques are developed, the Section invites industry personnel to attend teaching sessions or 'schools' to learn the new methods. The Section also organises conferences which aim to tap all available sources of expertise both within CSIRO and in other institutions and, whenever possible, from overseas, for the benefit of management-level staff from the meat industry.

Despite its heavy commitment to liaising with industry, the Industry Section remains an integral part of the Meat Research Laboratory. Consequently, the Section has available to it the accumulated knowledge and expertise of a large number of scientists and engineers, while the research staff of the Laboratory are kept aware of the problems besetting the industry at which their research is aimed.

A measure of the success of the Industry Section is that it has been necessary to double its size to cope with demands on its services. Furthermore, the processing industry has requested that in future the levy be collected on an indefinite basis and at double the present rate.

Shrinkproofing wool

New synthetic resins applied to wool fibres or wool fabric guarantee shrink-resistance of wool yarns and garments.

Under an electron microscope, the surface of a wool fibre is seen to be made up of a large number of overlapping scales with the projecting edges all pointing in the same direction—not unlike the trunk of a palm tree. When a wool garment is washed, the scales act like a ratchet, making it easier for a fibre within a yarn to move in the opposite direction to the way in which the scales are facing than in the same direction. The scales also act as minute barbs, locking adjacent, oppositely oriented fibres together. The

Scanning electron photomicrograph of a wool fibre. The scales on the surface of the fibre make it easier for it to move in one direction than in the other within the yarn structure, and also cause adjacent scales to lock together. The combination of preferential movement and scale locking leads to shrinkage.
(Magnification: ×15,700)

combination of the preferential movement and locking action during washing causes the garment to shrink in overall size.

Research undertaken by the three Divisions of the WOOL RESEARCH LABORATORIES—the DIVISIONS OF PROTEIN CHEMISTRY, TEXTILE INDUSTRY and TEXTILE PHYSICS—has improved our understanding of why wool fabrics shrink and led to the development of simple and cheap processes that impart shrink-resistance and enable wool garments to be machine-washed.

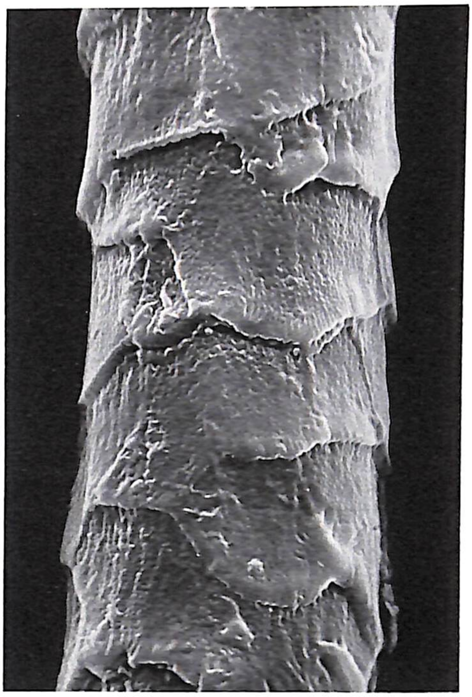
Early attempts to prevent shrinkage involved treating the wool scales with chemicals which produced a smoother surface and so prevented both the preferential movement and the scale-locking. Unfortunately, it is often difficult to confine the action of the chemicals to the scales alone and the feel of the wool, the strength and wearing properties are often affected detrimentally.

Nearly 30 years ago, the Laboratories began investigating the application of synthetic resins to prevent shrinkage of fibres. The Laboratories have concentrated on two approaches which have resulted in the chlorine-Hercosett and Sirolan BAP methods of shrinkproofing. In the first approach, the resin is applied to the wool prior to spinning and shrink-resistance is imparted by preventing both preferential movement and scale-locking. In the second approach, the resin is applied to the fabric and shrinkage is prevented by stopping preferential movement of the fibres.

In the first approach, scale-locking is prevented by completely coating the scales with a smooth film of resin. However, the development of resins that will spread over the whole surface of a wool fibre and adhere to it as a thin film when heat is applied to 'cure' the resin has proved difficult, and the search for better resins is part of the ongoing research of the Laboratories. A major advance occurred in the late 1960s when a technique was developed in which the fibres are first treated with a dilute solution of chlorine. This pretreatment aids the spreading and adhesion of the resin, Hercosett 57. The chlorine-Hercosett process is now used widely both in Australia and overseas.

In the second approach, the object is to link the fibres together with bridges of resin to prevent them from moving when the fabric is washed. If movement

Scanning electron photomicrograph of a wool fibre after coating with a shrink-resist resin. The resin masks the scales on the surface of the fibre, making it as easy for the fibre to move in either direction and also preventing scale locking. (Magnification: × 15,700)



Photographs: Dr C. A. Anderson

is prevented, there is no possibility of shrinkage. With this approach, there is no need for a resin film to spread over the whole surface of the fibre. The resin must merely adhere to portions of each fibre and, in effect, glue sections of adjacent fibres together.

Knitted products have been treated in this way for a number of years now, with polyisocyanate resins applied in a dry-cleaning fluid in modified dry-cleaning machines. The CSIRO permanent-press process, developed by the WOOL RESEARCH LABORATORIES and introduced in 1971, involves such treatment followed by steaming to give total 'easy care' properties. In this process, the resin is applied to the garment, the creases are pressed in, and steaming 'cures' the resin to give washability combined with permanent creases.

However, dry-cleaning machines are not standard equipment in the textile industry, and for widespread use, it is better to have cheap resins that can be applied by means of conventional textile machinery. This means that the resin must be soluble in water rather than dry-cleaning fluid. Modified

Scanning electron photomicrograph of wool fibres in a fabric that has been treated with a shrink-resist resin. The resin bonds fibres together, so preventing fibre movement which is necessary for shrinkage to occur. (Magnification: × 4,600) polyisocyanate resins, recently developed by the Laboratories, have now made this possible. The resins are dissolved in water and can be diluted with cheaper, softer resins which improve the feel of the treated fabric and reduce the cost of the process.

The procedure is very simple; the fabric is merely impregnated with resin solution and then dried. The process, called Sirolan BAP (Bisulphite Adducts of Polyisocyanates), was released throughout the world in 1976 after two years of extensive testing in industry in Australia and New Zealand.

The treated fabric can be machine-washed or dry-cleaned and will retain its finish for the effective life of the garment. The Sirolan BAP process works well even when spinning oils, lubricants and waxes are on the fabric. This means that jersey fabrics can, in most cases, be treated straight off the knitting machines without needing to scour them first.

The Australian Wool Corporation introduced a labelling scheme for autumn 1977, known as Superwash, to promote knitted wool garments and knitting yarns that are guaranteed to be machine washable. To be eligible to bear the Superwash label, garments and yarns must meet the very high standards of long-lasting resistance to shrinkage set by the Corporation. Similar standards and tests are used overseas, and the International Wool Secretariat expects that over 26 million sweaters will be sold under the label during 1977.

The well-established chlorine-Hercosett process has been the main method used worldwide for achieving the Superwash standards. Wool treated by the new Sirolan BAP process also easily meets these standards and, as it is simple and economical, use of the process is expected to extend as Superwash becomes more widespread.

Managing Australia's natural resources

Studies of the natural resources of Australia are providing a basis for evaluating land use options and assessing alternative management strategies.

Australia's land and water resources are a precious heritage for both present and future generations. If they are to satisfy the material and cultural needs of the population both now and in the future, they must be used wisely on the basis of sound, scientific knowledge. A region may contain many parcels of land which differ in their topographic, soil and vegetation characteristics. Since most of these parcels can be used for a variety of purposes, which may or may not be compatible, land use planners and decision makers require information about the resources and their potentialities and limitations for various uses, in order to make wise decisions about resource allocation and management.

The three Divisions of the LAND RESOURCES LABORATORIES—the DIVISIONS OF LAND USE RESEARCH, SOILS and LAND RESOURCES MANAGEMENT—are investigating different aspects of land and water use in a coordinated program aimed at providing such information.

The research is being approached from three angles. One line of approach is to compile resource inventories on both regional and continental scales in the form of maps and descriptions of climate, topography, soils, vegetation and other physical and biological characteristics. Note must also be taken of how the land is being used.

Another approach is to evaluate the suitability of resources for various uses in order to be able to predict the impact that any change in land use will have. Such evaluation is generally based on the observed consequences of past and current land uses and on a scientific understanding of various physical and biological processes which affect the productivity or deterioration of the land.

The third approach is to determine the options for the best use of an area in the light of individual, community and national needs. For instance, an area which has been used for forestry may later be required for agriculture. However, if the land also serves as a water catchment area, care would need to be taken to ensure that the change in land use did not lower the quality of the water supply. At this stage, the knowledge acquired through inventory-taking and subsequent analysis of the data, can be used to predict any significant consequences that might arise from a change in land use or from altering the management strategies used to direct the current choice of land use.

It is clearly impracticable to compile the necessary detailed data for every part of Australia within a reasonable time scale. The Divisions concerned have therefore developed their research along two main lines—broad inventories of resources covering the whole continent and very detailed studies of specific areas.

The first major inventory was of the soils of Australia. The soils map, which resulted from this work, is the most detailed ever produced on a continental scale anywhere in the world. It was published by the DIVISION OF SOILS in 1968. The Division is now undertaking more detailed studies of specific areas such as the red and yellow earth regions of northern Queensland.

Climatic data, supplied by the Bureau of Meteorology, have been assessed by the DIVISION OF LAND RESOURCES MANAGEMENT. Using these data, scientists at the Division have shown that with the present level of technology, two-thirds of Australia are too arid for agriculture or improved pastures. The different style of management required for these areas is described in this report in the article 'Keeping a watch on range condition'.

An inventory of water resources is now being compiled. This will include data on annual rainfall and, more importantly, the quantity of run-off water that can be collected and stored, and the variations in run-off that occur from year to year. To obtain this kind of information, the State water authorities, the Bureau of Meteorology and the DIVISION OF LAND USE RESEARCH are undertaking a cooperative project known as the Representative Basins Project. For this project, 93 river basins varying in size from 25 to 250 square kilometres were selected in a representative range of landscapes and climates. Each area is being instrumented so that data on rainfall, evaporation and run-off can be recorded. The collection of data presents some difficulties as many of the areas are remote and although certain instruments record measurements automatically, others must be operated manually. So far, information is being collected from 87 basins.

A major aspect of this program has been the development and maintenance of a computerised data bank for storing the information in an easily retrievable form. Initially the computer was only programmed to deal with information on surface water, but it has now been modified to handle data covering all aspects of investigations into surface water, ground water and water quality.

The sea coast and estuaries are valuable resource areas, but in the past they have received little attention from scientific surveys. The three Divisions of the LAND RESOURCES LABORATORIES are, however, now collaborating in a series of programs aimed at evaluating the resources in the coastal areas and assessing the impact of man's activities. The approach is two-pronged: the entire coastal area of the continent is being studied by aerial surveys backed up by ground studies and, at the same time, particular areas are being evaluated in-depth for different uses.

The coastal zone has been arbitrarily defined as the land lying within three kilometres of the coast—a total area of 100 000 square kilometres. At present, the DIVISION OF LAND USE RESEARCH is describing the coastal lands in terms of their geomorphology, structure and vegetation. This will provide a general inventory and enable the coastal environment to be classified into areas of similar terrain such as sandy beaches, rocky beaches, wide estuaries or coastal plains. This classification is important as the land use depends largely on the terrain and vegetation. It will also direct conservationists to those areas of the coast which are unique in land form or vegetation and may warrant some form of protection.

However, the problems associated with certain areas of the coastal zone are too pressing to wait for this survey to be completed and these areas are being evaluated separately. For instance, the DIVISION OF SOILS is investigating the dynamics of coastal sand masses north of Brisbane. These studies will provide basic information on the stability of the native landscapes as a rationale for future land use planning in fragile environments where holidaymakers, housing and road construction, and sand mining are disturbing and potentially destructive. On the other side of Australia, the coastal plain north of Perth was shown

The DIVISION OF SOILS is studying the stability of both bare and vegetated sand dunes in seven different ecosystems at Cooloola, Queensland. This aerial photograph, in false colour infra-red, of an active sandblow advancing into vegetated dunes shows the highly unstable coast and the exposed subsurface horizons of earlier soils; the shoreline, with ocean beyond, is on the right. The direction of the last sand-moving wind is indicated by drifts across the sandblow and behind tree stumps.

Measurements have shown that significant movements of sand also occur down the slopes of all the vegetated dunes due to water. Such movements occur even in areas of dense rain forest which were previously thought to be stable.

The false colour infra-red gives an indication of the state of health of the vegetation and also enables some species of trees to be distinguished. For example, the pink crowns are the brush box, *Tristania conferta*.

Photograph: QASCOPHOTO

in earlier surveys to consist of a series of sand dune systems of different ages. The DIVISION OF LAND RESOURCES MANAGEMENT is evaluating the systems in terms of their stability and other factors which are likely to be important as the Perth metropolitan area spreads northwards towards Moore River.

In another project, the DIVISION OF LAND USE RESEARCH is concentrating on the changes that are occurring as a result of industrial and recreational activities in a number of estuaries in New South Wales and upstream of the estuaries themselves. Estuaries are of major economic and recreational importance. They provide breeding and nursery areas for many species of fish and for oyster farming, and they offer the pleasures of swimming, sailing and other pastimes. They also provide a dumping ground for sewage effluents and other wastes. The amount of disturbance and pollution from human activities that an estuary can withstand before the aquatic life begins to suffer, depends on such factors as the amount of tidal flushing, the inflow of fresh water, and the quality of the incoming water.

The effects of man's activities are usually small at first and tend to pass unnoticed until they have built up to such proportions that the estuary can no longer serve as a breeding ground for fish, is unfit for oysters, or is obviously unsanitary. In an attempt to find an 'early warning system' for these changes, the DIVISION OF LAND USE RESEARCH is surveying and monitoring a number of estuaries which vary in the intensity of urban and industrial development along their shores and in their catchment areas. Study areas range from the highly industrialised areas of Wollongong (Lake Illawarra) to the almost untouched estuaries of southern New South Wales. The construction of a new dam on the Shoalhaven River will provide scientists at the Division with a rare opportunity to study the effects that such a massive diversion of water will have on the aquatic life of the Shoalhaven estuary.

The Land Evaluation Group of the DIVISION OF LAND USE RESEARCH is engaged in a different aspect of reviewing land use options. In a country with the many varied environments of Australia, it may be possible to select the best sites for crops by assessing the climatic and other environmental factors that are most favourable to their growth. The Group has developed a computer-based system for predicting the success of any crop at any given location, provided that details of the crop, site, weather and management strategies are known.

For example, by using the climatic data-bank, AUSTCLIMEANWK, which processes mean weekly climatic data for 750 stations around Australia, the Group has been able to show that the most favourable environment for growing tomatoes for processing is the narrow coastal plain between Perth and Geraldton. However, the distance from existing processing plants, the possible conflict in the future over allocating water to irrigation in the face of a water shortage in the Perth metropolitan area, and the distance from the population centres in the east of Australia, make the region less attractive.

The computer assessments show that the next best area is a relatively restricted region in the middle to upper Murray Valley. Although the production of tomatoes for processing has only recently begun there, this region is already providing a significant proportion of the total Australian production.

Comfort—at less cost

New initiatives in the design of buildings and their heating and cooling equipment can achieve comfortable indoor temperatures at reduced cost in both capital outlay and energy consumed.

About a tenth of the total amount of primary energy consumed in Australia each year is used for heating and cooling domestic and commercial buildings. The production of an acceptable thermal environment—that is the conditions of temperature, humidity and ventilation which satisfy the comfort, health and efficiency of most people—is thus a considerable drain on the nation's waning energy reserves. In addition, it is expensive in terms of capital outlay and running costs.

The DIVISIONS OF BUILDING RESEARCH and MECHANICAL ENGINEERING are collaborating in research aimed at improving the thermal environment while keeping the consumption of fossil fuels and the amounts of mechanical equipment as low as possible. The Divisions are examining two aspects of the problem. The first emphasises the potential for conserving energy by carefully selecting design features and construction materials. The second involves adapting existing technology or developing new techniques or equipment to provide a better thermal environment while reducing demands on fossil fuels.

The Divisions have developed computer programs to predict on an hourly basis the fluctuations in indoor temperature and the heating or cooling requirements for buildings at any given locality for periods of up to several years, provided the climate of the locality and details of the building plan and construction are known. Computer models of different types of heating and cooling systems are being used to improve the accuracy of predicting the amounts of energy that will be required to heat or cool any particular building. One such program, TEMPER, enables these requirements to be predicted even before the building is constructed, provided the climate of the locality is known. TEMPER has been made available commercially through the Association of Computer Aided Design and is being used extensively by architects and consulting engineers, particularly for designing office buildings. Other computer programs developed by the Divisions have been used by various government authorities.

The computer is also proving a powerful tool in assessing the relative merits of the many design features and construction materials that can help to control both daily and seasonal fluctuations in indoor temperature. THE DIVISION OF BUILDING RESEARCH has examined some of the alternative design features and construction materials in more detail. Computer simulations for a typical brick veneer house in Melbourne have shown that using reflective foil laminate in the wall cavity and rock-wool, 50 millimetres thick, above the ceiling could halve the annual heating requirements. The Division has also determined the optimum levels of insulation for each of the major Australian population centres.

It is, of course, well known that considerable savings in energy can be won by orienting buildings so that maximum use is made of winter sunlight while eliminating as much summer heat as possible. Heavy weave curtains, pelmets which restrict the circulation of air, and blinds all help to prevent heat losses from windows at night. Sunbreaks over windows and wide eaves are also instrumental in cutting down on summer heat and hence in reducing cooling requirements. Many other factors also contribute to the energy needs of buildings and it is generally necessary to compromise between factors which are of benefit during winter and those which are useful in summer. The Division is using computer studies to determine the combinations which will give satisfactory compromises for various climates. For instance, the Division has found that for a climate such as Melbourne's, cavity brick walls provide good heat control during summer but do not offer sufficient thermal resistance in winter. The use of foam insulation in the wall cavity provides a satisfactory compromise for both seasons.

The DIVISION OF BUILDING RESEARCH has also produced solar radiation tables for all capital cities as an aid to building designers. The tables quote the theoretical amounts of solar radiation falling on building surfaces on cloudless days and the subsequent theoretical gains in heat through glass shaded by sunbreaks of various widths. These figures enable designers to decide the dimensions of sunbreaks—eaves, verandas and so forth—needed to obtain maximum benefit throughout the year.

If the demands for an acceptable thermal environment are to be met efficiently and without excessive consumption of fossil fuels, mechanical equipment that meets these requirements must be available. Often existing equipment, designed in an era of relatively cheap and plentiful fossil fuels, is wasteful of energy. The DIVISION OF MECHANICAL ENGINEERING is investigating new concepts in design that are attuned to the new era of energy restraint.

In one of its programs, the Division is examining the use of heat and mass regenerators for space heating and cooling. These regenerators use the heat or 'coolness' extracted from exhaust air to warm or cool incoming air. Similarly, moisture exchanged with the exhaust air can be used to humidify or dehumidify incoming air.

In many localities, air can be cooled by using the cooling effect which results when water evaporates. In dry climates, the simple arrangement of direct evaporative cooling, which introduces water vapour into the air-conditioned space, is often an acceptable solution. An alternative is to use an indirect method of evaporative cooling in in which the exhaust air is cooled evaporatively and any excess moisture discharged to the outside. The coolness from the exhaust air is then transferred by means of a heat exchanger to the incoming air without increasing the humidity.

The Division has developed several systems that work on this principle of indirect evaporative cooling. The most recent of these is being installed at a new laboratory building at the Division. Individual air-conditioning units placed in the external wall of the building provide ample fresh air, cooled as required. The units have an extremely versatile control system and operate at very low levels of energy. Space heating for the winter, designed to operate on solar energy with occasional gas boosting, is incorporated in the design. Heat recovered from the exhaust air is fed back into the system, resulting in large economies of heating.

The Division will shortly test a complete air-conditioning installation at its Townsville, Qld, field station. The installation incorporates a special regenerator which can recover both heat and water vapour from exhaust air. This process offers significant savings in energy, particularly in humid, tropical regions.

In an alternative approach, scientists at the Division are examining chemical methods of dehumidification and space heating. Where dehumidification is necessary, water vapour can be removed chemically by passing the moist air over a bed of dessicant. Since heat is generated as the dessicant absorbs water, the bed of dessicant can also be used for heating purposes. For instance, cool moist air will be both dried and warmed as it is passed over the bed. The dessicant is easily regenerated for further use by heating it to drive off the moisture. The Division is currently studying the economics of these chemical systems, especially where solar energy or low-grade waste heat could be used to regenerate the chemicals. Such systems could prove particularly economical in the humid tropics where the cost of conventional types of air conditioning is high.

Also, selective radiative materials can result in a cooling effect and the DIVISION OF BUILDING RESEARCH is testing these materials to estimate their value as a means of space cooling. These materials, which emit radiation when facing a cloudless sky, produce a cooling effect with no input of energy. However, energy may be needed to circulate the coolness from where it is produced to other parts of the building. This system would have widest application in hot, relatively cloudless areas of the country.

The DIVISION OF MECHANICAL ENGINEERING is also examining the special cooling requirements of certain industries. The very hot conditions experienced in certain industrial processes cause severe thermal strain and discomfort to the workers, and reduce their effectiveness. Drink-bottle cleansing works, glass manufacturing plants and mining workshops are typical examples of situations where it is impossible or, at best, uneconomical, to use conventional methods of air conditioning. The buildings are large and must often—as in mining workshops—remain open to the environment. Massive and quite impractical inputs of cool air would be required in such circumstances. In a project which is partly sponsored by the

Localised cooling in industrial hot spots may be more effective and more economical than cooling an entire workshop or factory floor. In this test at the DIVISION OF MECHANICAL ENGINEERING, the air has been impregnated with smoke to allow identification of flow patterns in the air jet from a spot cooler.

Photograph: Neil Hamilton

Australian Engineering and Building Industries Research Association, the Division is developing equipment aimed at cooling individual workers or working zones rather than entire rooms. This is achieved by directing jets of cool air at certain localised areas, enveloping workers in a cocoon of coolness.

Further aspects of the Division's research on space heating and cooling are described in this report in the article entitled 'Energy research in CSIRO'.

The two Divisions have recently begun a project to build a low energy consumption house. Initially, the project is aimed at developing a computerised method of assessing the energy requirements of a building and, from this, designing low energy consumption houses for the major population centres of Australia. If the method proves feasible, the Divisions will build such a house and operate it for at least a year. This would provide valuable information for the general public and regulatory authorities on low energy consumption designs.

Solar energy would provide much of the building's energy requirements, particularly hot water. There are a variety of options for heating and cooling systems, and eight systems, including both conventional and new systems, will be incorporated into the computer analyses.

So far, assessments of the cost of such a dwelling indicate large savings to the householder in expenditure on fuel. Energy savings to the nation would depend on future energy demands and the rate at which low energy consumption houses could be built.

Disposing of coal-washery waste

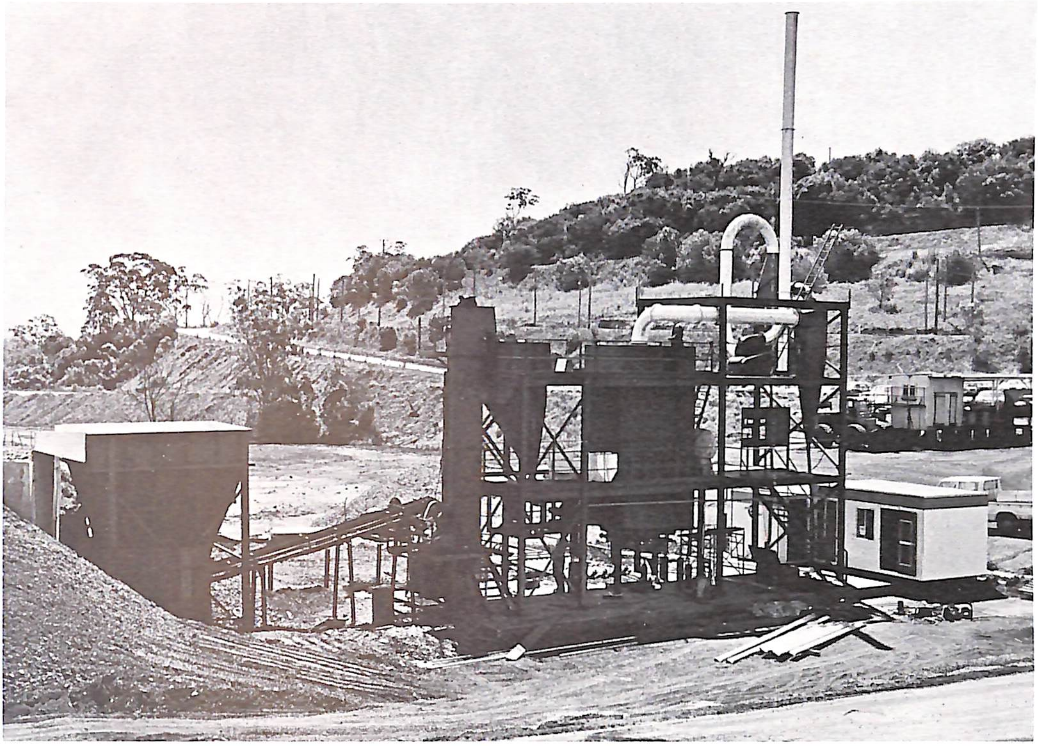
Fluidised-bed combustion offers the possibility of using the waste from coal washeries as a cheap source of energy. It also provides a solution to the increasing problem of disposing of washery waste.

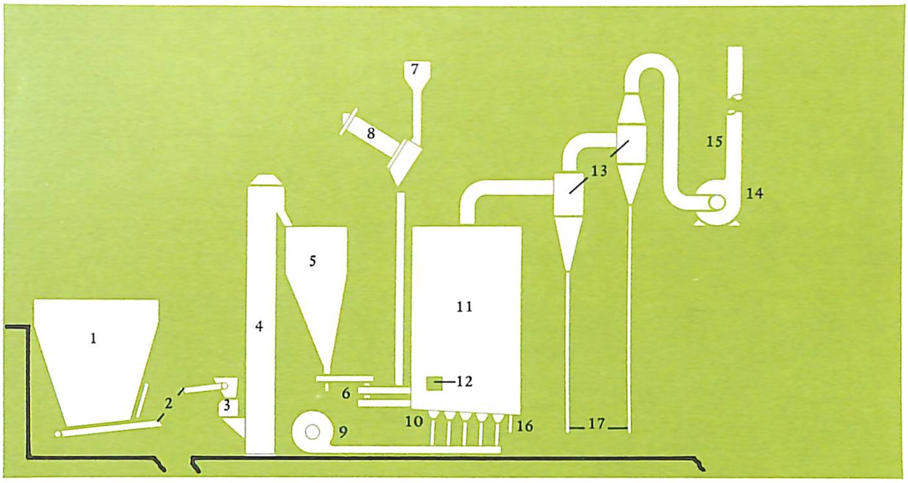
The production of clean coking coal is vital to Australia's industrial and economic growth. Exports are worth about $1000 million a year, while domestic consumption is currently worth around $25 million a year. However, about 15 million tonnes of waste accumulate each year as the coal is washed free from the shale and dirt which are mined with it. Since about one-third of the raw waste is a combustible coal-like material, washery waste can be regarded as a low-grade fuel. The amount of waste produced annually is the equivalent of a substantial amount of coal and hence of a considerable quantity of energy. However, as it is spread through a clay base, the waste does not normally burn easily and the energy potential has remained untapped.

At present, the waste is generally disposed of by dumping the coarse material in heaps, while the fine material is pumped as a slurry with water into artificial settling ponds. These practices present considerable economic and environmental problems. New regulations to protect the environment now make it essential for more acceptable ways to be found for disposing of the waste, while the energy situation demands increasing conservation of available reserves of fossil fuels.

Over the past three years the DIVISION OF PROCESS TECHNOLOGY, using a small experimental plant, has developed a process for burning both the coarse waste and the slurries in a fluidised-bed combustor. In this process, crushed

The Glenlee pilot plant for fluidised incineration of coal washery waste





1	main feed hopper	7	slurry feed tank	13	cyclones for fly ash separation
2	belt conveyer	8	slurry thickener	14	fan
3	crusher	9	airblower	15	stack
4	bucket elevator	10	air distributor system	16	burnt rejects discharge
5	crushed-waste feed bin	11	fluidised-bed combustor	17	fly ash outlets
6	screw feeders	12	preheat burner		

Photograph: Gordon Shrubb. Artwork: David Marshall waste is fed into a red-hot bed of inert ash particles which are kept suspended in a fluid-like state by a strong upward draught of air. This brings the crushed waste into close contact with both heat and air so that the combustible portion burns readily. A special device has been developed which uses a process of sedimentation to thicken slurries to the point where they, too, burn. Enough heat is generated to make the process self-sustaining. The heat is used to maintain combustion, but it could also be used to produce power.

The Division has estimated that the waste from a medium-sized washery could generate between 30 and 50 megawatts of power, so a fluidised-bed combustor, run in conjunction with a coal washery, could be regarded as a mini power station. Since the raw material is a waste and the combustion process self-sustaining, the energy would be obtained cheaply. Alternatively, the heat could be used to provide heating for industrial processes which would reduce the demand for liquid fuels in industry, or for drying coal which would reduce haulage costs for washed coal.

The end product of the combustion process is an inert, light-coloured, calcined shale which is tapped off from the bed or collected as fly ash in a series of dust traps or cyclones. The calcined shale is both cheaper and safer to dispose of than the unburnt material. The DIVISION OF BUILDING RESEARCH is investigating the possibility of converting it into a range of construction materials such as fired bricks and tiles, cement, and aggregate for making roads.

The DIVISION OF PROCESS TECHNOLOGY is now continuing its investigations on a pilot plant which was commissioned during May 1977 at the Glenlee coal washery. Initial results have been promising. The cost of constructing the plant was met by the Joint Coal Board, while Clutha Development Pty Ltd, which operates the Glenlee washery, provided the site and services. The pilot plant has about 30 times the capacity of the experimental rig, although it is still about 30 times smaller than a commerical plant would be. Divisional scientists will be using the plant to test waste from different washeries and to obtain large quantities of the calcined shale for commercial evaluation. They will also obtain data to assess the feasibility of building full-scale plants.

Grain dust for animal feed

About 300 tonnes of grain dust accumulate each week at Australian ports due to abrasion of the grain during mechanical handling. This material is potentially a valuable source of feed for animals. However, the dust contains high levels of insecticides used to protect stored grain against weevils. The grain is sprayed with insecticide as it moves along a conveyor belt and, because of the fineness of the dust, it absorbs proportionally far more insecticide. Consequently, its use for animal feed has been restricted. Alternative methods for disposing of the dust, such as burning or dumping, are expensive and potentially polluting.

Collaborative investigations by the DIVISIONS OF ENTOMOLOGY and ANIMAL PRODUCTION established the effectiveness of treating the dust with alkali to render the insecticides harmless. A system was then developed in which the alkali, sodium hydroxide (caustic soda), was added to the dust and the mixture pelleted. The heat of pelleting, combined with the presence of alkali, reduces the insecticides to negligible levels. This process has proved successful in commercial trials.

Monitoring water quality

Two instruments have been developed for long-term monitoring and for spot-checking salinity levels in water.

Two-thirds of Australia's enormous land mass of 7 700 000 square kilometres are arid or semi-arid. In these drier regions, ground water from bores is the main source of water and it is essential that this limited resource is managed as efficiently as possible. The Australian Water Resources Council (AWRC) is monitoring the quality of ground water in drier areas since variations in quality can render it unsuitable for consumption by human beings or livestock, or for irrigating crops.

Salinity—the amount of inorganic salts and especially of common salt that is dissolved in a sample of water—is directly related to the quality of the water. In rural areas, water quality is usually assessed in terms of salinity. Salinity measurements are also important in assessing the quality of water for use in urban areas, even though the criteria here are more complex and involve other factors relating to public health. One way of determining salinity is to measure the ability of the water to conduct electricity. Since the dissolved salts exist as charged particles, which can conduct an electric current, a measure of the conductivity is an accurate indication of the quantity of dissolved salts.

As many of the measurements must be made in remote areas, where access is difficult, the AWRC requested the help of the DIVISION OF CHEMICAL PHYSICS in developing an instrument which could operate under its own power for considerable periods of time, and could automatically take measurements at pre-set time intervals and store the data. The Division has designed and constructed a salinity recorder which satisfies these requirements and which, in addition, is constructed to reduce fouling and physical damage and to reduce possible vandalism.

The recorder's sensing head is a modification of one developed by scientists at the DIVISION OF FISHERIES AND OCEANOGRAPHY. The doughnut-shaped sensor is completely sealed in a plastic material which eliminates the problem of corrosion that can occur in conventional conductivity meters. The sensor consists of two transformers that are normally isolated from one another. When the head is immersed in water, the transformers are coupled, the degree of coupling depending on the amount of dissolved salts. The intervals at which measurements are taken are selected from a range of available time-intervals. The data are printed thermally onto paper tape in the body of the instrument and the spool of paper tape can be collected when the batteries are replaced.

Because the instrument can operate continuously for periods of up to 12 months without needing attention, it can be used to build up seasonal profiles of variations in water quality. The instrument has also been modified to make temperature measurements simultaneously so that the salinity readings can be corrected for both daily and seasonal changes in temperature.

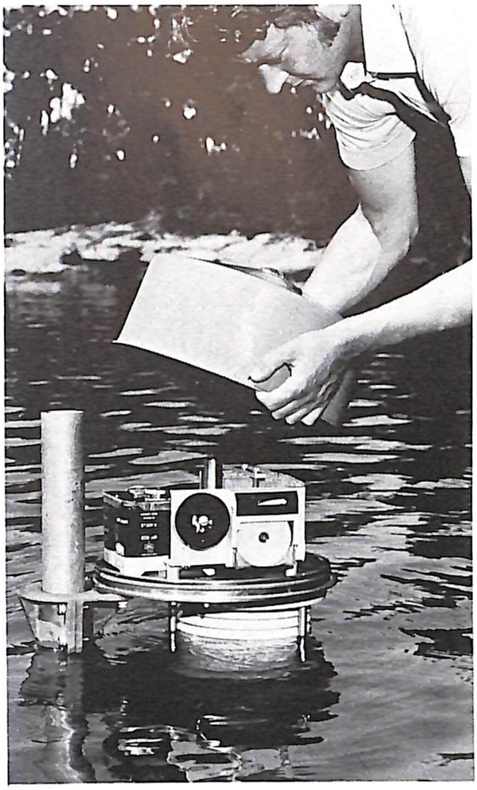
The Division is currently investigating a number of improvements and adaptations which would increase the usefulness and versatility of the basic instrument. For instance, if solar conversion panels were incorporated to charge the instrument's batteries during periods of sunlight, the batteries would then provide a continuous source of power. An even more exciting possibility would be to build into the instrument a 'microprocessor' or micro-computer. Progress in electronics has now made these units relatively cheap and a computerised instrument could carry out a complex series of operations and process the information so that it is recorded in its most usable form. The microprocessor could also control telemetry, transmitting data to any desired point by means of a radio link. This would mean that the instrument would need attention at only very infrequent periods for maintenance.

The DIVISION OF CHEMICAL PHYSICS has also used the same basic sensing head to develop a hand-held conductivity/salinity meter. With previous meters for this purpose, the electrodes used were prone to fouling or contamination on being immersed in the water sample.

The Division's hand-held instrument is based on a different principle that eliminates this problem. The instrument is operated, not by depressing a switch, but by touching the switch contacts with the index finger. The conductivity of the skin completes the circuit, and in doing so switches the instrument on. By avoiding the use of a conventional switch, it is possible to seal the instrument against dust and water.

The chief use of the hand-held salinity meter is for making spot-checks of, for example, industrial plant solutions, water supplies and polluted river-water. It is cheap and therefore readily available to individual farmers and fruitgrowers for checking the salinity of their bore or irrigation water before using it for stock or crops. This is an important application since livestock and crops are sensitive in varying degrees to the salt content of water.

Both the automatic salinity meter and the hand-held instrument are now being manufactured and marketed commercially.



The recorder for measuring water salinity developed by the DIVISION OF CHEMICAL PHYSICS is making an important contribution to the control of water quality in Australia. Here, the metal cover of the recorder is being removed to expose the thermal printer with its paper tape spools, the batteries and (to the rear) the integrated circuits which control the measuring process. The sensing head with its protective shroud can be seen under the instrument, half immersed in water. The instrument with its cover in position can be completely immersed in water; it can operate automatically for periods of up to 12 months without needing attention from an operator.

Photograph: Roger Lamb

Conservation in the rain forests

Studies of birds and plants in rain forests are revealing a complex interdependence which must be understood before conservation measures can be implemented.

The rain forests of north-eastern Queensland probably contain more than 700 species of trees, together with numerous vines, palms and epiphytes. As well as being the richest habitats in Australia in terms of the abundance and diversity of species of plants, these forests support the greatest diversity of birds and mammals. Many of these species of animals are entirely restricted to rain forests and some are found only in Australia.

Human activities have greatly reduced the size of the rain forests. Their area has shrunk in proportion to increasing use of rain forest areas for the purposes of agriculture and forestry. Already half of the rain forests in north-eastern Queensland have vanished and the bulk of the areas of lowland forest has been cleared. If the rich array of plants and animals is to be preserved, conservation measures are urgently needed. Studies undertaken by the DIVISIONS OF WILDLIFE RESEARCH, FOREST RESEARCH and PLANT INDUSTRY on the distribution and ecology of some of the plants and animals will provide a basis for conservation.

The fruit-eating birds make up a large section of the bird life, and in 1973 the DIVISION OF WILDLIFE RESEARCH completed a three-year study of the ecology of some of these species, specifically the cassowary and seven species of fruit pigeons, all of which were thought to be dependent on the diversity of plant life in the rain forests.

The study revealed that different species of plants bear fruit at different times of the year, producing a year-round supply for the birds. The diet of each species of bird changes through the year according to the fruit available and the particular preferences of the various species. The birds breed during the dry season when the supply of fruit is most abundant. The amount of fruit varies from year to year, and the breeding activity, and hence the number of birds, varies accordingly.

Most significantly, Divisional scientists discovered that each species of bird feeds on a different set of plants. Thus, a high diversity of plant species is essential if all these species are to survive. In turn the plants depend largely on the birds for dispersal of their seed. The seven species of pigeons alone took fruit from over 80 species of plants during the study period.

The DIVISION OF FOREST RESEARCH is interested in aspects of managing rain forests to provide enough suitable habitats for the diversity of fauna. Permanent reference plots have been established in the rain forests to monitor changes in the vegetation. Periodic checks on the plots should provide information which will help biologists to assess the value of various management systems.

The flowering and fruiting characteristics of rain forest trees are also being examined. In addition, taxonomic studies of rain forest trees belonging to the families Myrtaceae and Lauraceae are in progress. The fruit of many trees belonging to these two families makes up a significant portion of the birds' diet, yet the species of trees are poorly known both taxonomically and ecologically. Without basic information of this type, it is very difficult to make predictions on the long-term future of the fruit-eaters.

A map of the vegetation of the humid tropics of northern Queensland, prepared by researchers from the DIVISION OF PLANT INDUSTRY, could provide a framework for assessing the current state of, and predicting future trends in, populations of pigeons and other wildlife in the rain forests. It is also enabling the key habitats for wildlife to be identified. The map, in which the remnants of 15 types of rain forest and six areas that include rain forest among a mosaic of other types of vegetation are identified, shows that the habitats of the fruit pigeons and cassowary are becoming fragmented and often consist of narrow strips along streams in amongst a pattern of other vegetation types.

Some idea of the fragmentation of the rain forest and the complexity of other vegetation types in which the fragments are scattered can be gained by examining sections of the map in greater detail. For instance, in a typical five-kilometre square area near Tully, five different types of rain forest were found among three sclerophyll forests and areas cleared for sugar cane. The different types of vegetation are highly interdependent, and if the birds are to be preserved it is not enough simply to save the fragments of rain forest; whole mosaics of rain forest and other vegetation types must be preserved.

Standing up to cyclones

Recent experience has clearly shown that conventionally built houses in Australia's cyclone-prone regions have a low probability of adequately withstanding the cyclones that they will probably be subjected to during their lifetime. Investigations of buildings in Darwin have shown that many of the modifications made after assessing the damage from previous cyclones were insufficient in the face of cyclone Tracy which devastated Darwin in 1974.

If cyclone disasters are to be avoided in future, homes erected in cyclone areas will have to be built according to more wind-resistant designs, and existing homes will have to be modified to ensure a higher level of wind resistance.

The DIVISION OF BUILDING RESEARCH is studying the forces that wind can exert on buildings and the capacity of buildings to resist these forces. Wind forces are being assessed with the aid of a village of houses built to one-third of the actual size. Supplementary studies will be made on smaller models in a wind tunnel which is being built at the DIVISION OF MECHANICAL ENGINEERING. The structural performance of buildings is being investigated through laboratory load tests which enable the fatigue that a structure would suffer during a cyclone lasting several hours to be estimated, and through impact tests which allow the effects of impact of wind-driven debris to be assessed.

Results so far indicate that cyclone-resistant houses could be built, and at a reasonable cost.

Keeping out rain

Rain penetrating building facades causes millions of dollars of damage each year to internal finishes and furnishings. The DIVISION OF BUILDING RESEARCH is using a test rig to investigate the ability of a building facade to keep out wind-driven rain.

The rig, known as the SIROWET test rig, has been used by the Division to demonstrate the effectiveness of an architectural design technique, the 'drained joint principle'. Normally, joints in buildings are sealed to prevent rain from penetrating the walls. In contrast, the SIROWET rig allows rain to enter the joints between individual building panels, and between panels and windows. Once inside the joint, the water is prevented from penetrating further by a pressure equalisation and baffle system, and is drained away.

In a series of tests, the SIROWET rig was used to simulate a rainstorm in which water was driven against the facade and its joints, at a wind speed equivalent to 220 kilometres an hour. No leaks occurred.

The rig is shown here attached to a prototype building facade.

Photograph: Peter Lee

Computer techniques for weather forecasting and climate research

Computer techniques which simulate atmospheric processes are improving weather forecasting and leading to an understanding of longer term variations in climate.

Since the processes dealt with in atmospheric physics and chemistry are extremely complex, computer techniques must be used to solve the equations that describe them. Much of the atmospheric research undertaken by the ENVIRONMENTAL PHYSICS RESEARCH LABORATORIES involves the use of numerical 'models' which simulate atmospheric processes on a miniature scale, and complementary field and laboratory studies.

The 'models' are computer programs designed to solve complicated equations which describe the behaviour of the atmosphere in a specified area. The calculations must start from an initial state which must be fed into the computer. No computer could deal with the individual behaviour of the multitude of molecules and atmospheric particles in any area. Instead, only the behaviour of large masses of molecules and particles can be dealt with. For the purpose of weather forecasting, data on wind, temperature, rainfall and so forth are represented only at points marked out in a grid pattern covering the entire area. As these points are hundreds of kilometres apart, the model atmosphere is a gross simplification of the real one. For instance, eddies in the air occur on scales varying from the size of a pea to that of the whole earth. When the data are only represented at the grid points, the small eddies are inevitably missed, yet they have important roles in the overall scheme.

Thus, if the model is to represent the real behaviour of the atmosphere, the scientist is confronted with the daunting problem of arranging to include in his equations the effects of all the smaller movements and variations. The physical and chemical laws governing each particle and molecule are well known, but the unavoidable problem of dealing with the effects of small scale variations in physical elements such as temperature, pressure and wind will continue to tax the ingenuity of scientists for many years to come.

Before the models reached their present useful state of providing an insight into atmospheric processes and began to be applied in weather forecasting in some advanced countries, many other problems had to be solved. Two of the most basic problems were developing computers which were sufficiently powerful to process and store millions of instructions each second, and establishing adequate mathematical procedures for solving the millions of equations involved. The daily weather forecast, for instance, necessitates solving about 50 million mathematical equations and the only hope of arriving at satisfactory predictions is by using fast, modern, electronic computers to process the enormous amounts of data.

It is interesting to note that the first experimental numerical weather prediction, for a period of six hours, by the English meteorologist L. F. Richardson in 1918, was performed by hand, took six weeks to prepare and failed sadly, not because his equations were wrong, but because neither he nor anyone else knew how to specify the distribution of wind which must be in a state of delicate balance with the other weather data. Indeed, this scientific approach to weather forecasting had to be shelved for a generation until the electronic computer, ENIAC, came into use at Aberdeen, Maryland, in 1950.

Since then, technology in the fields of computing, communications and remote (satellite) observing has evolved to the extent that in the USA in 1976, forecasts for the major cities for periods of up to 36 hours could be almost left to the computers.

However, this advanced state of weather forecasting is presently out of reach in the southern hemisphere. Forecasts for several days require data from at least the whole hemisphere, and in the southern hemisphere the difficulties of establishing an adequate manned observing network to obtain comprehensive data appear to be insuperable. Fortunately, orbiting American satellites have been able to provide cloud photographs for the last 13 years and are now beginning to provide more sophisticated data from which the changes of temperature and moisture with altitude can be deduced fairly accurately. New refinements to this technology are bound to occur and are eagerly awaited.

A further boost to Australia's observing system will come from the Japanese Geostationary Meteorological Satellite to be stationed over Irian Jaya, Indonesia, later this year. It will give six-hourly cloud pictures of an area stretching from Japan to Tasmania and much information about wind derived from cloud movements. It will also help to track more accurately destructive cyclones like that which devastated Darwin in 1974.

THE AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE (ANMRC) was set up in 1969 to develop numerical methods for improving both the accuracy and range of weather forecasting, and for understanding the longer term variations in climate. The ANMRC is sponsored jointly by the Department of Science and CSIRO. In addition to constantly improving its prediction models, which are used by the Bureau of Meteorology in its daily forecasts, the ANMRC is investigating ways of extending the period of reliable forecasts to several days, and is also devising better ways of using the data from the United States' satellites.

Perhaps the most difficult but essential area of the ANMRC's charter is climate research. It is nationally important to know, for example, what makes one winter season markedly different from another, so that deviations from normal can be foreshadowed. It is also in the national interest to know the effect that increasing levels of carbon dioxide in the air, caused by burning coal and oil, will have on our climate, what effect aircraft traffic in the stratosphere or chemical pollutants introduced at ground level will have, and whether or when the earth will have another ice age.

The ANMRC has the facilities to study the atmospheric aspects of these problems. Numerical models simulating atmospheric behaviour are used in a series of controlled experiments in which conditions such as carbon dioxide levels or sea surface temperature are varied. Thus the effect of such variations on the real climate can be estimated.

In reality, however, the atmospheric aspect is only one facet of the problem. The interactions that occur between the atmosphere, the oceans, the earth's covering of snow and ice, and plant and animal life, and the effects of the varying heat of the sun, the debris thrown up by volcanoes, and the varying orbits of the earth and tilt of its axis must all be taken into account. Scientists at the ANMRC have made a start on investigating the interaction between air and water at the earth's surface. A simplified model has recently given some insight into the variations that can occur if this interaction is allowed for. An extension of this work will be to discover whether variations in sea surface temperature over the hemisphere could account for, or contribute to, the seasons of drought or flood that afflict various parts of Australia.

Smaller scale atmospheric problems, many of which are both interesting and locally important, can also be tackled by the technique of numerical modelling. The DIVISION OF ATMOSPHERIC PHYSICS has used numerical models in conjunction with field, laboratory and theoretical approaches to study some of these problems. These include the sea breezes that often trigger violent thunderstorms, air flow over mountains which has important effects on rainfall and clear air turbulence, and the behaviour of smoke-laden air in the Latrobe Valley. Such 'quality of life' issues will doubtless be much more thoroughly explored in the future.

The numerical work of the DIVISION OF CLOUD PHYSICS is more specialised and is largely concentrated upon the details of cloud formation and growth, and the production of rain. Sufficiently detailed information about such phenomena is not available from the normal meteorological network to serve as a basis for comparison with predictions from the theoretical models under development, and highly instrumented aircraft are used by the Division to make observations in the clouds themselves. For accurate predictions, the models should take into account not only the complex forces released but also the physical and chemical properties of the cloud nuclei and the minute moisture droplets, the raindrops and the hailstones. However, no computer would be capable of handling this mass of data, and scientists at the Division are endeavouring to find the best means of translating the amassed details into suitably simple forms.

The CSIRONET computing service

The DIVISION OF COMPUTING RESEARCH *provides a computing service to CSIRO Divisions and Commonwealth and State Government agencies from a large central computer, supported by an extensive communications network.*

In addition to carrying out research into computing techniques, the Division provides a computing service to users located throughout Australia. At present it is possible for nearly 2500 users registered with the Division to operate from any of the 13 major centres, scattered throughout Australia, at which the Division's facilities are available.

CSIRO's geographic circumstances require a service almost independent of locality. This has been achieved by providing a large centrally located computer (Cyber 76) in Canberra supported by an extensive network (CSIRONET) which enables jobs to be passed to and from the central computer.

A major central facility is a distinct advantage for several reasons.

- A large computer is more economical in terms of computing power per dollar of capital cost than a small computer.
- All users can take advantage of the large machine when necessary, even if most of their requirements are only for relatively small tasks.
- All the data stored in the central computer can be made available to users anywhere. This aspect is particularly important to CSIRO users as many research projects are collaborative and involve workers who are geographically separated.
- Large and expensive special purpose devices, for example, microfiche output, are available to all users.

The CSIRONET charges are calculated so that the service is self-supporting. In general, Commonwealth Government departments and instrumentalities and universities pay the same rates irrespective of their geographical location. State Government users, however, pay half as much again since State Governments do not contribute towards the capital cost of the equipment. Non-governmental bodies have access to the CSIRONET facilities only if comparable commercial facilities are not available, in which case charges are levied at commercial rates.

CSIRONET is the most extensive and versatile computing network in Australia. There are over 50 'nodes' throughout Australia, nine of which are owned by Government departments while the rest belong to CSIRO. A node consists of at least one input device (a card reader), one output device (a line printer), and several interactive terminals, all of which are controlled by Digital Equipment mini computers. Over 350 interactive terminals, belonging to CSIRO Divisions and other users, are connected to CSIRONET. Some of these are similar to typewriters and produce printed copy, some are like television screens and display letters and numbers, while other TV-like devices display graphs and diagrams. The choice of the type of interactive terminal depends on the kind of work being done as well as on personal preference.

The Cyber 76 can execute about 15 million instructions a second, and is able to store over half a million numbers or instructions in relatively high speed storage, while nearly 400 million data items can be stored on magnetic discs which are a relatively low speed storage medium. During a typical day, over 3000 batch jobs are processed, another 3000 on-line or interactive sessions are conducted, and over 100 000 pages of line printer output are sent to line printers at various nodes.

The article in this report entitled 'Computer techniques for weather forecasting and climate research' describes the application of the techniques of computer simulation and numerical modelling to weather forecasting. CSIRONET provides the service for this activity.

Finance and Buildings

General

While CSIRO's total expenditure for 1976/77 represented an increase of 14% over the 1975/76 level, in real terms there was a significant reduction in the Organization's level of staffing and funding compared with 1975/76. The staffing level of the Organization decreased as a result of a 1·3% reduction in the level of its staff ceiling for Appropriation funded activities, a reduction of 20% in the number of positions funded from the Wool Research Trust Fund and a slight decrease in positions supported from other fund sources.

The table below summarises the sources of CSIRO's funds for 1976/77 against the categories of expenditure.

The Organization's expenditure of $117·2 million of Appropriation Funds

Source of funds	Salaries and general running expenses ($)	Grants for studentships and grants to outside bodies ($)	Capital works and services and major items of equipment ($)	Total ($)
Appropriation, including revenue	117,181,753*	3,904,252	2,499,996	123,586,001
Wool Research Trust Fund	11,216,330	—	627,403	11,843,733
Meat Research Trust Account	2,552,450	—	8,755	2,561,205
Tobacco Industry Trust Account	21,462	—	—	21,462
Dairy Produce Research Trust Account	300,845	—	—	300,845
Wheat Research Trust Account	282,823	—	31,408	314,231
Fishing Industry Research Trust Account	135,032	—	51,253	186,285
Dried Fruits Research Trust Account	47,300	—	—	47,300
Chicken Meat Research Trust Account	—	—	78,391	78,391
Pig Industry Research Trust Account	25,564	—	743	26,307
Poultry Research Trust Account	—	—	10,429	10,429
Other contributors	5,578,794	—	3,182,799	8,761,593
Total	137,342,353	3,904,252	6,491,177	147,737,782

* Because of changed accounting procedures this amount includes $1,964,839 for computing, microanalytical and selective dissemination of information services which have not previously been reflected in this figure.

on salaries and general running expenses represents an increase of \$16·4 million over 1975/76. However, even after allowing for reductions in staff ceilings, \$9·3 million, or 57% of this increase, was absorbed by salary adjustments arising from Arbitration Determinations and by increments, reclassifications, and other inescapable commitments in the nature of salary. A further \$6·9 million was absorbed in offsetting increased costs of goods and services resulting from price rises and the occupation of new premises, including partial occupation of the new National Standards Laboratory at Bradfield Park. The remaining \$0·2 million was absorbed by commitments arising from the redeployment of staff previously funded by the Wool Research Trust Fund into Appropriation funded research programs.

Despite the reduction in staff levels, the Executive was able during the course of 1976/77 to redeploy some 70 positions into the expansion of activities in selected areas such as human nutrition, energy and fisheries and oceanography.

In regard to those research activities supported by Rural Industry Trust Funds, inflationary pressures on salaries and operating costs continued to make it difficult to maintain existing levels of research activities, and in the case of the Wool Research Trust Fund, the reduction in the real level of support for the Organization's sheep and wool research program in 1976/77 amounted to approximately 20%.

In addition to the money that CSIRO receives from the Government, from Industry and other contributors, some \$11·6 million was spent by the Department of Construction and the Department of Administrative Services on buildings and other works for CSIRO, and the acquisition of land. Some 84% of CSIRO's income was provided directly by the Commonwealth Government and Appropriation-derived General Revenue. Of the remaining 16%, some two-thirds was contributed from trust funds concerned with primary industries. Most of these funds are derived from a statutory levy on produce with a supporting contribution from the Commonwealth Government.

Buildings

As a result of the Government's policy of financial restraint in 1975–76 and 1976–77, a number of building projects have been deferred or have proceeded more slowly than would normally be the case. However, by the end of June, tenders had been let for all but one of the building projects included in the 1976–77 civil works program.

The construction of the National Measurement Laboratory at Bradfield Park, Sydney, continued to progress and it is expected that the whole laboratory complex will be completed during 1977.

Design work is continuing on the Australian National Animal Health Laboratory.

Work on the Centre for Animal Research and Development near Bogor, West Java, continued satisfactorily during the year and a number of buildings have been completed and occupied. This project is being undertaken by CSIRO in conjunction with the Australian Development Assistance Bureau.

Major projects completed during the year include:

FISHERIES AND OCEANOGRAPHY—Fisheries research laboratory at Marmion, W.A.—\$851,000.
COMPUTING RESEARCH—The third stage of a three-stage program totalling \$1,507,000 was completed during the year at Black Mountain, Canberra.

Major projects for which tenders were let during the year include:

BUILDING RESEARCH—Systems laboratory at Highett, Vic.—$887,000

CHEMICAL TECHNOLOGY—Laboratory pilot plant at Lower Plenty, Vic.—$443,000.

CLOUD PHYSICS—Laboratory extension at Epping, N.S.W.—$460,000.

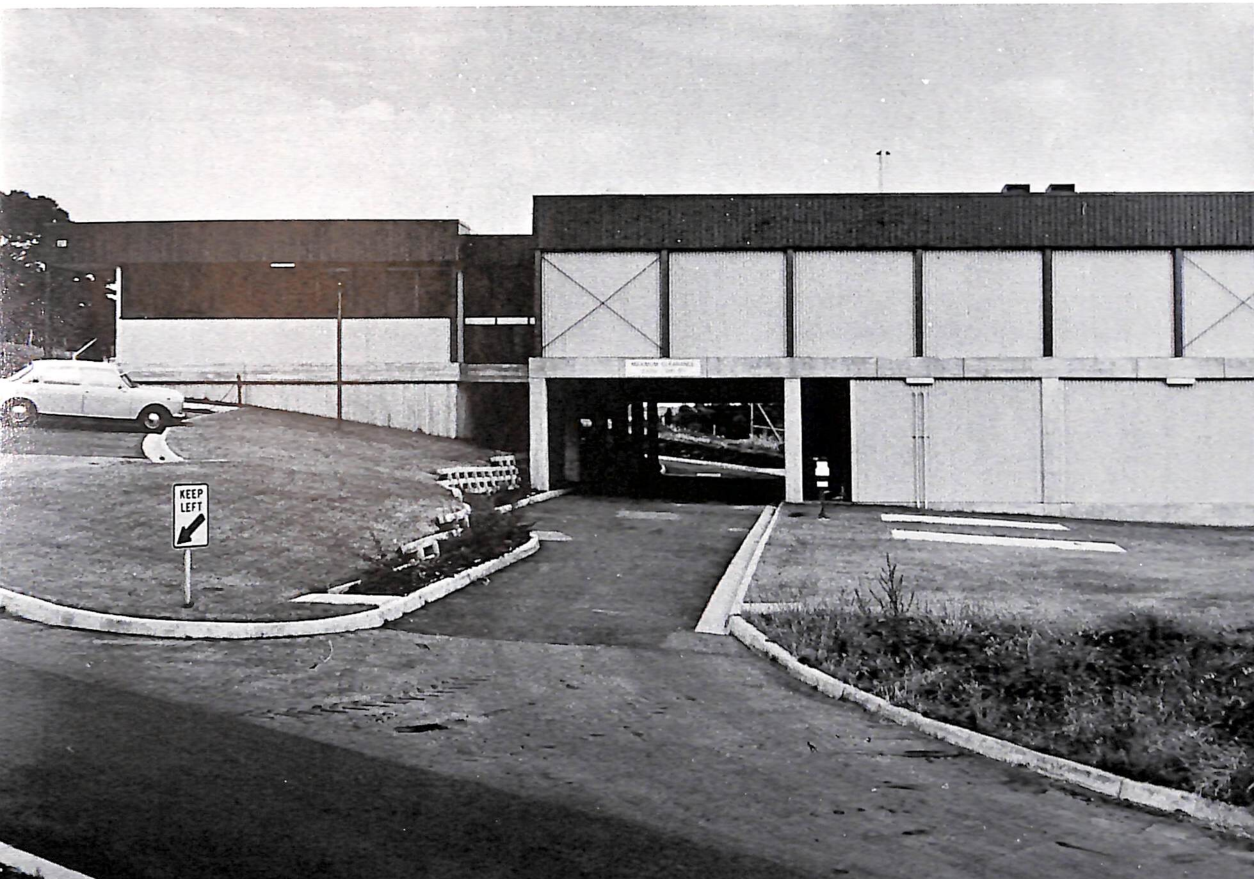
FOOD RESEARCH—Workshop and store complex at North Ryde, N.S.W.—$250,000.

LAND RESOURCES MANAGEMENT—Laboratory and offices at Alice Springs, N.T.—$735,000.

MINERALS RESEARCH LABORATORIES—Redevelopment of a laboratory for research into coal, minerals and iron ore at North Ryde, N.S.W.—$692,000.

The Specific Pathogen Free Poultry Building located at the DIVISION OF ANIMAL HEALTH's Maribyrnong Experiment Station. The building will house small flocks of poultry in isolators in a specific pathogen free environment.

Photograph: Eric Smith



Annual Expenditure

The following summary gives details of expenditure by CSIRO Divisions and Units on other than capital items from 1 July 1976 to 30 June 1977.

DIVISION OR UNIT	Appropriation Funds ($)	Contributory Funds ($)	Total ($)
Head Office			
The main items of expenditure under this heading are salaries and travelling expenses of the administrative staff at Head Office and the Regional Administrative Offices, salaries and expenses of officers at the Liaison Offices in London, Washington, Tokyo and Moscow and general office expenditure	8,864,196	36,557	8,900,753
Research Programs			
Animal Health and Reproduction			
Molecular and Cellular Biology Unit	930,762	668	931,430
Animal Health	4,380,694	1,096,758	5,477,452
Animal Production	3,785,689	3,183,123	6,968,812
Human Nutrition	1,470,483	27,074	1,497,557
Centre for Animal Research and Development, Indonesia	—	1,411,473	1,411,473
Plant Industry	6,576,799	556,173	7,132,972
Entomology and Wildlife			
Entomology	4,880,998	1,524,535	6,405,533
Wildlife Research	2,084,599	469,662	2,554,261
Horticulture and Irrigation			
Horticultural Research	1,397,491	58,465	1,455,956
Irrigation Research	1,146,513	48,861	1,195,374
Tropical Crops and Pastures	4,237,799	1,072,995	5,310,794
Land Resources			
Soils	3,675,087	67,359	3,742,446
Land Use Research	2,463,199	388,107	2,851,306
Land Resources Management	2,985,699	490,254	3,475,953
Forest Research	3,687,799	25,758	3,713,557
Processing of Agricultural Products			
Food Research	5,020,197	1,124,359	6,144,556
Wheat Research	146,994	162,497	309,491
Textile Industry	318,448	2,961,377	3,279,825
Textile Physics	446,061	1,872,912	2,318,973
Protein Chemistry	908,098	1,568,101	2,476,199
Fisheries and Oceanography			
Fisheries and Oceanography	5,341,597	111,096	5,452,693
Marine Biochemistry Unit	111,639	—	111,639
Chemical Research of Industrial Interest			
Applied Organic Chemistry (including Microanalytical Laboratory)	2,454,281	254,442	2,708,723
Chemical Physics	2,225,096	—	2,225,097
Chemical Technology	2,266,972	157,145	2,424,116

DIVISION OR UNIT	Appropriation Funds ($)	Contributory Funds ($)	Total ($)
Minerals and Solar Energy Research			
Mineral Research Laboratory, Clayton	1,807,798	22,347	1,830,145
Mineral Research Laboratory, Port Melbourne	2,761,397	123,456	2,884,853
Mineral Research Laboratory, Floreat Park	1,094,289	27,681	1,121,970
Mineral Research Laboratory, North Ryde	4,510,990	216,557	4,727,547
Baas Becking Geobiological Group	15,000	51,000	66,000
Solar Energy Studies Unit	102,761	5	102,766
Physical Research of Industrial Interest			
National Measurement Laboratory	6,822,467	—	6,822,467
General Physical Research			
Radiophysics	3,753,816	317,685	4,071,501
Atmospheric Physics	1,909,845	6,355	1,916,200
Cloud Physics	1,047,400	18,494	1,065,894
Environmental Mechanics	608,698	5,415	614,113
Australian Numerical Meteorology Research Centre	273,247	—	273,247
General Industrial Research			
Building Research	4,774,385	79,715	4,854,100
Tribophysics	2,055,298	57,494	2,112,792
Applied Geomechanics	1,662,292	311,255	1,973,547
Mechanical Engineering	1,662,998	119,470	1,782,468
Research Services			
Computing Research	2,654,093	267	2,654,360
Mathematics and Statistics	2,164,798	—	2,164,798
Contract Research	11,100	—	11,100
Extra-mural Grants	210,464	—	210,464
Australian Mineral Development Laboratories	80,000	—	80,000
Developmental projects	267,319	—	267,319
Information and Publications			
Central Information, Library and Editorial Section	3,092,256	—	3,092,256
Film and Video Centre	194,198	—	194,198
Miscellaneous	1,837,654	133,653	1,971,307
Grants			
Research Associations	843,821	—	843,821
Research Studentships	345,175	—	345,175
Other grants and contributions	2,715,256	—	2,715,256
Total expenditure	**121,086,005**	**20,160,600**	**141,246,605**

Capital Expenditure under CSIRO Control

The table which follows shows capital expenditure from funds made available directly to CSIRO. It includes expenditure on capital and developmental works and on items of equipment costing more than $20,000 each

DIVISION OR UNIT	Appropriation Funds ($)	Contributory Funds ($)	Total ($)
Head Office	8,112	—	8,112
Animal Health and Reproduction			
Molecular and Cellular Biology Unit	34,149	—	34,149
Animal Health	96,305	101,205	197,510
Animal Production	48,013	179,002	227,015
Human Nutrition	107,896	—	107,896
Centre for Animal Research and Development, Indonesia	—	2,990,800	2,990,800
Plant Industry	159,547	49,569	209,116
Entomology and Wildlife			
Entomology	105,458	—	105,458
Wildlife Research	48,179	—	48,179
Horticulture and Irrigation			
Horticultural Research	167,369	3,725	171,094
Irrigation Research	2,650	—	2,650
Tropical Crops and Pastures	93,767	54,484	148,251
Land Resources			
Soils	15,592	995	16,587
Land Use Research	46,498	—	46,498
Land Resources Management	84,080	2,182	86,262
Forest Research	48,452	—	48,452
Processing of Agricultural Products			
Food Research	309,582	401	309,983
Wheat Research	3,000	—	3,000
Textile Industry	—	78,660	78,660
Textile Physics	—	394,044	394,044
Protein Chemistry	1,053	54,448	55,501
Fisheries and Oceanography	77,260	51,253	128,513
Chemical Research of Industrial Interest			
Applied Organic Chemistry	12,449	—	12,449
Chemical Physics	7,340	—	7,340
Chemical Technology	81,180	—	81,180
Processing and Use of Mineral Products			
Mineral Research Laboratory, Clayton	2,000	—	2,000
Mineral Research Laboratory, Port Melbourne	97,849	—	97,849
Mineral Research Laboratory, Floreat Park	191	—	191
Mineral Research Laboratory, North Ryde	141,510	—	141,510
Physical Research of Industrial Interest			
National Measurement Laboratory	410,461	—	410,461
General Physical Research			
Radiophysics	60,924	—	60,924
Atmospheric Physics	46,416	—	46,416
Environmental Mechanics	3,859	—	3,859

General Industrial Research			
Building Research	48,516	—	48,516
Tribophysics	48,470	—	48,470
Mechanical Engineering	76,759	30,413	107,172
Research Services			
Computing Research	1,526	—	1,526
Information and Publications			
Central Information, Library and Editorial Section	595	—	595
A.C.T. Black Mountain Library	2,704	—	2,704
Tasmanian Regional Laboratory	285	—	285
Total capital expenditure	**2,499,996**	**3,991,181**	**6,491,177**

AUDITOR-GENERAL'S OFFICE
Canberra House, Marcus Clarke St.,
Canberra City, A.C.T. 2601
8 September 1977

The Honourable the Minister
for Science,
Parliament House,
CANBERRA, A.C.T.

Dear Sir,

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

In compliance with section 30(2) of the Science and Industry Research Act 1949, financial statements of the Commonwealth Scientific and Industrial Research Organization for the year ended 30 June 1977 have been submitted for my report. These comprise—

Summary of Receipts and Payments
Consolidated Statement of Payments
Statement of Payments—Special Account
Statement of Payments—Specific Research Account.

One set of the statements, which are in the form approved by the Treasurer, is attached.

I now report in terms of section 30(2) of the Act that in my opinion—

(a) the accompanying statements are based on accounts and financial records kept in accordance with the Act;
(b) the statements are in agreement with the accounts and financial records and, to the extent these are reflected in statements prepared on a cash rather than an accrual basis, show fairly the financial operations of the Organization; and
(c) the receipt, expenditure and investment of moneys, and the acquisition and disposal of other property, by the Organization during the year have been in accordance with the Act.

Yours faithfully,

(Sgd) D. R. STEELE CRAIK

(D. R. STEELE CRAIK)
AUDITOR-GENERAL

Summary of Receipts and Payments

	Funds held 1 July 1976 ($)	Receipts ($)	Total funds available ($)	Payments ($)	Funds held 30 June 1977 ($)
Special Account	455,442 (393,496)**	123,467,074* (104,735,593)	123,922,516 (105,129,089)	123,586,001 (104,673,647)	336,515 (455,442)
Specific Research Account	3,005,923 (2,059,078)	24,020,165 (24,413,821)	27,026,088 (26,472,899)	24,151,781 (23,466,977)	2,874,307+ (3,005,922)
Other Trust Moneys‡	267,426 (151,456)	1,686,060 (1,678,459)	1,953,486 (1,829,915)	1,521,903 (1,562,489)	431,583 (267,426)
Cafeteria Account§	5,903 (1,966)	1,176 (47,612)	7,079 (49,578)	7,079 (43,675)	— (5,903)
Total	**3,734,694** **(2,605,996)**	**149,174,475** **(130,875,485)**	**152,909,169** **(133,481,481)**	**149,266,764** **(129,746,788)**	**3,642,405** **(3,734,693)**

* Comprises:

	$	$
Appropriations—Consolidated Revenue Fund		
Operational	118,350,000	
Capital	2,500,000	
		120,850,000
Revenue and Other Receipts		
Sale of Publications	153,370	
Receipts in respect of expenditure of former years	212,967	
Sale of produce, including livestock	215,283	
Royalties from patents	84,371	
Fees for tests and other services	161,767	
Computing service charges	1,641,695	
Miscellaneous receipts	147,621	
		2,617,074
		123,467,074

** Figures in brackets refer to 1975/76 financial year.

+ Includes investments totalling $166,200.

‡ Moneys held temporarily on behalf of other organisations and individuals.

§ Operating receipts and expenses of CSIRO Cafeteria at Melbourne which was closed during 1976/77. Payments of $7,079 include accumulated profits of $3,579 repaid to Special Account and included in Miscellaneous receipts above.

V. D. Burgmann (*Chairman*)   I. C. Bogg (*Acting Senior Assistant Secretary, Finance and Properties*)

Consolidated Statement of Payments

1975/76 ($)		1976/77 ($)
	Head Office (including Regional Administrative Offices)	
5,962,401	Salaries and allowances	6,492,265
277,461	Travelling and subsistence	299,284
521,217	Postage, telegrams and telephone	574,670
1,390,325	Incidental and other expenditure	1,534,534
8,151,404		8,900,753
	Research Programs	
	Agricultural research	
13,931,914	Animal health and reproduction	16,286,724
6,434,580	Plant industry	7,132,972
8,075,780	Entomology and wildlife	8,959,794
2,483,717	Horticulture and irrigation	2,651,330
4,737,860	Tropical crops and pastures	5,310,794
9,195,449	Land resources	10,069,705
2,929,173	Forest research	3,713,557
12,565,552	Processing of agricultural products	14,529,044
4,713,880	Fisheries and oceanography	5,564,332
6,322,960	Chemical research of industrial interest	7,357,936
8,908,609	Mineral and solar energy research	10,733,281
5,810,400	Physical research of industrial interest	6,822,467
6,880,220	General physical research	7,940,955
9,583,703	General industrial research	10,722,907
3,271,579	Research services	5,388,041
2,758,357	Information and publications	3,286,454
1,291,225	Miscellaneous	1,971,307
109,894,958		128,441,600
	Grants	
771,526	Research associations	843,821
428,048	Research studentships	345,175
2,353,000	Other grants and contributions	2,715,256
3,552,574		3,904,252
	Capital Works and Services	
4,664,677	Buildings, works, plant and developmental expenditure	4,398,327
1,323,772	Major items of laboratory equipment	2,092,850
443,239	Expansion of CSIRO computer network	—
110,000	Construction of research vessel	—
6,541,688		6,491,177
	Other Trust Moneys	
580,313	Remittance of revenue from investigations financed from Industry Trust Accounts	607,501
982,176	Other miscellaneous remittances	914,402
1,562,489		1,521,903

1975/76 ($)		1976/77 ($)
	Cafeteria Account	
43,675	Operating expenses of CSIRO cafeteria at Melbourne	3,500
—	Transfer of balance to Miscellaneous receipts	3,579
43,675		7,079
129,746,788	**Total Expenditure**	**149,266,764**

V. D. Burgmann (*Chairman*)

I. C. Bogg (*Acting Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Special Account*

1975/76 ($)		1976/77 ($)
	Head Office (including Regional Administrative Offices)	
5,949,754	Salaries and allowances	6,475,954
277,461	Travelling and subsistence	299,206
521,217	Postage, telegrams and telephone	574,670
1,350,852	Incidental and other expenditure	1,514,366
8,099,284		8,864,196
	Research Programs	
	Agricultural research	
8,365,783	Animal health and reproduction	10,567,628
5,783,298	Plant industry	6,576,799
6,218,394	Entomology and wildlife	6,965,597
2,352,397	Horticulture and irrigation	2,544,004
3,878,298	Tropical crops and pastures	4,237,799
8,098,073	Land resources	9,123,985
2,903,215	Forest research	3,687,799
5,400,477	Processing of agricultural products	6,839,798
4,615,895	Fisheries and oceanography	5,453,236
5,939,368	Chemical research of industrial interest	6,946,349
8,521,854	Minerals and solar energy research	10,292,235
5,810,400	Physical research of industrial interest	6,822,467
6,661,027	General physical research	7,593,006
9,131,305	General industrial research	10,154,973
3,271,293	Research services	5,387,774
2,758,357	Information and publications	3,286,454
1,006,255	Miscellaneous	1,837,654
90,715,689		108,317,557
	Grants	
771,526	Research associations	843,821
428,048	Research studentships	345,175
2,353,000	Other grants and contributions	2,715,256
3,552,574		3,904,252
	Capital Works and Services	
599,919	Buildings, works, plant and developmental expenditure	699,997
1,152,943	Major items of laboratory equipment	1,799,999
443,239	Expansion of CSIRO computer network	—
110,000	Construction of research vessel	—
2,306,101		2,499,996
104,673,648	**Total Expenditure**	**123,586,001**

* Special Account refers to moneys paid to CSIRO out of the Consolidated Revenue Fund of the Commonwealth and other related moneys specifically covered by Section 26C of the Science and Industry Research Act 1949.

V. D. Burgmann (*Chairman*)   I. C. Bogg (*Acting Senior Assistant Secretary, Finance and Properties*)

Statement of Payments—Specific Research Account

1975/76 ($)		1976/77 ($)
	Head Office (including Regional Administrative Offices)	
12,647	Salaries and allowances	16,311
—	Travelling and subsistence	78
39,473	Incidental and other expenditure	20,168
52,120		36,557
	Research Programs	
	Agricultural research	
5,566,131	Animal health and reproduction	5,719,096
651,282	Plant industry	556,173
1,857,386	Entomology and wildlife	1,994,197
131,320	Horticulture and irrigation	107,326
859,562	Tropical crops and pastures	1,072,995
1,097,376	Land resources	945,720
25,958	Forest research	25,758
7,165,075	Processing of agricultural products	7,689,246
97,985	Fisheries and oceanography	111,096
383,592	Chemical research of industrial interest	411,587
386,755	Minerals and solar energy research	441,046
219,193	General physical research	347,949
452,398	General industrial research	567,934
286	Research services	267
284,970	Miscellaneous	133,653
19,179,269		20,124,043
	Capital Works and Services	
4,064,758	Buildings, works, plant and developmental expenditure	3,698,330
170,829	Major items of laboratory equipment	292,851
4,235,587		3,991,181
23,466,976	**Total Expenditure**	**24,151,781**

V. D. Burgmann (*Chairman*)   I. C. Bogg (*Acting Senior Assistant Secretary, Finance and Properties*)

Research Activities

The various CSIRO Divisions, their fields of research, and the location of their laboratories and field stations are as follows:

ANIMAL HEALTH

Diseases of livestock and poultry caused by bacteria, viruses, mycoplasmas, protozoa and plant poisons; external parasites—cattle tick, lice and biting insects—as potential transmitters of disease; worm parasites of sheep and cattle; immunology.

Melbourne, with laboratories in Sydney and Brisbane, with units at Armidale, N.S.W., Rockhampton and Townsville, Qld, and Perth. Field stations at Maribyrnong, Seymour and Werribee, Vic., Badgery's Creek, N.S.W., and Jimboomba, Qld.

ANIMAL PRODUCTION

Physiology, endocrinology, nutrition and ecology of sheep and cattle in relation to reproductive performance and improved efficiency of wool and meat production; development of practices which combine high levels of animal production with efficient fertiliser use; control of metabolic disorders in grazing ruminants; use of chemical methods for defleecing sheep; identifying causative factors that lead to losses from fleece rot and fly strike. Genetics and its application to Australian animal industries; genetics and the improvement of beef cattle, dairy cattle, sheep and poultry through breeding and selection.

Sydney, with the Genetics Research Laboratories at North Ryde, N.S.W., the Pastoral Research Laboratory at Armidale, N.S.W., the Bloat Research Unit at Melbourne, the Tropical Cattle Research Centre and National Cattle Breeding Station, 'Belmont', at Rockhampton, Qld, the Trace Element Research Unit at Perth, research stations at Armidale and Badgery's Creek, N.S.W., and a field investigation unit at Wollongbar, N.S.W.

APPLIED GEOMECHANICS

Studies of the environmental and geometric factors, *in situ* conditions, structural geology and material properties relevant to the mechanical behaviour of soil and rock masses; the prediction and monitoring of the performance of such masses; the application of established principles to examine the stability and assist in the design of surface and underground mines in both the metalliferous and coal sectors; similar applications in civil engineering to examine the behaviour of coastal and offshore structures, earth and rockfill dams, and building foundations.

Melbourne, with a laboratory in Adelaide and field stations at Cobar, N.S.W., and Mackay, Qld.

APPLIED ORGANIC CHEMISTRY

Application of chemistry to problems of national and industrial importance with particular interest in biological organic chemistry, polymer science, and energy and environmental studies.
Investigations into the application of organic chemistry to animal husbandry problems; chemical control of insects and ticks; chemical storage of solar energy; water pollution by heavy metals and organic compounds; development of specialised polymers; surface science; useful chemicals from coal.

Melbourne.

ATMOSPHERIC PHYSICS

Physical and chemical atmospheric processes that underlie and control the weather and climate, and are responsible for the distribution of airborne material (whether in solid, liquid or gaseous phase) including pollutants. This covers research into those aspects of the oceans that affect the atmosphere. Methods include field work, theoretical studies, laboratory and numerical models, and analyses of globally derived data.

Melbourne.

BUILDING RESEARCH

Development of the built environment, community planning and urban design; systems research; physical performance of buildings in relation to the well-being of occupants; building operations and economics; structural design and engineering; conversion of forest products for the production of wood-based building elements; conservation and rehabilitation; design and improvement of building components and systems; fire behaviour of plastics; development, processing and properties of building materials.

Melbourne.

CHEMICAL ENGINEERING

For research activities, see Minerals Research Laboratories.

Melbourne.

CHEMICAL PHYSICS

Development and application of chemico-physical techniques and instruments in the fields of spectroscopy, mass spectroscopy, electron diffraction, electron microscopy, X-ray diffraction, theoretical chemistry and solid-state chemistry.

Melbourne.

CHEMICAL TECHNOLOGY

Application of chemical technology and particularly polymer technology to developing ways whereby Australia's renewable and recycling resources can be more effectively utilised and protected. Investigations include fractionation of plants to produce fibre in conjunction with protein and other marketable products; studies of pulp and paper and the use of cellulose materials in packaging, writing, printing and building products; assessment of the technological potential of forest resources; technology of purifying and recycling water; liquid fuel production from cellulose; and bioenergetics.

Melbourne; the Agroindustrial Systems Program at Canberra with two officers at Townsville, Qld, and an experimental station at Lower Plenty, Vic.

CLOUD PHYSICS

Natural mechanisms of cloud and rain formation; artificial induction of rainfall by techniques such as cloud-seeding; studies of atmospheric particles.

Sydney.

COMPUTING RESEARCH

Properties of computer-operating systems, classification methods, picture processing and graphics, simulation languages and techniques and their applications, data-base management systems, development and implementation of computer languages. Provision of a scientific and technical computing service to users in other CSIRO Divisions, government departments and some universities by means of a computing network called CSIRONET which links the central computer in Canberra with smaller computers in all State capitals and certain other cities in various parts of Australia.

Canberra, with branch offices in Adelaide, Brisbane, Hobart, Melbourne, Perth, Sydney, *and at Armidale and Griffith, N.S.W., and Rockhampton and Townsville, Qld.*

ENTOMOLOGY

Taxonomy, ecology, population dynamics, genetics, behaviour, physiology and biochemistry of insects, particularly in relation to the development of methods of control that reduce or eliminate the disadvantages commonly associated with the use of pesticides. Special emphasis is placed on biological control of insect pests and weeds by introducing specific natural enemies into Australia.

Canberra, with laboratories in Brisbane, Perth and Sydney, and field stations at Armidale, Trangie, Warrawee and Wilton, N.S.W., Rockhampton and Amberley, Qld, Hobart, and Port Moresby, Papua New Guinea. The Division also has biological control units at Curitiba, Brazil, Montpellier, France, and Pretoria, South Africa.

ENVIRONMENTAL MECHANICS

Physical investigations of energy exchange and of the movement of natural and introduced substances (e.g. water, carbon dioxide, salts, fertilisers) in the environment, with special reference to plants, soils, and the lower layers of the atmosphere; their application to problems in agriculture, ecology, hydrology, meteorology, and industrial processes; mathematical aspects of ecology.

Canberra.

FISHERIES AND OCEANOGRAPHY

Survey and appraisal of certain marine fishery resources including rock lobsters, prawns and pelagic fisheries of the south-eastern area of Australia; biology of the western rock lobster and prawn species of commercial importance; biological, chemical and physical oceanography of south-east Indian Ocean and south-west Pacific Ocean; studies on the dynamics of Australian estuarine ecosystems.

Sydney, with regional laboratories in Brisbane and Perth, and a field laboratory at Karumba, Qld.

FOOD RESEARCH

Properties, preservation, processing, packaging, storage and transport of foods in relation to quality at the consumer level; microbial physiology and methodology; membrane structure and biochemistry; identification and evaluation of flavours; plant physiology; polyunsaturated meat and dairy products; new protein and dairy foods; treatment and utilisation of processing wastes.

Sydney, with the Meat Research Laboratory, Brisbane; Dairy Research Laboratory, Melbourne; Tasmanian Food Research Unit, Hobart.

FOREST RESEARCH

Long-term studies in such fields as resource assessment and production; tree pests, diseases, genetics and physiology; forest hydrology, ecology, taxonomy and harvesting; fire in forests.

Canberra, with laboratories in Hobart, Perth, Darwin, Atherton, Qld, Traralgon, Vic., and Mt Gambier, S.A.

HORTICULTURAL RESEARCH

Introduction and adaptation of fruit crops to Australian environments; breeding of wine and drying grapes; management of fruit trees and grapevines including effects of nematodes, viruses and salinity; processing of dried grapes; physiology and biochemistry of horticultural plants; domestication of Australian native plants.

Adelaide, with a laboratory and field station at Merbein, Vic., and with an officer stationed at both Darwin and Hobart.

HUMAN NUTRITION

The investigation of processes in human nutrition, including biochemical and physiological aspects of nutrition in relation to growth and development. Epidemiological studies of nutrition and human health.

Adelaide.

IRRIGATION RESEARCH

Crop growth, management and quality of irrigated crops, especially vegetables and oil-seed crops; water quality and management in irrigation; environmental plant physiology, and biochemistry and engineering aspects of intensive crop production.

Griffith.

LAND RESOURCES MANAGEMENT

Development of principles for management of land resources for efficient productivity consistent with their conservation. Environmental and societal implications of land use in pastoral, agricultural, forested and near-urban areas. Development of methods of processing and communicating data to assist land use decision making.

Perth, with laboratories at Deniliquin, N.S.W., Alice Springs, N.T., and field stations at Baker's Hill, W.A., and Deniliquin, N.S.W.

LAND USE RESEARCH

Inventory of land and water resources and assessment of their current and potential uses. Development of methods for relating these natural and socio-economic resources in developing balanced land use planning techniques; ecology and conservation of woodlands.

Canberra, with a laboratory at Lawes, Qld.

MATHEMATICS AND STATISTICS

The development of suitable mathematical models and methods of statistical analysis for research in agricultural, biological, environmental, industrial and physical sciences. Basic research in mathematics and statistics. The Division provides advisory and consultative services to other Divisions and outside bodies on mathematical and statistical problems.

Canberra, with officers stationed at Adelaide, Brisbane, Hobart, Melbourne, Perth and Sydney, and at Armidale, N.S.W., and Townsville, Qld.

MECHANICAL ENGINEERING

Utilization of recoverable energy resources; engineering associated with agricultural crop production and storage; human environmental engineering and noise control; underwater engineering; transportation engineering.

Melbourne.

MINERAL CHEMISTRY

For research activities, see Minerals Research Laboratories.

Melbourne.

MINERAL PHYSICS

For research activities, see Minerals Research Laboratories.

Sydney, with a laboratory in Melbourne.

MINERALOGY

For research activities, see Minerals Research Laboratories.

Perth, with laboratories in Canberra and Sydney.

MINERALS RESEARCH LABORATORIES

Field and laboratory work to help indicate where useful mineral deposits might occur in Australia; development of search and localisation techniques designed to provide direct evidence for the existence of petroleum and mineral deposits; the exploitation of properties of rocks and minerals to improve the efficiency of their mining, concentration and handling; the adaptation, improvement and control of methods for processing and treating mineral and other resources; the reduction, and possible utilisation, of solid, liquid and gaseous wastes from recovery and use of minerals, together with a study of atmospheric pollutants in urban and industrial environments; the assessment and utilisation of fossil fuels in Australia, including the conversion of coal into solid, liquid and gaseous fuels, and the development of alternative sources of energy and alternative processes for treatment of minerals and other materials designed to reduce the demand on scarce energy resources.

The Minerals Research Laboratories comprise the Divisions of Chemical Engineering, Mineral Chemistry, Mineral Physics, Mineralogy and Process Technology. For locations see separate entries.

NATIONAL MEASUREMENT LABORATORY

Establishment and maintenance of the Commonwealth legal standards for the measurement of physical quantities; problems associated with precise measurements; magnetic and dielectric properties of materials; solid-state physics; physics of fluids; optics; acoustics; solar physics; molecular collisions; air glow.

Sydney, with an optical observatory at the CSIRO Solar Observatory, Culgoora, N.S.W.

PLANT INDUSTRY

Research in the plant sciences as a basis for the development and utilisation of crops and pastures better adapted to Australian conditions; taxonomy and ecology of Australian vegetation.

Canberra, with a Cotton Research Unit at Narrabri, N.S.W., ecology units at Brisbane, and Waste Point, N.S.W., and experiment stations at Canberra and Burren Junction, N.S.W.

PROCESS TECHNOLOGY

For research activities, see Minerals Research Laboratories.

Sydney.

PROTEIN CHEMISTRY

Structure and chemistry of wool fibres as a basis for developing new and improved wool manufacturing processes; development of improved methods for preserving hides and skins and for leather manufacture; development of methods for producing physiologically active proteins for clinical use; structure and properties of proteins of meat and of plants.

Melbourne.

RADIOPHYSICS

Cosmic and solar radio astronomy; development of microwave instrument landing systems for aircraft.

Sydney, with the Australian National Radio Astronomy Observatory at Parkes, N.S.W., and a radio observatory at the CSIRO Solar Observatory, Culgoora, N.S.W.

SOILS

Physics, chemistry, mineralogy and biology of soils in relation to growth and health of plants, animals and man. Soils in relation to forestry, water supplies and land use problems in urban and rural areas.

Adelaide, with laboratories in Brisbane, Canberra, Hobart, and Townsville, Qld.

TEXTILE INDUSTRY

Development of new and improved methods and machinery for processing wool; development of new and improved textile products from wool; relationships between fleece properties and processing; new uses for wool; environmental studies; cotton processing.

Geelong.

TEXTILE PHYSICS

Development of methods of sampling and testing wool as an aid to marketing and manufacturing; studies of packaging and transport of wool; processing trials; physical properties and behaviour of wool and wool products; coloration of wool fabrics; physical and colloidal properties of coals, chars, and other mineral systems.

Sydney.

TRIBOPHYSICS

Properties, behaviour and utilisation of industrially important metals, alloys, ceramics and refractories; structure of these materials in relation to bulk properties such as strength and plasticity and surface reactions such as catalysis, adsorption and oxidation.

Melbourne.

TROPICAL CROPS AND PASTURES

Development of efficient systems for beef production in northern Australia (excluding arid zones); research on some tropical field crops; agronomic research integrated with work on introduction, selection and breeding of new pasture and crop varieties; studies on pasture and crop nutrition, genetics, physiology and biochemistry, and on legume nodulation and animal nutrition.

Brisbane, with laboratories at Townsville and Lawes, Qld, and field stations at Beerwah, Mundubberra, Samford and Woodstock, Qld, Katherine, N.T., and Kununurra, W.A.

WILDLIFE RESEARCH

Biology of birds and mammals, both native and introduced, in relation to pest control and conservation. Species investigated include those which are clearly pests, such as the rabbit, those which are exploited, such as the water-fowl and quail, and those which need to be conserved.

Canberra, with laboratories at Perth and Darwin, and staff located at North Ryde and Prospect, N.S.W.

In addition to the Divisions, CSIRO has five smaller research units. They are:

AUSTRALIAN NUMERICAL METEOROLOGY RESEARCH CENTRE

Development of numerical models which simulate atmospheric behaviour, and their use for the purpose of improving the accuracy and time scale of weather forecasts, and improving the understanding of the distribution and variations of climate on the earth.

Melbourne. The Centre is jointly sponsored by CSIRO and the Department of Science.

CENTRE FOR ANIMAL RESEARCH AND DEVELOPMENT

Research in the field of animal husbandry with the general aim of increasing the production and the efficiency of the livestock industries in Indonesia.

Bogor, West Java, Indonesia.

SOLAR ENERGY STUDIES UNIT

Development of policy and planning of research within CSIRO on the use of solar energy and advising Executive on allocation of resources; feasibility studies; analysis and provision of data; contact with research workers in Australia and overseas.

Melbourne.

MOLECULAR AND CELLULAR BIOLOGY UNIT

Molecular evolution of influenza virus; DNA breakage and repair and its application to the development of new antibiotic systems; mechanisms of differentiation and the properties of differentiation factors.

Sydney.

WHEAT RESEARCH UNIT

Structure and biochemistry of the wheat grain and relationship to flour quality; investigations into rapid methods of grain sampling and testing, including protein determination and wheat variety identification.

Sydney.

Organisation

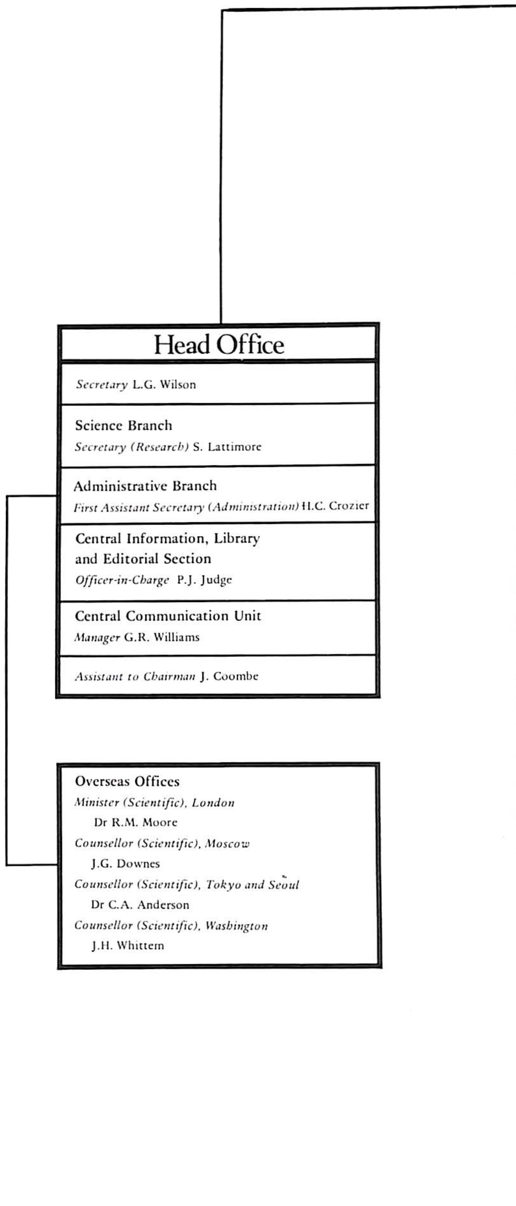
CSIRO has a total staff of about 6,950 people located in more than 100 laboratories and field stations throughout Australia. About one-third of the staff are scientists.

The Science and Industry Research Act 1949 provides for CSIRO to be governed by an Executive comprising a full-time Chairman, four other full-time members and four part-time members. The filling of an existing vacancy for a full-time member of the Executive has been deferred pending the outcome of the external inquiry into CSIRO. The Executive has adopted the practice of inviting senior members of its scientific staff to serve as associate members for a limited period to fulfil special needs; three persons are currently performing this function.

CSIRO has 37 research Divisions, each led by a Chief who is responsible to the Executive for the work of that Division. There are also five smaller research Units. A number of Divisions have been linked together in what are known as Group Laboratories.

The Executive is assisted in the implementation, administration and development of its policies by a Secretariat with headquarters in Canberra. Some administrative functions are undertaken at regional offices in Brisbane, Canberra, Melbourne, Perth and Sydney.

The chart opposite shows the organisational structure of CSIRO as at 1 July 1977.



Executive

Chairman
V.D. Burgmann

Members
- Dr N.K. Boardman
- Dr A.E. Pierce
- Professor Emeritus H.W. Worner

Part-time Members
- Professor M.E. Holman
- V.E. Jennings
- Sir William Vines
- Sir Frederick Wiltshire

Associate Members
- Dr K.A. Ferguson
- Dr R.J. Millington
- Dr J.P. Wild

Divisions and Chiefs

Animal Research Laboratories

Animal Health	Dr A.K. Lascelles
Animal Production	Dr T.W. Scott

Animal Research Laboratories Committee
Chairman Dr K.A. Ferguson

Applied Chemistry Laboratories

Applied Organic Chemistry	Dr D.H. Solomon
Chemical Technology	Dr D.E. Weiss

Applied Chemistry Laboratories Committee
Chairman Dr S.D. Hamann

Environmental Physics Research Laboratories

Atmospheric Physics	Dr G.B. Tucker
Cloud Physics	J. Warner
Environmental Mechanics	Dr J.R. Philip

Environmental Physics Research Laboratories
Chairman Dr C.H.B. Priestley

Land Resources Laboratories

Land Resources Management	R.A. Perry
Land Use Research	J.J. Basinski (*Acting*)
Soils	Dr A.E. Martin

Land Resources Laboratories Committee
Chairman Dr E.G. Hallsworth

Minerals Research Laboratories

Chemical Engineering	Dr D.F. Kelsall
Mineral Chemistry	Dr D.F.A. Koch
Mineral Physics	Dr K.G. McCracken
Mineralogy	A.J. Gaskin
Process Technology	A.V. Bradshaw

Minerals Research Laboratories
Director I.E. Newnham

Wool Research Laboratories

Protein Chemistry	Dr W.G. Crewther
Textile Industry	Dr D.S. Taylor
Textile Physics	A.R. Haly

Wool Research Laboratories Committee
Chairman Dr D.S. Taylor

Applied Geomechanics	Dr G.D. Aitchison
Building Research	Dr R.W.R. Muncey
Chemical Physics	Dr A.L.G. Rees
Computing Research	Dr P.J. Claringbold
Entomology	Dr D.F. Waterhouse
Fisheries and Oceanography	Dr K. Radway Allen
Food Research	M.V. Tracey
Forest Research	Dr M.F.C. Day
Horticultural Research	Dr J.V. Possingham
Human Nutrition	Dr B.S. Hetzel
Irrigation Research	Dr H.D. Barrs (*Acting*)
Mathematics and Statistics	Dr J.M. Gani
Mechanical Engineering	Dr B. Rawlings
Plant Industry	Dr L.T. Evans
Radiophysics	H.C. Minnett (*Acting*)
Tribophysics	Dr J.R. Anderson
Tropical Crops and Pastures	Dr E.F. Henzell
Wildlife Research	Dr H.J. Frith

National Measurement Laboratory
F.J. Lehany *Director*

Units and Officers-in-Charge

Solar Energy Studies
R.N. Morse *Director*

Wheat Research
E.E. Bond

Australian Numerical Meteorology Research Centre
R.H. Clarke

Centre for Animal Research and Development
A.F. Gurnett-Smith

Molecular and Cellular Biology
Dr G.W. Grigg (*Acting*)

Advisory Council

Executive

V. D. Burgmann, C.B.E., B.Sc., B.E. (*Chairman*)
N. K. Boardman, M.Sc., Ph.D., Sc.D., F.A.A.
Professor M. E. Holman, M.Sc., D.Phil., D.Sc., F.A.A. (part-time)
V. E. Jennings, B.E., M.I.E.(Aust.) (part-time)
A. E. Pierce, M.Sc., Ph.D., D.Sc., F.R.C.V.S., D.V.S.M., F.A.C.V.Sc.
Sir William Vines, C.M.G., A.A.S.A., F.C.I.S., L.C.A. (part-time)
Sir Frederick Wiltshire, C.B.E., B.A., F.A.I.M. (part-time)
Professor Emeritus H. W. Worner, D.Sc., F.I.M., F.R.A.C.I., M.A.I.M.M., F.I.E.Aust.

Chairmen of State Committees

QUEENSLAND—Professor F. N. Lahey, D.Sc.
SOUTH AUSTRALIA—A. M. Simpson, C.M.G., B.Sc.
TASMANIA—V. G. Burley, C.B.E., B.E., F.Mech.E. F.I.E.Aust., M.I.E.E., F.I.Prod.E., F.A.I.M., F.Aust.I.F.Sc.&Tech., F.I.D.Aust.
VICTORIA—Professor J. M. Swan, Ph.D., D.Sc., F.A.A., F.R.A.C.I.
WESTERN AUSTRALIA—L. C. Brodie-Hall, C.M.G., A.W.A.S.M.

Co-opted Members

C. K. Coogan, M.Sc., Ph.D.
Professor R. W. Cumming, B.E., A.M., M.E., C.Eng., M.I.E.(Aust.), A.F.R.Ae.S., F.H.F.S., A.B.Ps.Sc., M.A.Ps.S.
L. W. Davie, B.Sc., D.Phil.
J. H. Garrett, O.B.E.
H. A. Jenkins, M.Sc., M.B., B.S.
The Hon. C. R. Kelly
R. S. McInnes
B. W. Scott, M.B.A., B.Ec.
T. B. Swanson, C.B.E., M.Sc., F.R.A.C.I.

Representing Divisions

A. K. Lascelles, M.V.Sc., Ph.D.
R. W. R. Muncey, M.E.E., D.App.Sc.

State Committees

Queensland State Committee

Professor F. N. Lahey, D.Sc. (*Chairman*)
Professor R. S. F. Campbell, Ph.D., M.R.C., M.R.C.V.S., M.A.C.V.Sc.
C. H. Curtis, C.V.O., I.S.O.
A. M. Fraser, B.E., Ph.D., D.I.C., A.M.I.E.Aust., F.A.I.M.
K. E. Gibson, B.Sc.
B. H. Gunn, B.Comm., A.A.U.Q., A.A.S.A.
R. E. Harrison, B.Agr.Sc.
E. B. de N. Joyce, O.B.E.
I. W. Morley, I.S.O., B.M.E., B.Met.E.
Sir Leslie Price, O.B.E.
R. M. Reynolds
E. P. S. Roberts, C.M.G.
Professor Emeritus M. Shaw, M.Eng.. M.Mech.E., F.I.M.E., F.I.E.Aust.
W. J. D. Shaw, O.B.E.
Professor R. L. Specht, D.Sc., Ph.D.
Professor G. L. Wilson, B.Sc., D.Phil.

South Australian State Committee

A. M. Simpson, C.M.G., B.Sc. (*Chairman*)
C. W. Bonython, B.Sc., F.R.A.C.I., F.R.G.S., F.R.Met.S.
J. D. Cheesman, L.F.R.I.A., F.R.I.B.A., F.R.A.P.I., M.R.S.H.
A. D. Chenery
Professor A. M. Clark, M.Sc., Ph.D.
W. W. Forrest, B.Sc., Ph.D.
G. A. Fry, B.A., B.Tech., M.I.E.(Aust.), A.F.A.I.M.
B. J. Hailstone
J. E. Harris, B.E.
D. R. Hawkes
J. F. Jenkinson, A.A.S.A., A.C.I.S.
Brigadier J. G. McKinna, C.B.E., D.S.O., M.V.O., K.St.J., E.D., A.A.I.M.M., F.A.I.M.
L. W. Parkin, M.Sc., A.S.T.C.
Professor Emeritus J. A. Prescott, C.B.E., F.R.A.C.I., F.A.I.A.S., D.Sc., Hon.D.Agr.Sc., F.A.A., F.R.S.
H. C. Schmidt
E. W. Schroder, B.E., A.A.S.A.
H. Wilckens, F.I.O.B.(Lond.), F.A.I.B., F.A.I.M., F.I.O.A.(Lond.)

Tasmanian State Committee

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